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APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/788,498	10/27/2020	10820147	TX1000-C12	8054

59911 7590 10/07/2020
MITCH HARRIS, LLC - GENERAL
P.O. BOX 1269
ATHENS, GA 30603-1269

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 0 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site http://pair.uspto.gov for additional applicants):

Mark Jefferson Reed, Tucson, AZ;
Traxcell Technologies, LLC, Plano, TX;
Stephen Michael Palik, Redondo Beach, CA;

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/788,498	02/12/2020	Mark Jefferson Reed	TX1000-C12	8054

59911 7590 09/28/2020
MITCH HARRIS, LLC - GENERAL
P.O. BOX 1269
ATHENS, GA 30603-1269

EXAMINER	
PATEL, AJIT	

ART UNIT	PAPER NUMBER
2416	

MAIL DATE	DELIVERY MODE
09/28/2020	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

***Corrected* Notice of Allowability**	**Application No.** 16/788,498	**Applicant(s)** Reed et al.	
	Examiner AJIT PATEL	**Art Unit** 2416	**AIA (FITF) Status** No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1.☑ This communication is responsive to 7/2/20.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on ______.

2.☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on ______; the restriction requirement and election have been incorporated into this action.

3.☑ The allowed claim(s) is/are See Continuation Sheet . As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see **http://www.uspto.gov/patents/init_events/pph/index.jsp** or send an inquiry to **PPHfeedback@uspto.gov.**

4.☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a) ☐All b) ☐ Some *c) ☐ None of the:

1. ☐ Certified copies of the priority documents have been received.
2. ☐ Certified copies of the priority documents have been received in Application No. ______ .
3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

* Certified copies not received: ______ .

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5.☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date ______ .

Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6.☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1.☐ Notice of References Cited (PTO-892)
2.☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date ______.
3.☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material ______.
4.☑ Interview Summary (PTO-413), Paper No./Mail Date. ______.
5. ☑ Examiner's Amendment/Comment
6. ☐ Examiner's Statement of Reasons for Allowance
7. ☐ Other ______.

/AJIT PATEL/
Primary Examiner, Art Unit 2416

Continuation of 3. The allowed claim(s) is/are: 1,3-6,9-18,20-21,23-27 and 29-30

DETAILED ACTION

Notice of Pre-AIA or AIA Status

1. The present application is being examined under the pre-AIA first to invent provisions.

EXAMINER'S AMENDMENT

2. An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

Authorization for this examiner's amendment was given in an interview with Mr. Harris on 9/25/20.

3. The application has been amended as follows:

In claim 6 (original), line 1, "2" has been changed to --1--.

In claim 20 (original), line 1, line 1, "19" has been changed to --14 --.

Conclusion

4. Any inquiry concerning this communication or earlier communications from the examiner should be directed to AJIT PATEL whose telephone number is (571)272-3140. The examiner can normally be reached on Monday-Friday 9AM-5PM.

Examiner interviews are available via telephone, in-person, and video conferencing using a USPTO supplied web-based collaboration tool. To schedule an interview, applicant is encouraged to use the USPTO Automated Interview Request (AIR) at http://www.uspto.gov/interviewpractice.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, NOEL BEHARRY can be reached on 571-270-5630. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see https://ppair-my.uspto.gov/pair/PrivatePair. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/AJIT PATEL/
Primary Examiner, Art Unit 2416

Examiner-Initiated Interview Summary	**Application No.** 16/788,498	**Applicant(s)** Reed et al.		
	Examiner AJIT PATEL	**Art Unit** 2416	**AIA (First Inventor to File) Status** No	**Page** **1 of 1**

All Participants (applicant, applicants representative, PTO personnel)	**Title**	**Type**
AJIT PATEL	Primary Examiner	Telephonic
Mr. Harris		

Date of Interview: 25 September 2020

Issues Discussed:

Other

The examiner and the attorney discussed the dependency of original claims 6 and 20. The attomey authorized the examiner's amendment.

/AJIT PATEL/ Primary Examiner, Art Unit 2416	

Applicant is reminded that a complete written statement as to the substance of the interview must be made of record in the application file. It is the applicants responsibility to provide the written statement, unless the interview was initiated by the Examiner and the Examiner has indicated that a written summary will be provided. See MPEP 713.04

Please further see:

MPEP 713.04

Title 37 Code of Federal Regulations (CFR) § 1.133 Interviews, paragraph (b)

37 CFR § 1.2 Business to be transacted in writing

Applicant recordation instructions: It is not necessary for applicant to provide a separate record of the substance of interview.

Examiner recordation instructions: Examiners must summarize the substance of any interview of record. A complete and proper recordation of the substance of an interview should include the items listed in MPEP 713.04 for complete and proper recordation including the identification of the general thrust of each argument or issue discussed, a general indication of any other pertinent matters discussed regarding patentability and the general results or outcome of the interview, to include an indication as to whether or not agreement was reached on the issues raised.

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/788,498	02/12/2020	Mark Jefferson Reed	TX1000-C12	8054

59911 7590 09/04/2020
MITCH HARRIS, LLC - GENERAL
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ATHENS, GA 30603-1269

EXAMINER	
PATEL, AJIT	
ART UNIT	PAPER NUMBER
2416	
MAIL DATE	DELIVERY MODE
09/04/2020	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

PTOL-90A (Rev. 04/07)

UNITED STATES PATENT AND TRADEMARK OFFICE

Commissioner for Patents
United States Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450
www.uspto.gov

In re Application of	:	
Reed et al.	:	
Application No. 16/788,498	:	
Filed: February 12, 2020	:	DECISION ON PETITION
For: MOBILE WIRELESS DEVICE	:	
PROVIDING OFF-LINE AND ON-LINE	:	
GEOGRAPHIC NAVIGATION	:	
INFORMATION		

This is a Notice regarding the request for acceptance of a fee deficiency submission under 37 CFR 1.28(c) filed June 15, 2020.

The Office no longer investigates or rejects original or reissue applications under 37 CFR 1.56. 1098 Off. Gaz. Pat. Office 502 (January 3, 1989). Therefore, nothing in this Notice is intended to imply that an investigation was done.

The fee deficiency submission under 37 CFR 1.28(c) is **<u>ACCEPTED</u>**. Accordingly, status as a small entity has been removed and any future fee(s) submitted must be paid at the undiscounted rate.

Inquiries related to this communication should be directed to LaShawn Marks at (571) 272-7141.

/JOANNE L BURKE/
Lead Paralegal Specialist, OPET

United States Patent and Trademark Office

Office of the Chief Financial Officer

Document Code:WFEE

User :C41722

Sale Accounting Date:08/31/2020

Sale Item Reference Number	Effective Date
16788498	06/15/2020

Document Number	Fee Code	Fee Code Description	Amount Paid	Payment Method
I20208U907415612	1461	1.28(C) SUBMISSIONS - APPLIC FILE FEE	$4,185.00	Salea

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
16/788,498	02/12/2020	Mark Jefferson Reed	TX1000-C12

CONFIRMATION NO. 8054

PUBLICATION NOTICE

OC000000118673349

59911
MITCH HARRIS, LLC - GENERAL
P.O. BOX 1269
ATHENS, GA 30603-1269

Title:MOBILE WIRELESS DEVICE PROVIDING OFF-LINE AND ON-LINE GEOGRAPHIC NAVIGATION INFORMATION

Publication No.US-2020-0236496-A1
Publication Date:07/23/2020

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently http://www.uspto.gov/patft/.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Public Records Division. The Public Records Division can be reached by telephone at (571) 272-3150 or (800) 972-6382, by facsimile at (571) 273-3250, by mail addressed to the United States Patent and Trademark Office, Public Records Division, Alexandria, VA 22313-1450 or via the Internet.

In addition, information on the status of the application, including the mailing date of Office actions and the dates of receipt of correspondence filed in the Office, may also be accessed via the Internet through the Patent Electronic Business Center at www.uspto.gov using the public side of the Patent Application Information and Retrieval (PAIR) system. The direct link to access this status information is currently https://portal.uspto.gov/pair/PublicPair. Prior to publication, such status information is confidential and may only be obtained by applicant using the private side of PAIR.

Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Office of Data Managment, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), by mail or fax, or via EFS-Web.

By mail, send to: Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

By fax, send to: (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

59911 7590 05/26/2020

MITCH HARRIS, LLC - GENERAL
P.O. BOX 1269
ATHENS, GA 30603-1269

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being transmitted to the USPTO via EFS-Web or by facsimile to (571) 273-2885, on the date below.

(Typed or printed name)

(Signature)

(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/788,498	02/12/2020	Mark Jefferson Reed	TX1000-C12	8054

TITLE OF INVENTION: MOBILE WIRELESS DEVICE PROVIDING OFF-LINE AND ON-LINE GEOGRAPHIC NAVIGATION INFORMATION

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$500	$0.00	$0.00	$500	08/26/2020

EXAMINER	ART UNIT	CLASS-SUBCLASS
PATEL, AJIT	2416	455-456300

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-09 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 Mitch Harris, Atty at Law, LLC
2 Andrew M. Harris
3 ______

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document must have been previously recorded, or filed for recordation, as set forth in 37 CFR 3.11 and 37 CFR 3.81(a). Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE: TRAXCELL TECHNOLOGIES, LLC

(B) RESIDENCE: (CITY and STATE OR COUNTRY): PLANO TX

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☒ Corporation or other private group entity ☐ Government

4a. Fees submitted: ☒ Issue Fee ☐ Publication Fee (if required) ☐ Advance Order - # of Copies ______

4b. Method of Payment: *(Please first reapply any previously paid fee shown above)*

☒ Electronic Payment via EFS-Web ☐ Enclosed check ☐ Non-electronic payment by credit card (Attach form PTO-2038)

☐ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment to Deposit Account No. ______

5. **Change in Entity Status** (from status indicated above)

☐ Applicant certifying micro entity status. See 37 CFR 1.29

☐ Applicant asserting small entity status. See 37 CFR 1.27

☒ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature /Andrew Mitchell Harris #42,638/ Date 07-13-2020

Typed or printed name Andrew Mitchell Harris Registration No. 42,638

Electronic Patent Application Fee Transmittal

Application Number:	16788498
Filing Date:	12-Feb-2020
Title of Invention:	MOBILE WIRELESS DEVICE PROVIDING OFF-LINE AND ON-LINE GEOGRAPHIC NAVIGATION INFORMATION
First Named Inventor/Applicant Name:	Mark Jefferson Reed
Filer:	Andrew Mitchell Harris
Attorney Docket Number:	TX1000-C12

Filed as Large Entity

Filing Fees for **Utility under 35 USC 111(a)**

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
UTILITY APPL ISSUE FEE	1501	1	1000	1000

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**1000**

Electronic Acknowledgement Receipt

EFS ID:	39978940
Application Number:	16788498
International Application Number:	
Confirmation Number:	8054
Title of Invention:	MOBILE WIRELESS DEVICE PROVIDING OFF-LINE AND ON-LINE GEOGRAPHIC NAVIGATION INFORMATION
First Named Inventor/Applicant Name:	Mark Jefferson Reed
Customer Number:	59911
Filer:	Andrew Mitchell Harris
Filer Authorized By:	
Attorney Docket Number:	TX1000-C12
Receipt Date:	13-JUL-2020
Filing Date:	12-FEB-2020
Time Stamp:	12:25:12
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$1000
RAM confirmation Number	E20207CC28115925
Deposit Account	
Authorized User	

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Issue Fee Payment (PTO-85B)	TX1000-C12_ptol85b_07-13-20.pdf	117014 b812d5954d5f711624787e263f63850fed2e6039	no	1
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	30699 e5749144b745913550e591aa508ca1d86d5621af	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	147713		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY.DOCKET NO./TITLE	REQUEST ID
16/788,498	02/12/2020	Traxcell Technologies, LLC	TX1000-C12	116137

Acknowledgement of Loss of Entitlement to Entity Status Discount

The entity status change request below filed through Private PAIR on 07/07/2020 has been accepted.

CERTIFICATIONS:

Change of Entity Status:

☒ Applicant changing to regular undiscounted fee status.
NOTE: Checking this box will be taken to be notification of loss of entitlement to small or micro entity status, as applicable.

This portion must be completed by the signatory or signatories making the entity status change in accordance with 37 CFR 1.4(d)(4).

Signature:	/Andrew Mitchell Harris #42,638/
Name:	Andrew Mitchell Harris
Registration Number:	42638

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/788,498	02/12/2020	Mark Jefferson Reed	TX1000-C12	8054

59911 7590 07/02/2020
MITCH HARRIS, LLC - GENERAL
P.O. BOX 1269
ATHENS, GA 30603-1269

EXAMINER	
PATEL, AJIT	

ART UNIT	PAPER NUMBER
2416	

MAIL DATE	DELIVERY MODE
07/02/2020	PAPER

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PTOL-90A (Rev. 04/07)

CORRECTED ***Notice of Allowability***	**Application No.** 16/788,498	**Applicant(s)** Reed et al.	
	Examiner AJIT PATEL	**Art Unit** 2416	**AIA (FITF) Status** No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1.☑ This communication is responsive to IDS filed on 6/26/20.
☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on ______.

2.☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on ______; the restriction requirement and election have been incorporated into this action.

3.☑ The allowed claim(s) is/are See Continuation Sheet . As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see **http://www.uspto.gov/patents/init_events/pph/index.jsp** or send an inquiry to **PPHfeedback@uspto.gov.**

4.☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a) ☐All b) ☐ Some *c) ☐ None of the:

1. ☐ Certified copies of the priority documents have been received.
2. ☐ Certified copies of the priority documents have been received in Application No. ______ .
3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

* Certified copies not received: ______ .

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5.☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date ______ .

Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

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Attachment(s)

1.☐ Notice of References Cited (PTO-892)
2.☑ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date ______.
3.☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material ______.
4.☐ Interview Summary (PTO-413), Paper No./Mail Date. ______.
5. ☐ Examiner's Amendment/Comment
6. ☐ Examiner's Statement of Reasons for Allowance
7. ☐ Other ______.

/AJIT PATEL/
Primary Examiner, Art Unit 2416

Continuation of 3. The allowed claim(s) is/are: 1,3-6,9-18,20-21,23-27 and 29-30

Search Notes	Application/Control No. 16/788,498	Applicant(s)/Patent Under Reexamination Reed et al.
	Examiner AJIT PATEL	Art Unit 2416

CPC - Searched*		
Symbol	Date	Examiner

CPC Combination Sets - Searched*		
Symbol	Date	Examiner

US Classification - Searched*			
Class	Subclass	Date	Examiner

* See search history printout included with this form or the SEARCH NOTES box below to determine the scope of the search.

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/788,498	Reed et al.
	Examiner	**Art Unit**
	AJIT PATEL	2416

Search Notes		
Search Notes	**Date**	**Examiner**
IPR2019-00324 Reviewed Petition for Inter Partes Review of U.S.Patent No. 9,642,024.	05/07/2020	AP
IPR2019-00326 Reviewed Petition for Inter Partes Review of U.S.Patent No. 9,510,320.	05/07/2020	AP
IPR2019-00327 Reviewed Petition for Inter Partes Review of U.S.Patent No. 8,977,284.	05/07/2020	AP
Inventor name searched	05/20/2020	AP
H04W4/023;H04W64/006;H04W24/02;G01S5/0252;H04W4/029; H04W4/02;H04W8/02;H04B17/318-LIMITED SEARCHED	05/20/2020	AP
(H04W$/$).CPC.-LIMITED SEARCHED	05/20/2020	AP
(H04B$/$).CPC.-LIMITED SEARCHED	05/20/2020	AP
(G01S$/$).CPC.-LIMITED SEARCHED	05/20/2020	AP
EAST	05/20/2020	AP
EAST	06/30/2020	AP

Interference Search			
US Class/CPC Symbol	**US Subclass/CPC Group**	**Date**	**Examiner**
	See EAST for interference searched	05/20/2020	AP

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	1	"5625668".PN.	USPAT	OR	ON	2020/06/29 22:59

6/29/2020 11:01:03 PM

PTO/SB/08a (07-09)
Approved for use through 11/30/2020. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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Substitute for form 1449A/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet 1 of 2

Complete if Known	
Application Number	16/788,498
Filing Date	2/12/2020
First Named Inventor	Reed et al.
Art Unit	2416
Examiner Name	Patel, Ajit
Attorney Docket Number	TX1000-C12

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number: Number - Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		US-5,625,668	04-29-1997	Loomis, et al.	
		US-			
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FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Foreign Patent Document: Country Code[3] - Number[4] - Kind Code[5] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]

Examiner Signature	/AJIT PATEL/	Date Considered	06/30/2020

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. [1]Applicant's unique citation designation number (optional). [2]See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. [3]Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). [4]For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [5]Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST. 16 if possible. [6]Applicant is to place a check mark here if English language Translation is attached.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /A.P/

Substitute for form 1449B/PTO				Complete if Known	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT				**Application Number**	16/788,498
				Filing Date	2/12/2020
				First Named Inventor	Reed et al.
				Art Unit	2416
(Use as many sheets as necessary)				Examiner Name	Patel, Ajit
Sheet	2	of	2	Attorney Docket Number	TX1000-C12

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
		Notice of Allowance in 16/557,277 mailed on 05/13/2020, 54 pages (pp. 1-54 in pdf).	
		Notice of Allowance in 16/557,277 mailed on 06/08/2020, 12 pages (pp. 1-12 in pdf).	
		Notice of Allowance in 16/779,590 mailed on 05/14/2020, 48 pages (pp. 1-48 in pdf).	

Examiner Signature	/AJIT PATEL/	Date Considered	06/30/2020

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.
[1]Applicant's unique citation designation number (optional). [2]Applicant is to place a check mark here if English language Translation is attached.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /A.P/

Substitute for form 1449A/PTO	Complete if Known	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT	Application Number	16/788,498
(Use as many sheets as necessary)	Filing Date	2/12/2020
	First Named Inventor	Reed et al.
	Art Unit	2416
	Examiner Name	Patel, Ajit
Sheet 1 of 2	Attorney Docket Number	TX1000-C12

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number: Number - Kind Code[2] *(if known)*	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		US-5,625,668	04-29-1997	Loomis, et al.	
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FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Foreign Patent Document: Country Code[3] - Number[4] - Kind Code[5] *(if known)*	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. [1]Applicant's unique citation designation number (optional). [2]See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. [3]Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). [4]For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [5]Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST. 16 if possible. [6]Applicant is to place a check mark here if English language Translation is attached.

Substitute for form 1449B/PTO				*Complete if Known*	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT				**Application Number**	16/788,498
				Filing Date	2/12/2020
				First Named Inventor	Reed et al.
				Art Unit	2416
(Use as many sheets as necessary)				Examiner Name	Patel, Ajit
Sheet	2	of	2	Attorney Docket Number	TX1000-C12

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
		Notice of Allowance in 16/557,277 mailed on 05/13/2020, 54 pages (pp. 1-54 in pdf).	
		Notice of Allowance in 16/557,277 mailed on 06/08/2020, 12 pages (pp. 1-12 in pdf).	
		Notice of Allowance in 16/779,590 mailed on 05/14/2020, 48 pages (pp. 1-48 in pdf).	

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.
[1]Applicant's unique citation designation number (optional). [2]Applicant is to place a check mark here if English language Translation is attached.

Electronic Patent Application Fee Transmittal

Application Number:	16788498
Filing Date:	12-Feb-2020
Title of Invention:	MOBILE WIRELESS DEVICE PROVIDING OFF-LINE AND ON-LINE GEOGRAPHIC NAVIGATION INFORMATION
First Named Inventor/Applicant Name:	Mark Jefferson Reed
Filer:	Andrew Mitchell Harris
Attorney Docket Number:	TX1000-C12

Filed as Large Entity

Filing Fees for **Utility under 35 USC 111(a)**

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
SUBMISSION- INFORMATION DISCLOSURE STMT	1806	1	240	240
	Total in USD ($)			**240**

Electronic Acknowledgement Receipt

EFS ID:	39843743
Application Number:	16788498
International Application Number:	
Confirmation Number:	8054
Title of Invention:	MOBILE WIRELESS DEVICE PROVIDING OFF-LINE AND ON-LINE GEOGRAPHIC NAVIGATION INFORMATION
First Named Inventor/Applicant Name:	Mark Jefferson Reed
Customer Number:	59911
Filer:	Andrew Mitchell Harris
Filer Authorized By:	
Attorney Docket Number:	TX1000-C12
Receipt Date:	26-JUN-2020
Filing Date:	12-FEB-2020
Time Stamp:	16:51:56
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$240
RAM confirmation Number	E20206PG54161570
Deposit Account	
Authorized User	

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Other Reference-Patent/App/Search documents	TX1000-C10_NoticeOfAllowance_05-13-20.pdf	2784985 2922b84cabb01ca3d16142bb9b4e660c6a49916b	no	54

Warnings:

Information:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
2	Other Reference-Patent/App/Search documents	TX1000-C10_NoticeOfAllowance_06-08-20.pdf	518660 9b025276ba5936a3c4f5c8744937cf16eb84f229	no	12

Warnings:

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Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
3	Other Reference-Patent/App/Search documents	TX1000-C11_NoticeOfAllowance_05-14-20.pdf	2485844 96c99ea3ede6521a7d3a4e703a385046d41c425a	no	48

Warnings:

Information:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
4		TX1000-C12_IDS_06-26-20.pdf	265950 378b68e5fa77ba0bb2e5eba22c69aeb553757509	yes	4

Multipart Description/PDF files in .zip description

Document Description	Start	End
Transmittal Letter	1	2
Information Disclosure Statement (IDS) Form (SB08)	3	4

Warnings:

Information:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
5	Fee Worksheet (SB06)	fee-info.pdf	30707 5b43bc1f8008a9fc10297f46b1969590395945d7	no	2

Warnings:

Information:

Total Files Size (in bytes):	6086146

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s): Reed et al. Serial No.: 16/557,277 Filed: 8/30/2019 Title: WIRELESS NETWORK AND METHOD FOR SUGGESTING CORRECTIVE ACTION IN RESPONSE TO DETECTING COMMUNICATIONS ERRORS Attorney Docket No.: TX1000-C10	Group Art Unit: 2416 Examiner: PATEL, AJIT

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

INFORMATION DISCLOSURE STATEMENT

Dear Sir:

This Information Disclosure Statement is submitted:

__ under 37 CFR 1.97(b), or
(Within three months of filing national application; or date of entry of international application; or before mailing date of first office action on the merits; whichever occurs last)

__ under 37 CFR 1.97(c) together with either a:
__ Statement under 37 CFR 1.97(e), or
__ a $240.00 fee under 37 CFR 1.17(p), or
(After the CFR 1.97(b) time period, but before final action or notice of allowance, whichever occurs first)

X under 37 CFR 1.97(d) together with a:
X Statement under 37 CFR 1.97(e), and
X a $240.00 fee set forth in 37 CFR 1.17(p).
(Filed after final action or notice of allowance, whichever occurs first, but before payment of the issue fee)

X Applicant(s) submit herewith Form PTO 1449-Information Disclosure Citation together with copies, of patents, publications or other information of which applicant(s) are aware, which applicant(s) believe(s) may be material to the examination of this application and for which there may be a duty to disclose in accordance with 37 CFR 1.56.

The undersigned certifies that this IDS is being submitted under **37 C.F.R. 1.97(d)** after the mailing of a Final Office Action, Notice of Allowance or other action closing prosecution in the application, and:

(1) That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement; or

(2) That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in § 1.56(c) more than three months prior to the filing of the information disclosure statement.

While this Information Disclosure Statement may be "material" pursuant to 37 C.F.R. 1.56, it is not intended to constitute an admission that any patent, publication or other information referred to herein is "prior art" for this invention unless specifically designated as such.

In accordance with 37 C.F.R. 1.97(g) the filing of this Information Disclosure Statement shall not be construed to mean that a search has been made or that no other material information as defined in 37 CFR 1.56 (b) exists.

Any fee required above for the submission of this IDS has been paid via EFS-WEB. However, in the event that another fee is required in connection with the enclosed Information Disclosure Statement, the Commissioner of Patents and Trademarks is authorized to charge Deposit Account No. 50-3808 for the necessary amount.

It is requested that the information disclosed herein be made of record in this application.

Respectfully submitted,

/Andrew Mitchell Harris #42,638/

Andrew Mitchell Harris
Attorney/Agent for Applicant(s)
Reg. No. 42638

Date: June 26, 2020

Telephone No.: 866-553-4918

United States Patent and Trademark Office

Office of the Chief Financial Officer

Document Code:WFEE

User :67142

Sale Accounting Date:06/25/2020

Sale Item Reference Number	Effective Date
16788498	06/15/2020

Document Number	Fee Code	Fee Code Description	Amount Paid	Payment Method
I20206OE53172604	1599	MAINTENANCE/PETITION INTERNAL FEE CODE	$4,185.00	Credit Card

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OPAP JUN 1 9 2020 PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s): Reed	
Application No.: 16/788,498	Art Unit: 2416
Filed: 02/12/2020 02/12/2020	Examiner: Patel, Ajit
Title: MOBILE WIRELESS DEVICE PROVIDING OFF-LINE AND ON-LINE GEOGRAPHIC NAVIGATION INFORMATION	2020 JUN 23 PM 2:52 USPTO RECEIPTS ACCOUNTING DIVISION
Attorney Docket No.: TX1000-C12	

I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to "Commissioner for Patents, PO BOX 1450, Alexandria, VA 22313-1450" on **6/15/2020**

Signature ______________________.

Typed or printed name : Andrew Mitchell Harris

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Mitch Harris, Atty at Law, LLC
PO Box 1269
Athens, GA 30603-1269

FEE DEFICIENCY SUBMISSION UNDER 37 CFR §1.28(c)

Dear Sir:

The Fees itemized in the Table below were erroneously paid in good faith at the small entity discounted rate, but should have been paid at the undiscounted rate due to a change in entity status. Please charge the total fee deficiency recited in the Table below to the credit card specified on the attached PTO-2038 Credit Card Payment Form.

Fee Type	Large Entity Fee	Amount Paid	Date Paid	Amount Due
surcharge	$160	$80	2/12/2020	$80
exam fee	$760	$380	2/12/2020	$380
basic filing fee	$300	$75	2/12/2020	$225
Size fee	$1,200	$600	2/12/2020	$600
extra total claims	$1,000	$500	2/12/2020	$500
Search Fee	$660	$330	2/12/2020	$330
Track I request	$4,000	$2,000	2/12/2020	$2,000
processing fee	$140	$70	2/12/2020	$70
				TOTAL FEE DEFICIENCY: $4185

No additional fees should be incurred by this Letter, but if there are any fees incurred by this Letter, please deduct them from Deposit Account NO. 50-3808.

Respectfully Submitted,

Andrew Mitchell Harris
Attorney/Agent for Applicant(s)
Reg. No. 42638

Mitch Harris, Atty at Law, L.L.C.
P.O. Box 1269
Athens, GA 30603-1269
Tel. 866-553-4918

From: mitch@harrispatent.com
To: Patel, Ajit
Subject: 16/788,498 Examiner''s Amendment
Date: Monday, May 18, 2020 6:58:18 PM
Attachments: TX1000-C12_ProposedExaminerAmendment_05-18-20.docx

Dear Examiner Patel,

Attached is a document with claims language for a proposed examiner's amendment in the above-captioned application

Best Regards,

Mitch Harris
U.S. Registered Patent Attorney
Mitch Harris, Atty at Law, L.L.C.
P.O. Box 1269 Athens, GA 30603-1269
866-553-4918 (voice or fax)
847-461-1595 (International voice/fax)

-----Original Message-----
From: mitch@harrispatent.com <mitch@harrispatent.com>
Sent: Wednesday, May 13, 2020 12:12 PM
To: 'ajit.patel@uspto.gov' <ajit.patel@uspto.gov>
Subject: 16/788,498 Examiner Interview

Dear Examiner Patel,

I received your voice mail. Thank you. 11AM tomorrow is fine.

Best Regards,

Mitch Harris
U.S. Registered Patent Attorney

Mitch Harris, Atty at Law, L.L.C.
P.O. Box 1269 Athens, GA 30603-1269
866-553-4918 (voice or fax)
847-461-1595 (International voice/fax)

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s): Reed	
Application No.: 16/788,498	Art Unit: 2416
Filed: 02/12/2020	Examiner: Patel, Ajit
Title: MOBILE WIRELESS DEVICE PROVIDING OFF-LINE AND ON-LINE GEOGRAPHIC NAVIGATION INFORMATION	
Attorney Docket No.: TX1000-C12	

VIA E-MAIL to:

Examiner Patel

PROPOSED EXAMINER'S AMENDMENT

Dear Examiner Patel:

In conjunction with your telephone call of 05/14/2020 proposing an Examiner's Amendment, Applicant submits the following proposed Claims for an Examiner's Amendment in conformity with your request and authorizes entry thereof if the amendment places the Application in condition for Allowance.

IN THE CLAIMS

Please amend the claims in accordance with the following mark-up copy:

1. (Original) A wireless communications system including:

a first radio-frequency transceiver within a wireless mobile communications device and an associated first antenna to which the first radio-frequency transceiver is coupled, wherein the first radio-frequency transceiver is configured for radio-frequency communication with a wireless communications network;

a first processor within the wireless mobile communications device coupled to the at least one first radio-frequency transceiver programmed to receive information indicative of a location of the wireless mobile communications device ~~from the wireless communications network~~ and generate an indication of a location of the wireless mobile communications device with respect to geographic features according to mapping information stored within the wireless mobile communications device, and wherein the first processor determines user navigation information and displays ~~to~~ the user navigation information according to the location of the wireless mobile communications device with respect to the geographic features and a destination specified ~~by the user~~ at the wireless mobile communications device, wherein the first processor further sends the user navigation information to the network as a number of segments, wherein at least one other processor outside the network updates the user navigation information in conformity with traffic congestion information accessible to the at least one other processor outside the network by computing a numerical value for the segments corresponding to the expected time to travel through the segments, updates the user navigation information in conformity with the numerical values for the segments, and sends the updated user navigation information to the wireless mobile communications device;

at least one second radio-frequency transceiver and an associated at least one second antenna of the wireless communications network to which the second radio-frequency transceiver is coupled; and

a second processor coupled to the at least one second radio-frequency transceiver programmed to acquire the information indicative of a location of the wireless mobile communications device, wherein the second processor selectively acquires the information indicative of a location of the wireless mobile communications device dependent on the setting of preference flags, wherein the second processor acquires the information indicative of a location of the wireless mobile communications device if the preference flags are set to a state that permits tracking ~~of the user~~ of the wireless mobile communications device, and wherein the second processor does not acquire the information indicative of the location of the wireless mobile communications device if the preference flags are set to a state that prohibits tracking of the wireless mobile communications device.

2. (Canceled)

3. (Currently Amended) The wireless communications system of Claim 1, wherein the first processor is further programmed to:

determine whether or not the mapping information stored within the wireless mobile communications device is sufficient to display the navigation information ~~to the user~~;

responsive to the first processor determining that the mapping information is sufficient, the processor displaying the navigation information ~~to the user~~;

responsive to the first processor determining that the mapping information is not sufficient, the first processor requesting additional mapping information from at least one other processor outside the wireless communications network; and

responsive to the first processor requesting additional mapping information from at least one other processor outside the wireless communications network, the first processor receiving the additional mapping information from the at least one other processor outside the wireless communications network and the first processor displaying the navigation information ~~to the user~~ using the additional mapping information.

4. (Original) The wireless communications system of Claim 3, wherein the first processor further updates the mapping information stored within the wireless mobile communications device with the additional information received from the wireless communications network.

5. (Currently Amended) The wireless communications system of Claim 4, wherein the first processor, responsive to not receiving the additional mapping information from the wireless communications network, ~~displaying~~ displays a notice ~~to the user~~ that the destination could not be found.

6. (Original) The wireless communications system of Claim 2, wherein the first processor further requests from the wireless communications network, traffic congestion information, wherein the first processor receives the requested traffic congestion information and determines the user navigation information in conformity with the received traffic congestion information.

Claims 7-8 are canceled.

9. (Currently Amended) The wireless communications system of Claim 1~~7~~, wherein the another processor determines whether or not the updated user navigation information already exists in the wireless mobile communications device, and does not transmit the updated user navigation information to the wireless mobile communications device if the updated user navigation information already exists in the wireless mobile communications device.

10. (Original) The wireless communications system of Claim 1, wherein the first processor further sends the indication of a location of the wireless mobile communications device with respect to the geographic features to the network, wherein at least one other processor outside the network receives the indication of a location of the wireless mobile communications device, determines the user navigation information in conformity with the location of the wireless mobile communications device and transmits the user navigation information to the wireless mobile communications device.

11. (Original) The wireless communications system of Claim 1, wherein the preference flags are specified by ~~the user of~~ the wireless mobile communications device and transmitted to the at least one second radio-frequency transceiver.

12. (Original) The wireless communications system of Claim 1, wherein the preference flags have more than two states including at least: a first state that prohibits tracking of the mobile wireless communications device, a second state that permits open access to the location of the wireless mobile communications device and information associated with the wireless mobile communications device, and a third state that provides access to the information indicative of the location of the wireless mobile communications device but not information associated with the wireless mobile communications device other than a generic identifier, and wherein the second processor provides information about ~~the~~ a user of the wireless mobile communications device to at least one other processor outside the network in conformity with permissions specified by the preference flags.

13. (Currently Amended) The wireless communications system of Claim 12, wherein the preference flags have more than three states, including at least a fourth state that provides access to the location of the wireless mobile communications device and demographic information associated with the wireless mobile communications device, but not a name of the user associated with the wireless mobile communications device or other private information.

14. (Currently Amended) A method of providing navigation information within a wireless communications network, the method comprising:

at a wireless mobile communications device coupled to the wireless communications network and having a first radio-frequency transceiver coupled to an associated first antenna, receiving information indicative of a location of the mobile wireless communications device;

within the wireless mobile communications device, a first processor within the wireless mobile communications device coupled to the first radio-frequency transceiver generating an indication of a location of the at least one wireless mobile communications device with respect to geographic features according to mapping information retrieved from a storage within the wireless mobile communications device;

the first processor determining user navigation information;

sending the user navigation information to the at least one other processor outside the network as a number of segments;

at a remote location within the at least one other processor outside the network, updating the user navigation information in conformity with traffic congestion information accessible to the remote location within the network by computing a numerical value for the segments corresponding to the expected time to travel through the segments, and wherein the updating is performed in conformity with the numerical values for the number of segments;

sending the updated user navigation information to the wireless mobile communications device;

the first processor displaying ~~to the user~~ the user navigation information according to the location of the wireless mobile communications device with respect to the geographic features and a destination specified by ~~the user at~~ the wireless mobile communications device;

within the wireless communications network, a second processor coupled to at least one second radio-frequency transceiver coupled to an associated second antenna selectively acquiring the information indicative of a location of the wireless mobile communication device in dependence on a setting of preference flags, wherein the selectively acquiring the information indicative of a location of the wireless mobile communications device if the preference flags are set to a state that permits tracking of the user of the wireless mobile communications device, and wherein the selectively determining does not acquire the information indicative of a location of the wireless mobile communications device if the preference flags are set to a state that prohibits tracking of the wireless mobile communications device.

15. (Original)The method of Claim 14, further comprising within the wireless mobile communications device, determining the user navigation information.

16. (Currently Amended) The method of Claim 15, further comprising:

within the wireless mobile communications device, determining whether or not the mapping information stored within the wireless mobile communications device is sufficient to display the navigation information ~~to the user~~;

responsive to determining that the mapping information is sufficient, displaying the navigation information ~~to the user~~;

responsive to determining that the mapping information is not sufficient, requesting additional mapping information from at least one other processor outside the wireless communications network; and

responsive to the requesting additional mapping information from the at least one other processor outside the wireless communications network, receiving the additional mapping information from the at least one other processor outside the wireless communications network and displaying the navigation information ~~to the user~~ using the additional mapping information.

17. (Original) The method of Claim 16, further comprising updating the mapping information stored within the wireless mobile communications device with the additional information received from the at least one other processor outside the wireless communications network.

18. (Currently Amended) The method of Claim 16, further comprising responsive to not receiving the additional mapping information from the at least one other processor outside the wireless communications network, displaying a notice ~~to the user~~ that the destination could not be found.

19. (Canceled)

20. (Original) The method of Claim 19, further comprising, at the remote location, determining whether or not the updated user navigation information already exists in the wireless mobile communications device, and wherein the transmitting of the updated user navigation information is not performed if the updated user navigation information already exists in the wireless mobile communications device.

21. (Original) The method of Claim 14, further comprising:

requesting from the at least one other processor outside the wireless communications network, traffic congestion information;

receiving the requested traffic congestion information at the mobile wireless communications device; and

determining the user navigation information in conformity with the received traffic congestion information.

22. (Canceled)

23. (Original) The method of Claim 14, further comprising:

at the wireless mobile communications device, sending the location of the wireless mobile communications device with respect to the geographic features to at least one other processor outside the network;

receiving the location of the wireless mobile communications device at the at least one other processor outside the network; and

at a remote at least one other processor outside the network, determining the user navigation information in conformity with the location of the wireless mobile communications device; and

transmitting the user navigation information to the wireless mobile communications device.

24. (Currently Amended) The method of Claim 14, wherein the preference flags are specified by ~~the~~ a user associated with ~~of~~ the wireless mobile communications device, and wherein the method further comprises transmitting the preference flags to the at least one second radio-frequency transceiver.

25. (Currently Amended) The method of Claim 14, wherein the preference flags have more than two states including at least: a first state that prohibits tracking of the mobile wireless communications device, a second state that permits open access to the location of the wireless mobile communications device and information associated with the wireless mobile communications device, and a third state that provides access to the location of the wireless mobile communications device but not information associated with the wireless mobile communications device other than a generic identifier, and wherein method further comprises the second processor providing information about a ~~the~~ user ~~of~~ associated with the wireless mobile

communications device to at least one other processor outside the wireless network in conformity with permissions specified by the preference flags.

26. (Original) The method of Claim 25, wherein the preference flags have more than three states, including at least a fourth state that provides access to the location of the wireless mobile communications device and demographic information associated with the wireless mobile communications device, but not a name of the user associated with the wireless mobile communications device or other private information.

27. (Currently Amended) A wireless mobile communications device including:

a radio-frequency transceiver and an associated antenna to which the radio-frequency transceiver is coupled, wherein the radio-frequency transceiver is configured for radio-frequency communication with a wireless communications network; and

a first processor coupled to the at least one radio-frequency transceiver programmed to receive a location of the wireless mobile communications device and generate an indication of a location of the at least one wireless mobile communications device with respect to geographic features according to mapping information stored within the wireless mobile communications device, wherein the first processor determines whether or not the mapping information stored within the wireless mobile communications device is sufficient to display the navigation information to the user, responsive to the first processor determining that the mapping information is not sufficient, the first processor requesting additional mapping information from at least one other processor outside the wireless communications network and responsive to the first processor requesting additional mapping information from the at least one other processor outside the wireless communications network, receiving the additional mapping information from the at least one other processor outside the wireless communications network and updating the mapping information stored within the wireless mobile communications device, wherein the first processor determines and displays the navigation information to the user using the additional mapping information, the location of the wireless mobile communications device with respect to the geographic features and a destination specified by the user at the wireless mobile communications device, and wherein the first processor communicates to the mobile communications network a setting of preference flags, wherein the first processor further sends the user navigation information to the at least one other processor outside of the network, wherein the at least one other processor outside of the network updates the user navigation information in conformity with traffic congestion information accessible to the other processor coupled to the network and transmits the updated user navigation information to the mobile device, wherein the first processor further sends the user navigation information to the at least one other processor outside of the network as a number of segments, and wherein the at least one other processor outside of the network computes a numerical value for each segment corresponding to the expected time to travel through the segment and wherein the user navigation information is updated in conformity with the numerical values for the number of segments, wherein ~~whereby~~ the mobile communications network selectively acquires information indicative of a location of the mobile communications device and communicates the information indicative of a location of the wireless mobile communications device to the wireless mobile communications device dependent on the setting of the preference flags, wherein if the preference flags are set to a state that permits tracking of the user of the wireless mobile communications device the at least one other processor outside the wireless communications network receives the location of the wireless mobile communications device, and wherein if the preference flags are set to a state that prohibits tracking of the wireless mobile communications device, the at least one other processor outside the wireless communications network does not receive the location of the wireless mobile communications device.

28. (Canceled)

29. (Currently Amended) The wireless mobile communications device of Claim 27 ~~28~~, wherein the another processor determines whether or not the updated user navigation information already exists in the wireless mobile communications device, and does not transmit the updated user navigation information to the mobile device if the updated user navigation information already exists in the wireless mobile communications device.

30. (Original) The wireless mobile communications device of Claim 27, wherein the preference flags have more than two states including at least: a first state that prohibits tracking of the mobile wireless communications device, a second state that permits open access to the location of the wireless mobile communications device and information associated with the wireless mobile communications device, and a third state that provides access to the location of the wireless mobile communications device but not information associated with the wireless mobile communications device other than a generic identifier, whereby the wireless communications network processor provides information about the user of the wireless mobile communications device in conformity with permissions specified by the preference flags.

Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

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First Named Inventor	Reed
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Art Unit	-- Unknown --
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Examiner Initials		Document Number	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
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		US-6,716,101-B1	04-06-2004	Meadows, et al.	
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	Filing Date	2/12/2020
	First Named Inventor	Reed
	Examiner Name	-- Unknown --
	Art Unit	-- Unknown --
	Attorney Docket No.	TX1000-C12

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		US-6,799,047-B1	09-28-2004	Bahl, et al.	
		US-6,026,304	02-15-2000	Hilsenrath, et al.	
		US-6,393,294-B1	05-21-2002	Perez-Breva, et al.	
		US-6,269,246-B1	07-31-2001	Rao, et al.	
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		US-7,079,945-B1	07-18-2006	Kaplan	
		US-6,374,177-B1	04-16-2002	Lee, et al.	
		US-20020164998-A1	11-07-2002	Younis	
		US-20030065442-A1	04-03-2003	Touney	
		US-6,405,123-B1	06-11-2002	Rennard, et al.	
		US-6,615,131-B1	09-02-2003	Rennard, et al.	
		US-20020115453-A1	08-22-2002	Poulin, et al.	
		US-6,725,156-B2	04-20-2004	Kaplan	
		US-6,947,837-B2	09-20-2005	Fukushima, et al.	
		US-7,149,625-B2	12-12-2006	Mathews, et al.	
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		US-4,912,705	03-27-1990	Paneth, et al.	
		US-5,526,357	06-11-1996	Jandrell	
		US-5,548,583	08-20-1996	Bustamante	
		US-20020198985-A1	12-26-2002	Fraenkel, et al.	
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		US-20050282540-A1	12-22-2005	Motamedi, et al.	
		US-6,505,048-B1	01-07-2003	Moles, et al.	
		US-7,085,555-B2	08-01-2006	Zellner, et al.	
		US-6,678,516-B2	01-13-2004	Nordman, et al.	
		US-5,471,649	11-28-1995	Rees, et al.	
		US-5,857,155	01-05-1999	Hill, et al.	
		US-5,425,076	06-13-1995	Knippelmier	
		US-6,445,917-B1	09-03-2002	Bark, et al.	
		US-6,859,463-B1	02-22-2005	Mayor, et al.	
		US-6,188,883-B1	02-13-2001	Takemura	
		US-6,128,507	10-03-2000	Takai	
		US-5,875,398	02-23-1999	Snapp	
		US-6,285,688-B1	09-04-2001	Henderson, et al.	
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		US-6,317,596-B1	11-13-2001	Elwin	
		US-5,570,373	10-29-1996	Wing	
		US-5,790,940	08-04-1998	Laborde, et al.	
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		US-6,445,916-B1	09-03-2002	Rahman	
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		US-5,603,093	02-11-1997	Yoshimi, et al.	
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		US-6,847,916-B1	01-25-2005	Ying	
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		US-6,985,901-B1	01-10-2006	Sachse, et al.	
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		US-8,107,608-B2	01-31-2012	Sheha, et al.	
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		US-7,158,880-B2	01-02-2007	Geiger, et al.	
		US-20010036224-A1	11-01-2001	Demello, et al.	
		US-20020032521-A1	03-14-2002	Machii, et al.	
		US-6,700,534-B2	03-02-2004	Harris	
		US-6,738,711-B2	05-18-2004	Ohmura, et al.	
		US-7,409,429-B2	08-05-2008	Kaufman, et al.	
		US-20020184418-A1	12-05-2002	Blight	
		US-20030005316-A1	01-02-2003	Girard	
		US-7,249,100-B2	07-24-2007	Murto, et al.	
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		US-7,570,958-B2	08-04-2009	Krasner, et al.	
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		US-6,496,776-B1	12-17-2002	Blumberg, et al.	
		US-7,126,527-B2	10-24-2006	Bajikar	
		US-7,213,048-B1	05-01-2007	Parupudi, et al.	
		US-5,295,180	03-15-1994	Vendetti, et al.	
		US-6,912,376-B1	06-28-2005	Smith, et al.	
		US-6,236,359-B1	05-22-2001	Watters, et al.	
		US-5,806,018	09-08-1998	Smith, et al.	
		US-6,850,736-B2	02-01-2005	McCune, Jr.	
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		US-6,091,362	07-18-2000	Stilp, et al.	
		US-5,768,686	06-16-1998	LeBlanc, et al.	
		US-6,070,072	05-30-2000	Dorenbosch, et al.	
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Examiner: /AJIT PATEL/ Date Considered: 05/18/2020

EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /A.P/

Substitute for form 1449/PTO	Complete if Known	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT	Application Number	**16/788,498**
	Filing Date	2/12/2020
	First Named Inventor	Reed
	Examiner Name	-- Unknown --
	Art Unit	-- Unknown --
	Attorney Docket No.	TX1000-C12

NON PATENT LITERATURE		
Examiner Initial		Include name of author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.
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	First Named Inventor	Reed
	Examiner Name	-- Unknown --
	Art Unit	-- Unknown --
	Attorney Docket No.	TX1000-C12

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Substitute for form 1449/PTO **INFORMATION DISCLOSURE STATEMENT BY APPLICANT**	**Complete if Known**	
	Application Number	**16/788,498**
	Filing Date	2/12/2020
	First Named Inventor	Reed
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Bibliographic Data

Application No: 16/788,498

Foreign Priority claimed: ○ Yes ◉ No

35 USC 119 (a-d) conditions met: ☐ Yes ☑ No | ☐ Met After Allowance

Verified and Acknowledged: /AJIT PATEL/

Examiner's Signature | Initials

Title: MOBILE WIRELESS DEVICE PROVIDING OFF-LINE AND ON-LINE GEOGRAPHIC NAVIGATION INFORMATION

FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
02/12/2020	455	2416	TX1000-C12
RULE			

APPLICANTS

Traxcell Technologies, LLC, Plano, TX,

INVENTORS

Mark Jefferson Reed Tucson, AZ, UNITED STATES

Stephen Michael Palik Redondo Beach, CA, UNITED STATES

CONTINUING DATA

This application is a CON of 16557277 08/30/2019

16557277 is a CON of 16116215 08/29/2018 PAT 10448209

16116215 is a CON of 15880852 01/26/2018 PAT 10390175

15880852 is a CON of 15717138 09/27/2017 PAT 9918196

15717138 is a CON of 15468265 03/24/2017 PAT 9888353

15468265 is a CON of 15297222 10/19/2016 PAT 9642024

15297222 is a CON of 14642408 03/09/2015 PAT 9510320

14642408 is a CON of 11505578 08/17/2006 PAT 8977284

11505578 is a CIP of 10255552 09/24/2002ABN

10255552 has PRO of 60391469 06/26/2002

10255552 has PRO of 60383528 05/28/2002

10255552 has PRO of 60383529 05/28/2002

10255552 has PRO of 60381249 05/16/2002

10255552 has PRO of 60353379 01/30/2002

10255552 has PRO of 60352761 01/29/2002

10255552 has PRO of 60335203 10/23/2001

10255552 has PRO of 60327327 10/04/2001

FOREIGN APPLICATIONS

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EXAMINER	
PATEL, AJIT	
ART UNIT	**PAPER NUMBER**
2416	

DATE MAILED: 05/26/2020

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/788,498	02/12/2020	Mark Jefferson Reed	TX1000-C12	8054

TITLE OF INVENTION: MOBILE WIRELESS DEVICE PROVIDING OFF-LINE AND ON-LINE GEOGRAPHIC NAVIGATION INFORMATION

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$500	$0.00	$0.00	$500	08/26/2020

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

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(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/788,498	02/12/2020	Mark Jefferson Reed	TX1000-C12	8054

TITLE OF INVENTION: MOBILE WIRELESS DEVICE PROVIDING OFF-LINE AND ON-LINE GEOGRAPHIC NAVIGATION INFORMATION

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$500	$0.00	$0.00	$500	08/26/2020

EXAMINER	ART UNIT	CLASS-SUBCLASS
PATEL, AJIT	2416	455-456300

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❏ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

❏ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-09 or more recent) attached. **Use of a Customer Number is required.**

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(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1____________________

2____________________

3____________________

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document must have been previously recorded, or filed for recordation, as set forth in 37 CFR 3.11 and 37 CFR 3.81(a). Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❏ Individual ❏ Corporation or other private group entity ❏ Government

4a. Fees submitted: ❏Issue Fee ❏Publication Fee (if required) ❏Advance Order - # of Copies ____________

4b. Method of Payment: *(Please first reapply any previously paid fee shown above)*

❏ Electronic Payment via EFS-Web ❏ Enclosed check ❏ Non-electronic payment by credit card (Attach form PTO-2038)

❏ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment to Deposit Account No. __________

5. **Change in Entity Status** (from status indicated above)

❏ Applicant certifying micro entity status. See 37 CFR 1.29

❏ Applicant asserting small entity status. See 37 CFR 1.27

❏ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature ____________________ Date ____________________

Typed or printed name ____________________ Registration No. ____________________

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/788,498	02/12/2020	Mark Jefferson Reed	TX1000-C12	8054

59911 7590 05/26/2020
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EXAMINER	
PATEL, AJIT	
ART UNIT	**PAPER NUMBER**
2416	

DATE MAILED: 05/26/2020

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 30 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	**Application No.** 16/788,498	**Applicant(s)** Reed et al.	
	Examiner AJIT PATEL	**Art Unit** 2416	**AIA (FITF) Status** No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1.☑ This communication is responsive to 2/12/20.

☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on ______.

2.☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on ______; the restriction requirement and election have been incorporated into this action.

3.☑ The allowed claim(s) is/are 1,3-6,9-18,20-21,23-27 and 29-30 . As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see **http://www.uspto.gov/patents/init_events/pph/index.jsp** or send an inquiry to **PPHfeedback@uspto.gov.**

4.☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a) ☐All b) ☐ Some *c) ☐ None of the:

1. ☐ Certified copies of the priority documents have been received.
2. ☐ Certified copies of the priority documents have been received in Application No. ______ .
3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

* Certified copies not received: ______ .

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5.☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.

☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date ______ .

Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6.☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1.☑ Notice of References Cited (PTO-892)
2.☑ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date ______.
3.☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material ______.
4.☑ Interview Summary (PTO-413), Paper No./Mail Date. ______.
5. ☑ Examiner's Amendment/Comment
6. ☑ Examiner's Statement of Reasons for Allowance
7. ☐ Other ______.

/AJIT PATEL/
Primary Examiner, Art Unit 2416

DETAILED ACTION

Notice of Pre-AIA or AIA Status

1. The present application is being examined under the pre-AIA first to invent provisions.

EXAMINER'S AMENDMENT

2. An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

Authorization for this examiner's amendment was given in an interview with Mr. Harris on 5/18/20.

3. The application has been amended as follows:

1. (Currently amended) A wireless communications system including:

a first radio-frequency transceiver within a wireless mobile communications device and an associated first antenna to which the first radio-frequency transceiver is coupled, wherein the first radio-frequency transceiver is configured for radio-frequency communication with a wireless communications network;

a first processor within the wireless mobile communications device coupled to the at least one first radio-frequency transceiver programmed to receive information indicative of a location of the wireless mobile communications device ~~from the wireless communications network~~ and generate an indication of a location of the wireless mobile communications device with respect to geographic features according to mapping information stored within the wireless mobile communications device, and wherein the first processor determines user navigation information and displays ~~to~~ the user navigation information according to the location of the wireless mobile communications device with respect to the geographic features and a destination specified ~~by the user~~ at the wireless mobile communications device, wherein the first processor further sends the user navigation information to the network as a number of segments, wherein at least one other processor outside the network updates the user navigation information in conformity with traffic congestion information accessible to the at least one other processor outside the network by computing a numerical value for the segments corresponding to the expected time to travel through the segments, updates the user navigation information in conformity with the numerical values for the segments, and sends the updated user navigation information to the wireless mobile communications device;

at least one second radio-frequency transceiver and an associated at least one second antenna of the wireless communications network to which the second radio-frequency transceiver is coupled; and

a second processor coupled to the at least one second radio-frequency transceiver programmed to acquire the information indicative of a location of the wireless mobile communications device, wherein the second processor selectively acquires the information indicative of a location of the wireless mobile communications device dependent on the setting of preference flags, wherein the second processor acquires the information indicative of a location of the wireless mobile communications device if the preference flags are set to a state that permits tracking ~~of the user~~ of the wireless mobile communications device, and wherein the second processor does not acquire the information indicative of the location of the wireless mobile communications device if the preference flags are set to a state that prohibits tracking of the wireless mobile communications device.

2. (Canceled)

3. (Currently Amended) The wireless communications system of Claim 1, wherein the first processor is further programmed to:

determine whether or not the mapping information stored within the wireless mobile communications device is sufficient to display the navigation information ~~to the user~~;

responsive to the first processor determining that the mapping information is sufficient, the processor displaying the navigation information ~~to the user~~;

responsive to the first processor determining that the mapping information is not sufficient, the first processor requesting additional mapping information from at least one other processor outside the wireless communications network; and

responsive to the first processor requesting additional mapping information from at least one other processor outside the wireless communications network, the first processor receiving the additional mapping information from the at least one other processor outside the wireless communications network and the first processor displaying the navigation information ~~to the user~~ using the additional mapping information.

4. (Original) The wireless communications system of Claim 3, wherein the first processor further updates the mapping information stored within the wireless mobile communications device with the additional information received from the wireless communications network.

5. (Currently Amended) The wireless communications system of Claim 4, wherein the first processor, responsive to not receiving the additional mapping information from the wireless communications network, ~~displaying~~ displays a notice ~~to the user~~ that the destination could not be found.

6. (Original) The wireless communications system of Claim 2, wherein the first processor further requests from the wireless communications network, traffic congestion information, wherein the first processor receives the requested traffic congestion information and determines the user navigation information in conformity with the received traffic congestion information.

Claims 7-8 are canceled.

9. (Currently Amended) The wireless communications system of Claim 1~~7~~, wherein the another processor determines whether or not the updated user navigation information already exists in the wireless mobile communications device, and does not transmit the updated user navigation information to the wireless mobile communications device if the

updated user navigation information already exists in the wireless mobile communications device.

10. (Original) The wireless communications system of Claim 1, wherein the first processor further sends the indication of a location of the wireless mobile communications device with respect to the geographic features to the network, wherein at least one other processor outside the network receives the indication of a location of the wireless mobile communications device, determines the user navigation information in conformity with the location of the wireless mobile communications device and transmits the user navigation information to the wireless mobile communications device.

11. (Original) The wireless communications system of Claim 1, wherein the preference flags are specified by ~~the user of~~ the wireless mobile communications device and transmitted to the at least one second radio-frequency transceiver.

12. (Original) The wireless communications system of Claim 1, wherein the preference flags have more than two states including at least: a first state that prohibits tracking of the mobile wireless communications device, a second state that permits open access to the location of the wireless mobile communications device and information associated with the wireless mobile communications device, and a third state that provides access to the information indicative of the location of the wireless mobile communications device but not information associated with the wireless mobile communications device other than a generic identifier, and wherein the second processor provides information

about ~~the~~ a user of the wireless mobile communications device to at least one other processor outside the network in conformity with permissions specified by the preference flags.

13. (Currently Amended) The wireless communications system of Claim 12, wherein the preference flags have more than three states, including at least a fourth state that provides access to the location of the wireless mobile communications device and demographic information associated with the wireless mobile communications device, but not a name of the user associated with the wireless mobile communications device or other private information.

14. (Currently Amended) A method of providing navigation information within a wireless communications network, the method comprising:

at a wireless mobile communications device coupled to the wireless communications network and having a first radio-frequency transceiver coupled to an associated first antenna, receiving information indicative of a location of the mobile wireless communications device;

within the wireless mobile communications device, a first processor within the wireless mobile communications device coupled to the first radio-frequency transceiver generating an indication of a location of the at least one wireless mobile communications device with respect to geographic features according to mapping information retrieved from a storage within the wireless mobile communications device;

the first processor determining user navigation information;

sending the user navigation information to the at least one other processor outside the network as a number of segments;

at a remote location within the at least one other processor outside the network, updating the user navigation information in conformity with traffic congestion information accessible to the remote location within the network by computing a numerical value for the segments corresponding to the expected time to travel through the segments, and wherein the updating is performed in conformity with the numerical values for the number of segments;

sending the updated user navigation information to the wireless mobile communications device;

the first processor displaying ~~to the user~~ the user navigation information according to the location of the wireless mobile communications device with respect to the geographic features and a destination specified by ~~the user at~~ the wireless mobile communications device;

within the wireless communications network, a second processor coupled to at least one second radio-frequency transceiver coupled to an associated second antenna selectively acquiring the information indicative of a location of the wireless mobile communication device in dependence on a setting of preference flags, wherein the selectively acquiring the information indicative of a location of the wireless mobile communications device if the preference flags are set to a state that permits tracking of the user of the wireless mobile communications device, and wherein the selectively determining does not acquire the information indicative of a location of the wireless mobile communications device if the preference flags are set to a state that prohibits tracking of the wireless mobile communications device.

15. (Original)The method of Claim 14, further comprising within the wireless mobile communications device, determining the user navigation information.

16. (Currently Amended) The method of Claim 15, further comprising:

within the wireless mobile communications device, determining whether or not the mapping information stored within the wireless mobile communications device is sufficient to display the navigation information ~~to the user~~;

responsive to determining that the mapping information is sufficient, displaying the navigation information ~~to the user~~;

responsive to determining that the mapping information is not sufficient, requesting additional mapping information from at least one other processor outside the wireless communications network; and

responsive to the requesting additional mapping information from the at least one other processor outside the wireless communications network, receiving the additional mapping information from the at least one other processor outside the wireless communications network and displaying the navigation information ~~to the user~~ using the additional mapping information.

17. (Original) The method of Claim 16, further comprising updating the mapping information stored within the wireless mobile communications device with the additional information received from the at least one other processor outside the wireless communications network.

18. (Currently Amended) The method of Claim 16, further comprising responsive to not receiving the additional mapping information from the at least one other processor outside the wireless communications network, displaying a notice ~~to the user~~ that the destination could not be found.

19. (Canceled)

20. (Original) The method of Claim 19, further comprising, at the remote location, determining whether or not the updated user navigation information already exists in the wireless mobile communications device, and wherein the transmitting of the updated user navigation information is not performed if the updated user navigation information already exists in the wireless mobile communications device.

21. (Original) The method of Claim 14, further comprising:

requesting from the at least one other processor outside the wireless communications network, traffic congestion information;

receiving the requested traffic congestion information at the mobile wireless communications device; and

determining the user navigation information in conformity with the received traffic congestion information.

22. (Canceled)

23. (Original) The method of Claim 14, further comprising:

at the wireless mobile communications device, sending the location of the wireless mobile communications device with respect to the geographic features to at least one other processor outside the network;

receiving the location of the wireless mobile communications device at the at least one other processor outside the network; and

at a remote at least one other processor outside the network, determining the user navigation information in conformity with the location of the wireless mobile communications device; and transmitting the user navigation information to the wireless mobile communications device.

24. (Currently Amended) The method of Claim 14, wherein the preference flags are specified by ~~the~~ a user associated with ~~of~~ the wireless mobile communications device, and wherein the method further comprises transmitting the preference flags to the at least one second radio-frequency transceiver.

25. (Currently Amended) The method of Claim 14, wherein the preference flags have more than two states including at least: a first state that prohibits tracking of the mobile wireless communications device, a second state that permits open access to the location of the wireless mobile communications device and information associated with the wireless mobile communications device, and a third state that provides access to the location of the wireless mobile communications device but not information associated with the wireless mobile communications device other than a generic identifier, and wherein method further comprises the second processor providing information about a ~~the~~ user ~~of~~ associated with the wireless mobile communications device to at least one other processor outside the wireless network in conformity with permissions specified by the preference flags.

26. (Original) The method of Claim 25, wherein the preference flags have more than three states, including at least a fourth state that provides access to the location of the wireless mobile communications device and demographic information associated with

the wireless mobile communications device, but not a name of the user associated with the wireless mobile communications device or other private information.

27. (Currently Amended) A wireless mobile communications device including:

a radio-frequency transceiver and an associated antenna to which the radio-frequency transceiver is coupled, wherein the radio-frequency transceiver is configured for radio-frequency communication with a wireless communications network; and

a first processor coupled to the at least one radio-frequency transceiver programmed to receive a location of the wireless mobile communications device and generate an indication of a location of the at least one wireless mobile communications device with respect to geographic features according to mapping information stored within the wireless mobile communications device, wherein the first processor determines whether or not the mapping information stored within the wireless mobile communications device is sufficient to display the navigation information to the user, responsive to the first processor determining that the mapping information is not sufficient, the first processor requesting additional mapping information from at least one other processor outside the wireless communications network and responsive to the first processor requesting additional mapping information from the at least one other processor outside the wireless communications network, receiving the additional mapping information from the at least one other processor outside the wireless communications network and updating the mapping information stored within the wireless mobile communications device, wherein the first processor determines and displays the navigation information to the user using the additional mapping information, the location of the wireless mobile communications device with respect to the geographic features and a destination specified by the user at the wireless mobile communications device, and wherein the first processor communicates to the mobile communications network a setting of preference flags, wherein the first processor further sends the user navigation information to the at least one other processor outside of the network, wherein the at least one other processor outside of the network updates the user navigation information in conformity with traffic congestion information accessible to the other processor coupled to the network and transmits the updated user navigation information to the mobile device, wherein the first processor further sends the user navigation information to the at least one other processor outside of the network as a number of segments, and wherein the at least one other processor outside of the network computes a numerical value for each segment corresponding to the expected time to travel through the segment and wherein the user navigation information is updated in conformity with the numerical values for the number of segments, wherein ~~whereby~~ the mobile communications network selectively acquires information indicative of a location of the mobile communications device and communicates the information indicative of a location of the wireless mobile communications device to the wireless mobile communications device dependent on the setting of the preference flags, wherein if the preference flags are set to a state that permits tracking of the user of the wireless mobile communications device the at least one other processor outside the wireless communications network receives the location of the wireless mobile communications device, and wherein if the preference flags are set to a state that prohibits tracking of the wireless mobile communications device, the at least one other processor outside the wireless communications network does not receive the location of the wireless mobile communications device.

28. (Canceled).

29. (Currently Amended) The wireless mobile communications device of Claim 27 ~~28~~, wherein the another processor determines whether or not the updated user navigation information already exists in the wireless mobile communications device, and does not transmit the updated user navigation information to the mobile device if the updated user navigation information already exists in the wireless mobile communications device.

30. (Original) The wireless mobile communications device of Claim 27, wherein the preference flags have more than two states including at least: a first state that prohibits tracking of the mobile wireless communications device, a second state that permits open access to the location of the wireless mobile communications device and information associated with the wireless mobile communications device, and a third state that provides access to the location of the wireless mobile communications device but not information associated with the wireless mobile communications device other than a generic identifier, whereby the wireless communications network processor provides information about the user of the wireless mobile communications device in conformity with permissions specified by the preference flags.

EXAMINER'S AMENDMENT

Allowable Subject Matter

4. The following is an examiner's statement of reasons for allowance: The prior art of Stilp fail to disclose

1. A wireless communications system including:

a first radio-frequency transceiver within a wireless mobile communications device and an associated first antenna to which the first radio-frequency transceiver is coupled, wherein the first radio-frequency transceiver is configured for radio-frequency communication with a wireless communications network;

a first processor within the wireless mobile communications device coupled to the at least one first radio-frequency transceiver programmed to receive information indicative of a location of the wireless mobile communications device and generate an indication of a location of the wireless mobile communications device with respect to geographic features according to mapping information stored within the wireless mobile communications device, and wherein the first processor determines user navigation information and displays the user navigation information according to the location of the wireless mobile communications device with respect to the geographic features and a destination specified at the wireless mobile communications device, wherein the first processor further sends the user navigation information to the network as a number of segments, wherein at least one other processor outside the network updates the user navigation information in conformity with traffic congestion information accessible to the at least one other processor outside the network by computing a numerical value for the segments corresponding to the expected time to travel through the segments, updates the user navigation information in conformity with the numerical values for the segments, and sends the updated user navigation information to the wireless mobile communications device;

at least one second radio-frequency transceiver and an associated at least one second antenna of the wireless communications network to which the second radio-frequency transceiver is coupled; and

a second processor coupled to the at least one second radio-frequency transceiver programmed to acquire the information indicative of a location of the wireless mobile communications device, wherein the second processor selectively acquires the information indicative of a location of the wireless mobile communications device dependent on the setting of preference flags, wherein the second processor acquires the information indicative of a location of the wireless mobile communications device if the preference flags are set to a state that permits tracking of the wireless mobile communications device, and wherein the second processor does not acquire the information indicative of the location of the wireless mobile communications device if the preference flags are set to a state that prohibits tracking of the wireless mobile communications device.

14. A method of providing navigation information within a wireless communications network, the method comprising:

at a wireless mobile communications device coupled to the wireless communications network and having a first radio-frequency transceiver coupled to an associated first antenna, receiving information indicative of a location of the mobile wireless communications device;

within the wireless mobile communications device, a first processor within the wireless mobile communications device coupled to the first radio-frequency transceiver generating an indication of a location of the at least one wireless mobile communications device with respect to geographic features according to mapping information retrieved from a storage within the wireless mobile communications device;

the first processor determining user navigation information;

sending the user navigation information to the at least one other processor outside the network as a number of segments;

at a remote location within the at least one other processor outside the network, updating the user navigation information in conformity with traffic congestion information accessible to the remote location within the network by computing a numerical value for the segments corresponding to the expected time to travel through the segments, and wherein the updating is performed in conformity with the numerical values for the number of segments;

sending the updated user navigation information to the wireless mobile communications device;

the first processor displaying the user navigation information according to the location of the wireless mobile communications device with respect to the geographic features and a destination specified by the wireless mobile communications device;

within the wireless communications network, a second processor coupled to at least one second radio-frequency transceiver coupled to an associated second antenna selectively acquiring the information indicative of a location of the wireless mobile communication device in dependence on a setting of preference flags, wherein the selectively acquiring the information indicative of a location of the wireless mobile communications device if the preference flags are set to a state that permits tracking of the user of the wireless mobile communications device, and wherein the selectively determining does not acquire the information indicative of a location of the wireless mobile communications device if the preference flags are set to a state that prohibits tracking of the wireless mobile communications device.

27. A wireless mobile communications device including:

a radio-frequency transceiver and an associated antenna to which the radio-frequency transceiver is coupled, wherein the radio-frequency transceiver is configured for radio-frequency communication with a wireless communications network; and

a first processor coupled to the at least one radio-frequency transceiver programmed to receive a location of the wireless mobile communications device and generate an indication of a location of the at least one wireless mobile communications device with respect to geographic features according to mapping information stored within the wireless mobile communications device, wherein the first processor determines whether or not the mapping information stored within the wireless mobile communications device is sufficient to display the navigation information to the user, responsive to the first processor determining that the mapping information is not sufficient, the first processor requesting additional mapping information from at least one other processor outside the wireless communications network and responsive to the first processor requesting additional mapping information from the at least one other processor outside the wireless communications network, receiving the additional mapping information from the at least one other processor outside the wireless communications network and updating the mapping information stored within the wireless mobile communications device, wherein the first processor determines and displays the navigation information to the user using the additional mapping information, the location of the wireless mobile communications device with respect to the geographic features and a destination specified by the user at the wireless mobile communications device, and wherein the first processor communicates to the mobile communications network a setting of preference flags, wherein the first processor further sends the user navigation information to the at least one other processor outside of the network, wherein the at least one other processor outside of the network updates the user navigation information in conformity with traffic congestion information accessible to the other processor coupled to the network and transmits the updated user navigation information to the mobile device, wherein the first processor further sends the user navigation information to the at least one other processor outside of the network as a number of segments, and wherein the at least one other processor outside of the network computes a numerical value for each segment corresponding to the expected time to travel through the segment and wherein the user navigation information is updated in conformity with the numerical values for the number of segments, wherein the mobile communications network selectively acquires information indicative of a location of the mobile communications device and communicates the information indicative of a location of the wireless mobile communications device to the wireless mobile communications device dependent on the setting of the preference flags, wherein if the preference flags are set to a state that permits tracking of the user of the wireless mobile communications device the at least one other processor outside the wireless communications network receives the location of the wireless mobile communications device, and wherein if the preference flags are set to a state that prohibits tracking of the wireless mobile communications device, the at least one other processor outside the wireless communications network does not receive the location of the wireless mobile communications device.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Conclusion

5. Any inquiry concerning this communication or earlier communications from the examiner should be directed to AJIT PATEL whose telephone number is (571)272-3140. The examiner can normally be reached on Monday-Friday 9AM-5PM.

Examiner interviews are available via telephone, in-person, and video conferencing using a USPTO supplied web-based collaboration tool. To schedule an interview, applicant is encouraged to use the USPTO Automated Interview Request (AIR) at http://www.uspto.gov/interviewpractice.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, NOEL BEHARRY can be reached on 571-270-5630. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see https://ppair-my.uspto.gov/pair/PrivatePair. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/AJIT PATEL/
Primary Examiner, Art Unit 2416

Examiner-Initiated Interview Summary	**Application No.** 16/788,498	**Applicant(s)** Reed et al.	
	Examiner AJIT PATEL	**Art Unit** 2416	**AIA (FITF) Status** No

All participants (applicant, applicant's representative, PTO personnel):

(1) AJIT PATEL.

(3) _____.

(2) Mr. M. Harris.

(4) _____.

Date of Interview: 18 May 2020.

Type: ☑ Telephonic ☐ Video Conference
☐ Personal [copy given to: ☐ applicant ☐ applicant's representative]

Exhibit shown or demonstration conducted: ☐ Yes ☑ No.
If Yes, brief description: _____.

Issues Discussed ☐ 101 ☐ 112 ☐ 102 ☐ 103 ☑ Others
(For each of the checked box(es) above, please describe below the issue and detailed description of the discussion)

Claim(s) discussed: 1-30.

Identification of prior art discussed: N/A.

Substance of Interview
(For each issue discussed, provide a detailed description and indicate if agreement was reached. Some topics may include: identification or clarification of a reference or a portion thereof, claim interpretation, proposed amendments, arguments of any applied references etc...)

The examiner and the attorney discussed about the allowable subject matter in the dependent claims. The attorney agreed to incorporate the allowable subject matter in all independent claims and authorized the examiner's amendment. The attorney also agreed to file the TD related to U. S. Pat. # 9549388..

Applicant recordation instructions: It is not necessary for applicant to provide a separate record of the substance of interview.

Examiner recordation instructions: Examiners must summarize the substance of any interview of record. A complete and proper recordation of the substance of an interview should include the items listed in MPEP 713.04 for complete and proper recordation including the identification of the general thrust of each argument or issue discussed, a general indication of any other pertinent matters discussed regarding patentability and the general results or outcome of the interview, to include an indication as to whether or not agreement was reached on the issues raised.

☐ Attachment

/AJIT PATEL/
Primary Examiner, Art Unit 2416

# Notice of References Cited	Application/Control No. 16/788,498	Applicant(s)/Patent Under Reexamination Reed et al.	
	Examiner AJIT PATEL	Art Unit 2416	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	CPC Classification	US Classification
*	A	US-6492944-B1	12-2002	Stilp; Louis A.	G01S5/0284	342/387
	B					
	C					
	D					
	E					
	F					
	G					
	H					
	I					
	J					
	K					
	L					
	M					

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	CPC Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Issue Classification

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/788,498	Reed et al.
	Examiner	**Art Unit**
	AJIT PATEL	2416

CPC

Symbol					Type	Version
H04W	/	4	/	023	F	2013-01-01
H04W	/	4	/	02	I	2013-01-01
H04W	/	8	/	02	I	2013-01-01
G01S	/	5	/	0252	I	2013-01-01
H04W	/	24	/	02	I	2013-01-01
H04B	/	17	/	318	I	2015-01-15
H04W	/	4	/	029	I	2018-02-01
H04W	/	64	/	006	I	2013-01-01

CPC Combination Sets

Symbol					Type	Set	Ranking	Version
	/		/					

NONE (Assistant Examiner) (Date)	**Total Claims Allowed:** 24	
/AJIT PATEL/ Primary Examiner, Art Unit 2416 20 May 2020 (Primary Examiner) (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 9

U.S. Patent and Trademark Office Part of Paper No.: 20200518

Issue Classification	Application/Control No. 16/788,498	Applicant(s)/Patent Under Reexamination Reed et al.
	Examiner AJIT PATEL	Art Unit 2416

INTERNATIONAL CLASSIFICATION				
CLAIMED				
H04W	/	4	/	02
H04W	/	4	/	029

NON-CLAIMED				
	/		/	

US ORIGINAL CLASSIFICATION	
CLASS	SUBCLASS

CROSS REFERENCES(S)						
CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)					

NONE (Assistant Examiner) (Date)		Total Claims Allowed: 24	
/AJIT PATEL/ Primary Examiner, Art Unit 2416 (Primary Examiner)	20 May 2020 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 9

U.S. Patent and Trademark Office

Part of Paper No.: 20200518

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/788,498	Reed et al.
	Examiner	Art Unit
	AJIT PATEL	2416

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☑ T.D. ☐ R.1.47

CLAIMS

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
1	1	7	10		19		28								
	2	8	11	16	20	23	29								
2	3	9	12	17	21	24	30								
3	4	10	13		22										
4	5	11	14	18	23										
5	6	12	15	19	24										
	7	13	16	20	25										
	8	14	17	21	26										
6	9	15	18	22	27										

NONE (Assistant Examiner)	(Date)	**Total Claims Allowed:** 24	
/AJIT PATEL/ Primary Examiner, Art Unit 2416 (Primary Examiner)	20 May 2020 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 9

U.S. Patent and Trademark Office

Part of Paper No.: 20200518

Search Notes

Application/Control No.	Applicant(s)/Patent Under Reexamination
16/788,498	Reed et al.
Examiner	**Art Unit**
AJIT PATEL	2416

CPC - Searched*		
Symbol	**Date**	**Examiner**

CPC Combination Sets - Searched*		
Symbol	**Date**	**Examiner**

US Classification - Searched*			
Class	**Subclass**	**Date**	**Examiner**

* See search history printout included with this form or the SEARCH NOTES box below to determine the scope of the search.

Search Notes		
Search Notes	**Date**	**Examiner**
IPR2019-00324 Reviewed Petition for Inter Partes Review of U.S.Patent No. 9,642,024.	05/07/2020	AP
IPR2019-00326 Reviewed Petition for Inter Partes Review of U.S.Patent No. 9,510,320.	05/07/2020	AP
IPR2019-00327 Reviewed Petition for Inter Partes Review of U.S.Patent No. 8,977,284.	05/07/2020	AP
Inventor name searched	05/20/2020	AP
H04W4/023;H04W64/006;H04W24/02;G01S5/0252;H04W4/029; H04W4/02;H04W8/02;H04B17/318-LIMITED SEARCHED	05/20/2020	AP
(H04W$/$).CPC.-LIMITED SEARCHED	05/20/2020	AP
(H04B$/$).CPC.-LIMITED SEARCHED	05/20/2020	AP
(G01S$/$).CPC.-LIMITED SEARCHED	05/20/2020	AP
EAST	05/20/2020	AP

Search Notes	Application/Control No. 16/788,498	Applicant(s)/Patent Under Reexamination Reed et al.
	Examiner AJIT PATEL	Art Unit 2416

Interference Search			
US Class/CPC Symbol	US Subclass/CPC Group	Date	Examiner
	See EAST for interference searched	05/20/2020	AP

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	202705	(H04W4/023 or H04W64/006 or H04W24/02 or G01S5/0252 or H04W4/029 or H04W4/02 or H04W8/02 or H04B17/318).cpc.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/20 19:27
L2	32	(Stephen near2 Palik).in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/20 19:30
L3	773	(Mark near2 Reed).in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/20 19:30
L4	1	2 and (geographic and location and map$5 and flag and state and track$5 and permit and prohibit)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/20 19:33
L5	1	3 and (geographic and location and map$5 and flag and state and track$5 and permit and prohibit)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/20 19:34
L6	8192	1 and @ad<"20011004"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/20 19:35
L7	162	6 and ((location or position) same (device or mobile or wtru or station or ue or (user adj equipment) or phone or apparatus) same map$3 same stor$4)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/20 19:41

L8	0	7 and (navigat$5 same information same number same segment same value same expected same time same travel)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/20 19:43
L9	0	7 and (set$4 same flag same preference same (location or position) same track$4 same permit$5 same prohibit$4)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/20 19:45
L10	1	6 and (set$4 same flag same preference same (location or position) same track$4 same permit$5 same prohibit$4)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/20 19:45
L11	0	10 and (navigat$5 same information same number same segment same value same expected same time same travel)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/20 19:47
L12	1691811	(H04W$/$).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/20 19:49
L13	955752	(H04B$/$).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/20 19:50
L14	502699	(G01S$/$).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/20 19:50
L15	2821006	12 OR 13 OR 14	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/20 19:51

L16	525281	15 and @ad<"20011004"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/20 19:51
L17	1238	16 and ((location or position) same (device or mobile or wtru or station or ue or (user adj equipment) or phone or apparatus) same map$3 same stor$4)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/20 19:52
L18	0	17 and (navigat$5 same information same number same segment same value same expected same time same travel)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/20 19:53
L19	0	17 and (set$4 same flag same preference same (location or position) same track$4 same permit$5 same prohibit$4)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/20 19:54
L20	1	16 and (set$4 same flag same preference same (location or position) same track$4 same permit$5 same prohibit$4)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/20 19:54
L21	0	20 and (navigat$5 same information same number same segment same value same expected same time same travel)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/20 19:56
L22	59	16 and ((location or position) same (device or mobile or wtru or station or ue or (user adj equipment) or phone or apparatus) same map$3 same stor$4 same user same navigation same information)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/20 19:59
L23	0	22 and (traffic same congestion same navigation same information same segment same travel same update)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/20 20:01

L24	0	22 and ((location or position) same (device or mobile or wtru or station or ue or (user adj equipment) or phone or apparatus) same preference same flag same track$5 same set$4)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/20 20:03

EAST Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L25	2667	(generat$4 same location same map$4 same information same stor$4).clm.	US-PGPUB; USPAT	OR	ON	2020/05/20 20:05
L26	105	(geographic same information same location same display same destination).clm.	US-PGPUB; USPAT	OR	ON	2020/05/20 20:07
L27	2	(navigation same information same traffic same congestion same travel same segment same update same numerical same value).clm.	US-PGPUB; USPAT	OR	ON	2020/05/20 20:09
L28	1	(set$4 same location same preference same flag same permit same prohibit).clm.	US-PGPUB; USPAT	OR	ON	2020/05/20 20:10
L29	1	25 and 26 and 27 and 28	US-PGPUB; USPAT	OR	ON	2020/05/20 20:11

5/20/2020 8:11:59 PM

Doc Code: DIST.E.FILE **Document Description: Electronic Terminal Disclaimer - Filed**	PTO/SB/26 U.S. Patent and Trademark Office Department of Commerce

Electronic Petition Request	**TERMINAL DISCLAIMER TO OBVIATE A DOUBLE PATENTING REJECTION OVER A "PRIOR" PATENT**
Application Number	16788498
Filing Date	12-Feb-2020
First Named Inventor	Mark Reed
Attorney Docket Number	TX1000-C12
Title of Invention	MOBILE WIRELESS DEVICE PROVIDING OFF-LINE AND ON-LINE GEOGRAPHIC NAVIGATION INFORMATION

☒ Filing of terminal disclaimer does not obviate requirement for response under 37 CFR 1.111 to outstanding Office Action

☒ This electronic Terminal Disclaimer is not being used for a Joint Research Agreement.

Owner	Percent Interest
Traxcell Technologies, LLC	100%

The owner(s) with percent interest listed above in the instant application hereby disclaims, except as provided below, the terminal part of the statutory term of any patent granted on the instant application which would extend beyond the expiration date of the full statutory term of prior patent number(s)

9549388

as the term of said prior patent is presently shortened by any terminal disclaimer. The owner hereby agrees that any patent so granted on the instant application shall be enforceable only for and during such period that it and the prior patent are commonly owned. This agreement runs with any patent granted on the instant application and is binding upon the grantee, its successors or assigns.

In making the above disclaimer, the owner does not disclaim the terminal part of the term of any patent granted on the instant application that would extend to the expiration date of the full statutory term of the prior patent, "as the term of said prior patent is presently shortened by any terminal disclaimer," in the event that said prior patent later:
- expires for failure to pay a maintenance fee;
- is held unenforceable;
- is found invalid by a court of competent jurisdiction;
- is statutorily disclaimed in whole or terminally disclaimed under 37 CFR 1.321;
- has all claims canceled by a reexamination certificate;
- is reissued; or
- is in any manner terminated prior to the expiration of its full statutory term as presently shortened by any terminal disclaimer.

◉ Terminal disclaimer fee under 37 CFR 1.20(d) is included with Electronic Terminal Disclaimer request.

- ○ I certify, in accordance with 37 CFR 1.4(d)(4), that the terminal disclaimer fee under 37 CFR 1.20(d) required for this terminal disclaimer has already been paid in the above-identified application.

Applicant claims the following fee status:

- ◉ Small Entity
- ○ Micro Entity
- ○ Regular Undiscounted

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

THIS PORTION MUST BE COMPLETED BY THE SIGNATORY OR SIGNATORIES

I certify, in accordance with 37 CFR 1.4(d)(4) that I am:

- ◉ An attorney or agent registered to practice before the Patent and Trademark Office who is of record in this application

  Registration Number 42638

- ○ A sole inventor
- ○ A joint inventor; I certify that I am authorized to sign this submission on behalf of all of the inventors as evidenced by the power of attorney in the application
- ○ A joint inventor; all of whom are signing this request

Signature	/Andrew Mitchell Harris #42,638/
Name	Andrew Mitchell Harris

*Statement under 37 CFR 3.73(b) is required if terminal disclaimer is signed by the assignee (owner).
Form PTO/SB/96 may be used for making this certification. See MPEP § 324.

Electronic Patent Application Fee Transmittal

Application Number:	16788498
Filing Date:	12-Feb-2020
Title of Invention:	MOBILE WIRELESS DEVICE PROVIDING OFF-LINE AND ON-LINE GEOGRAPHIC NAVIGATION INFORMATION
First Named Inventor/Applicant Name:	Mark Jefferson Reed
Filer:	Andrew Mitchell Harris
Attorney Docket Number:	TX1000-C12

Filed as Small Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
STATUTORY OR TERMINAL DISCLAIMER	2814	1	160	160
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**160**

Doc Code: DISQ.E.FILE
Document Description: Electronic Terminal Disclaimer – Approved

Application No.: 16788498

Filing Date: 12-Feb-2020

Applicant/Patent under Reexamination: Reed

Electronic Terminal Disclaimer filed on May 19, 2020

☒ APPROVED

This patent is subject to a terminal disclaimer

☐ DISAPPROVED

Approved/Disapproved by: Electronic Terminal Disclaimer automatically approved by EFS-Web

U.S. Patent and Trademark Office

Electronic Acknowledgement Receipt

EFS ID:	39478577
Application Number:	16788498
International Application Number:	
Confirmation Number:	8054
Title of Invention:	MOBILE WIRELESS DEVICE PROVIDING OFF-LINE AND ON-LINE GEOGRAPHIC NAVIGATION INFORMATION
First Named Inventor/Applicant Name:	Mark Jefferson Reed
Customer Number:	59911
Filer:	Andrew Mitchell Harris
Filer Authorized By:	
Attorney Docket Number:	TX1000-C12
Receipt Date:	19-MAY-2020
Filing Date:	12-FEB-2020
Time Stamp:	12:51:39
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$160
RAM confirmation Number	E20205IC51355088
Deposit Account	
Authorized User	

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Terminal Disclaimer-Filed (Electronic)	eTerminal-Disclaimer.pdf	33722 d1282fc50d0de76141a1ced3d3a1689fdf9f3f85	no	2
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	30710 815eee9523edf23fd411fd1911a8cddc5943cdf8	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	64432		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/788,498	02/12/2020	Mark Jefferson Reed	TX1000-C12	8054

59911 7590 04/28/2020
MITCH HARRIS, LLC - GENERAL
P.O. BOX 1269
ATHENS, GA 30603-1269

EXAMINER	
NGO, RICKY QUOC	

ART UNIT	PAPER NUMBER
2464	

MAIL DATE	DELIVERY MODE
04/28/2020	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

PTOL-90A (Rev. 04/07)

Decision Granting Request for Prioritized Examination (Track I)	**Application No.** 16/788,498	**Applicant(s)** Reed et al.	
	Examiner APRIL M WISE	**Art Unit** OPET	**AIA (FITF) Status** No

1. THE REQUEST FILED 12 February 2020 IS **GRANTED** .

The above-identified application has met the requirements for prioritized examination

A. ☑ for an original nonprovisional application (Track I).

B. ☐ for an application undergoing continued examination (RCE).

2. **The above-identified application will undergo prioritized examination**. The application will be accorded special status throughout its entire course of prosecution until one of the following occurs:

A. filing a **petition for extension of time** to extend the time period for filing a reply;

B. filing an **amendment to amend the application to contain more than four independent claims, more than thirty total claims** , or a multiple dependent claim;

C. filing a **request for continued examination** ;

D. filing a notice of appeal;

E. filing a request for suspension of action;

F. mailing of a notice of allowance;

G. mailing of a final Office action;

H. completion of examination as defined in 37 CFR 41.102; or

I. abandonment of the application.

Telephone inquiries with regard to this decision should be directed to undersigned at (571)272-1642.

In his/her absence, calls may be directed to Petition Help Desk at (571) 272-3282.

/APRIL M WISE/
Paralegal Specialist, Office of Petitions

U.S. Patent and Trademark Office
PTO-2298 (Rev. 02-2012)

Attorney Docket Number: TX1000-C2

In place of PTO/SB/01

DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention:	MACHINE FOR PROVIDING A DYNAMIC DATABASE OF GEOGRAPHIC LOCATION INFORMATION FOR A PLURALITY OF WIRELESS DEVICES AND PROCESS FOR MAKING SAME

As the below named inventor, I hereby declare that:

This declaration is directed to:

☐ The attached application, or

☒ United States application or PCT international application number 14/642,408 filed on 3/9/2015.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I acknowledge the duty to disclose to the Patent and Trademark Office all information known to me to be material to patentability of the subject matter claimed in this application, as "materiality" is defined in 37 C.F.R. 1.56, which I understand includes information that is not cumulative to information already of record, or being made of record in the application, and that (1) establishes, by itself or in combination with other information, a prima facie case of unpatentability of a claim; or (2) refutes, or is inconsistent with, a position the applicant takes in: (i) opposing an argument of unpatentability relied on by the Patent Office, or (ii) asserting an argument of patentability.

I DECLARE THAT ALL STATEMENTS MADE OF MY OWN KNOWLEDGE ARE TRUE AND THAT ALL STATEMENTS MADE ON INFORMATION AND BELIEF ARE BELIEVED TO BE TRUE; AND FURTHER THAT THESE STATEMENTS WERE MADE WITH THE KNOWLEDGE THAT WILLFUL FALSE STATEMENTS AND THE LIKE SO MADE ARE PUNISHABLE BY FINE OR IMPRISONMENT, OR BOTH, UNDER SECTION 1001 OF TITLE 18 OF THE UNITED STATES CODE AND THAT SUCH WILLFUL FALSE STATEMENTS MAY JEOPARDIZE THE VALIDITY OF THE APPLICATION OR ANY PATENT ISSUED THEREON.

LEGAL NAME OF INVENTOR

Inventor: Stephen Michael Palik Date: 8/2/2015

Signature: [signature]

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

Electronic Acknowledgement Receipt

EFS ID:	39202244
Application Number:	16788498
International Application Number:	
Confirmation Number:	8054
Title of Invention:	MOBILE WIRELESS DEVICE PROVIDING OFF-LINE AND ON-LINE GEOGRAPHIC NAVIGATION INFORMATION
First Named Inventor/Applicant Name:	Mark Jefferson Reed
Customer Number:	59911
Filer:	Andrew Mitchell Harris
Filer Authorized By:	
Attorney Docket Number:	TX1000-C12
Receipt Date:	20-APR-2020
Filing Date:	12-FEB-2020
Time Stamp:	11:44:31
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Oath or Declaration filed	TX1000-C2_Declaration_Palik_signed.pdf	27517 b5c9d488bacc25aef1b51ce63ca3d6ea236a9c87	no	1

Warnings:

The page size in the PDF is too large. The pages should be 8.5 x 11 or A4. If this PDF is submitted, the pages will be resized upon entry into the Image File Wrapper and may affect subsequent processing	
Information:	
Total Files Size (in bytes):	27517

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

United States Patent and Trademark Office

Office of the Chief Financial Officer

Document Code:WFEE

User :C46153

Sale Accounting Date:04/15/2020

Sale Item Reference Number	Effective Date
16788498	02/12/2020

Document Number	Fee Code	Fee Code Description	Amount Paid	Payment Method
I20204EC22041461	2051	LATE FILING FEE FOR OATH OR DECLARATION	$80.00	Deposit Account

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
16/788,498	02/12/2020		1965	TX1000-C12	30	3

CONFIRMATION NO. 8054

FILING RECEIPT

OC000000116271273

59911
MITCH HARRIS, LLC - GENERAL
P.O. BOX 1269
ATHENS, GA 30603-1269

Date Mailed: 04/15/2020

Receipt is acknowledged of this non-provisional utility patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF FIRST INVENTOR, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection.

Please verify the accuracy of the data presented on this receipt. If an error is noted on this Filing Receipt, please submit a written request for a corrected Filing Receipt, including a properly marked-up ADS showing the changes with strike-through for deletions and underlining for additions. If you received a "Notice to File Missing Parts" or other Notice requiring a response for this application, please submit any request for correction to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections provided that the request is grantable.

Inventor(s)

Mark Jefferson Reed, Tucson, AZ;
Stephen Michael Palik, Redondo Beach, CA;

Applicant(s)

Traxcell Technologies, LLC, Plano, TX;

Power of Attorney: The patent practitioners associated with Customer Number 59911

Domestic Priority data as claimed by applicant

This application is a CON of 16/557,277 08/30/2019
which is a CON of 16/116,215 08/29/2018 PAT 10448209
which is a CON of 15/880,852 01/26/2018 PAT 10390175
which is a CON of 15/717,138 09/27/2017 PAT 9918196
which is a CON of 15/468,265 03/24/2017 PAT 9888353
which is a CON of 15/297,222 10/19/2016 PAT 9642024
which is a CON of 14/642,408 03/09/2015 PAT 9510320
which is a CON of 11/505,578 08/17/2006 PAT 8977284
which is a CIP of 10/255,552 09/24/2002 ABN
which claims benefit of 60/383,528 05/28/2002
and claims benefit of 60/352,761 01/29/2002
and claims benefit of 60/335,203 10/23/2001
and claims benefit of 60/383,529 05/28/2002
and claims benefit of 60/391,469 06/26/2002
and claims benefit of 60/353,379 01/30/2002

and claims benefit of 60/381,249 05/16/2002
and claims benefit of 60/327,327 10/04/2001

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.) - None.
Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

Permission to Access Application via Priority Document Exchange: Yes

Permission to Access Search Results: Yes

Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

If Required, Foreign Filing License Granted: 04/15/2020

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 16/788,498**

Projected Publication Date: 07/23/2020

Non-Publication Request: No

Early Publication Request: No
**** SMALL ENTITY ****
Title

MOBILE WIRELESS DEVICE PROVIDING OFF-LINE AND ON-LINE GEOGRAPHIC NAVIGATION INFORMATION

Preliminary Class

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4258).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

GRANTED

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

SelectUSA

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The U.S. offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to promote and facilitate business investment. SelectUSA provides information assistance to the international investor community; serves as an ombudsman for existing and potential investors; advocates on behalf of U.S. cities, states, and regions competing for global investment; and counsels U.S. economic development organizations on investment attraction best practices. To learn more about why the United States is the best country in the world to develop technology, manufacture products, deliver services, and grow your business, visit http://www.SelectUSA.gov or call +1-202-482-6800.

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number
16/788,498

APPLICATION AS FILED - PART I

FOR	NUMBER FILED (Column 1)	NUMBER EXTRA (Column 2)	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	75		N/A	
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	330		N/A	
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	380		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	30 minus 20 =	* 10	x 50 =	500	OR		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	3 minus 3 =	*	x 230 =	0.00			
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			600			
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				0.00			
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	1885		TOTAL	

APPLICATION AS AMENDED - PART II

AMENDMENT A

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
Application Size Fee (37 CFR 1.16(s))									
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

AMENDMENT B

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	RATE($)	ADDITIONAL FEE($)	OR	RATE($)	ADDITIONAL FEE($)
Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
Application Size Fee (37 CFR 1.16(s))									
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
16/788,498	02/12/2020	Mark Jefferson Reed	TX1000-C12

CONFIRMATION NO. 8054

59911
MITCH HARRIS, LLC - GENERAL
P.O. BOX 1269
ATHENS, GA 30603-1269

INFORMAL NOTICE

OC000000116271274

Date Mailed: 04/15/2020

INFORMATIONAL NOTICE TO APPLICANT

Applicant is notified that the above-identified application contains the deficiencies noted below. No period for reply is set forth in this notice for correction of these deficiencies. However, if a deficiency relates to the inventor's oath or declaration, the applicant must file an oath or declaration in compliance with 37 CFR 1.63, or a substitute statement in compliance with 37 CFR 1.64, executed by or with respect to each actual inventor no later than the expiration of the time period set in the "Notice of Allowability" to avoid abandonment. See 37 CFR 1.53(f).

The item(s) indicated below are also required and should be submitted with any reply to this notice to avoid further processing delays.

- A properly executed inventor's oath or declaration has not been received for the following inventor(s):
  Stephen Michael Palik

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/fasrat/

Substitute for form 1449/PTO **INFORMATION DISCLOSURE STATEMENT BY APPLICANT**	**Complete if Known**	
	Application Number	**16/788,498**
	Filing Date	2/12/2020
	First Named Inventor	Reed
	Examiner Name	-- Unknown --
	Art Unit	-- Unknown --
	Attorney Docket No.	TX1000-C12

Examiner Initials		Document Number	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		US-10,390,175-B2	08-20-2019	Reed, et al.	
		US-9,888,353-B2	02-06-2018	Reed, et al.	
		US-9,642,024-B2	05-02-2017	Reed, et al.	
		US-9,549,388-B2	01-17-2017	Reed, et al.	
		US-9,510,320-B2	11-29-2016	Reed, et al.	
		US-8,977,284-B2	03-10-2015	Reed	
		US-20030134648-A1	07-17-2003	Reed	
		US-9,918,196-B2	03-13-2018	Reed, et al.	
		US-10,448,209	10-15-2019	Reed, et al.	
		US-20200015039-A1	01-09-2020	Reed, et al.	
		US-16/779,590	02-01-2020	Reed, et al.	
		US-6,931,256-B2	08-16-2005	Mandyam	
		US-6,334,047-B1	12-25-2001	Andersson, et al.	
		US-7,689,240-B2	03-30-2010	Anderson	
		US-7,120,392-B2	10-10-2006	Chu, et al.	
		US-6,157,838	12-05-2000	Di Huo, et al.	
		US-7,574,230-B1	08-11-2009	Oh, et al.	
		US-6,298,306-B1	10-02-2001	Suarez, et al.	
		US-7,634,266-B2	12-15-2009	McDougall, et al.	
		US-6,751,443-B2	06-15-2004	Haymes, et al.	
		US-7,333,820-B2	02-19-2008	Sheha, et al.	
		US-8,218,507-B2	07-10-2012	Palmer, et al.	
		US-7,853,267-B2	12-14-2010	Jensen	
		US-6,901,264	05-31-2005	Myr	
		US-3,419,865	12-31-1968	Chisholm	
		US-4,494,119	01-15-1985	Wimbush	
		US-5,873,040	02-16-1999	Dunn, et al.	
		US-5,930,515	07-27-1999	Ducharme, et al.	
		US-6,308,073-B1	10-23-2001	Petty, et al.	
		US-7,366,522-B2	04-29-2008	Thomas	
		US-6,799,049-B1	09-28-2004	Zellner, et al.	

Examiner: Date Considered:

EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

Substitute for form 1449/PTO	Complete if Known	
	Application Number	**16/788,498**
	Filing Date	2/12/2020
INFORMATION DISCLOSURE STATEMENT BY APPLICANT	First Named Inventor	Reed
	Examiner Name	-- Unknown --
	Art Unit	-- Unknown --
	Attorney Docket No.	TX1000-C12

Examiner Initials		Document Number	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		US-4,908,629	03-13-1990	Apsell, et al.	
		US-4,891,650	01-02-1990	Sheffer	
		US-6,249,252-B1	06-19-2001	Dupray	
		US-6,249,680-B1	06-19-2001	Wax, et al.	
		US-6,167,275	12-26-2000	Oros, et al.	
		US-6,091,956	07-18-2000	Hollenberg	
		US-6,633,761-B1	10-14-2003	Singhal, et al.	
		US-5,561,704	10-01-1996	Salimando	
		US-5,694,335	12-02-1997	Hollenberg	
		US-6,150,961	11-21-2000	Alewine, et al.	
		US-20150309295-A1	10-29-2015	Cocker, et al.	
		US-7,082,365-B2	07-25-2006	Sheha, et al.	
		US-20020052786-A1	05-02-2002	Kim, et al.	
		US-5,933,100	08-03-1999	Golding	
		US-6,052,598	04-18-2000	Rudrapatna, et al.	
		US-6,362,783-B1	03-26-2002	Sigiura, et al.	
		US-6,505,114-B2	01-07-2003	Luciani	
		US-6,314,365-B1	11-06-2001	Smith	
		US-6,490,521-B2	12-03-2002	Wiener	
		US-6,401,035-B2	06-04-2002	Jin	
		US-6,654,683-B2	11-25-2003	Jin, et al.	
		US-7,389,179-B2	06-17-2008	Jin, et al.	
		US-6,151,505	11-21-2000	Larkins, et al.	
		US-6,292,743-B1	09-18-2001	Pu, et al.	
		US-6,111,539	08-29-2000	Mannings, et al.	
		US-5,504,482	04-02-1996	Schreder	
		US-5,712,899	01-27-1998	Pace, II	
		US-6,295,502-B1	09-25-2001	Hancock, et al.	
		US-6,542,816-B1	04-01-2003	Ito, et al.	
		US-5,959,577	09-28-1999	Fan, et al.	
		US-6,088,594	07-11-2000	Kingdon, et al.	
		US-6,677,894-B2	01-13-2004	Sheynblat, et al.	
		US-6,603,977-B1	08-05-2003	Walsh, et al.	

Examiner: Date Considered:

EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

Substitute for form 1449/PTO	Complete if Known	
	Application Number	**16/788,498**
	Filing Date	2/12/2020
INFORMATION DISCLOSURE STATEMENT BY APPLICANT	First Named Inventor	Reed
	Examiner Name	-- Unknown --
	Art Unit	-- Unknown --
	Attorney Docket No.	TX1000-C12

Examiner Initials		Document Number	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		US-6,243,030-B1	06-05-2001	Levine	
		US-6,442,394-B1	08-27-2002	Valentine, et al.	
		US-6,950,745-B2	09-27-2005	Agnew, et al.	
		US-6,853,915-B2	02-08-2005	Hubschneider, et al.	
		US-5,911,773	06-15-1999	Mutsuga, et al.	
		US-6,163,751	12-19-2000	Van Roekel	
		US-6,278,941-B1	08-21-2001	Yokoyama	
		US-6,341,255-B1	01-22-2002	Lapidot	
		US-7,260,473-B2	08-21-2007	Abe,et al.	
		US-6,421,607-B1	07-16-2002	Gee, et al.	
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	Art Unit	-- Unknown --
	Attorney Docket No.	TX1000-C12

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		US-7,149,201-B2	12-12-2006	Hunzinger	
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		US-5,835,061	11-10-1998	Stewart	
		US-6,650,902-B1	11-18-2003	Richton	
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		US-6,014,090	01-11-2000	Rosen, et al.	
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		US-6,492,944-B1	12-10-2002	Stilp	
		US-5,519,760	05-21-1996	Borkowski, et al.	
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		US-6,317,604-B1	11-13-2001	Kovach, Jr., et al.	
		US-6,952,181-B2	10-04-2005	Karr, et al.	
		US-6,236,365-B1	05-22-2001	LeBlanc, et al.	
		US-6,961,562-B2	11-01-2005	Ross	
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		US-20040093289-A1	05-13-2004	Bodin	
		US-6,557,139-B2	04-29-2003	Bohnke	
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		US-7,689,240-B2	03-30-2010	Anderson	
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		US-7,616,950-B2	11-10-2009	Pearson, et al.	
		US-8,862,106-B2	10-14-2014	Salisbury, et al.	
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		US-7,808,369-B2	10-05-2010	Brinton, et al.	
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		US-6,804,626-B2	10-12-2004	Manegold, et al.	
		US-7,117,121-B2	10-03-2006	Brinton, et al.	
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		US-5,844,522	12-01-1998	Sheffer, et al.	
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		US-6,662,023-B1	12-09-2003	Helle	
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		US-6,466,565-B1	10-15-2002	Wax, et al.	
		US-6,111,538	08-29-2000	Schuchman, et al.	
		US-8,994,591-B2	03-31-2015	Dupray, et al.	
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		US-6,393,294-B1	05-21-2002	Perez-Breva, et al.	
		US-6,269,246-B1	07-31-2001	Rao, et al.	
		US-7,164,883-B2	01-16-2007	Rappaport, et al.	
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		US-5,799,154	08-25-1998	Kuriyan	
		US-20020152303-A1	10-17-2002	Dispensa	
		US-6,839,552-B1	01-04-2005	Martin	

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		US-7,079,945-B1	07-18-2006	Kaplan	
		US-6,374,177-B1	04-16-2002	Lee, et al.	
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		US-6,405,123-B1	06-11-2002	Rennard, et al.	
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		US-6,725,156-B2	04-20-2004	Kaplan	
		US-6,947,837-B2	09-20-2005	Fukushima, et al.	
		US-7,149,625-B2	12-12-2006	Mathews, et al.	
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		US-6,285,688-B1	09-04-2001	Henderson, et al.	
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		US-6,445,916-B1	09-03-2002	Rahman	
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		US-7,093,286-B1	08-15-2006	King	
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		US-5,706,333	01-06-1998	Grenning, et al.	
		US-6,640,101-B1	10-28-2003	Daniel	
		US-6,144,861	11-07-2000	Sundelin, et al.	
		US-20020072358-A1	06-13-2002	Schneider, et al.	
		US-6,487,394-B1	11-26-2002	Ue, et al.	
		US-6,847,916-B1	01-25-2005	Ying	
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		US-6,560,461-B1	05-06-2003	Fomukong, et al.	
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		US-5,819,177	10-06-1998	Vucetic, et al.	
		US-6,775,544-B2	08-10-2004	Ficarra	
		US-6,594,483-B2	07-15-2003	Nykanen, et al.	
		US-8,199,696-B2	06-12-2012	Sarkar, et al.	
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		US-6,070,083	05-30-2000	Watters, et al.	
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		US-6,850,766-B2	02-01-2005	Lau, et al.	
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		US-5,497,412	03-05-1996	Lannen, et al.	
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59		TX1000-C12_IDS.pdf	296622 9a79e24e0a6b087dbd80cd20171a2fe5da7bafae	yes	28

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Transmittal Letter	1	2
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(54) **Monitoring of network performances in a mobile network**

Überwachung von Netzleistungsparametern in einem mobilen Netz

Contrôle de paramétres de performance d'un réseau mobile

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Description

INTRODUCTION

[0001] 2. The present invention relates generally to a system for measuring quality of service in a wireless network. More particularly, the present invention relates to a system for measuring quality of service in a wireless network using multiple remote units and a back end processor.

BACKGROUND OF THE INVENTION

[0002] 3. There are two major technical fields that have shown explosive growth over the past few years: the first is wireless communications and the second is use of data services, particularly the Internet. These two technical fields both require a set of specialized tools in order to measure their quality of service. Interestingly, wireless communications and data services are beginning to converge. Unfortunately, this convergence has not been accompanied by the development of appropriate specialized tools to measure data quality of service in the wireless network.

[0003] 4. The growth of wireless communications has been astounding. Twenty years ago, there was virtually no use of wireless communications devices such as cellular phones. In contrast, the market penetration for wireless devices in the U.S. in 1999 was 32 percent The current forecast is that 80 percent of the U.S. population will be wireless subscribers by 2008.

[0004] 5. There are a variety of specialized tools that are used to measure quality of service over wireless networks. These include the following (just to name a few examples):

Ascom QVoice (including QVoice unattended);
Ericsson TEMS, RSAT-2000, Benchmarker, CellAD, and CeNA;
Nokia TOM;
Safco VoicePrint, DataPrint, and WalkAbout;
Comarco BaseLINE and Gen II;
Grayson Surveyor;
ZK CellTest DX136 and DXC;
Ameritec Swarm;
Neopoint Datalogger; and
Qualcomm QCTest Retriever and QCTest CAIT.

[0005] 6. The general deficiency with these tools is that they were primarily developed to measure voice quality and/or RF parameters over the wireless system and not to measure data quality. Some of them have been modified to include some rudimentary data measurements; however, they are not optimized for performing wireless data measurements. In particular, they do not allow unattended measurement of wireless data from multiple remote units in a statistically significant manner with remote control from a back end processor.

[0006] 7. The classical way of measuring voice quality of service and/or RF parameters in a wireless network involves sending out technicians to drive test the network. The drive test includes placing the test instrument in a vehicle and running a test script that either generates or receives a voice test signal. The receiving end of the communication link uses a DSP containing a model of human hearing to analyze the received voice sample and produce an associated quality score. In addition, some of the systems measure other system parameters such as SINAD, noise, distortion, received signal level, and call progress statistics.

[0007] 8. Unfortunately, the classical method of measuring voice quality of service and/or RF parameters does not function very well for measuring data quality of service. In order to make statistically significant measurements of data quality of service over a wireless network, it is necessary to make multiple measurements from multiple remote devices. Furthermore, a measurement of data quality is inherently different from the other types of measurements due to the effects of latency and other effects that are specific to data.

[0008] 9. Most of the existing measurement devices do not have this capability for a variety of reasons. The price of the test instruments range anywhere from $5K to $100K. This makes it price prohibitive to field a statistically significant fleet of remote devices. Thus, what is needed are remote devices designed for unattended operation that is remotely controlled by a back end processor in order to reduce manpower costs. Additionally, what is needed are remote devices that are optimized for performing measurements that are useful over wireless data networks, such as latency for Web page access or delay in SMS message delivery.

[0009] 10. The growth of data services has been just as astounding as the growth rate for the wireless industry. The largest driving force behind the growth of data services has been the enormous growth of the Internet. For example, there were 130 Web sites in June 1993, 230,000 Web sites in June of 1996, and 10 million Web sites at the end of 1999.

[0010] 11. There have been a variety of specialized tools developed to measure the data quality of service over the Internet.

[0011] 12. U.S. Patent No. 6,006,260 to Barrick, Jr. et al. (assigned to Keynote Systems, Inc) discloses a method for gathering latency experienced by a user over a network. The steps of the method include a user browser sending a GET command to retrieve an HTML page with an embedded Java script. The Java script starts a timer and generates a GET command to retrieve an HTML page. When the page is received, the timer is stopped and the timer information along with cookie data stored on the browser machine is sent to a relay server that logs the information.

[0012] 13. U.S. patent No. 5, 657,450 to Rao et al. teaches the provision of time estimates for long-running distal source access operations using an intermediate server close to the client workspace.

[0013] 14. U.S. patent No. 5, 796, 952 to Owen et al. discloses a method for monitoring a user's time of page browsing.

[0014] 15. U.S. patent No. 6, 012,096 to Link et al. teaches a method for monitoring client-to-client network latency for gaming applications. The method involves a ping, response, and response-response protocol.

[0015] 16. Unfortunately, none of these patents teach a method which is appropriate for performing data quality of service measurements over a wireless network.

[0016] A system has been proposed in EP-A 0837615 for a cellular telephone system. A remotely commanded test telephone makes a wireless connection to a cellular system that implements a voice loop to assess the quality of the cellular voice connection. This system does not utilize a control modem. Thus, the test telephone will not be mobile and cannot truly emulate the circumstances of a mobile cellular telephone.

[0017] 17. As previously mentioned, there is a tremendous convergence taking place that combines the wireless network with data services. Dataquest estimates that the U. S. wireless data market (including phones, PDAs, laptops, and the like.) will grow from 3 million subscribers in 1999 to 36 million subscribers in 2003. Ericsson is estimating that 1 billion wireless units will be in use worldwide by 2003 and that 40 percent (400 million) of these units will be employed by data users. Furthermore, Ericsson is predicting that 2003 will be the crossover year in which wireless Web access will exceed wired Web access.

[0018] 18. As a further measure of the explosive growth of the convergence of the wireless systems and the Internet, one can look at projections for the number of wireless portal subscribers. According to the Strategis Group, the number of wireless portals will increase from 300,000 in 2000, to 9.8 million in 2003, and finally to 24.8 million in 2006.

[0019] 19. A variety of technical advancements have accelerated the convergence of Internet access over wireless devices. In 1997, three competing handset vendors (Nokia, Ericsson, and Motorola) and a small software company (Phone.com, formerly Unwired Planet) joined forces to create a standard way to transmit Internet data to wireless phones without occupying too much bandwidth. The result of this collaboration was development of the wireless application protocol (WAP). One basic component of WAP was development of the WML (Wireless Markup Language, replacing the previous Phone.com Handheld Device Markup Language, HDML) that compresses Web content in comparison to HTML. Additionally, the WAP forum developed standards for the use of microbrowsers in mobile devices.

[0020] 20. Unfortunately, the development of wireless Web access technology has significantly outpaced the development of wireless data measurements tools.
Accordingly, there is a tremendous need for specific test tools to address the converging technologies of wireless systems and data communications.

SUMMARY OF THE INVENTION

[0021] 21. In order to meet this need, a measuring tool is provided for measuring data quality of service over the wireless network. This tool was designed from the ground up with a variety of specific attributes.

[0022] The invention is defined by the subject-matter of the independent system claim 1.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023]

38. FIGS. 1a-g show a generic communication network with a variety of wireless communication paths connected to the Internet.

39. FIG. 1a shows the communication path for the traffic data in a standard wired Internet measurement system.

40. FIG. 1b shows the communication path for the traffic data during a circuit switched data connection in accordance with an embodiment of the invention.

41. FIG. 1c shows the communication path for the traffic data during a packet switched data connection in accordance with an embodiment of the invention.

42. FIG. 1d shows the communication path for the traffic data during an SMS message transmission in accordance with an embodiment of the invention.

43. FIG. 1e shows the communication path for the traffic data during a WAP data connection in accordance with an embodiment of the invention.

44. FIG. 1f shows the communication path for the traffic data during a WAP data connection in accordance with a further embodiment of the invention.

45. FIG. 1g shows the communication path for the traffic data during a WAP data connection, including a WAP monitoring processor, in accordance with a further embodiment of the invention.

46. FIG. 1h shows the communication path for the control link in accordance with an embodiment of the invention.

47. FIG. 2a shows the system architecture in accordance with one embodiment of the invention.

48. FIG. 2b shows the system architecture in accordance with a further embodiment of the invention.

tion.

49. FIG. 2c shows the system architecture in accordance with another embodiment of the invention.

50. FIG. 2d shows the system architecture in accordance with a further embodiment of the invention.

51. FIG. 2e shows the system architecture in accordance with another embodiment of the invention.

52. FIGS. 3a through 3d show a variety of basic architectures for remote units according to various embodiments of the invention.

53. FIG. 3a shows the basic architecture for the remote unit.

54. FIG. 3b shows another architecture for the remote unit with separate control link modem and traffic modem.

55. FIG. 3c shows another architecture for the remote unit with separate control link modem and multiple traffic modems.

56. FIG. 3d shows a further architecture for the remote units that include multiple peripherals in accordance with one embodiment of the invention.

57. FIGS. 4a through 4d show a variety of alternate implementations for the remote unit.

58. FIG. 4a shows a hardware implementation of the remote unit using either a laptop or handheld unit.

59. FIG. 4b shows a hardware implementation of the remote units using a single board computer (SBC).

60. FIG. 4c shows the organization of the software-defined radio.

61. FIG. 4d shows the organization of the software in the remote unit.

62. FIG. 5a shows the architecture of the back end processor.

63. FIG. 5b shows the architecture of the back end processor.

64. FIG. 5c shows the architecture for the portal.

65. FIG. 6a shows examples of some of the fields in the remote unit originated packets (both data and signaling).

66. FIG. 6b shows examples of some of the fields in the back end processor originated packets (both data and signaling).

67. FIG. 7a shows a method for measuring data quality of service in a wireless network.

68. FIG. 7b shows a method for measuring data quality of service in a wireless network, including at least one step related to the wireless network infrastructure.

69. FIG. 7c shows a method for measuring data quality of service in a wireless network, including at least one additional order independent step.

70. FIG. 8a shows a bar graph output of download times from different portals.

71. FIG. 8b shows a bar graph output of download times across different wireless networks.

72. FIG. 8c shows a bar graph output of call completion percentage across different wireless networks.

73. FIG. 8d shows a trending graph output of call completion percentage across different wireless networks.

74. FIG. 8e shows a bar graph output of average download times with a breakdown of the network latency at the WAP gateway.

75. FIG. 8f shows a pie chart of error statistics for wireless access of Yahoo.

76. FIG. 9 illustrates a system according to an exemplary embodiment of the present invention.

77. FIG. 10 illustrates remote units (PUPPIs) in the exemplary system.

78. FIG. 11 illustrates processes that each contain software modules that are responsible for specific tasks.

79. FIG. 12 illustrates a router is used as the interface between an external communication line and a LAN that is connected to the PUPPIs.

80. FIG. 13 illustrates the basic architecture for the Back End according to the exemplary embodiment.

81. FIG. 14 illustrates two basic software modules included in the Back End.

82. FIG. 15 illustrates hardware architecture for the Back End according to the exemplary embodiment.

DETAILED DESCRIPTION

I. OVERVIEW

[0024] 83. In order to understand the present invention, it is helpful to compare the communication path of current data measurements tools with the communication path. FIGS. 1a-g show a generic communication network with a variety of wireless communication paths connected to the Internet. It is well known to those of ordinary skill in the art that these figures illustrate a generic network that is used for illustrative purposes. For example, in some cellular networks there is a base station controller connected to multiple base stations between their connections to the MSC. As another example, the WAP gateway, packet data gateway, and PSTN connection may be replaced in some wireless networks by a single device that is directly connected to the MSC.

[0025] 84. FIG. 1a shows the communication path (heavy broken line) for the traffic data in a standard wired Internet measurement system. The traffic data flows between the user machine **124** over the Internet **122** to a standard application server **126** that will generally be serving an HTML page.

[0026] **85.** FIG. 1b shows the communication path (heavy broken line) for the traffic data during a circuit switched data connection. The traffic data passes from the remote unit **102-1to** the base station **106,** MSC **108,** PSTN **110,** ISP **112,** Internet **122,** and to a standard application server **126.** The standard application server 126 may be serving an HTML page, for example.

[0027] **86.** FIG. 1 c shows the communication path (heavy broken line) for the traffic data during a packet switched data connection The traffic data passes from the remote unit **102-1** to the base station **106,** MSC **108,** operator backbone **114,** packet data gateway **118,** Internet **122,** and standard application server 126. For example, the standard application server 126 may be serving an HTML page.

[0028] **87.** FIG. 1d shows the communication path (heavy broken line) for the traffic data during an SMS message transmission. If the SMS message is being delivered to the remote unit **102-1**, the traffic data passes from a standard application server **126** to the Internet 122, SMSC 116, operator backbone **114,** MSC **108,** base station **106,** and remote unit **102-1**.

[0029] **88.** FIG. 1e shows the communication path (heavy broken line) for the traffic data during a WAP data connection. If the remote unit **102-1** is accessing a WAP server **128,** the traffic data passes from the remote unit **102-1** to a base station **106**, MSC **108,** operator backbone **114,** WAP gateway **120**, Internet **122,** and WAP server **128.** For example, the traffic data path shown in FIG. 1e allows for latency measurements for wireless Web page access or e-commerce transactions.

[0030] **89.** It is important to note that although the term WAP is being applied to the wireless Internet protocol, the principles of the present invention are not limited to a WAP implementation. The present invention may be implemented using any wireless Internet protocol, including HDML and any future wireless Internet protocols that may be developed. The following examples are provided of some competing technologies that for the purposes of this disclosure will be considered to be functionally equivalent to WAP. For example, the Web content can be delivered as text messaging or as an SMS message (as proposed by Xypoint or GoSMS) so that it is compatible with existing cellular phones. Alternatively, the Web content can be delivered as existing HTML Internet content for wireless devices as proposed by Spyglass' Prism technology or Japan's iMode. As a further example, the content can be processed through a template model that reads existing HTML content and fits the data to a template optimized for various types of wireless phones such as the system proposed by Everypath.com. As another example, the data content can be delivered to a Palm Pilot or other PDA or handheld device that uses a proprietary protocol.

[0031] 90. Additionally, it is noted that the present invention is not limited to use of the Internet, as it may be effectively practiced using any broad-reach network regardless of hardware implementation specifics. Accordingly, the term Wireless Data Protocol (WDP) will be used interchangeably with the generically used term WAP to describe the protocol used for wireless data access.

[0032] 91. FIG. 1 f shows the communication path (heavy broken line) for the traffic data during a WAP data connection. If the remote unit **102-1** is accessing the benchmark WAP server **130,** the traffic data passes from the remote units **102-1** to a base station **106,** MSC 108, operator backbone **114,** WAP gateway **120,** and to the benchmark WAP server **130.** This configuration allows latency measurements without including the uncertainties of the latency through the Internet **122** itself. In other words, the configuration in FIG. 1f allows measurements of the latency due to the wireless network itself with no contribution from the Internet **122.**

[0033] 92. FIG. 1g shows the communication path (heavy broken line) for the traffic data during a WAP data connection, including a WAP monitoring processor **132.** The WAP monitoring processor **132** may be implemented as monitoring software installed and running on the WAP Gateway **120** or as software installed on a separate machine attached to the WAP Gateway 120. The software would monitor traffic through the WAP Gateway **120** and provide metrics such as throughput, latency and lost packet information. This configuration would allow the wireless network and the Internet 122 itself to be analyzed and monitored separately, thus providing performance information for each. Furthermore, the WAP Monitoring Processor **132** would be able to collect protocol information directly from the WAP Gateway **120** that may not be available to the multiple remote units **(102-1** through **102**-N).

[0034] 93. The monitoring software may run as a separate application on the WAP Gateway **120,** or may be embedded into the WAP Gateway software itself and run as part of the entire gateway application. The monitoring software would have a mechanism for collecting metrics and passing that information to the back end processor through the internet, wireless network, or through some other means. The monitoring software may temporarily store results locally, and perform some pre-processing on the data prior to forwarding it to the back end processor.

[0035] 94. FIG. 1h shows the communication path for the control link. The control link is used to remotely control the remote units **140, 142, 144, 146** from the back end processor **148.** Specifically, the process in the back end processor **148** that communicates with the remote units **140, 142, 144, 146** is the fleet management process, which will be discussed in detail later.

[0036] 95. The remote units can be either mobile **140, 142, 144** or stationary **146.** The mobile units **140, 142, 144** can be mounted in a variety of vehicles such as taxis, police cars, buses, postal vehicles, delivery vehicles, fleet vehicles, just to give a few examples. The stationary remote units **146** can be mounted in any area in which the public congregates and uses wireless devices. This includes airports, bus stations, and train stations just to provide a few examples.

[0037] 96. A variety of communication technologies are available to implement the control link. The control link can be implemented as data running over any of the current wireless networks such as CDMA, iDEN, TDMA, or GSM just to name a few examples. Additionally, the control link can be implemented over the AMPS network using CDPD for example. Alternatively, the control link can be implemented using a two-way data system such as ARDIS, MOBITEX, SKYTEL, and the like.

II. SYSTEM ARCHITECTURE

[0038] 97. FIG. 2a shows the system architecture in accordance with one embodiment of the invention. As previously described, the invention comprises multiple remote units (**202-1** - **202-N)** that may be either mobile or stationary. Each remote unit may include a location unit **(202a-1- 202a-N)** that allows the remote unit to accurately determine its location. Furthermore, each remote unit includes a communications link **(202b-1 - 202b-N)** that provides for both the control link and the traffic data. The communications link **202b-1** communicates over a communication network **210** that passes the information to a communication server **212** that connects to a data network **220.** The data network 220 can be a public data network, such as the Internet, or a private data network. A back end processor **224** is connected to the data network **220** for handling control link information, both commands and responses, and traffic data. In addition, the customers **222** are also connected to the data network so that they can access the back end processor **224.**

[0039] 98. FIG. 2b shows the system architecture in accordance with a further embodiment of the invention. The system in FIG. 2b differs from the system shown in FIG. 2a in that the control link network and the traffic data network are two separate communication networks. Each remote unit (e.g., **202-1)** may include a location unit **202a-1** that allows the remote unit **202-1** to accurately determine its location. Furthermore, each remote unit **202-1** includes a control link communication module **202c-1** and a traffic data communication module **202d-1.** The control link **202c-1** passes commands and response information through communication network A **210A** and communication server A **212A** to the data network **220.** The traffic data communication module **202d-1** passes traffic data through communication network B (210B) and communications server B **(212B)** to the data network **220.** A back end processor **224** is connected to the data network 220 for handling control link information, both commands and responses, and traffic data. In addition, the customers **222** are also connected to the data network **220** so that they can access the back end processor **224.**

[0040] 99. FIG. 2c shows the system architecture in accordance with another embodiment of the invention. The system shown in FIG. 2c differs from the system shown in FIG. 2b in that each remote unit (e.g., **202-1)** may have multiple traffic modules **(202d1-1 - 202dN-1).** Each remote unit **202-1** may include a location unit **202a-1** that allows the remote unit to accurately determine its location. Additionally, each remote unit **202-1** includes a control link communication module **202c-1** and includes multiple traffic data communication modules **(202d1-1 - 202dN-1).** The control link passes command and response information through communication network A **210A** and communication server A **212A** to the data network **220.** Each traffic data communication module 1 through N **(202d1-1- 202dN-1)** passes traffic data through communication network B-1 **(210B-1)** through B-N **(210B-N),** respectively, and through communication servers B-1 **(212B-1)** through B-N **(212B-N),** respectively, to the data network **220.** A back end processor **224** is connected to be data network **220** for handling control link information, both commands and responses, and traffic data. In addition, the customers **222** are also connected to the data network **220** so that they can access the back end processor **224.**

[0041] 100. FIG. 2d shows the system architecture in accordance with a further embodiment of the invention. The system in FIG. 2d differs from the system shown in FIG. 2c in that multiple control link communication networks may be used. This is particularly important in systems in which the remote units are deployed in different cities. It may be preferable in this case to use a different control link communication network in different cities depending on the wireless system coverage and the data pricing structure.

[0042] 101. Each remote unit **(202-1- 202-N)** may include a location unit **(202a-1- 202a-N)** that allows the remote unit to accurately determine its location. Furthermore, each remote unit **(202-1 - 202-N)** includes a control link communication module **(202c-1- 202c-N)** and includes multiple traffic data communication modules **(202d1-1- 202dN-1- 202d1-N - 202dN-N).** The control link passes commands and response information through one of communication network A-1 **(210A-1)** through A-N **(210A-N** depending on the appropriate communication network for the specific remote unit. Each control link communication network A-1 **(210A-1)** through A-N **(210A-N)** is connected to a respective communication server A-1 **(212A-1)** through A-N **(212A-N)** which allows command and response information to be passed to the data network. Each traffic data communication module 1 **(202d1-1)** through N **(202d1-N)** passes traffic data through communication network B-1 **(21OB-1)** through B-N **(210B-N),** respectively, and through communication servers B-1 **(212B-1)** through B-N **(212B-N),** respectively, to the data network. A back end processor **224** is connected to the data network **220** for handling control link information, both commands and responses, and traffic data. In addition, the customers **222** are also connected to the data network **220** so that they can access the back end processor **224.** 102. FIG. 2e shows the system architecture in accordance with another embodiment of the invention. The system in FIG. 2e differs from the system shown in FIG. 2d in that both mobile and stationary remote units are shown. Because the traffic data communication channels in FIG. 2e are the same as those in FIG. 2d, they have been omitted in order to simplify the diagram. The control links for the mobile remote units **(202-1 through 202-N)** are the same as those described in FIG. 2d.

[0043] 103. Each stationary remote unit **(202-X through 202-Y)** may include a location unit **(202a-X through 202a-Y)** that allows the remote unit to accurately determine its location. The location unit **(202a-X through 202a-Y)** is generally optional in the stationary remote units since their location is presumably known. The stationary remote units each include a control link module **(202c-X through 202c-Y)** which is connected via a respective wired line to a respective communication network C-1 **(210C-1)** through C-N **(210C-N)** and associated communication server C-1 **(212C-1)** through C-N **(212C-N)** which allows command and response information to be passed to the data network **220.** A back end processor **224** is connected to be data network **220** for handling control link information, both commands and responses, and traffic data. In addition, the customers **222** are also connected to the data network **220** so that they can access the back end processor **224.**

III. REMOTE UNIT

[0044] 104. The remote unit has a variety of attributes. The remote unit should preferably be portable in terms of size and weight so it can be deployed in a vehicle or in a stationary public area. Possible vehicles include buses, police vehicles, taxis, postal vehicles, delivery vehicles, and fleet vehicles just to name a few. Examples of stationary public areas include airports, train stations, bus stations, and any public area where large numbers of people use wireless devices.

[0045] 105. Another attribute of the remote unit is that it is mountable either in a vehicle or in a public area. There are a variety of methods that can be used for mounting the remote unit. For example, the remote units can be mounted to a DIN bar that is commonly used for industrial equipment. Alternatively, the remote units can be mounted using a standard bracket, tie device, fabric strap, bolts, or adhesive device such as Velcro, for example.

[0046] 106. A further attribute of the remote unit is that it is able to withstand a wide temperature range such as the industrial temperature range of -40 degrees C to + 80 degrees C, for example. This attribute allows deployment of the remote unit in a wide range of geographical environments. Furthermore, it allows deployment of the remote unit in places such as the trunk of a vehicle in which airflow is limited.

[0047] 107. Another attribute of the remote unit is the ability to withstand vibration. This attribute is important since many of the remote units may be deployed in vehicles and will be subjected to severe vibration. There are a variety of standard techniques that can be used to improve the vibration performance of the remote unit. These include using frequency absorbing mounting materials and potting the components on the printed circuit board for added stability.

[0048] 108. A further attribute of the remote unit is that it meets all local standards for emissions, both radiated and conductive. For example in United States, the emissions from most digital devices are covered by FCC part 15 and emissions from cellular devices are covered by FCC part 22. In Europe, there generally are directives which cover radiated emissions, conductive emissions, and radiated immunity and which must be met in order to receive the CE mark.

[0049] 109. Another attribute of the remote unit is the ability to handle the input power source. First, the remote unit should include some type of power regulation. This is particularly important in a vehicular environment in which the power provided by the vehicle battery is very noisy. Additionally, the remote unit should include the ability to power any external modules or peripherals that are going to be attached to the main control unit. Furthermore, the remote units may include some form of battery backup with an automatic charger so that the remote unit in a mobile environment does not drain the vehicle battery when the ignition is turned off. This requirement is not as important in a stationary deployment since the power can be provided from an AC outlet using a DC transformer. However, one may choose to include the battery and charger in this configuration also in order to provide battery backup in the event of an AC power failure. Finally, the remote unit may include some form of sleep mode which is used to conserve power during periods of sporadic activity.

[0050] 110. The remote unit will now be described with regard to a variety of embodiments in accordance with the invention. FIGS. 3 a through 3d show a variety of basic architectures for the remote unit. FIGS. 4a through 4d show a variety of possible implementations for the remote unit.

[0051] 111. FIG. 3a shows the basic architecture for the remote unit. The remote unit **300** comprises a control unit **302,** a location unit **304,** and a control link and traffic modem **306.** The control unit **302** is the main control device for the remote unit **300** and is connected to the location unit **304** and the control link and traffic modem **306.** The location unit **304** determines the location of the remote unit **300**.

[0052] 112. The control link and traffic modem 306 shown in FIG. 3a is used to communicate with the back end processor **224.** The control link and traffic modem **306** is connected to the control unit **302** in order to send and receive control information and traffic information. The control unit is generally running a main program that controls the location unit **304** and the control link and traffic modem **306.**

[0053] 113. There are a variety of ways in which the location unit **304** can determine the location in accordance with the invention. The location unit **304** may comprise a GPS receiver such as those manufactured by Trimble, Ashtech, Garmin, or Magellan, for example. If the location unit **304** is a GPS receiver, the connection to the control unit 302 may be a serial communication link. In another embodiment, the location unit 304 may comprise a GPS daughterboard such as those manufactured by Avocet, Trimble, Ashtech, or Rockwell, for example. If the location unit **304** is a GPS daughterboard, the connection to the control unit **302** is usually through a proprietary connector mounted on the control unit **302.** The control of the GPS daughterboard is generally accomplished using a serial connection. In a further exemplary embodiment of the invention, the location unit **304** may comprise a GPS chipset or a single GPS chip which is mounted directly on the control unit **302** and which has a bus interface. Furthermore, any of the GPS implementations of the location unit can include differential GPS using RTCM or RTCA corrections or alternatively can include WAAS capabilities.

[0054] 114. It is well known to those of ordinary skill in the art that there are a variety of alternative implementations for the location unit that don't involve standard GPS. For example, one can use a distributed GPS system, such as the one developed by SnapTrack, in which part of the GPS functionality is handled by a centralized server. Another alternative location option is the use of a triangulation technique using either angle of arrival or time difference of arrival information. Although the generic term triangulation is used, there is no requirement that three measurement points be used. A further location option is the use of RF fingerprinting, such as that developed by U.S. Wireless, which determines the unit location based on a multipath signature.

[0055] 115. Those of ordinary skill in the art will understand that FIGS. 2a-e, 3a-d, and 4a show logical antennas rather than physical antennas. These logical antennas can be combined in virtually any combination into a single physical antenna or groups of physical antennas depending on the specific requirements.

[0056] 116. FIG. 3b shows another architecture for the remote unit **300** with separate control link modem **308** and traffic modem **310**. FIG. 3b differs from FIG. 3a in that the single control link and traffic modem **306** has been divided into a separate control link modem **308** and traffic modem **310.** The advantage of separating the control link modem **308** from the traffic modem **310** is that it allows the remote unit **300** to communicate control information and traffic information over different communication networks.

[0057] 117. It is well known to those of ordinary skill in the art that there are variety of implementations for both the traffic modem and the control link modem that will be referred to collectively as modem units. The modem units may comprise a handset that is connected to the control unit using a special serial cable. The modem units may comprise a modem module that is connected to the control unit using a special serial cable. The modem units may comprise a PCMCIA card that is connected to the control unit using a PCMCIA socket. The modem units may comprise a custom modem that is implemented on either a separate printed circuit board or on the same printed circuit board as the control unit. The modem units may comprise a software-defined radio (SDR) in which most of the radio functionality is implemented in software. The software can be running either on a separate printed circuit board or on the same printed circuit board as the control unit. The control link modem may comprise a 2-way data device, such as the RIM Blackberry or Motorola CreataLink, which interfaces to the control unit via a serial connection.

[0058] 118. The traffic modem **310** is selected so that it can work over a wireless network using a particular wireless standard. For example, the wireless network can be AMPS, iDEN, CDMA, TDMA, GSM, ARDIS, MOBITEX, or CDPD. It should be noted that these standards are listed as examples and are not meant to limit the scope of the invention. It is well known to those of ordinary skill in the art that other wireless network standards such as W-CDMA, PHS, i-Burst, NAMPS, ETACS, WLL, UMTS, TETRA, and NMT may also be supported just to name a few more examples.

[0059] 119. The traffic modem **310** may implement more than one wireless standard. For example, QUAL-

COMM manufactures dual mode phones that support both CDMA and AMPS operation. In addition, if the traffic modem **310** is implemented using a software-defined radio then it is possible to implement all of the above-mentioned standards using a single hardware platform.

[0060] 120. The control link modem 308 is also selected so that it can work over a wireless network using a particular wireless standard. For example, the wireless network can also be AMPS, iDEN, CDMA, TDMA, GSM, ARDIS, MOBITEX, or CDPD. A primary factor in selecting a wireless standard for the control link modem is the pricing policy for transmitting control link information.

[0061] 121. FIG. 3c shows another architecture for the remote unit 300 with a control link modem and multiple traffic modems **310-1 - 310-N** FIG. 3c differs from FIG. 3b because it includes multiple traffic modems rather than a single traffic modem. The remote unit **300** architecture of FIG. 3c includes a control unit **302** that is connected to a location unit **304,** control link modem **308,** and traffic modems 1 **(310-1)** through N **(310-N).**

[0062] 122. **FIG.** 3d illustrates a remote unit that includes multiple peripherals. The remote unit **300** architecture of FIG. 3d includes a control unit **302** that is connected to a location unit **304,** a control link modem **308,** traffic modems 1 **(310-1)** through N **(310-N,** battery backup **312,** external storage **314,** a wireless LAN device **316,** and an RF scanner **318.** The location unit **304,** control link modem **308,** and traffic modems 1 **(310-1)** through N **(310-N)** are implemented in the same manner as discussed above with reference to FIG. 3c.

[0063] 123. The battery backup **312,** shown in FIG. 3d, provides power to the remote unit **300** when the main power is not available. If the remote unit **300** is mounted in a vehicle, the battery backup **312** is used when the vehicle ignition is turned off in order to ensure that the remote unit **300** does not drain the vehicle battery while the vehicle is parked. If the remote unit **300** is mounted in a stationary location, the battery backup **312** may be used to provide power if the main power is cut off due to a power failure in the building. The battery backup **312** includes a battery and a battery charger. The battery can be made from a variety of known rechargeable technologies such as sealed lead acid, NiCad, NiMH, and Lithium for example.

[0064] 124. The external storage **314** provides a temporary storage capability for data that is not immediately sent back to the back end processor **224.** There are a variety of reasons for storing data in the external storage **314.** For example, if layer 3 network data is collected for the wireless network it is possible to produce 1 Mbyte/hour/technology of data. It may be prohibitively expensive to send this much data back to the back end processor **224** via the control link modem **308.** Accordingly, the data can be stored locally in the external storage **314** and be downloaded at a later time using an alternate path.

[0065] 125. As another example, the collected data may be queued for transmission when the vehicle ignition is turned off. It may be preferable not to transmit the stored data until the ignition is turned back on in order to prevent unnecessary draining of the battery backup mechanism **312.** Accordingly, the data can be stored locally in the external storage **314** and queued for transmission in at a later time over the control link modem **308** when the vehicle ignition is turned on.

[0066] 126. It is well known to those of ordinary skill in the art that the external storage **314** can be implemented in a variety of ways. For example, the external storage is implemented as a PCMCIA Flash card that plugs into a PCMCIA socket on the control unit. As another example, the external storage 314 can be a SANdisk that is connected to the control unit via a proprietary connector. Alternatively, the external storage **314** is implemented using a moving storage device such as a specialized hard drive, for example a PCMCIA hard drive module. However, in mobile environments it is preferable to implement the external storage with no moving parts in order to improve the reliability of the remote unit.

[0067] 127. The wireless LAN device **316** allows high-speed data transmission over short distances. The wireless LAN device **316** is implemented, for example, using Bluetooth technology. The wireless LAN device **316** provides an alternative path for downloading data that is stored on the external storage **314.** For example, if the remote unit 300 is mounted in a taxi and layer 3 wireless network data is stored from an earlier collection operation, then the wireless LAN device 316 is free to communicate with a wireless LAN controller (not shown) located at the taxi dispatch center in order to transmit the data back to the back end processor **224.** As an alternative example, the wireless LAN device **316** can be used to communicate with a local I/0 device (not shown) that can be used in a delivery truck to allow communications between a central dispatch and the delivery truck operator.

[0068] 128. The RF scanner **318** allows increased functionality for the remote unit **300** by increasing the capabilities for performing RF optimization of the wireless network. The RF scanner **318** allows the collection of more RF data then is traditionally available through the traffic modems **(310-1 - 310-N).** For example, the RF scanner 318 has a much more flexible input bandwidth since it is not forced to listen to a single traffic channel on the wireless network. Additionally, if the RF scanner **318** is optimized for CDMA collection, it can collect a variety of valuable CDMA network parameters such as measuring Io in the channel, despreading the spreading codes, measuring Ec/Io, and measuring chip delay. The RF scanner **318** can be implemented by using a commercial scanner or by developing a custom scanner, for example, using a software-defined radio.

[0069] 129. FIG. 4a shows a hardware implementation of the remote unit **400** using either a laptop or handheld unit **402**. The laptop or handheld unit **402** is connected to a GPS receiver **404,** control link modem **408,**

and traffic modem **410.** The laptop or handheld unit runs any of a variety of operating systems such as Windows 95/NT/CE, Linux, or Palm OS, for example. The peripheral devices **404, 408, 410** are connected to the laptop or handheld unit **402** via serial ports, PCMCIA ports, Ethernet, or USB as appropriate. The laptop or handheld unit **402** should have device drivers for all of the peripheral devices that are either built into the operating system or written in a higher-level language. Furthermore, the laptop or handheld unit **402** runs a main program that allows extraction of the location information from the GPS receiver **404** and sends and receives communication over the control and traffic channels.

[0070] 130. FIG. 4b shows a hardware implementation of the remote units using a single board computer (SBC). The single board computer can be purchased off-the-shelf from a variety of vendors such has SBS, ADS, or Datalogic for example. Alternatively, the single board computer can be custom designed for the specific remote unit application. FIG. 4b shows a typical architecture for the single board computer including a microprocessor 420 which is connected via an address and data bus to a boot ROM **424,** Flash memory **426,** DRAM/SRAM **428,** a PCMCIA socket **430,** a UART **432,** a USB interface **434,** an Ethernet interface **436,** a CAN interface **438,** a wireless LAN device **440,** and an optional A/D & D/A interface **442.** The microprocessor 420 may also have direct connections to a temperature sensor **444,** display interface **446,** and general-purpose I/O. Additionally, the single board computer may include power management circuitry **448** that is connected to switched power, power, and ground, and additionally connected to an optional backup battery **450.**

[0071] 131. It is well known to those of ordinary skill in the art that the single board computer can be implemented using a variety of different technologies. For example, the microprocessor can be a StrongARM, ARM, Pentium, PowerPC, Motorola 68000, and the like. Furthermore, a variety of operating systems are available such as Windows CE, Windows 95/98, Windows NT, Linux, Palm OS, VXWorks, OS-9, PSOS, and the like. The serial ports from the UART **432,** or directly from the microprocessor **420,** are used to interface to peripheral devices such has the traffic modem **410** or the GPS receiver **404** and should have configurable bit rates, word size, start bits, stop bits, parity bit and the ability to operate at either TTL or RS-232 voltage levels.

[0072] 132. FIG. 4c shows the organization of a software-defined radio. All of the elements of the soflware-defined radio 460 can be combined in any combination depending on the requirements. The elements include an RF scanner **462,** a control link modem **464,** traffic modems 1 **(466-1)** through N (466-N), a location unit **468,** and a wireless LAN device **470.** The advantage of using a software-defined radio architecture is that it allows implementation of multiple standards simultaneously on a single hardware device. This can greatly reduce the cost of the remote unit. The underlying architectural concepts for the software-defined radio **460** are well known to those of ordinary skill in the art and are discussed in articles in numerous journals such as the IEEE Communications Magazine.

[0073] 133. FIG. 4d illustrates organization of the software in the remote unit. At the lowest level is the operating system **476** that provides basic functionality for the hardware platform. The remote unit can run a variety of operating systems such as Windows 95/NT/CE, Linux, Palm OS, VXWorks, QNX, or pSOS for example. Furthermore, depending on the requirements, it is possible to use no operating system and write platform-specific code to implement the lower level routines.

[0074] 134. At the next level, the remote unit software includes device drivers **478,** utilities **480,** protocols, **482** and user interface modules **484.** The device drivers **478** allow communication with the peripheral devices such as the GPS receiver **404** and the wireless modems, for example. The utilities **480** support lower-level functions such as encryption and compression, for example. The protocols **482** support any protocols that are needed in the remote unit such as a WAP browser, TCP/IP, X.25, and any proprietary packet protocols, for example. The user interface module **484** includes all of the functionality required for local control of the remote unit such as a simple menuing system. It is well known to those of ordinary skill in the art that some or all of these modules may also be built into the operating system.

[0075] 135. At the next level, the remote unit software optionally includes a variety of additional modules such as a pre-processing module **486,** DB/Storage module **488,** and a software-defined radio module **490.** The pre-processing module **486** may be used to pre-process the collected data. This is particularly helpful in an operational scenario in which large quantities of data are collected and need to be reduced in order to conserve control link bandwidth. The DB/Storage module **488** may be used to store and organize the requested missions and/or the collected data. The software-defined radio module **490** is implemented as described above with reference to FIG. 4c.

[0076] 136. The main application **492** is at the next level and performs the higher-level routines. For example, the main application **492** is used to receive missions over the control link, execute the missions, and transmit the mission data over the control link.

[0077] 137. In the implementations described above, the control unit **302** is shown as being a general purpose computer in the form of a laptop or handheld unit **402.** Although this has certain advantages in terms of flexibility of programming, the invention may also be implemented using special purpose computers in lieu of general purpose computers.

IV. BACK END PROCESSOR

[0078] 138. FIG. 5a shows the architecture of the back end processor **500**. The back end processor **500** includes the following processing elements: fleet management **502,** test traffic generator **504,** post processor 506, user interface **508,** portal **510,** mapping **512,** and billing and accounting **514.** These processing elements are interconnected by a data network **516.** It is well known to those of ordinary skill in the art that the data network **516** can be either a LAN, WAN, inter processing communications within a computer or network, or any combination of the above.

[0079] 139. FIG. 5b shows the architecture of the back end processor **500**. The back end processor includes the following processing elements: fleet management **530,** test traffic generator **532,** post processor **534,** user interface **536,** and portal 538 including a mapping element **538a** and a billing and accounting element **538b.** In addition, the fleet management element **530** is connected to a collected data database **540,** mission database **542,** and remote unit database **544;** the post-processing element **534** is connected to a post-processed database **546** and the collected data database **540,** and the portal **538** is connected to a mapping database **548** and a billing and accounting database **550.**

[0080] 140. The fleet management element **530** is the main interface in the back end processor for communicating with the remote units. The fleet management element keeps track of the remote units by accessing data in the remote unit database **544,** performs mission planning and coordination based upon information provided from the user interface **536,** sends and receives information to the test traffic generator **532** in order to generate terrestrial originated calls, and sends and receives commands and responses to the remote units via the control link.

[0081] 141. The fleet management element **530** receives mission requests from the user interface 536 and stores the information in the mission database **542.** It then performs a scheduling function based on the requested missions stored in the mission database **542** as compared with the remote units available as determined by availability information stored in the remote unit database **544.** The scheduled missions are stored in the mission database **542** as requested missions and are sent at the appropriate time to the remote units over the control link. The requested missions can be stored and sent as a batch of missions or can be sent as individual missions depending on the requirements.

[0082] 142. The information received by the fleet management element **530** is stored in the collected data database **540** and forwarded to the post processor element **534** that stores raw mission data and also performs post processing and stores the post processing results.

[0083] 143. The post processing involves processing of the received data for either RF/network parameters related to the wireless system or statistical information related to the wireless data access.

[0084] 144. The analysis of the RF/network parameters can be accomplished in a variety of ways such as those discussed in Provisional Patent Application No. 60/149,888 entitled "Wireless Telephone Network Optimization" that was filed on August 19, 1999, and which is incorporated by reference herein in its entirety for all purposes. This provisional disclosure provides a simulation environment to develop optimum coverage-related parameters for sectors of a wireless network. This simulation environment allows a network engineer to vary parameters of a virtual model of the wireless network and observe how the changes affect coverage. The provisional disclosure further provides an optimization algorithm to optimize hand off timing parameters for sectors in a wireless network. The optimization algorithm analyzes measured data regarding network coverage and regional terrain to arrive at a report containing recommended values for window size parameters (code division systems) or time advance parameters (time division systems).

[0085] 145. The post processing for statistical analysis involves the wireless data access that is accomplished using the traffic modem in the remote unit. The statistical analysis allows the combination of various collected information in order to produce reports for specific customers. For example, the latency of WAP accesses to a specific URL is measured over several different wireless networks and displayed on a bar graph. Further examples of statistical analysis and report generation are discussed in the operation section with respect to FIGS. 8a-8f.

[0086] 146. The user interface element **536** is connected to the fleet management element **530** in order to schedule missions based on requirements entered by the customers. Additionally, the user interface element **536** is connected to the post-processing element **534** to allow users to generate special queries, access previously stored queries, or access reports that are generated from the post processed data. The user interface element 536 is also connected to the portal **538** to allow access for the customers **560** from a connected data network such as the Internet **562.**

[0087] 147. The portal element **538** acts as an operating system providing a variety of low-level functions for multiple applications. The portal **538** includes a mapping element **538a** and a billing and accounting element **538b.** The portal **538** is connected to databases **548, 550** for the mapping information and the billing accounting information. In addition, the portal **538** is connected to the data network **562,** such as the Internet, to allow customer entry into the system. The portal is also connected to the post processor **535** to allow access of the post-processed data for visualization with the mapping software, for example.

[0088] 148. FIG. 5c shows the architecture for the portal **570** in accordance with one embodiment of the invention. The portal **570** acts as an operating system providing common low-level functions for a variety of applications and acting as an interface for customer access through the Internet. The portal **570** functions are organized into four major groups: databases **572,** GUI controls **574,** workgroup functions **576,** and security **578.** The database **572** functions include terrain, morphology, buildings, and billing and accounting. The GUI controls **574** include mapping/GIS, charts, and virtual reality. The workgroup functions **576** include access controls and threaded dialogue. The security functions **578** include login, partitioning, and audit trails. The portal also includes an API **580** that allows access to various applications.

IV. CONTROL LINK COMMUNICATION PROTOCOL

[0089] 149. The control link allows communications between the multiple remote units and the back end processor. There are a variety of possible protocols for the control link. The communication protocol can be a standard protocol such as TCP/IP, WAP, or X.25, for example, or a proprietary protocol that is optimized for the required communications, or some combination of a standard and proprietary protocol.

[0090] 150. In accordance with one embodiment of the invention, a proprietary packet protocol is used. One issue regarding the packet protocol is the issue of acknowledgments for packets.

[0091] 151. Acknowledgments can be handled in a variety of ways. They can be sent as an individual packet for each substantive packet sent. This is the heartiest mechanism but it is bandwidth inefficient. Alternatively, acknowledgments can be sent as a field of a subsequent packet using a packet numbering scheme to indicate which previous packet is being acknowledged. This method requires more overhead at each end of the communication link in order to keep track of previously sent packets, but is more efficient in terms of bandwidth used. As another alternative, the acknowledgment system can be handled by the communication system itself so that the packet protocol does not have to address the issue. For example, many two-way data systems have a built-in acknowledgment system so that packet delivery is virtually guaranteed. In this case, it is not required to include acknowledgments in the packet protocol since they are handled at another level.

[0092] 152. There are two basic types of packets: signaling packets and data packets

[0093] 153. The signaling packets are originated either at the remote unit or at the back end processor. Some examples of remote unit originated packets are ignition on, ignition off, and status update. The Ignition on packet indicates that the vehicle ignition has been turned on and the ignition off packet indicates that the vehicle ignition has been turned off. These packets are used by the back end processor in order to properly schedule data collection in a mobile remote unit. The status update packet indicates the current status of the remote unit.

[0094] 154. Some examples of back end originated packets are reset and status request. The reset packet is used to remotely reset the remote unit. The status request packet is used to remotely request status information for a remote unit.

[0095] 155. The data packets are also either originated at the remote unit or at the back end processor. The back end originated data packets generally consist of mission requests and the remote unit originated data packets generally consist of mission data.

[0096] 156. FIG. 6a shows examples of some of the fields in the remote unit originated packets (both data and signaling) **610.** Some examples of the packet fields include a packet type ID **610a,** remote unit ID **610b,** date and time **610c,** message number **610d,** mission ID number **610e,** location information **610f,** payload information **610g,** and checksum *information* **610h.** The packet type ID field **610a** indicates the type of packet so that the back end processor will know how to parse the packet for the proper fields. The remote unit ID field **610b** is used to identify the remote unit sending the packet. The date and time field **610c** indicates the date and time that the measurement is taken. The message number field **610d** is used to keep track of the message for acknowledgment purposes. The mission ID number field **610e** is used by data packets to indicate the corresponding back end mission that caused generation of the packet's payload information. The location information field **610f** indicates the remote unit location at the time of data collection. The checksum information field **610h** is used in order to ensure the integrity of the packet information. The term checksum is used generically to refer to any type of error correction and/or error detection method to ensure packet integrity.

[0097] 157. The remote unit originated data packet's payload information field 610g can take a variety of forms. It may include call statistics such as connect time, call duration, whether the call failed to connect or was dropped, and the like. Additionally, it may include basic RF engineering measurements such as RSSI, BER, FER, SQE, and the like. Furthermore, the payload information may include Layer 3 information that discloses call routing data and information regarding the configuration of the wireless network. The Layer 3 information may be collected in totality or filtered by pre-processing in the remote unit depending on the amount of information desired. In addition, the payload may include application information such as the access latency for a WAP page or the delay in receipt of an SMS message.

[0098] 158. FIG. 6b shows examples of some of the fields in the back end processor originated packets (both data and signaling) **620**. Some examples of the packet fields include a packet type ID **620a,** remote unit ID **620b,** date and time **620c,** message number **620d,** mission ID number **620e,** payload information **620f,** and checksum information **620g.** The packet type ID field **620a** indicates the type of packet so that the remote unit will know how to parse the packet for the proper fields. The remote unit ID field **620b** is used to identify the remote unit receiving the packet. The date and time field

620c indicates the date and time that the packet is sent. The message number field **620d** is used to keep track of the message for acknowledgment purposes. The mission ID number field **620e** is used by data packets to indicate the back end mission that will cause generation of the packet's payload information. The checksum information field **620g** is used in order to ensure the integrity of the packet information. The term checksum is used generically to refer to any type of error correction and/or error detection method to ensure packet integrity.

[0099] 159. The back end processor originated data packet's payload information field 620f can take a variety of forms. It may include mission info regarding the type of data to collect including the type of access (WAP, circuit switched data, etc), a trigger related to the time (or range of times) to make the test call, a trigger related to the location (or range of locations) to make the test call, a wireless system to test (if the remote unit supports multiple wireless traffic standards), a target phone number or URL, and whether the call is mobile or terrestrial originated.

[0100] 160. It should be noted that the packet field types described above are for illustrative purposes and in no way limit the actual fields that may be used.

[0101] 161. The information in the packet can be sent as either ASCII or binary data. ASCII is useful since some two-way data systems are used for paging and will only pass ASCII text information. Binary storage is useful because it is more bandwidth efficient than ASCII. Furthermore, the packet information can be compressed by a variety of standard methods such as null compression, run-length compression, keyword encoding, adaptive Huffman coding, Lempel-Ziv coding, and the like. Additionally, the packet information can be encrypted by a variety of standard methods such as DES, triple DES, RSA, PGP, and the like.

[0102] 162. In accordance with one embodiment of the invention, the packets are combined in larger files for transmission over the control link. This is advantageous in an environment in which the control network charges a fixed charge per packet. Accordingly, larger files may be more cost effective. Furthermore, it may be advantageous to store the collected information at the remote unit for transmission at a later time. This can occur if Layer 3 information is collected since the data may be collected faster than it can be sent over the control link. Additionally, the collected information may be stored at the remote unit if the vehicle ignition is turned off during a mission in a mobile environment. This occurs because the system tries to reduce transmissions when the ignition is off in order to extend battery life.

V. METHOD FOR MEASURING

[0103] 163. FIG. 7a shows a method for measuring data quality of service in a wireless network. The method includes the steps of sending command information 702, performing measurements 704, and receiving response information 706.

[0104] 164. For example, the step of sending command information 702 may include using a back end processor to send either data or signaling packets to the remote units of a measuring system such as the one described previously. Furthermore, the step of performing measurements 704 may include performing any of a variety of measurements such as latency of wireless Internet access, e-commerce transactions, wireless messaging, or push technologies. The step of receiving response information 706 may include responses to status inquiries or data related to the measurements collected during the step of performing measurements 704.

[0105] 165. FIG. 7b shows a method for measuring data quality of service in a wireless network, including at least one step related to the wireless network infrastructure. The method includes the sending 702, performing 704, and receiving 706 steps described with respect to FIG. 7a. Additionally, the method includes steps of monitoring a WAP Gateway 710 and Benchmarking at a WAP Gateway 712.

[0106] 166. The step of monitoring the WAP Gateway 710 may include monitoring traffic through the WAP Gateway and providing metrics such as throughput, latency and lost packet information. Furthermore, the monitoring step 710 may allow the collection of protocol information directly from the WAP Gateway that may not be available to the multiple remote units. The step of benchmarking at the WAP Gateway 712 may allow latency measurements without including the uncertainties of the latency through the Internet or data network itself. This allows the provision of data indicating a breakdown between the latency of the wireless network and the data network.

[0107] 167. It is important to note that in regard to steps 710 and 712 that the closeness to the WAP gateway is described from a logical, not a physical, standpoint. It will be appreciated by those of ordinary skill in the art that these process steps can be accomplished with well known techniques in which the monitoring or benchmarking element is located far away from the WAP gateway. Furthermore as previously discussed, the term WAP is being used generically to describe any type of wireless Internet protocol, including HDML, WAP competitors, and any future wireless Internet protocols that may be developed.

[0108] 168. FIG. 7c shows a method for measuring data quality of service in a wireless network, including at least one additional order independent step. The method includes the sending 702, performing 704, and receiving 706 steps described with respect to FIG. 7a. Additionally, the method includes steps of accessing from the Internet 720, scheduling missions 722, generating test traffic 724, storing at a remote unit 726, preprocessing at a remote unit 728, post-processing at the back end 730, and organizing remote unit information 732.

[0109] 169. The step of accessing from the Internet

720 may include the ability to access the measuring system from the Internet through a portal to set up missions and retrieve reports generated from the post-processed data, for example. The step of scheduling missions 722 may include establishing parameters related to the specific data to be collected by the system. For example, these parameters may include some of the following: type of access - WAP, SMS, Instant Messaging, Push data, and the like.; type of Device - WAP, PDA, Pager, wireless modem, and the like.; trigger - time of call, location of remote unit, or some combination; wireless system - Sprint, Nextel, AT&T, and the like.; call Info - Target phone#, URL, type of transaction, etc; and mobile or terrestrial originated call. The step of generating test traffic 724 may include generation of SMS messages or other data packets to be sent to the remote units, for example.

[0110] 170. The step of storing at the remote unit 726 may include the storing of missions and of collected data at the remote unit. The step of pre-processing at the remote unit 728 may include processing received data prior to storing the data or transmitting it to the back end processor. The step of post-processing at the back end 730 may involve processing of the received data for either RF/network parameters related to the wireless system or statistical information related to the wireless data access. The step of organizing remote unit information may include storage of remote unit identification information in a remote unit database, storage of collected data in a collected data database, or storage of post-processed data in a post-processed data database, for example.

[0111] 171. It should be noted that the flow arrows in FIGS. 7a-7c are shown merely for illustrative purposes and do not reflect a required order for the method steps.

VI. OPERATIONAL AND BUSINESS MODEL

[0112] 172. The previous sections of this description have discussed a method and system for measuring data quality of service in a wireless network using multiple remote units and a back end processor. The method and system may also include an element that is located within the wireless network infrastructure, for example, at the WAP gateway to monitor the wireless data protocol and to perform benchmarking measurements. 173.

[0113] 174. Rather than selling measurement equipment as a final product, the system, as defined by the invention, preferably sells the collected data and statistics generated from the collected data as the final product. The trade name for this service is preferably "Bitwise." The data and statistics generated by the system do not need to be real-time, but as previously disclosed the system will support near real-time data if desired. Typically, the data will be collected and analyzed over a period of time such as a day, week, month, or even a year depending on the user's requirements.

[0114] 175. The types of data collected include latency, call statistics (such as call completion, call dropped, etc), BER/FER, and various wireless network parameters such as RSSI and Layer 3 information. For example, the latency time is a measure of the access time for a WML page from a WAP server or the time to complete a Web transaction. Furthermore, the system can divide the latency measurement into the wired network and wireless network contribution through the use of a component located at the WAP gateway.

[0115] 176. Furthermore, the remote units can be used to perform additional functions that have value in vertical markets. For example, if the remote units are fielded in a mobile environment in a fleet of vehicles, the remote units can provide automatic vehicle location (AVL) in addition to data quality of service measurements. Additionally, the position data from the mobile remote units could be processed to provide near real-time traffic information that could be disseminated, for example, over the Internet.

[0116] 177. There are a variety of possible pricing strategies for the data and statistics produced by the system. The user may be charged per minute of system use or per transaction. Alternatively, the user may be charged per city, per wireless carrier, and per month for the requisite data and statistics. Furthermore, the post-processing element produces aggregate industry-wide statistics, for example comparing different wireless carriers or content providers, which is preferably packaged and sold as a separate product.

[0117] 178. The customers for the system have a variety of common attributes. They are dot.com and e-commerce companies that are targeting wireless device users by porting their content and commerce to wireless web sites. Furthermore, they generally have a need for timely dissemination of content and transactions and have a keen interest in a positive customer experience.

[0118] 179. The customers can be divided into a variety of different groups. They can be wireless operators who wish to measure the performance of their networks in order to increase traffic and optimize performance. Furthermore, the customers can be wireless portals and/or ISPs such as AOL, Yahoo, Alta Vista, MSN, Lycos, and Excite, just to name a few examples. Additionally, the customers can be content providers in a variety of fields such as the service arena providing financial, weather, or traffic content; the internet auction arena involving time-sensitive bidding information; the instant messaging arena such as the AOL Anytime, Anywhere program; and the push data technology arena in which information such as airline information and traffic updates are pushed to the mobile device.

[0119] 180. The reasons that customers would use the system, in accordance with an embodiment of the invention, are fairly straightforward. It allows the customer to see the wireless Internet transaction through the end user's eyes in terms of their experience when accessing content and conducting transactions from wireless devices. In addition, it allows the customers a method for evaluating and comparing the performance of the wireless networks that are delivering the content. Furthermore, it allows the wireless operators and the content providers solid data to pinpoint bottlenecks and performance problems in the network. Additionally, it provides information to alert staff to critical service failures so corrective action can be taken in a timely manner.

[0120] 181. There are a variety of potential measurements that can be taken. Each measurement is referred to as a mission. Some examples of missions include retrieval of a WML page, completion of an e-commerce transaction, receiving pushed data content, performing a secure transaction, and performing benchmarking of different parts of the network by using a component located at the WAP gateway.

[0121] 182. There are a variety of methods for inputting requested missions. If the customer wishes, they can discuss their requirements with the system operator and allow the system operator to enter the missions. Alternatively, a user interface in the back end processor allows the customers to enter their own missions over the Internet by entering through the portal.

[0122] 183. The parameters for a mission may include at least the following items:

Type of access - WAP, SMS, Instant Messaging, Push data, and the like.
Type of Device - WAP, PDA, Pager, wireless modem, and the like.
Trigger - time of call, location of remote unit, or some combination
Wireless System - Sprint, Nextel, AT&T, and the like.
Call Info - Target phone#, URL, type of transaction, etc
Mobile or Terr. Originated.

[0123] 184. The output of the system can be obtained in a variety of ways. Generally, customers can set up formatted reports that will be generated periodically with the requested data and statistical information. The reports are obtainable in a variety of ways such as viewed using a Web browser, sent as an attachment to e-mail, sent as a file using FTP or some other protocol, or sent via normal mail just to name a few examples. The reports can be arranged in a variety of formats depending on the customer requirements with examples provided in the following figures.

[0124] 185. FIG. 8a shows a bar graph output **810** of download times from different portals. The y-axis of the bar graph relates to the average download time in seconds and the x-axis relates to the city in which the measurement was performed. The three bars represent measurements for Yahoo, AOL, and a portal index of measurements over all portals. The statistics shown are for all wireless carriers, with a measurement interval of 15 minutes between 6 AM and 12 PM, for the period from 03/01/00 to 03/07/00.

[0125] 186. FIG. 8b shows a bar graph output **820** of download times across different wireless networks. The y-axis of the bar graph relates to the average download time in seconds and the x-axis relates to the city in which the measurement was performed. The three bars represent measurements for Nextel, Sprint PCS, and AT&T Wireless. The statistics shown are for access to Yahoo, with a measurement interval of 30 minutes between 6 AM and 9 PM, for the period from 03/01/00 to 03/07/00.

[0126] 187. FIG. 8c shows a bar graph output 830 of call completion percentage across different wireless networks. The y-axis of the bar graph relates to the call completion percentage and the x-axis relates to the city in which the measurement was performed. The three bars represent measurements for Nextel, Sprint PCS, and AT&T Wireless. The statistics shown are for access to Yahoo, with a measurement interval of 30 minutes between 6 AM and 9 PM, for the period from 03/01/00 to 03/07/00.

[0127] 188. FIG. 8d shows a trending graph output 840 of call completion percentage across different wireless networks. The y-axis of the bar graph relates to the call completion percentage and the x-axis relates to the city in which the measurement was performed. The three bars represent measurements for Nextel, Sprint PCS, and AT&T Wireless. The statistics shown are for access to Yahoo, with a measurement interval of 15 minutes between 6 AM and 9 PM, for the period from 03101/00 to 03/07/00.

[0128] 189. FIG. 8e shows a bar graph output **850** of average download times with a breakdown of the network latency at the WAP gateway. The y-axis of the bar graph relates to the average download time in seconds and the x-axis relates to the city in which the measurement was performed. The bars represent measurements for Nextel with statistics shown for access to Yahoo, with a measurement interval of 60 minutes between 12 PM and 12 PM, for the period from 03/01/00 to 03/07/00.

[0129] 190. FIG. 8f shows a pie chart **860** of error statistics for wireless access of Yahoo. The sectors of the pie chart show DNS lookup failure, connection timeout, page timeout, content errors, and successful error-free connections. The statistics represent error statistics for all carriers with statistics shown for access to Yahoo, with a measurement interval of 60 minutes between 12 PM and 12 PM, for the period from 03101/00 to 03/07/00.

VII. EXEMPLARY EMBODIMENT

[0130] 191. Referring to FIG. 9, a system according to an exemplary embodiment of the present invention has two major components: Remote units (a.k.a. PUPPIs) 910, 920 which perform measurements related to Internet content delivery over wireless networks, and a Back End 930 that controls the remote units 910, 920 and performs data collection and storage.

[0131] 192. The basic control of the PUPPI **910** consists of commands sent from the Back End **930** to the PUPPI **910** and responses sent from the PUPPI **910** to the Back End **930.** The commands are generally missions that direct the PUPPI **910** to collect data from a particular wireless content provider within a particular time period. The responses are generally the results of these collection missions. The PUPPI's physical interface to the control link **950** is a modem **912** that allows communication over a communication link **940,** such as the PSTN, or over a data network, such as the Internet. The control link **950** can be implemented in a wired configuration, as shown in FIG. 9, or in wireless configuration using a wireless modem.

[0132] 193. The PUPPI's physical device for performing wireless measurements generally is a standard handset **914** that is connected to the PUPPI control unit via a serial cable. However, any wireless device such as a wireless modem module, PDA, RIM device, pager, etc can be used depending on the wireless network to be tested. Additionally, the software module with the appropriate WDP will be selected based on the wireless network to be tested.

[0133] 194. Referring to FIG. 10, the remote units (PUPPIs) in the exemplary system include a control unit **916** for controlling the remote unit, a test traffic modem **914** for performing measurements over the wireless network, and a control link modem **912** for passing commands and responses between the remote unit **910** and the back end processor **930** (refer to FIG. 9).

[0134] 195. The control unit 916 may be implemented as a PC, a laptop, a handheld computer, or an embedded computer, to name but a few examples. The test traffic modem **914** may be implemented as a standard handset or a modem module, either of which should include an external antenna. The control link modem **912** may be implemented as a standard POTS modem (using a dedicated phone line), a DSL modem, ISDN modem, or an equivalent system.

[0135] 196. The internal hardware interface for the PUPPI is embodied as an RS-232 serial connection between the control unit **916** and the test traffic modem **914** (generally a handset). Alternatively, the connection can be implemented using a USB port, Firewire port,, PCMCIA, or any other appropriate interface for the test traffic modem. The internal hardware interface between the control unit **916** and the control link modem **912** will depend upon the control link modem selected. If a standard V.90 modem (56.6 kbit/s) is used, then it can be housed inside the control unit case and plugged in to the PCI system bus or connected via an Ethernet connection over a LAN. If a DSL modem (or other advanced data modem) is used, then it will be connected to the control unit with an appropriate interface. If a wireless link control modem **912** is used, it will communicate with the control unit **916** via an appropriate interface, such as a serial port.

[0136] 197. The PUPPIs in the exemplary system are stationary indoor units or mobile units, including an external wireless antenna, under remote control from the back end using a special scripting language.

[0137] 198. The PUPPI is designed to simulate a subscriber using a WAP enabled handset or any WDP-enabled wireless device. WAP handsets have mini-browsers loaded onto the handset to allow this functionality. Because of limitations on the ability to control and track data on the handset itself, the exemplary remote unit may move the web browsing functionality from the handset to the control unit, where full browser control and data tracking is possible. In this case, the handset will be used for a dial-up networking connection which will provide access to the wireless data network, and will allow packets to flow between the WAP browser on the control unit and the WAP gateway at the operator's switch via the handset.

[0138] 199. The PUPPI software includes three main processes, a test process, a control process, and a logging process. The test process is responsible for all aspects of measurement. The control process is responsible for all communications with the Back End system. The logging process is responsible for logging all events from each process and generating alarms.

[0139] 200. Referring to FIG. 11, processes are illustrated that each contain software modules that are responsible for specific tasks.

[0140] 201. The Main Control Module (MCM) **1104** is responsible for all management and control of the PUPPI unit. Some of the functions that the MCM is responsible for are listed as follows:

- Tasking Modules with Measurements
- Handling Timing Issues
- Starting and Stopping Measurements
- Responding to Diagnostics Requests
- Receiving Task Lists
- Sending Collected Data

[0141] 202. The test link connection module (TLCM) **1108** manages the test link connection. The test link connection is used by the data modules to collect information from the wireless data network. The test link connection includes of a dial-up networking connection to support modules requiring wireless data, and a direct handset connection for modules requiring transport information.

[0142] 203. The GPS module (GPSM) **1112** can optionally be included to provide GPS information to the Main Control Module. For example, the time information provided by the GPS Module can be used by the MCM to provide very accurate time stamps for the collected data. Furthermore, in a mobile environment the location information from the GPS Module can be used to provide position information. The term GPS is being used generically to refer to any type of position location technology including a distributed GPS (*e.g.* SnapTracks) and Time Difference of Arrival or Time Angle of Arrival *(e.g.* TruePosition). These additional forms of location determination may include the addition of a location server to the system.

[0143] 204. The WAP/WML data module (WDM) **1116** is responsible for performing all WAP related tasks. Embedded within the module will be WAP browser capabilities. The WDM is responsible for handling all WAP gateway login requests and security key exchanges. As previously discussed, the exemplary embodiment can include a WDM to collect data on any WDP, depending on the network that is being tested.

[0144] 205. The transport data module (TDM) **1120** is responsible for collecting all transport related data such as signal strength, quality, etc. This module is designed to be transport specific, and is loaded based on the transport technology being used (i.e. CDMA, iDEN, TDMA, GSM, etc.) Because data is collected differently for each transport technology, the module may be run in parallel with other modules (e.g. iDEN) or may need to be run serially while other modules are not collecting data (e.g. CDMA).

[0145] 206. The SMS module (SMSM) **1124** is responsible for collecting SMS information related to a specific wireless network. For example, the SMS message can be either transmitted or received by the module. The SMS module is able to track the difference between the time of SMS transmission and reception in order to determine the latency in the system.

[0146] 207. The PDA module (PDAM) **1128** is responsible for collecting information related to PDA access of data via a wireless network. The possible PDAs to be used can include, but are not limited to, Palm, Pocket PC, Handspring, RIM, etc.

[0147] 208. The Push Notification Module (PNM) **1132** is responsible for collecting information related to data that is pushed via a wireless network to the remote device. For example, the Phone.com gateway includes a utility for pushing data to the remote device using WAP. There are a variety of other ways in which data can be pushed to the remote device.

[0148] 209. The Passive Monitoring Module (PMM) **1136** will be responsible for collecting information related to passive monitoring of a wireless network. This differs from the latency measurement function because there is no need for the process to generate any information *(i.e.* it only needs to monitor and passively receive information). For example, the PMM listens to the control channel and collects Layer 3 information.

[0149] 210. The Wireless Web Data Module (WWDM) **1140** will be responsible for performing tasks related to the chosen wireless web standard. This module is similar to the WAP/WML module but is used in networks in which other wireless web protocols (such as HDML, i-MODE, etc.) are used rather than WML. These protocols are generically referred to as WDP (Wireless Data Protocol).

[0150] 211. The HTML Data Module (HTDM) **1144** is responsible for performing HTML tasks. This module is similar to the WAP/WML module but is used in networks in which HTML is used rather than WML.

[0151] 212. The E-Mail Data Module (EDM) **1148** is responsible for performing e-mail tasks. This includes the ability to both transmit and receive e-mails at the remote device over the wireless network.

[0152] 213. The FTP Data Module (FDM) **1152** is responsible for performing FTP tasks that involve the transmission of files. Although this module is referred as FTP (based on the TCP/IP file transmission protocol) this module will be able to implement a variety of file transmission protocols including future protocols which may be developed to move files over wireless networks.

[0153] 214. The Packet Sniffing Module (PSM) **1156** is responsible for performing packet sniffing tasks. This includes the ability to decode and log low level packet information similar to the functionality on a LAN packet sniffer.

[0154] 215. The Multimedia Data Module (MMDM) **1160** is responsible for performing tasks related to the transmission or reception of various types of multimedia data. For example, the multimedia data could be music files such as MP3 compressed music or some form of streaming video using a variety of different compression standards.

[0155] 216. The Status Module (StatM) **1164** is responsible for providing status information related to the remote unit. This is accomplished in any of a variety of alternative ways. For example, the Status Module can be responsible for providing periodic "heartbeats" which are monitored by the Back End to ensure that the remote unit is still alive and well. These heartbeats may be embodied a simple message which just states the unit is alive, or they may be embodied as more sophisticated messages including status information such as the available memory, amount of memory used, current configuration, temperature, etc. As another alternative, the system may be embodied with the Back End polling the remote units and the Status Module responding to the requests. In a further alternative, the system may include both heartbeats and polled status responses.

[0156] 217. The optional control link connection module (CLCM) **1168** manages (if implemented) the control link connection. The control link connection is used by the PUPPI unit to send and receive messages from the back end software. This module is optional and may be left out in implementations that use a higher level protocol to maintain the link between the remote units and the back end. For example, if the remote units run a database with setup info and collected data, the back end can communicate with the remote units by simply accessing their individual databases using remote database communications.

[0157] 218. Each data module logs collected information to a local database via the logging module (LM) **1172.** This module handles data logging requests from each module.

[0158] 219. The alarm module (AM) **1176** allows the setting of alarm conditions and produce alarms if an alarm condition is reached. For example, if data is being stored at the remote unit, an alarm condition may be set if the on-board storage is more than 80% full in order to prevent a storage overflow from occurring.

[0159] 220. Each software module has a defined method of communicating with the PUPPI Main Control Module (MCM) **1104.** The MCM **1104** has the ability to send requests to each module and receive responses. MCM **1104** requests may include status checks, tasks, etc. Each module will communicate with the logging module (LM) **1172** to log results.

[0160] 221. The WAP Data Module (WDM) **1116** communicates with the WAP Gateway using UDP. The Control Link Module (CLM) **1168** communicates with the back end server using TCP/IP.

[0161] 222. The exemplary system has remote control capability. A remote access application (e.g., PC Anywhere or an equivalent thereof) is loaded onto each PUPPI unit to allow full remote access to the PUPPI unit. This software is configured to automatically execute and enter a host mode when the machine is started. While running, the application remains in host mode, waiting for connections from external machines.

[0162] 223. The exemplary system also has application protection capabilities. Each PUPPI unit may include a special hardware card that can be used to force a machine reboot if software problems are encountered. The Main Control Module (MCM) **1104** will be tasked with monitoring each process to verify that each is running properly. If any process does not respond to the MCM's request within a predefined period of time, the hardware card will automatically reboot the machine.

[0163] 224. For a stationary PUPPI in a controlled environment, an exemplary PUPPI control unit is advantageously implemented as a standard rack mounted PC. For a mobile PUPPI, there are a variety of possible embodiments depending on the operating environment. The PUPPI hardware can include a separate enclosure for shielding the handset from the PC. The handset enclosure includes access for a serial cable for control purposes and a port for an external antenna.

[0164] 225. In the event that multiple technologies are required at a remote location, a variety of options are available to implement them. For example, a single PUPPI unit with multiple serial ports can be set up to implement multiple technologies. The only limit to this approach is the processing power and storage capacity of the PUPPI to support multiple technologies. Alternatively, each PUPPI can support a single technology and be connected via a LAN with the ability to communicate with the Back End.

[0165] 226. Referring to FIG. 12, for example, a router **1200** is used as the interface between an external communication line **1210** (such as a DSL or dialup line) and a LAN **1220** that is connected to the PUPPIs **1230.**

[0166] 227. In FIG. 13, the basic architecture for the Back End according to the exemplary embodiment is illustrated.

[0167] 228. The Back End performs the following major functions:

- Performing fleet management of the PUPPIs to include sending commands and receiving responses using the control link, and performing queuing of missions based on measurement scripts
- Maintaining a database of PUPPI information
- Maintaining a database of requested and scheduled collection missions
- Maintaining a database of collected data
- Providing a user interface for entering collection mission tasking and extracting collected data

[0168] 229. The user interface **1310** to the system is a simple interface that allows users to prepare test scripts over the Internet **1320** to collect data, and to extract the collected data. The other major component of the Back End provides Fleet Management and Data Management for the PUPPI fleet **1330,** the scheduled missions **1340,** and the collected data 1350.

[0169] 230. The Back End is implemented using commercial-grade PCs and standard software and database tools.

[0170] 231. The back end software preferably includes a fleet manager application, a centralized database server, and a web server. The fleet manager software allows the system operator to do the following:

- Define measurement
- Assign measurements to PUPPIs
- Query PUPPIs for diagnostic information
- Start and stop PUPPI measurements
- Query PUPPIs for configuration information
- Schedule delivery of measurements
- Query PUPPIs for measurement results

[0171] 232. All data collected from the PUPPIs is stored on a centralized database server. The database contains detailed information about the measurements, assignments, configuration information, etc. The data to be collected by the system is entered through a scripting language.

[0172] 233. Referring to FIG. 14, two basic software modules included in the Back End are illustrated. The modules, the Queue Builder Module **1410** and the Scheduler Module **1420,** convert the mission requests from the script to an actual mission to be executed on the PUPPI.

[0173] 234. The Queue Builder Module **1410** takes the information from the script and converts it to a queue of data collection missions for the PUPPIs. The scheduler **1420** takes the information in the queue and converts it to a list of tasks at regular intervals (e.g. daily) that are sent to the PUPPIs and then executed. The resulting data is extracted from the PUPPI database **1430**

after it is collected.

[0174] 235. Referring to FIG. 15, hardware architecture for the Back End according to the exemplary embodiment is illustrated. The Back End hardware includes, at a minimum, a scalable configuration of commercial servers **1510, 1520, 1530** that support 24/7 operations. By design, significantly less data flows between a WAP client and server than between an Internet client and server. Many of the tasks handled by an Internet client (e.g. DNS lookup request and response) have been moved from the client to the server (or gateway) under WAP. Additionally, WAP-based WML pages differ from Internet based HTML pages. WML pages introduce the concept of decks and cards. WML pages contain decks that may have one or many cards. Each card is similar to a single page or screen view. A deck usually contains a collection of cards. When a user requests a URL from a WAP device, many times a deck with several cards is downloaded to the browser. Once the entire deck is downloaded, the user can move between screens without requesting that new content be downloaded from the server.

[0175] 236. The exemplary system is configured to collect information that is specific to WAP-based browsing. The following metrics can be collected by the exemplary system. Web download would involve simulating a user downloading a single web page. Listed below is an example of the type of information that is collectable.

- **GET Time & Date**
  The time and date that the browser issued a GET command requesting a URL.
- **URL Address**
  Address of the URL being retrieved.
- **Deck Text Size**
  The size in bytes of the text portion of the deck and all associated cards.
- **Image Count**
  A count of the number of images embedded in a deck.

[0176] 237. For each image, the following information may be collected:

- **Image Size**
  The size in bytes of the image.
- **Image Time**
  The time to download the image.
- **Image URL**
  The URL of the image.
- **Total Deck Time**
  The amount of time required to download the entire deck and associated images.
- **Total Deck Bytes**
  The total number of bytes within the deck (text and images)
- **Result**
  Whether the web download was successful or not.

[0177] 238. Web navigation measurements involve simulating a user navigating to a page other than the page defined by the main URL. For example, a customer may desire to know how long it takes to navigate to the financial news section on the Bloomberg site.

[0178] 239. All of the information listed in the Web Download section can be collected for each deck that was downloaded as part of the navigation task. Additionally, the information listed below may also be collected pending a technical assessment by Invertix.

- **Total Cards**
  The total number of cards (or screens) to reach final destination.
- **Total Decks**
  The total number of decks that had to be downloaded to reach final destination.
- **Total Navigation Time**
  The amount of time required to navigate to the final destination.
- **Total Navigation Bytes**
  The total number of bytes downloaded to navigate to the final destination.
- **Result**
  Whether the web navigation was successful or not.

[0179] 240. Web transactions generally involve components of the Web Download and Web Navigation methods. Web transactions are defined as any action that requires the user to input information to obtain some result. Some examples would include inputting one's zip code to retrieve the weather, inputting a ticker symbol to retrieve a stock quote; or inputting one's billing information to purchase a book. Web transactions would collect all of the metrics included above for Web Download and Web Navigation. Additionally, the information listed below may also be collected.

- **Time for Response**
  Time for the network to respond to a user's input.
- **Result**
  Whether the user input was accepted / successful or not.

[0180] 241. A full web transaction may require that a user input information on multiple screens. Metrics for each user input and response would be collected. The success or failure of a transaction would be based on the data that is returned in response to the request.

VIII. Data Mining Functionality

[0181] 242. The disclosure thus far has emphasized the collection and storage of the data. However, the issue of handling the data in a manner that adds value to the end customer is valuable and adds to the economic viability of the system. The collected data can be warehoused and mined to produce added value.

[0182] 243. Telecom service providers (wireless carriers, ISPs, CLECs, ILECs, Satellite, and IXCs) can build wireless data portals and integrate their back office stove-pipe data systems into a single data warehouse platform. In addition, telecom operators may build and operate wireless portals to make billing and other customer care data available to subscribers through an interactive, customizable Web and/or wireless data interface.

[0183] 244. A data translation application is configured to collect data from various vendor-independent business areas (billing, customer care, marketing, network performance, etc.) and host it in a single data warehouse with specific vertical dimensional partitions. The data warehouse's data mode is configured to facilitate and speed up reporting.

[0184] 245. According to a preferred embodiment, data mining is implemented (for example, using MicroStrategy's Intelligent E-Business Platform) so as to allow end users to use a graphical front-end web-based interface to perform analytical online queries on the underlying data and create reports tailored to specific needs. Report details range from a high-level management report where users can drill down and across to atomic-level data.

[0185] 246. Tools enable advanced call center management applications to do the following:

- Increase employee productivity and reduce response times through detailed analysis of call volumes and patterns,
- Improve call center effectiveness by reporting on trouble ticket resolution,
- Make information available to the marketing staff for the development of customer campaigns, and
- Increase customer loyalty by keeping them informed through personalized messaging about network performance and problem resolution.

[0186] 247. Effective marketing is critical for retaining customers as well as for acquiring new ones. Ensuring that customers have the optimal plan for their usage habits helps to boost revenue and reduce churn by enabling managers to plan marketing strategy to create new product offerings, analyze pricing, and assess the profitability impact of new offerings.

[0187] 248. A portal provides subscribers with a single point of access to information for data, analysis and dissemination. As a personalized web-based gateway to information, it allows users to subscribe to key information, personalize it for their needs, and specify the desired frequency for its delivery, all through a single web-based interface. As one example, such functionality is powered by MicroStrategy InfoCenter. The portal is designed for large-scale deployments and includes an asynchronous update server, a high-speed interface cache, and clustering to meet the needs of large-scale implementations. Adaptable to many user requirements, the Telco Portal can provide the Telco Operator with the ability for its internal community to:

- analyze costs and revenues,
- adapt pricing and promotions maintain quality of service,
- improve sales and customer service,
- optimize customer loyalty programs, and
- reduce churn.

[0188] 249. A portal also provides network operations and performance personnel with a powerful reporting tool that maps counties and trunk traffic activities. Daily, weekly, and monthly reports are automatically generated and pushed to appropriate personnel. Users can set rules for alerts and have messages sent to their mobile devices based on certain criteria triggers. Such functionality is advantageously powered by MicroStrategy Broadcaster.

IX. Combination of Diverse Systems

[0189] 250. The system is described as a stand-alone system in the explication of the embodiments above. However, in accordance with a further embodiment of the invention, the system is combined with one or more secondary data collection systems.

[0190] 251. One such secondary data collection system functions to collect some of the same data as gathered by a system according to the exemplary embodiment, above. This secondary system collects that data and sends it to a system according to the exemplary embodiment for processing.

[0191] 252. Another such secondary data collection system functions to collect data that is different than the data collected by the exemplary system. The data from the secondary system and the exemplary system are be combined, either pre- or post-processing, in order to produce value-added reports for customers.

[0192] 253. According to an alternative embodiment, a system embodied according to the present invention collects additional data (beyond the standard data types discussed above) that is then exported for use by the secondary system, either pre- or post-processing.

[0193] 254. Additionally, it is noted that a back end installation according to the present invention is not limited only to the control of remote measurement units. The back end portion of a system according to the present invention is useful for providing scheduling, control, and data gathering for a variety of other system (for example, data collecting sensors, telecommunications network operation centers for either wired or wireless systems, telecommunication QOS network operation centers, surveillance and security systems, automated adjustment of wireless network base station parameters, etc.).

[0194] 255. A third implementation paradigm is also appropriate in the case of networks that already have well established back end operations. As opposed to the stand-alone and master controller paradigms discussed above, a back end according to the present invention may be implemented as an added set of functionalities as a part of an already existing network back end installation. Any additional hardware needed to implement the functions of the present invention's back end are simply integrated into those of an existing system, with the existing system being re-programmed to provide services as described above.

[0195] The scope of the invention is limited only by the appended claims.

Claims

1. A measuring system for measuring data quality of service on at least one traffic wireless network, comprising:

   a plurality of remote units (300) for performing measurements on the at least one traffic wireless network, each of the plurality of remote units (300) implementing a Wireless Data Protocol, WDP, client, each of the plurality of remote units (300) comprising:

   at least one test traffic modem (310) adapted to connect to one or more of the at least one traffic wireless networks,
   characterized by:
   a control link modem (308), and
   a control unit coupled to the test traffic modem and to the control link modem; and

   a back end processor (224) for remotely controlling the plurality of remote units (300) the back end processor (224) being in communication with each of the plurality of remote units (300) via a control link and exchanging commands and responses with the control link modem via the control link;

   wherein selected ones of the plurality of remote units simulate operation of a WDP enabled wireless device by having the WDP client access the at least one traffic wireless network via the test traffic modem (310).

2. The measuring system of claim 1, wherein the test traffic modem comprises a wireless handset.

3. The measuring system of claim 1, wherein the test traffic modem comprises a wireless modem module.

4. The measuring system of claim 1, wherein the control link modem comprises a POTS modem, and the control link comprises a dedicated phone line.

5. The measuring system of claim 1, wherein the control link modem comprises a DSL modem, and the control link comprises a DSL line.

6. The measuring system of claim 1, wherein the control link modem comprises an ISDN modem, and the control link comprises an ISDN line.

7. The measuring system of claim 1, wherein the WDP client is implemented in the control unit.

8. The measuring system of claim 1, wherein the WDP client is implemented in the test traffic modem.

9. The measuring system of claim 1, wherein the WDP client comprises a WAP browser.

10. The measuring system of claim 1, wherein the WDP client comprises an iMode browser.

11. The measuring system of claim 1, wherein the remote unit simulates a subscriber using the WDP enabled wireless device.

12. The measuring system of claim 1, wherein one or more of the remote units includes a transport data-module, TDM, that collects transport related data.

13. The measuring system of claim 1, wherein one or more of the remote units includes a Short Message Service, SMS, module that collects SMS information.

14. The measuring system of claim 1, wherein one or more of the remote units includes a Personal Digital Assistant, PDA, module that collects PDA information.

15. The measuring system of claim 1, wherein one or more of the remote units includes a Push Notification Module, PNM, that collects information related to data that is pushed.

16. The measuring system of claim 1, wherein one or more of the remote units includes a Passive Monitoring Module, PMM, that collects information related to passive monitoring of the at least one traffic wireless network.

17. The measuring system of claim 1, wherein one or more of the remote units includes an HTML Data Module that collects information related to HTML.

18. The measuring system of claim 1, wherein one or more of the remote units includes a Packet Sniffing Module, PSM, that performs packet sniffing.

19. The measuring system of claim 1, wherein one or more of the remote units includes a Multimedia Data Module, MMDM, that performs tasks related to multimedia data.

20. The measuring system of claim 1, wherein one or more of the remote units includes a database providing storage for the measurements.

21. The measuring system of claim 1, wherein the back end processor includes a database providing storage for the measurements.

22. The measuring system of claim 1, wherein the back end processor includes a scheduler module that schedules the measurements.

23. The measuring system of claim 1, wherein the back end processor includes a data mining module that analyzes the measurements.

24. The measuring system of claim 1, wherein one or more of the remote units is stationary.

25. The measuring system of claim 1, wherein one or more of the remote units is mobile.

26. The measuring system of claim 1, wherein the back end processor is implemented in a stand-alone configuration.

27. The measuring system of claim 1, wherein the back end processor is implemented so as to provide command and control of diverse systems beyond the measuring system.

28. The measuring system of claim 1, wherein the back end processor is implemented so as to gather test data from one or more secondary systems distinct from the remote units.

29. The measuring system of claim 1, wherein the back end processor is implemented by adapting a pre-existing back end installation to incorporate a set of added functionalities.

30. The measuring system of claim 1 wherein:

the test traffic modem is selected from the group consisting of: a wireless handset and a wireless modem module,

wherein a Wireless Application Protocol, WAP, browser is implemented via the control unit or the test traffic modem; and
wherein selected one of the plurality of remote units simulates a subscriber using a WAP-enabled wireless device by having the WAP browser access the at least one traffic wireless network via the test traffic modem.

31. The measuring system of claim 1 wherein the back end processor comprises: a fleet database providing storage of information concerning the plurality of remote units; mission schedule database providing storage of information concerning measurement missions to be carried out by the plurality of remote units; and
a fleet management server in communication with each of the plurality of remote units via respective control links and adapted to exchange commands and responses with selected ones of the plurality of remote units, the fleet management server effecting communication with the remote units based on information accessed from the fleet database, the commands being based on information accessed from the mission schedule database;
wherein the fleet management server commands certain of the plurality of remote units to simulate operation of a WDP enabled wireless device by having the WDP client access the at least one traffic wireless network.

Patentansprüche

1. Messsystem zum Messen der Datenqualität des Dienstes mindestens eines kabellosen Verkehrsnetzwerks, umfassend:

eine Mehrzahl von fernen Einheiten (300) für die Durchführung von Messungen mindestens eines kabellosen Netzwerks, wobei jede der Mehrzahl von fernen Einheiten (300) einen Klienten eines kabellosen Datenprotokolls, WDP, in Gang setzt, jede der Mehrzahl von fernen Einheiten (300) umfasst:

mindestens ein Testverkehrsmodem (310), das angepasst ist, eines oder mehrere des mindestens einen kabellosen Verkehrsnetzes zu verbinden,
gekennzeichnet durch

ein Steuerverbindungsmodem (308), und

eine Steuereinheit, die mit dem Testverkehrsmodem und dem

Steuerverbindungsmodem gekuppelt ist, und

ein Backend-Prozessor (224) für die Fernsteuerung der Mehrzahl von fernen Einheiten (300), wobei der Backend-Prozessor (224) unter Kommunikation mit jeden der Mehrzahl von fernen Einheiten (300) über eine Steuerverbindung steht, und Befehle und Antworten mit dem Steuerverbindungsmodem über die Steuerverbindung austauscht;

wobei ausgewählte Einheiten der Mehrzahl von fernen Einheiten den Betrieb eines WDP-fähigen kabellosen Geräts simulieren indem der WDF-Klient Zugang zu mindestens einem kabellosen Verkehrsnetzwerk über das Testverkehrsmodem hat (310).

2. Messsystem nach Anspruch 1, worin das Testverkehrsmodem ein kabelloses Handgerät umfasst.

3. Messsystem nach Anspruch 1, worin das Testverkehrsmodem ein kabelloses Modemmodul umfasst.

4. Messsystem nach Anspruch 1, worin das Steuerverbindungsmodem ein POTS-Modem umfasst und die Steuerverbindung eine zugeordnete Telefon-Linie umfasst.

5. Messsystem nach Anspruch 1, worin das Steuerverbindungsmodem ein DSL-Modem umfasst und die Steuerverbindung eine zugeordnete DSL-Linie umfasst.

6. Messsystem nach Anspruch 1, worin das Steuerverbindungsmodem ein IDSN-Modem umfasst und die Steuerverbindung eine zugeordnete IDSN-Linie umfasst.

7. Messsystem nach Anspruch 1, worin der WDP-Klient in der Steuereinheit verwirklicht ist.

8. Messsystem nach Anspruch 1, worin der WDP-Klient im Testverkehrsmodem verwirklicht ist.

9. Messsystem nach Anspruch 1, worin der WDP-Klient einen WAP-Browser umfasst.

10. Messsystem nach Anspruch 1, worin der WDP-Klient einen iMode Browser umfasst.

11. Messsystem nach Anspruch 1, worin die ferne Einheit einen Abonnenten simuliert, wobei ein WDF-fähiges kabelloses Gerät verwendet wird.

12. Messsystem nach Anspruch 1, worin die eine oder die Mehrzahl von fernen Einheiten ein Datentransportmodul, TDM, umfasst, das in Beziehung stehende Daten transportiert.

13. Messsystem nach Anspruch 1, worin die eine oder die Mehrzahl von fernen Einheiten einen Kurzmitteilungsdienst, SMS, umfasst, der SMS-Informationen sammelt.

14. Messsystem nach Anspruch 1, worin die eine oder die Mehrzahl von fernen Einheiten ein Modul eines persönlichen digitalen Assistenten, PDA, umfasst, das PDS-Informationen sammelt.

15. Messsystem nach Anspruch 1, worin die eine oder die Mehrzahl von fernen Einheiten ein Push-Benachrichtigungsmodul, PNM, umfasst, das in Beziehung stehende gepushte Informationen sammelt.

16. Messsystem nach Anspruch 1, worin die eine oder die Mehrzahl von fernen Einheiten ein passives Überwachungsmodul, PMM, umfassen, das in Beziehung stehende Informationen für die passive Überwachung mindestens eines kabellosen Verkehrsnetzwerks sammelt.

17. Messsystem nach Anspruch 1, worin die eine oder die Mehrzahl von fernen Einheiten ein HTML Datentransportmodul umfassen, das mit HTML in Beziehung stehende Informationen transportiert.

18. Messsystem nach Anspruch 1, worin die eine oder die Mehrzahl von fernen Einheiten ein Packetsniffingmodul, PSM, umfasst, das Packetsniffing durchführt.

19. Messsystem nach Anspruch 1, worin die eine oder die Mehrzahl von fernen Einheiten ein Multimediadatenmodul, MMDM, umfasst, das Aufgaben durchführt, die sich auf Multimediadaten beziehen.

20. Messsystem nach Anspruch 1, worin die eine oder die Mehrzahl von fernen Einheiten eine Datenbank, umfassen, die eine Speicherung der Messungen durchführt.

21. Messsystem nach Anspruch 1, worin der Backend-Prozessor, eine Datenbank, umfasst, die eine Speicherung der Messungen durchführt.

22. Messsystem nach Anspruch 1, worin der Backend-Prozessor ein Terminplanmodul umfasst, das eine Speicherung der Messungen durchführt.

23. Messsystem nach Anspruch 1, worin der Backend-Prozessor ein Datensuchmodul umfasst, das die Messungen analysiert.

24. Messsystem nach Anspruch 1, worin die eine oder die Mehrzahl von fernen Einheiten stationär sind.

25. Messsystem nach Anspruch 1, worin die eine oder die Mehrzahl von fernen Einheiten mobil sind.

26. Messsystem nach Anspruch 1, worin der Backend-Prozessor in einer frei stehenden Konfiguration ausgeführt ist.

27. Messsystem nach Anspruch 1, worin der Backend-Prozessor so ausgestaltet ist, dass er Befehle und Steuerungen für verschiedene Systeme ausserhalb des Messsystems ausführen kann.

28. Messsystem nach Anspruch 1, worin der Backend-Prozessor so ausgeführt ist, dass er Versuchsdaten von einem oder mehreren sekundären Systemen erfassen kann, die verschieden von den fernen Einheiten sind.

29. Messsystem nach Anspruch 1, worin der Backend-Prozessor so ausgestaltet ist, dass eine vorher existierende Backend-Installation übernommen werden kann, um einen Satz von zusätzlichen Funktionalitäten einzuverleiben.

30. Messsystem nach Anspruch 1, worin:

das Testverkehrsmodem ausgewählt ist aus der Gruppe bestehend aus: kabelloses Handgerät und kabelloses Modemmodul; und

worin ein Wireless Application Protocol , WAP, -Browser über die Steuereinheit oder das Testverkehrsmodem ausgeführt wird; und

worin die ausgewählte Einheit oder Mehrzahl von fernen Einheiten einen Abonnenten simulieren, der ein WAP-fähiges kabelloses Gerät verwendet, indem es durch den WAP-Browser Zugang zu dem mindestens einen kabellosen Verkehrsnetzwerk via dem Testverkehrsmodem besitzt.

31. Messsystem nach Anspruch 1, worin der Backend-Prozessor enthält: eine Flottendatenbank zur Speicherung von Informationen, die sich auf die Mehrzahl von fernen Einheiten beziehen; eine Missions-Terminplanungsdatenbank zur Speicherung von Informationen, die sich auf die Messungsmissionen beziehen, die durchzuführen sind, durch die eine oder die Mehrzahl von fernen Einheiten; und

ein Flottenmanagementserver in Kommunikation mit jeder der einen oder Mehrzahl von fernen Einheiten über entsprechende Steuerverbindungen und der angepasst ist, Befehle und Antworten mit ausgewählten Einheiten der einen oder der Mehrzahl von fernen Einheiten auszutauschen, wobei der Flottenmanagementserver die Kommunikation mit den fernen Einheiten erbringt, auf Basis von Informationen, welche die Flottendatenbank zugänglich macht, wobei die Befehle auf Informationen basieren, die aus der Missionsterminplanungsdatenbank zugänglich sind;

wobei der Flottenmanagementserver für gewisse der Mehrzahl von fernen Einheiten den Steuerbefehl führt, um den Betrieb eines WDP-fähigen kabellosen Geräts zu simulieren, indem der WDP-Klient Zugang zu dem mindestens einen kabellosen Verkehrsnetzwerk besitzt.

Revendications

1. Système de mesure pour mesurer la qualité de données de service d'au moins un réseau de trafic sans fil, comprenant :

une pluralité d'unités à distance (300) pour effectuer des mesures sur au moins un réseau de trafic sans fil, chacune des unités à distance (300) de cette pluralité réalisant un client de protocole de données sans fil WDP, chacune des unités à distance (300) de cette pluralité comprenant:

au moins un modem de test de trafic (310) agencé pour se connecter à un ou plusieurs du au moins un réseau de trafic sans fil, **caractérisé par** :

un modem de commande de lien (308) et

une unité de commande accouplée au modem de test de trafic et au modem de commande de lien; et

un processeur terminal (224) pour commander à distance la pluralité d'unités à distance (300), le processeur terminal (224) étant en communication avec chacune des unités à distance (300) de cette pluralité via un lien de commande et échangeant des commandes et des réponses avec le modem de commande de lien via le lien de commande;

système dans lequel des unités sélectionnées parmi la pluralité des unités à distance simulent l'opération d'un dispositif sans fil mis en service par un WDP en donnant accès au client WDP audit au moins un réseau de trafic sans fil par l'intermédiaire du modem de test de trafic (310).

2. Système de mesure selon la revendication 1, dans lequel le modem de test de trafic est un combiné sans fil.

3. Système de mesure selon la revendication 1, dans lequel le modem de test de trafic est un module de modem sans fil.

4. Système de mesure selon la revendication 1, dans lequel le modem de commande de lien comprend un modem POTS, et le lien de commande comprend une ligne de téléphone spécialisée.

5. 0 Système de mesure selon la revendication 1, dans lequel le modem de commande de lien comprend un modem DSL et le lien de commande est une ligne DSL.

6. Système de mesure selon la revendication 1, dans lequel le modem de commande de lien comprend un modem RNIS et le lien de commande est une ligne RNIS.

7. Système de mesure selon la revendication 1, dans lequel le client WDP est incorporé dans l'unité de commande.

8. Système de mesure selon la revendication 1, dans lequel le client WDP est incorporé dans le modem de test de trafic.

9. Système de mesure selon la revendication 1, dans lequel le client WDP comprend un navigateur WAP.

10. Système de mesure selon la revendication 1, dans lequel le client WDP comprend un navigateur imode.

11. Le système de mesure selon la revendication 1, dans lequel l'unité à distance simule un abonné utilisant le dispositif sans fil mis en service par WDP.

12. Système de mesure selon la revendication 1, dans lequel une ou plusieurs des unités à distance comprend un module de données de transport, TDM, qui collectionne des données se référant au transport.

13. Système de mesure selon la revendication 1, dans lequel une ou plusieurs des unités à distance comprend un service à message court, SMS, qui collectionne des informations de SMS.

14. Système de mesure selon la revendication 1, dans lequel une ou plusieurs des unités à distance comprennent un module d'assistant numérique personnel, PDA, qui collectionne des informations PDA.

15. Système de mesure selon la revendication 1, dans lequel une ou plusieurs des unités à distance comprend un module de notification poussée, PNM, qui collectionne des informations sur des données qui sont poussées.

16. Système de mesure selon la revendication 1, dans lequel une ou plusieurs des unités à distance comprennent un module de surveillance passive, PMM, qui collectionne des informations par rapport à une surveillance passive du au moins un réseau de trafic sans fil.

17. Système de mesure selon la revendication 1, dans lequel une ou plusieurs des unités à distance comprennent un module de données HTML qui collectionne des informations en relation avec le HTLM.

18. Système de mesure selon la revendication 1, dans lequel une ou plusieurs des unités à distance comprennent un module de reniflement de paquets, PSM, qui effectue un reniflement de paquets.

19. Système de mesure selon la revendication 1, dans lequel une ou plusieurs des unités à distance comprennent un module de données multimédia, MMDM, qui effectue des tâches en relation avec des données multimédia.

20. Système de mesure selon la revendication 1, dans lequel une ou plusieurs des unités à distance comprennent une base de données permettant l'enregistrement des mesures.

21. Système de mesure selon la revendication 1, dans lequel le processeur terminal comprend une base de données permettant l'enregistrement des mesures.

22. Système de mesure selon la revendication 1, dans lequel le processeur terminal comprend un module de planning qui établit le planning des mesures.

23. Système de mesure selon la revendication 1, dans lequel le processeur terminal comprend un module d'exploitation de données qui analyse les mesures.

24. Système de mesure selon la revendication 1, dans lequel une ou plusieurs des unités à distance sont stationnaires.

25. Système de mesure selon la revendication 1, dans lequel une ou plusieurs des unités à distance sont mobiles.

26. Système de mesure selon la revendication 1, dans lequel le processeur final est incorporé dans une configuration isolée.

27. Système de mesure selon la revendication 1, dans lequel le processeur final est configuré de façon à fournir la commande et le contrôle de plusieurs systèmes en dehors du système de mesure.

28. Système de mesure selon la revendication 1, dans lequel le processeur final est réalisé de façon à recueillir des données de test à partir d'un ou plusieurs systèmes secondaires différents des unités à distance.

29. Système de mesure selon la revendication 1, dans lequel le processeur final est réalisé par l'adaptation d'une installation finale déjà existante et l'incorporation d'un jeu de fonctionnalité ajoutées.

30. Système de mesure selon la revendication 1, dans lequel :

le modem de test de trafic est choisi dans le groupe composé d'un combiné sans fil et d'un module de modem sans fil,

dans lequel une unité sélectionnée parmi la pluralité des unités à distance simule un abonné qui utilise un dispositif sans fil servi par WAP en faisant accéder le navigateur WAP audit au moins un réseau de trafic sans fil par l'intermédiaire du modem de test de trafic.

31. Système de mesure selon la revendication 1, dans lequel le processeur terminal comprend : une base de données de groupe permettant l'enregistrement d'informations concernant la pluralité d'unités à distance; une base de données de planning de missions permettant l'enregistrement d'informations concernant les missions de mesure à effectuer par la pluralité d'unités à distance; et

un serveur de gestion de groupe en communication avec chacune des unités à distance de la pluralité d'unités via des liens de commande respectifs et adapté à l'échange des commandes et des réponses avec des unités à distance sélectionnées parmi la pluralité d'unités, le serveur de gestion de groupe assurant une communication avec les unités à distance sur la base d'informations reprises de la base de données de groupe, les commandes étant fondées sur des informations reçues de la base de données de planning de missions;

dans lequel le serveur de gestion de groupe commande certaines unités de la pluralité d'unités à distance afin de simuler l'opération d'un dispositif sans fil mis en service par un WDP en donnant accès au client WDP audit au moins un réseau da trafic sans fil.

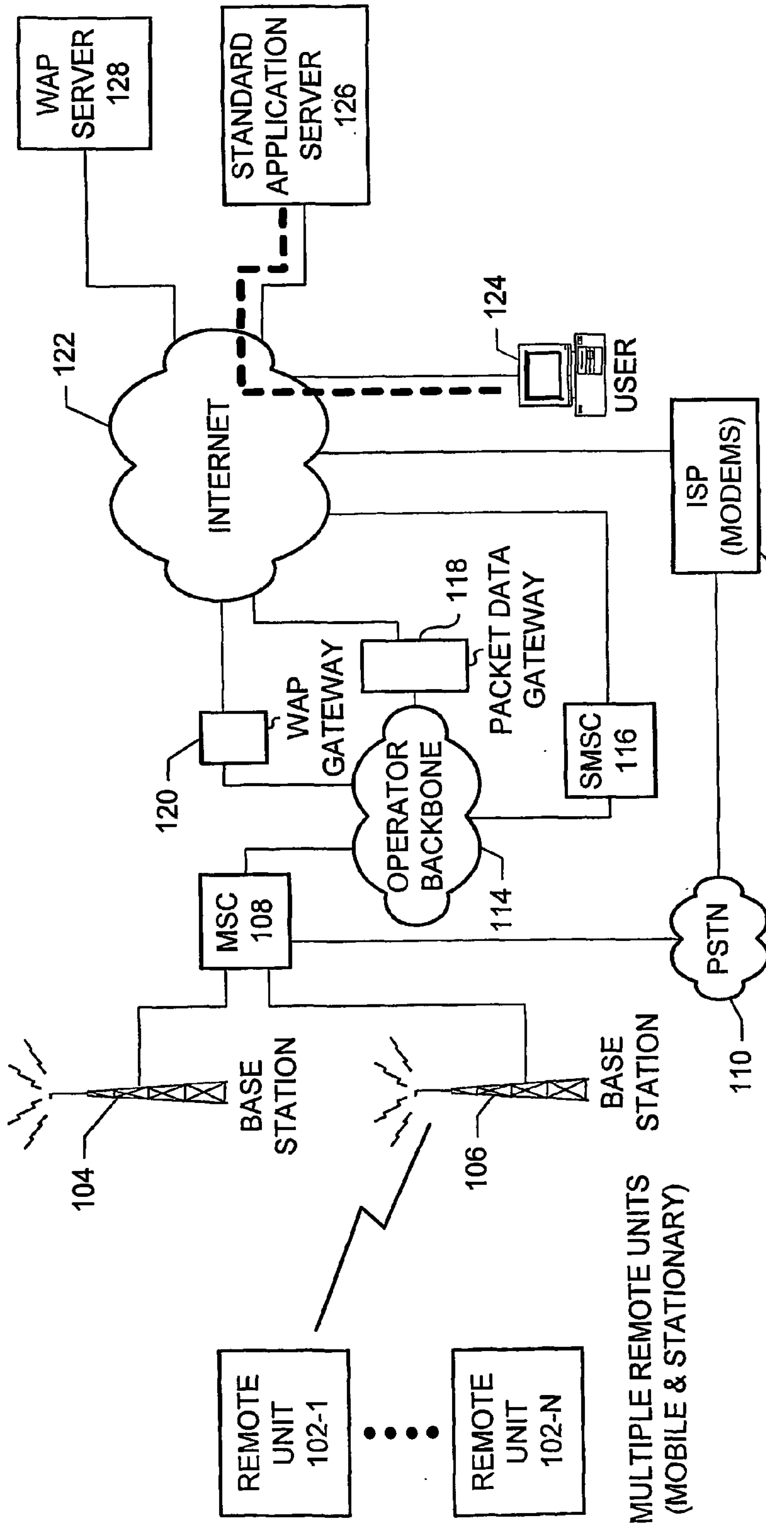

WAP SERVER 128
STANDARD APPLICATION SERVER 126
INTERNET
122
124
USER
ISP (MODEMS)
112
118
PACKET DATA GATEWAY
WAP GATEWAY
120
OPERATOR BACKBONE
114
SMSC 116
MSC 108
PSTN
110
BASE STATION
104
BASE STATION
106
REMOTE UNIT 102-1
REMOTE UNIT 102-N
MULTIPLE REMOTE UNITS (MOBILE & STATIONARY)

FIG. 1a

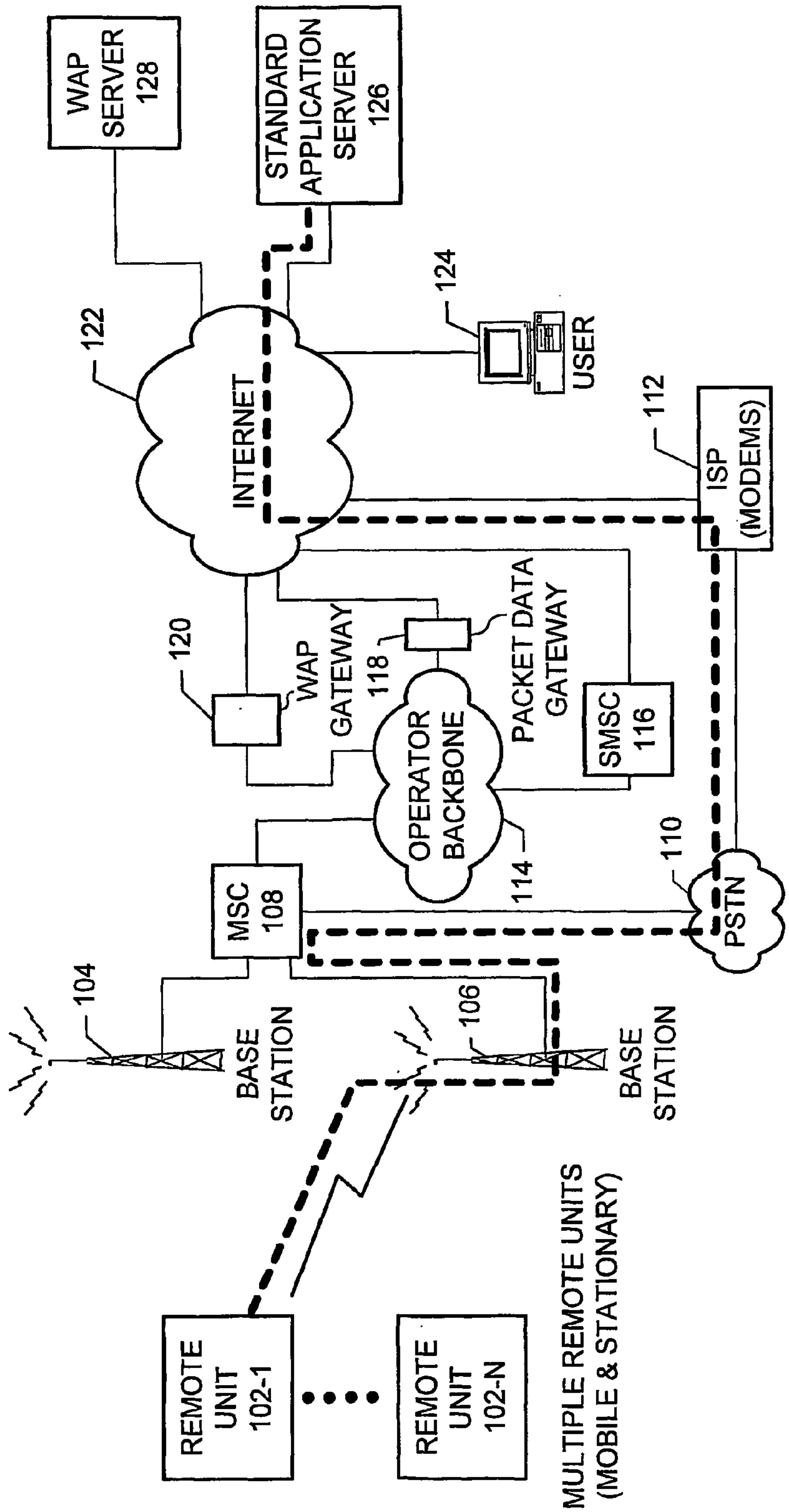
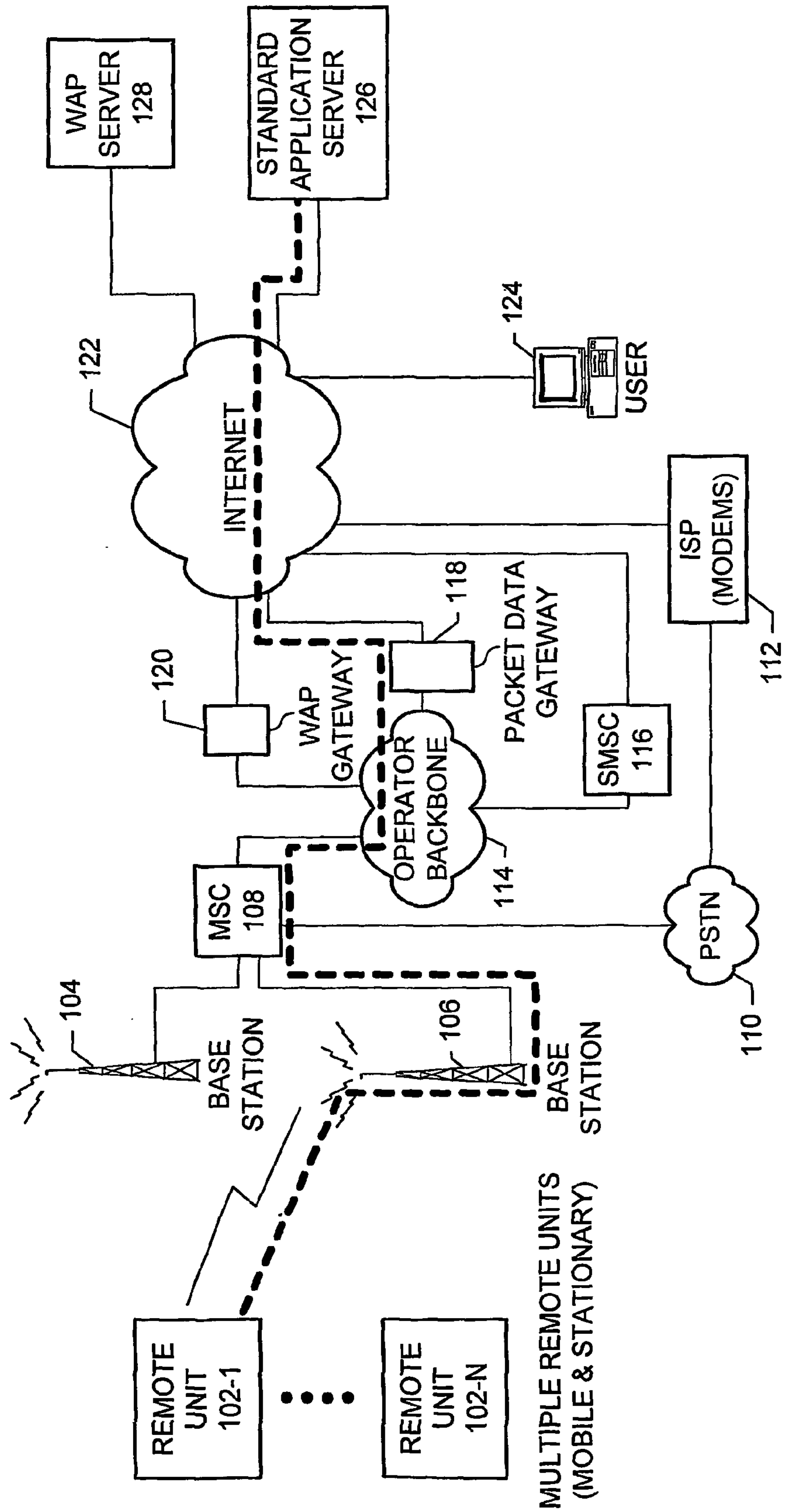

WAP SERVER 128
STANDARD APPLICATION SERVER 126
122
INTERNET
124
USER
112
ISP (MODEMS)
120
WAP GATEWAY
118
PACKET DATA GATEWAY
OPERATOR BACKBONE
114
SMSC 116
110
PSTN
MSC 108
104
BASE STATION
106
BASE STATION
REMOTE UNIT 102-1
REMOTE UNIT 102-N
MULTIPLE REMOTE UNITS (MOBILE & STATIONARY)

FIG. 1b



WAP SERVER 128
STANDARD APPLICATION SERVER 126
122
INTERNET
124
USER
ISP (MODEMS)
112
118
PACKET DATA GATEWAY
120
WAP GATEWAY
OPERATOR BACKBONE
114
SMSC 116
MSC 108
PSTN
110
104
BASE STATION
106
BASE STATION
REMOTE UNIT 102-1
REMOTE UNIT 102-N
MULTIPLE REMOTE UNITS (MOBILE & STATIONARY)

FIG. 1c

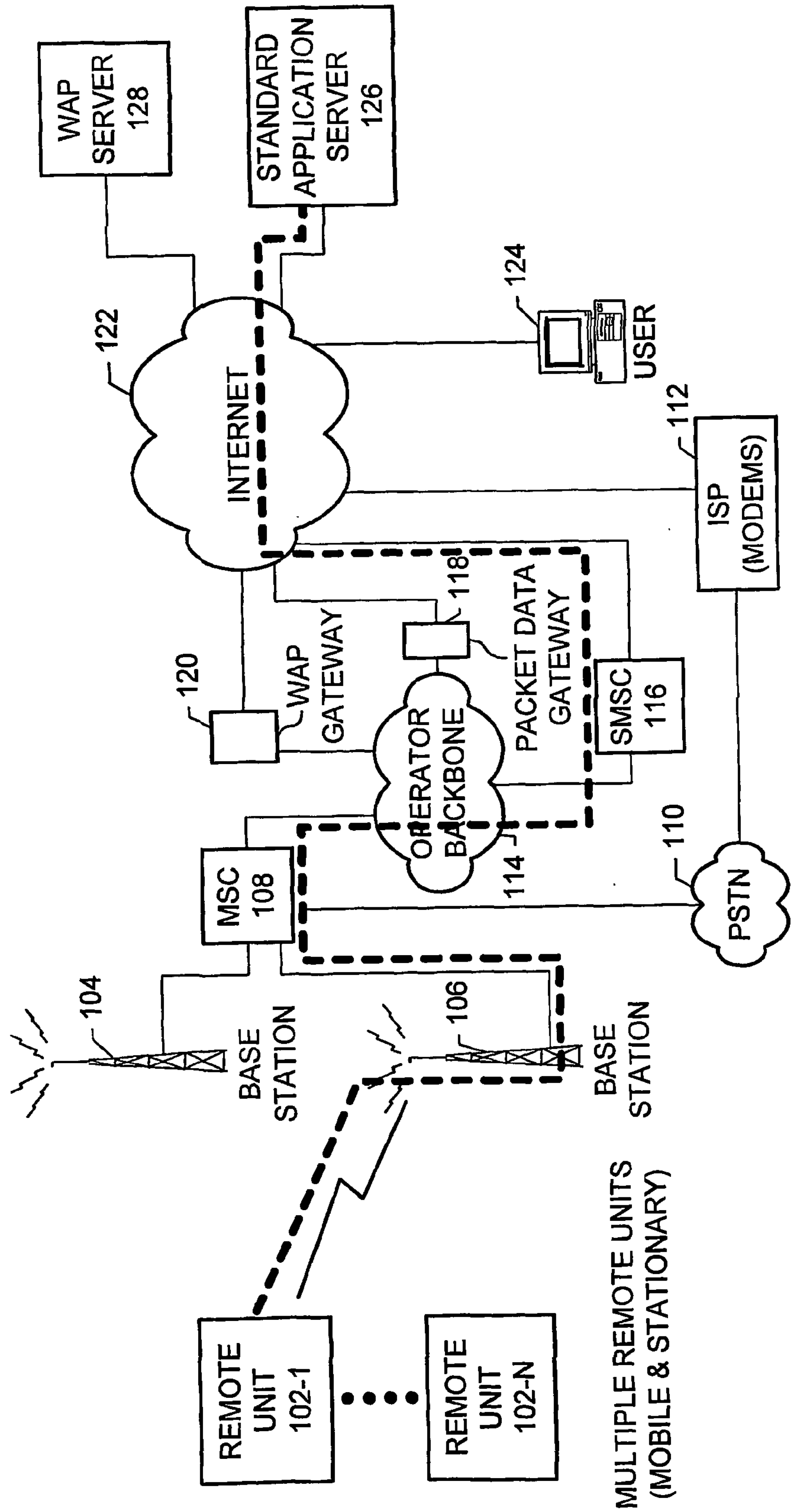

REMOTE UNIT 102-1
REMOTE UNIT 102-N
MULTIPLE REMOTE UNITS (MOBILE & STATIONARY)
104
BASE STATION
106
BASE STATION
MSC 108
110
PSTN
114
OPERATOR BACKBONE
120
WAP GATEWAY
118
PACKET DATA GATEWAY
SMSC 116
112
ISP (MODEMS)
122
INTERNET
124
USER
WAP SERVER 128
STANDARD APPLICATION SERVER 126

FIG. 1d

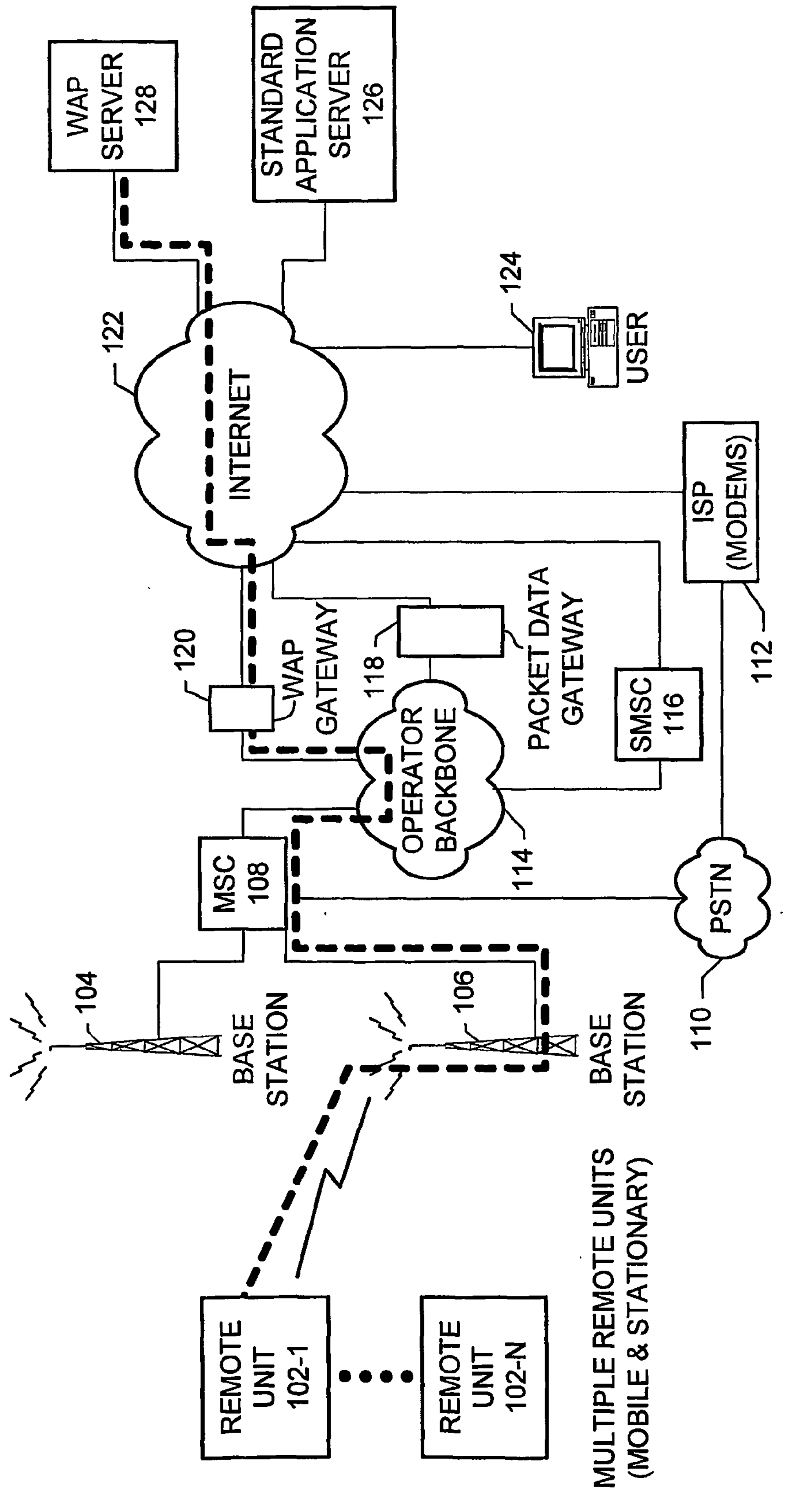

WAP SERVER 128
STANDARD APPLICATION SERVER 126
122
INTERNET
124
USER
ISP (MODEMS)
112
120
WAP GATEWAY
118
PACKET DATA GATEWAY
SMSC 116
OPERATOR BACKBONE
114
MSC 108
PSTN
110
104
BASE STATION
106
BASE STATION
REMOTE UNIT 102-1
REMOTE UNIT 102-N
MULTIPLE REMOTE UNITS (MOBILE & STATIONARY)

FIG. 1e

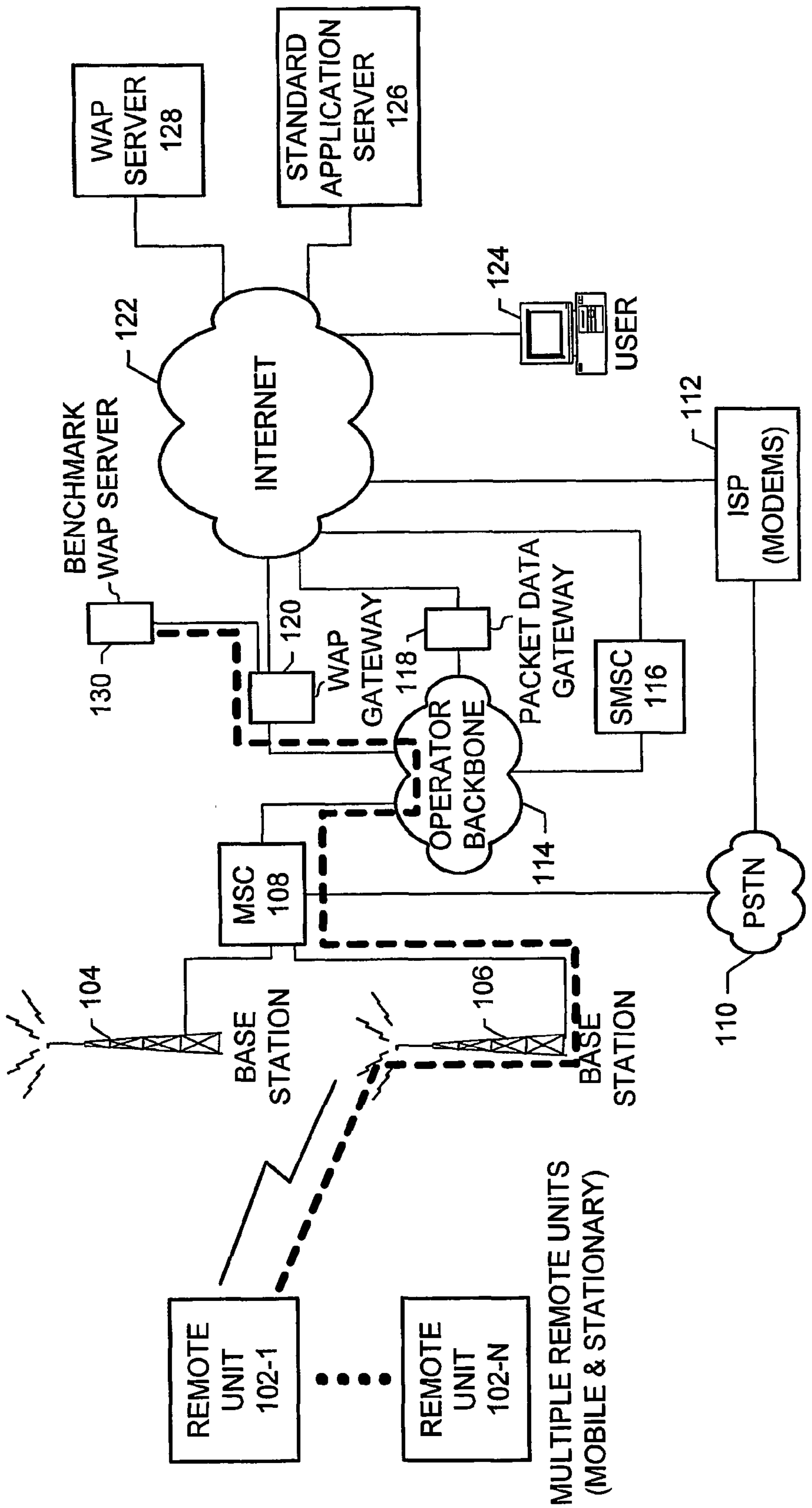

REMOTE UNIT 102-1
REMOTE UNIT 102-N
MULTIPLE REMOTE UNITS (MOBILE & STATIONARY)
104
BASE STATION
106
BASE STATION
MSC 108
PSTN
110
OPERATOR BACKBONE
114
WAP GATEWAY
120
118
PACKET DATA GATEWAY
SMSC 116
130
BENCHMARK WAP SERVER
INTERNET
122
ISP (MODEMS)
112
124
USER
WAP SERVER 128
STANDARD APPLICATION SERVER 126

FIG. 1f

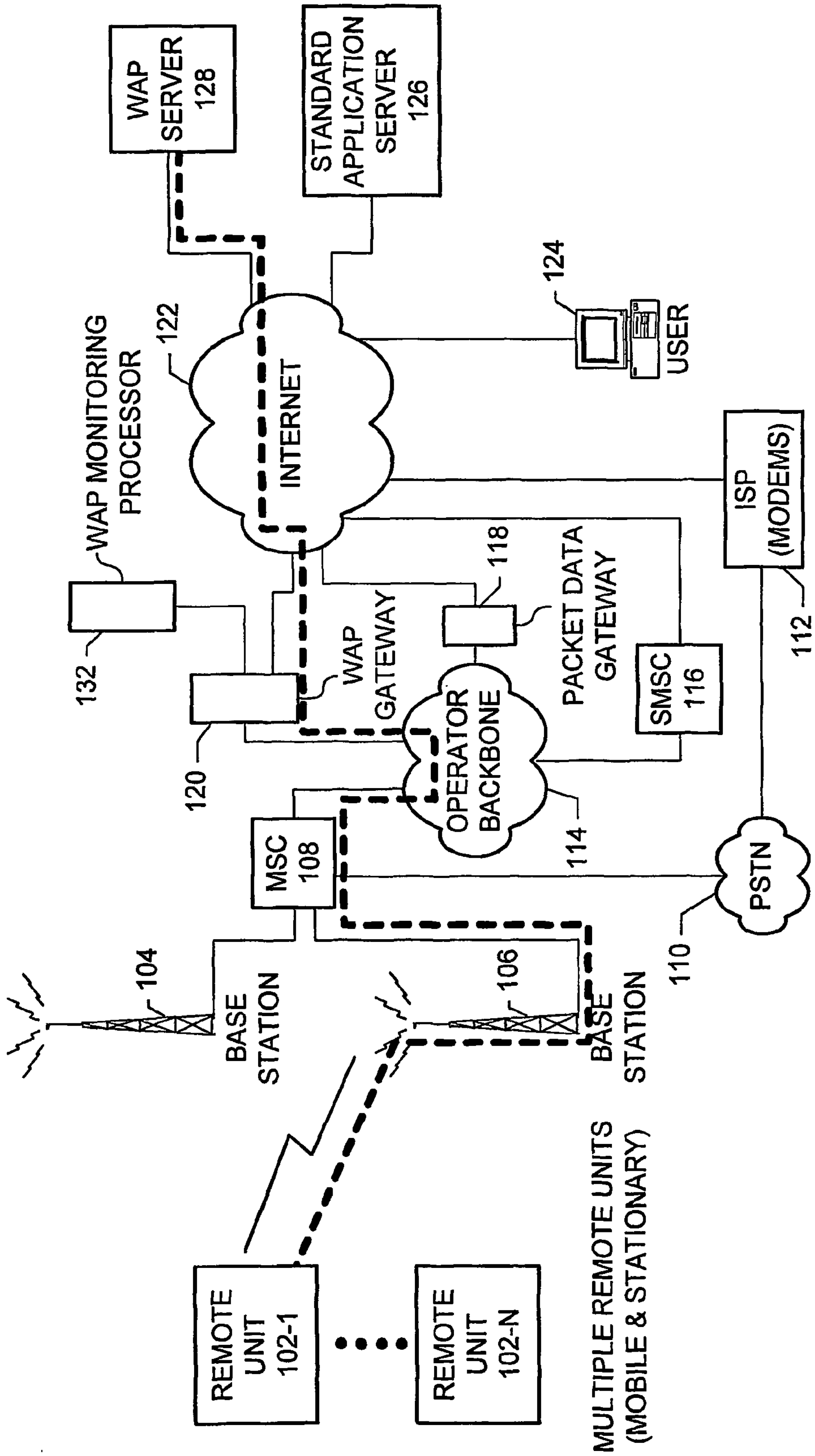

WAP SERVER 128
STANDARD APPLICATION SERVER 126
WAP MONITORING PROCESSOR
122
INTERNET
124
USER
ISP (MODEMS)
112
118
PACKET DATA GATEWAY
SMSC 116
132
WAP GATEWAY
120
OPERATOR BACKBONE
114
MSC 108
PSTN
110
104
BASE STATION
106
BASE STATION
REMOTE UNIT 102-1
REMOTE UNIT 102-N
MULTIPLE REMOTE UNITS (MOBILE & STATIONARY)

FIG. 1g

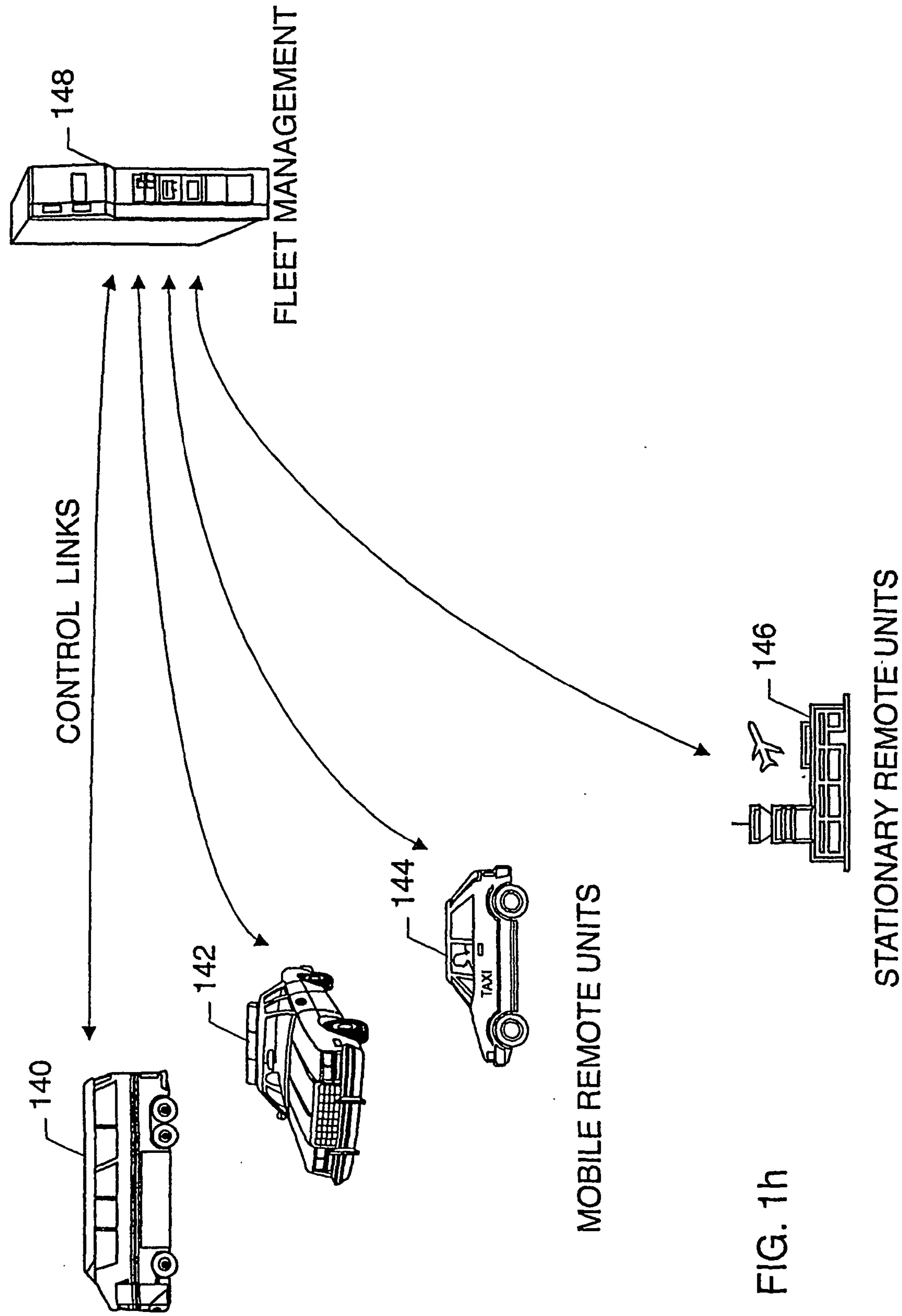

148
FLEET MANAGEMENT
CONTROL LINKS
140
142
144
TAXI
MOBILE REMOTE UNITS
146
STATIONARY REMOTE UNITS

FIG. 1h

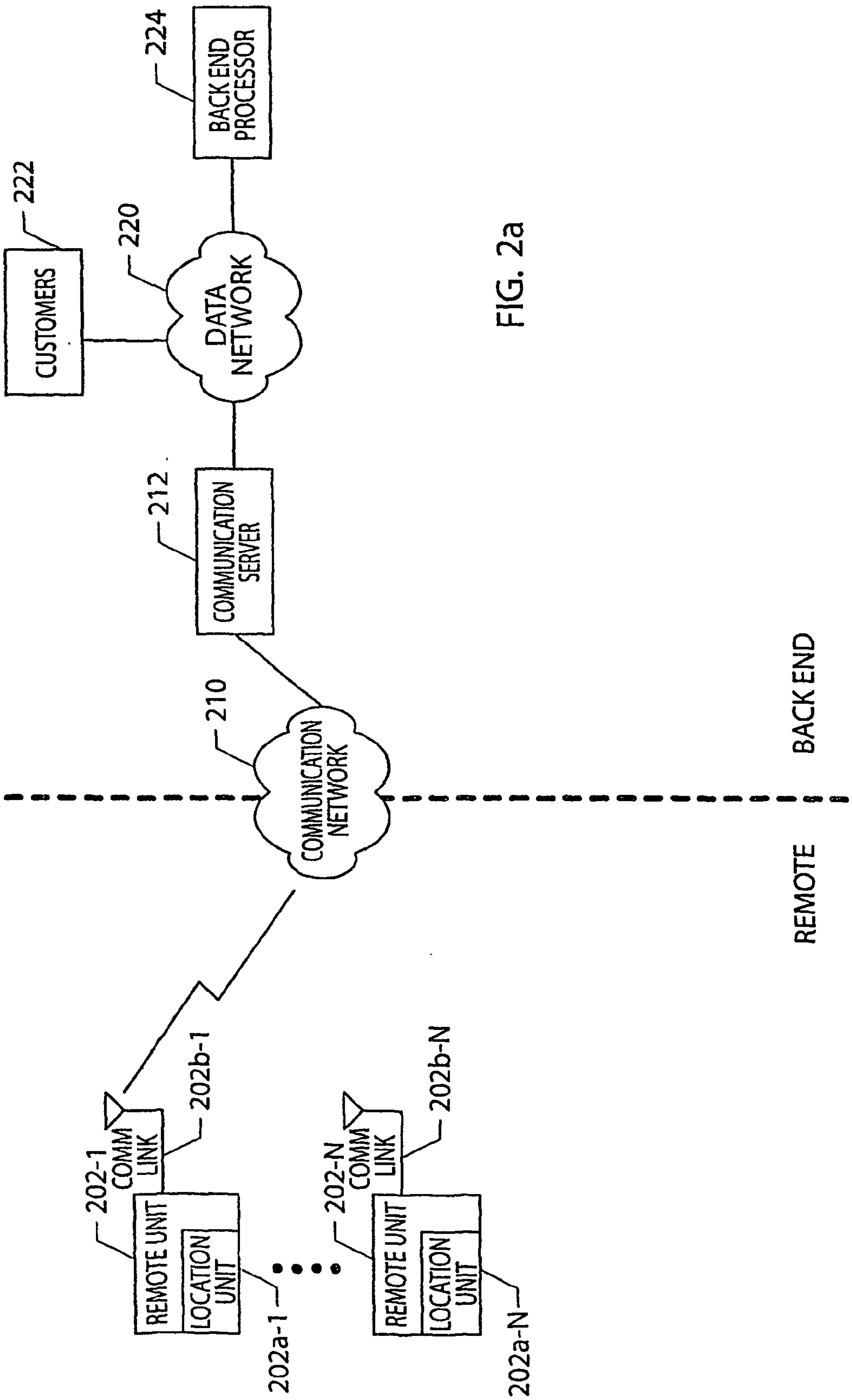

BACK END PROCESSOR
224
CUSTOMERS
222
DATA NETWORK
220
COMMUNICATION SERVER
212
COMMUNICATION NETWORK
210
BACK END
REMOTE
202-1
COMM LINK
202b-1
REMOTE UNIT
LOCATION UNIT
202a-1
202-N
COMM LINK
202b-N
REMOTE UNIT
LOCATION UNIT
202a-N

FIG. 2a

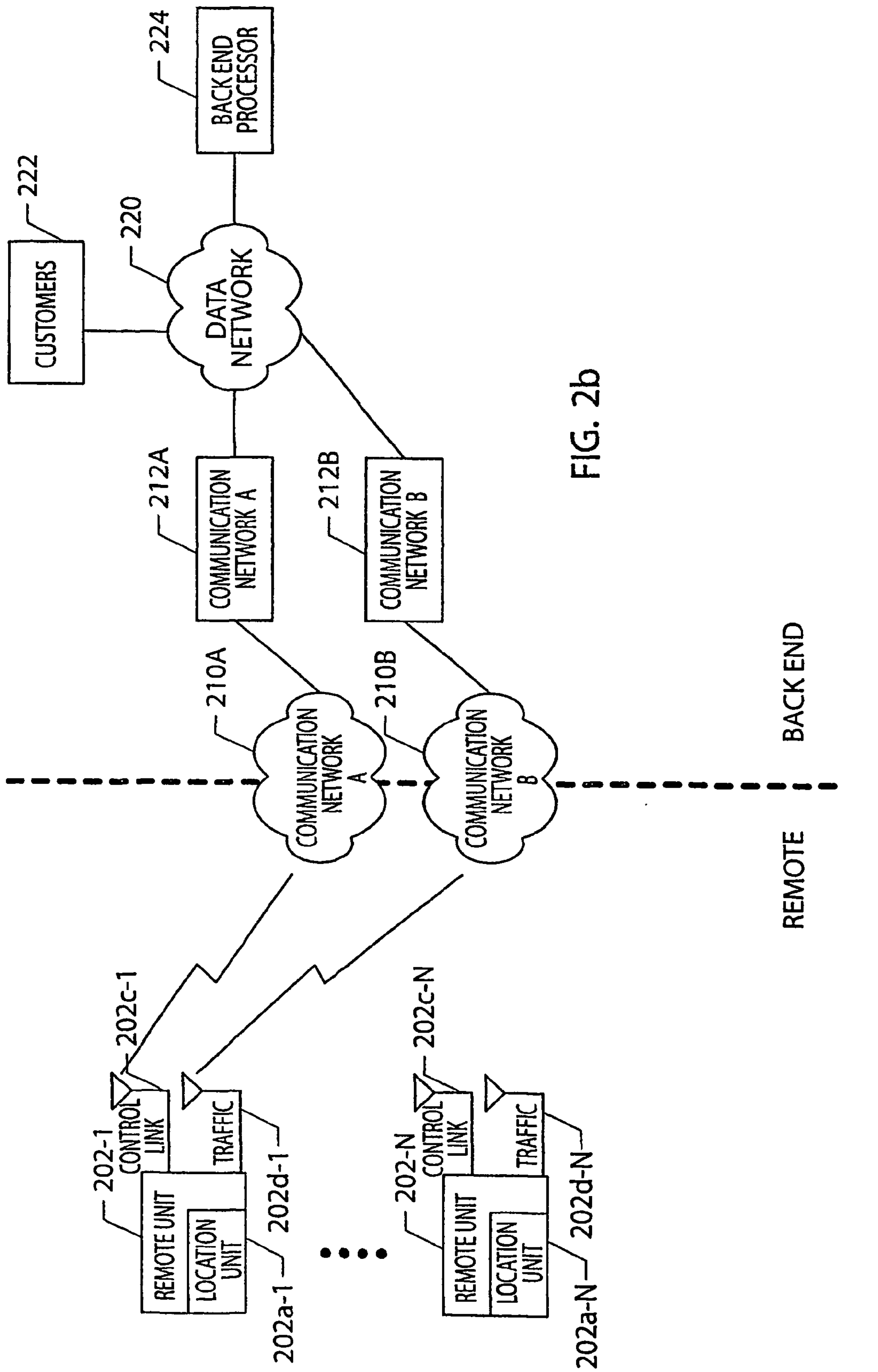

CUSTOMERS
222
DATA NETWORK
220
BACK END PROCESSOR
224
COMMUNICATION NETWORK A
212A
COMMUNICATION NETWORK B
212B
210A
COMMUNICATION NETWORK A
210B
COMMUNICATION NETWORK B
BACK END
REMOTE
202c-1
202-1
CONTROL LINK
TRAFFIC
202d-1
REMOTE UNIT
LOCATION UNIT
202a-1
202c-N
202-N
CONTROL LINK
TRAFFIC
202d-N
REMOTE UNIT
LOCATION UNIT
202a-N

FIG. 2b

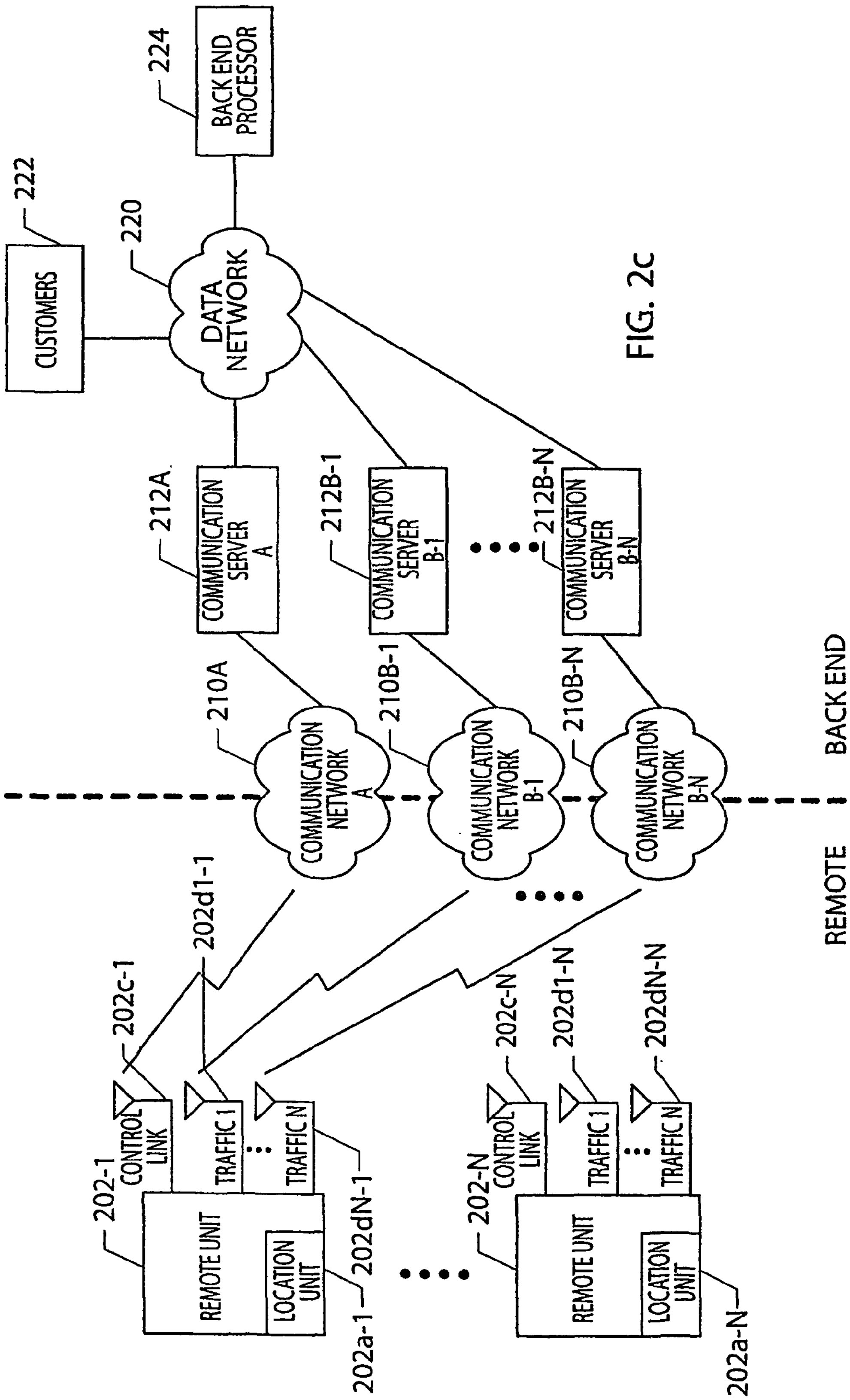

CUSTOMERS
222
BACK END PROCESSOR
224
DATA NETWORK
220
COMMUNICATION SERVER A
212A
COMMUNICATION SERVER B-1
212B-1
COMMUNICATION SERVER B-N
212B-N
COMMUNICATION NETWORK A
210A
COMMUNICATION NETWORK B-1
210B-1
COMMUNICATION NETWORK B-N
210B-N
BACK END
REMOTE
202d1-1
202c-1
CONTROL LINK
TRAFFIC 1
TRAFFIC N
202-1
REMOTE UNIT
LOCATION UNIT
202dN-1
202a-1
202c-N
202d1-N
202dN-N
202-N
202a-N

FIG. 2c

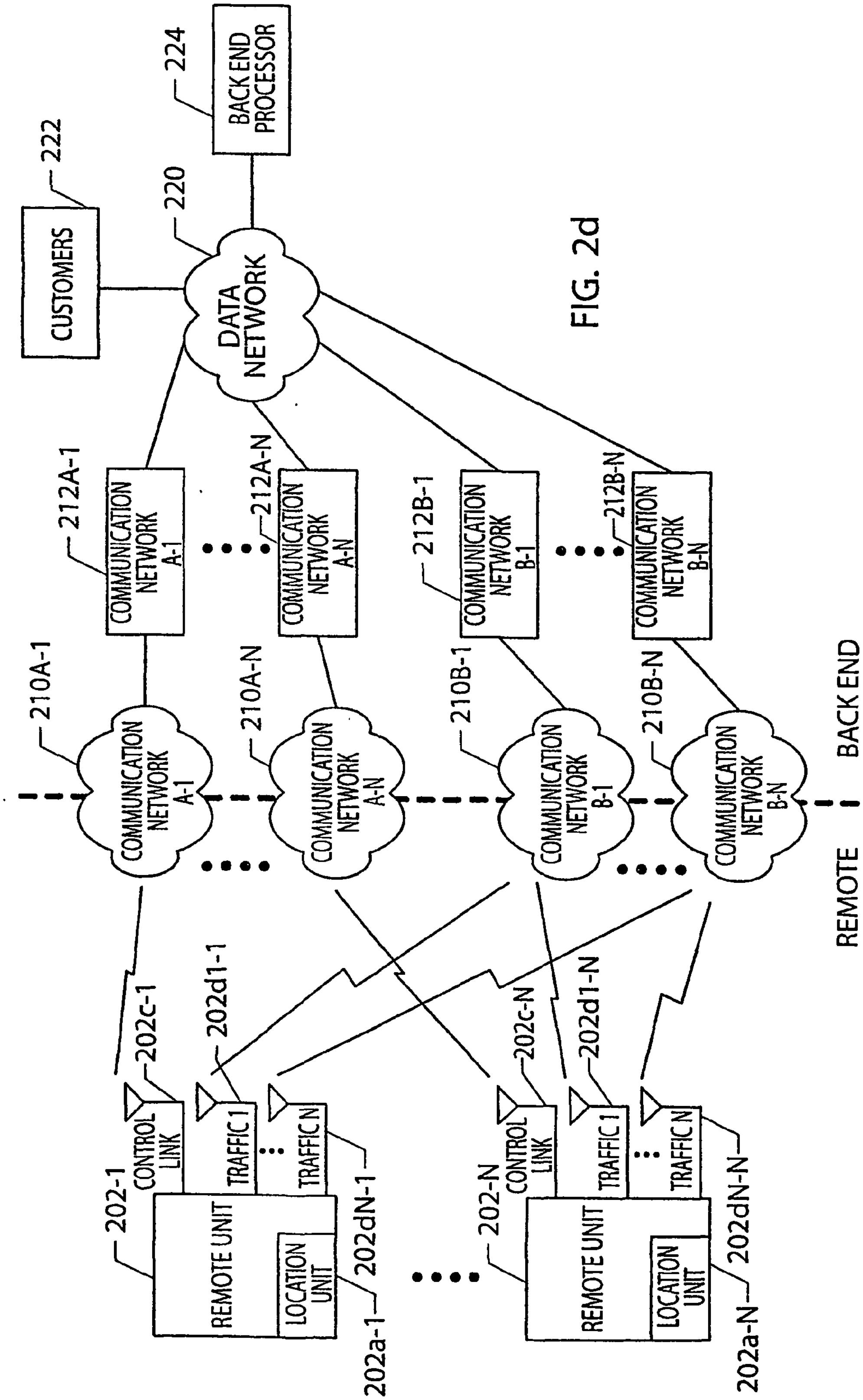

CUSTOMERS
222
DATA NETWORK
220
BACK END PROCESSOR
224
COMMUNICATION NETWORK A-1
212A-1
COMMUNICATION NETWORK A-N
212A-N
COMMUNICATION NETWORK B-1
212B-1
COMMUNICATION NETWORK B-N
212B-N
COMMUNICATION NETWORK A-1
210A-1
COMMUNICATION NETWORK A-N
210A-N
COMMUNICATION NETWORK B-1
210B-1
COMMUNICATION NETWORK B-N
210B-N
BACK END
REMOTE
202c-1
202d1-1
202c-N
202d1-N
CONTROL LINK
TRAFFIC 1
TRAFFIC N
202-1
202dN-1
REMOTE UNIT
LOCATION UNIT
202a-1
202-N
202dN-N
202a-N

FIG. 2d

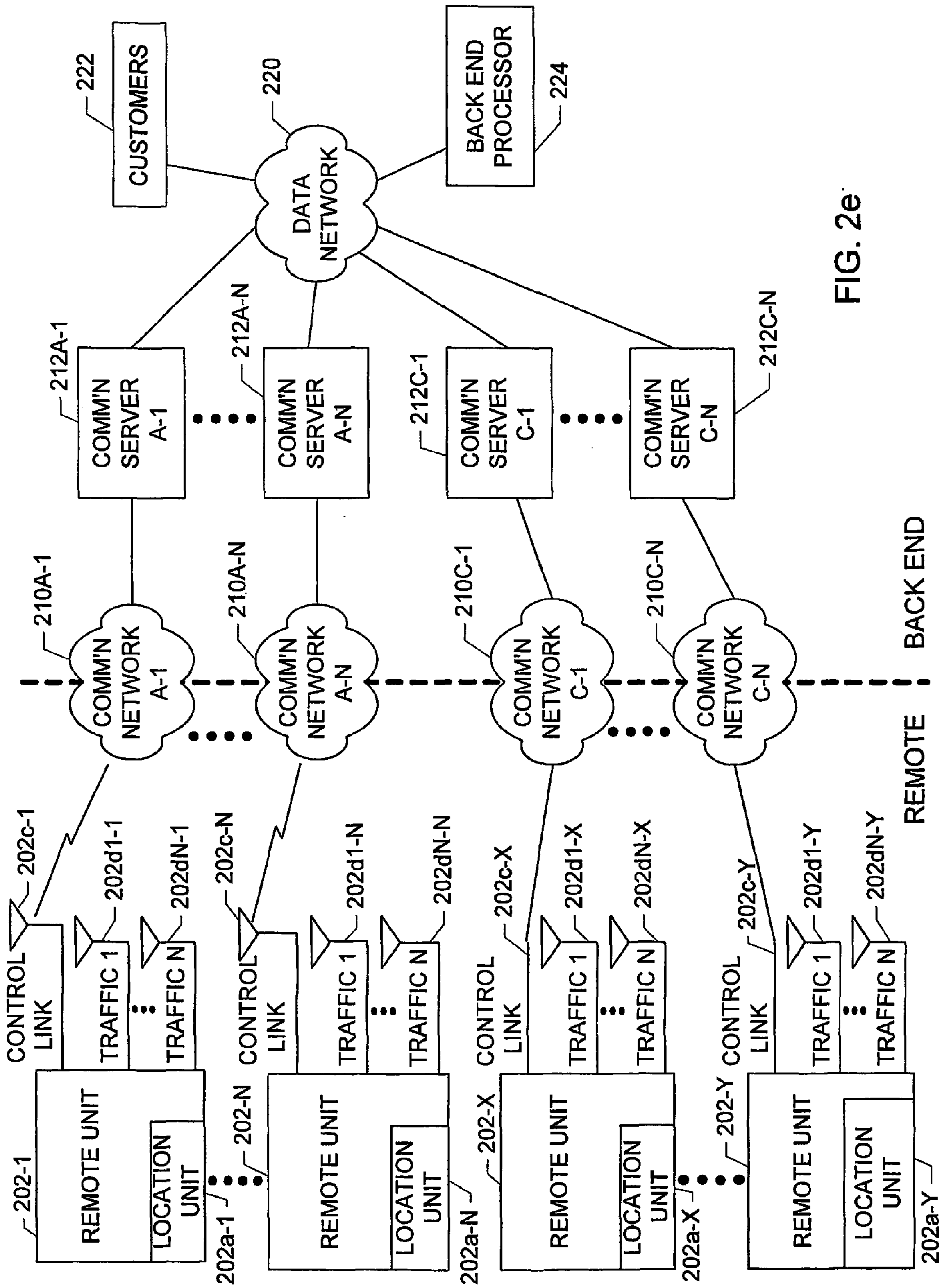

CUSTOMERS
222
DATA NETWORK
220
BACK END PROCESSOR
224
COMM'N SERVER A-1
212A-1
COMM'N SERVER A-N
212A-N
COMM'N SERVER C-1
212C-1
COMM'N SERVER C-N
212C-N
COMM'N NETWORK A-1
210A-1
COMM'N NETWORK A-N
210A-N
COMM'N NETWORK C-1
210C-1
COMM'N NETWORK C-N
210C-N
BACK END
REMOTE
CONTROL LINK
TRAFFIC 1
TRAFFIC N
202c-1
202d1-1
202dN-1
202c-N
202d1-N
202dN-N
202c-X
202d1-X
202dN-X
202c-Y
202d1-Y
202dN-Y
REMOTE UNIT
LOCATION UNIT
202-1
202a-1
202-N
202a-N
202-X
202a-X
202-Y
202a-Y

FIG. 2e

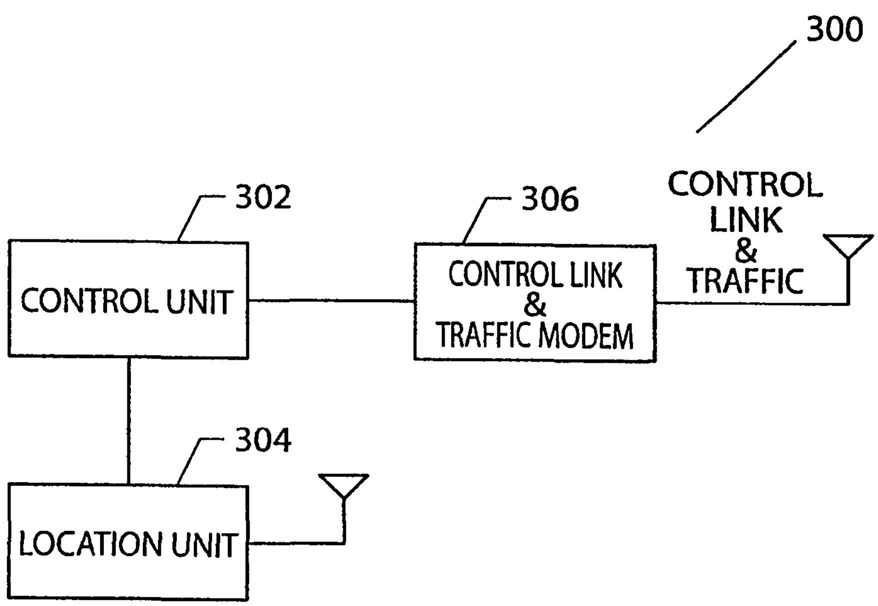

300
302
306
CONTROL UNIT
CONTROL LINK & TRAFFIC MODEM
CONTROL LINK & TRAFFIC
304
LOCATION UNIT

FIG. 3a

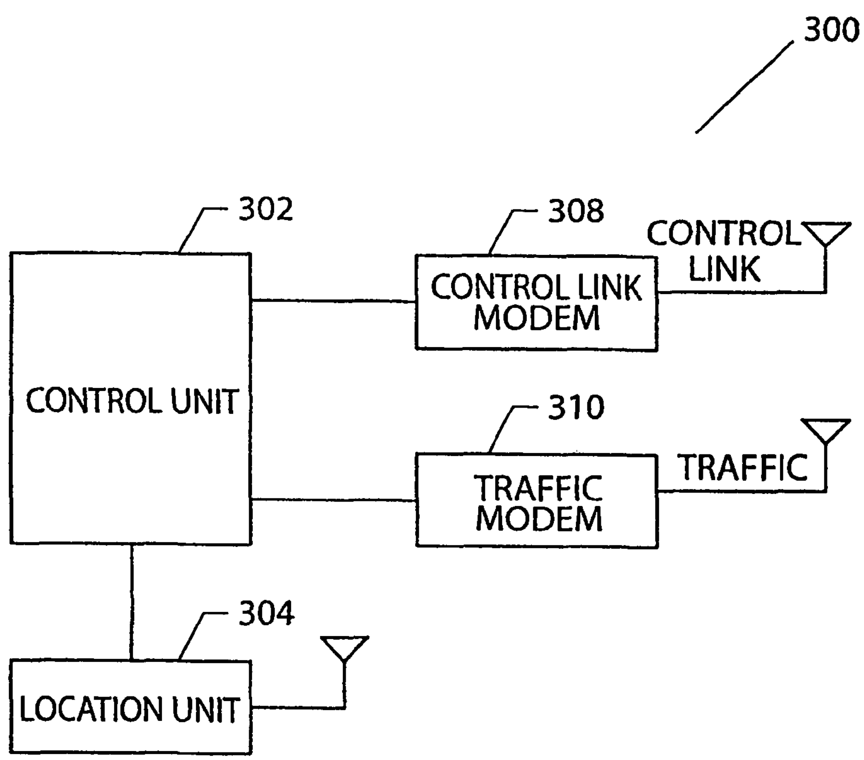

300
302
CONTROL UNIT
308
CONTROL LINK
MODEM
CONTROL
LINK
310
TRAFFIC
MODEM
TRAFFIC
304
LOCATION UNIT

FIG. 3b

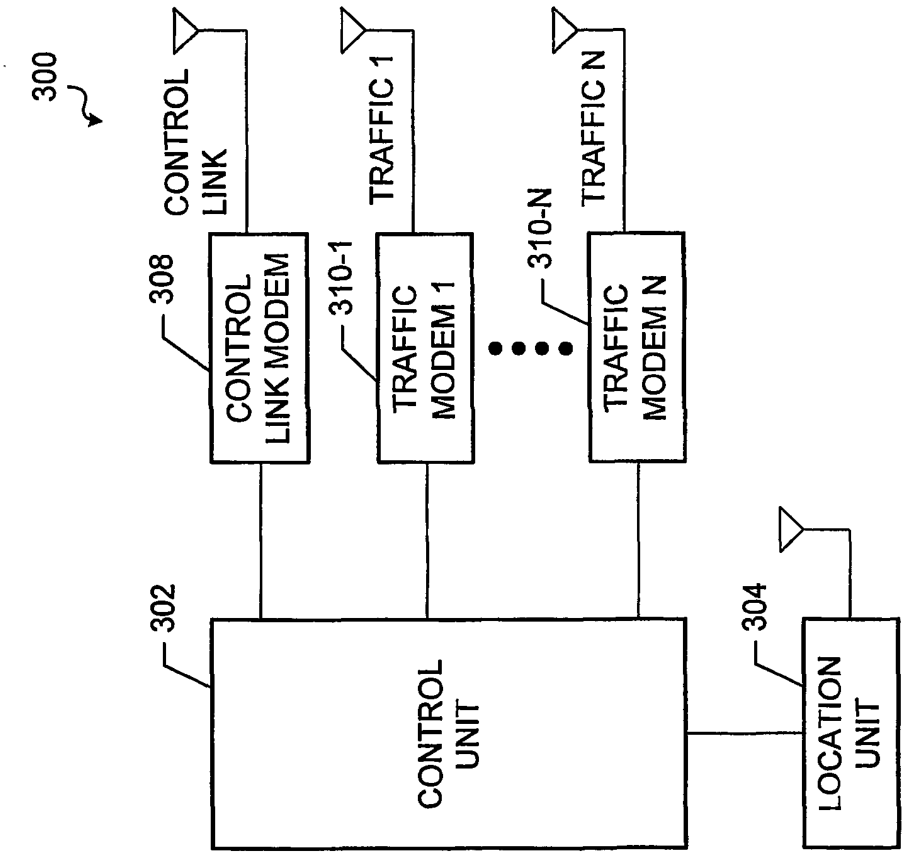

300
CONTROL LINK
TRAFFIC 1
TRAFFIC N
308
CONTROL LINK MODEM
310-1
TRAFFIC MODEM 1
310-N
TRAFFIC MODEM N
302
CONTROL UNIT
304
LOCATION UNIT

FIG. 3c

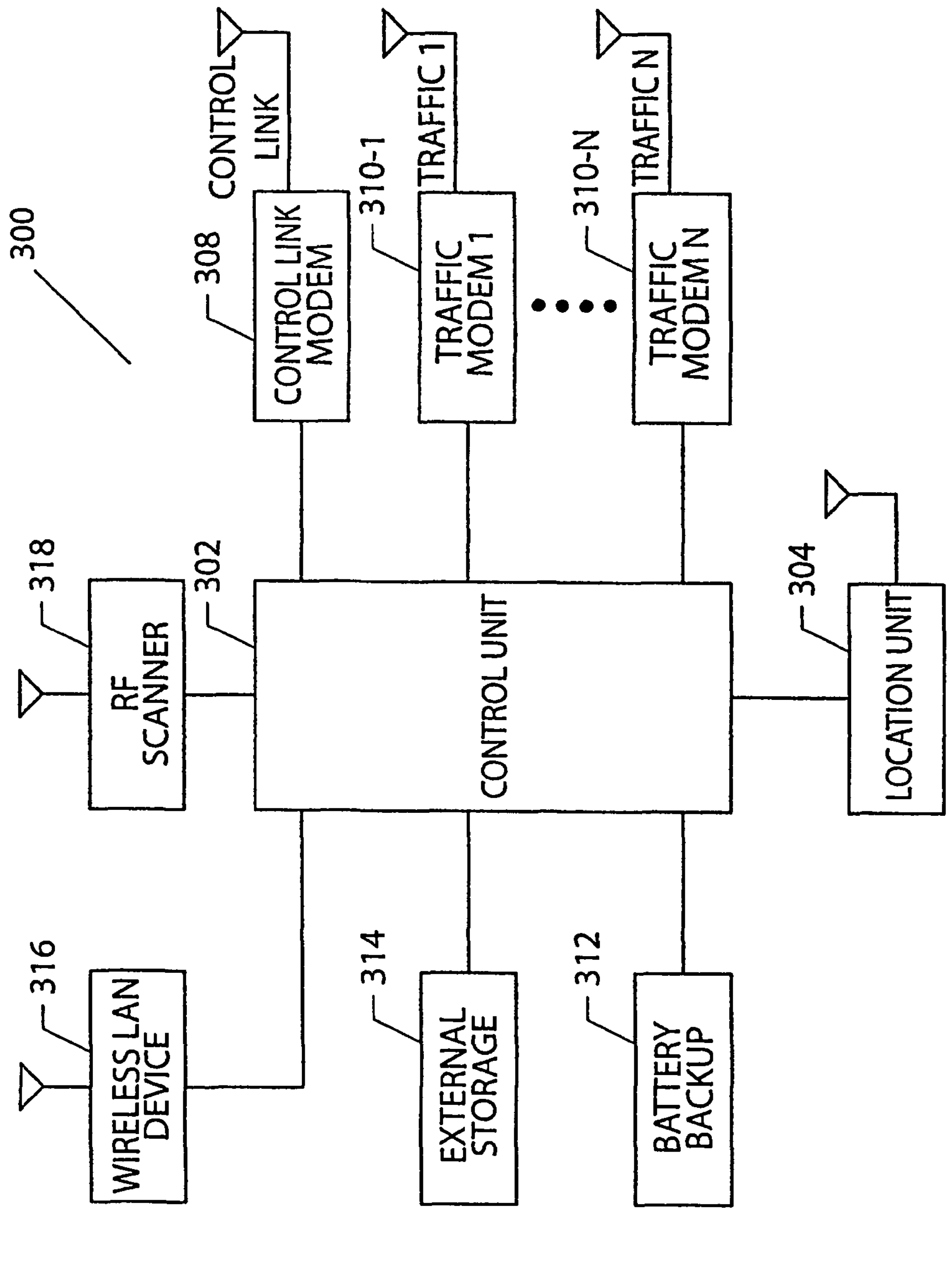

300
CONTROL LINK
308
CONTROL LINK MODEM
TRAFFIC 1
310-1
TRAFFIC MODEM 1
TRAFFIC N
310-N
TRAFFIC MODEM N
318
RF SCANNER
302
CONTROL UNIT
304
LOCATION UNIT
316
WIRELESS LAN DEVICE
314
EXTERNAL STORAGE
312
BATTERY BACKUP

FIG. 3d

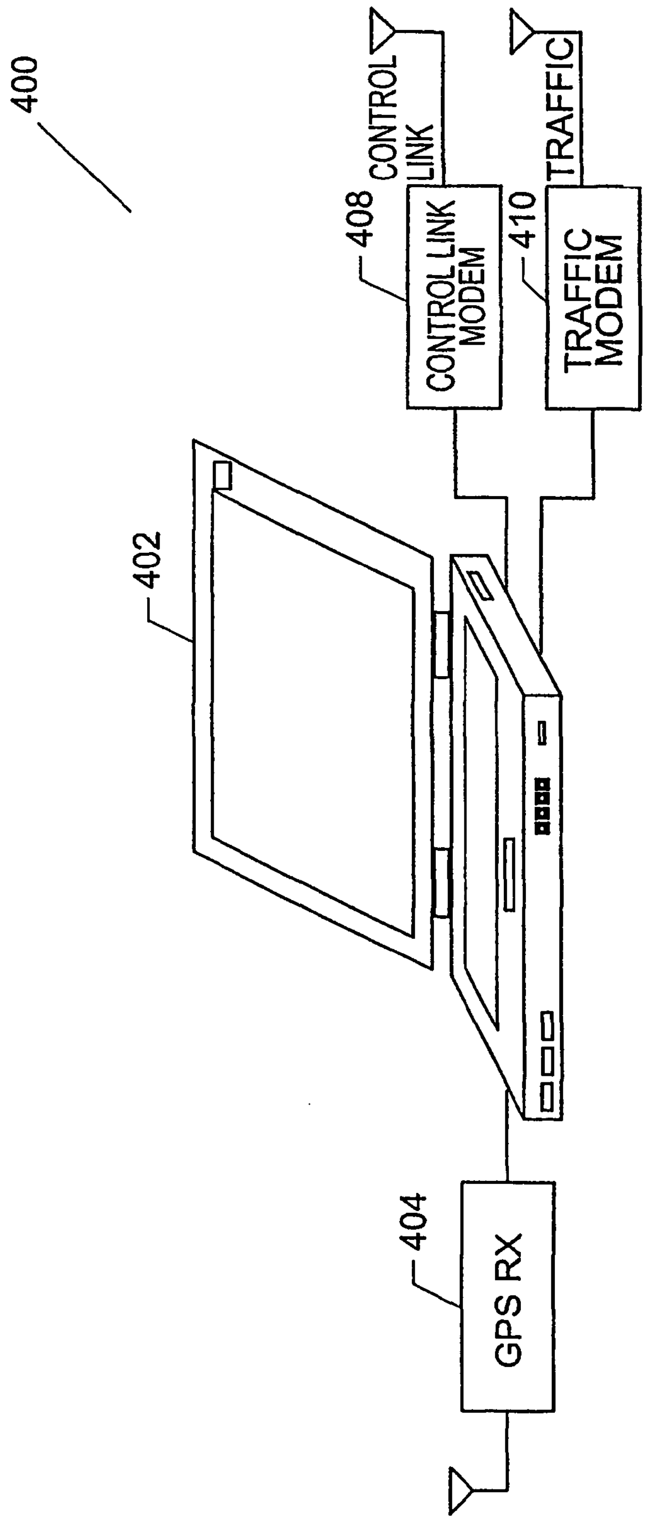

400
402
404
GPS RX
408
CONTROL LINK MODEM
CONTROL LINK
410
TRAFFIC MODEM
TRAFFIC

FIG. 4a

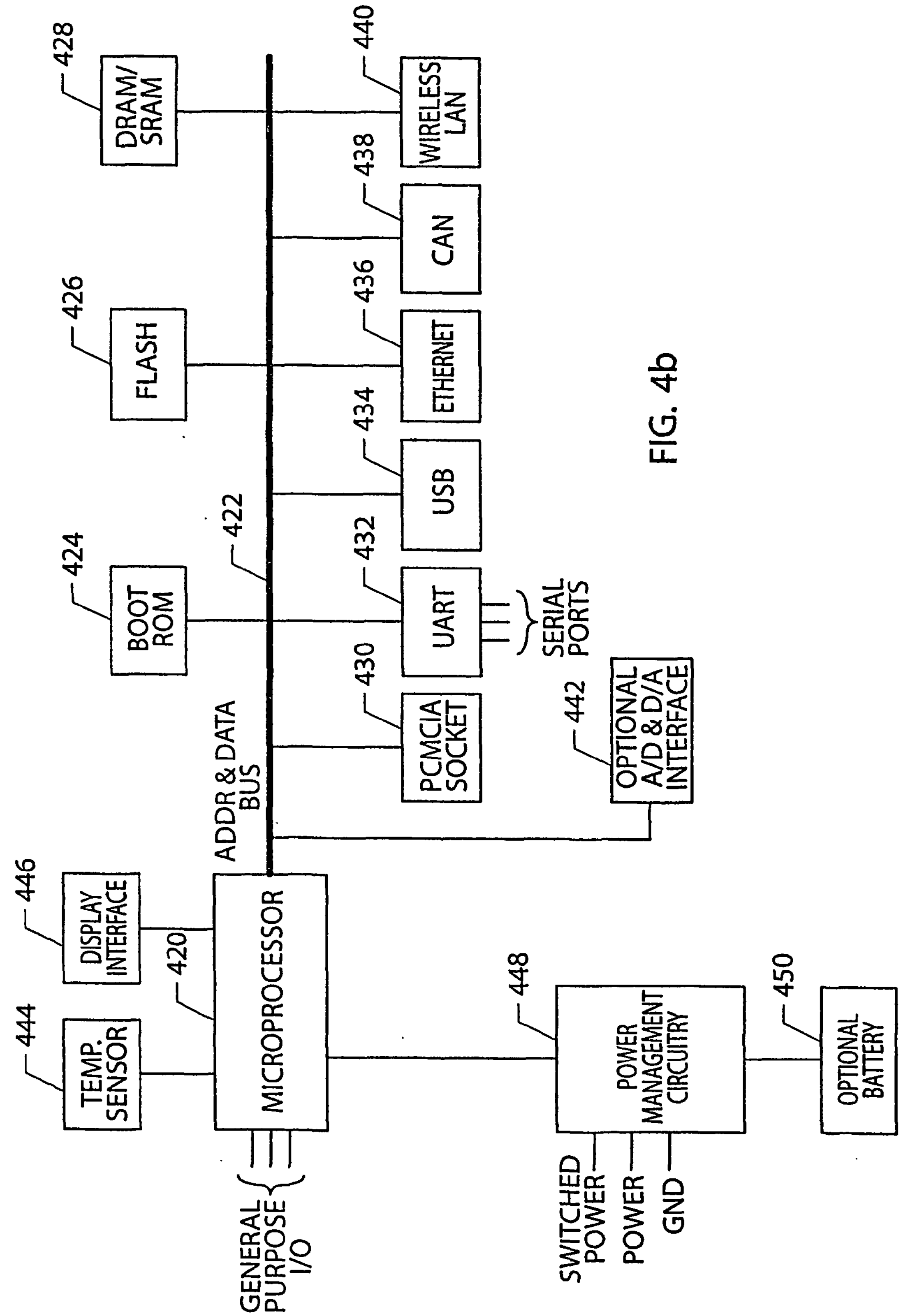

428
DRAM/ SRAM
426
FLASH
424
BOOT ROM
422
ADDR & DATA BUS
440
WIRELESS LAN
438
CAN
436
ETHERNET
434
USB
432
UART
SERIAL PORTS
430
PCMCIA SOCKET
442
OPTIONAL A/D & D/A INTERFACE
446
DISPLAY INTERFACE
444
TEMP. SENSOR
420
MICROPROCESSOR
GENERAL PURPOSE I/O
448
POWER MANAGEMENT CIRCUITRY
450
OPTIONAL BATTERY
SWITCHED POWER
POWER
GND

FIG. 4b

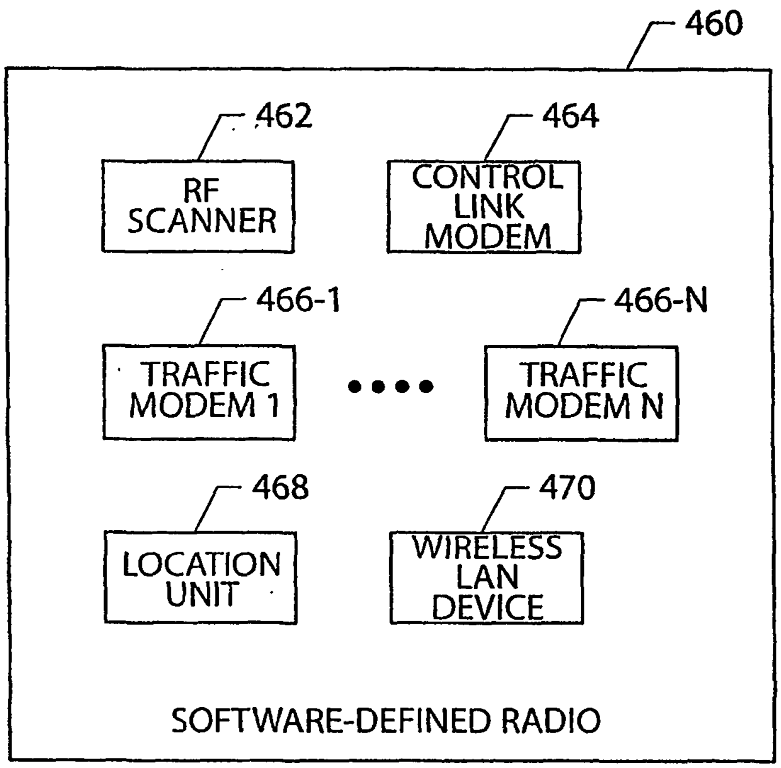

460
462
RF SCANNER
464
CONTROL LINK MODEM
466-1
TRAFFIC MODEM 1
466-N
TRAFFIC MODEM N
468
LOCATION UNIT
470
WIRELESS LAN DEVICE
SOFTWARE-DEFINED RADIO

FIG. 4c

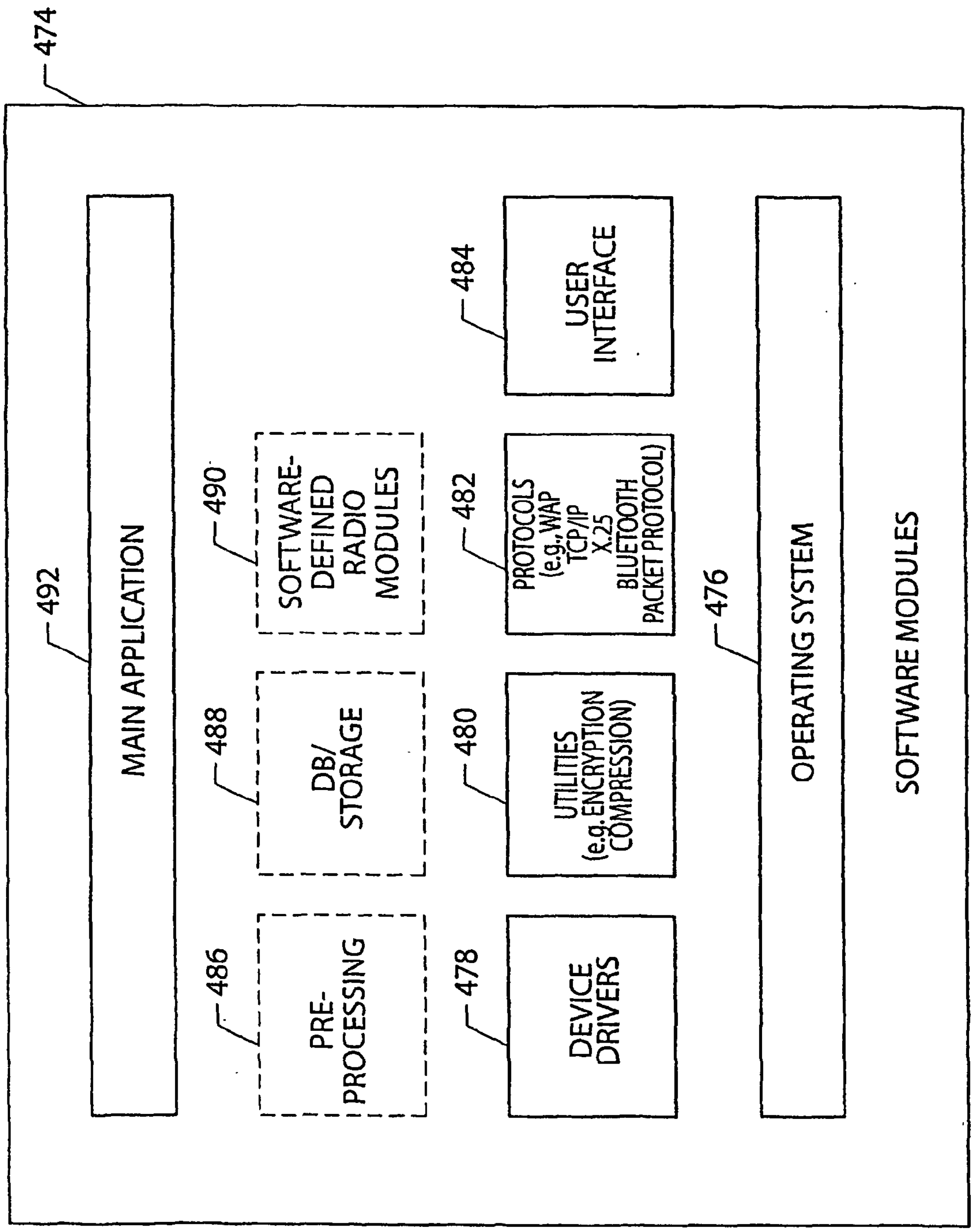

474
492
MAIN APPLICATION
486
PRE-PROCESSING
488
DB/STORAGE
490
SOFTWARE-DEFINED RADIO MODULES
478
DEVICE DRIVERS
480
UTILITIES (e.g. ENCRYPTION COMPRESSION)
482
PROTOCOLS (e.g., WAP TCP/IP X.25 BLUETOOTH PACKET PROTOCOL)
484
USER INTERFACE
476
OPERATING SYSTEM
SOFTWARE MODULES

FIG. 4d

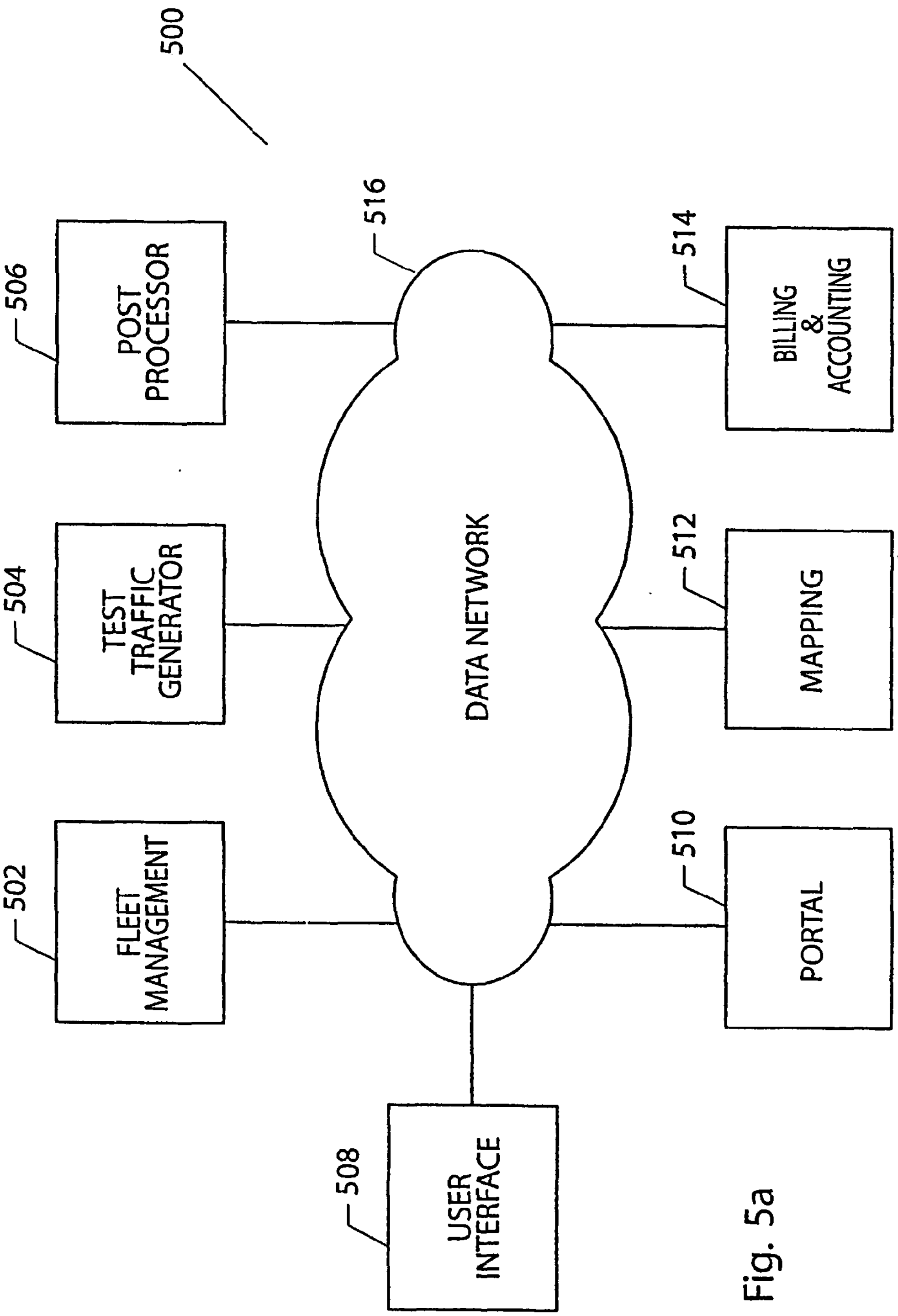

500
506
POST PROCESSOR
504
TEST TRAFFIC GENERATOR
502
FLEET MANAGEMENT
516
DATA NETWORK
514
BILLING & ACCOUNTING
512
MAPPING
510
PORTAL
508
USER INTERFACE

Fig. 5a

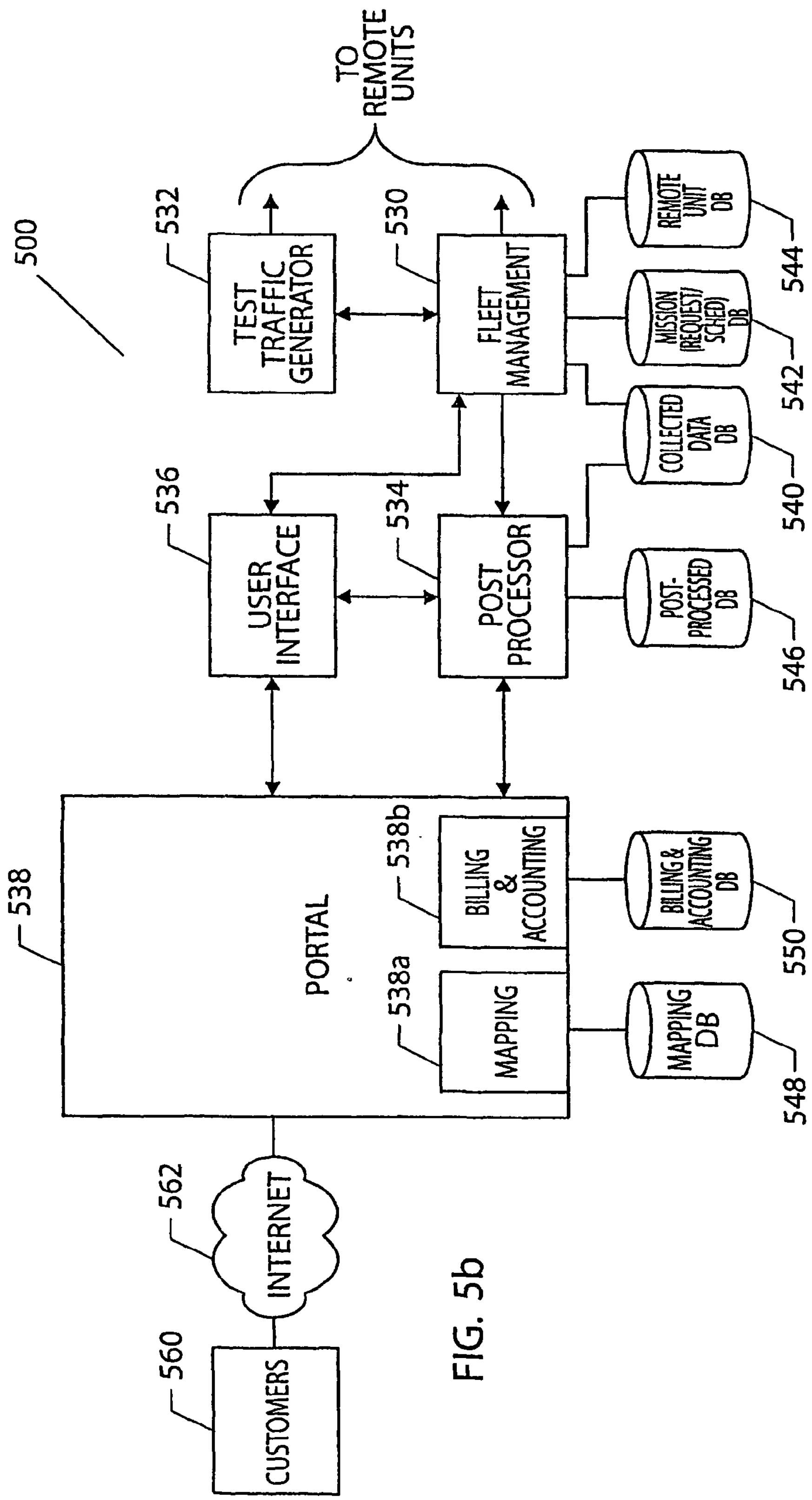

500
TO REMOTE UNITS
532
TEST TRAFFIC GENERATOR
530
FLEET MANAGEMENT
536
USER INTERFACE
534
POST PROCESSOR
REMOTE UNIT DB
544
MISSION (REQUEST/ SCHED) DB
542
COLLECTED DATA DB
540
POST-PROCESSED DB
546
538
PORTAL
538b
BILLING & ACCOUNTING
538a
MAPPING
BILLING & ACCOUNTING DB
550
MAPPING DB
548
562
INTERNET
560
CUSTOMERS

FIG. 5b

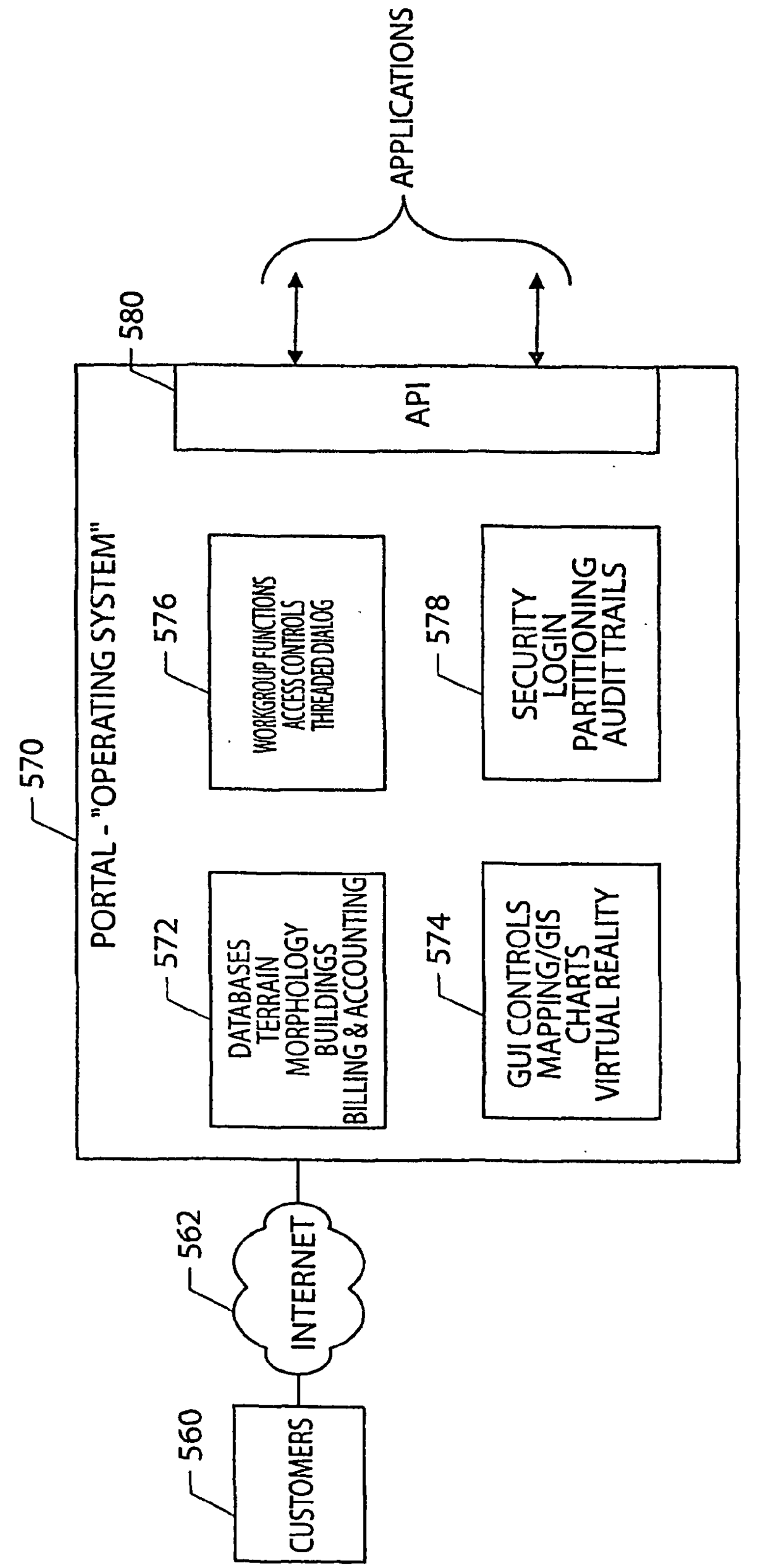

APPLICATIONS
580
API
570
PORTAL - "OPERATING SYSTEM"
576
WORKGROUP FUNCTIONS
ACCESS CONTROLS
THREADED DIALOG
578
SECURITY
LOGIN
PARTITIONING
AUDIT TRAILS
572
DATABASES
TERRAIN
MORPHOLOGY
BUILDINGS
BILLING & ACCOUNTING
574
GUI CONTROLS
MAPPING/GIS
CHARTS
VIRTUAL REALITY
562
INTERNET
560
CUSTOMERS

FIG. 5c

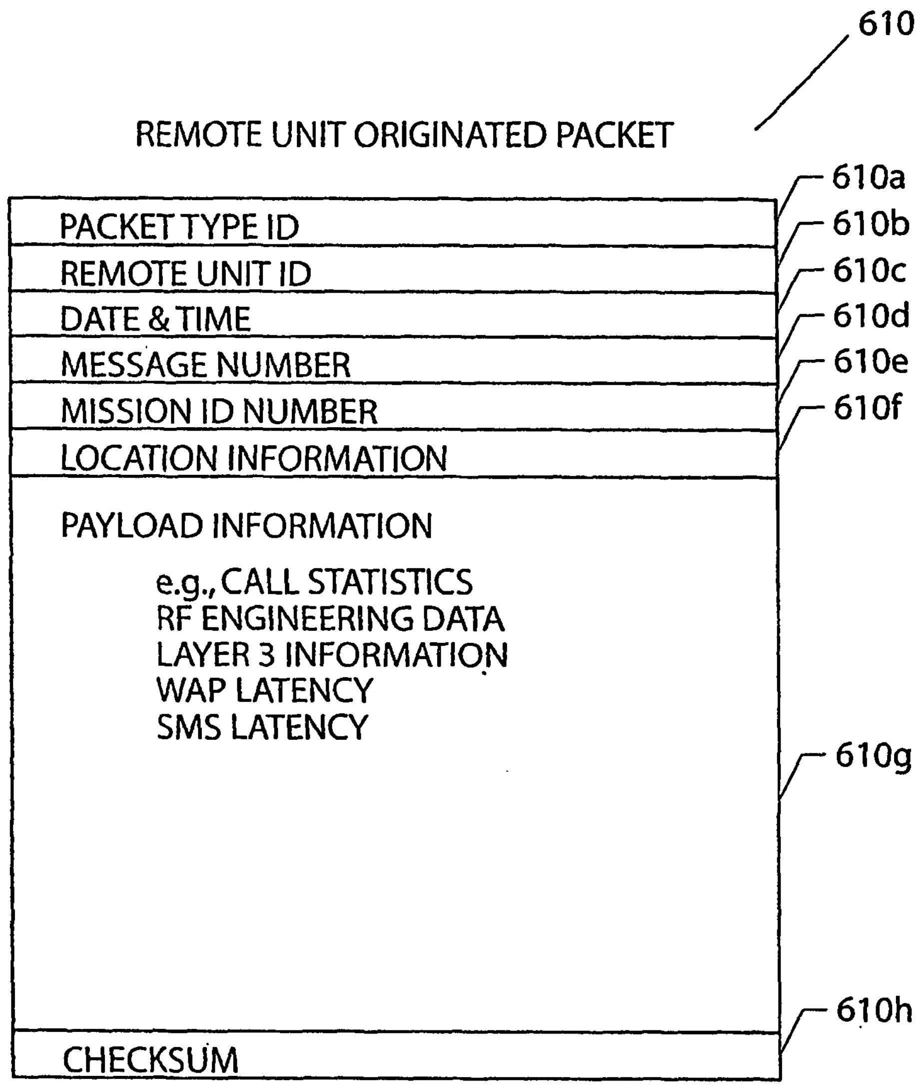

610
REMOTE UNIT ORIGINATED PACKET
610a
610b
610c
610d
610e
610f
PACKET TYPE ID
REMOTE UNIT ID
DATE & TIME
MESSAGE NUMBER
MISSION ID NUMBER
LOCATION INFORMATION
PAYLOAD INFORMATION
e.g., CALL STATISTICS
RF ENGINEERING DATA
LAYER 3 INFORMATION
WAP LATENCY
SMS LATENCY
610g
610h
CHECKSUM

FIG. 6a

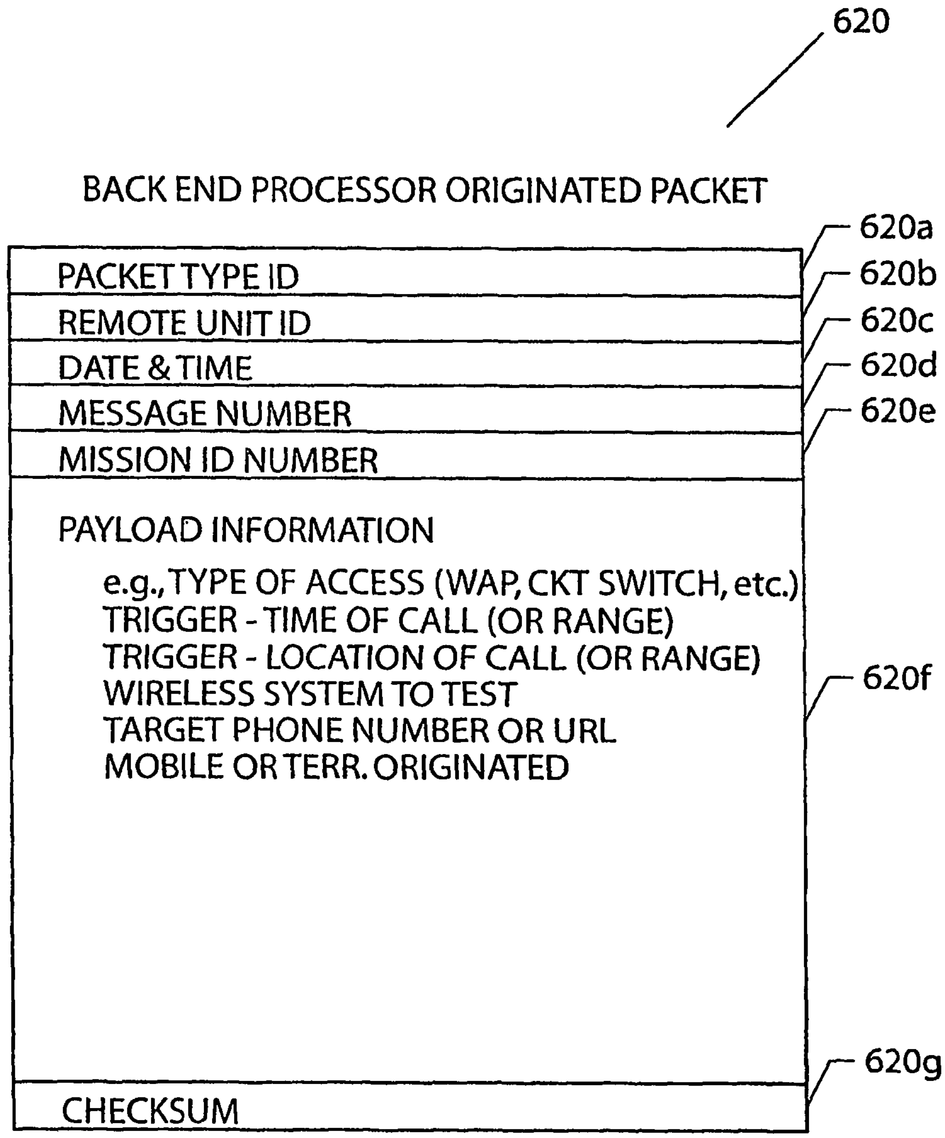

620
BACK END PROCESSOR ORIGINATED PACKET
620a
PACKET TYPE ID
620b
REMOTE UNIT ID
620c
DATE & TIME
620d
MESSAGE NUMBER
620e
MISSION ID NUMBER
PAYLOAD INFORMATION
e.g., TYPE OF ACCESS (WAP, CKT SWITCH, etc.)
TRIGGER - TIME OF CALL (OR RANGE)
TRIGGER - LOCATION OF CALL (OR RANGE)
WIRELESS SYSTEM TO TEST
TARGET PHONE NUMBER OR URL
MOBILE OR TERR. ORIGINATED
620f
620g
CHECKSUM

FIG. 6b

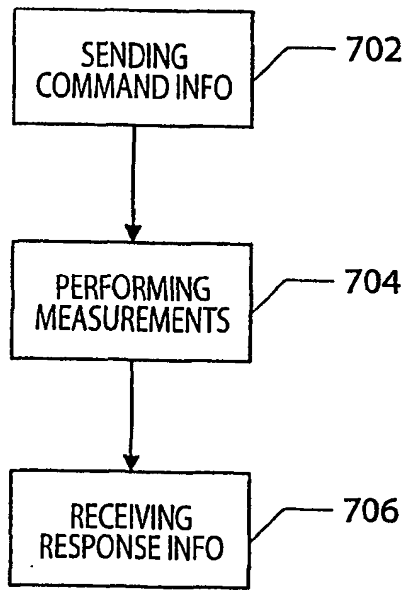

SENDING COMMAND INFO
702
PERFORMING MEASUREMENTS
704
RECEIVING RESPONSE INFO
706

FIG. 7a

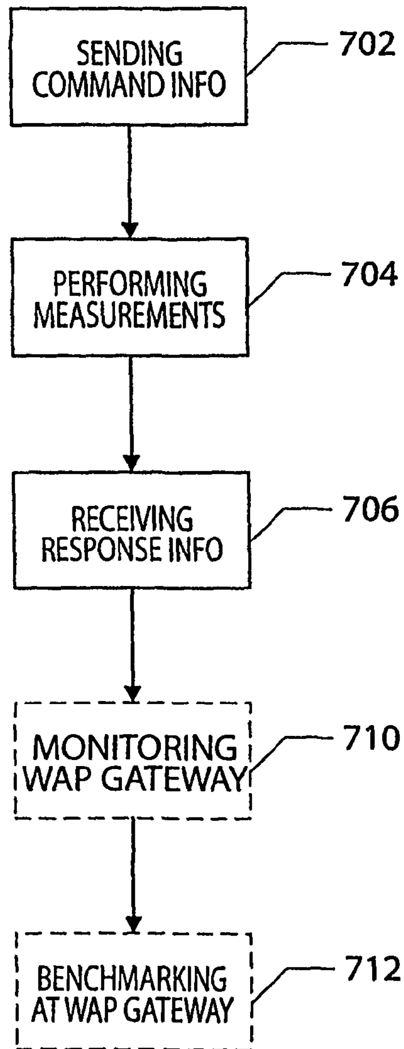

SENDING COMMAND INFO
702
PERFORMING MEASUREMENTS
704
RECEIVING RESPONSE INFO
706
MONITORING WAP GATEWAY
710
BENCHMARKING AT WAP GATEWAY
712

FIG. 7b

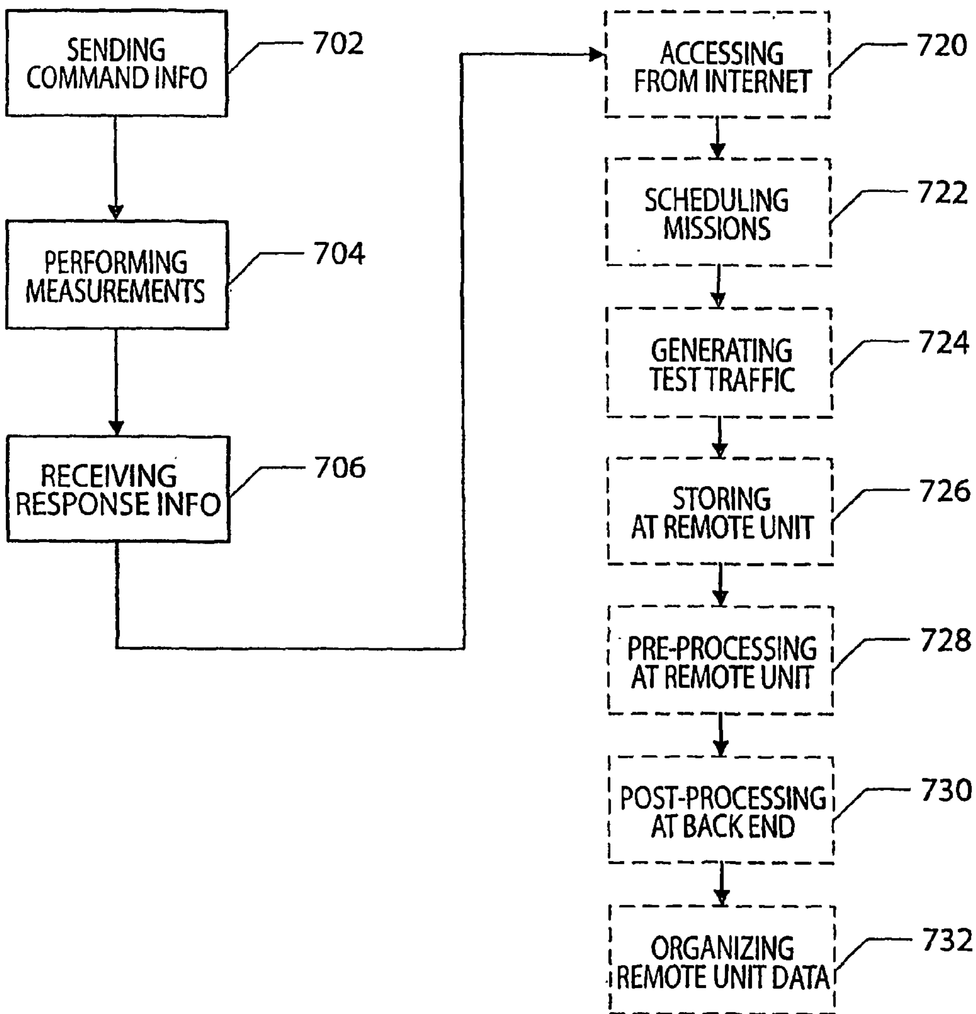

SENDING COMMAND INFO
702
PERFORMING MEASUREMENTS
704
RECEIVING RESPONSE INFO
706
ACCESSING FROM INTERNET
720
SCHEDULING MISSIONS
722
GENERATING TEST TRAFFIC
724
STORING AT REMOTE UNIT
726
PRE-PROCESSING AT REMOTE UNIT
728
POST-PROCESSING AT BACK END
730
ORGANIZING REMOTE UNIT DATA
732

FIG. 7c

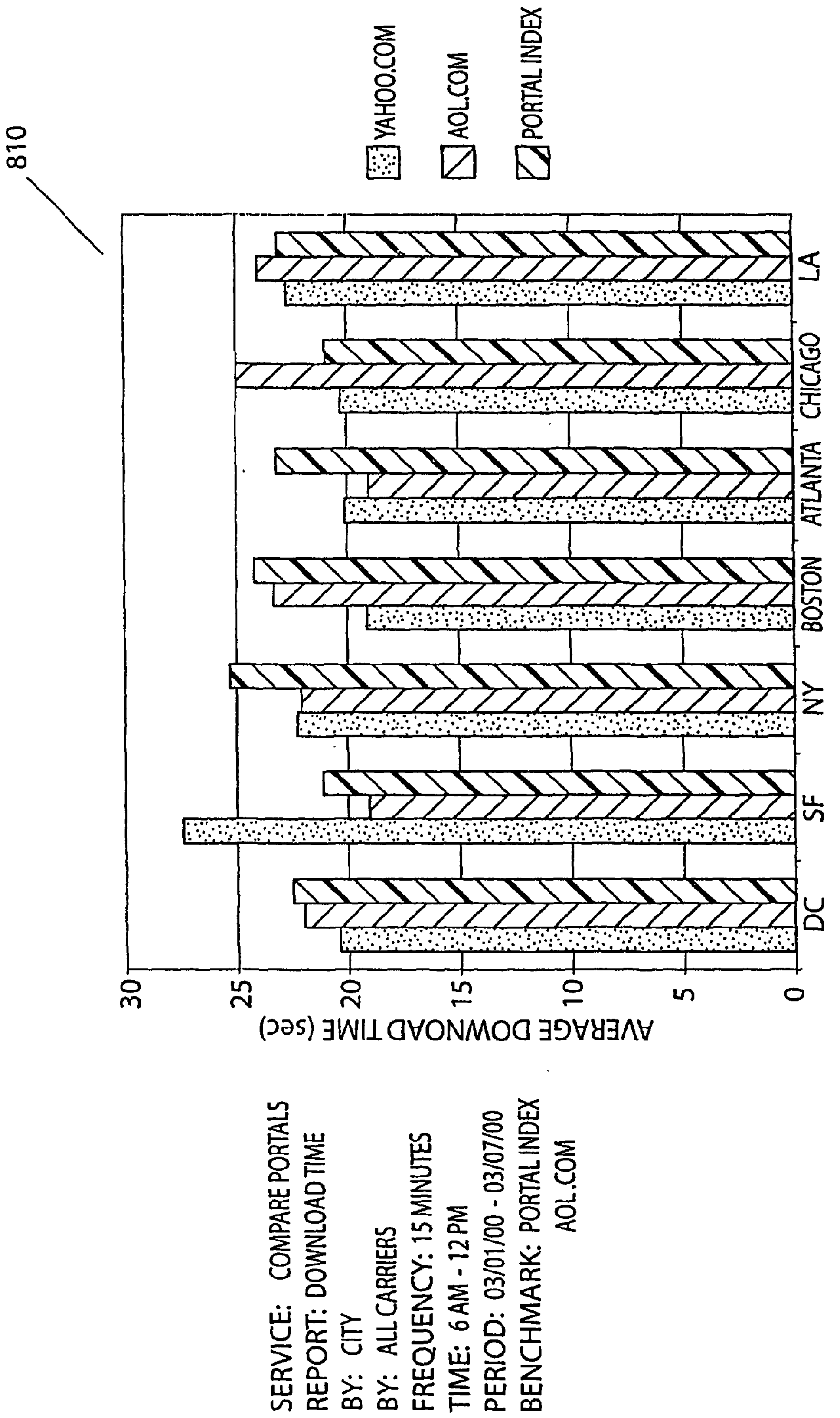

810
YAHOO.COM
AOL.COM
PORTAL INDEX
AVERAGE DOWNOAD TIME (sec)
30
25
20
15
10
5
0
DC
SF
NY
BOSTON
ATLANTA
CHICAGO
LA
SERVICE: COMPARE PORTALS
REPORT: DOWNLOAD TIME
BY: CITY
BY: ALL CARRIERS
FREQUENCY: 15 MINUTES
TIME: 6 AM - 12 PM
PERIOD: 03/01/00 - 03/07/00
BENCHMARK: PORTAL INDEX
AOL.COM

FIG. 8a

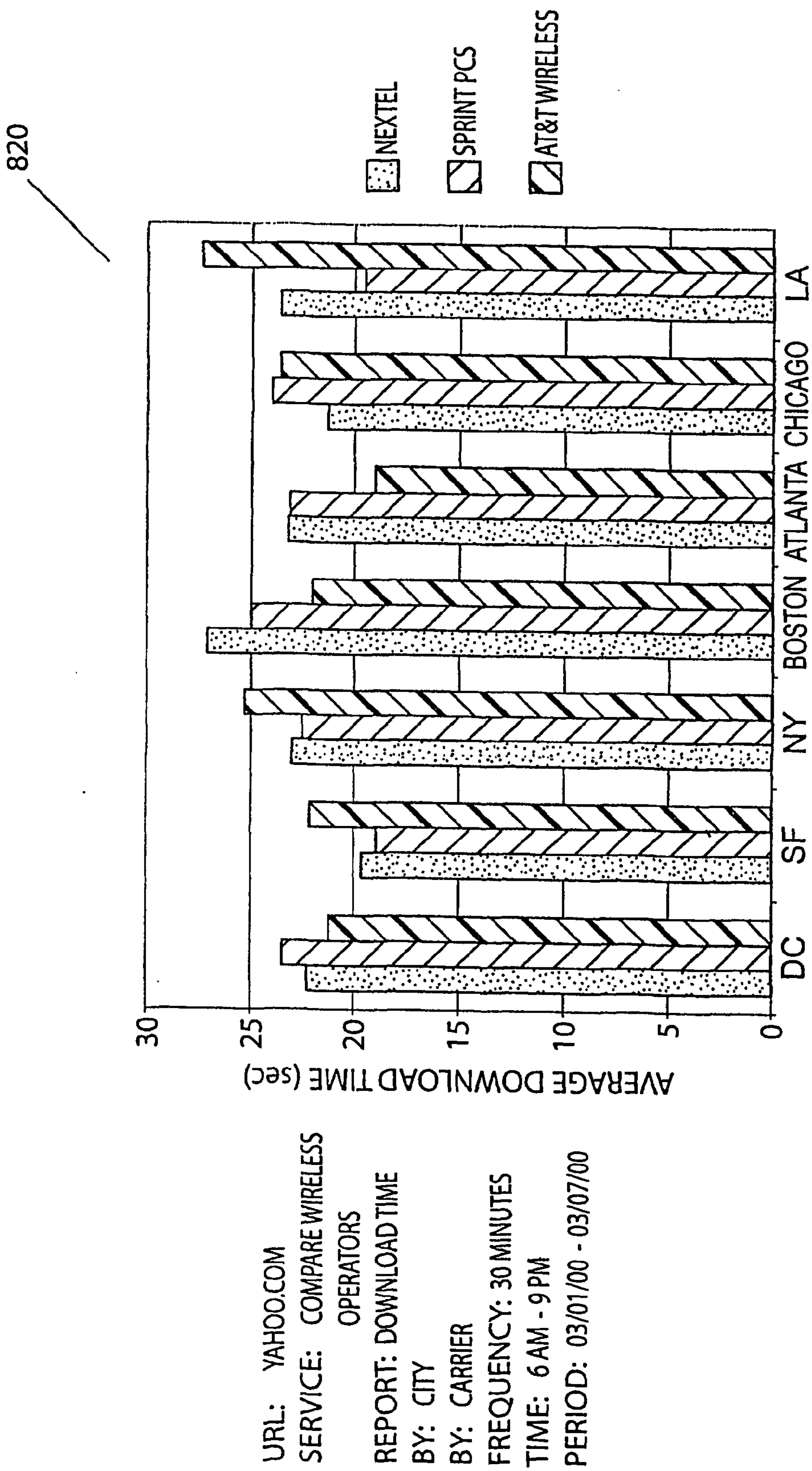

820
NEXTEL
SPRINT PCS
AT&T WIRELESS
AVERAGE DOWNLOAD TIME (sec)
0
5
10
15
20
25
30
DC
SF
NY
BOSTON
ATLANTA
CHICAGO
LA
URL: YAHOO.COM
SERVICE: COMPARE WIRELESS OPERATORS
REPORT: DOWNLOAD TIME
BY: CITY
BY: CARRIER
FREQUENCY: 30 MINUTES
TIME: 6 AM - 9 PM
PERIOD: 03/01/00 - 03/07/00

FIG. 8b

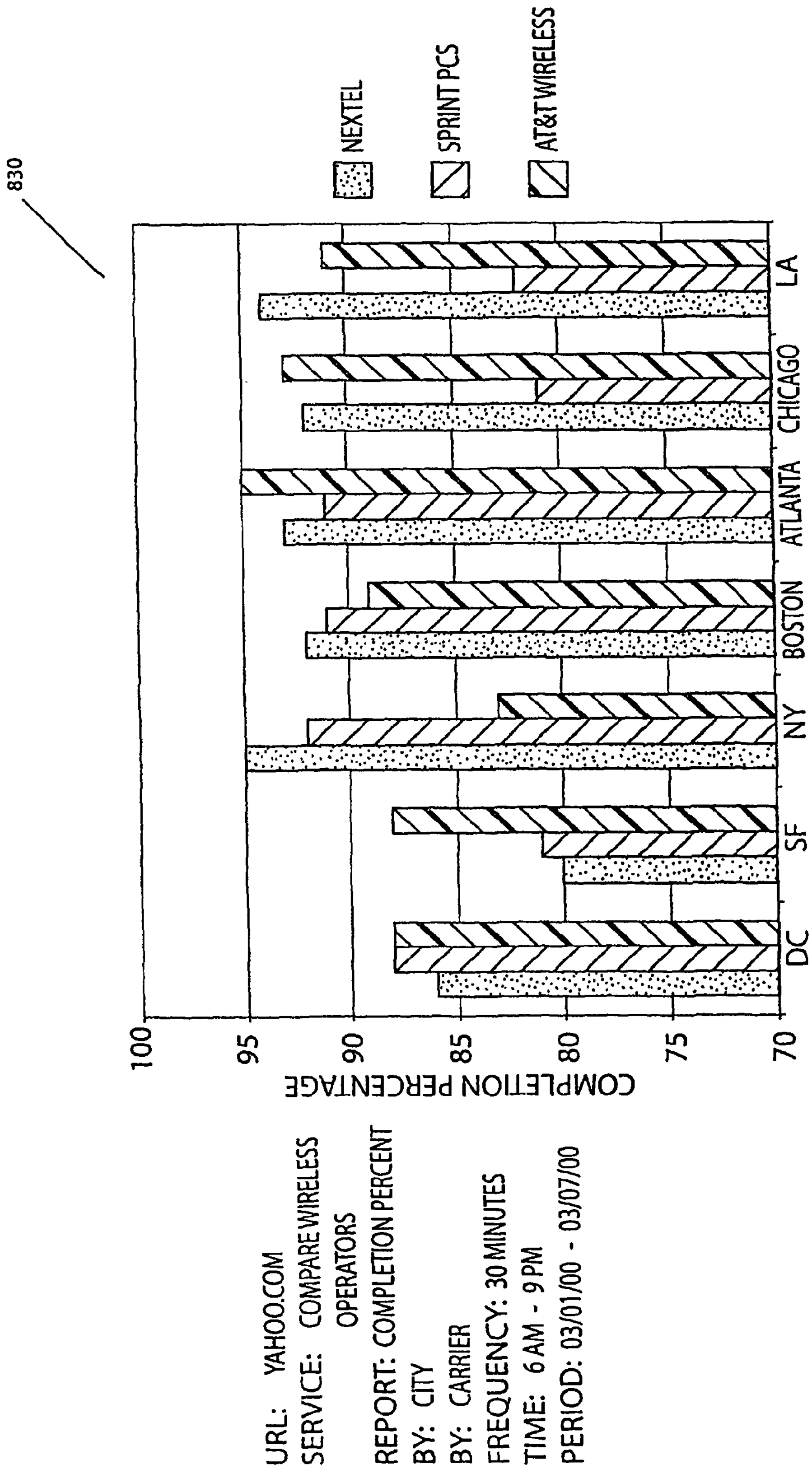

830
NEXTEL
SPRINT PCS
AT&T WIRELESS
100
95
90
85
80
75
70
COMPLETION PERCENTAGE
DC
SF
NY
BOSTON
ATLANTA
CHICAGO
LA
URL: YAHOO.COM
SERVICE: COMPARE WIRELESS OPERATORS
REPORT: COMPLETION PERCENT
BY: CITY
BY: CARRIER
FREQUENCY: 30 MINUTES
TIME: 6 AM - 9 PM
PERIOD: 03/01/00 - 03/07/00

FIG. 8c

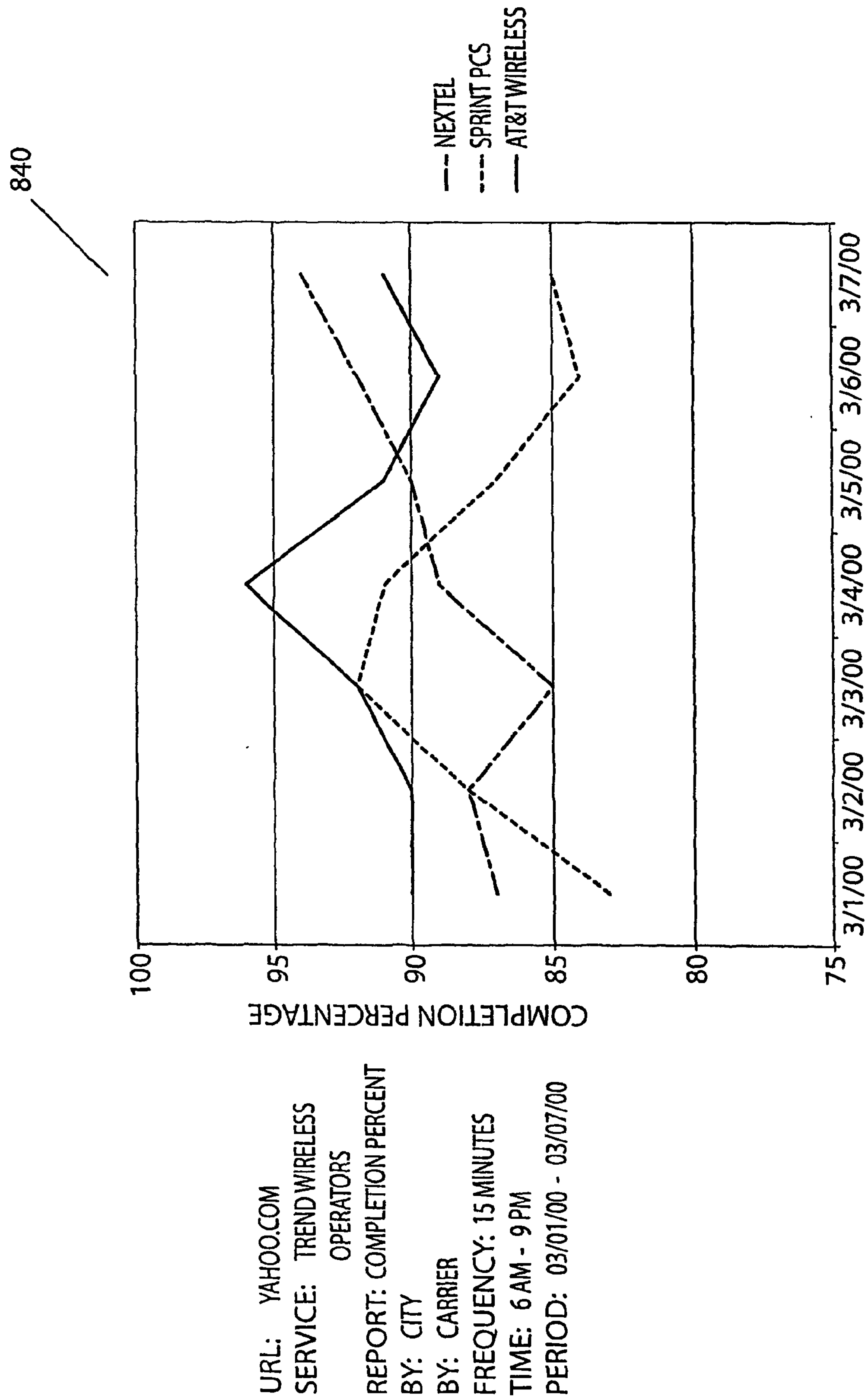

840
NEXTEL
SPRINT PCS
AT&T WIRELESS
100
95
90
85
80
75
COMPLETION PERCENTAGE
3/1/00
3/2/00
3/3/00
3/4/00
3/5/00
3/6/00
3/7/00
URL: YAHOO.COM
SERVICE: TREND WIRELESS OPERATORS
REPORT: COMPLETION PERCENT
BY: CITY
BY: CARRIER
FREQUENCY: 15 MINUTES
TIME: 6 AM - 9 PM
PERIOD: 03/01/00 - 03/07/00

FIG. 8d

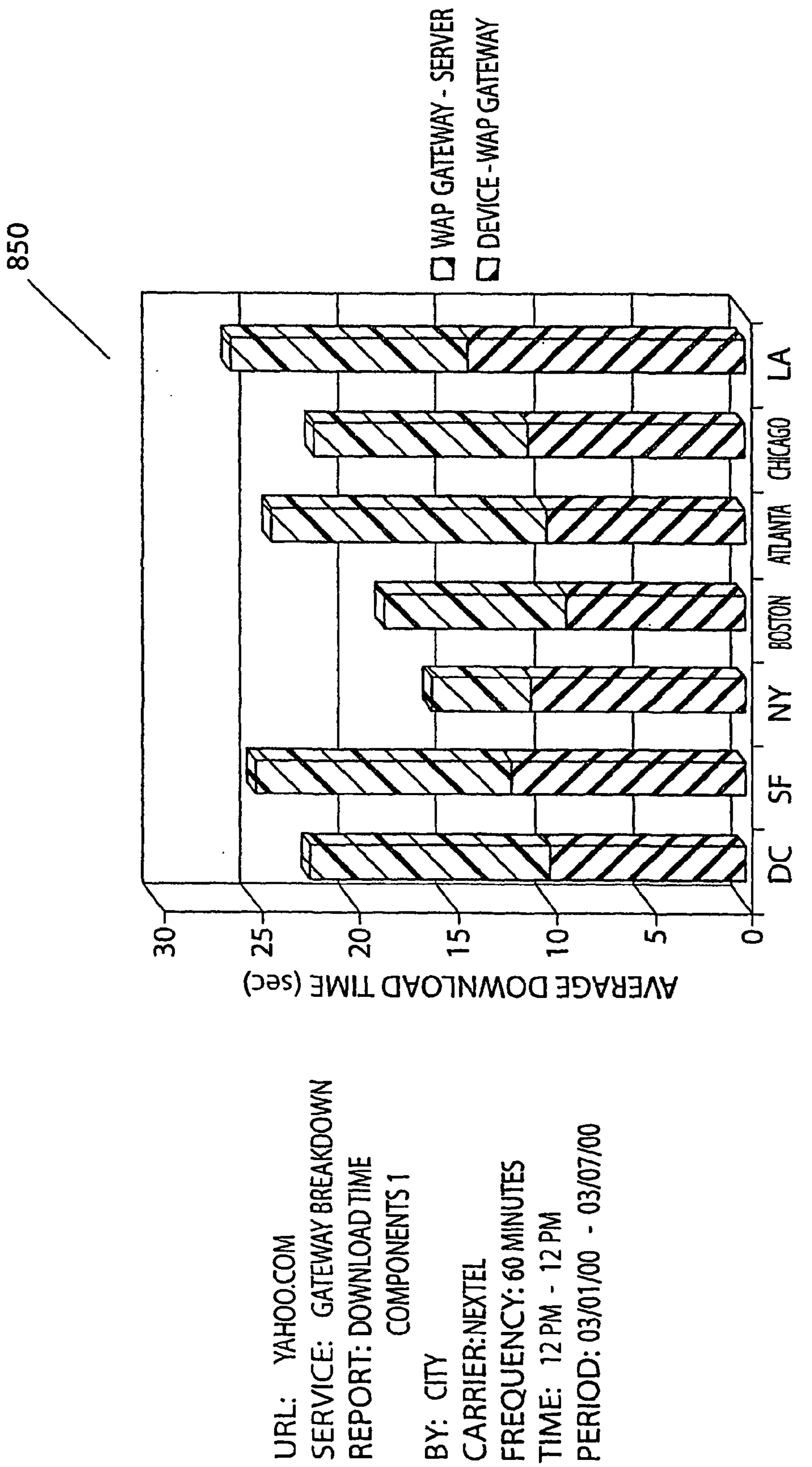

850
WAP GATEWAY - SERVER
DEVICE - WAP GATEWAY
AVERAGE DOWNLOAD TIME (sec)
30
25
20
15
10
5
0
DC
SF
NY
BOSTON
ATLANTA
CHICAGO
LA
URL: YAHOO.COM
SERVICE: GATEWAY BREAKDOWN
REPORT: DOWNLOAD TIME COMPONENTS 1
BY: CITY
CARRIER: NEXTEL
FREQUENCY: 60 MINUTES
TIME: 12 PM - 12 PM
PERIOD: 03/01/00 - 03/07/00

FIG. 8e

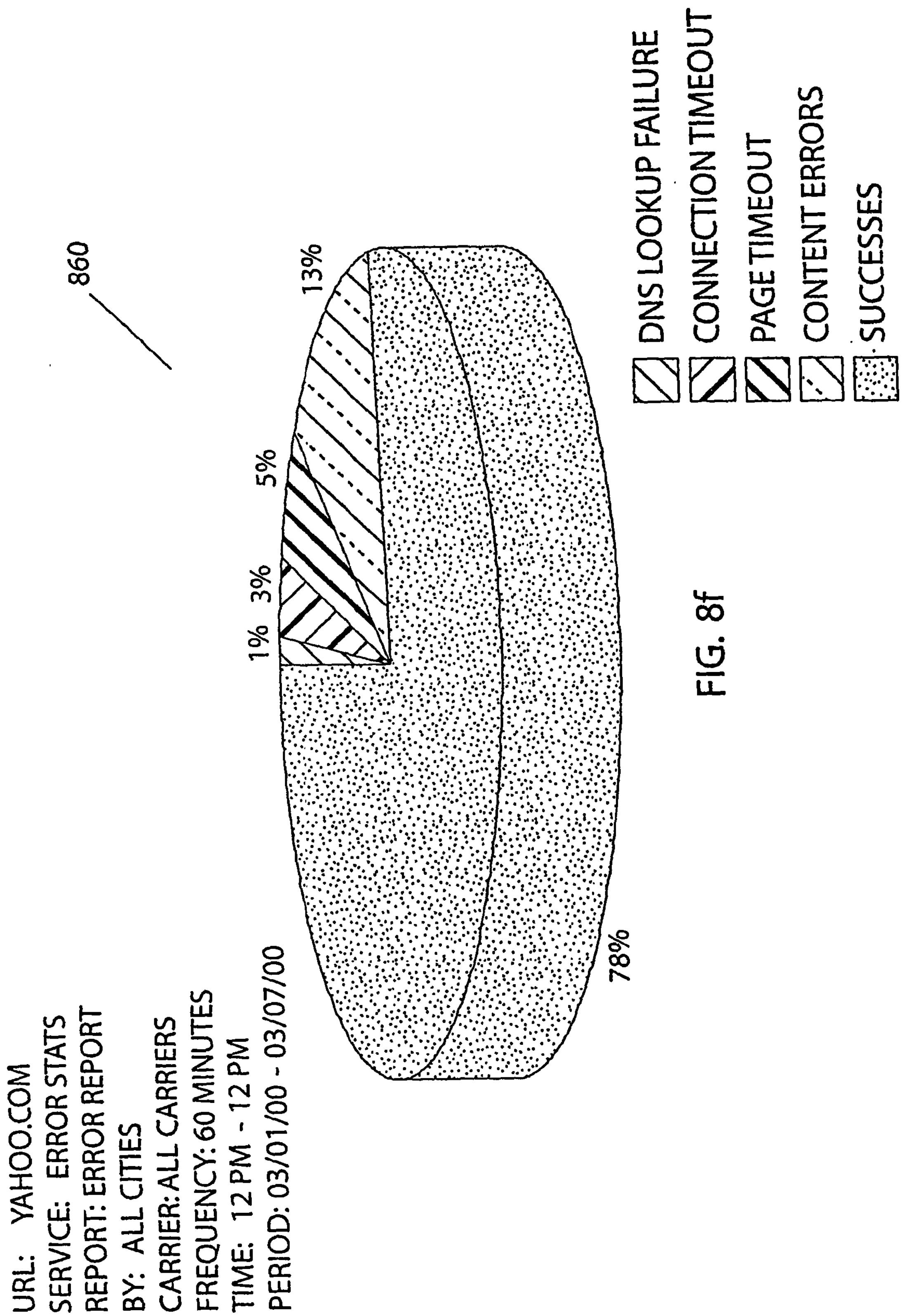

860
URL: YAHOO.COM
SERVICE: ERROR STATS
REPORT: ERROR REPORT
BY: ALL CITIES
CARRIER: ALL CARRIERS
FREQUENCY: 60 MINUTES
TIME: 12 PM - 12 PM
PERIOD: 03/01/00 - 03/07/00
1%
3%
5%
13%
78%
DNS LOOKUP FAILURE
CONNECTION TIMEOUT
PAGE TIMEOUT
CONTENT ERRORS
SUCCESSES

FIG. 8f

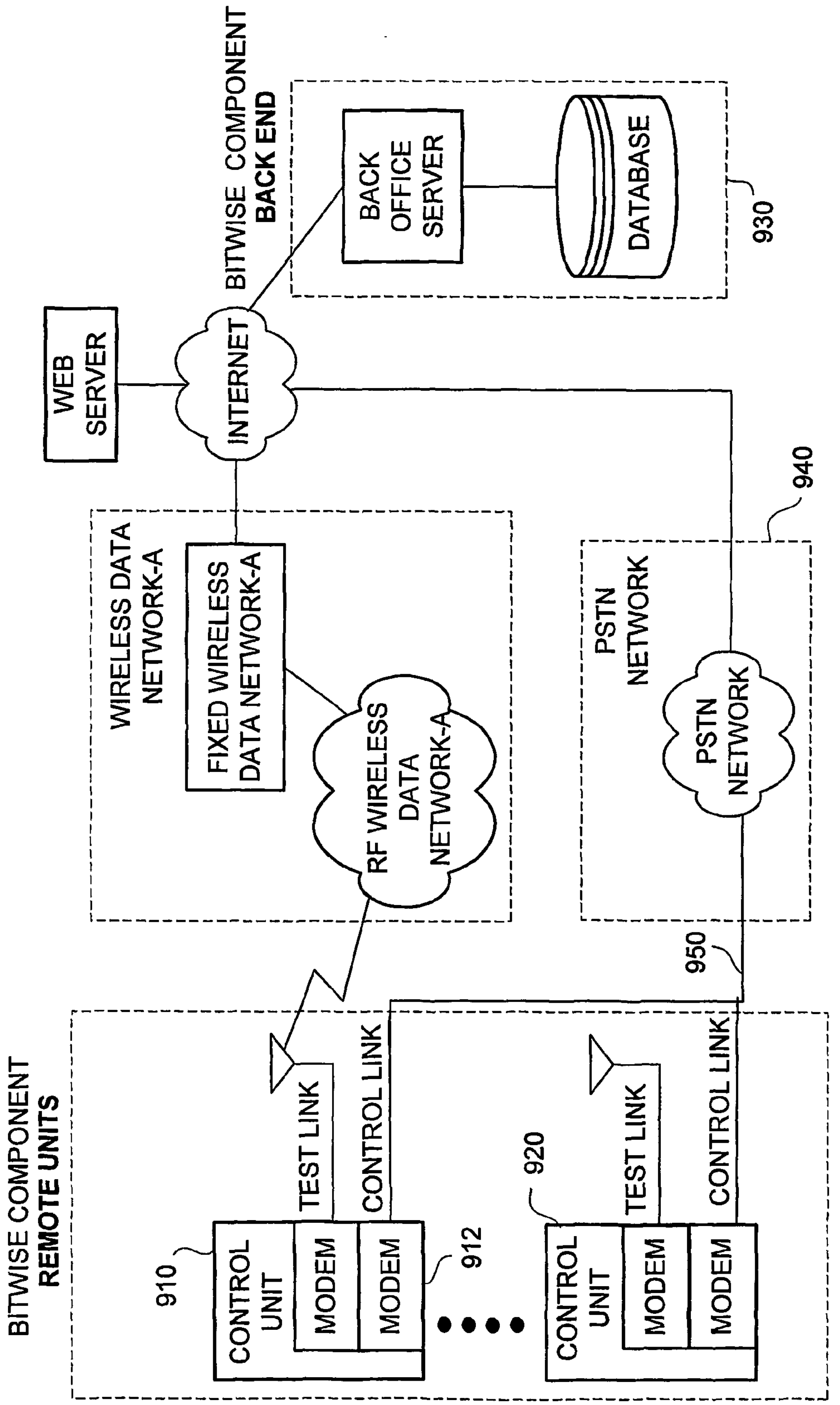

BITWISE COMPONENT
BACK END
WEB SERVER
INTERNET
BACK OFFICE SERVER
DATABASE
930
WIRELESS DATA NETWORK-A
FIXED WIRELESS DATA NETWORK-A
RF WIRELESS DATA NETWORK-A
940
PSTN NETWORK
PSTN NETWORK
950
BITWISE COMPONENT
REMOTE UNITS
910
CONTROL UNIT
MODEM
MODEM
912
TEST LINK
CONTROL LINK
920
CONTROL UNIT
MODEM
MODEM
TEST LINK
CONTROL LINK

FIG. 9

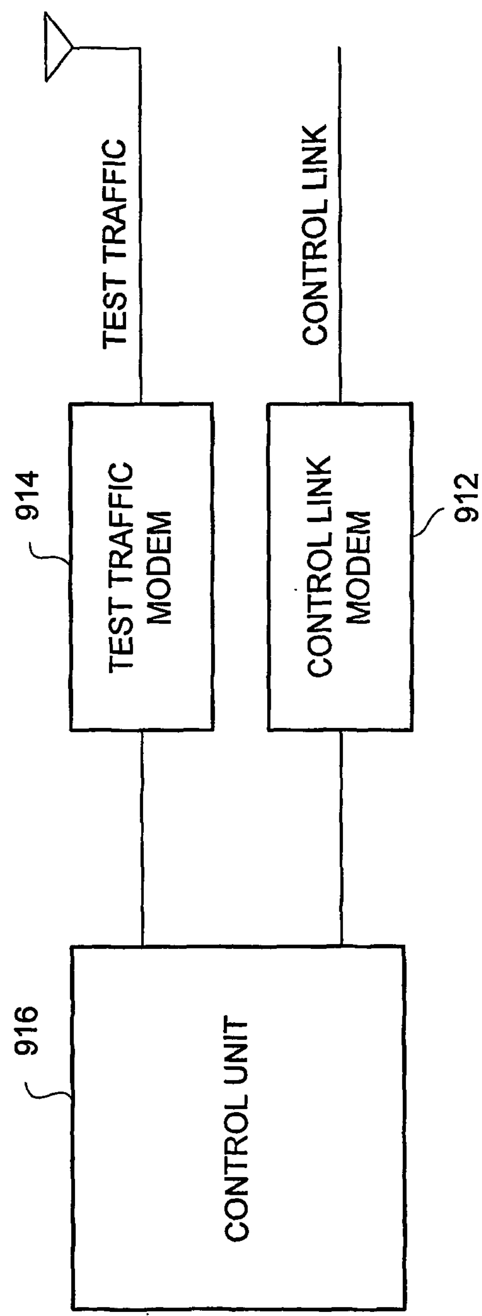

TEST TRAFFIC
CONTROL LINK
914
TEST TRAFFIC MODEM
CONTROL LINK MODEM
912
916
CONTROL UNIT

FIG. 10

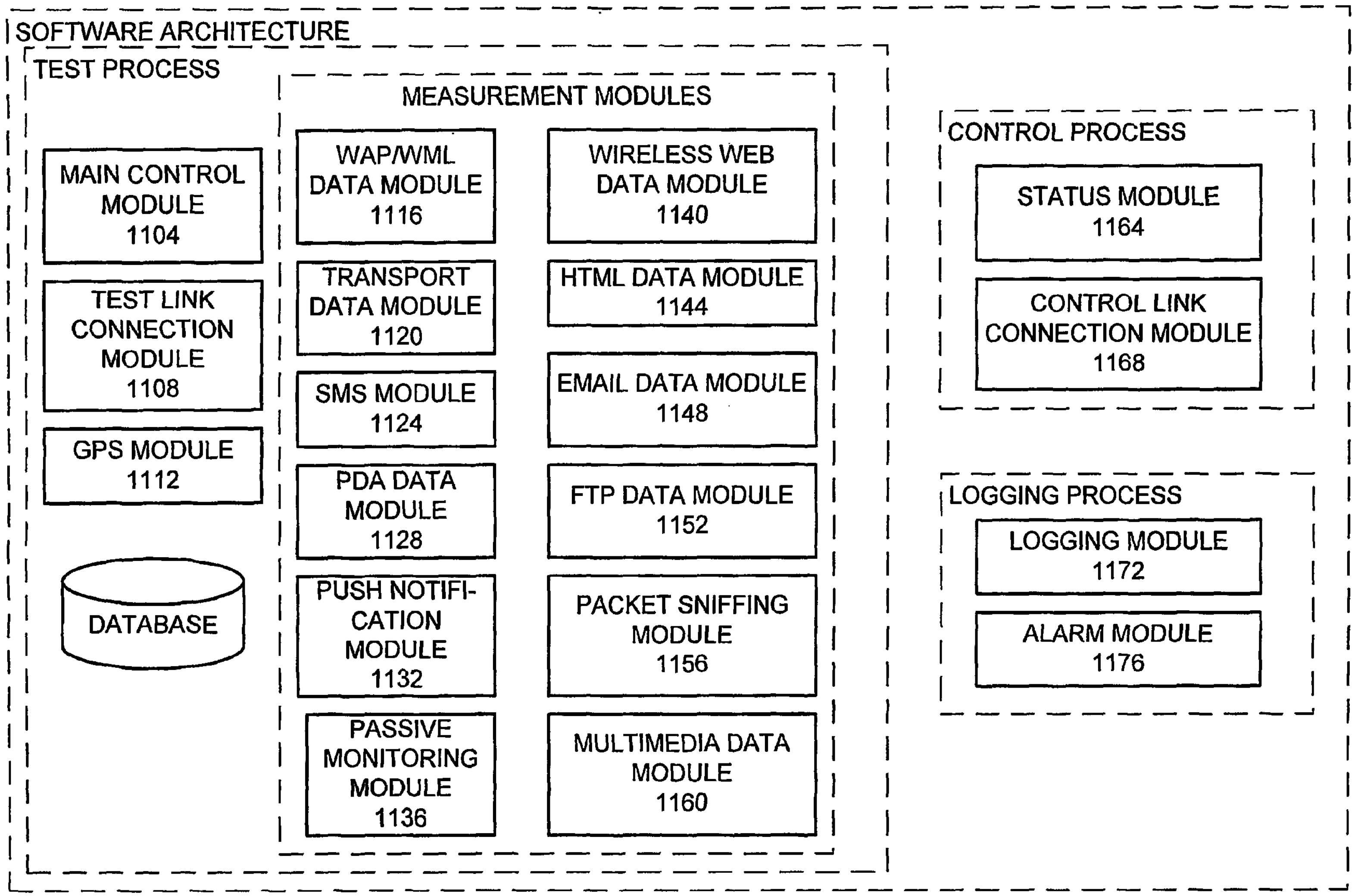

SOFTWARE ARCHITECTURE
TEST PROCESS
MAIN CONTROL MODULE 1104
TEST LINK CONNECTION MODULE 1108
GPS MODULE 1112
DATABASE
MEASUREMENT MODULES
WAP/WML DATA MODULE 1116
TRANSPORT DATA MODULE 1120
SMS MODULE 1124
PDA DATA MODULE 1128
PUSH NOTIFI-CATION MODULE 1132
PASSIVE MONITORING MODULE 1136
WIRELESS WEB DATA MODULE 1140
HTML DATA MODULE 1144
EMAIL DATA MODULE 1148
FTP DATA MODULE 1152
PACKET SNIFFING MODULE 1156
MULTIMEDIA DATA MODULE 1160
CONTROL PROCESS
STATUS MODULE 1164
CONTROL LINK CONNECTION MODULE 1168
LOGGING PROCESS
LOGGING MODULE 1172
ALARM MODULE 1176

FIG. 11

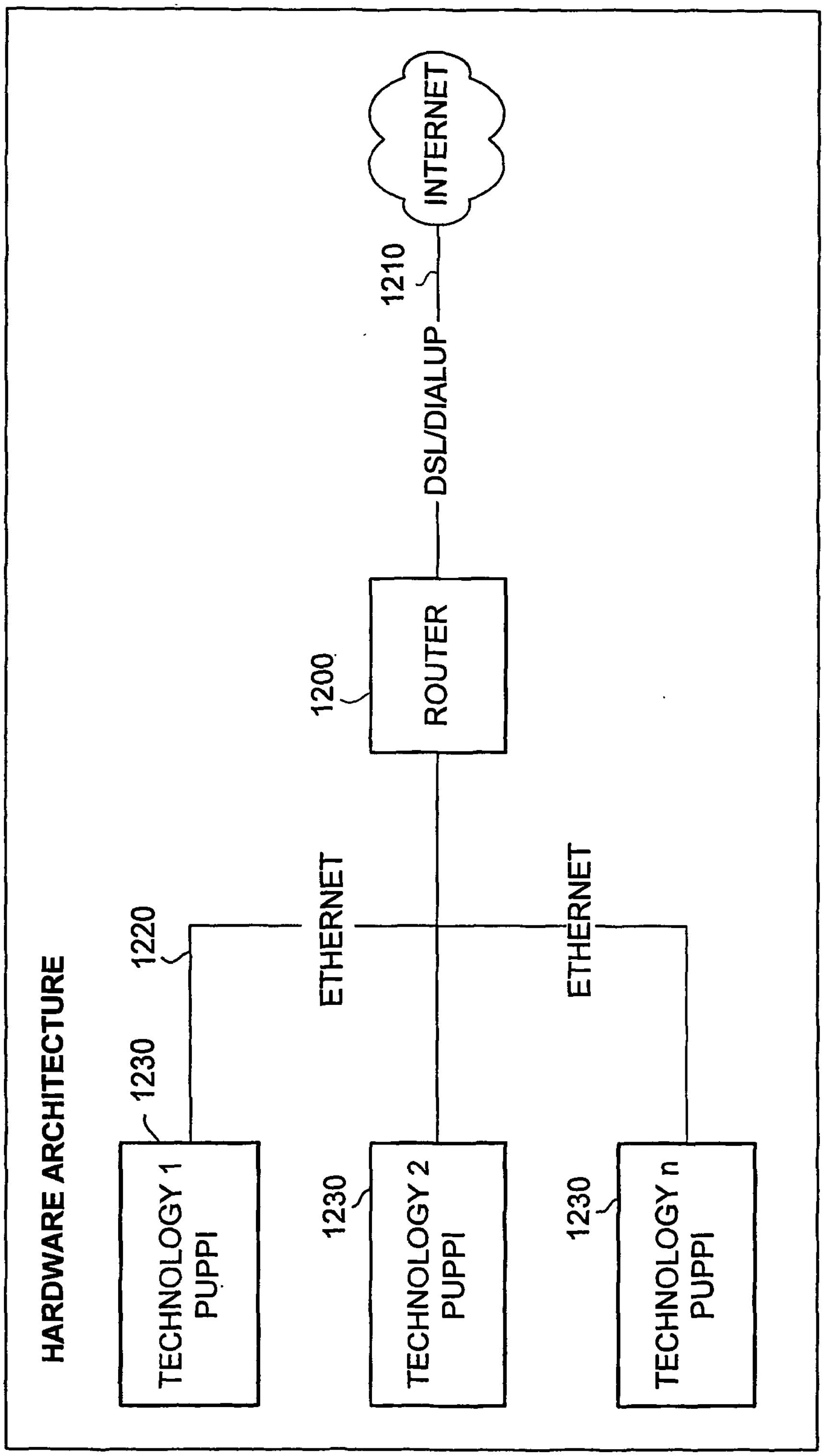

HARDWARE ARCHITECTURE
TECHNOLOGY 1
PUPPI
TECHNOLOGY 2
PUPPI
TECHNOLOGY n
PUPPI
1230
1230
1230
1220
ETHERNET
ETHERNET
ROUTER
1200
DSL/DIALUP
1210
INTERNET

FIG. 12

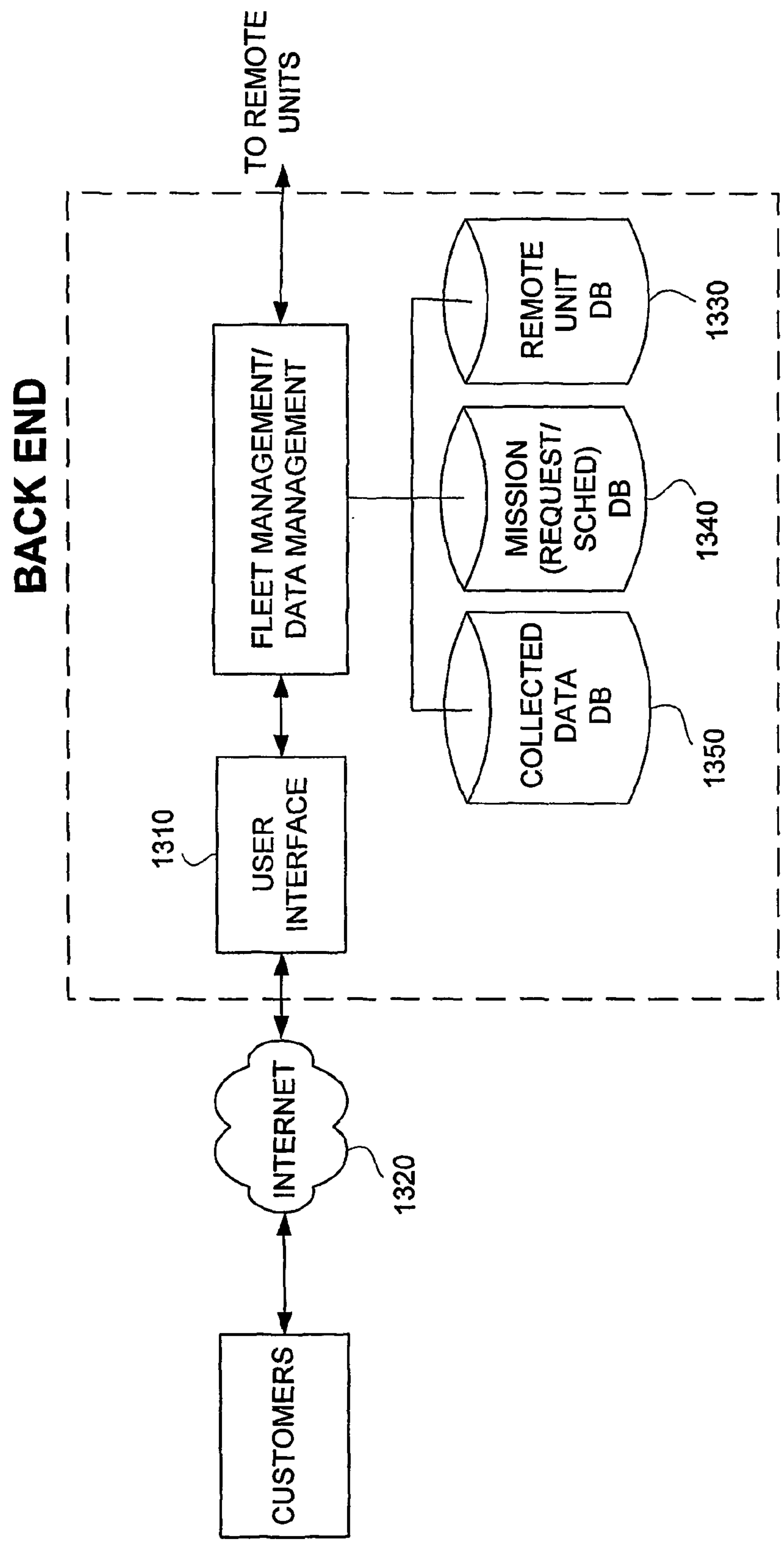

BACK END
TO REMOTE UNITS
FLEET MANAGEMENT/ DATA MANAGEMENT
USER INTERFACE
1310
REMOTE UNIT DB
1330
MISSION (REQUEST/ SCHED) DB
1340
COLLECTED DATA DB
1350
INTERNET
1320
CUSTOMERS

FIG. 13

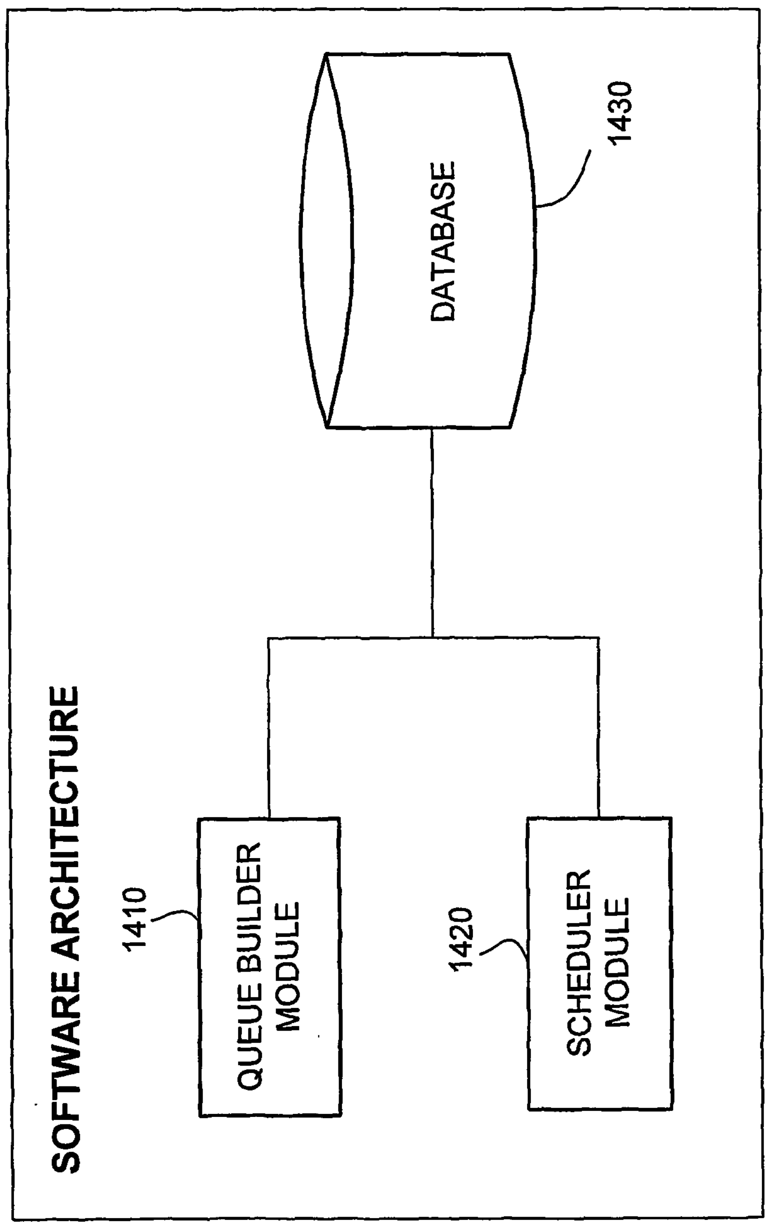

SOFTWARE ARCHITECTURE
QUEUE BUILDER MODULE
1410
SCHEDULER MODULE
1420
DATABASE
1430

FIG. 14

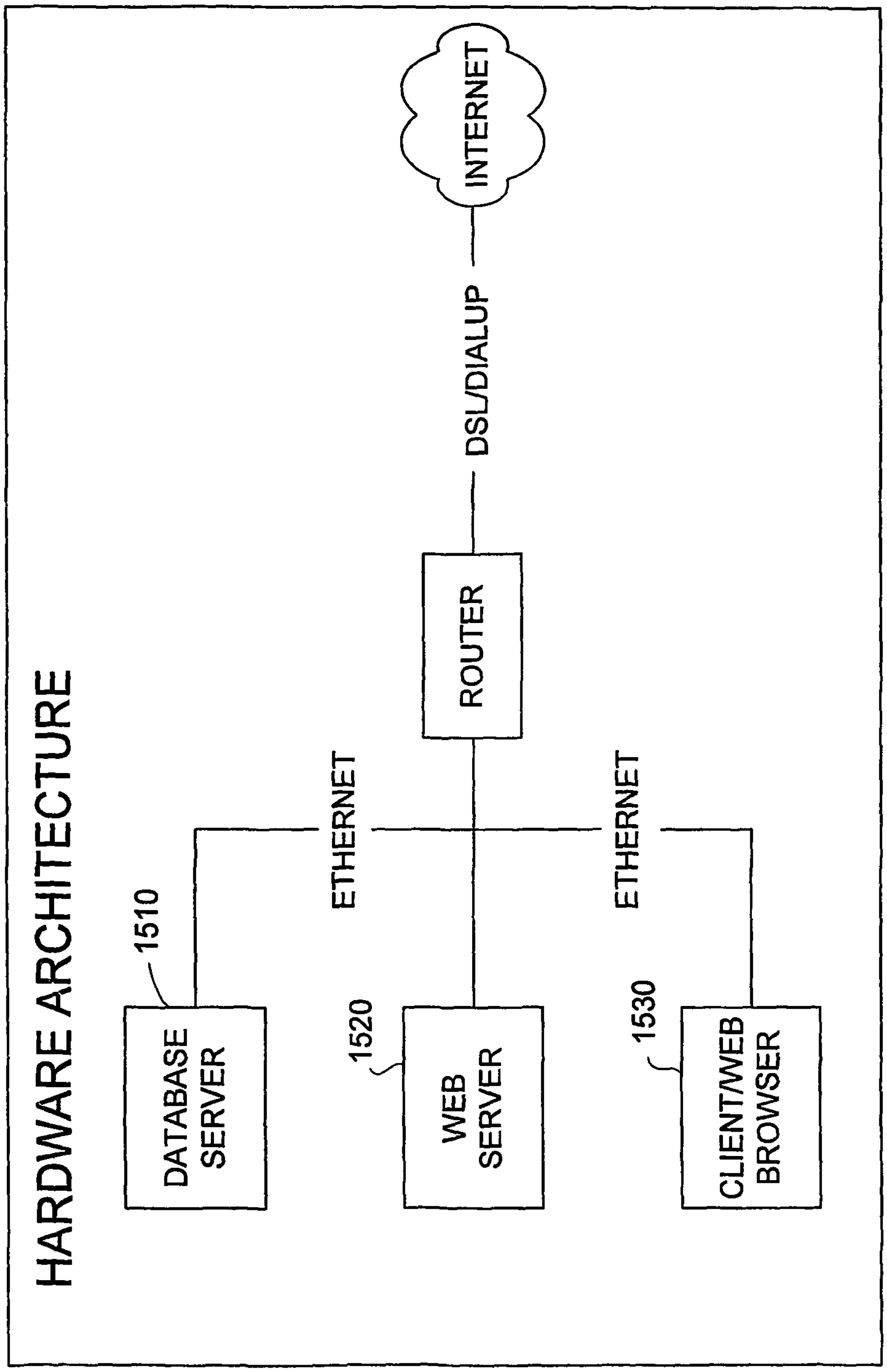

HARDWARE ARCHITECTURE
INTERNET
DSL/DIALUP
ROUTER
ETHERNET
ETHERNET
1510
DATABASE SERVER
1520
WEB SERVER
1530
CLIENT/WEB BROWSER

FIG. 15

CORRECTED VERSION*

PCT

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International Bureau

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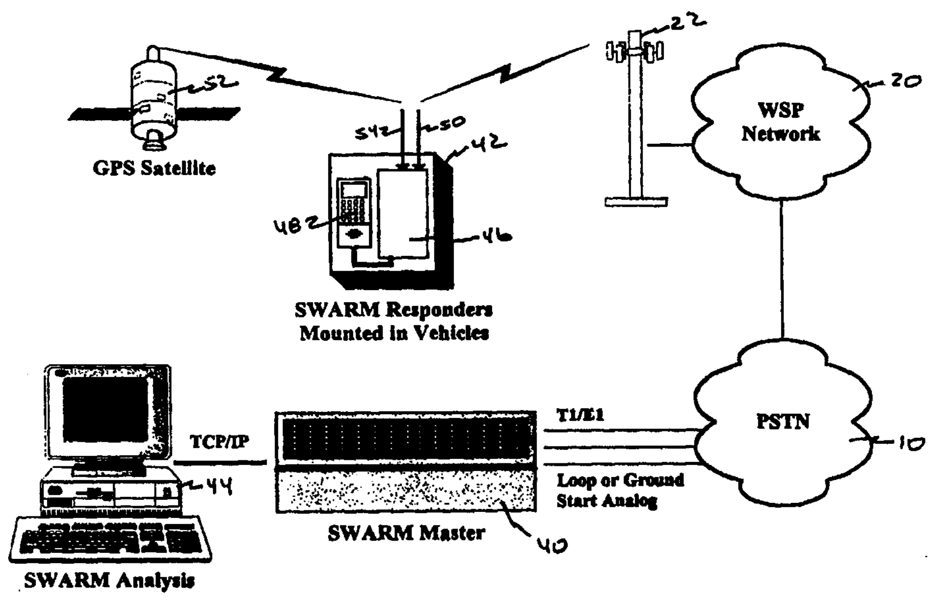
(54) Title: APPARATUS AND METHODS FOR AUTOMATED TESTING OF WIRELESS COMMUNICATIONS SYSTEMS

(57) Abstract



Apparatus and methods are provided for testing a wireless service provider network through a virtual subscriber system. In one aspect of this invention, a method for testing a wireless service provider network generally comprises the steps of initiating outbound call attempts under control of a master to multiple automatic, mobile responders, receiving calls at at least some of the responders, monitoring parameters relating to the wireless service provider network and transmitting information indicative of those parameters to the master. Parameters testable through the system include audio quality testing, including 23–tone testing, quantitative testing of audio quality, RF power testing, frequency testing and spectrum analysis testing. In the preferred method, testing may be performed by multiple responder units displaced throughout the geography of the wireless service provider, so as to provide real time indication of the network quality. Preferably, a global positioning system is utilized to provide location information regarding a responder's position. In yet another aspect of this invention, a method for testing communication between two wireless communication devices is provided. A master initiates a call to a first responder including a first wireless communication device, the first wireless communication device initiates a call over the network to a second wireless communication device in a second responder, testing is performed, and the results of the testing are provided to the master via the network. Wireless communication devices and networks testable with these inventions include at least mobile phone systems and PCS systems.

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LT	Lithuania
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LV	Latvia
MC	Monaco
MD	Republic of Moldova
MG	Madagascar
MK	The former Yugoslav Republic of Macedonia
ML	Mali
MN	Mongolia
MR	Mauritania
MW	Malawi
MX	Mexico
NE	Niger
NL	Netherlands
NO	Norway
NZ	New Zealand
PL	Poland
PT	Portugal
RO	Romania
RU	Russian Federation
SD	Sudan
SE	Sweden
SG	Singapore
SI	Slovenia
SK	Slovakia
SN	Senegal
SZ	Swaziland
TD	Chad
TG	Togo
TJ	Tajikistan
TM	Turkmenistan
TR	Turkey
TT	Trinidad and Tobago
UA	Ukraine
UG	Uganda
US	United States of America
UZ	Uzbekistan
VN	Viet Nam
YU	Yugoslavia
ZW	Zimbabwe

DESCRIPTION

APPARATUS AND METHODS FOR AUTOMATED TESTING OF WIRELESS COMMUNICATIONS SYSTEMS

Field of the Invention

This invention relates to the field of automated test equipment. More particularly, it relates to automated test equipment for wireless communication systems, especially cellular communications systems and personal communications systems.

Background of the Invention

Various wireless communication systems have been known in the art. Personal wireless communication systems are available in various forms and formats. Currently, cellular telephone systems are a popular form of wireless personal communication systems. Additionally, personal communication services (PCS) systems are now available.

Fig. 1 shows a diagramatic view of a typical wireless service provider network. Broadly, the complete system includes the public switched telephone network 10, the wireless service provider network 20 and wireless subscriber users 30. The public switched network 10 serves in a conventional manner to provide switched communications among various callers. The wireless service provider network 20 generally comprises a distribution network, most typically including a radio frequency distribution network of cell sites 22. The cell sites 22 provide a wireless communication link to mobile communication devices or mobile phones 32. Mobile phones 32 are known by various terms, and come in various technologies, examples of such terminology and technology include, but are not limited to, wireless cellular, flip phones, cellular phones, mobile telephones, cell phones and PCS phones. Generally, within the wireless service provider network 20, one or more cell sites 22 are linked to a base station controller 24. In turn, one or more base station controllers 24 are linked to a mobile telephone switching center 26. The communication link 12 between the public switch network 10 and the wireless service provider 20, as well as communication links 28 among the various components of the wireless service provider network 20, are typically digital land-based or microwave carrier systems. For example, T1, T3 or SONET facilities may be utilized.

The particular system architecture within a given wireless service provider network 20 currently tend to be manufacturer specific. Current manufacturers of such systems include Motorola, LM Ericsson, Nortel, Hughes Network Systems, Astronet and Lucent Technologies. Mobile phones 32 are available from many commercial sources.

Historically, mobile phones 32 were analog systems. More recently, mobile phones 32 include dual-mode mobile phones which support both analog and digital transmission systems. In addition to the providers of the wireless service network equipment, identified previously, current mobile phone manufacturers also include Oki, Samsung, Toshiba and NEC.

Cell sites 22 are geographically distributed throughout a region served by a given wireless service provider. As the cell site 22 has a limited geographic coverage area, wireless service providers have been required to determine service area coverage through various methods. Predictive models of coverage area have been utilized. Further, "drive tests" have been utilized in which a technician affiliated with the wireless service provider moves about the geography of the region covered by the wireless service provider. Typically, a skilled field engineer drives a vehicle including sophisticated test equipment throughout the region believed to be covered by the wireless service provider. Commonly, the testing is initiated by causing a call to be placed from the mobile test equipment to a land-based, receiving location. A communication path is thereby established between the mobile test equipment and the receiving station. The initiation of the call from the mobile test equipment is initiated by the technician. Tests typically performed include detailed radio frequency and system performance test data measuring radio frequency strength, frequency, noise, co-channel interference as well as other relevant parameters. Usually, the test data is collected and archived within the mobile test vehicle. The test data collected by the mobile unit is then often times combined with data from multiple other mobile units upon their return to the land-based facility.

Such "drive tests" utilizing dedicated testing vehicles is subject to a number of disadvantages. First, the testing for the entire wireless service provider network is not made in real time, as the test data resides in multiple vehicles, not at a central site. Second, the costs associated with such dedicated vehicles is very high. A fully equipped vehicle used in a drive test often costs from $100,000 to $250,000. Further, a skilled field engineer is required to operate the equipment and conduct the tests. Generally, multiple tasks must be performed in operating such systems, for example, the field engineer often collects the data, whereas then that data must be entered by yet another person for processing, and later for display. Yet further intervention is required for modifications or upgrading of the equipment such as for upgrading software through revisions, bug-fixes or feature additions.

Yet another type of testing performed on wireless service provider networks are cell simulation. The term call simulator has many synonyms, including, but not limited to, load tester, load box, line simulator and bulk call generator. All of these terms generally relate to devices which serve to simulate calls. Typically, a call simulator serves to automatically generate outbound calls through the wireless service provider network to various intended called parties. Typically, the called parties are individuals having a mobile phone. Various information regarding the placement of calls, such as number of attempts and call completion percentages, may be generated at the load box end of the system. Typically, the called parties may be requested to manually record various data regarding the call, such as location of the received call and some subjective assessment of the call quality.

Test equipment has been utilized in which a dedicated phone testing unit is placed in a vehicle. The unit is adapted to work with a specific manufacturer's phone. Calls may be placed from and received by the dedicated phone, with network parameters under test including network coverage, quality, and identification of location of existing problems. A GPS capability is provided to provide location information. The parameter information is stored to a PCMCIA flash disk. This data may be transferred by a technician after storage for collection and analysis by the system.

In yet another system, a ruggedized personal computer is placed in a mobile vehicle for wireless network provider testing. The system utilizes actual speech samples to monitor the system quantitatively utilizing a mean opinion scoring measurement. The mobile test unit consists of an embedded PC, audioprocessing hardware, GPS receiver and one or more cellular transceivers. The mobile test unit automatically places and receives calls to and from the field test unit while being driven over a selected or random route.

Wireless service providers have long sought methods for conducting coverage tests which provide usable system quality and performance data without the requirement for such time intensive and costly field engineer drive tests, and to make audio quality tests using traditional test methods without the need to depend on subjective Mean Opinion Score quality rating measurements. This invention is directed towards a solution of these long standing concerns.

Summary of the Invention

Apparatus and methods for automated testing of wireless communications systems is provided. In one aspect of the inventive method, testing of the wireless service provider network generally comprises the steps of, first, initiating one or more outbound call attempts under control of a master to one or more automatic mobile responders, second, receiving calls from at least some of the automatic, mobile responders, third, monitoring parameters relating to the wireless service provider network and fourth, transmitting information between the responder and master indicative of the parameters. Testing of the wireless service provider may be in any form or parameter, and especially includes quantitative testing of the wireless service provider network. Other parametric testing optionally includes radio frequency power level testing, frequency testing, audio quality testing, especially through the use of the 23-tone test, and spectrum analysis. Optionally, the testing method further includes the step of analyzing the information transmitted, preferably from multiple responders to the master. In this way, information may be obtained from multiple automatic mobile responders located throughout the geography covered by the wireless service provider network, thereby providing real-time assessment of the network.

The system level invention comprises a system for testing a wireless network which generally comprises an analysis system coupled to a master, where the master serves to automatically place calls, and optionally to receive calls, when connected to a wireless network or public switched network. The system includes one or more responders adapted to automatically communicate through the wireless service provider network with the master. The responders are provided with an antenna connection for communication with the wireless service provider RF (radio frequency) network and include a receptacle adapted to receive one or more wireless communication device. In accordance with one aspect of this invention, one or more standard mobile phones of any manufacturer may be utilized to emulate regular wireless subscriber calls. The mobile phones used in the responder architecture may alternatively be VLSI-chip-level mobile phones, test phone or any combination thereof. A responder control system typically includes a wireless control device controller, parametric testing systems and digital signal processing capability. Preferably, the system is equipped with a global positioning system which provides some or all of the position, time and velocity of the responder unit.

In yet another aspect of this invention, apparatus and method are provided for testing communications between a first wireless communication device and a second wireless communication device over a wireless service provider network. Generally, the apparatus and steps comprise utilizing a master to initiate a call to a first responder including a first wireless communication device, wherein the first responder is instructed to effectuate a subsequent call to the second wireless communication device in the second responder. Once the call is placed between the first wireless communication device and second wireless communication device, testing is performed. At least one of the first and second responders communicates with the master to provide test data regarding the call between the first wireless communication device and the second wireless communication device.

In one aspect of this invention, a testing system is provided whereby "virtual subscribers" are provided by automated, mobile responder units. In the preferred embodiment, the responders are of sufficiently small size so as to readily fit within a typical automobile trunk, and are more particularly preferred to be substantially smaller than the volume of the trunk, preferably less than one cubic foot. In this way, the responders may be placed in vehicles which are not dedicated to the testing function, but have a independent purpose. For example, responders may be included in vehicles that cover regular, thorough routes, such as postal or public transit vehicles, or in vehicles which cover relatively regular routes with some degree of variation, such as delivery vehicles, or in vehicles which cover random routes, and may go into and out of the service area, such as taxis, or vehicles owned by the wireless service provider. While the responders typically would be located within a mobile vehicle, at least certain of the responders within a system may be immobile without varying from the invention described herein.

In yet another aspect of this invention, the system may be utilized to emulate any feature or function of the wireless service provider and to test implementation of that feature.

By way of example, certain systems permit a mobile telephone number to be changed to another area code. Certain models permit mobile phones telephone numbers to be changed remotely. The system of this invention would permit the changing of the telephone number of the mobile phone, when permitted, either locally at the responder or remotely, to permit testing of this feature. In this way, accuracy of roaming and number verification systems can be achieved. This particular test would serve to verify the home location register (HLR) used by wireless service providers. Yet other features of such a test system would permit testing of an authentication system center (AUC) which manages the security data for subscriber authentication. Similarly, the equipment identify register (EIR) which stores the data of mobile equipment (ME) or ME-related data.

Accordingly, it is an object of this invention to provide an improved apparatus and method for providing usable system quality and performance data.

It is yet another object of this invention to provide an apparatus and system which provides information regarding a wireless network without requiring drive tests by skilled field engineers.

It is yet a further object of this invention to provide a system which serves to improve the quality and reliability of wireless communications systems.

Brief Description of the Drawings

Fig. 1 shows a diagrammatic view of a wireless service provider network.

Fig. 2 shows a diagrammatic view of the subscriber wireless automated remote measurement system.

Fig. 3 shows a block diagram description of the analysis software components for the subscriber wireless automated remote measurement system.

Fig. 4 shows a perspective view of the responder equipment.

Fig. 5 shows a block diagram view of the main hardware components of the responder system.

Fig. 6 shows a flowchart for the responder program flow.

Fig. 7 shows a flowchart for the inside weight for command sequence.

Fig. 8 shows a flowchart for the received call-back instructions sequence.

Fig. 9 shows a flowchart for a send-current location/time sequence.

Fig. 10 shows a flowchart for the send oldest unsent unsuccessful call destails sequence.

Fig. 11 shows a flowchart for the 23-tone test receiving and scoring sequence.

Fig. 12 shows a flowchart for a network access test.

Fig. 13 shows a flowchart for an audio quality test.

Fig. 14 shows a flowchart for an unsuccessful completion test.

Fig. 15 shows a flowchart for a dropped call test.

Detailed Description of the Invention

Fig. 2 shows a diagrammatic view of primary elements of the subscriber wireless automated remote measuring system in one aspect of this invention. A call simulator 40 serves to initiate telephone calls. Preferably, the call simulator 40 emulates telephone calls placed over lines 56 through the public switched telephone network 10 and the wireless service provider network 20 to a responder 42 via the cell site 22. The call simulator 40 preferably includes the ability to receive calls originated from the responder 42. Call simulators are available from many commercial sources including Ameritec Corporation (FeatureCall™ system), Zarak Systems, Inc. (Abacus: Advanced Bulk Call Simulator), Teradyne (Hammer product line), and Redcom (TeleTraffic Generator).

The responder 42 serves to generate and/or receive calls. Further, it preferably performs parametric measurements of test calls and network status over the wireless network through one or more cellular telephone interfaces. The responder typically would include one or more wireless communication device 48, such as a mobile phone or PCS device.

In the preferred embodiment of the subscriber wireless automated remote measuring system, the responder 42 is capable of providing geographic position information. Most preferably, the responder 42 provides geographic position information through use of the global positioning system. In such a global positioning system, a satellite 52 provides positional information to the responder 42 as received by antenna 54. The responder 42 preferably provides the positional information via antenna 50 during a telephonic communication between the responder 42 and the line simulator 40 and analyzer 44.

In operation, the responder 42 may be deployed to various geographic locations.

In the preferred mode, the responder 42 would be included within a vehicle so as to travel through the service area. Automated coverage testing may be achieved through the use of such mobile responder units. In the preferred embodiment, the responder units 42 operate remotely under control of the master 40. Most preferably, numerous responders 42 are provided in separate vehicles or locations throughout the service area, preferably in separate vehicles, so as to provide data to the master 40 and analyzer 44 under remote control from the master 40.

In one main intended application, this test methodology and equipment enables the wireless service provider the ability to validate service area predictive model data and to provide a survey of the quality of service and network status throughout a designated service area utilizing the wireless service providers subscriber's mobile phones. While the system may be utilized to test for any telephony related problem consistent with the goals and objects of this invention, the main types of problems contemplated are as follows. First, unsuccessful network access may be monitored. Such an unsuccessful network access is an uplink problem wherein the wireless subscriber is unable to originate calls from a mobile phone. Secondly, the system may check for audio quality. Typically, simulation of voice conversation is performed over a wireless connection and measured from the wireless subscribers location. Both downlink call simulation and uplink call simulation may be tested. Third, unsuccessful call completion may be monitored. An unsuccessful call is defined as any call, either uplink and/or downlink, not completed as dialed. Fourth, dropped calls may be monitored. This generally is defined as any call terminated before a call termination command is initiated by either the calling or called party. Generally, the responder 42 is preferably located within a vehicle, most preferably a vehicle which moves through a relatively large geographic area within the wireless service provider region. Examples of vehicles preferably utilized with the methods of the system include: postal or public transit vehicles (such as those that cover regular, thorough routes), delivery vehicles (such as those that cover regular routes which vary somewhat), taxis or other wireless service provider vehicles (such as those which cover random routes and sometimes go into and out of the service area). Alternatively, the responder 42 may be placed at a fixed location.

Fig. 3 shows a flowchart for the subscriber wireless automated remote measurement system analysis methods. The master 60 bi-directionally interfaces with a graphical user interface system 62, such as the FeatureCall™ system. The master 60 accesses the test processor 64. The test processor 64 in turn interacts with the database 66. The database 66 bi-directionally accesses a configuration screen and data manager 68 various reports 70, standard and custom, may be prepared. Generally, the subscriber wireless automated remote measuring system analysis consists of the test processor 64, database 66, configuration screen and data manager 68 and report generator 70.

The database 66 must be of sufficient capacity, speed and sophistication to achieve the goals and objectives of this invention. Generally, a relational database management system (RDBMS) is utilized. In the preferred embodiment, the database 66 is Oracle Work Group for Windows NT. Among its various functions, the database 66 serves as a repository for test results and preferably contains configuration information. The test processor 64, among other tasks, receives messages from the master 60 and translates them into SQL for the oracle database. Preferably, the test processor 64 is able to connect to multiple masters 60. Optionally, feedback may be provided from the test processor 64 to the master 60. The report package 70 preferably includes a graphical user interface (GUI) application to display test results and print reports. Derived values, e.g., signal to noise ratio, may be calculated by the report package 70. The configuration screens and data manager package 68 preferably serves to save data captured by the system for future analysis. Generally, system 68 is a file management system for augmentation of the database 66. Optionally, the system 68 may be incorporated into the report package 70.

Optionally, a geological information system for GIS may be utilized in conjunction with the system disclosed herein. Typically, a geological information system provides through mapping software a system in which previously compiled geographic data may be combined with newly collected and/or processed information to provide a composite image. Such software is available from many sources, including ESRI (Environmental Systems Research Institute, Inc.), who offer programs including, but not limited to, ArcView, MapObjects, and ARC/INFO. Overlays may be utilized on the underlying data, such as location of cell sites, commercially existing map grids (e.g., Thomas Brother map grids) or other relevant points of interest, either geographical or man-made.

The analysis components identified in Fig. 3 may be run on a single Windows NT workstation or notebook, or any other system which is compatible with the objects of this invention, such as Unix platforms, whether in a single work station or client-server configuration. Utilizing current technology, the system requirements would include: a single Pentium or PentiumPro processor running at or above 133 MHZ, 1.5 Gb available disk space, 48 Mb of RAM, a CD-ROM, 10 base-T network card, and Windows NT 3.51 SPx or Windows NT 4.0 SPx.

Fig. 4 shows an exploded, perspective view of the responder 80 in one physical implementation. Overall, the responder 80 may be relatively compact, such as to fit within a standard vehicle trunk, and is most preferably relatively compact, in the preferred embodiment being 8 inches x 11 inches x 2.5 inches, or smaller. A base 82 is connected to a lid 84 such as by operation of a key lock system 88 which cooperatively secures the lid 84, base 82 and bracket 86. Preferably, the lid 84 is locked to the base 82 via a lock assembly 88. The bracket 86 preferably includes flanges 90 disposed on the bottom of the base to permit mounting of the responder 80, such as on the floor of a vehicle trunk. Optionally, a bracket may be utilized to facilitate vehicle trunk or side-wall installations.

The interior of the responder 80 is preferably divided into two major components, the components being divided by a shield 92 so as to form a first compartment 94 and a second compartment 96. The first compartment 94 may contain, preferably, one or more mobile phones 48, and may be alternatively designated as the mobile phone compartment 94. The second compartment 96 may contain responder electronics and be alternatively designated as the responder electronics compartment 96. One or more printed circuit boards 98 may be supported from the base 82 via standoffs 100. The printed circuit boards 98 may include the circuitry for the responder and, optionally, the global positioning satellite daughter board standoffs.

In yet another aspect of this invention, the combination of a standard subscriber mobile phone and a component or chip-level mobile phone may be utilized on-line simultaneously on two separate cellular or PCS calls. The results of these two separate calls may be coordinated and correlated by the analysis system.

The first compartment 94, when adapted for holding the mobile phone, preferably includes foam rubber material on both the base 82 and the lid 84. This foam rubber material serves to receive the mobile phone 48 within a nest so as to support the mobile phone 48 during vehicle motion. Optionally, a mobile phone window 102 is provided in the lid 84 to permit user observation of the mobile phone 48 panel.

The second compartment 96 is connected to the first compartment 94 by a connector 104 passing through shield 92. The mobile phone connector 106 meets with connector 104 and connects to the mobile phone 48. The mobile phone connector 106 is typically unique depending upon the type of mobile phone 48 utilized. The software utilized by the responders cellular telephone controller serves to configure the system for the specific brand of mobile telephone then utilized within the responder 80.

The responder 80 includes various connections to external. An antenna connection 108 and global positioning satellite antenna connector 110 are provided. A barrier strip 112 or water tight connector preferably provides for connection to ground 114, battery 116 and vehicle ignition 118. Preferably, provision is made to reduce risk of electrical error from electrostatic discharge through use of O-rings or elastomeric gaskets for sealing.

Fig. 5 shows an electrical block diagram of the responder electronics. A microprocessor 110, such as Zilog microprocessor, is coupled to an address bus 112, databus 114 and control signal lines 116. A power supply 118 provides power to the system, and preferably comprises the vehicle battery. A regulator/sensor 120 provides a low battery voltage flag signal to the microprocessor 110 via the address but 112. The regulator 120 optionally couples to a mobile phone variable voltage regulator 122, which in turn is connected to the mobile phone input/output port 124. The mobile phone input/output port 124 is preferably coupled to an analog to digital codec 126 providing phone/audio input/output. The A/D codec 126 is coupled to buses, such as address bus 112 and databus 114. Preferably, the A/D codec 126 is coupled to a digital signal processing chip 128, such as a 2171 DSP chip. The mobile phone input/output port 124 is further connected for mobile phone data and control signal communication to the mobile phone controller 130. The mobile telephone 130 is coupled to the buses, such as the address bus 112 and databus 114. External computer input/output 132 is likewise coupled to the buses.

Various control signals 134 are provided to various electronics. Chip select is effected via coupling between the address bus 112 and the control signal interface 134. Optionally, an electronically programmable logic device (EPLD) 136 connects the chip select and control signal interface 134.

Optionally, a global positioning satellite system is utilized. A GPS daughter board 136 is coupled to the database 114. An antenna 138 connects to the daughter board 136.

Fig. 6 is a software flowchart for the responder program flow. At start-up 140, cold start begins when the power rises above 11.4 volts in a nominally 12 volt system. Initialization 142 includes some or all of the following: global reset, start z-180 program, initialize digital signal processor and mobile telephone controller (CTC) initialize mobile phone, set call-back count to 0 and set call sequence number to 0. At "phone on" decision block 144, if the phone is not on, decision block 146 waits until the phone is turned on manually. If the phone is on, the call-back count block 148 is checked for count equals zero. If the count does not equal zero, then a call is placed to the master 150, which if not successful, block 158, is logged in the circular queue 160. A recheck is then made of the call-back count equally zero 148. If the call-back count is zero in decision block 148, the system waits for a call at block 162, receives the call at block 164, and performs a command at block 166. When completed, the system hangs up at step 168.

Fig. 7 is a flowchart for the inside wait for command program flow. After initiation at the wait for command block 170, the sequence checks the vehicle power status 172 after which the "phone off-hook" decision block 174 is reached. If the phone is off hook at block 174, the hang up mobile phone block 176 is executed and a return 178 is made to the wait for command block 170. If the phone is not off hook as determined in decision block 174, decision block 182 queries whether valid DTMF command has been received at block 180. If valid DTMF commands have been received at decision block 180, various commands may be directed, including one or more of the following: receive call back instructions 182, send current location and/or time 184, send oldest unsent unsuccessful call details 186, and receive and score 23-tone test 188. If no valid DTMF are received at block 180, the program flows into block 172. In an alternative implementation, rather than utilizing DTMF tones for communication, a modem may be utilized. Whether transmitted via DTMF or modem, it is preferred that an error checking procedure be utilized with the data transmission.

Fig. 8 shows a flowchart for the receive call back instructions sequence. The master (e.g., master 40 in Fig. 2 or 60 in Fig. 3) establishes the call 190 to the responder (e.g., 42 in Fig. 2) and transmits a prompting command and parameters at block 192 after which the master proceeds to the done with command block 194. The responder initially is in the wait for command state 196. During the transmit command "11" and parameters state 192, the responder is in a corresponding receive command "11" and parameters state 198. After receipt of the command and parameters, the call back number and call back counts are saved at block 200. The responder then returns to the wait for command state 196.

Fig. 9 shows the flowchart for the send current location/time sequence. The master begins with the established call block 210. The system then transmits command "12" 212 to the responder. The responder begins in a wait for command state 214. After the transmit a prompting command step 212, the responder receives the prompting command in block 216. While the master is in the wait for reply state 218, the responder composes the result in state 220 and sends the result in state 222 to the master where it receives the result in state 224. After sending the result, the responder returns to the wait for command state 214. After the master receives the result in step 224, it sends the result to the test processor in block 226 after which the program is placed in a done with command state 228.

Fig. 10 shows a flowchart for the send oldest unsent unsuccessful call details program flow. The master begins with the establish call block 230. The master then transmits a prompting command at block 232 to the responder, which initially in the wait for command state 234 and then receives the prompting command in state 236. While the master is in a wait for reply state 238, the responder finds the data in the circular queue state 240, and sends the result at block 242 to the master who receives the result at block 244. The master then sends the result to the test processor at step 246, after which the master is done with the command at block 248.

Fig. 11 is a flowchart for the 23-tone test receiving and scoring sequence. The 23-tone test is described in one or more of the following United States Patents No. 4,301,536, 4,417,337 and 4,768,203, incorporated herein by reference. The master establishes the call at block 250, acquires digital signal processing (DSP) resource at block 252 and transmits a prompting command at block 56 to the responder. The responder begins in a wait state 256, and receives the command from state 254 at the responder side in state 258. While the master waits a period of time, e.g., 500 milliseconds at block 260, the responder during that wait interval 260 prepares a DSP to receive the 23-tone sequence at block 262. The master sends the tones at step 264 and the receiver receives the tones at step 266. Alternatively, or in combination, the responder may be commanded to transmit the 23-tone test to the master for analysis of the uplink path audio quality. The responder then processes bins and prepares results at step 268, sending the result at step 270 to the master which receives them at step 272. The responder then proceeds to a wait for command state 256. Upon receipt of results of step 272, the master sends the results to the test processor at step 274 after which it is placed in a done with command state 276.

Fig. 12 shows a flowchart for the network access test. After start block 280, a call is placed to the mobile phone at step 282 after which call back instructions are sent at step 284. The system then hangs up and waits for a call at step 286, and is optionally subject to a time out 288. If the call is placed, the call is then accepted at step 290, where upon a request for the current location is made at step 292. A request for the oldest unsent unsuccessful call details step 294 is made. At decision block 296, if the system has not received all unsent data, the system loops to yet again request the oldest unsent unsuccessful call detail step 294. If all unsent data has been received as determined at decision block 296, decision block 298 determines whether more call attempts are necessary. If not, the program flows to a done state 300, whereas if more call attempts are required the program flows to the hang up and wait for call state 286.

Fig. 13 shows a flowchart for an audio quality test. From start block 310, a call is placed to the mobile phone at step 312, upon which a request is made for the current location in step 314 as determined by the responder. Thereafter, a 23-tone test is conducted at step 316. Alternatively, or in combination, the responder may be commanded to transmit the 23-tone test to the master for analysis of the uplink path audio quality. Decision block 318 determines if the loop is done. If the loop is not done, another call to the mobile phone at step 312 is made. If the loop 318 is done, the system hangs up at step 320, and is placed in a done state 322. With regard to tone tests, such as the 23-tone test, the system may be full duplex, half duplex or simplex.

Fig. 14 shows a flowchart for an unsuccessful completion test. From start block

330, a call is placed to the mobile phone at step 332. After a request for the current location in step 334, the results are logged in the master at step 336. Thereafter, the system hangs up at step 338. As determined by decision block 340, if the loop is not done, the system loops back to the call mobile phone step 332, whereas if the loop 340 is done the system goes to a done state 342.

Fig. 15 shows a flowchart for a dropped call test. From the start block 350, a call is placed to the mobile phone in step 352. The results are logged in the master at step 354. Thereafter, for a predetermined period of time the system waits while tracking the current location and time at step 356. At decision block 358, if the call is still up, the system hangs up at step 360 and logs a successful call to the test processor at step 362. If the call is not still up at decision block 358, it is logged as a dropped call to the test processor at step 364. At the loop done decision block 366, if the loop is not done, a call mobile phone step 352 is executed. If the loop done 366 is completed, the system goes to a done state 368.

Although the foregoing invention has been described in some detail by way of illustration and example for purposes of clarity and understanding, it may be readily apparent to those of ordinary skill in the art in light of the teachings of this invention that certain changes and modifications may be made thereto without departing from the spirit or scope of the appended claims.

We Claim:

1. A method for testing a wireless service provider network comprising the steps of:

initiating one or more outbound call attempts under control of a master to one or more automatic, mobile responders,

receiving calls at at least some of the automatic, mobile responders,

monitoring parameters of the network during the call between the master and the automatic, mobile responder, and

transmitting information indicative of the parameters to the master.

2. The method of claim 1 for testing a wireless service provider network wherein the parameter tested includes quantitative and qualitative testing.

3. The method of claim 1 for testing a wireless service provider network wherein the testing includes audio quality testing.

4. The method of claim 3 for testing a wireless service provider network wherein the audio quality testing includes a 23-tone test.

5. The method of claim 4 for testing a wireless service provider network wherein the 23-tone test is in half duplex.

6. The method of claim 4 for testing a wireless service provider network wherein the 23-tone test is full duplex.

7. The method of claim 4 for testing a wireless service provider network wherein the 23-tone test is simplex.

8. The method of claim 1 for testing a wireless service provider network wherein the testing includes monitoring the radio frequency power.

9. The method of claim 1 for testing a wireless service provider network wherein the testing includes monitoring frequency.

10. The method of claim 1 for testing a wireless service provider network wherein the testing includes spectrum analysis.

11. The method of claim 1 for testing a wireless service provider network further including collection and transmission of information regarding global positioning.

12. The method of claim 11 for testing a wireless service provider network wherein the global positioning information includes position.

13. The method of claim 11 for testing a wireless service provider network wherein the global positioning information includes the time as provided by the global positioning system.

14. The method of claim 11 for testing a wireless service provider network wherein the velocity of the mobile responder is determined.

15. The method of claim 1 for testing a wireless service provider network wherein the transmission of information indicative of the parameters is performed in a call initiated by the master to the responder.

16. The method of claim 1 for testing a wireless service provider network wherein the step of transmitting information indicative of the parameters is performed in a call initiated by the responder to the master.

17. The method of claim 1 for testing a wireless service provider network further including the step of analyzing the information transmitted to the master.

18. The method of claim 1 for testing a wireless service provider further including

the step of displaying the information provided from the responders to the master.

19. The method of claim 1 for testing a wireless service provider network further including the step of archiving data supplied to the master in real time.

20. The method of claim 1 for testing a wireless service provider network further including the step of displaying information regarding the network in real time.

21. The method of claim 1 for testing a wireless service provider network further including the step of displaying geological information systems data in real time.

22. The method of claim 1 for testing a wireless service provider network further including the step of collecting data regarding calls not received.

23. A method for testing communication between a first wireless communication device and a second wireless communication device over a wireless service provider network, comprising the steps of:

first, initiating a call from a master to a first responder including the first wireless communication device,

second, initiating a call from the first wireless communication device to the second wireless communication device in a second responder over the wireless service provider network,

monitoring parameters of the call, and

communicating to the master information regarding the call between the first wireless communication device and the second wireless communication device.

24. The method of claim 23 for testing communication between wireless communication devices wherein at least one of the first and second wireless communication devices is a mobile phone.

25. The method of claim 23 for testing communication between wireless

communication devices wherein at least one of the first and second wireless communication devices is a personal communications systems device.

26. A system for testing a wireless communication network comprising:

a master for automatically initiating calls, adapted for connection to a switched network including a wireless service provider network,

one or more wireless responders adapted to automatically communicate with the master via the switched network, and

an analysis system for receiving information from the responders through the wireless network in real time for providing test results regarding the wireless network.

27. The system of claim 26 for testing a wireless network wherein the analysis system includes a test processor.

28. The system of claim 26 for testing a wireless network wherein the analysis system includes a database for archiving test information.

29. The system of claim 26 for testing a wireless network wherein the analysis system includes a graphical user interface.

30. The system of claim 26 for testing a wireless network wherein the public switch network further includes the public switched telephone network.

31. A mobile responder for testing a wireless service provider network between a base station including a master and a wireless communication device located at the mobile responder, comprising:

an antenna connection adapted for communication with the wireless service provider network,

a wireless communication device receptacle adapted to receive a wireless communication device,

a responder control system including,

a wireless communication device controller,

a parametric test system, and

a test result provision system adapted to provide test results to the master, and

a power connection for providing power to the responder control system.

32. The mobile responder of claim 31 for testing a wireless service provider network wherein the responder includes two or more separate compartments.

33. The mobile responder of claim 32 wherein a first compartment is adapted to receive the wireless communication device.

34. The mobile responder of claim 32 wherein a second compartment includes the responder control system.

35. The mobile responder of claim 32 further including a pass through connection between the compartments.

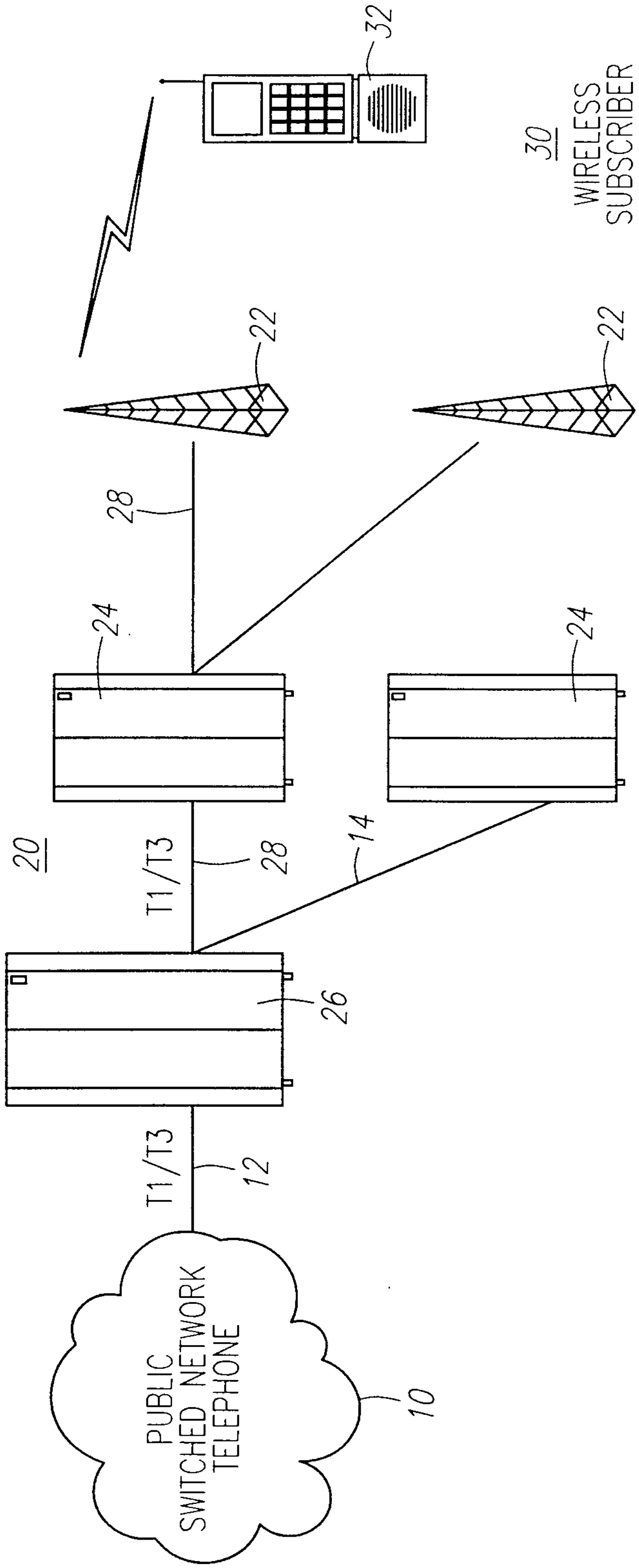

PUBLIC
SWITCHED NETWORK
TELEPHONE
10
T1/T3
12
26
T1/T3
28
20
14
24
24
28
22
22
32
30
WIRELESS
SUBSCRIBER

FIG. 1

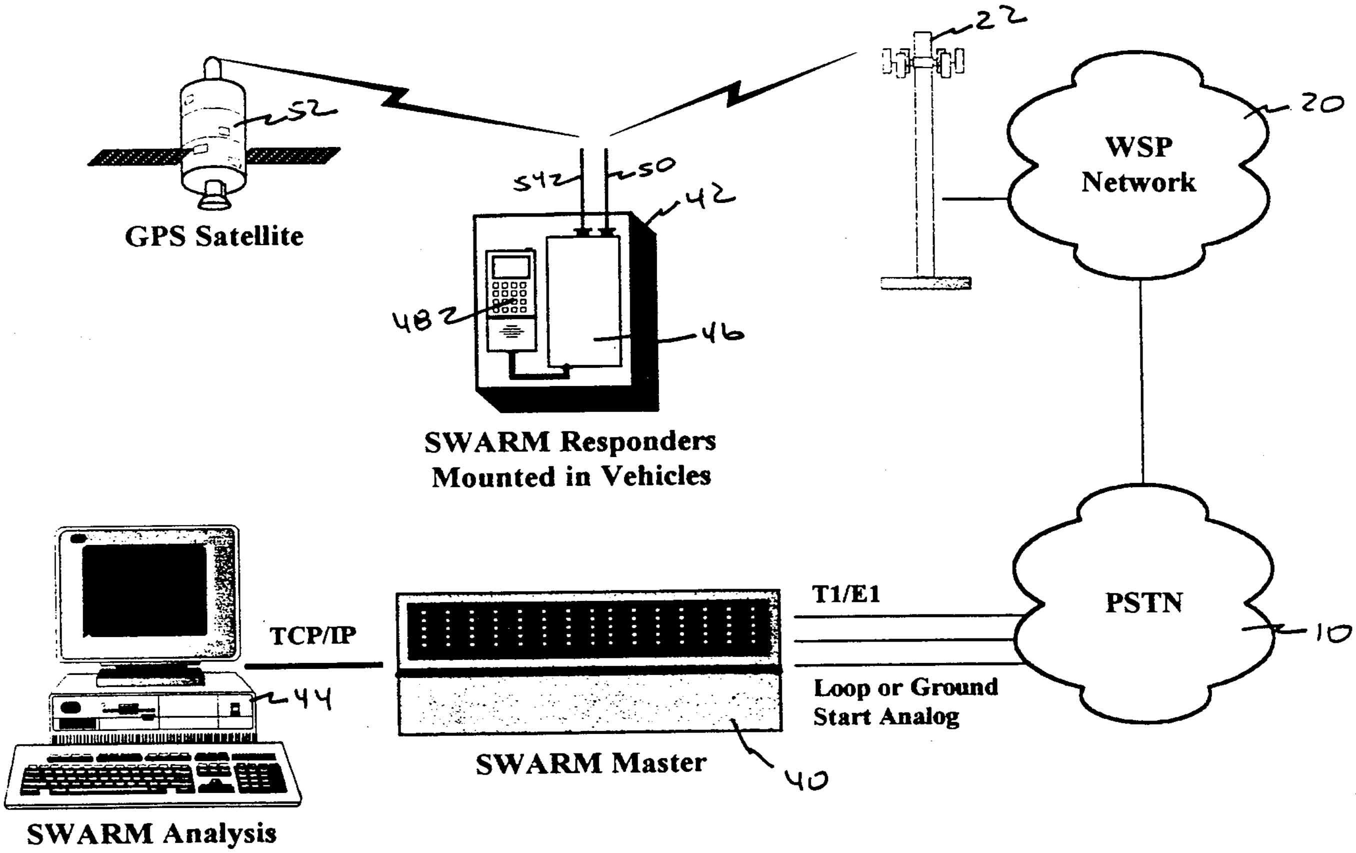

22
20
WSP
Network
252
GPS Satellite
542
250
42
482
46
SWARM Responders
Mounted in Vehicles
TCP/IP
T1/E1
PSTN
10
44
Loop or Ground
Start Analog
SWARM Master
40
SWARM Analysis

FIG2

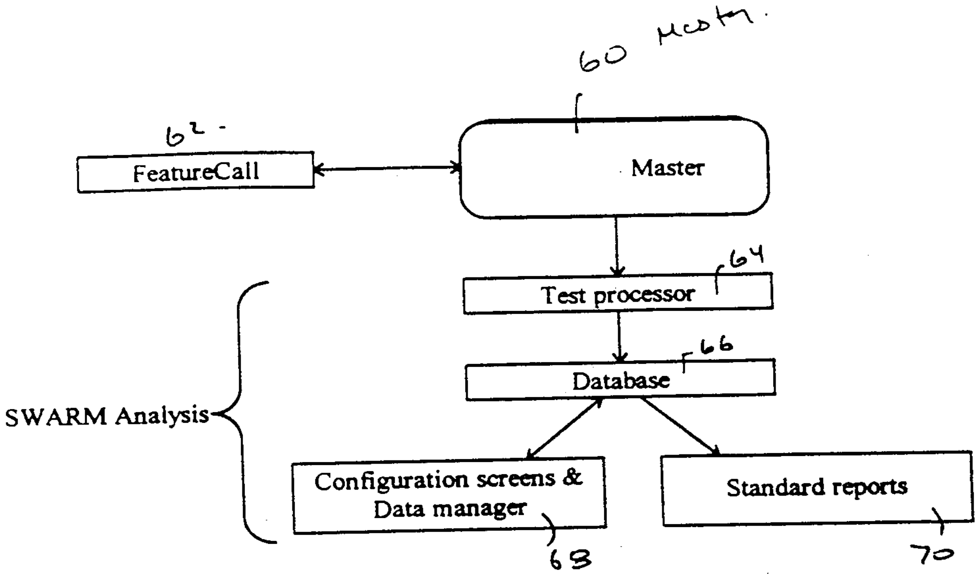

60 Master
62
FeatureCall
Master
Test processor
64
Database
66
SWARM Analysis
Configuration screens & Data manager
68
Standard reports
70

Fig. 3

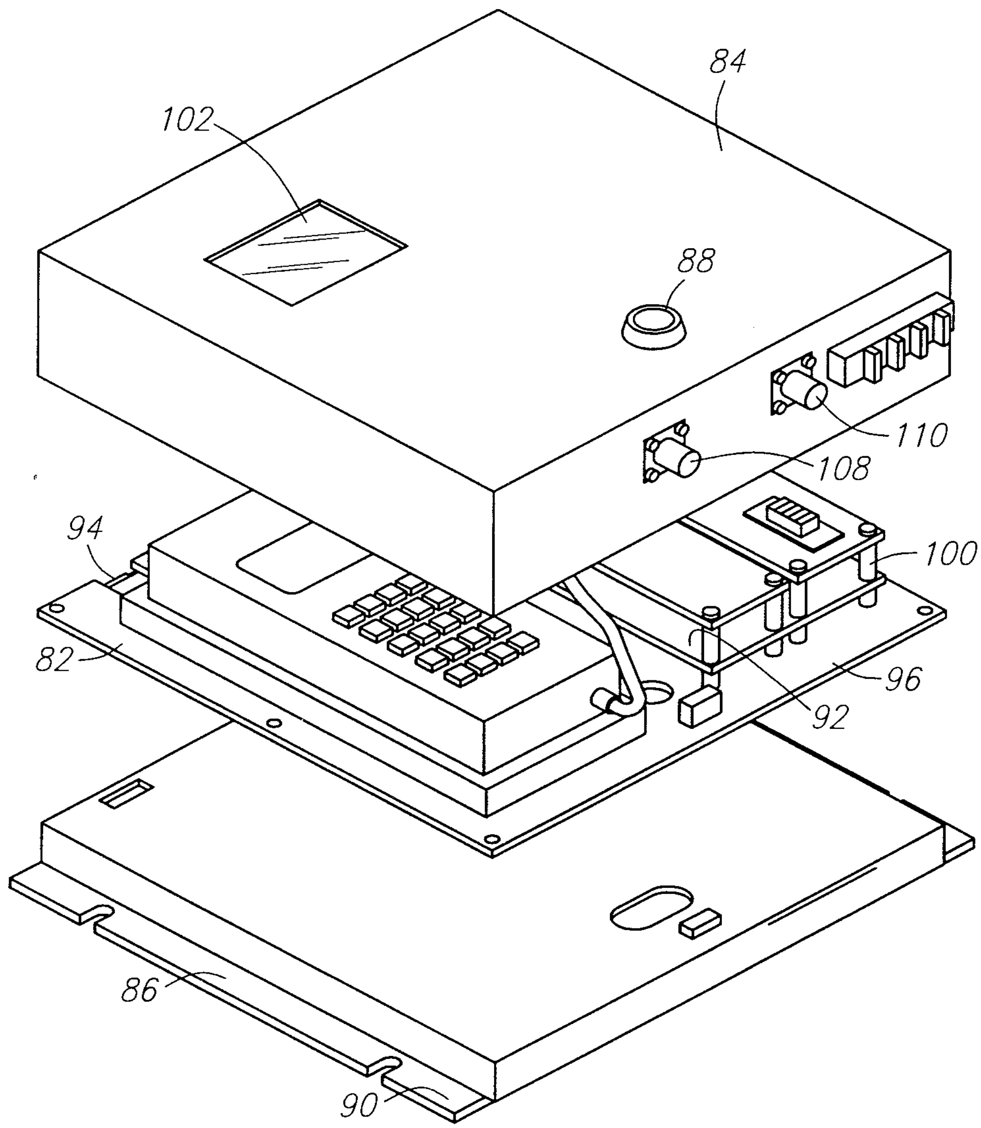


FIG. 4

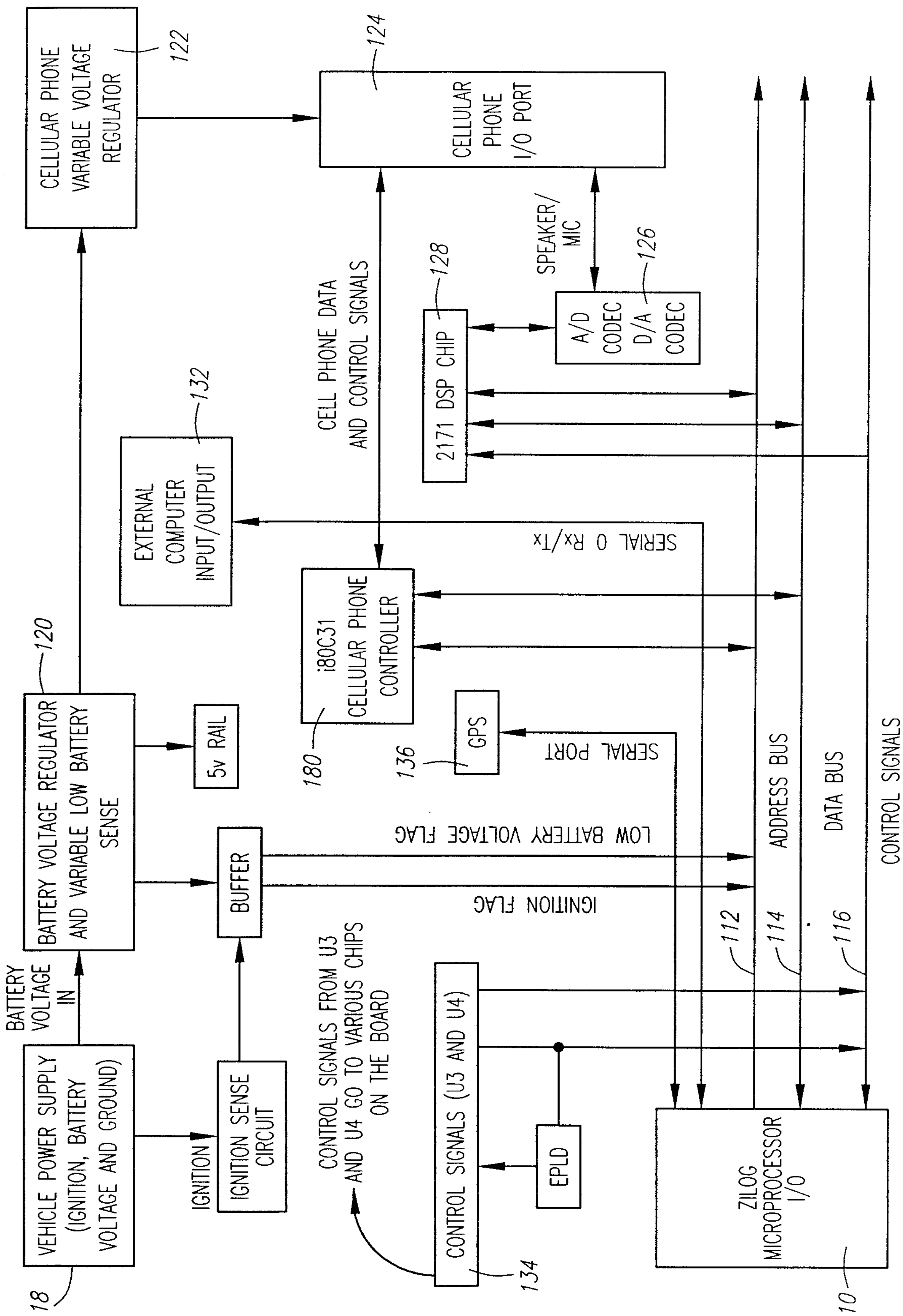

CELLULAR PHONE VARIABLE VOLTAGE REGULATOR
122
124
CELLULAR PHONE I/O PORT
SPEAKER/ MIC
126
A/D CODEC D/A CODEC
128
2171 DSP CHIP
CELL PHONE DATA AND CONTROL SIGNALS
132
EXTERNAL COMPUTER INPUT/OUTPUT
SERIAL 0 Rx/Tx
120
BATTERY VOLTAGE REGULATOR AND VARIABLE LOW BATTERY SENSE
5v RAIL
i80C31 CELLULAR PHONE CONTROLLER
180
GPS
136
SERIAL PORT
BUFFER
LOW BATTERY VOLTAGE FLAG
IGNITION FLAG
ADDRESS BUS
DATA BUS
CONTROL SIGNALS
112
114
116
BATTERY VOLTAGE IN
VEHICLE POWER SUPPLY (IGNITION, BATTERY VOLTAGE AND GROUND)
118
IGNITION
IGNITION SENSE CIRCUIT
CONTROL SIGNALS FROM U3 AND U4 GO TO VARIOUS CHIPS ON THE BOARD
CONTROL SIGNALS (U3 AND U4)
134
EPLD
ZILOG MICROPROCESSOR I/O
110

FIG. 5

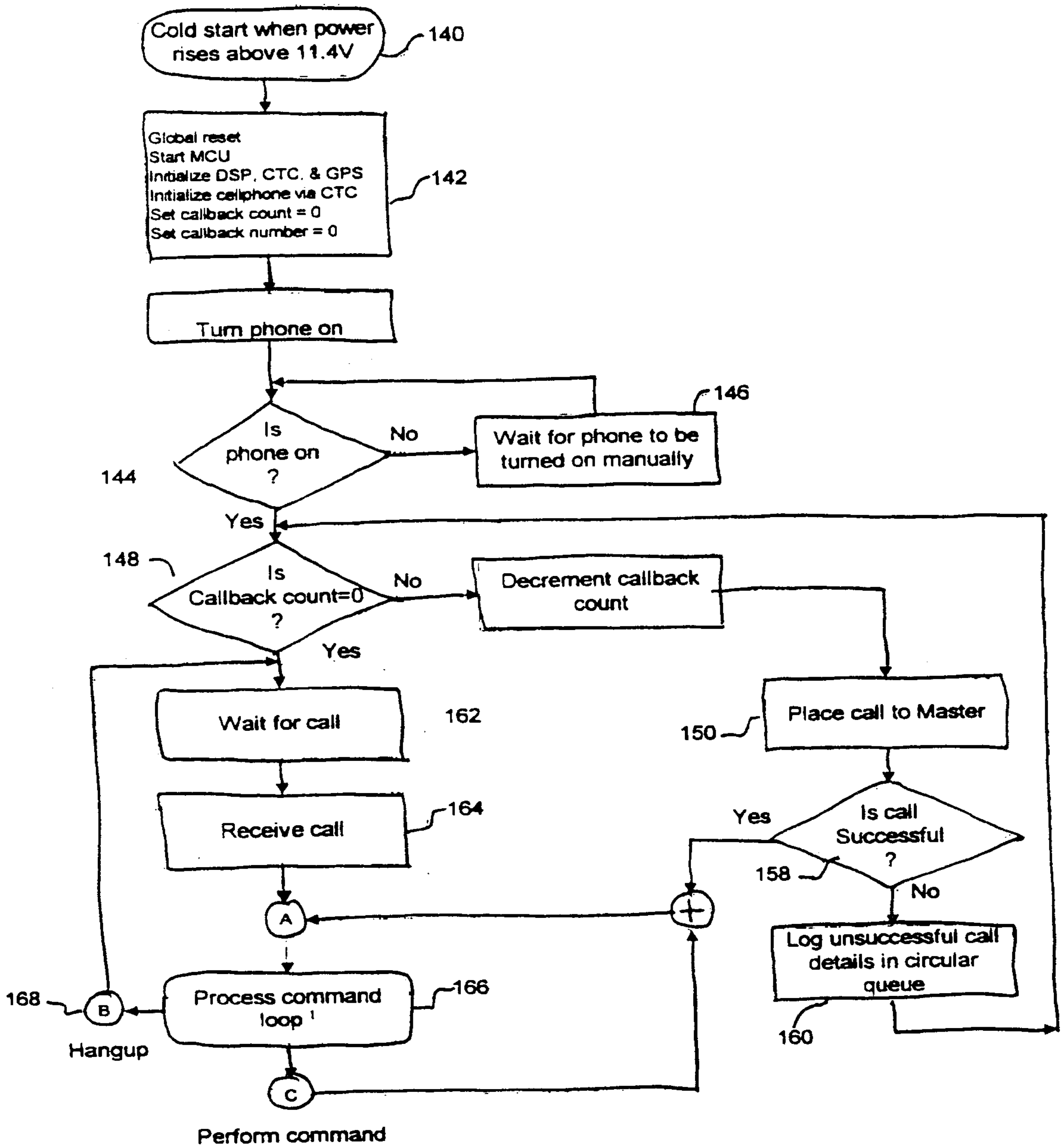
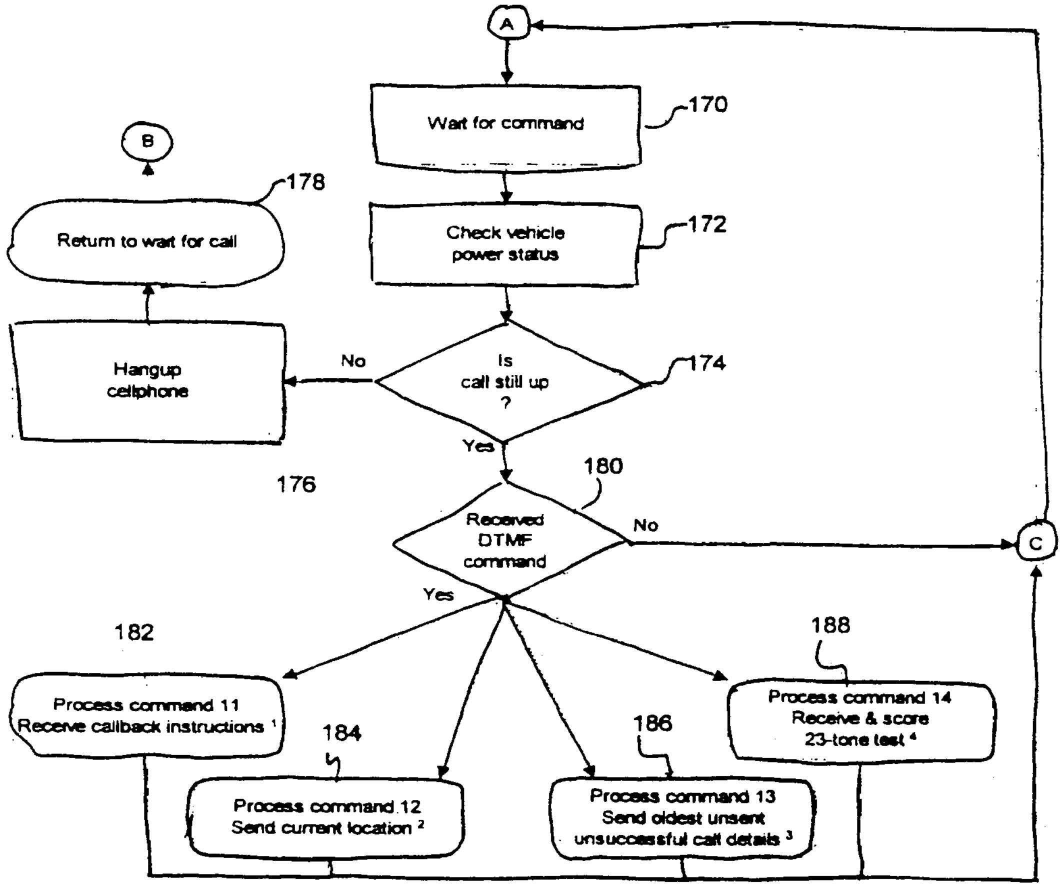

Cold start when power rises above 11.4V
140
Global reset
Start MCU
Initialize DSP, CTC, & GPS
Initialize cellphone via CTC
Set callback count = 0
Set callback number = 0
142
Turn phone on
Is phone on ?
144
No
Wait for phone to be turned on manually
146
Yes
148
Is Callback count=0 ?
No
Decrement callback count
Yes
Wait for call
162
Place call to Master
150
Receive call
164
Yes
Is call Successful ?
158
No
A
Log unsuccessful call details in circular queue
160
168
B
Hangup
Process command loop [1]
166
C
Perform command

Figure 6



1. COMMAND SEQUENCE FLOWCHART: (1 of 4) Command 11: Receive Callback Instructions
2. COMMAND SEQUENCE FLOWCHART: (2 of 4) Command 12: Send Current Location
3. COMMAND SEQUENCE FLOWCHART: (3 of 4) Command 13: Send Oldest Unsent Unsuccessful Call Details
4. COMMAND SEQUENCE FLOWCHART: (4 of 4) Command 14: Receive & Score 23-Tone test

Figure 7

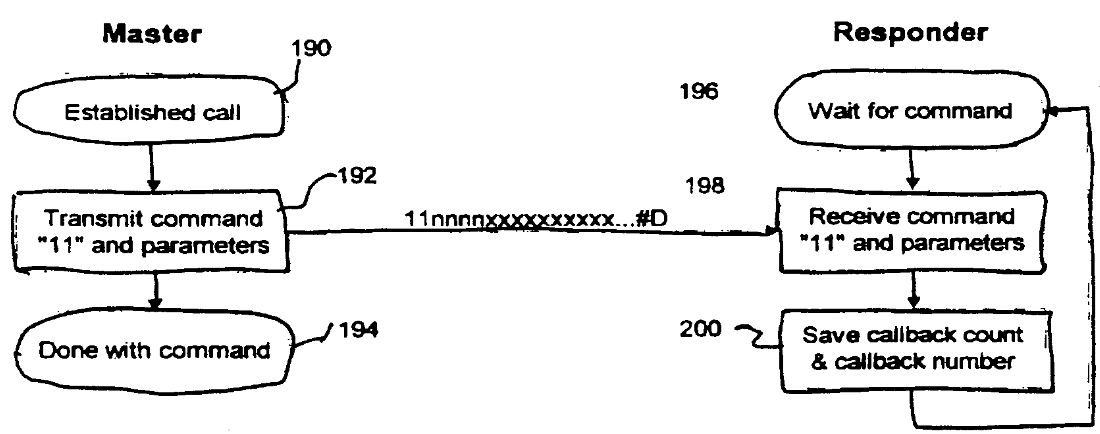


Figure 8

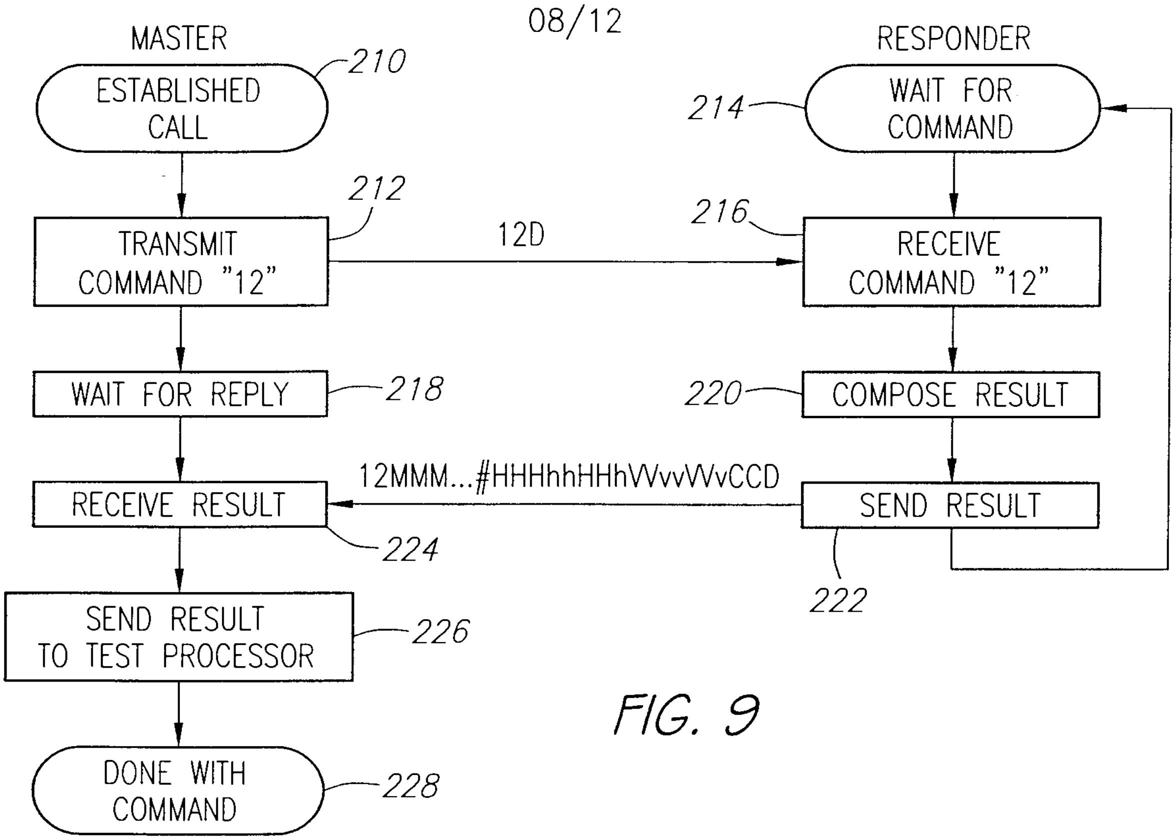

MASTER
ESTABLISHED CALL
210
RESPONDER
WAIT FOR COMMAND
214
212
TRANSMIT COMMAND "12"
12D
216
RECEIVE COMMAND "12"
WAIT FOR REPLY
218
220
COMPOSE RESULT
12MMM...#HHHhhHHhVVvvVVvCCD
RECEIVE RESULT
SEND RESULT
224
222
SEND RESULT TO TEST PROCESSOR
226
DONE WITH COMMAND
228

FIG. 9

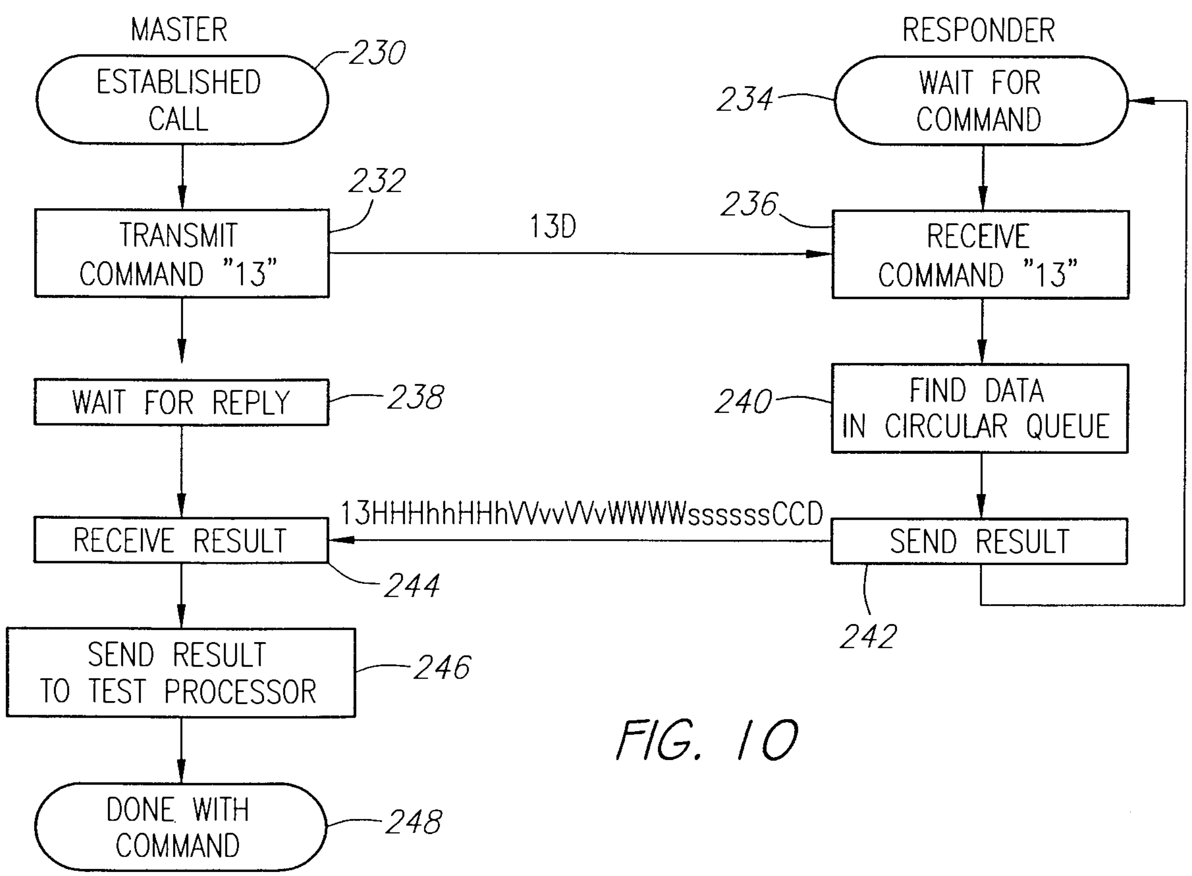

MASTER
ESTABLISHED CALL
230
RESPONDER
WAIT FOR COMMAND
234
232
TRANSMIT COMMAND "13"
13D
236
RECEIVE COMMAND "13"
WAIT FOR REPLY
238
240
FIND DATA IN CIRCULAR QUEUE
13HHHhhHHhVVvvVVvWWWWssssssCCD
RECEIVE RESULT
SEND RESULT
244
242
SEND RESULT TO TEST PROCESSOR
246
DONE WITH COMMAND
248

FIG. 10

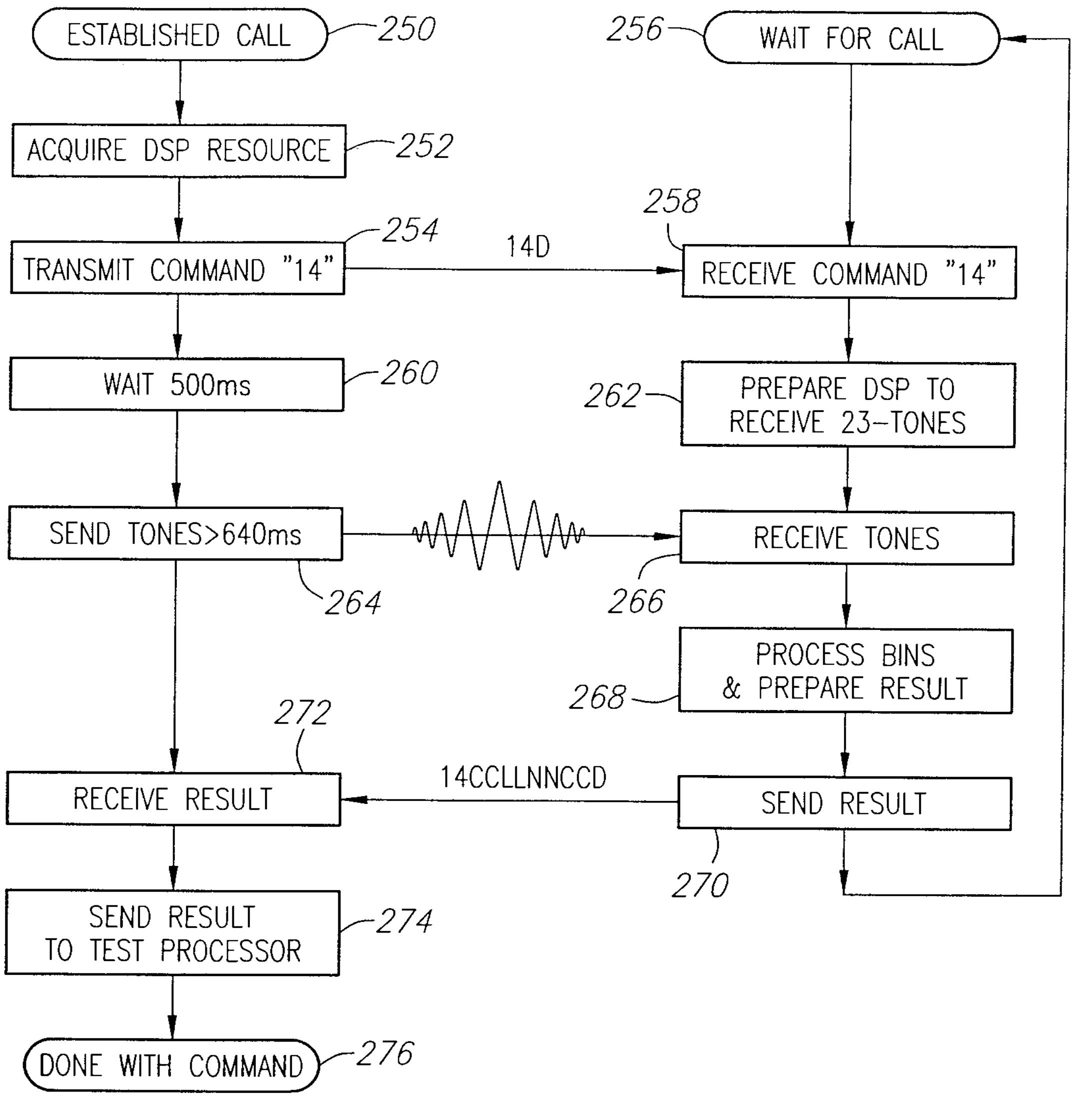

ESTABLISHED CALL
250
ACQUIRE DSP RESOURCE
252
TRANSMIT COMMAND "14"
254
14D
WAIT 500ms
260
SEND TONES>640ms
264
RECEIVE RESULT
272
14CCLLNNCCD
SEND RESULT TO TEST PROCESSOR
274
DONE WITH COMMAND
276
WAIT FOR CALL
256
RECEIVE COMMAND "14"
258
PREPARE DSP TO RECEIVE 23-TONES
262
RECEIVE TONES
266
PROCESS BINS & PREPARE RESULT
268
SEND RESULT
270

FIG. 11

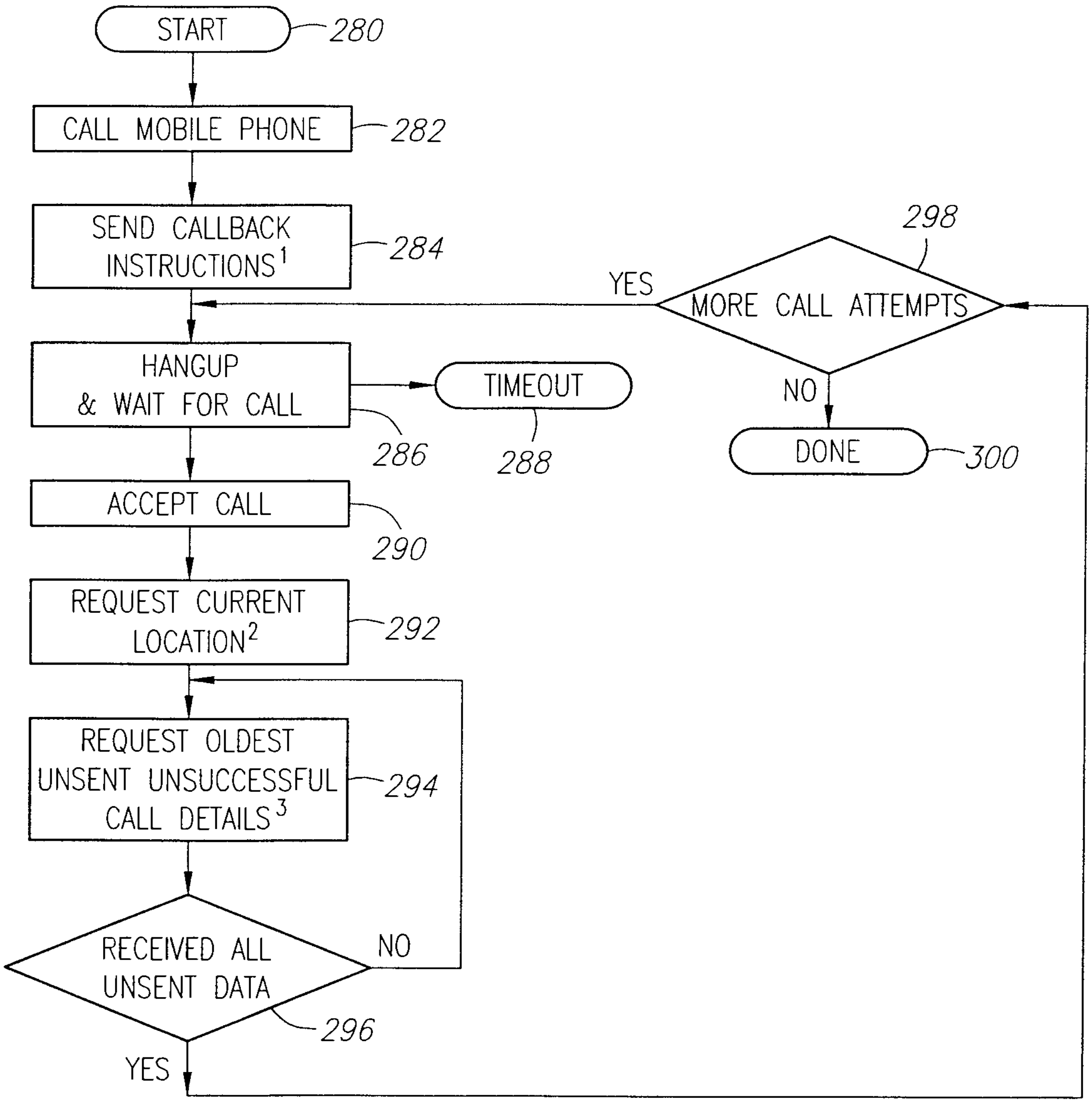

START
280
CALL MOBILE PHONE
282
SEND CALLBACK INSTRUCTIONS1
284
HANGUP & WAIT FOR CALL
286
TIMEOUT
288
ACCEPT CALL
290
REQUEST CURRENT LOCATION2
292
REQUEST OLDEST UNSENT UNSUCCESSFUL CALL DETAILS3
294
RECEIVED ALL UNSENT DATA
296
NO
YES
MORE CALL ATTEMPTS
298
YES
NO
DONE
300

FIG. 12

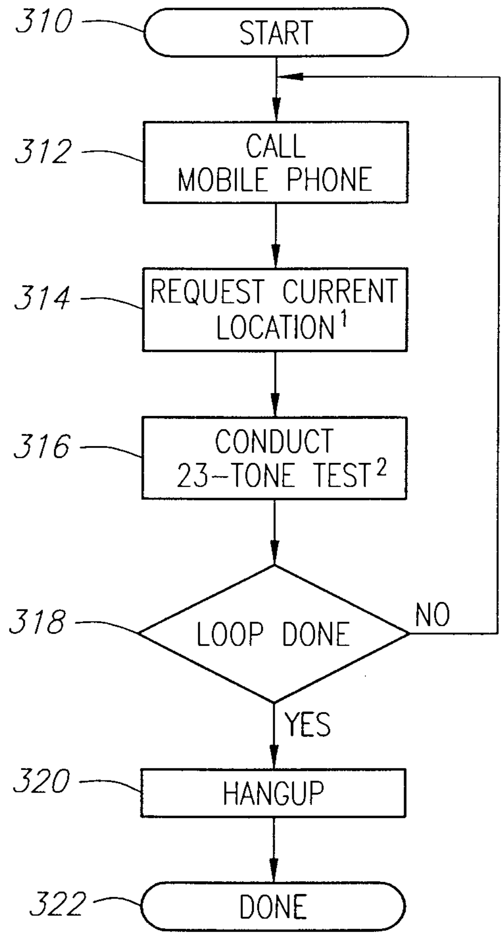

310
START
312
CALL
MOBILE PHONE
314
REQUEST CURRENT
LOCATION 1
316
CONDUCT
23-TONE TEST 2
318
LOOP DONE
NO
YES
320
HANGUP
322
DONE

FIG. 13

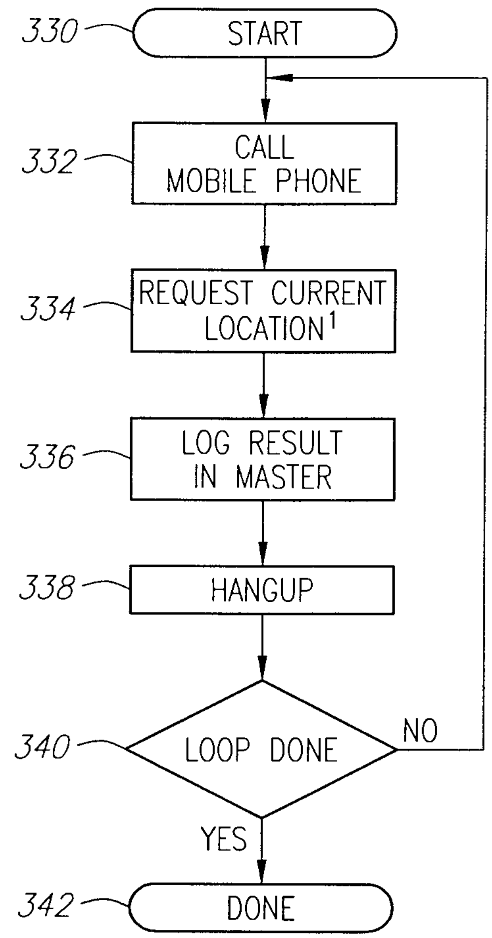

330
START
332
CALL
MOBILE PHONE
334
REQUEST CURRENT
LOCATION 1
336
LOG RESULT
IN MASTER
338
HANGUP
340
LOOP DONE
NO
YES
342
DONE

FIG. 14

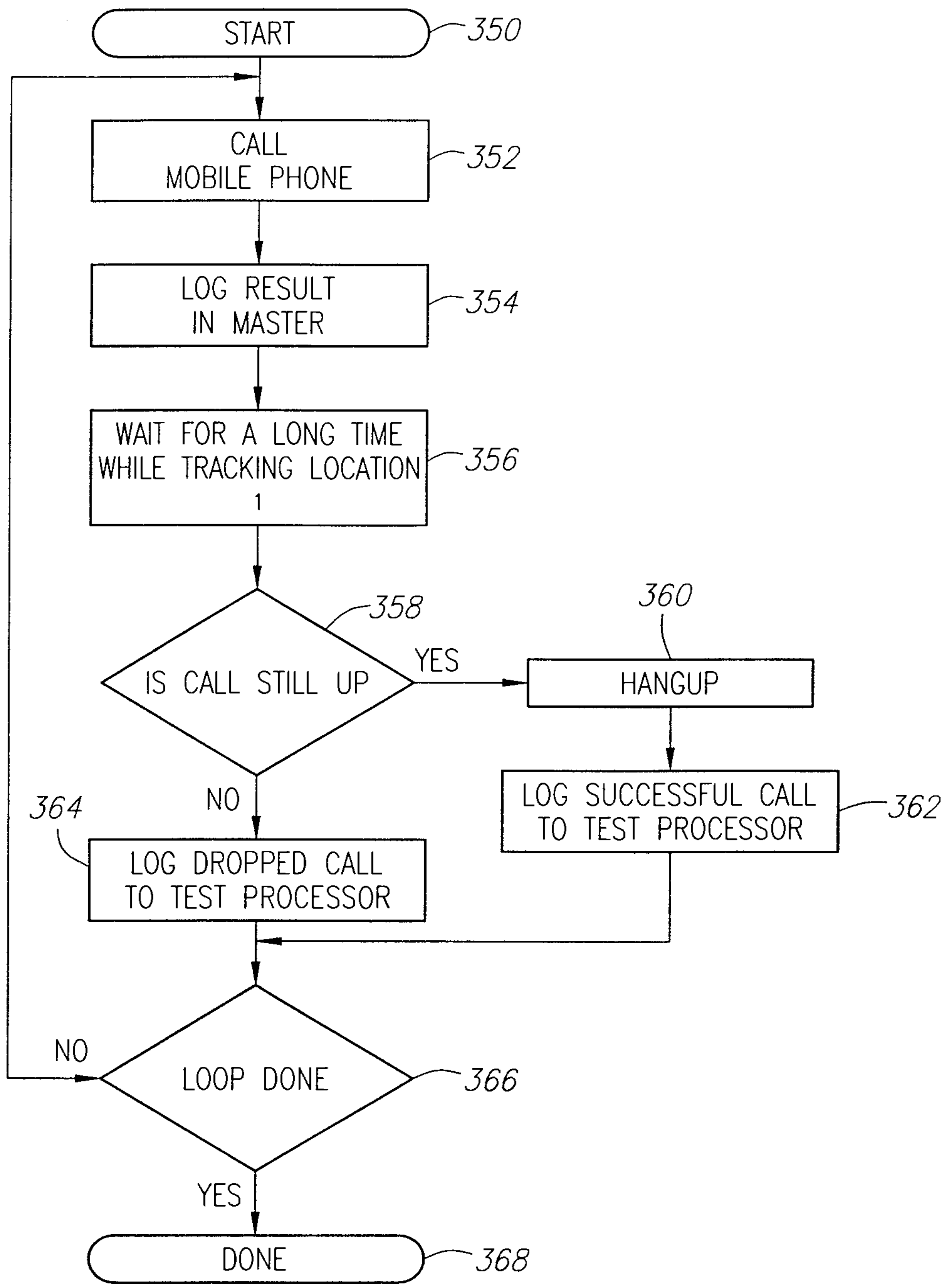

START
350
CALL
MOBILE PHONE
352
LOG RESULT
IN MASTER
354
WAIT FOR A LONG TIME
WHILE TRACKING LOCATION
1
356
358
IS CALL STILL UP
YES
360
HANGUP
NO
364
LOG DROPPED CALL
TO TEST PROCESSOR
LOG SUCCESSFUL CALL
TO TEST PROCESSOR
362
NO
LOOP DONE
366
YES
DONE
368

FIG. 15

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(54) **Messaging and status indication for wireless communication devices**

(57) The present invention relates to a wireless communication system (100) having a storage device (112) for storing a list containing status information and identifiers for a plurality of previously identified wireless communication devices (102). A processor in a mobile communication device can retrieve and store a list containing status information and identifiers for a plurality of previously identified mobile devices from a remote server device and display them on the display screen thereof. By utilizing subscriber status information a user can determine the status of a mobile device associated with the intended recipient of a call or message prior to any attempt to contact that person. The interaction between the mobile device used by the user and the monitored mobile devices can be through a phone call or a text message, either of which can be initiated with minimal device interaction by using embedded contact information.

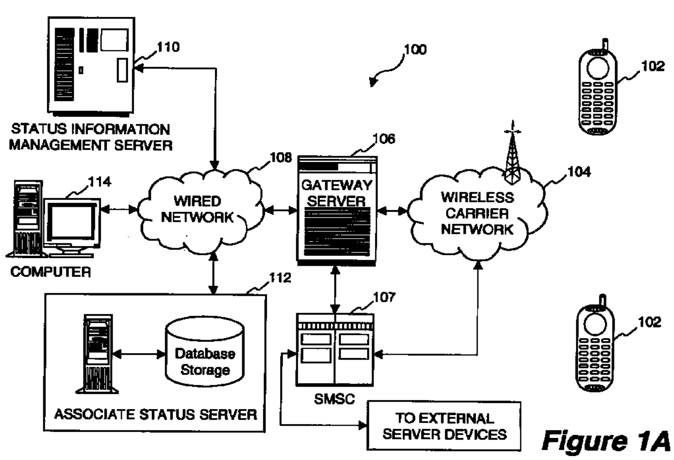


Figure 1A

EP 1 071 295 A2

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to wireless communication systems and, more particularly, to a wireless communication system utilizing subscriber status information to enable a user to determine the status of a mobile device associated with the intended recipient of a call or message prior to any attempt to contact that person.

2. Description of the Related Art

[0002] There are already several hundred million subscribers to wireless communication services throughout the world. With this proliferation of wireless communications, it is becoming more and more likely that parties will interact with one another in instances where the only means of communication for one or both parties is through wireless communication systems. Wireless communication refers to the situation in which at least one party is making use of a portable, wireless two-way interactive communication device and a wireless network. Portable, wireless two-way interactive communication devices can, for example, include personal digital assistants (PDAs), two-way pagers, palm-sized computers and mobile phones.

[0003] Wireless carriers operate wireless networks that support wireless communications between parties. These carriers, such as providers of cellular phone or pager services, typically have knowledge of the activation status (e.g. on or off) of serviced devices. Wireless carriers also tend to know the location of the portable wireless two-way interactive communication devices of its subscribers, at least within its range of coverage. This activation and location information may be used by wireless carriers for the purpose of centrally managing calls to and from its subscribers (e.g., tracking position or automatic call redirection).

[0004] Often one or both of the parties want to communicate with each other in real- time. Such real-time communications is offered by portable wireless two-way interactive devices, referred to as mobile devices herein, such as mobile or cellular phones and two-way pagers. However, even when one or both parties have mobile devices, real-time communications between them are available only when their mobile devices are in a mode of operation capable of receiving incoming communications. Hence, when one attempts to reach another party having a mobile device, which may be powered off (also referred to as off-line), the call does not go through. Instead, the calling party may hear a message to the effect of "the subscriber you have called is either out of range or the phone off." In this situation, the calling party has wasted time trying to contact an inactive mobile device. From the perspective of the carriers, their limited resources (e.g. channel capacity) have been utilized in an inefficient and unprofitable (i.e. calls to inactive devices are generally not billed) manner to contact an inactive mobile device.

[0005] It would be desirable to have apparatuses and methods which facilitate obtaining and using information regarding mobile device status information for mobile devices of interest.

SUMMARY OF THE INVENTION

[0006] The present invention is directed to a communication system that makes available and utilizes status information so that users of the communication system are informed about the status of monitored mobile devices of interest before attempting to interact with those mobile devices. Subscribers having this service will have available near real-time information as to which associates (i.e. individuals or groups of interest to the subscriber for purposes of communication) may be contacted immediately and which associates are unavailable. Additional information relating to why an associate of interest is unavailable (e.g. "I'm in a meeting") or when they plan to be available may also be provided. Since many users will choose not to call mobile devices that are deactivated, wireless carriers may experience a reduction in unbilled resource utilization, since subscribers are generally not billed for calls to inactive devices. The interaction between the mobile device of the user and the monitored mobile devices can be through a phone call or a text message, either of which can be rapidly achieved with minimal user effort by the inventive apparatus and method.

[0007] Furthermore, the invention can be implemented in numerous ways, including as a method, an apparatus or device, a user interface, a computer readable medium, and a system. Several embodiments of the invention are discussed below.

[0008] As a mobile device, one embodiment of the invention includes a display screen, and computer program code for causing the display screen to display (i) an identifier for each of one or more portable, wireless two-way interactive communication device(s) and (ii) a status indicator pertaining to each of the one or more mobile devices, and a processor operatively connected to the display screen, wherein the processor operates to execute the program code.

[0009] As a method for operating a mobile device having a display screen, one embodiment of the invention includes the stages of receiving status information for one or more monitored mobile devices, and producing a screen display on the display screen in accordance with the status information received. The screen display produced may include identifiers for the monitored mobile devices and status indicators pertaining to the monitored mobile devices, with the status indicators indicating whether the monitored mobile devices were active or inactive during the last monitoring cycle. The screen display may include a short message from a user associated with a particular monitored mobile device (e.g. "I'm in a meeting").

[0010] As a user interface for a mobile device having a display screen and an user interface, one embodiment of the invention includes: a list of users from an address book associated with a first mobile device, one or more of the users being associated with other mobile devices; and a status indication indicating an operational status of a mobile device associated with one of the users on the list. The list of users and their status indications are displayed on the display screen of the first mobile device. Navigation through the list of users in an address book and selection of individual users is achieved using the user interface of the first mobile device.

[0011] As a computer readable medium including computer program code for operating a mobile device having a display screen, one embodiment of the invention includes: computer program code for receiving status information (e.g. identifiers, short messages and activation status for designated mobile devices); and computer program code for producing a screen display on the display screen in accordance with the status information. The screen display may include an identifier, a short message and a status indicator for designated mobile devices, the status indicator indicating whether the designated devices are active or inactive. Optionally, the computer readable medium may include code for interacting with a user to designate mobile devices for which status information is required.

[0012] As a computer readable medium including computer program code for operating a mobile device having a display screen, another embodiment of the invention includes: computer program code for receiving status information (e.g. an identifier, a short message and an activation status for designated mobile devices); computer program code for storing said received status information; computer program code for comparing user entered identifiers (e.g. a dialled phone number) with the received interface information; and computer program code for performing a desired action when an attempt is made to interact with a designated mobile device having an inactive status indicator or a designated mobile device experiences a change in its status.

[0013] The advantages of the present invention are numerous. Different embodiments or implementations may yield one or more of the following advantages. One advantage of the invention is that users can be informed of status information pertaining to designated mobile devices. Another advantage of the invention is that users are able to send, receive and reply to short messages to and from associates having mobile devices (e.g. instant messaging). Still another potential advantage of the invention is that status alerts can be provided when designated mobile devices experience a change in status. Yet another advantage of the invention is a privacy control mechanism that allows the users of the monitored mobile devices to control the release of their own operational status information since there may be occasions where the user does not want this information released or desires to have control of the release of this information.

[0014] Other aspects and advantages of the invention will become apparent from the following detailed description taken in conjunction with the accompanying drawings, which illustrate, by way of example, the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The present invention will be readily understood by the following detailed description in conjunction with the accompanying drawings, wherein like reference numerals designate like structural elements, and in which:

Figure 1A is a block diagram of a wireless communication system which may be utilized to implement the method of the present invention;

Figure 1B is an illustration of a mobile device which may be used in conjunction with the wireless communication system described in Figure 1A to implement the method of the present invention;

Figure 2A is a diagram of a proxy server device which may be used in conjunction with the wireless communication system described in Figure 1A to implement the method of the present invention;

Figure 2B is a diagram of a representative data structure for a user account, which may be used to implement the method of the present invention;

Figure 2C is a block diagram of a mobile device which may be used in conjunction with the wireless communication system described in Figure 1A to implement the method of the present invention;

Figure 2D is a block diagram of a database which may be used in implementing the method of the present invention;

Figure 3A is a flow diagram showing the stages of the client-side associates list processing according to one embodiment of the invention;

Figure 3B is a flow diagram showing the stages of the server-side associates list request processing according to one embodiment of the invention;

Figure 3C is a flow diagram which provides additional details relating to access rights associated with the status information described in Figure 3B.

Figures 4A and 4B are flow diagrams which provide additional details of the client-side associates list processing described in Figure 3A;

Figure 4C illustrates screen displays representative operations for an associates list having iconic status indicators according to one embodiment of the invention;

Figure 4D illustrates screen illustrates an interactive associates list processing method according to an embodiment of the invention;

Figure 5A is a flow diagram of the steps involved in notification processing according to one embodiment of the invention;

Figure 5B is a block diagram of a presence detection system according to one embodiment of the invention;

Figure 6A is a flow diagram of application notification processing according to one embodiment of the invention;

Figure 6B illustrates a representative high priority notification message screen display;

Figure 6C illustrates a representative alert inbox screen display having a brief alert message;

Figure 6D is a flow diagram of message read and reply processing according to one embodiment of the invention;

Figure 6E illustrates a representative text message screen display that may be displayed on the display screen of the mobile device;

Figure 7A is a flow diagram of privacy settings processing according to one embodiment of the invention;

Figure 7B illustrates representative screen displays presenting an associates list and menu screens for setting of an alert; and

Figure 8 is a flow diagram of address book processing according to one embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0016] The present invention is directed to a communication system that makes use of status information so that users of the communication system are informed about the status of designated portable wireless two-way interactive devices (also referred to as mobile devices herein) before attempting to establish contact with those devices. The method of communication between the mobile devices can be through a phone call or a text-based message, either of which can be rapidly achieved with minimal user effort (e.g. softkey activation). As such, a user of a mobile device is able to have an indication that the mobile device/associate (or devices/associates) of interest were active during a recent monitoring cycle prior to attempting to contact that device/associate (or devices/associates).

[0017] Mobile devices include, but are not limited to personal digital assistants (PDA) portable devices, cellular phones, palm-sized computing devices, and wireless capable remote controllers. It is not unusual for such devices to have less than 1% of the computing resources found in a personal computer. These mobile devices typically have a small display screen and a limited user interface mechanism (e.g., a phone keypad) for user interactions with server devices and wireless networks providing mobile subscriber services. These characteristics are useful in achieving the desired size, weight, power and mobility features which have proven to be important for mass-market mobile devices.

[0018] Embodiments of the invention are discussed below with reference to Figures 1A-8. However, those skilled in the art will readily appreciate that the detailed description given herein with respect to these figures is for explanatory purposes as the invention extends beyond these limited embodiments.

[0019] Figure 1A is a block diagram of a wireless communication system 100 which may be utilized to implement the method of the present invention. The wireless communication system 100 typically includes a plurality of mobile devices 102. The mobile devices 102 are supported by a wireless carrier network 104 that facilitates voice and data communications to and from the mobile devices 102. The wireless carrier network 104 couples to a wired network 108 through a gateway server 106. The wired network 108 is, for example, the Internet, a local area network (LAN), or a wide area network (WAN). The wireless carrier network 104 can be any of a variety of types of wireless networks, for example, Cellular Digital Packet Data (CDPD), Global System for Mobile Communications (GSM), Code Division Multiple Access (CDMA), Personal Handy Phone System (PHS) and Time Division Multiple Access (TDMA) networks.

[0020] Gateway server 106 can be referred to as a proxy server for the mobile devices 102 of wireless carrier network 104. Since the communication protocol used in wireless carrier network 104 is often different from that used in the wired network 108, one of the functions of the gateway server 106 is to translate from one communication protocol to another. One of ordinary skill in the art would understand that the functions of gateway server 106 may be performed by a network server device which includes or is capable of including a connection mechanism between wireless carrier network 104 and wired network 108.

[0021] Wireless communication system 100 includes a status information management server 110 and an associate status server 112, which may be a separate server device or its functions may be performed by gateway server 106. According to the present invention, mobile devices 102 can display and otherwise process lists of monitored associates, which may indicate not only an identifier for the users associated with particular mobile devices, but also status information for those mobile devices and short messages from the users (e.g. "I'll be available after 2 PM").

[0022] Status information management server 110 retrieves and stores status information for a plurality of mobile devices serviced by wireless network 104. Wireless network 104 monitors device status information for serviced devices for use in conjunction with network operation and maintenance. Associate status server 112 maintains a list or record of mobile devices/associates to be monitored for the subscribers (also referred to as users) of mobile devices 102. Status information for the monitored mobile devices/associates is managed and updated as required. In accordance with the principles of the present invention, this information may include monitored device activation status, changes in activation status and short messages from the users of the monitored devices.

[0023] A wireless carrier infrastructure is associated with wireless carrier network 104. For example, the wireless carrier infrastructure generally includes a base station and an operations and maintenance center. The base station controls radio or telecommunication links with the mobile devices serviced. The operations and maintenance center typically includes a mobile switching center that performs the switching of calls between the mobile devices and other fixed or mobile network users. Further, the operations and maintenance center manages mobile services, such as authentication and oversees the proper operation and setup of the wireless network. The wireless carrier infrastructure also maintains user accounts for each of the mobile network users. Status information for the mobile device may be associated with a user account. This status information may include user identification information, device activation status, and a short message from the user or location information.

[0024] According to one embodiment, the communication protocol used by status information management server 110 and the wired network 108 is the well known HyperText Transfer Protocol (HTTP) or Secure HyperText Transfer Protocol (HTTPS), a secure version of HTTP, and runs on Transmission Control Protocol (TCP). In one embodiment, the communication protocol between the wireless communication devices 102 and the gateway server 106 via the wireless carrier network 104 is Handheld Device Transport Protocol (HDTP) (formerly known as Secure Uplink Gateway Protocol (SUGP)) or Wireless Access Protocol (WAP).

[0025] The associate's list and short messages may be generated in a markup language such as Handheld Device Markup Language (HDML) and Wireless Markup Language (WML). HDML and WML are similar to HyperText Markup Language (HTML) in that they are tag based document languages. HDML and WML use a set of commands or statements specified in a group of cards (referred to as a deck) that specify how information is to be displayed on a display screen of the mobile devices 102 and how the mobile devices 102 operate with respect to user interaction with the display screen. Normally, a number of cards are grouped into the deck and the deck is exchanged between the mobile devices 102 and gateway server 106. Further, as would be understood by one having ordinary skill in the art, the invention may be practised by directly coupling the wireless carrier network 104 to the wired network 108 without using the gateway server 106. Alternatively, a server device contained within the framework of the wired network 108 could perform the functions of the gateway server 106.

[0026] Note that the mobile devices 102 can also be referred to as wireless client devices or wireless communication devices. The mobile devices 102 can take a variety of forms, including personal digital assistants (PDAs), mobile telephones (e.g., cellular telephones), etc. Typically, as noted above, the mobile devices 102 include a screen display and have processing capabilities, which is less robust than that associated with conventional personal computers.

[0027] Figure 1B is an illustration of a mobile device 150, which may be used in conjunction with the wireless communication system described in Figure 1A to implement the method of the present invention. Mobile device 150 may be, for example, a mobile telephone suitable for use as mobile devices 102 illustrated in Figure 1A. The wireless communication device 150 includes a display screen 152, a keypad 154, softkeys (156A and 156B) and associated softkey identifiers 158A and 158B that allows a user thereof to interact with mobile device 150. Additionally, the mobile device 150 includes a speaker 158 and a microphone 160 as may be found in conventional mobile telephones.

[0028] Keypad 154 includes, in one embodiment, a typical phone keypad and various control buttons, such as generic buttons and navigation (e.g., upward and downward arrow) buttons. The typical phone keypad includes twelve buttons, of which ten buttons are consecutively numbered 0 to 9, one button is for "*" sign, and another button is for "#" sign. Although not necessary for practising the invention, the keypad 154 provides convenient means for a user to interact with mobile device 150. It should be understood, by one having ordinary skill in the art, that having a phone keypad is not a requirement to practice the present invention. Some mobile devices have no physical keys at all, such as those palm-sized computing devices that use soft keys or icons as an input mechanism.

[0029] In accordance with the principles of the present invention, a user of a mobile device (e.g. mobile device 102) has access to status information relating to one or more monitored mobile devices. The particular mobile devices selected for monitoring may be associated with a user/network application (e.g. an address book), input by the user directly, or generated by a third party as a result of some affiliation between the user/mobile device receiving the status information and the users/mobile devices being monitored. Regardless of the means of identification, a list or grouping of mobile devices to be monitored for a particular user is stored on a server device (e.g. associates status server 112). The associates status server 112 periodically requests status information for monitored mobile device. These requests are forwarded to the status information management server 110 which retrieves the requested status information for the monitored mobile devices from associated network resources (i.e. a Home Location Register (HLR) or a Visitor Location

Register (VLR) associated with a monitored mobile device). This information is stored and passed to the requesting entity (e.g. users of mobile devices 102) exercising control over the list/grouping of monitored mobile devices described above. One of ordinary skill in the art would understand that the functions of the status information management server 110 and the associates status server 112 may be performed by a single server device. Additionally, the functions of both the status information management server 110 and the associates status server 112 may be performed by gateway server 106.

[0030] Figure 2A is a block diagram of a gateway server device 200, which may be used in conjunction with the wireless communication system described in Figure 1A to implement the method of the present invention. Gateway server device 200 is, for example, gateway server 106 of Figure 1A. Gateway server device 200 is coupled between the wired network 108 and the wireless carrier network 104 of Figure 1A and performs tasks associated with network access, protocol conversion and account management. To avoid obscuring the primary aspects of the present invention, well-known methods, procedures, components and circuitry associated with gateway server device 200 are not described in detail.

[0031] Gateway server device 200 includes a Land Control Protocol (LCP) interface 202 that couples to wired network 108, and a Wireless Control Protocol (WCP) interface 206 that couples to the wireless carrier network 104. A server module 210 is coupled between the LCP interface 202 and the WCP interface 206.

[0032] Server module 210 performs traditional server processing as well as protocol conversion processing from one communication protocol to another communication protocol (i.e. between the protocol used by wireless networks and protocols used by the wired networks). According to one embodiment, the protocol conversion processing can be implemented as a separate module referred to as a mapper. In the case of protocol conversion between HDTP and HTTP, the conversion is a data mapping relationship. As would be understood by those skilled in the art, WCP interface 206 can be readily replaced by another interface module when the wireless carrier network 104 uses a different communication protocol; the same is true of LCP interface 202 when the wired network 108 uses a different communication protocol.

[0033] The server module 210 also includes an account manager 212 and an account interface 214. Account manager 212 manages a plurality of user accounts for the mobile devices serviced by the proxy server device 200. It is understood that the user accounts may be stored in another network server coupled to the proxy server device 200. In other words, the user accounts can be kept in a database that is physically placed in another computing device coupled to the wired network 108.

[0034] Gateway server device 200 also includes a processor 218 and a storage component 220. Processor 218 performs operations in accordance with instructions from server module 210. It would be understood by those skilled in the art that gateway server device 200 is a piece of hardware equipment that includes one or more processors (e.g., processor 218), working memory (e.g., storage 220), buses, interfaces and other components. Server module 210 includes program code, which causes proxy server device 200 to perform designated tasks. It would also be understood by those skilled in the art that proxy server device 200, may perform the functions of the associates status server (e.g. 112 of Figure 1A).

[0035] Figure 2B is a diagram of a representative data structure 222 for a user account, which may be used to implement the method of the present invention. As previously noted gateway server device 200, which may be gateway server 106 of Figure 1A, maintains user accounts for various users or subscribers. These user accounts are also known as subscriber accounts. The representative data structure 222 includes a device ID field 224, a subscriber ID field 226, and a user information field 228. Device ID field 224 includes a device ID, and subscriber ID field 226 includes a subscriber ID. For example, in Figure 2B, the representative device ID is "93845823", and the representative subscriber ID is "861234567-10900_pn.mobile.xyz.net". The user information 228 can include account configuration information, user preferences, etc. These lists or groups of mobile devices/associates to be monitored may be stored in association with the user account file for the entity receiving the status information for the monitored mobile devices.

[0036] Figure 2C is a block diagram of a mobile device 250, which may be used in conjunction with the wireless communication system described in Figure 1A to implement the method of the present invention. Mobile device 250 includes a WCP interface 252 that couples to wireless network 104 via a radio-frequency (RF) transceiver (not shown) to receive incoming and outgoing signals. A device identifier (ID) storage 254 supplies a device ID via WCP interface 252.

[0037] The device ID identifies a specific code that is associated with mobile device 250. The device ID is used by gateway server device 200 to associate the mobile device 250 with a user account stored in the gateway server device 200. The device ID can be a phone number of the device or a combination of an IP address and a port number. An example of a combination of an IP address and a port number is 204.163.165.132:01905 where 204.163.165.132 is the IP address and 01905 is the port number. The device ID is further associated with a subscriber ID (i.e. in the Equipment Identification Registry (EIR) and the Home Location Registry (HLR)) authorized by a wireless carrier network as part of the procedures to activate a subscriber account for the mobile device 250. The subscriber ID may take the form of, for example, 861234567-10900_pn.mobile.att.net by AT&T Wireless Service. The subscriber ID is a unique identification for mobile device 250. Each of the mobile devices serviced by a proxy server device (e.g. gateway server device 106 of Figure 1) has a unique device ID that is associated with a respective user account.

[0038] Mobile device 250 also includes voice circuitry 266 (e.g., a speaker and a microphone) and the associated hardware (e.g., an encoder/decoder 264, a processor 268 and keypad circuitry 262) which provide telephony functions in a telephone mode of operation which is separate and distinct from a data mode of operation used when interfacing with a proxy server device. In the telephone mode of operation, a user can cause mobile device 250 to place a phone call to another party having a phone, either wireless or land-based.

[0039] Mobile device 250 includes a client module 256, which works in conjunction with processor 268 and the working memory 258 to perform the processing tasks performed by mobile device 250. These include: establishing a communication session with a proxy server device via a wireless network, requesting and receiving data via the wireless network, displaying information on the mobile device display screen through the use of display circuitry 260, and receiving user input from a user via a keypad controlled by keypad circuit 262. Additionally, client module 256 contains computer code to cause processor 268 to execute instructions to control the operation of, among other things, a browser. In one embodiment, the browser is a micro-browser, which typically requires less computing power and memory than the HTML browsers used in personal computers. One such micro-browser is available from Phone.com located at 800 Chesapeake Drive, Redwood City, CA 94063, the assignee of the present invention.

[0040] Figure 2D is a block diagram of database storage 280, which may be used in conjunction with the implementation of the method of the present invention. Database storage 280 includes a status data store 282, an associates mapping data store 284, and a message data store 286. Status data store 282 stores status information for monitored mobile devices on the user's associate list. Associates mapping data store 284 stores the user's lists of associates and any information required to retrieve status information for those associates (e.g. user identifiers and access rights). Message data store 286 stores messages being exchanged between subscribers or users of the wireless communication system 100. More specifically, message data store 286 stored in the database 280 may be used to store "instant text messages" that can be exchanged between mobile devices. Some of these messages may be stored by the user of a monitored mobile device and scheduled for delivery when an inquiry is made as to the status of that device. For example, if the user of a monitored mobile device intends to have their device off for the weekend they can create and store a message to that effect.

[0041] The status data store 282 stores, updates and manages status information for monitored mobile devices on a user's list. This status information includes the activation status of the monitored mobile device. The activation status may be active (on-line) , inactive (off-line) or inactive with the time period of inactivity given. The activation status represents the last known activation status of the monitored device as registered during a preceding monitoring cycle. Active or on-line typically means that the mobile device is registered with a wireless network and can send and receive messages (e.g. phone calls or data messages). A representative SQL table of a relational database that can implement the status data store 282 is as follows:

```
Create table associate_status_tbl (
  associate_id varchar2(128) not null,
  status varchar2(32),
  name   varchar2(256),
  phone  varchar2(128),



         primary key(sub_no)
      );
```

[0042] In this example, the associate identifier column represents an internal identifier used by the status data store 282 to identify a subscriber. The status column is used to hold the status of the subscriber's mobile device. The name column contains the subscriber's name. The phone column contains the phone number of the subscriber's mobile device. Hence, this SQL table not only provides status information for associates but also related information such as phone number and name, which may be used by user interfaces to facilitate communications.

[0043] The associate mapping data store 284 stores data identifying the associates of the user. The associate mapping data store 284 may also store information relating to the wireless carrier network providing service to the associate's mobile device and alert types to be provided. A representative SQL table of a relational database that can implement the associate mapping data store 284 is as follows:

```
create table associate_mapping_tbl (
  rid             integer        not null,
  subscriber      varchar2(128),
  associate       varchar2(128),
  status          varchar2(32),
  presence_alert  varchar2(32),
  message_alert   varchar2(32)
);
```

[0044] The subscriber column is the unique identifier representing the user (subscriber). The associate column is the unique identifier representing an associate of the subscriber (i.e., an associate is on the subscriber's associate list). The unique identifier representing an associate of the subscriber may include information relating to the carrier network providing service to the associate. The status column is used to hold the status of the subscriber's mobile device as registered during the most recent monitoring cycle. The message alert column determines whether the subscriber desires a message alert when the activation status of a monitored mobile device changes.

[0045] Note that alerts relating to activation status changes in monitored mobile devices may be sent to parties other than the subscriber who initiated status monitoring. For example, consider the situation where a subscriber desired to set up a teleconference with a plurality of associates having mobile devices and one of the associates was off-line. When the activation status of the off-line associate changes an alert could be sent to all parties concerned, notifying them that the teleconference could (or would) now proceed.

[0046] The message data store 286 is responsible for storing the text messages that users send to each other. A representative SQL table of a relational database that can implement the message data store 286 is as follows:

```
create table buddy_msg_tbl
 (
     subscriber     varchar2(128),
     associate      varchar2(128),
     rid            integer,
     message        varchar2(1024),
     name           varchar2(256),
     phone          varchar2(128),
     need_alert     char(1),
     read           char(1),
     sent_date      date not null,
     primary key (sub_no, rid)
 );
```

[0047] The message column contains the message, and the sent_date column contains the date the message was sent. The need_alert column provides an indication that the subscriber desires an alert when the activation status of a monitored associate's mobile device changes.

[0048] Figure 3A is a flow diagram showing the stages of the client-side associates list processing operation 300 according to one embodiment of the present invention. The associates list processing operation 300 is, for example, performed on a mobile device, such as the mobile devices 102 illustrated in Figure 1A.

[0049] Associates list processing operation 300 is initiated by user interaction via the user interface of the mobile device. Once initiated, a request for associates information is sent at 302 to the associates status server (e.g. associates status server 112 of Figure 1A). Then a determination is made 304 as to whether a reply to the request has been received from the associates status server. When a determination is made 304 that the reply has not yet been received, the associates list processing operation 300 awaits the reception of the reply until the reply is received or a time-out is reached. Once the reply to the request (e.g. an associates list including status information) has been received, the associates list, with status information including mobile device activation status, is processed (e.g. displayed) by the requesting device 306.

[0050] Next, a determination is made 308 as to whether user input has been received. Once user input has been received, a determination is made 309 as to whether the user has requested to discontinue the associates list processing operation 300. For example, a user may determine that the mobile device for an associate of interest is off-line and may want to end processing. When the determination is made 309 that the associates list processing operation 300 is to end, the associates list processing operation 300 is terminated. Otherwise, if the mobile device for the associate of interest is on-line, a decision 310 determines whether a text message or a voice call (or some other communications method such as causing the contacted device to vibrate or make some sound or perform some other task) is to be made or sent to the selected one of the associates of the displayed associates list. Here, both the sending and receiving communication devices are assumed to support both text messages (e.g., instant messages), voice calls and/or other communication means (e.g. audio and non-audio alerts). Often, a user desiring to communicate with an associate will prefer sending a short text message to the associate -such as when either user is in a meeting and cannot carry on a voice call but can discretely send a short text message.

[0051] When a determination is made 310 that a voice call is to be attempted, a call to the selected associate may be initiated 312. On the other hand, when the determination is made 310 that a text message is to be sent, the mobile device enters a text entry mode of operation where a user of the mobile device may enter a text message. Next, the entered text message is sent 316 to the selected associate. After the text message is sent the associates list processing operation 300 is complete and ends.

[0052] According to the principles of the present invention, a list or grouping of mobile devices to be monitored for a requesting mobile device is maintained and managed on a remote server device (e.g. associates status server 112 of Figure 1A). When a user of the monitoring mobile device requests, this list or grouping is forwarded via a wireless communication network (e.g. wireless carrier network 104 of Figure 1A) in a format that may be processed by the requesting mobile device. That format may take any suitable form, for example, a markup language such as HDML, WML, XML, HTML, or cHTML. Once received by the requesting mobile device, the list or grouping may be displayed and the user of the requesting mobile device may take some action based on the information contained in the list or grouping. That action may be an attempt to contact one or more of the users of one of the monitored mobile devices based on contact information (e.g. phone numbers or URIs) embedded in or otherwise associated with the list or grouping.

[0053] Figure 3B is a flow diagram of associate status information request processing operation 350 by a server device having access to that information according to one embodiment of the present invention. The associates status information request processing operation 350 is, for example, performed by the Status Information Management Server System 110 as illustrated in Figure 1A.

[0054] Associates status information processing operation 350 begins with a determination 352 as to whether a request for status information for one or more associates on an associates list (i.e., the monitored mobile devices associated with users of interest) has been received at a first server device having access to that information. The request may be sent by a second server device (e.g. associate status server 112 of Figure 1A) acting on behalf of a mobile device (e.g. mobile devices 102 of Figure 1A) or by the mobile device itself. It is important to note that the functions of the status information management server (e.g. 110 of Figure 1A) and the associate status server may be performed by the same server device if the monitoring and monitored mobile devices belong to the same wireless carrier network.

[0055] The associate of interest may be identified by a subscriber identifier retrieved from a database (e.g., associates mapping data store 284). Next, a determination is made at 354 as to whether the requestor has access rights to the requested status information. The user of a monitored mobile device would typically need to provide some indication that the requested information may be released. For example, when the account for the monitored mobile device is set up, the user could specify that this information may be universally released when requested or a request for a release could be sent to the user. Access rights are described in further detail below.

[0056] If the user has access rights to the requested status information, then the information is retrieved at 356. Otherwise the process is terminated. The retrieved status information and related information is forwarded to the requesting entity 358 (i.e. associate status server 112) and ultimately to the monitoring mobile device in a suitable format. For example, with a mobile device using a network browser supporting HDML, then one suitable display format would be an HDML deck in which a series of screen displays are provided within the deck. The suitable display format could also be a text file or a markup language such as WML, HTML, XML, compact HTML or any suitable file format. Information relating to the status of monitored mobile devices may also be presented to the user using symbols (e.g. icons), sounds and other notification methods.

[0057] Figure 3C is a flow diagram which provides additional details relating to access rights which may be associated with the status information described above. When a request for status information for a designated mobile device (i.e. Mobile Device *A*) is received at 362, where that request is associated with a subscriber's associates list (i.e. Subscriber *B's* List), then a determination is made at 364 as to whether the subject subscriber (i.e. Subscriber *B*) has received permission from the user of the subject mobile device (i.e. Mobile Device *A*) to receive the requested status information. If the subject subscriber has permission to receive the requested status information (access rights), then the requested status information for the subject mobile device (i.e. Mobile Device *A*) is retrieved at 366 and the subject subscriber's list (i.e. Subscriber *B's* List) is updated.

[0058] According to the principles of the present invention, a list of mobile devices allowing access to their status information may be generated and associated with a monitoring mobile device. The status information for the monitored mobile devices, which may include device activation status, device status change or a short message from the user of one of the monitored mobile devices, is retrieved from the wireless network entity which tracks such information. This information may be stored on an intermediate server device (e.g. associates status server 112 of Figure 1A) where it is managed and updated as required. When the monitoring mobile device requests this information, a file in a suitable format (e.g. a markup language) is forwarded. Once received, the monitoring mobile device processes this file. When the user of the monitoring mobile device examines the associates list or attempts to contact one of the monitored associates, status information relating to the monitored mobile devices is presented on the display screen (or via some other aspect of the user interface) of the monitoring mobile device. This allows the user to make an informed decision as to whether or when (or how) to contact the user of one of the monitored mobile devices.

[0059] Figures 4A and 4B are flow diagrams which provide additional details of the client-side associates list processing operation 400 described in conjunction with Figure 3A above. The associates list processing operation 400 is, for example, performed by a client application that is executed by a mobile device, such as the mobile devices 102 illustrated in Figure 1A.

[0060] Associates list processing operation 400 is initiated when a user of a mobile device requests the display of a current associates list. Once initiated, a request for an associate list is sent 402 to the server device having access to the status information (e.g., associate status manager 112 of Figure 1A). Then, a determination is made 404 as to whether a reply has been received to the request. If a reply has not yet been received, the associates list processing operation 400 awaits the reception of the reply from the server device processing the request or a expiration of a predefined time period. Once a determination is made 404 that the reply has been received, an associates list and associated status information are displayed 406. The associates list can be provided as text or may be provided in a format such as a deck of HDML cards. Such HDML cards could include a priority designator, a message body, or a Universal Resource Locator (URL) that points to another deck of cards which may provide information needed for subsequent actions.

[0061] At this point, as explained in detail below, the associates list processing operation 400 waits for a user of the mobile device to interact with the mobile device to make a selection, typically a selection with respect to designation of one of the associates on the associates list being displayed. As discussed below, in this embodiment, associates list processing operation 400 controls designation of an associate, creating and sending text messages, initiating voice calls, or other processing tasks.

[0062] Once the associates list and any associated status information are displayed 406, a determination is made 408 as to whether a user input has been received. If the determination is made 408 that a user input has not yet been received, associates list processing operation 400 awaits the reception of a user input or a timeout. Once the determination has been made 408 that a user input has been received, a determination is made 410 as to whether the user input is an associate selection. When the determination is made 410 that the user has selected a particular associate, a status indicator for the selected associate is displayed 412 (if not already displayed) and any associated messages are also displayed (i.e. "In a Meeting Till 5"). Status indicators may be displayed/updated for all monitored associates when the associates list is displayed/updated or status information may be provided only when a particular associate is selected.

[0063] When a determination is made 410 that a user input is not an associate selection, then another determination is made 414 as to whether the user input is a voice call request. When the determination is made 414 that the user input is a voice call request, a call confirmation is displayed 416. The display 416 of the call confirmation is optional but can be useful to inform the user of the phone number or address to be called. The call is placed at 420 to the selected number. Following the placement of the call, the associates list processing operation 400 is complete and ends.

[0064] When the determination is made 414 that the user input is not a voice call request, another determination is made 422 as to whether the user input is a text message request. When the determination is made 422 that the user input is a text message request, a text entry area is displayed 424. The text entry area allows the user to enter the text for the text message to be sent. Another determination is then made 426 as to whether a user has finished providing the text for the text message and has requested to send the text message. Once the determination is made 426 that the text message has been entered in the text display area and a request to send the text message has been received, then the text message is sent 428 to the selected associate. After the text message has been sent 428, the associates list processing operation 400 is complete and ends.

[0065] Note that since the call or text message was requested through the associates list, the user of the mobile device performing the associates list processing operation 400 is able to determine whether the mobile device of the associate of interest is able or unable to receive a message (a text message or a voice call) before attempting to deliver the message. Note also that the user of the mobile device performing the associates list processing operation 400 need not enter the phone number or address of the associate designated for receipt of a message because that information may be extracted from the associates list by means well known in the art.

[0066] When the determination is made 422 that the user input is not a text message request, another determination is made 430 as to whether the user input is for another type of request. When the determination is made 430 that the user input is another type of request, other processing may be performed 432 as required. Such other processing can vary widely with implementation, but may include forwarding a message (voice or text) to an alternate device associated with the monitored mobile device or causing the mobile device of interest to perform some task (e.g. an audio or non-audio alert). Following this other processing, the associates list processing operation 400 is complete and ends.

[0067] Alternatively, when the determination is made 430 that the user input is not another type of request, another determination is made 434 as to whether the user desires to end the associates list processing operation 400. As an example, once the associates list processing operation 400 is terminated (or otherwise ends), the client application on the wireless communication device can transition to another mode or application. When the determination is made 434 that a termination request has been received, the associates list processing operation 400 is complete and ends. On the other hand, when the decision 434 determines that a termination request has not been received, then the associates list processing operation 400 returns to 408 as is shown in Figures 4A and 4B.

[0068] As an example of a representative graphical user interface for the associates list processing operation 400, Figure 4C illustrates screen displays associated with presenting an associates list and sending a text message. Initially, a screen display 450 having an associates list 451 is displayed. Here, presumably, the user of the mobile device having screen display 450 displayed on its display screen lists "Bill Jobs", "Steve Gates" and "John Doe" as associates within the associates list 451. Screen display 450 also includes a selection indicator 452 indicating the particular one of the entries being selected. In this example, the first entry ("Bill Jobs") is selected. Screen display 450 also displays status indicators 454, 456 and 457. The status indicators 454, 456 and 457 are displayed based on the status information for the selected associate's mobile device. The status indicators 454 and 456 displayed adjacent to "Bill Jobs" and "Steve Gates" respectively indicate that these associates have their mobile device active (or on-line) as of the last monitoring cycle. The status indicator 457 displayed adjacent "John Doe" indicates that the associate's mobile device is inactive (or off-line) as of the last monitoring cycle. The screen display 450 also provides a "Contact" softkey 458 which enables the user to send either a text or voice message to the selected associate, and a "Menu" softkey 460 which enables the user to refresh the display screen with a Menu screen display offering the user additional choices.

[0069] Upon user selection of the "Contact" softkey 458 with the selected associate being "Bill Jobs", a screen display 462 is presented on the display screen. The screen display 462 indicates the associate and provides the user with a choice of message type, namely, place a voice call or send a text message. The screen display 462 also includes a selection indicator 464 that the user can control to pick the message type to be used. The screen display 462a shows the voice call message type being selected, and thus has a "Call" softkey 466. When the user activates the "Call" softkey 466, the voice call is invoked. Alternatively, when the select indicator 464 indicates that a text message is desired, screen display 462b is presented on the display screen. In this case, the softkey 466 is a "Send" softkey 468. Upon activation of the "Send" softkey 468, a screen display 470 is presented on the display screen and allows the user to enter text for a text message.

[0070] In one embodiment, the status information management server system returns a deck of cards (e.g., HDML or WML cards) to the mobile device that implement the associates list with associated status information. The deck of cards, for example, can be used to implement the display screens 450, 462a, 462b and 470 shown in Figure 4C.

[0071] Figure 4D illustrates screen illustrates an interactive associates list processing method according to an embodiment of the invention. In this alternate embodiment a user attempting to contact "John Doe" by dialling his phone number 480 when his mobile device is listed as inactive might see a screen display like that presented in screen display 484. In this example, the associates mobile device activation status information is stored in the background and an attempt to dial a number for a particular mobile device having an off-line status indication causes a text message to be generated which indicates that "John Doe's" phone is inactive but gives the user the option of trying the call anyway or requesting notification when "John Doe's "phone becomes active 490.

[0072] Figure 5A is a flow diagram of the steps involved in notification processing operation 500 according to one embodiment of the invention. Notification processing operation 500 is, for example, performed by a network browser or client-application executing on a mobile device. Notification processing operation 500 begins with a determination 502 as to whether an alert is requested. In effect, when an alert is requested, notification processing operation 500 is initialized. In particular, when a determination is made 502 that an alert is requested, a list of alert types is displayed 504, for example, on the display screen of the mobile device. Then, one of the alert types is selected 506 by a user of the mobile device. Next, an alert of the selected type is setup 508 for a selected associate. Typically, the alert is setup by notifying the status information management system (110 of Figure 1A) that an alert should be sent to the mobile device of the user (of the monitoring mobile device) when a designated mobile device displays a status change. Following alert setup 508, the establish-notification processing operation 500 is complete and ends.

[0073] Figure 5B is a block diagram of a presence detection system 550 according to one embodiment of the invention. The presence detection system 550 includes a status information management server 552, which couples to a gateway server device 554, a Short Message Service Center (SMSC) 556, and a mobile switching center 558. Presence detection server 552 is a network server that collects and consolidates availability information for monitored mobile devices from various sources. Status information management server 552 can integrate with a variety of network elements in order to gather a near real time portrait of the status information for a plurality of monitored mobile devices. The precise integration technique will depend on the particular wireless network the mobile device is utilizing. For example, in a North American CDMA (IS-95) wireless network, the status information management server 552 can integrate with an IS-41 network to gather IS-41 events, such as mobile activation. In a GSM network, the status information management server 552 could gather MAP events. Similarly, in other types of networks, the status information management server, or a functional equivalent, will gather status information relating to designated monitored mobile devices.

[0074] The status information management server 552 will also be capable of gathering events and information from other network elements, including the gateway server device 554 and the SMSC 556. In one embodiment, the status information management server 552 receives a variety of platform-specific events, and applies techniques specific to those events in order to determine subscriber availability. For example, gateway server device 554 knows when the subscriber's mobile device has registered for a browsing session, and can report this as an event. As another example, the SMSC 556 knows when messages are pending for the user (i.e., indicating user unavailability). As still another example, the mobile switching center 558 will know when the mobile device registers with the network, when it misses a periodic re-registration, etc. These events can be analysed to obtain a reliable indication of the overall status of a monitored mobile device. For example, if the SMSC 556 reports that messages are pending, then the mobile device is marked as not available. Later, the MSC 558 may report that the mobile device has registered on the network, indicating that the mobile device is once again available.

[0075] In one embodiment, status information stored in the status data store 282 and the associate mapping data store 284 is used to trigger status notifications. The status information management server 552 is responsible for updating the status field in the status data store 282. A representative algorithm for these purposes is as follows:

> Find all users in the status data store 282 (associate_status_tbl) who are on someone's associate list and whose status in the status data store 282 is different than the status in the associate mapping data store 284 (friend_mapping_tbl). If the data store where an SQL database, this would be accomplished by the following:
>
> SELECT
>
> B.rid, B.subscriber, A.status, A.name, A.phone, B.presence_alert
>
> FROM
>
> associate_status_tbl A, associate_mapping_tbl B
>
> WHERE
>
> A.subscriber = B.associate AND NOT A.status = B.status
>
> For each such user, then (i) update the status in the associate mapping data store 284 with the value in the more current status in the status data store 282, and (ii) send a notification to the subscriber indicating that the associate's status has changed, provided the subscriber desires to receive such notifications (and is authorized to receive such information).

[0076] Figure 6A is a flow diagram of application notification processing operation 600 according to one embodiment of the invention. Application notification processing operation 600 is initialized when a mobile device receives an alert notification. The alert notification pertains to an alert previously setup in accordance, for example, with the establish notification processing operation 500 illustrated in Figure 5A.

[0077] The application notification processing operation 600 begins with a determination 602 as to whether a status alert has been received. Once a status alert has been received, the application notify processing operation 600 is effectively initialized. Once initialized, the received status alert is placed 604 in an alert inbox. The alert typically resides in the memory of the mobile device that received the status alert. In other words, the incoming status alert is associated with the particular mobile device that previously setup the alert request. Next, a determination is made 606 as to whether the received status alert is a high priority alert. When the determination is made 606 that the received status alert is a high priority alert, a notification message informing of the status change that invoked the status alert is displayed 608. When the received status alert is not a high priority alert, a decision is made 606 which causes the displaying 608 of the notification message to be bypassed or delayed.

[0078] In general, the priority levels for the alerts can include high priority, medium priority, low priority and no priority. Different actions can be setup as responses to each type of priority. For example, with high priority, a message can immediately pop-up on the display screen and a beep can be caused to occur. With a minimum priority, no message pop up occurs, but the mobile device can be caused to emit a beep. With low priority, a light or symbol can be caused to flash. With no priority, no notification is performed.

[0079] Following the display 608 of the notification message or following the decision 606 when the displaying 608 is bypassed, a determination is made 610 as to whether a status alert message is to be viewed. When the determination is made 610 that a request to view the status alert message has not been received, another determination is made 612 as to whether a quit has been requested. When a termination request is received, the application notify processing operation 600 ends. Alternatively, when a termination request has not been received, the application notify processing operation 600 repeats as illustrated in Figure 6A. On the other hand, when the decision 610 determines there has been a request to view the status alert message, the status alert message is displayed 614. Thereafter, the application notify processing 600 can prepare and send a reply message to the sender. The processing used to prepare and send a replay message can be similar to the blocks 308-318 of Figure 3A.

[0080] As an example of a representative graphical user interface for the application notify processing operation 600, Figures 6B and 6C illustrate representative screen displays that can appear on the display screen of the mobile device and which are related to receiving status alerts. Figure 6B illustrates a representative high priority notification message screen display 620. Here, the user of the mobile device having the screen display 620 displayed on its display screen has "Bill Jobs" as an associate and requested a high priority alert when "Bill Jobs" comes on-line. The high priority notification message pops up on the display screen to immediately notify the user of the mobile device. In this example, the high priority notification message screen display 620 includes a message statement 622 ("Bill Jobs is on-line"), a time stamp 624 indicating when "Bill Jobs" came on-line, and a phone number 626 for "Bill Jobs". The screen display 620 also provides an "OK" softkey 628 and a "Call" softkey 630 which enables the user to send either a text or voice message to the associate that is the subject of the alert.

[0081] Figure 6C illustrates a representative alert inbox screen display 632 having a brief alert message 634. The brief alert message 634 indicates that "Bill Jobs" is on-line. The alert inbox screen display 632 is displayed on the display screen when the inbox is selected. The screen display 620 also provides an "OK" softkey 628, which enables the user to receive more details (such as the screen display 620) pertaining to the alert or to send either a text or voice message to the selected associate.

[0082] Figure 6D is a flow diagram of message read and reply processing operation 650 according to one embodiment of the invention. Message read and reply processing operation 650 is performed by a mobile device upon receiving an incoming text message. Message read and reply processing operation 650 begins with a decision 652 as to whether a text message has been received. In effect, decision 652 causes message read and reply processing 650 to be invoked once a text message has been received. After receiving the text message, the text message is displayed 654. As an example, many mobile devices have an inbox for receiving incoming text messages. Hence, the text message can be stored in the inbox for subsequent retrieval by a user of the mobile device. Once the text message is retrieved from the inbox, it is displayed on the display screen of the mobile device.

[0083] After the text message has been displayed, message read and reply processing operation 650 determines at decision 656 whether a user input has been received. If no user input has been received, decision 656 causes message read and reply processing 650 to await user input. Once user input has been received, a determination is made 658 as to whether the user input is a voice call request. When a determination is made 658 that the user input is a voice call request, a call is placed 660 to the sender. Here, the recipient of the text message is able to efficiently place a call to the sender of the text message to provide a response to the message during the voice call. After the call has been placed to the sender, message read and reply processing operation 650 is complete and ends.

[0084] Alternatively, when the determination is made 658 that the user input is not a voice call request, another determination is made 662 as to whether the user input is a text message request. When the determination is made 662 that the user input is a text message request, a reply message is prepared and sent 664. After the reply message has been sent, the message read and reply processing operation 650 is complete and ends.

[0085] When the user input is neither a voice call request, or a text message request a determination is made 666 as to whether the user input is a termination request. When the user input is a termination request, message read and reply processing operation 650 is complete and ends. Alternatively, when the user input is not a termination request, the message read and reply processing operation 650 repeats the decision 656 and subsequent processing stages.

[0086] FIG. 6E illustrates a representative text message screen display 670 that is displayed on the display screen of the mobile device. Text message screen display 670 includes a sender designation 672, a message body 674 and a telephone number indicator 676 for the sender. Here, the message body 674 contains a question for the recipient -- "Want to have lunch?". The user of the mobile device that has received the incoming text message can then either directly call the sender using a "Call" softkey 678, or prepare and send a reply text message using a "Reply" softkey 680. When the user of the mobile device selects the "Reply" softkey 680, a screen display 682 is presented on the display screen of the mobile device. The screen display 682 is a reply text entry screen that enables the user of the mobile device to enter a reply text message. Screen display 682 also includes a "Send" softkey 684, which enables the user to send the reply message to the sender of the original text message.

[0087] Figure 7A is a flow diagram of privacy settings processing operation 700 according to one embodiment of the invention. Privacy settings processing operation700 begins with a determination 702 as to whether a privacy adjustment is requested. When the determination is made 702 that a privacy adjustment is requested, privacy setting processing operation 700 is initialized; otherwise, the privacy settings processing operation 700 is bypassed. For example, the user of a mobile device could use the this operation to limit or prevent status monitoring of their mobile device.

[0088] Once privacy setting processing operation 700 is initialized, a list of privacy settings are displayed 704. For example, the list of privacy settings is displayed on a display screen of the mobile device. Next, one of the privacy settings is selected 706. Here, a user of the mobile device views the list of privacy settings being displayed 704 and selects one of the privacy settings to be utilized with respect to the mobile device. Then, a privacy indicator for the subscriber is set 708 based on the selected privacy setting. Here, the privacy indicator for the user (subscriber) is stored in a database (e.g., associate mapping data store 284 of database storage 280) for subsequent retrieval. For example, the database storage can be database storage 112 illustrated in Figure 1A or database 280 illustrated in Figure 2D. After the privacy indicator for the subscriber is set 708, the privacy settings processing operation 700 is complete and ends.

[0089] As an example of a representative graphical user interface for privacy settings processing operation 700, Figure 7B illustrates representative screen displays presenting a associates list and setting of alert priorities. Initially, a screen display 750 having an associates list 751 is displayed. Here, presumably, the user of the mobile device having screen display 750 displayed on its display screen has "Bill Jobs", "Steve Gates" and "John Doe" as associates. These three associates are contained within associates list 751. Screen display 750 also includes a selection indicator 752 indicating the particular one of the entries being selected. In this example, the first entry ("Bill Jobs") is selected. The screen display 750 also displays activation status indicators 755, 756 and 757. The activation status indicators for each of the entries of associates list 751 are generated based on the status information. The status indicator 756 displayed adjacent "Steve Gates" indicates that associate "Steve Gates" has his mobile device active (or on-line) as of the last monitoring cycle. The status indicators (755 and 757) displayed adjacent to associates "Bill Jobs" and "John Doe" respectively, provides an indication that these associates have their devices inactive (or off-line) as of the most recent monitoring cycle. Screen display 750 also provides a "Talk" softkey 756 which enables a user to send either a text or voice message to the selected associate, and a "Menu" softkey 758 which enable the user to refresh the display screen with a Menu screen display offering the user additional choices. Additionally, indicator 754 provides an indication to the user that a change of status alert has been set for associate "Steve Gates".

[0090] Upon user selection of the "Menu" softkey 758 where the selected associate is "Bill Jobs", a screen display 760 is presented on the display screen. The screen display 760 indicates a list of menu items available to the user, namely, Alerts, Privacy, and Add Associate operations. Screen display 760 also includes a select indicator 762 indicating the particular one of the entries (operations) being selected. In this example, the first entry ("Alerts") is selected. Screen display 760 also provides an "OK" softkey 764 to invoke the selected entry (operation).

[0091] Upon user selection of the "OK" softkey 764 with the "Alerts" being selected, a screen display 766 is presented on the display screen. Screen display 766 indicates a list of alert types available to the user, namely, high, medium, low and none. Screen display 766 also includes a select indicator 768 indicating the particular one of the alert types being selected. In this example, the first alert type ("High") is selected. The screen display 766 also provides an "OK" softkey 764 to invoke the selected alert type.

[0092] Additionally, the user of a monitored mobile device can choose to have their status information augmented with user supplied information. For example, the user can input a text string such as "I am in a meeting" or "I am busy" or "I am available" or an iconic symbol with a well-known or predefined meaning. This information is combined with the network status information (e.g. active or inactive) to provide a near realtime indication of a monitored user's status and availability for exchanging messages.

[0093] The associates list may be associated with or used in conjunction with applications resident within the mobile device. Address book applications, calendar applications and email applications are examples of such applications. For example, the associates list could be generated from a users address book or local contact list. Changes to the address book would be reflected in the associates list and the user would not be required to make duplicate entries. One of ordinary skill in the art would understand that the process is also applicable to network applications (e.g. an address book resident on a network server but managed from the mobile device).

[0094] Figure 8 is a flow diagram of an address book processing operation 800 according to one embodiment of the invention. Address book processing operation 800 is, for example, performed by a client-side application for the wireless communication device. The address book processing operation 800 need not be performed by a network browser operable on the mobile device, but can be a stand alone application or embedded within another functional application, such as an address book application.

[0095] The address book processing operation 800 initially activates an address book 802. Here, the address book is displayed on a display screen of the mobile device. The address book, for example, includes names and telephone numbers for people or businesses. The address book (or phone book) can also include addresses for the people or the businesses. The people or businesses within the address book may be referred to as contacts. The address book is provided by an address book application that executes on the mobile device.

[0096] Next, status information for the contacts in the address book is obtained 804. As an example, the status information can be obtained from a server and database such as the server 110 and associate status server 112 illustrated in Figure 1A. Next, contacts in the address book are displayed 806 with the associated status information. By displaying the status information associated with the contacts, the user of the mobile device using the address book can determine whether communication devices (and perhaps what communication devices if any), are in use (active) by their contacts listed in the address book.

[0097] Next the user is queried 808 as to whether the user desires to initiate communications with one of the contacts in the address book. When a determination is made 808 that the user does desire to initiate communications with one of the contacts in the address book, another determination is made 810 as to whether the message to be sent is a text message or a voice call. When the determination is made 810 that the message to be sent is a voice call, a call to the selected contact is placed 812. On the other hand, when the determination is made 810 that the message to be sent is a text message, the text message is provided 814. For example, the text message can be provided by data entry from a user of the mobile device. Next, the text message is sent 816 to the selected contact. After the text message has been sent 816 or after the call to the selected contact is placed 812, address book processing operation 800 is complete and the routine ends.

[0098] Alternatively, when a determination is made 808 that a message (text or voice) is not to be sent (i.e., a communications is not to be initiated), another determination is made 818 as to whether a termination request has been received. When a determination is made 818 that a termination request has been received, address book processing operation 800 is complete and ends. On the other hand, when the a determination is made 818 that a termination request has not been received, then address book processing operation 800 returns to repeat the decision 808 and subsequent blocks.

[0099] In accordance with the principles of the present invention, status information relating to one or more monitored devices is presented to the user of a monitoring mobile device. In one embodiment, the status information includes a status indicator (e.g. a symbol or icon) which provides an indication of the operational status (e.g. on or off) of a monitored device. Generally, a remote mobile device is active if it is able to receive messages (e.g., voice calls or text messages). In the case of a cellular phone, active means that the cellular phone is turned on and within range of a supporting wireless network carrier. On the other hand, inactive may mean that the cellular phone is either turned off or not in contact with the wireless network providing service. Note that due to various possible network and system delays, the status information obtained may not actually reflect the current status of monitored devices. Thus, the status information reflects the status of the monitored mobile device as was indicated during the most recent monitoring cycle for which information could be obtained.

[0100] Note that while Figures 4C and 7B use a particular symbol for the status indicator, any suitable symbol or other visual indication may be used. Other indicators, symbols, alphanumeric characters, icons, or other visually distinct objects may be used to indicate the status of remote devices. The status information can also be more specific in terms of the information conveyed by using one or more status indicators. Namely, status indicators could indicate that the associated mobile device is active, was recently active, not active or has an unknown activation status. The status indicators could also indicate whether the mobile device is in use or out of range. Also, in the case where the monitored status information is unknown, such an indication could be displayed. Additionally, the status identifier or an additional identifier or symbol can be provided to indicate whether the telephone number associated with the remote device corresponding to a contact is for a land-based phone or a wireless phone. Still further, the status indicators could vary as a function of the type of communications device.

[0101] The invention can take the form of a computer readable code on a computer readable medium (i.e. a substrate). The computer readable medium is a data storage device that can store data, which can thereafter, be read by a computer system. Examples of a computer readable medium include read-only memory, random-access memory, CD-ROMs, magnetic tape, optical data storage devices and carrier waves. The computer readable medium can be distributed over a network coupled computer system so that the computer readable code is stored and executed in a distributed fashion.

[0102] The advantages of the invention are numerous. Different embodiments or implementations may yield one or more of the following advantages. One advantage of the invention is that users can be visually informed of status information pertaining to other communication devices, even wireless communication devices. Another advantage of the invention is that user are able to send, receive and reply to test messages with associates on wireless communication devices with great ease. Still another potential advantage of the invention is that status alerts can be provided when friends or associates come on-line with their wireless communication devices. Yet another advantage of the invention is a privacy control mechanism that allows users to control the dissemination of their status information. Yet another advantage of the invention is that wired communications devices, even desktop computers, can utilize the features of the invention.

[0103] The many features and advantages of the present invention are apparent from the written description, and thus, it is intended by the appended claims to cover all such features and advantages of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation as illustrated and described. Hence, all suitable modifications and equivalents may be considered to fall within the scope of the invention.

Claims

1. A method of providing status information to a wireless communication device for a plurality of mobile device, the method comprising:-

    retrieving status information for the plurality of designated mobile devices;
    generating a file containing identifiers for the plurality of designated mobile devices and the retrieved status information; and
    forwarding the generated file to the wireless communication device.

2. A method as recited in claim 1 further comprising:-

    omitting status information for those mobile devices among the plurality of designated mobile devices for which an associated user provides an indication that status information should not be released to third parties; and
    omitting status information for those mobile devices among the plurality of designated mobile devices when an associated user has not provided an indication that status information may be released to third parties.

3. A method as recited in claim 1 or 2 further comprising:-

    requesting access rights for status information from those mobile devices among the plurality of designated mobile devices for which the wireless client device does not have access rights;
    receiving a request for status information monitoring, the request including identifiers for the one or more mobile devices to be monitored.

4. A method as recited in any preceding claim further comprising:-

    forwarding the generated file to one or more of the plurality of designated mobile devices.

5. A method as recited in any preceding claim further comprising:-

    forwarding the generated file to a designated communication device.

6. A method for interacting with a wireless communication device having a display screen and user interface, the method comprising:-

    retrieving status information for a plurality of previously identified mobile devices at predetermined intervals;
    generating a list including a representation of the retrieved status information and an identifier for each of the plurality of previously identified mobile devices; and
    forwarding the list to the wireless communication device.

7. A method as recited in claim 6 wherein the representation of the retrieved status information is an alphanumeric string and wherein the representation of the retrieved status information is a symbolic indicator.

8. A method as recited in claim 6 or 7 further comprising:-

    obtaining identifiers for designated communication devices that are to receive the list; and
    forwarding the list to the designated devices.

9. A computer product executable by a computing device, the computer product including computer

program code for providing status information on the display screen of a wireless communication device, the computer product comprising:-

computer program code for retrieving a list containing status information for a plurality of previously identified mobile devices; and
computer program code for displaying the list containing identifiers and status information for the plurality of previously identified mobile devices on the display screen of the wireless communication device.

10. A computer product executable by a computing device, the computer product including computer program code for providing status information on the display screen of a wireless communication device, the computer product comprising:-

computer program code for establishing an alert request relating to changes in device status for one or more mobile devices among a plurality of previously identified mobile devices; and
computer program code for receiving an alert in accordance with the alert request when one or more of the previously identified mobile devices is indicated as having an altered status.

11. A computer product as recited in claim 10 further comprising:-

computer program code for determining whether the alert priority exceeds a predetermined priority level; and
computer program code for immediately displaying a notification message informing of status change that triggered the alert when the alert priority is greater than the predetermined priority level.

12. A wireless communication device having a display screen and user interface, the device comprising:-

a storage device for storing a list containing status information and identifiers for a plurality of previously identified mobile devices;
a memory for storing program code for a processor; and
a processor coupled to said storage device and said memory, wherein the processor operates to execute the program code stored in the memory to retrieve and store a list containing status information and identifiers for a plurality of previously identified mobile devices from a remote server device and display it on the display screen of the wireless communication device.

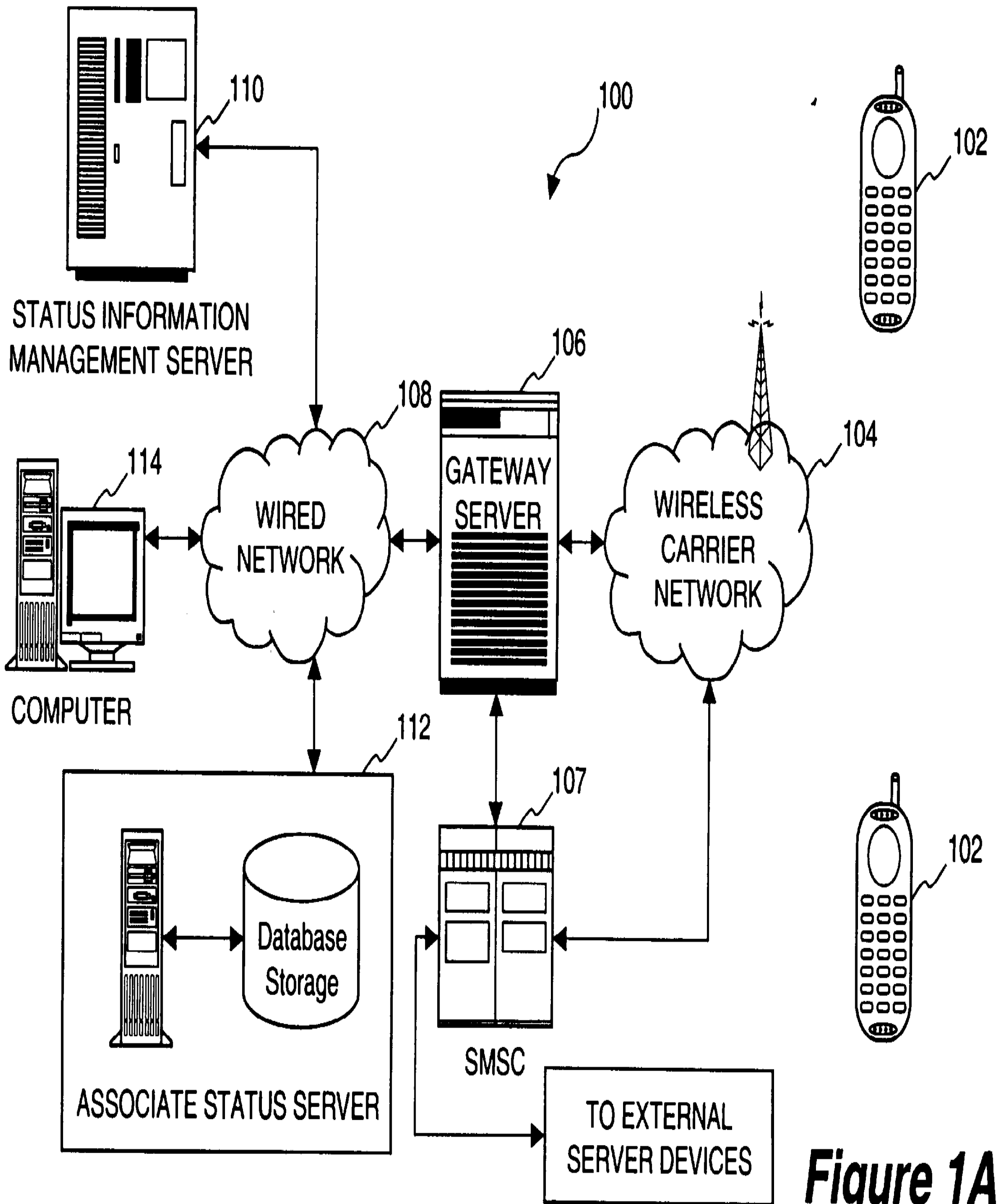

100
110
STATUS INFORMATION MANAGEMENT SERVER
102
106
108
104
114
WIRED NETWORK
GATEWAY SERVER
WIRELESS CARRIER NETWORK
COMPUTER
112
107
102
Database Storage
ASSOCIATE STATUS SERVER
SMSC
TO EXTERNAL SERVER DEVICES

Figure 1A

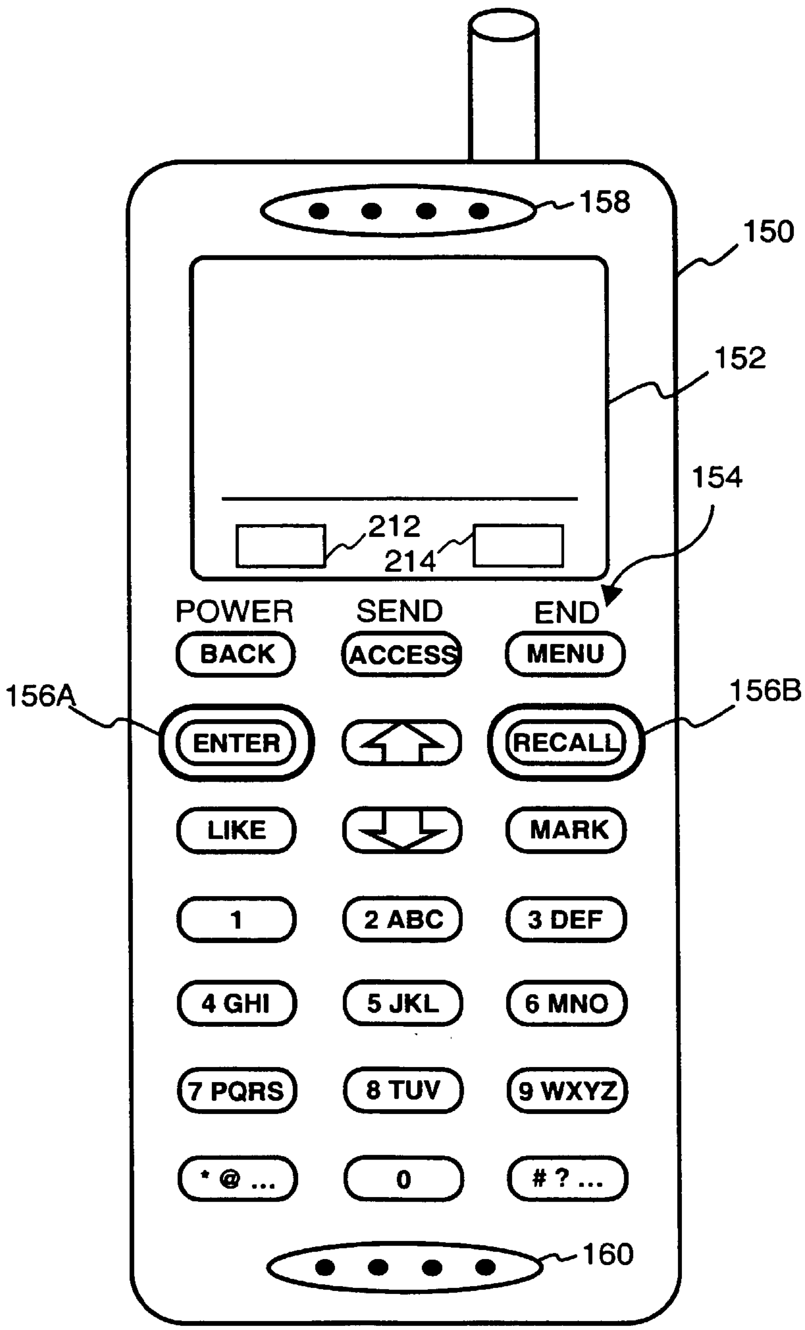
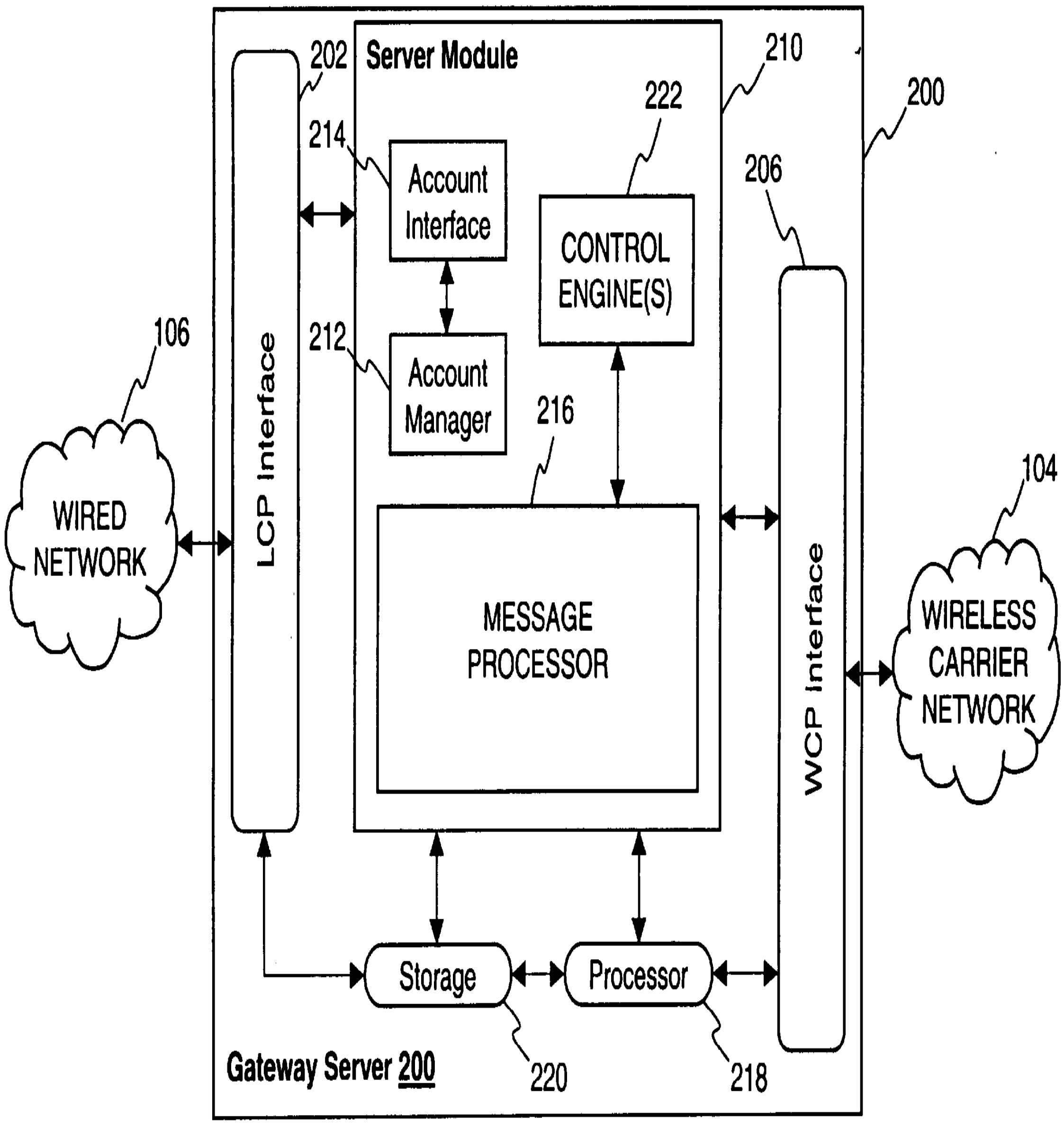

158
150
152
154
212
214
POWER
SEND
END
BACK
ACCESS
MENU
156A
156B
ENTER
RECALL
LIKE
MARK
1
2 ABC
3 DEF
4 GHI
5 JKL
6 MNO
7 PQRS
8 TUV
9 WXYZ
* @ ...
0
? ...
160

Figure 1B



Server Module
202
210
200
222
214
Account Interface
206
CONTROL ENGINE(S)
106
212
Account Manager
216
LCP Interface
WIRED NETWORK
104
MESSAGE PROCESSOR
WCP Interface
WIRELESS CARRIER NETWORK
Storage
Processor
Gateway Server 200
220
218

Figure 2A

222

DEVICE IDENTIFICATION	SUBSCRIBER IDENTIFICATION	USER INFORMATION
93845823	86123467-10900_PN.MOBILE.XYZ.NET	(GSM...)
224	226	228
•	•	•
•	•	•
•	•	•

Figure 2B

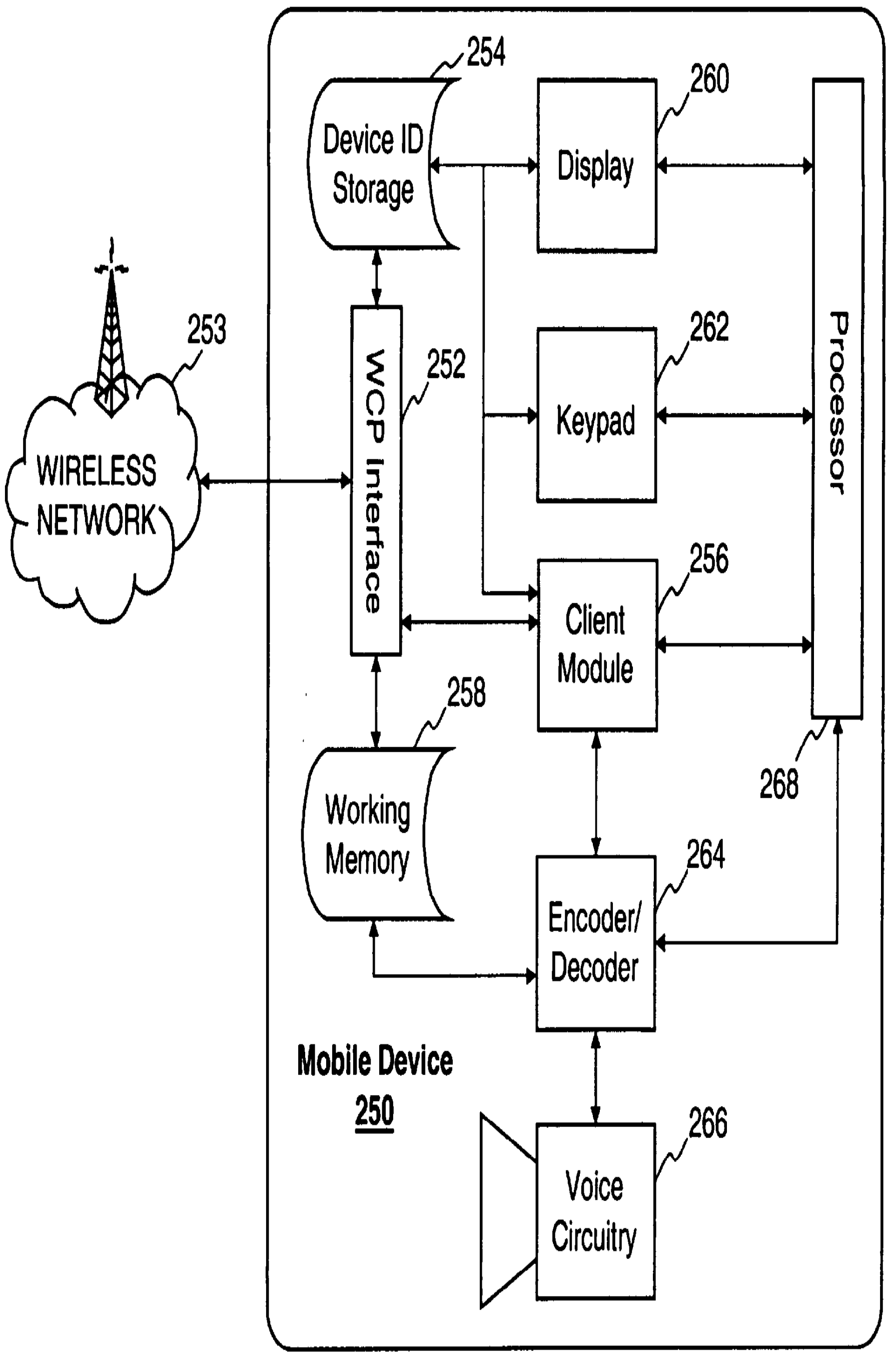

WIRELESS NETWORK
253
Device ID Storage
254
WCP Interface
252
Display
260
Keypad
262
Client Module
256
Working Memory
258
Encoder/ Decoder
264
Voice Circuitry
266
Processor
268
Mobile Device
250

Figure 2C

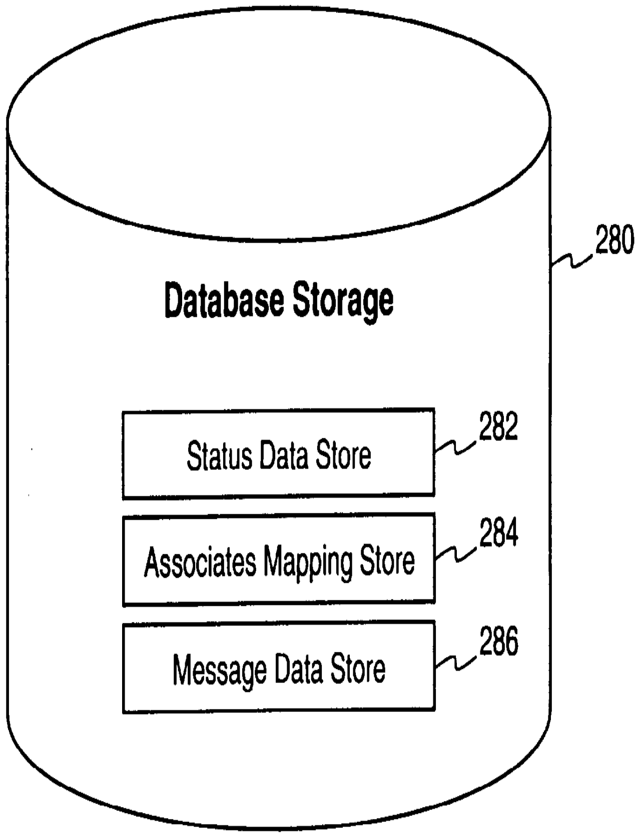
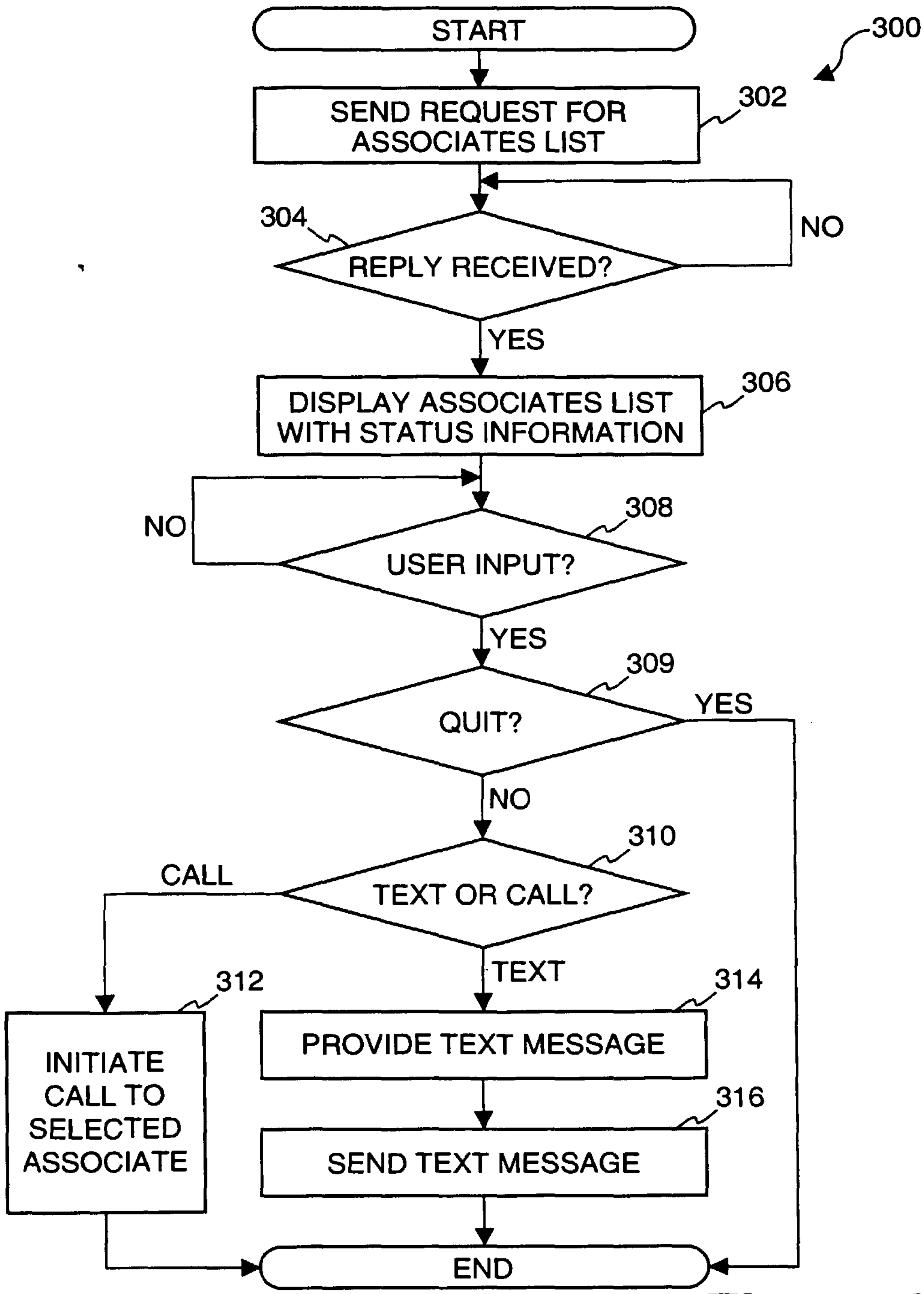

Database Storage
280
Status Data Store
282
Associates Mapping Store
284
Message Data Store
286

Figure 2D



300
START
SEND REQUEST FOR ASSOCIATES LIST
302
304
REPLY RECEIVED?
NO
YES
DISPLAY ASSOCIATES LIST WITH STATUS INFORMATION
306
NO
308
USER INPUT?
YES
309
QUIT?
YES
NO
310
CALL
TEXT OR CALL?
TEXT
312
314
INITIATE CALL TO SELECTED ASSOCIATE
PROVIDE TEXT MESSAGE
316
SEND TEXT MESSAGE
END

Figure 3A

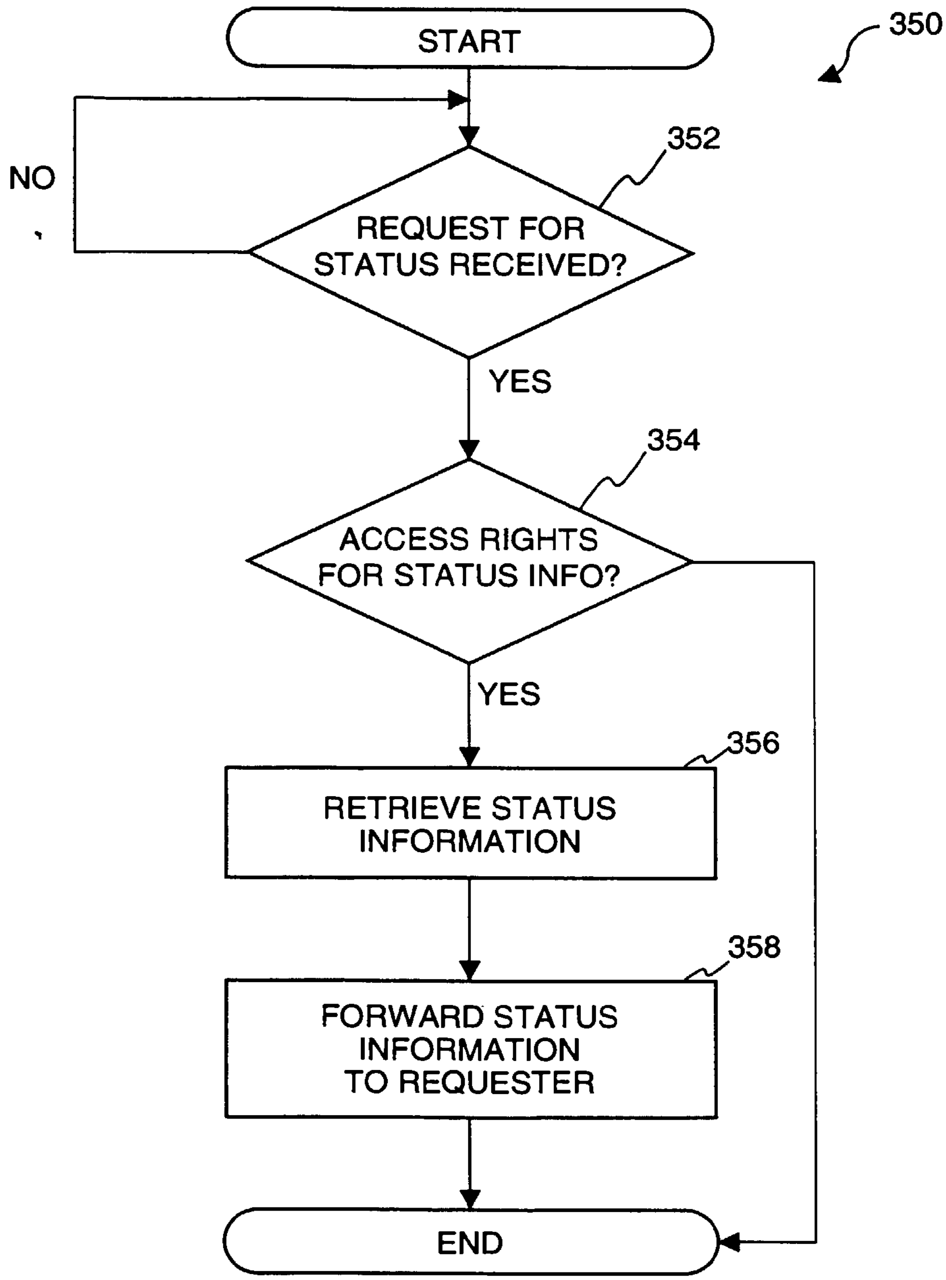

350
START
352
NO
REQUEST FOR STATUS RECEIVED?
YES
354
ACCESS RIGHTS FOR STATUS INFO?
YES
356
RETRIEVE STATUS INFORMATION
358
FORWARD STATUS INFORMATION TO REQUESTER
END

Figure 3B

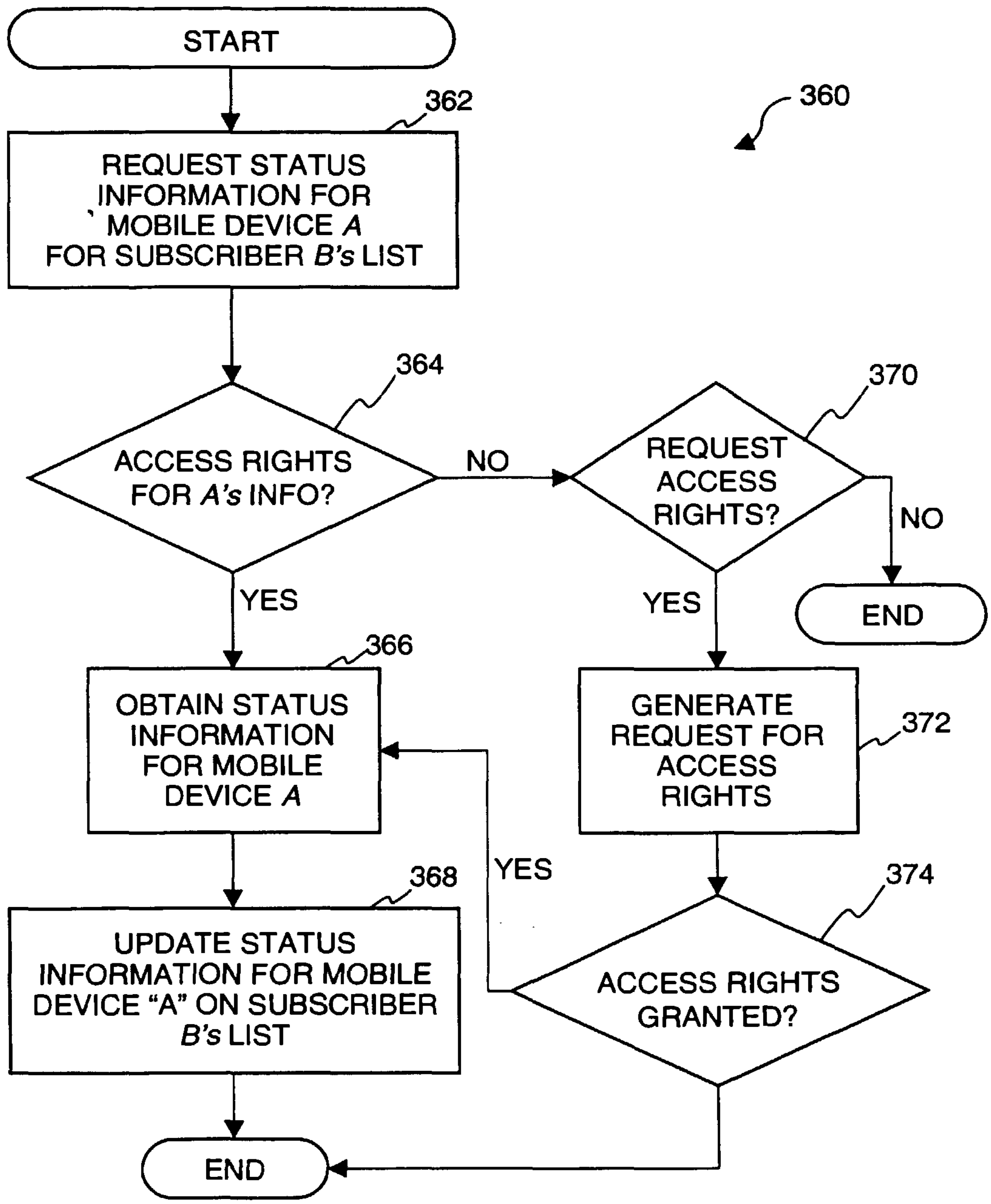

START
362
360
REQUEST STATUS INFORMATION FOR MOBILE DEVICE A FOR SUBSCRIBER B's LIST
364
370
ACCESS RIGHTS FOR A's INFO?
NO
REQUEST ACCESS RIGHTS?
NO
YES
YES
END
366
OBTAIN STATUS INFORMATION FOR MOBILE DEVICE A
GENERATE REQUEST FOR ACCESS RIGHTS
372
368
YES
374
UPDATE STATUS INFORMATION FOR MOBILE DEVICE "A" ON SUBSCRIBER B's LIST
ACCESS RIGHTS GRANTED?
END

Figure 3C

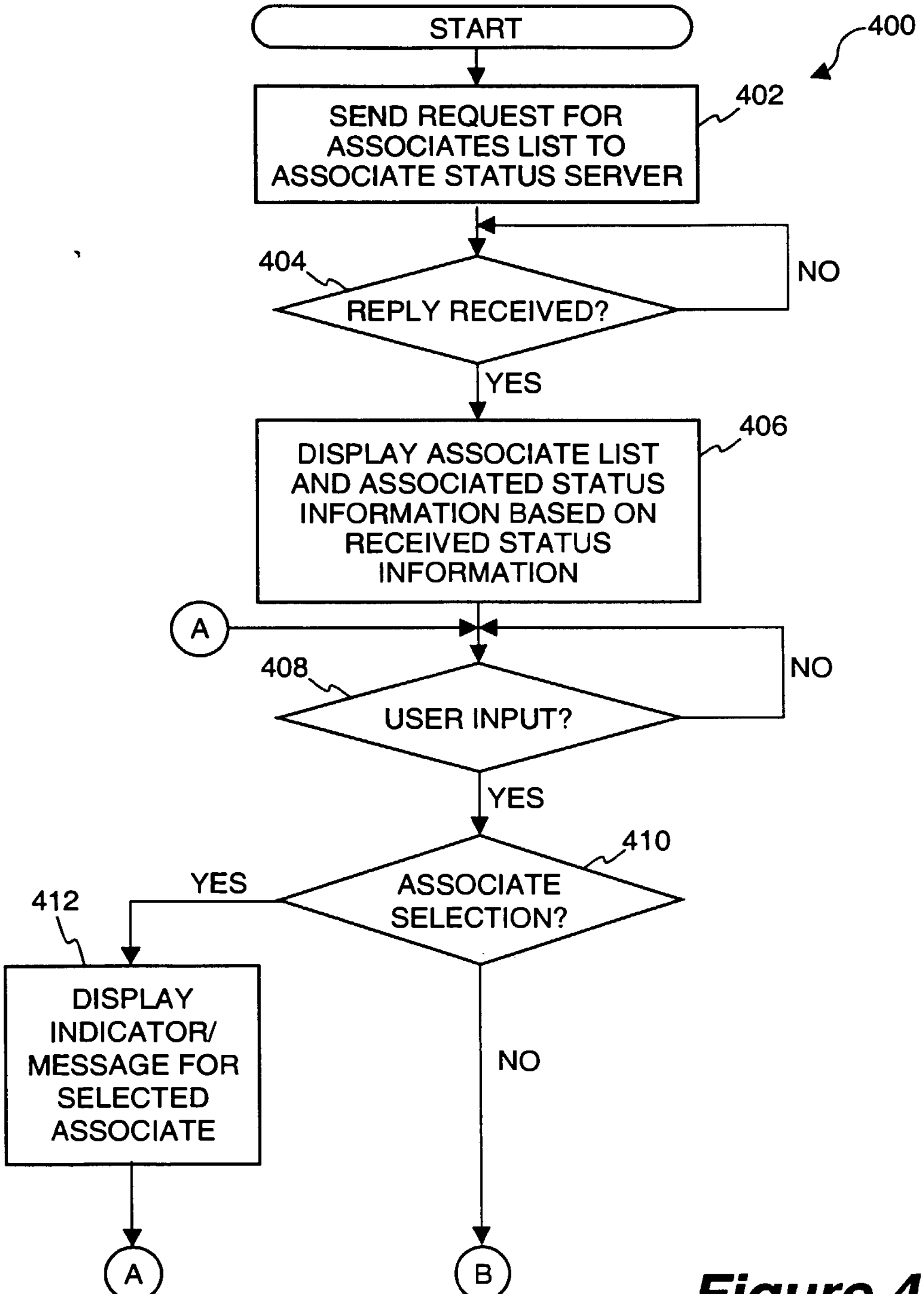

START
400
402
SEND REQUEST FOR ASSOCIATES LIST TO ASSOCIATE STATUS SERVER
404
REPLY RECEIVED?
NO
YES
406
DISPLAY ASSOCIATE LIST AND ASSOCIATED STATUS INFORMATION BASED ON RECEIVED STATUS INFORMATION
A
408
USER INPUT?
NO
YES
410
ASSOCIATE SELECTION?
YES
412
DISPLAY INDICATOR/ MESSAGE FOR SELECTED ASSOCIATE
NO
A
B

Figure 4A

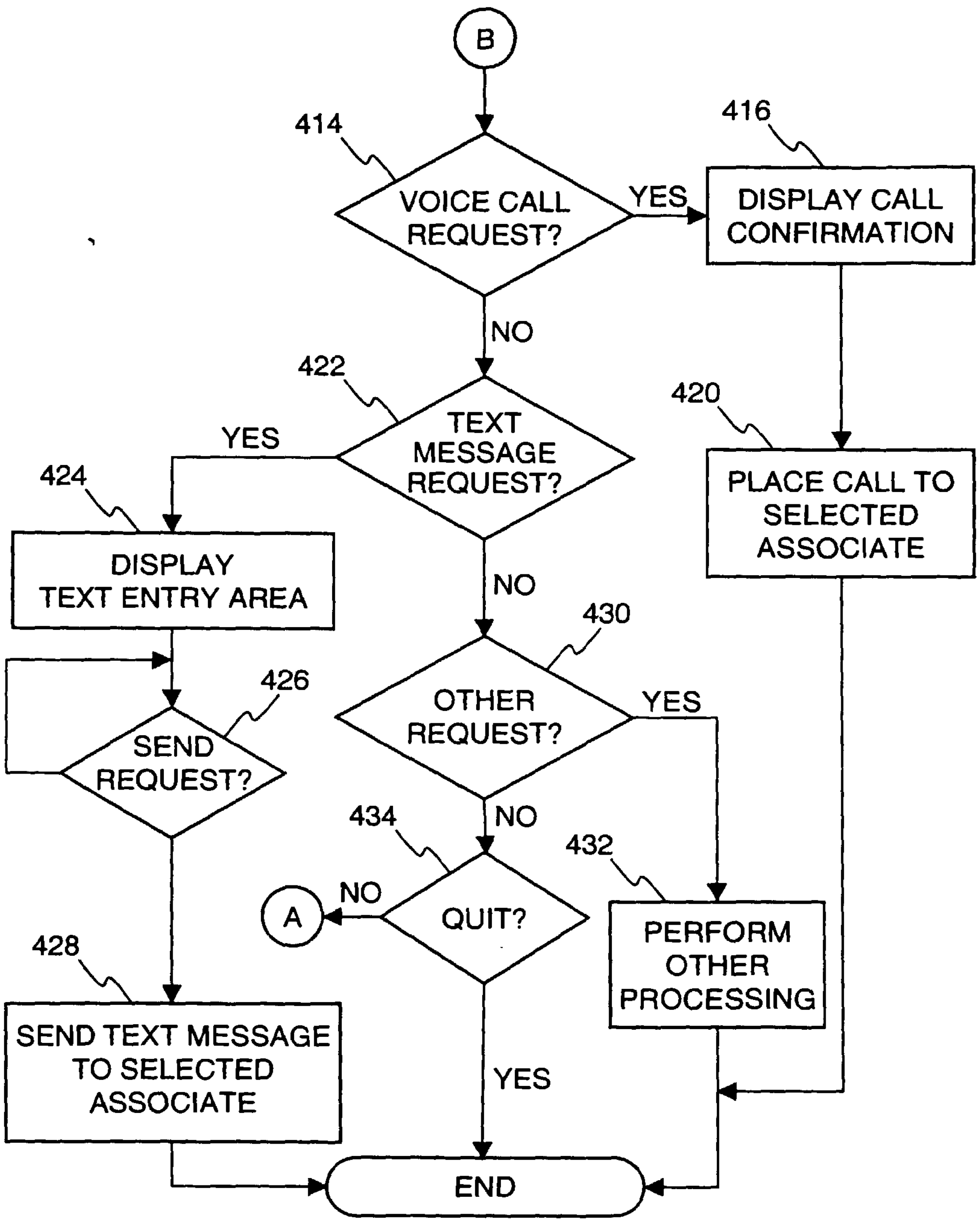

B
414
VOICE CALL REQUEST?
YES
416
DISPLAY CALL CONFIRMATION
NO
422
TEXT MESSAGE REQUEST?
YES
420
PLACE CALL TO SELECTED ASSOCIATE
424
DISPLAY TEXT ENTRY AREA
NO
430
426
SEND REQUEST?
OTHER REQUEST?
YES
434
NO
432
A
NO
QUIT?
PERFORM OTHER PROCESSING
428
SEND TEXT MESSAGE TO SELECTED ASSOCIATE
YES
END

Figure 4B

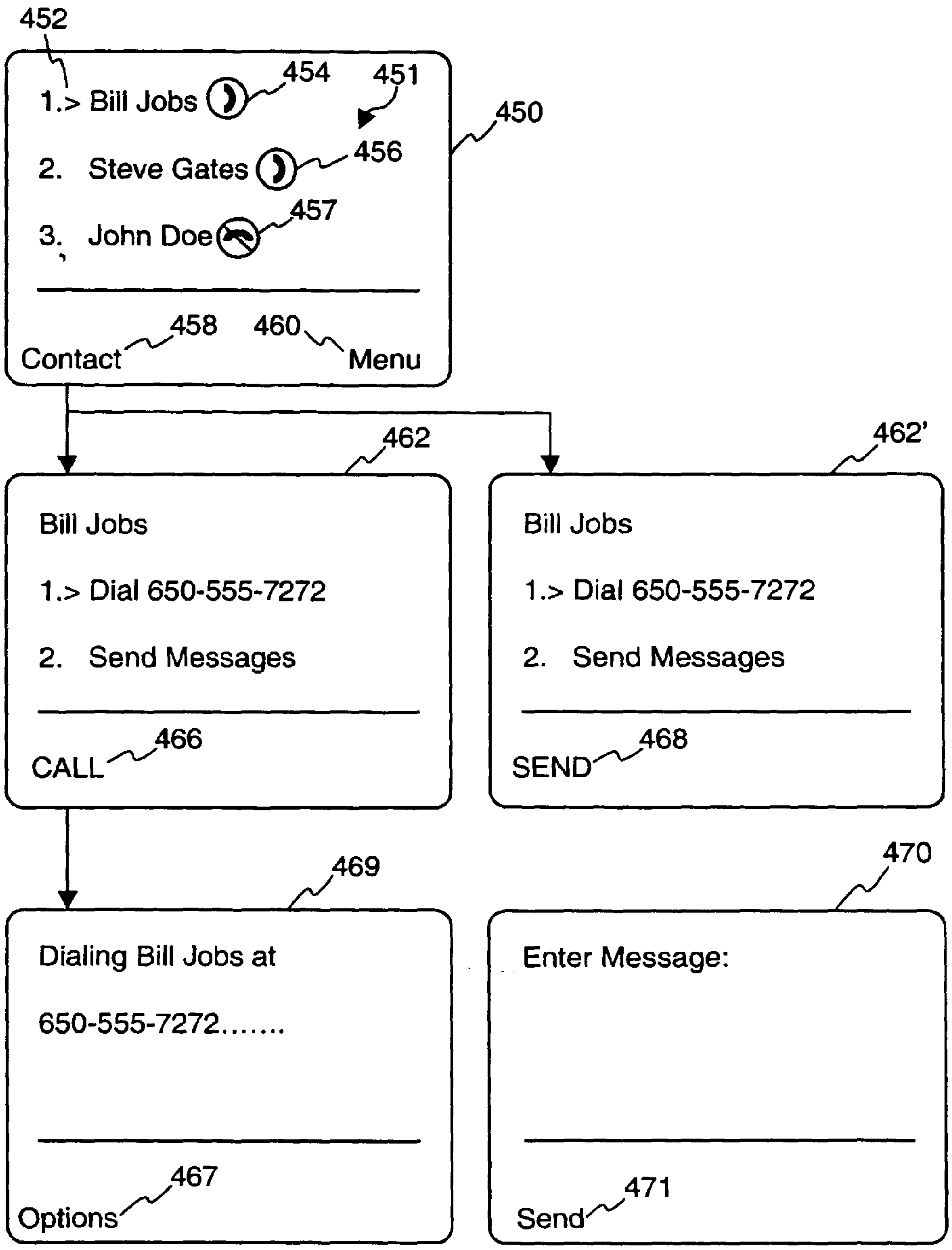

452
1.> Bill Jobs
454
451
450
2. Steve Gates
456
3. John Doe
457
458
460
Contact
Menu
462
462'
Bill Jobs
1.> Dial 650-555-7272
2. Send Messages
CALL
466
Bill Jobs
1.> Dial 650-555-7272
2. Send Messages
SEND
468
469
470
Dialing Bill Jobs at
650-555-7272.......
Options
467
Enter Message:
Send
471

Figure 4C

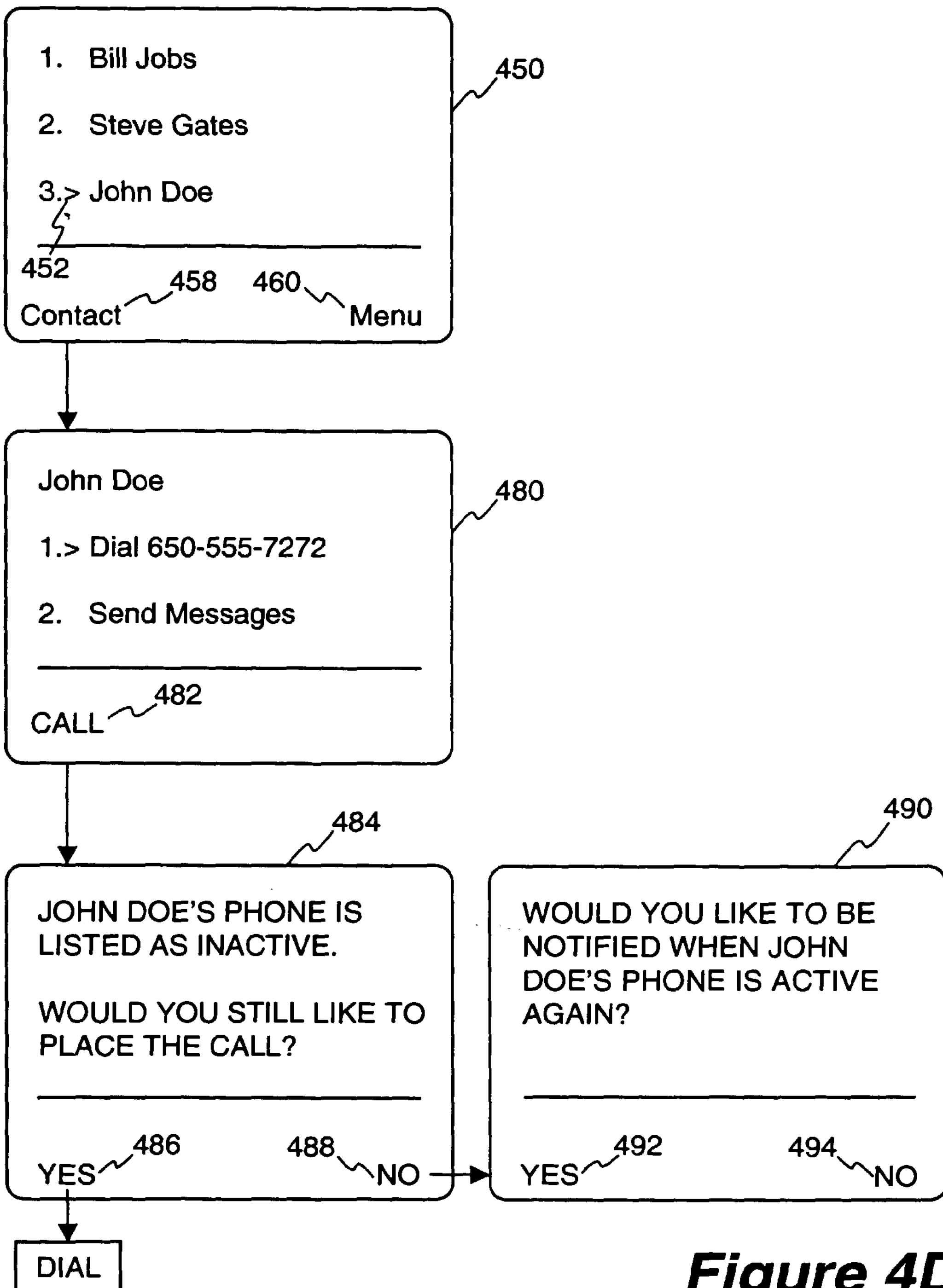

1. Bill Jobs
2. Steve Gates
3.> John Doe
452
Contact
458
460
Menu
450
John Doe
1.> Dial 650-555-7272
2. Send Messages
CALL
482
480
484
JOHN DOE'S PHONE IS LISTED AS INACTIVE.
WOULD YOU STILL LIKE TO PLACE THE CALL?
YES
486
488
NO
DIAL
490
WOULD YOU LIKE TO BE NOTIFIED WHEN JOHN DOE'S PHONE IS ACTIVE AGAIN?
YES
492
494
NO

Figure 4D

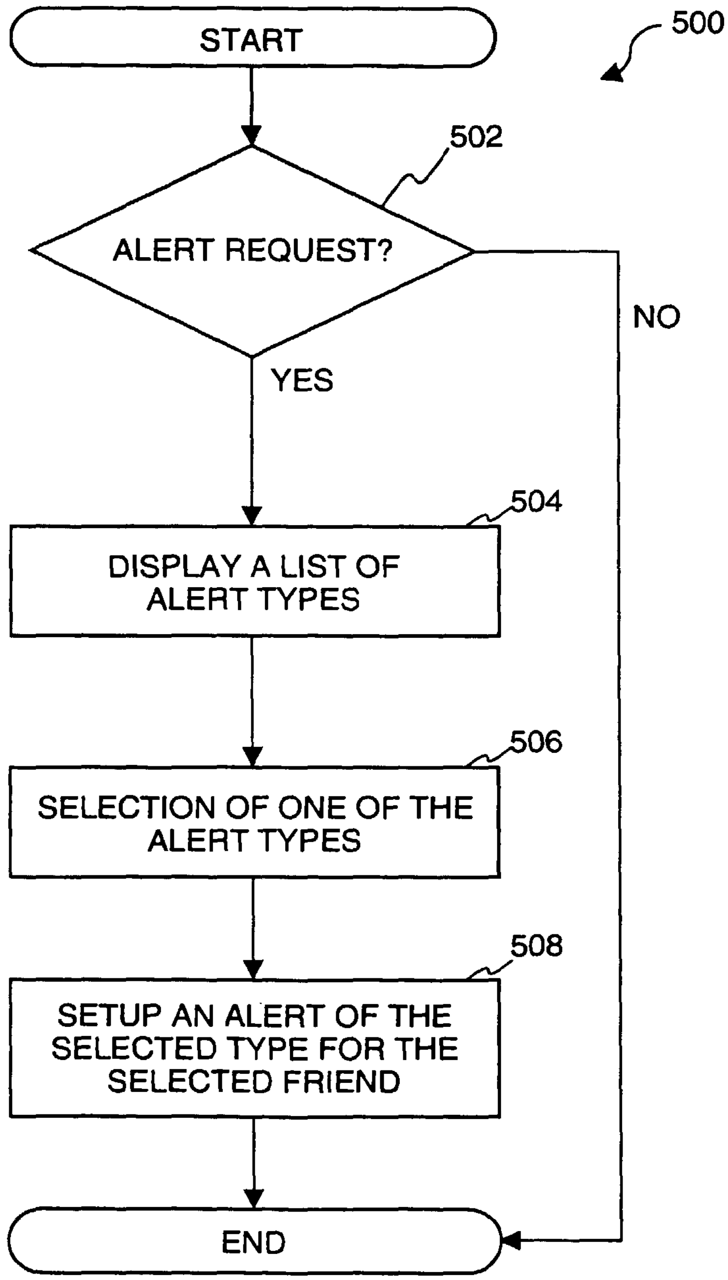

500
START
502
ALERT REQUEST?
NO
YES
504
DISPLAY A LIST OF ALERT TYPES
506
SELECTION OF ONE OF THE ALERT TYPES
508
SETUP AN ALERT OF THE SELECTED TYPE FOR THE SELECTED FRIEND
END

Figure 5A

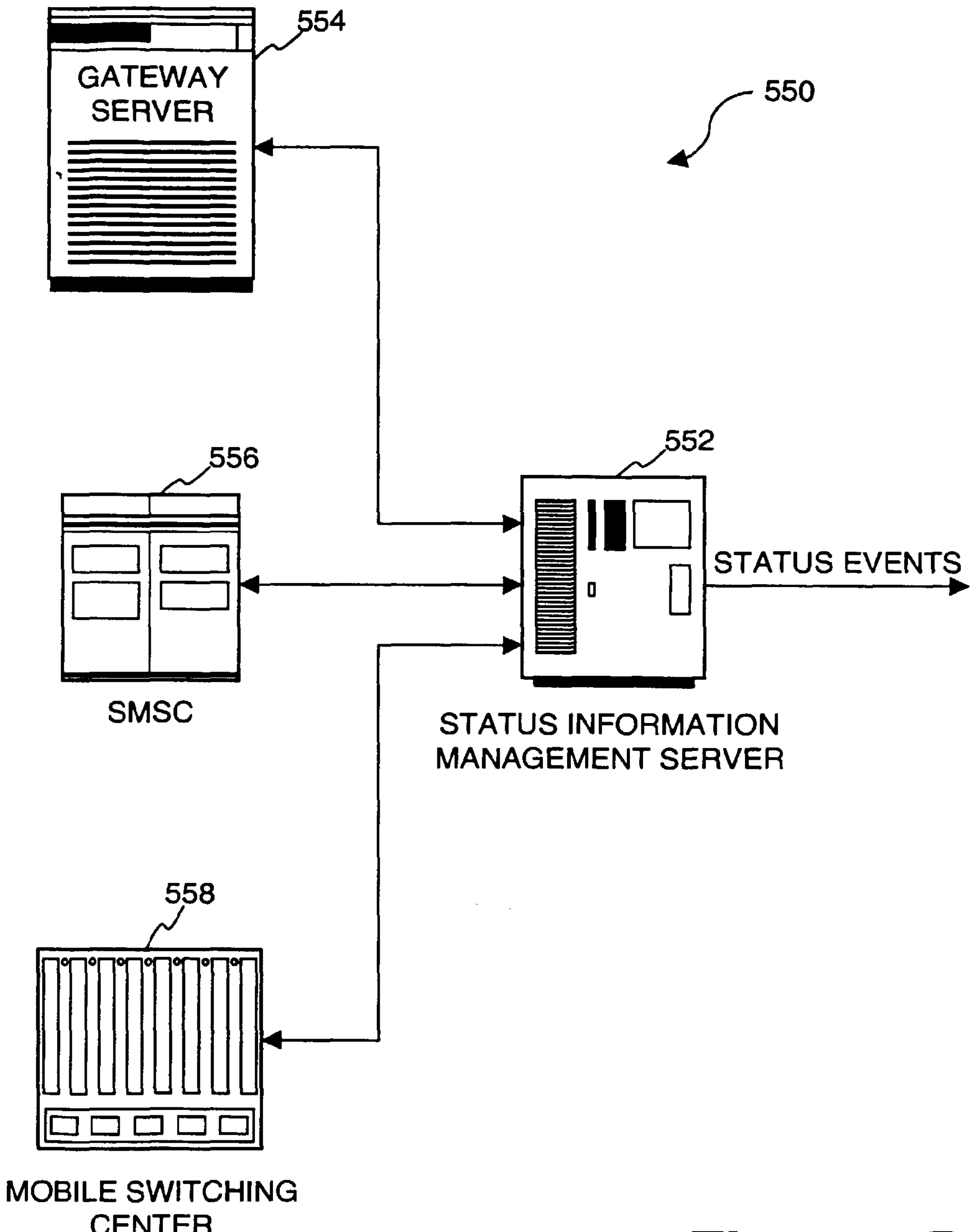
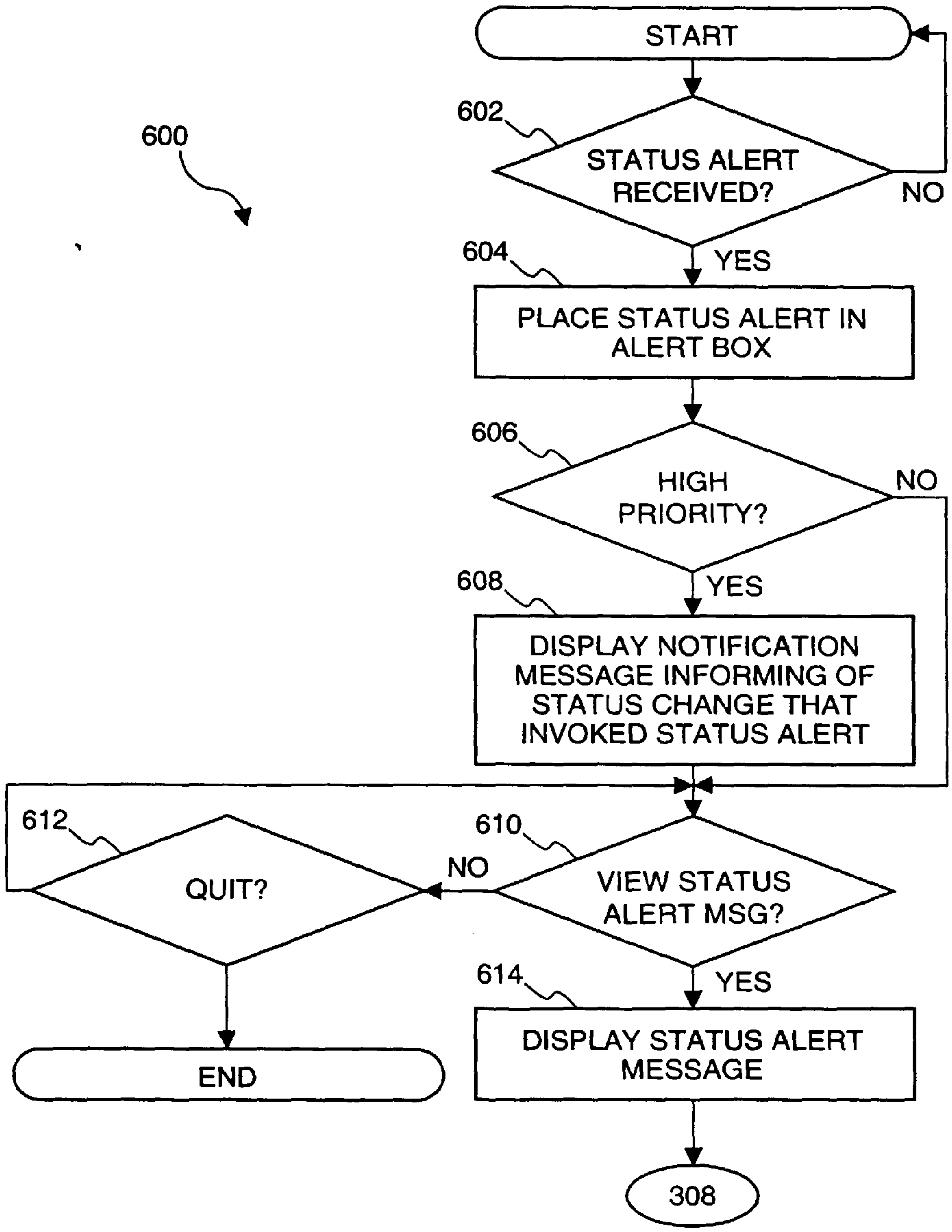

554
GATEWAY
SERVER
550
556
552
STATUS EVENTS
SMSC
STATUS INFORMATION
MANAGEMENT SERVER
558
MOBILE SWITCHING
CENTER

Figure 5B



600
START
602
STATUS ALERT RECEIVED?
NO
604
YES
PLACE STATUS ALERT IN ALERT BOX
606
HIGH PRIORITY?
NO
608
YES
DISPLAY NOTIFICATION MESSAGE INFORMING OF STATUS CHANGE THAT INVOKED STATUS ALERT
612
QUIT?
610
NO
VIEW STATUS ALERT MSG?
614
YES
END
DISPLAY STATUS ALERT MESSAGE
308

Figure 6A

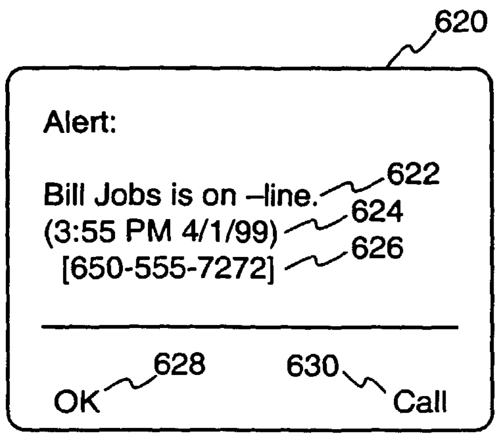


Figure 6B

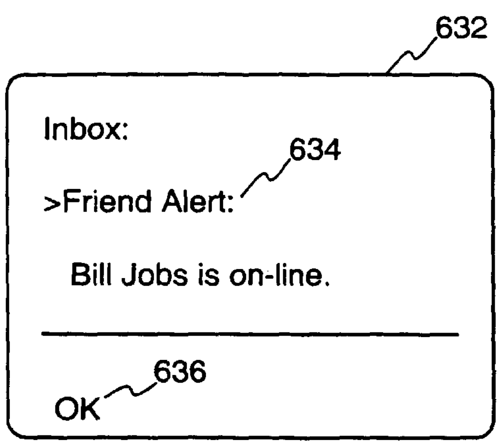


Figure 6C

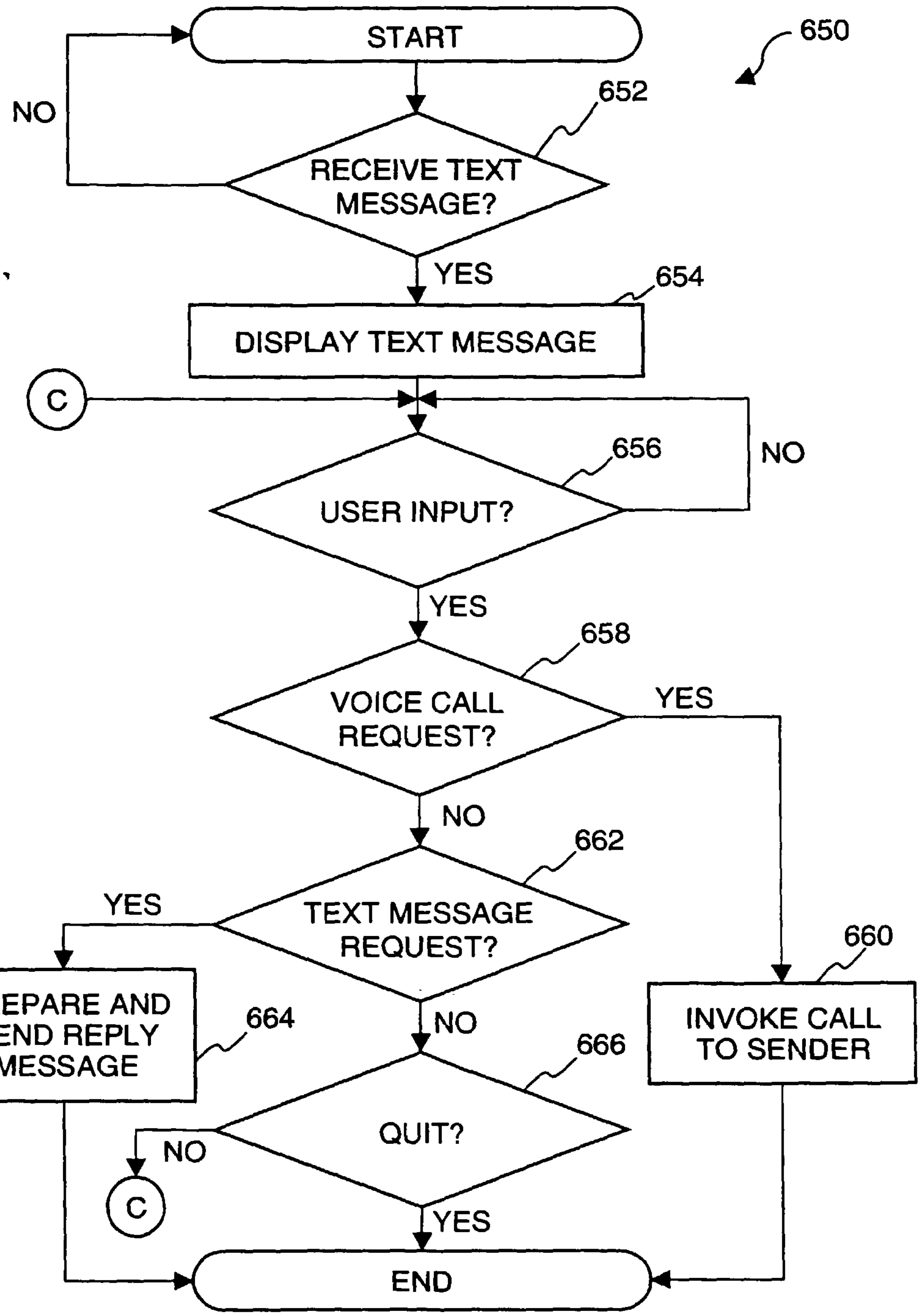
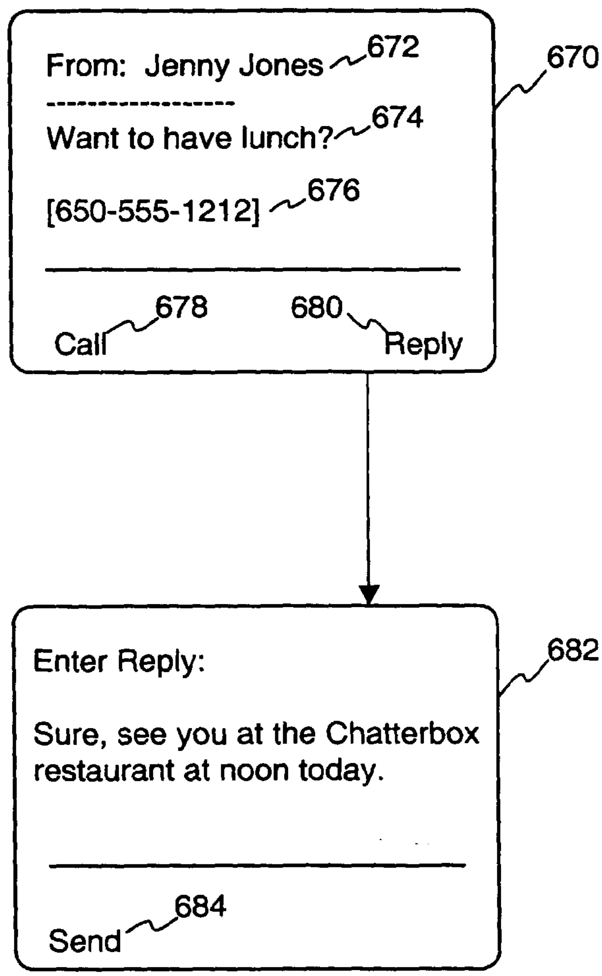

650
START
NO
652
RECEIVE TEXT MESSAGE?
YES
654
DISPLAY TEXT MESSAGE
C
656
NO
USER INPUT?
YES
658
VOICE CALL REQUEST?
YES
NO
662
YES
TEXT MESSAGE REQUEST?
660
PREPARE AND SEND REPLY MESSAGE
664
NO
666
INVOKE CALL TO SENDER
QUIT?
NO
C
YES
END

Figure 6D


From: Jenny Jones
672

Want to have lunch?
674
[650-555-1212]
676
670
Call
678
680
Reply
Enter Reply:
Sure, see you at the Chatterbox restaurant at noon today.
682
Send
684

Figure 6E

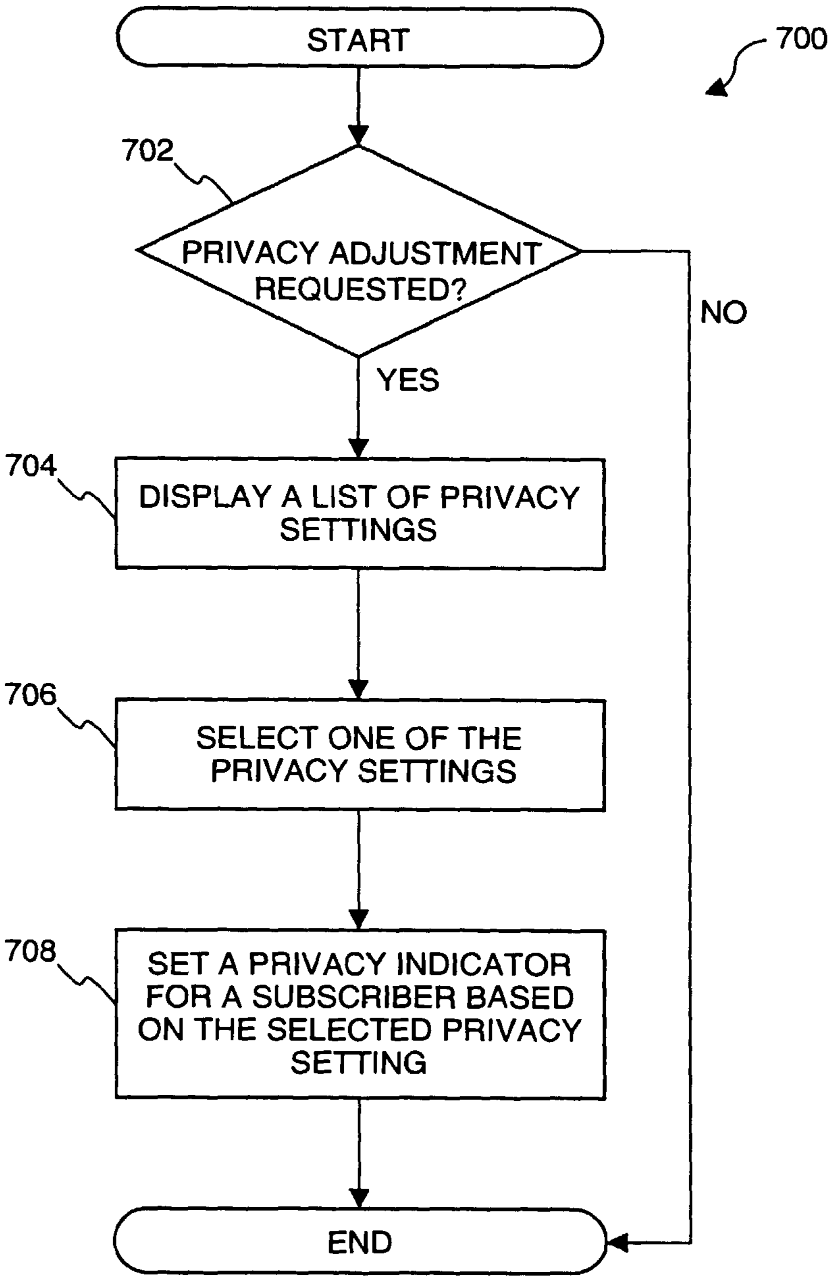

START
700
702
PRIVACY ADJUSTMENT REQUESTED?
NO
YES
704
DISPLAY A LIST OF PRIVACY SETTINGS
706
SELECT ONE OF THE PRIVACY SETTINGS
708
SET A PRIVACY INDICATOR FOR A SUBSCRIBER BASED ON THE SELECTED PRIVACY SETTING
END

Figure 7A

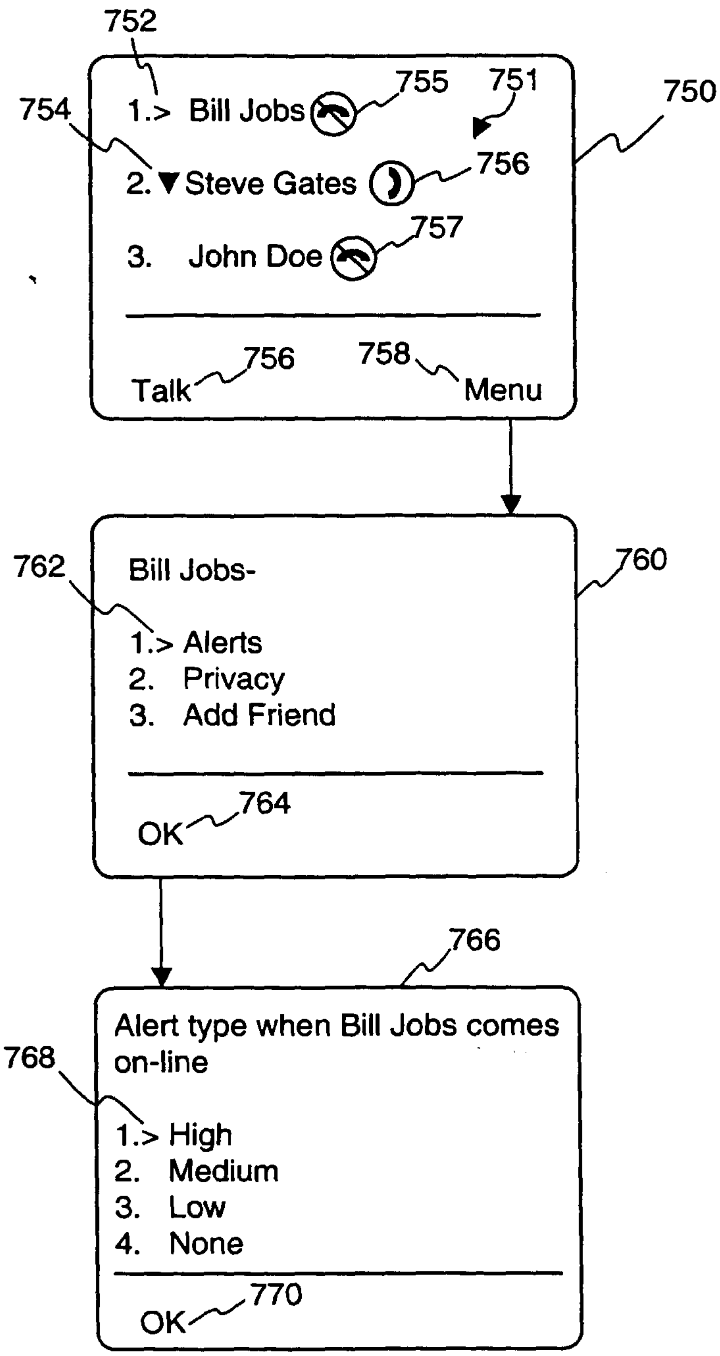

752
754
1.> Bill Jobs
755
751
750
2. ▼Steve Gates
756
757
3. John Doe
Talk
756
758
Menu
762
Bill Jobs-
760
1.> Alerts
2. Privacy
3. Add Friend
OK
764
766
Alert type when Bill Jobs comes on-line
768
1.> High
2. Medium
3. Low
4. None
OK
770

Figure 7B

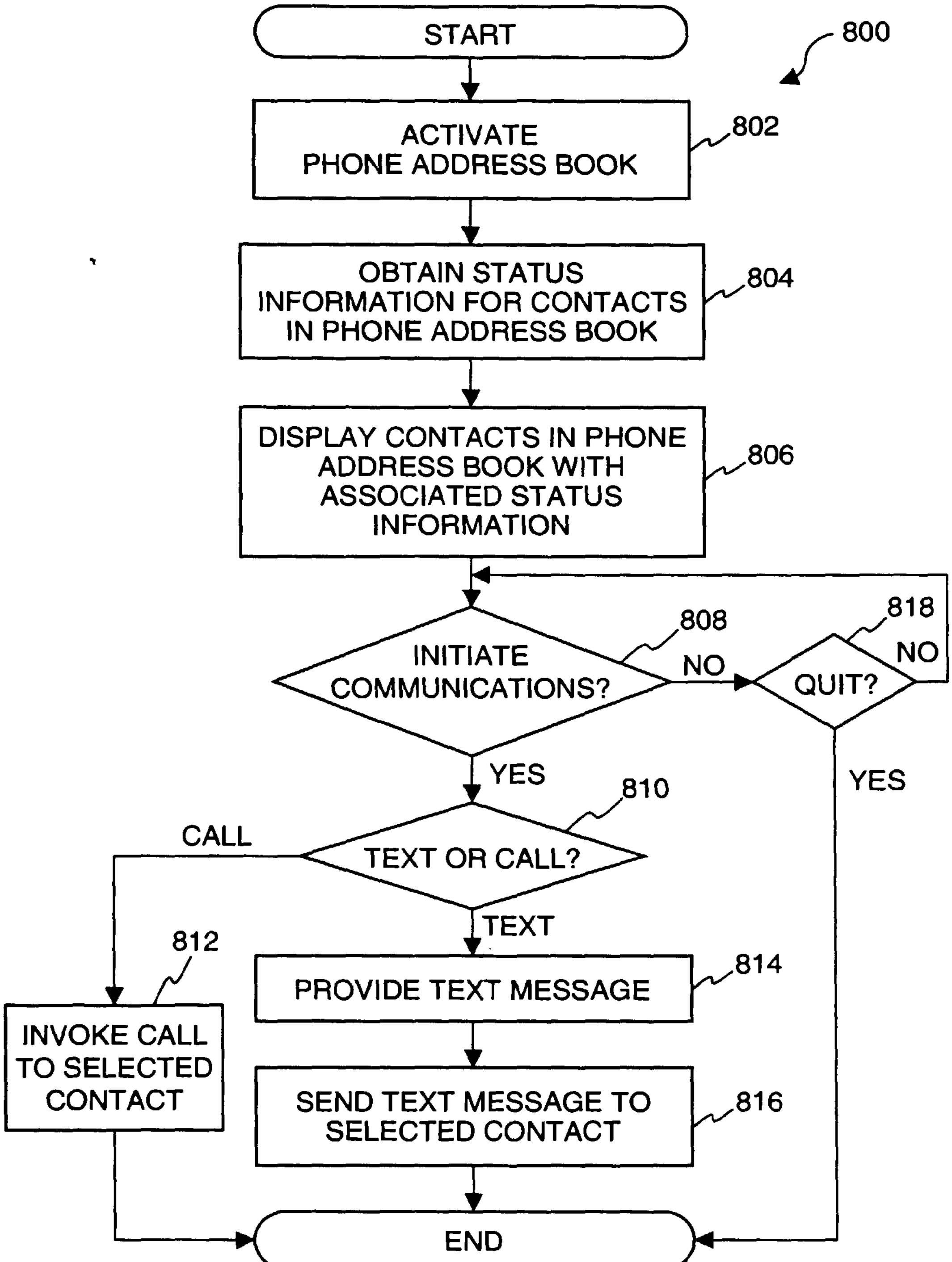

START
800
ACTIVATE PHONE ADDRESS BOOK
802
OBTAIN STATUS INFORMATION FOR CONTACTS IN PHONE ADDRESS BOOK
804
DISPLAY CONTACTS IN PHONE ADDRESS BOOK WITH ASSOCIATED STATUS INFORMATION
806
808
INITIATE COMMUNICATIONS?
NO
818
QUIT?
NO
YES
YES
810
CALL
TEXT OR CALL?
TEXT
812
INVOKE CALL TO SELECTED CONTACT
PROVIDE TEXT MESSAGE
814
SEND TEXT MESSAGE TO SELECTED CONTACT
816
END

Figure 8

Bibliographic data: JPH07250381 (A) — 1995-09-26

INFORMATION SERVICE SYSTEM

Inventor(s): SHIMADA KOUSOU + (SHIMADA KOUSOU)

Applicant(s): FUJITSU LTD + (FUJITSU LTD)

Classification:
- **international:** (IPC1-7): H04Q7/38
- **cooperative:**

Application number: JP19940042178 19940314

Priority number(s): JP19940042178 19940314

Abstract of JPH07250381 (A)

PURPOSE:To serve optimum road guide information from a center to a caller by storing road guidance information in a database. CONSTITUTION:When a caller desires to receive the service of guide information, the caller calls a center equipment 24 via a handy-phone PHP terminal equipment 23 and a radio base station 22 in a resident service area. In this case, the station 22 sends position information of the terminal equipment 23 to the center equipment 24. The equipment 24 registers received position information of the terminal equipment 23 via the station 22 for each number of PHP terminals. Then the caller uses the terminal equipment 23 to send desired destination information to the equipment 24. The equipment 24 uses the received destination information and the caller position information as a key to retrieve the database 25 and sends corresponding data (road guide information) to the terminal equipment 23. Thus, the caller obtains optimum road guide information from a current position till the destination.

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特開平7－250381

(43)公開日　平成７年(1995)９月26日

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		7605－5K	Ｈ０４Ｂ　7/26	１０９	Ｈ
		7605－5K		１０９	Ｔ
		7605－5K	Ｈ０４Ｑ　7/04		Ｄ

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(22)出願日　平成６年(1994)３月14日

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富士通株式会社内

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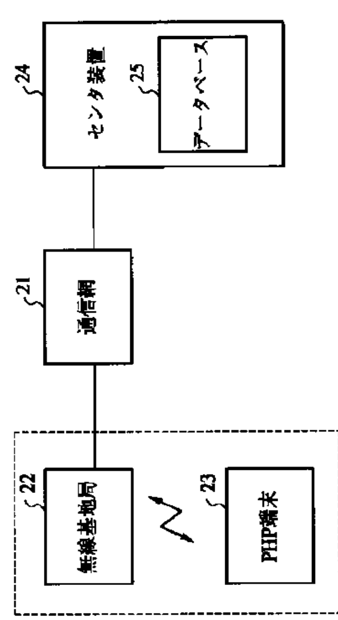
(54)【発明の名称】　情報提供サービス方式

(57)【要約】

【目的】ＰＨＰシステムにおいて、ＰＨＰ端末に対して、センタ側から各種の情報を提供する情報提供サービスに関し、発信者の位置と目的地とによって定まる最適な道案内情報を、センタ側から発信者に提供可能にすることを目的とする。

【構成】ＰＨＰ端末２３が、無線基地局２２と無線回線を介して接続することによって、無線基地局２２が接続された通信網２１との間で相互に通信を行うＰＨＰシステムにおいて、データベース２５を有するセンタ装置２４を通信網２１に設けて、このデータベース２５に、ＰＨＰ端末の位置と目的地とに対応する道案内情報を格納することによって、ＰＨＰ端末２３の位置情報と、ＰＨＰ端末２３から送られた目的地情報とに応じて、センタ装置２４が、このデータベース２５から読み出した道案内情報を、無線基地局２２を介してＰＨＰ端末２３に送信するように構成する。

本発明の原理的構成を示す図



【特許請求の範囲】

【請求項１】　パーソナル・ハンディフォン（以下ＰＨＰと略す）からなる移動端末（以下ＰＨＰ端末という）（２３）が、無線基地局（２２）と無線回線を介して接続することによって、該無線基地局（２２）が接続された通信網（２１）との間で相互に通信を行うＰＨＰシステムにおいて、
ＰＨＰ端末の位置と目的地とに対応する道案内情報を格納したデータベース（２５）を有するセンタ装置（２４）を前記通信網（２１）に設け、
前記ＰＨＰ端末（２３）の位置情報と、該ＰＨＰ端末（２３）から送られた目的地情報とに応じて、該センタ装置（２４）が前記データベース（２５）から読み出した道案内情報を前記無線基地局（２２）を介して該ＰＨＰ端末（２３）に送信することを特徴とする情報提供サービス方式。

【請求項２】　前記通信網（２１）が、公衆網（１）であることを特徴とする請求項１に記載の情報提供サービス方式。

【請求項３】　前記通信網（２１）が、構内交換機（８）で構成されたネットワークであることを特徴とする請求項１に記載の情報提供サービス方式。

【請求項４】　前記構内交換機（８）が、公衆ＰＨＰサービスを提供するものであることを特徴とする請求項３に記載の情報提供サービス方式。

【請求項５】　前記ＰＨＰ端末（２３）の位置情報が、該ＰＨＰ端末（２３）が接続されている無線基地局（２２）によって定まる、該無線基地局のサービスエリアであることを特徴とする請求項１に記載の情報提供サービス方式。

【請求項６】　前記ＰＨＰ端末（２３）の位置情報が、該ＰＨＰ端末（２３）から前記無線基地局（２２）を介して送信された、該無線基地局のサービスエリア以外の位置情報であることを特徴とする請求項１に記載の情報提供サービス方式。

【請求項７】　前記ＰＨＰ端末（２３）の位置情報が、該ＰＨＰ端末（２３）がＧＰＳ装置（１７）を介して得たものであることを特徴とする請求項６に記載の情報提供サービス方式。

【請求項８】　前記目的地情報が、前記ＰＨＰ端末（２３）から前記無線基地局（２２）を介してＰＢ信号または制御信号によって送信されたものであることを特徴とする請求項１に記載の情報提供サービス方式。

【請求項９】　前記目的地情報が、前記センタ装置（２４）から送られた目的地リストから選択されたものであることを特徴とする請求項８に記載の情報提供サービス方式。

【請求項１０】　前記目的地情報が、前記ＰＨＰ端末（２３）においてＩＣカード，フロッピー・ディスクまたはＣＤ－ＲＯＭ駆動装置（６１）によってＩＣカード，フロッピー・ディスクまたはＣＤ－ＲＯＭから読み出して表示装置（５１）において表示された目的地リストから選択した目的地に対応するコードからなることを特徴とする請求項８に記載の情報提供サービス方式。

【請求項１１】　前記目的地情報が、前記ＰＨＰ端末（２３）から送られた電話番号によって示されるものであることを特徴とする請求項８に記載の情報提供サービス方式。

【請求項１２】　前記目的地情報が、前記ＰＨＰ端末（２３）から音声で送信された情報を、前記センタ装置（２４）において音声認識装置（１４）によって認識したものであることを特徴とする請求項１に記載の情報提供サービス方式。

【請求項１３】　前記道案内情報が、前記センタ装置（２４）から音声によって送信されることを特徴とする請求項１に記載の情報提供サービス方式。

【請求項１４】　前記道案内情報が、前記センタ装置（２４）から文字または画像によって送信されることを特徴とする請求項１に記載の情報提供サービス方式。

【請求項１５】　前記道案内情報が、前記センタ装置（２４）から送信されてファクシミリ装置（７）において出力される文字または画像からなることを特徴とする請求項１４に記載の情報提供サービス方式。

【請求項１６】　請求項１に記載の情報提供サービス方式において、前記ＰＨＰ端末（２３）が定期的に位置情報を送出するとともに、前記センタ装置（２４）が、該ＰＨＰ端末（２３）が最初の位置から目的地まで移動する間に経過した位置が、前回の道案内情報に含まれていないことを判定したとき、該位置から目的地までの道案内情報を追加的に送出することを特徴とする情報提供サービス方式。

【請求項１７】　前記センタ装置（２４）が、前記ＰＨＰ端末（２３）ごとのアクセス権を登録するアクセス権登録部（１５）を有し、該アクセス権を登録されたＰＨＰ端末のみの前記道案内情報取得のためのアクセスを許すことを特徴とする請求項１に記載の情報提供サービス方式。

【請求項１８】　前記アクセス権登録部（１５）において、情報ごとのアクセス権を登録したことを特徴とする請求項１７に記載の情報提供サービス方式。

【請求項１９】　前記アクセス権登録部（１５）において、前記ＰＨＰ端末（２３）ごと、または情報ごとのパスワードを登録し、前記ＰＨＰ端末（２３）が該パスワードを送信したときのみ、前記センタ装置（２４）が、前記道案内情報取得のためのアクセスを許すことを特徴とする請求項１７または１８に記載の情報提供サービス方式。

【請求項２０】　前記パスワードが、ＩＣカード，フロッピー・ディスクまたはＣＤ－ＲＯＭに書き込まれた情報を、前記ＰＨＰ端末（２３）が読み出すことによって

送信されることを特徴とする請求項１９に記載の情報提供サービス方式。

【請求項２１】　前記センタ装置（２４）が料金管理部（１８）を備え、ＩＣカード，フロッピー・ディスクまたはＣＤ－ＲＯＭに書き込まれた情報を、前記ＰＨＰ端末（２３）が読み出すことによって送信された情報を受信したとき、割引料金によって前記道案内情報を提供することを特徴とする請求項１に記載の情報提供サービス方式。

【請求項２２】　前記センタ装置（２４）が、前記ＰＨＰ端末（２３）または簡易端末（４）の位置情報を登録する位置情報登録部（１３）を備え、他のＰＨＰ端末から位置検索の照会があったとき、該位置情報登録部（１３）を検索して、前記ＰＨＰ端末（２３）または簡易端末（４）の位置情報を送出することを特徴とする請求項１に記載の情報提供サービス方式。

【請求項２３】　前記センタ装置（２４）が、前記ＰＨＰ端末の位置検索権を登録する検索権登録部（１６）を備え、前記他のＰＨＰ端末から位置検索の照会があったとき、該検索権登録部（１６）において位置検索権が登録されているときのみ、該他のＰＨＰ端末の位置検索を許すことを特徴とする請求項２２に記載の情報提供サービス方式。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は、パーソナル・ハンディフォン（ＰＨＰ）システムにおいて、ＰＨＰ端末からの発信者に対して、センタ側から各種の情報を提供する、情報提供サービスに関し、特に発信者の位置と目的地という複数の条件によって定まる最適な道案内情報を、センタ側から発信者に提供できるようにするための、情報提供サービス方式に関するものである。

【０００２】ＰＨＰシステムは、ディジタル方式のコードレスフォンの子機が、その親機以外に、戸外に設けられた基地局、または事務所等の室内に設けられた基地局等と、無線回線を介して接続することによって、親局や基地局が接続されている公衆網または構内交換機（ＰＢＸ）との間で通信を行うことができるようにしたものであって、今後、実用化されようとしているものである。

【０００３】このようなＰＨＰシステムにおいて、ＰＨＰ端末からの発信者に対して、複数の基地局に共通に設けられたセンタ装置から、種々の情報を提供する情報提供サービスが考えられている。本発明は、その一つとして、基地局のサービスエリアが比較的狭いことを利用して、基地局ごとにそのサービスエリアによって示される発信者の位置情報と、発信者の希望する目的地という複数の条件によって定まる道案内情報を、センタ側から発信者に提供するための、情報提供サービス方式を提案することを目的としている。なお、発信者の位置情報は、他の方法によって送信することも可能である。

【０００４】この場合、発信者の位置と、希望する目的地とに応じて、最適な道案内情報を提供できれば、サービス性を一段と向上することができる。例えば、発信者の位置に応じた、最適な店舗の案内や観光地案内等のサービスを提供できれば便利である。さらに、発信者が定期的に位置情報をセンタ側に送信することによって、発信者が正当なルートから外れた場合に、センタ装置から警告または追加の案内情報を発信するサービスも可能である。

【０００５】ＰＨＰシステムによる公衆サービスは、近い将来提供される予定になっている。その場合、基地局は、比較的狭いサービスエリアに対応して、適当な密度で設けられることになるが、基地局の設置密度によっては、サービスを受けられない地域が残ることも考えられる。このような観点からは、本発明によるサービスは、例えば、地下街，デパート店内，遊園地，広い事業所等の特定エリア内で利用するのが、より効果的である。

【０００６】

【従来の技術】従来、移動通信サービスとしては、

⑴　携帯電話／自動車電話（アナログ方式およびディジタル方式）

⑵　家庭用のコードレス電話（アナログ方式）

⑶　事業所用のシステムコードレス電話（アナログ方式）

等が既に用いられている。

【０００７】

【発明が解決しようとする課題】しかしながら、これらの既存の移動通信サービスは、本発明において目的とする、発信者の位置に応じて最適な情報を提供するサービスを行うためには、必ずしも好適ではない。すなわち、

【０００８】⑴に示す携帯電話／自動車電話サービスは、一つの基地局がカバーする範囲が広いため、発信者が通信する基地局のサービスエリアによって、発信者の位置を示す方式を適用することは不適当である。

【０００９】⑵に示す家庭用のコードレス電話や、⑶に示す事業所用のシステムコードレス電話サービスは、サービスを提供するエリアが極端に狭いため、そのサービスエリアを位置情報として用いることが不適当であることと、アナログ方式を採用しているため、制御情報の送受信が難しい等の制約がある。

【００１０】本発明は、このような従来技術の課題を解決しようとするものであって、ＰＨＰシステムにおいて、発信者がＰＨＰ端末から発信した無線信号を受信した、発信者に最寄りの基地局の位置によって発信者の位置を規定することで、発信者の位置情報を設定し、発信者の位置情報と、発信者の希望する目的地とによって定まる最適な道案内情報を、センタ側に設けられたデータベースに基づいて、発信者に提供できるようにすることを目的としている。

【００１１】

【課題を解決するための手段】図１は、本発明の原理的構成を示したものであって、２１は通信網を示し、２２は通信網２１に接続された無線基地局である。２３は、無線基地局２２のサービスエリア（点線で示す）内にあるＰＨＰ端末を示す。２４は通信網２１に設けられたセンタ装置であって、道案内情報を出力するためのデータベース２５を有している。データベース２５には、発信者からの目的地等の要求条件と、発信者の位置情報とによって定まる道案内情報が予め格納されている。

【００１２】本発明は、図１に示された原理的構成において、課題を解決するために、次のような各種の手段を備える。

(1) パーソナル・ハンディフォン（ＰＨＰ）からなる移動端末（ＰＨＰ端末）が、無線基地局と無線回線を介して接続することによって、この無線基地局が接続された通信網との間で相互に通信を行うＰＨＰシステムにおいて、ＰＨＰ端末の位置と目的地とに対応する道案内情報を格納したデータベースを有するセンタ装置を通信網に設け、ＰＨＰ端末の位置情報と、ＰＨＰ端末から送られた目的地情報とに応じて、センタ装置がデータベースから読み出した道案内情報を無線基地局を介してＰＨＰ端末に送信する。

【００１３】(2) (1) の場合に、通信網が、公衆網であることを特徴とする。

【００１４】(3) (1) の場合に、通信網が、構内交換機で構成されたネットワークであることを特徴とする。

【００１５】(4) (3) の場合に、構内交換機が、公衆ＰＨＰサービスを提供するものであることを特徴とする。

【００１６】(5) (1) の場合に、ＰＨＰ端末の位置情報が、このＰＨＰ端末が接続されている無線基地局によって定まる、この無線基地局のサービスエリアであることを特徴とする。

【００１７】(6) (1) の場合に、ＰＨＰ端末の位置情報が、このＰＨＰ端末から無線基地局を介して送信された、この無線基地局のサービスエリア以外の位置情報であることを特徴とする。

【００１８】(7) (6) の場合に、ＰＨＰ端末の位置情報が、このＰＨＰ端末がＧＰＳ装置を介して得たものであることを特徴とする。

【００１９】(8) (1) の場合に、目的地情報が、ＰＨＰ端末から無線基地局を介してＰＢ信号または制御信号によって送信されたものであることを特徴とする。

【００２０】(9) (8) の場合に、目的地情報が、センタ装置から送られた目的地リストから選択されたものであることを特徴とする。

【００２１】(10) (8) の場合に、目的地情報が、ＰＨＰ端末においてＩＣカード，フロッピー・ディスクまたはＣＤ－ＲＯＭ駆動装置によってＩＣカード，フロッピー・ディスクまたはＣＤ－ＲＯＭから読み出して表示装置において表示された目的地リストから選択した目的地に対応するコードからなることを特徴とする。

【００２２】(11) (8) の場合に、目的地情報が、ＰＨＰ端末から送られた電話番号によって示されるものであることを特徴とする。

【００２３】(12) (1) の場合に、目的地情報が、ＰＨＰ端末から音声で送信された情報を、センタ装置において音声認識装置によって認識したものであることを特徴とする。

【００２４】(13) (1) の場合に、道案内情報が、センタ装置から音声によって送信されることを特徴とする。

【００２５】(14) (1) の場合に、道案内情報が、センタ装置から文字または画像によって送信されることを特徴とする。

【００２６】(15) (14)の場合に、道案内情報が、センタ装置から送信されてファクシミリ装置において出力される文字または画像からなることを特徴とする。

【００２７】(16) (1) の場合に、ＰＨＰ端末が定期的に位置情報を送出するとともに、センタ装置が、このＰＨＰ端末が最初の位置から目的地まで移動する間に経過した位置が、前回の道案内情報に含まれていないことを判定したとき、この位置から目的地までの道案内情報を追加的に送出することを特徴とする。

【００２８】(17) (1) の場合に、センタ装置が、ＰＨＰ端末ごとのアクセス権を登録するアクセス権登録部を有し、アクセス権を登録されたＰＨＰ端末のみの、道案内情報取得のためのアクセスを許すことを特徴とする。

【００２９】(18) (17)の場合に、アクセス権登録部において、情報ごとのアクセス権を登録したことを特徴とする。

【００３０】(19) (17)または(18)の場合に、アクセス権登録部において、ＰＨＰ端末ごと、または情報ごとのパスワードを登録し、ＰＨＰ端末がこのパスワードを送信したときのみ、センタ装置が、道案内情報取得のためのアクセスを許すことを特徴とする。

【００３１】(20) (19)の場合に、パスワードが、ＩＣカード，フロッピー・ディスクまたはＣＤ－ＲＯＭに書き込まれた情報を、ＰＨＰ端末が読み出すことによって送信されることを特徴とする。

【００３２】(21) (1) の場合に、センタ装置が料金管理部を備え、ＩＣカード，フロッピー・ディスクまたはＣＤ－ＲＯＭに書き込まれた情報を、ＰＨＰ端末が読み出すことによって送信された情報を受信したとき、割引料金によって道案内情報を提供することを特徴とする。

【００３３】(22) (1) の場合に、センタ装置が、ＰＨＰ端末または簡易端末の位置情報を登録する位置情報登録部を備え、他のＰＨＰ端末から位置検索の照会があったとき、位置情報登録部を検索して、ＰＨＰ端末または簡易端末の位置情報を送出することを特徴とする。

【００３４】(23) (22)の場合に、センタ装置が、ＰＨＰ端末の位置検索権を登録する検索権登録部を備え、他

のＰＨＰ端末から位置検索の照会があったとき、検索権登録部において位置検索権が登録されているときのみ、他のＰＨＰ端末の位置検索を許すことを特徴とする。

【００３５】

【作用】図2は、本発明の原理を説明するシーケンス図であって、図1に示された、ＰＨＰ端末２３，無線基地局２２，センタ装置２４およびデータベース２５に対応して、それぞれの動作を示している。

【００３６】発信者は、案内情報の提供を受けようとする場合、ＰＨＰ端末２３を介して、所在するサービスエリアの無線基地局２２を経由して、センタ装置２４を呼び出す。このとき、無線基地局２２は、ＰＨＰ端末２３の位置情報をセンタ装置２４に送信する。センタ装置２４では、無線基地局２２を介して受信したＰＨＰ端末２３の位置情報を、ＰＨＰ端末の番号ごとに登録する。

【００３７】次に、発信者は、希望する目的地の情報を、ＰＨＰ端末２３からセンタ装置２４に送信する。センタ装置２４は、受信した目的地情報と発信者の位置情報とをキーとして、データベース２５を検索し、対応するデータ（道案内情報）をＰＨＰ端末２３に送信する。

【００３８】これによって、発信者は、現在位置から目的地までの、最適な道案内情報を入手することができる。

【００３９】

【実施例】図3は、本発明の実施例(1) を示したものであって、道案内情報提供サービスを実現する構成を示している。図3において、１は公衆網を示している。2は公衆網に接続されたＰＨＰシステムの基地局であって、点線で示すサービスエリアを有している。3はＰＨＰシステムの端末（以下ＰＨＰ端末という）である。１０は公衆網１に接続されたセンタ装置であって、データベース１１－１と、制御部１２とを有している。データベース１１－１には、発信者の位置と目的地の情報に対応して、最適な道案内情報を予め格納している。制御部１２は公衆網１との間で通信を行って、本発明の情報提供サービスに必要な各種の制御を行う。これら各部には、図１に示された原理的構成における対応する部分の番号を（　）を付して示している。また、図4は、実施例(1) における各部の動作を説明するシーケンス図である。

【００４０】本実施例における、道案内情報提供時の動作は、次のようにして行われる。

(1) 発信者は、ＰＨＰ端末３を介して、基地局２を経由してセンタ装置１０を呼び出す。

(2) 基地局2は、ＰＨＰ端末３の位置情報（ＰＨＰ端末がどの基地局のサービスエリアにいるかを示す情報）をセンタ装置１０に送信する。

【００４１】(3) センタ装置１０は、基地局２から受信したＰＨＰ端末３の位置情報を、ＰＨＰ端末番号ごとに登録する。

(4) 発信者は、目的地情報を、プッシュボタン（ＰＢ）信号または制御信号によって、ＰＨＰ端末３を介して、基地局２を経由してセンタ装置１０に送信する。

【００４２】(5) センタ装置１０は、基地局２を経由して受信した目的地情報と登録した発信者の位置情報とをキーとして、データベース１１－１を検索して、対応するデータ、すなわちＰＨＰ端末3の位置から目的地までの道案内情報を、音声によって、ＰＨＰ端末３に送信する。

(6) これによって、発信者は、自局の位置から目的地までの、最適な道案内情報を受け取ることができる。

【００４３】図5は、本発明の実施例(2) を示したものであって、特定エリアにおける道案内情報提供サービスを実現する構成を示したものである。図3におけると同じものを同じ番号で示し、８は構内交換機である。

【００４４】実施例(2) によれば、事業所等の特定エリアにおいて、構内交換機８で構成されたネットワークで、道案内情報提供のサービスを実現することができる。図5において、構内交換機８は、ＰＨＰサービスを提供するものであって、特定エリアにおいて、図3に示された公衆網１と同様な動作を行う。その他の部分の構成，動作は実施例(1) の場合と同様である。実施例(2) によれば、特定エリアにおいても、実施例(1) の場合と同様な、道案内情報提供のサービスを実現することができる。

【００４５】図6は、本発明の実施例(3) を示したものであって、公衆ＰＨＰサービスを利用して、道案内情報提供サービスを実現する構成を示したものであって、図３におけると同じものを同じ番号で示している。

【００４６】実施例(3) によれば、公衆ＰＨＰサービスを利用して、道案内情報提供のサービスを実現することができる。図6において、公衆網１は、ＰＨＰサービスを提供するものであって、実施例(2) においてＰＨＰサービスを提供する構内交換機８と同様な動作を行う。その他の部分の構成，動作は実施例(2) の場合と同様である。実施例(3) によれば、公衆エリアにおいても、実施例(1) の場合と同様な、道案内情報提供のサービスを実現することができる。

【００４７】図7は、本発明の実施例(4) を示したものであって、追加道案内情報提供サービスを実現する構成を示したものである。図3におけると同じものを同じ番号で示し、２－１，２－２はそれぞれ基地局であって、それぞれ点線で示すサービスエリアを有している。１１－２はデータベースであって、ＰＨＰ端末の位置情報と目的地とに対応した最適な道案内情報と、目的地までに経由する地点（サービスエリアを通過する基地局）の位置情報とを予め格納している。また、図8は、実施例(4) における各部の動作を説明するシーケンス図である。

【００４８】本実施例における、最適な道案内情報と、目的地までに経由した地点での位置情報提供時の動作

は、次のようにして行われる。
(1) 発信者は、基地局２－１のサービスエリア内の(a)地点で、道案内情報の提供を受けるため、ＰＨＰ端末３を介して、(a) 地点に最寄りの基地局２－１を経由してセンタ装置１０を呼び出す。
(2) これによって発信者は、実施例(1) と同様にして、(a) 地点から目的地までの最適な道案内情報を受け取る。
【００４９】(3) ＰＨＰ端末３は、発信者が目的地に到達するまで、定期的に位置情報を送信する。例えば、基地局２－２のサービスエリア内の(b) 地点に移動したとき、位置情報を送信したとする。
(4) センタ装置１０は、基地局２－２から送信された(b) 地点の位置情報（ＰＨＰ端末3の位置情報）が、データベース１１－２に格納された(a) 地点から目的地へ行くために経由する地点の位置情報に含まれているか否かを判定する。
【００５０】(5) もしも、この位置情報がデータベース１１－２に格納されていなければ、センタ装置１０は、ＰＨＰ端末３に対して、新たに(b) 地点から目的地までの、追加道案内情報を送信する。
【００５１】実施例(4) によれば、発信者が正しい経路から外れた場合に、経路を修正して目的地に達するための新たな道案内情報を、追加して受け取ることができるようになる。
【００５２】図9は、本発明の実施例(5) を示したものであって、道案内情報提供サービスの変形例を示し、図3におけると同じものを同じ番号で示している。また、図１０は、実施例(5) における各部の動作を説明するシーケンス図である。
【００５３】本実施例における、最適な道案内情報提供時の動作は、次のようにして行われる。
(1) 発信者は、ＰＨＰ端末３を介して、基地局２を経由してセンタ装置１０を呼び出す。
(2) 発信者は、別の手段で知り得た自局の位置情報を、ＰＢ信号または制御信号によって、ＰＨＰ端末３を介して、基地局２を経由してセンタ装置１０に送信する。
【００５４】(3) 次に、発信者は、希望する目的地の情報を、ＰＢ信号または制御信号によって、ＰＨＰ端末３を介して、基地局２を経由してセンタ装置１０に送信する。
(4) センタ装置１０は、基地局２を経由して受信した目的地情報と発信者の位置情報とをキーとして、データベース１１－１を検索して、対応するデータ、すなわちＰＨＰ端末３の位置から目的地までの道案内情報を、音声によって、ＰＨＰ端末３に送信する。
【００５５】(5) これによって、発信者は、その位置する基地局サービスエリアから目的地までの、最適な道案内情報を受け取ることができる。
【００５６】実施例(5) によれば、発信者が、顕著な地理的特徴や建築物等の具体的な位置情報を知り得た場合、より詳細な道案内情報を受け取ることができるようになる。
【００５７】図１１は、本発明の実施例(6) を示したものであって、ＧＰＳ（Global Positioning System ）機能を利用した道案内情報提供サービスを実現する構成を示している。図3におけると同じものを同じ番号で示し、１７はＰＨＰ端末３に設けられたＧＰＳ装置である。また、図１２は、実施例(6) における各部の動作を説明するシーケンス図である。
【００５８】本実施例における、ＧＰＳ機能を利用した道案内情報提供時の動作は、次のようにして行われる。
(1) 発信者は、ＰＨＰ端末３を介して、基地局２を経由してセンタ装置１０を呼び出す。
(2) 発信者は、ＧＰＳ装置１７を駆動して知り得た自局の位置情報を、ＰＢ信号または制御信号によって、ＰＨＰ端末３を介して、基地局２を経由してセンタ装置１０に送信する。
【００５９】(3) 次に、発信者は、希望する目的地の情報を、ＰＢ信号または制御信号によって、ＰＨＰ端末３を介して、基地局２を経由してセンタ装置１０に送信する。
(4) センタ装置１０は、基地局２を経由して受信した目的地情報と発信者の位置情報とをキーとして、データベース１１－１を検索して、対応するデータ、すなわちＰＨＰ端末３の位置から目的地までの道案内情報を、音声によって、ＰＨＰ端末３に送信する。
【００６０】(5) これによって、発信者は、自局の位置から目的地までの、最適な道案内情報を受け取ることができる。
【００６１】実施例(6) によれば、発信者がＧＰＳ装置によって具体的な位置情報を知り得た場合、より詳細な道案内情報を受け取ることができるようになる。
【００６２】図１３は、本発明の実施例(7) を示したものであって、本発明の道案内情報提供サービスにおける目的地提示方式を示し、図3におけると同じものを同じ番号で示している。また、図１４は、実施例(7) における各部の動作を説明するシーケンス図である。
【００６３】本実施例における、道案内情報提供時の動作は、次のようにして行われる。
(1) 発信者は、ＰＨＰ端末３を介して、基地局２を経由してセンタ装置１０を呼び出す。
(2) 基地局2は、ＰＨＰ端末3の位置情報（ＰＨＰ端末がどの基地局のサービスエリアにいるかを示す情報）を、センタ装置１０に送信する。
【００６４】(3) センタ装置１０は、基地局２から受信したＰＨＰ端末３の位置情報を、ＰＨＰ端末番号ごとに登録する。
(4) センタ装置１０は、ＰＨＰ端末３に対し、目的地リストを音声ガイダンスによって送信する。

【００６５】(5) 発信者は、受信した目的地リスト中から希望する目的地を選択し、ＰＢ信号または制御信号によって、目的地情報をＰＨＰ端末３を介して、基地局２を経由してセンタ装置１０に送信する。このとき、１回で目的地を選択しないで、ＰＨＰ端末３とセンタ装置１０との間で、何回かデータをやりとりして、段階的に目的地を選択する方法も考えられる。

【００６６】(6) センタ装置１０は、基地局２を経由して受信した目的地情報と登録した発信者の位置情報とをキーとして、データベース１１－１を検索して、対応するデータ、すなわちＰＨＰ端末３の位置から目的地までの道案内情報を、音声によって、ＰＨＰ端末３に送信する。

【００６７】(7) これによって、発信者は、自局の位置から目的地までの、最適な道案内情報を受け取ることができる。

【００６８】実施例(7) によれば、発信者は受信した目的地リスト中から、希望する目的地を選択できるので、目的地の選定がより容易になる。

【００６９】図１５は、本発明の実施例(8) を示したものであって、音声入力を利用した道案内情報提供サービスを実現する構成を示している。図３におけると同じものを同じ番号で示し、センタ装置１０において、１４は音声認識装置である。また、図１６は、実施例(8) における各部の動作を説明するシーケンス図である。

【００７０】本実施例における、音声入力による道案内情報提供時の動作は、次のようにして行われる。

(1) 発信者は、ＰＨＰ端末３を介して、基地局２を経由してセンタ装置１０を呼び出す。

(2) 基地局２は、ＰＨＰ端末３の位置情報（ＰＨＰ端末がどの基地局のサービスエリアにいるかを示す情報）を、センタ装置１０に送信する。

【００７１】(3) センタ装置１０は、基地局２から受信したＰＨＰ端末３の位置情報を、ＰＨＰ端末番号ごとに登録する。

(4) 発信者は、希望する目的地を、音声によって、ＰＨＰ端末３を介して、基地局２を経由してセンタ装置１０に送信する。

【００７２】(5) センタ装置１０は、基地局２を経由して音声によって受信した目的地情報を音声認識装置１４で認識して、発信者が希望する目的地を解析し、得られた目的地情報と登録した発信者の位置情報とをキーとして、データベース１１－１を検索して、対応するデータ、すなわちＰＨＰ端末３の位置から目的地までの道案内情報を、音声によって、ＰＨＰ端末３に送信する。

(6) これによって、発信者は、自局の位置から目的地までの、最適な道案内情報を受け取ることができる。

【００７３】実施例(8) によれば、発信者は音声によって目的地情報を送信することができるので、ＰＢ信号や制御信号による場合と比べて、より操作が容易になる。

【００７４】図１７は、本発明の実施例(9) を示したものであって、本発明の道案内情報提供サービスにおける電話番号を利用した目的地提示方式を示し、図３におけると同じものを同じ番号で示している。また、図１８は、実施例(9) における各部の動作を説明するシーケンス図である。

【００７５】本実施例における、道案内情報提供時の動作は、次のようにして行われる。

(1) 発信者は、ＰＨＰ端末３を介して、基地局２を経由してセンタ装置１０を呼び出す。

(2) 基地局２は、ＰＨＰ端末３の位置情報（ＰＨＰ端末がどの基地局のサービスエリアにいるかを示す情報）を、センタ装置１０に送信する。

【００７６】(3) センタ装置１０は、基地局２から受信したＰＨＰ端末３の位置情報を、ＰＨＰ端末番号ごとに登録する。

(4) 発信者は、目的地の電話番号を、ＰＢ信号または制御信号によって、ＰＨＰ端末３を介して、基地局２を経由してセンタ装置１０に送信する。

【００７７】(5) センタ装置１０は、基地局２を経由して受信した目的地情報と登録した発信者の位置情報とをキーとして、データベース１１－１を検索して、対応するデータ、すなわちＰＨＰ端末３の位置から目的地までの道案内情報を、音声によって、ＰＨＰ端末３に送信する。

(6) これによって、発信者は、自局の位置から目的地までの、最適な道案内情報を受け取ることができる。

【００７８】実施例(9) によれば、発信者は電話番号によって目的地の指定を行うことができるので、目的地情報の入力がより容易になる。

【００７９】図１９は、本発明の実施例(10)を示したものであって、道案内情報提供サービスにおける、ＩＣカード，フロッピーディスクまたはＣＤ－ＲＯＭを利用した目的地指定方式を実現する構成を示している。図３におけると同じものを同じ番号で示し、６はＰＨＰ端末である。ＰＨＰ端末６において、５１は文字または画像の表示装置、６１はＩＣカード，フロッピーディスクまたはＣＤ－ＲＯＭの駆動装置である。また図２０は、実施例(10)における各部の動作を説明するシーケンス図である。

【００８０】本実施例における、ＩＣカード，フロッピーディスクまたはＣＤ－ＲＯＭを利用した道案内情報提供時の動作は、次のようにして行われる。この際、ＩＣカード，フロッピーディスクまたはＣＤ－ＲＯＭには、予め目的地のリストが書き込まれているものとする。

(1) 発信者は、ＰＨＰ端末６を介して、基地局２を経由してセンタ装置１０を呼び出す。

(2) 基地局２は、ＰＨＰ端末６の位置情報（ＰＨＰ端末がどの基地局のサービスエリアにいるかを示す情報）を、センタ装置１０に送信する。

【0081】(3) センタ装置１０は、基地局２から受信したＰＨＰ端末６の位置情報を、ＰＨＰ端末番号ごとに登録する。
(4) ＰＨＰ端末６では、駆動装置６１によって、ＩＣカード，フロッピーディスクまたはＣＤ－ＲＯＭを駆動して、書き込まれている目的地のリストを読み取って、表示装置５１上に表示する。発信者は、この表示によって希望する目的地を選択する。
【0082】(5) ＰＨＰ端末６は、ＰＢ信号または制御信号によって、選択された目的地に対応するコードを、基地局２を経由してセンタ装置１０に送信する。
(6) センタ装置１０は、基地局２を経由して受信した目的地のコードと登録した発信者の位置情報とをキーとして、データベース１１－１を検索して、対応するデータ、すなわちＰＨＰ端末６の位置から目的地までの道案内情報を、文字または画像情報として、ＰＨＰ端末６に送信する。
【0083】(7) ＰＨＰ端末６では、送られた文字または画像情報を、表示装置５１上に表示する。これによって、発信者は、自局の位置から目的地までの、最適な道案内情報を受け取ることができる。
【0084】実施例(10)によれば、ＩＣカード，フロッピーディスクまたはＣＤ－ＲＯＭに書き込まれている目的地リストによって目的地をコード化して入力できるので、目的地情報の入力がより容易になる。
【0085】図２１は、本発明の実施例(11)を示したものであって、文字または画像による道案内情報提供サービスを実現する構成を示している。図３におけると同じものを同じ番号で示し、５はＰＨＰ端末であって、ＰＨＰ端末５において、５１は文字または画像の表示装置である。また図２２は、実施例(11)における各部の動作を説明するシーケンス図である。
【0086】本実施例における、文字または画像による道案内情報提供時の動作は、次のようにして行われる。
(1) 発信者は、ＰＨＰ端末５を介して、基地局２を経由してセンタ装置１０を呼び出す。
(2) 基地局２は、ＰＨＰ端末５の位置情報（ＰＨＰ端末がどの基地局のサービスエリアにいるかを示す情報）を、センタ装置１０に送信する。
【0087】(3) センタ装置１０は、基地局２から受信したＰＨＰ端末５の位置情報を、ＰＨＰ端末番号ごとに登録する。
(4) 発信者は、目的地情報を、ＰＨＰ端末５から、ＰＢ信号または制御信号によって、基地局２を経由してセンタ装置１０に送信する。
【0088】(5) センタ装置１０は、基地局２を経由して受信した目的地情報と登録した発信者の位置情報とをキーとして、データベース１１－１を検索して、対応するデータ、すなわちＰＨＰ端末５の位置から目的地までの道案内情報を、文字または画像情報として、ＰＨＰ端末５に送信する。
(6) ＰＨＰ端末５では、送られた文字または画像情報を、表示装置５１上に表示する。これによって、発信者は、自局の位置から目的地までの、最適な道案内情報を受け取ることができる。
【0089】実施例(11)によれば、道案内情報を文字または画像として表示することができるので、道案内情報の認識がより容易になる。
【0090】図２３は、本発明の実施例(12)を示したものであって、道案内情報のファクシミリ出力サービスを実現する構成を示している。図３におけると同じものを同じ番号で示し、７は基地局２に設けられたファクシミリ（ＦＡＸ）装置である。また図２４は、実施例(12)における各部の動作を説明するシーケンス図である。
【0091】本実施例における、道案内情報提供時の動作は、次のようにして行われる。
(1) 発信者は、ＰＨＰ端末３を介して、基地局２を経由してセンタ装置１０を呼び出す。
(2) 基地局２は、ＰＨＰ端末３の位置情報（ＰＨＰ端末がどの基地局のサービスエリアにいるかを示す情報）を、センタ装置１０に送信する。
【0092】(3) センタ装置１０は、基地局２から受信したＰＨＰ端末３の位置情報を、ＰＨＰ端末番号ごとに登録する。
(4) 発信者は、目的地情報を、ＰＨＰ端末３から、ＰＢ信号または制御信号によって、基地局２を経由してセンタ装置１０に送信する。
【0093】(5) センタ装置１０は、基地局２を経由して受信した目的地情報と登録した発信者の位置情報とをキーとして、データベース１１－１を検索して、対応するデータ、すなわちＰＨＰ端末３の位置から目的地までの最適な道案内情報を、基地局２に接続されたファクシミリ装置７に出力するとともに、その旨を音声でＰＨＰ端末３に通知する。
(6) 発信者は、基地局２に接続されたファクシミリ装置７から、自局の位置から目的地までの、最適な道案内情報を受け取ることができる。
【0094】また、発信者が、情報を出力すべきファクシミリ装置の電話番号を、ＰＨＰ端末３から基地局２を経由してセンタ装置１０に送信し、センタ装置１０が、発信者から指定された番号のファクシミリ装置に、道案内情報を送信するようにしてもよい。
【0095】実施例(12)によれば、発信者は道案内情報をファクシミリ情報として受け取ることができるので、道案内情報の入手がより容易になる。
【0096】図２５は、本発明の実施例(13)を示したものであって、道案内情報提供サービスにおいて発信者のアクセス権のチェックを行う場合の構成を示している。図３におけると同じものを同じ番号で示し、センタ装置１０において、１５はＰＨＰ端末ごとにアクセス権を予

め登録したアクセス権登録部である。また図２６は、実施例(13)における各部の動作を説明するシーケンス図であって、(a) はアクセス権がない場合を示し、(b) はアクセス権がある場合を示している。

【００９７】本実施例における、道案内情報提供時の動作は、次のようにして行われる。
(1) 発信者は、ＰＨＰ端末３を介して、基地局２を経由してセンタ装置１０を呼び出す。基地局２は、ＰＨＰ端末３からの着呼要求とともに、発信者番号（ＰＨＰ端末３の電話番号）をセンタ装置１０に送信する。
(2) センタ装置１０は、基地局２から着呼要求とともに通知された発信者番号をもとに、アクセス権登録部１５を検索して、ＰＨＰ端末３のアクセス権をチェックし、もしもアクセス権がなければ着信を拒否する。

【００９８】(3) ＰＨＰ端末３がアクセス権を有していれば、センタ装置１０は着信を受付け、基地局２に応答を送信する。
(4) 基地局２は、ＰＨＰ端末３の位置情報（ＰＨＰ端末がどの基地局のサービスエリアにいるかを示す情報）を、センタ装置１０に送信する。

【００９９】(5) センタ装置１０は、基地局２から送信されたＰＨＰ端末３の位置情報を、ＰＨＰ端末番号ごとに登録する。
(6) 発信者は、目的地情報を、ＰＨＰ端末３から、ＰＢ信号または制御信号によって、基地局２を経由してセンタ装置１０に送信する。

【０１００】(7) センタ装置１０は、基地局２を経由して受信した目的地情報と登録した発信者の位置情報とをキーとして、データベース１１－１を検索して、対応するデータ、すなわちＰＨＰ端末３の位置から目的地までの最適な道案内情報を、音声でＰＨＰ端末３に送信する。
(8) このようにして、発信者は、アクセス権がある場合のみセンタ装置１０に着信し、自局の位置から目的地までの、最適な道案内情報を受け取ることができる。

【０１０１】実施例(13)によれば、発信者のアクセス権をチェックしてから道案内情報を提供するので、不正な道案内情報の提供が行われることを防止できる。

【０１０２】図２７は、本発明の実施例(14)を示したものであって、道案内情報提供サービスにおいて情報ごとのアクセス権のチェックを行う場合の構成を示している。図２５におけると同じものを同じ番号で示し、センタ装置１０において、１５はＰＨＰ端末ごとに各情報ごとのアクセス権を予め登録したアクセス権登録部である。また図２８は、実施例(14)における各部の動作を説明するシーケンス図であって、(a) はアクセス権がない場合を示し、(b) はアクセス権がある場合を示している。

【０１０３】本実施例における、道案内情報提供時の動作は、次のようにして行われる。
(1) 発信者は、ＰＨＰ端末３を介して、基地局２を経由してセンタ装置１０を呼び出す。
(2) 基地局２は、ＰＨＰ端末３の位置情報（ＰＨＰ端末がどの基地局のサービスエリアにいるかを示す情報）を、センタ装置１０に送信する。

【０１０４】(3) センタ装置１０は、基地局２から送信されたＰＨＰ端末３の位置情報を、ＰＨＰ端末番号ごとに登録する。
(4) 発信者は、目的地情報を、ＰＨＰ端末３から、ＰＢ信号または制御信号によって、基地局２を経由してセンタ装置１０に送信する。

【０１０５】(5) センタ装置１０は、アクセス権登録部１５を検索して、ＰＨＰ端末３のその情報に対するアクセス権をチェックする。もしもアクセス権がないときは、サービスを利用できない旨をＰＨＰ端末３に通知する。
(6) センタ装置１０は、もしもＰＨＰ端末３にアクセス権があれば、基地局２を経由して受信した目的地情報と登録した発信者の位置情報とをキーとして、データベース１１－１を検索して、対応するデータ、すなわちＰＨＰ端末３の位置から目的地までの最適な道案内情報を、音声でＰＨＰ端末３に送信する。

【０１０６】(7) このようにして、発信者は、アクセス権がある場合のみ、自局の位置から目的地までの、最適な道案内情報を受け取ることができる。

【０１０７】実施例(14)によれば、発信者の情報ごとのアクセス権をチェックしてから道案内情報を提供するので、不正な道案内情報の提供が行われることを防止できる。

【０１０８】さらに、アクセス登録部１５に、ＰＨＰ端末ごとに各案内情報に対するアクセス権のほかにパスワードを登録しておき、(4) のステップでサービスメニュー番号とともにパスワードを送信することによって、センタ装置１０が、アクセス権のチェックと合わせてパスワードもチェックするようにしてもよい。

【０１０９】また、アクセス権登録部１５を設けないで、(4) のステップでサービスメニュー番号とともに特定の人だけが知っているパスワードを送信し、センタ装置１０が、パスワードをチェックすることによって、アクセス権をチェックするようにしてもよい。

【０１１０】図２９は、本発明の実施例(15)を示したものであって、道案内情報提供サービスにおいてパスワードによるアクセス権のチェックを行う場合の構成を示している。図３におけると同じものを同じ番号で示し、センタ装置１０において、１５はＰＨＰ端末ごとのアクセス権とともにパスワードを予め登録したアクセス権登録部である。また図３０は、実施例(15)における各部の動作を説明するシーケンス図であって、(a) はアクセス権がない場合を示し、(b) はアクセス権がある場合を示している。

【０１１１】本実施例における、道案内情報提供時の動作は、次のようにして行われる。
(1) 発信者は、ＰＨＰ端末３を介して、基地局２を経由してセンタ装置１０を呼び出す。
(2) 基地局２は、ＰＨＰ端末３の位置情報（ＰＨＰ端末がどの基地局のサービスエリアにいるかを示す情報）を、センタ装置１０に送信する。

【０１１２】(3) センタ装置１０は、基地局２から受信したＰＨＰ端末３の位置情報を、ＰＨＰ端末番号ごとに登録する。
(4) センタ装置１０は、ＰＨＰ端末３に対して、パスワードを入力するように、音声で通知する。

【０１１３】(5) 発信者は、パスワードを、ＰＨＰ端末３から、ＰＢ信号または制御信号によって、基地局２を経由してセンタ装置１０に送信する。

【０１１４】(6) センタ装置１０は、アクセス権登録部１５を検索し、ＰＨＰ端末３から送信されたパスワードをチェックし、もしもパスワードが正しくなければ、その旨をＰＨＰ端末３に通知する。

【０１１５】(7) センタ装置１０は、パスワードが正しければ、ＰＨＰ端末３に対して、目的地情報を入力するように、音声で通知する。
(8) 発信者は、目的地情報を、ＰＨＰ端末３から、ＰＢ信号または制御信号によって、基地局２を経由してセンタ装置１０へ送る。

【０１１６】(9) センタ装置１０は、基地局２を経由して受信した目的地情報と登録した発信者の位置情報とをキーとして、データベース１１－１を検索して、対応するデータ、すなわちＰＨＰ端末３の位置から目的地までの最適な道案内情報を、音声でＰＨＰ端末３に送信する。
(10) このようにして、発信者は、パスワードが正しい場合のみ、自局の位置から目的地までの、最適な道案内情報を受け取ることができる。

【０１１７】本実施例では、ＰＨＰ端末ごとにパスワードを設定したが、ＰＨＰ端末ごとにかつ情報ごとにパスワードを設定し、ＰＨＰ端末ごとにかつ情報ごとにパスワードをチェックするようにすることも可能である。

【０１１８】実施例(15)によれば、発信者のパスワードをチェックしてから、道案内情報を提供するので、不正な道案内情報の提供が行われることを防止できる。

【０１１９】図３１は、本発明の実施例(16)を示したものであって、道案内情報提供サービスにおいて、ＩＣカード，フロッピーディスクまたはＣＤ－ＲＯＭを利用して、アクセス権のチェックを行う場合の構成を示している。図１９におけると同じものを同じ番号で示し、センタ装置１０において、１５はＰＨＰ端末ごとのアクセス権とともにパスワードを予め登録したアクセス権登録部である。また図３２は、実施例(16)における各部の動作を説明するシーケンス図である。

【０１２０】本実施例における、道案内情報提供時の動作は、次のようにして行われる。この際、ＩＣカード，フロッピーディスクまたはＣＤ－ＲＯＭには、予め特別な情報（パスワード）が書き込まれているものとする。
(1) 発信者は、ＰＨＰ端末６を介して、基地局２を経由してセンタ装置１０を呼び出す。
(2) 基地局２は、ＰＨＰ端末６の位置情報（ＰＨＰ端末がどの基地局のサービスエリアにいるかを示す情報）を、センタ装置１０に送信する。

【０１２１】(3) センタ装置１０は、基地局２から受信したＰＨＰ端末６の位置情報を、ＰＨＰ端末ごとに登録する。
(4) 発信者は、ＰＨＰ端末６を操作して、ＩＣカード，フロッピーディスクまたはＣＤ－ＲＯＭに予め書き込まれている特別な情報（パスワード）を、基地局２を経由してセンタ装置１０に送信する。

【０１２２】(5) センタ装置１０は、アクセス権登録部１５を検索し、ＰＨＰ端末６から送信されたパスワードをチェックする。
(6) 発信者は、目的地情報を、ＰＨＰ端末６から、ＰＢ信号または制御信号によって、基地局２を経由してセンタ装置１０へ送る。

【０１２３】(7) センタ装置１０は、基地局２を経由して受信した目的地情報と登録した発信者の位置情報とをキーとして、データベース１１－１を検索して、対応するデータ、すなわちＰＨＰ端末６の位置から目的地までの最適な道案内情報を、音声または文字または画像でＰＨＰ端末６に送信する。
(8) このようにして、発信者は、特別な情報（パスワード）が書き込まれたＩＣカード，フロッピーディスクまたはＣＤ－ＲＯＭを所有している場合のみ、自局の位置から目的地までの、最適な道案内情報を受け取ることができる。

【０１２４】実施例(16)によれば、特別な情報（パスワード）が書き込まれたＩＣカード，フロッピーディスクまたはＣＤ－ＲＯＭを所有している場合のみ、道案内情報の提供を受けることができるので、不正な道案内情報の提供が行われることを防止できる。

【０１２５】図３３は、本発明の実施例(17)を示したものであって、道案内情報提供サービスにおいて、ＩＣカード，フロッピーディスクまたはＣＤ－ＲＯＭを利用して、料金割引サービスを行う場合の構成を示している。図３１におけると同じものを同じ番号で示し、センタ装置１０において、１８は利用料金の管理を行う料金管理部である。また図３４は、実施例(17)における各部の動作を説明するシーケンス図である。

【０１２６】本実施例における、道案内情報提供時の動作は、次のようにして行われる。この際、ＩＣカード，フロッピーディスクまたはＣＤ－ＲＯＭには、予め特別な情報（料金割引権を示す）が書き込まれているものと

する。
(1) 発信者は、ＰＨＰ端末６を介して、基地局２を経由してセンタ装置１０を呼び出す。
(2) 基地局２は、ＰＨＰ端末６の位置情報（ＰＨＰ端末がどの基地局のサービスエリアにいるかを示す情報）を、センタ装置１０に送信する。
【０１２７】(3) センタ装置１０は、基地局２から受信したＰＨＰ端末６の位置情報を、ＰＨＰ端末ごとに登録する。
(4) 発信者は、ＰＨＰ端末６を操作して、ＩＣカード，フロッピーディスクまたはＣＤ－ＲＯＭに予め書き込まれている特別な情報（料金割引権を示す）を、基地局２を経由してセンタ装置１０に送信する。
【０１２８】(5) センタ装置１０は、特別な情報を認識して、料金を割り引く旨を料金管理部１８に通知する。
(6) 発信者は、目的地情報を、ＰＨＰ端末６から、ＰＢ信号または制御信号によって、基地局２を経由してセンタ装置１０へ送る。
【０１２９】(7) センタ装置１０は、基地局２を経由して受信した目的地情報と登録した発信者の位置情報とをキーとして、データベース１１－１を検索して、対応するデータ、すなわちＰＨＰ端末６の位置から目的地までの最適な道案内情報を、音声または文字または画像でＰＨＰ端末６に送信する。
(8) このようにして、発信者は、割引料金で、自局の位置から目的地までの、最適な道案内情報を受け取ることができる。
【０１３０】実施例(17)によれば、料金割引権を示す特別な情報が書き込まれたＩＣカード，フロッピーディスクまたはＣＤ－ＲＯＭを所有していることによって、割引料金で道案内情報を提供されるという、特別の利益を受けることができるようになる。
【０１３１】図３５は、本発明の実施例(18)を示したものであって、位置検索サービスを実現する構成を示している。図3におけると同じものを同じ番号で示し、２－１，２－２は無線基地局（以下単に基地局という）、３－１，３－２はそれぞれ基地局２－１，２－２のサービスエリア（点線で示す）内に存在するＰＨＰ端末である。センタ装置１０において、１３はＰＨＰ端末の位置情報を登録する位置情報登録部である。また図３６は、実施例(18)における各部の動作を説明するシーケンス図である。
【０１３２】本実施例における、位置検索サービス時の動作は、次のようにして行われる。
(1) ＰＨＰ端末３－１を持つ発信者Ａは、定期的に自局の位置情報をセンタ装置１０に送信する。例えば発信者Ａが、基地局２－１のゾーンである(a) 地点にいて、自局の位置情報をセンタ装置１０に送信したとする。
(2) センタ装置１０は、位置情報登録部１３のＰＨＰ端末３－１対応部分に、(a) 地点（基地局２－１）の位置情報を登録する。
【０１３３】(3) ＰＨＰ端末３－２を持つ発信者Ｂは、発信者Ａの位置を検索するためにセンタ装置１０にアクセスし、位置検索サービスコードと、発信者Ａが持つＰＨＰ端末３－１の電話番号を、ＰＨＰ端末３－２から、ＰＢ信号または制御信号によって、基地局２－２を経由してセンタ装置１０へ送る。
(4) センタ装置１０は、位置情報登録部１３を検索して、ＰＨＰ端末３－１対応の位置情報を、音声でＰＨＰ端末３－２へ送信する。
【０１３４】実施例(18)によれば、ＰＨＰ端末の位置情報を定期的にセンタ装置に登録することによって、このＰＨＰ端末の位置を、他のＰＨＰ端末が検索することができるようになる。
【０１３５】図３７は、本発明の実施例(19)を示したものであって、簡易端末の位置検索サービスを実現する構成を示している。図３５におけると同じものを同じ番号で示し、４は基地局２－１のサービスエリア（点線で示す）内に存在する簡易端末であって、定期的に位置情報をセンタ装置１０に自動送信する機能を有している。また図３８は、実施例(19)における各部の動作を説明するシーケンス図である。
【０１３６】本実施例における、位置検索サービス時の動作は、次のようにして行われる。
(1) 簡易端末４を持つ発信者Ａは、定期的に自局の位置情報をセンタ装置１０に送信する。例えば発信者Ａが、基地局２－１のゾーンである(a) 地点にいて、自局の位置情報をセンタ装置１０に送信したとする。
(2) センタ装置１０は、位置情報登録部１３の簡易端末４対応部分に、(a) 地点（基地局２－１）の位置情報を登録する。
【０１３７】(3) ＰＨＰ端末３－２を持つ発信者Ｂは、発信者Ａの位置を検索するためにセンタ装置１０にアクセスし、位置検索サービスコードと、発信者Ａが持つ簡易端末４の電話番号を、ＰＨＰ端末３－２から、ＰＢ信号または制御信号によって、基地局２－２を経由してセンタ装置１０へ送る。
(4) センタ装置１０は、位置情報登録部１３を検索して、簡易端末４対応の位置情報を、音声でＰＨＰ端末３－２へ送信する。
【０１３８】実施例(19)によれば、簡易端末の位置情報を定期的にセンタ装置に登録することによって、簡易端末の位置を、ＰＨＰ端末が検索することができるようになる。
【０１３９】図３９は、本発明の実施例(20)を示したものであって、位置検索サービスにおける検索権のチェックを行う場合の構成を示している。図３５におけると同じものを同じ番号で示し、センタ装置１０において、１６はＰＨＰ端末相互間の検索権を登録する検索権登録部である。また図４０は、実施例(20)における各部の動作

を説明するシーケンス図であって、(a) は検索権がある場合を示し、(b) は検索権がない場合を示している。

【０１４０】本実施例における、位置検索サービス時の検索権チェックの動作は、次のようにして行われる。

(1) ＰＨＰ端末３－１を持つ発信者Ａは、定期的に自局の位置情報をセンタ装置１０に送信する。例えば発信者Ａが、基地局２－１のゾーンである(a) 地点にいて、自局の位置情報をセンタ装置１０に送信したとする。

(2) センタ装置１０は、位置情報登録部１３のＰＨＰ端末３－１対応部分に、(a) 地点（基地局２－１）の位置情報を登録する。

【０１４１】(3) ＰＨＰ端末３－２を持つ発信者Ｂは、発信者Ａの位置を検索するためにセンタ装置１０にアクセスし、位置検索サービスコードと、発信者Ａが持つＰＨＰ端末３－１の電話番号を、ＰＨＰ端末３－２から、ＰＢ信号または制御信号によって、基地局２－２を経由してセンタ装置１０へ送る。

(4) センタ装置１０は、検索権登録部１６を検索し、ＰＨＰ端末３－２が、ＰＨＰ端末３－１の位置を検索する検索権を持つか否かをチェックする。そして検索権があれば、位置情報登録部１３を検索して、ＰＨＰ端末３－１対応の位置情報を、音声でＰＨＰ端末３－２へ送信する。

【０１４２】(5) センタ装置１０は、もしもＰＨＰ端末３－２が、ＰＨＰ端末３－１の位置を検索するための検索権を有しないときは、検索できない旨をＰＨＰ端末３－２に音声で通知する。

【０１４３】実施例(20)によれば、ＰＨＰ端末相互間の位置検索権をチェックしてから、ＰＨＰ端末の位置検索を行うので、ＰＨＰ端末が不正に他のＰＨＰ端末の位置検索を行うことを防止できる。

【０１４４】なお、各実施例についての上述の説明は、ＰＨＰ端末の場合について行ったが、本発明の情報提供サービス方式は、ＰＨＰシステムに限るものでなく、他の移動通信システム全般についても適用可能なものである。

【０１４５】

【発明の効果】以上説明したように本発明によれば、ＰＨＰ端末を利用した情報提供サービスにおいて、発信者の位置情報と、発信者の希望する目的地とによって、最適な道案内情報をセンタ装置から発信者に提供することが可能になる。

【０１４６】これによって、発信者の位置に応じて最適な店舗案内，観光地案内等のサービスを提供することができる。また他のＰＨＰ端末の位置を検索するサービスを提供することもできる。

【図面の簡単な説明】

【図１】本発明の原理的構成を示す図である。

【図２】本発明の原理を説明するシーケンス図である。

【図３】本発明の実施例(1) を示す図である。

【図４】実施例(1) における各部の動作を説明するシーケンス図である。

【図５】本発明の実施例(2) を示す図である。

【図６】本発明の実施例(3) を示す図である。

【図７】本発明の実施例(4) を示す図である。

【図８】実施例(4) における各部の動作を説明するシーケンス図である。

【図９】本発明の実施例(5) を示す図である。

【図１０】実施例(5) における各部の動作を説明するシーケンス図である。

【図１１】本発明の実施例(6) を示す図である。

【図１２】実施例(6) における各部の動作を説明するシーケンス図である。

【図１３】本発明の実施例(7) を示す図である。

【図１４】実施例(7) における各部の動作を説明するシーケンス図である。

【図１５】本発明の実施例(8) を示す図である。

【図１６】実施例(8) における各部の動作を説明するシーケンス図である。

【図１７】本発明の実施例(9) を示す図である。

【図１８】実施例(9) における各部の動作を説明するシーケンス図である。

【図１９】本発明の実施例(10)を示す図である。

【図２０】実施例(10)における各部の動作を説明するシーケンス図である。

【図２１】本発明の実施例(11)を示す図である。

【図２２】実施例(11)における各部の動作を説明するシーケンス図である。

【図２３】本発明の実施例(12)を示す図である。

【図２４】実施例(12)における各部の動作を説明するシーケンス図である。

【図２５】本発明の実施例(13)を示す図である。

【図２６】実施例(13)における各部の動作を説明するシーケンス図であって、(a) はアクセス権がない場合を示し、(b) はアクセス権がある場合を示す。

【図２７】本発明の実施例(14)を示す図である。

【図２８】実施例(14)における各部の動作を説明するシーケンス図であって、(a) はアクセス権がない場合を示し、(b) はアクセス権がある場合を示す。

【図２９】本発明の実施例(15)を示す図である。

【図３０】実施例(15)における各部の動作を説明するシーケンス図であって、(a) はアクセス権がない場合を示し、(b) はアクセス権がある場合を示す。

【図３１】本発明の実施例(16)を示す図である。

【図３２】実施例(16)における各部の動作を説明するシーケンス図である。

【図３３】本発明の実施例(17)を示す図である。

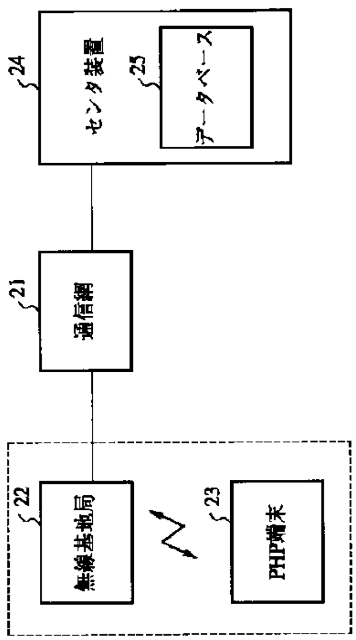
【図３４】実施例(17)における各部の動作を説明するシーケンス図である。

【図３５】本発明の実施例(18)を示す図である。

【図３６】実施例(18)における各部の動作を説明するシーケンス図である。
【図３７】本発明の実施例(19)を示す図である。
【図３８】実施例(19)における各部の動作を説明するシーケンス図である。
【図３９】本発明の実施例(20)を示す図である。
【図４０】実施例(20)における各部の動作を説明するシーケンス図であって、(a) は検索権がある場合を示し、(b) は検索権がない場合を示す。
【符号の説明】
１　　公衆網
４　　簡易端末
７　　ファクシミリ装置
８　　構内交換機
１３　　位置情報登録部
１４　　音声認識装置
１５　　アクセス権登録部
１６　　検索権登録部
１７　　ＧＰＳ装置
１８　　料金管理部
２１　　通信網
２２　　無線基地局
２３　　ＰＨＰ端末
２４　　センタ装置
２５　　データベース
５１　　表示装置
６１　　ＩＣカード，フロッピー・ディスクまたはＣＤ－ＲＯＭ駆動装置

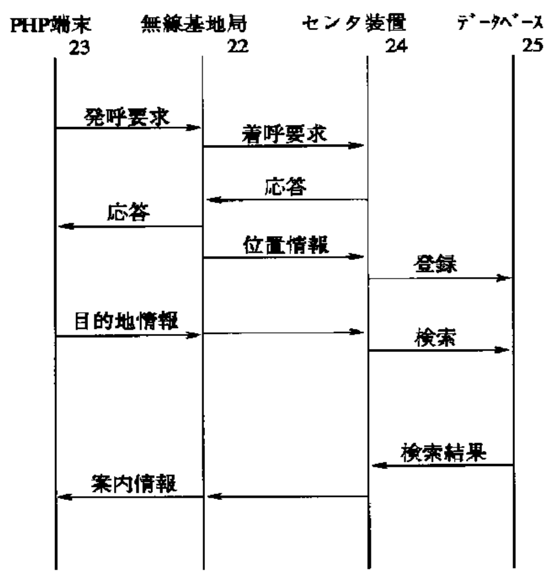
【図１】

本発明の原理的構成を示す図



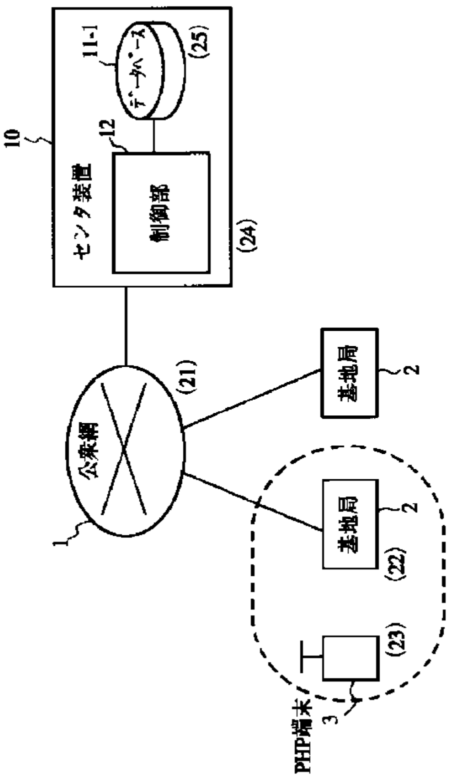
【図２】

本発明の原理を説明するシーケンス図



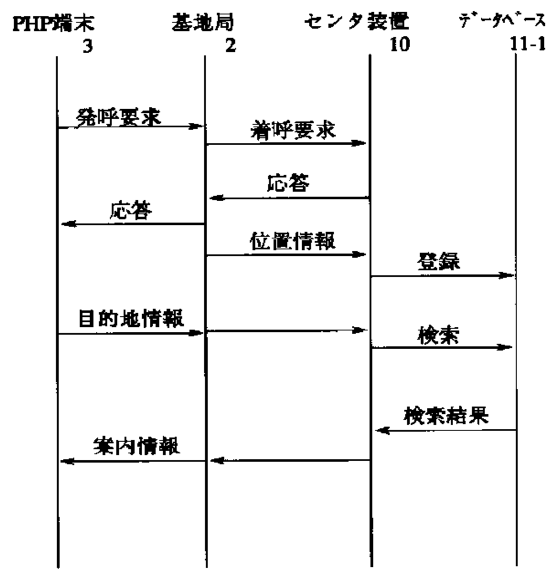
【図３】

本発明の実施例 (1)を示す図



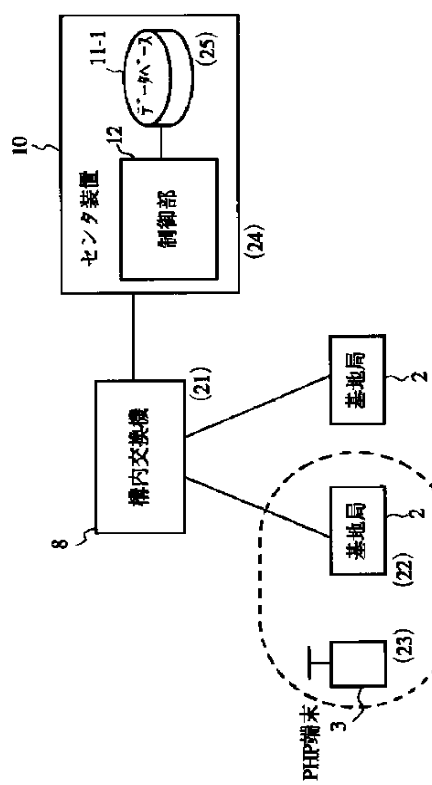
【図４】

実施例(1)における各部の動作を
説明するシーケンス図



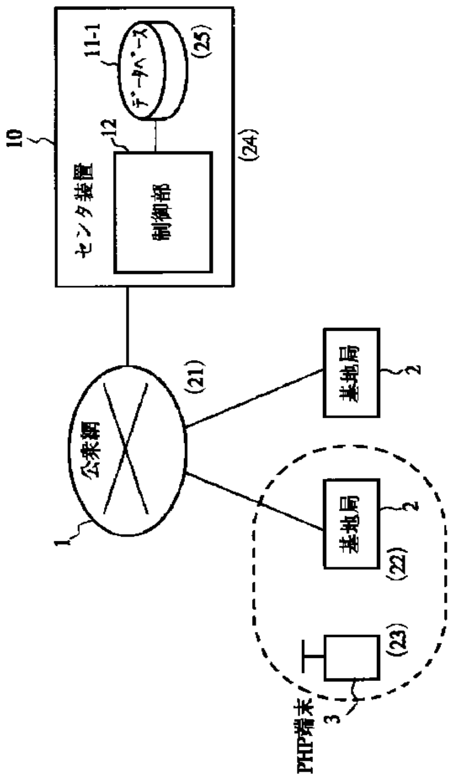
【図５】

本発明の実施例 (2)を示す図



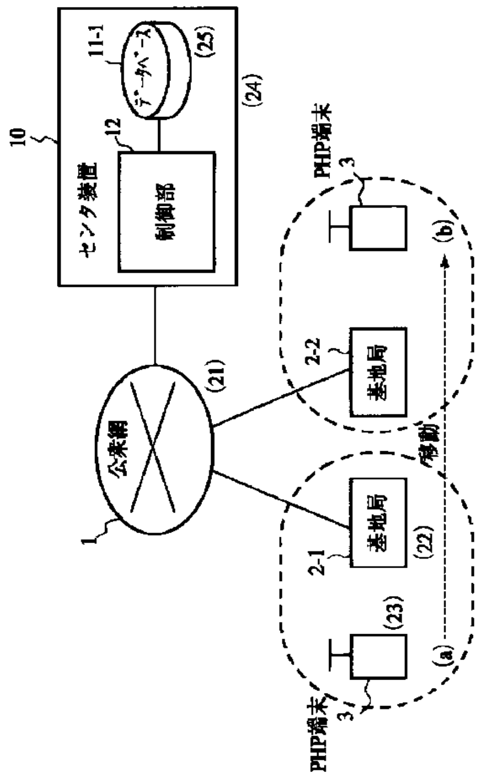
【図6】

本発明の実施例（3）を示す図



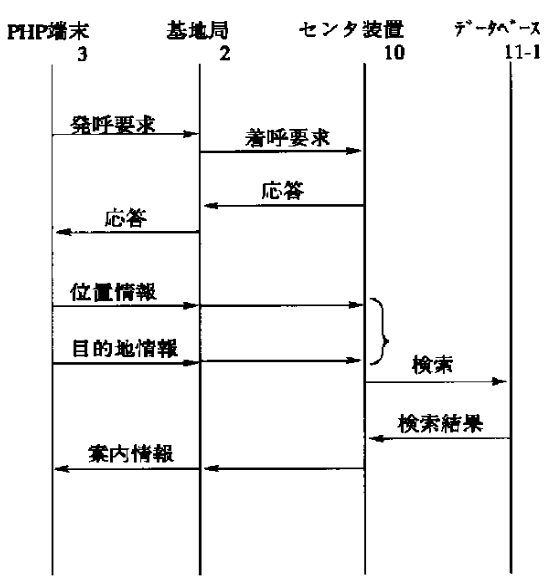
【図7】

本発明の実施例（4）を示す図



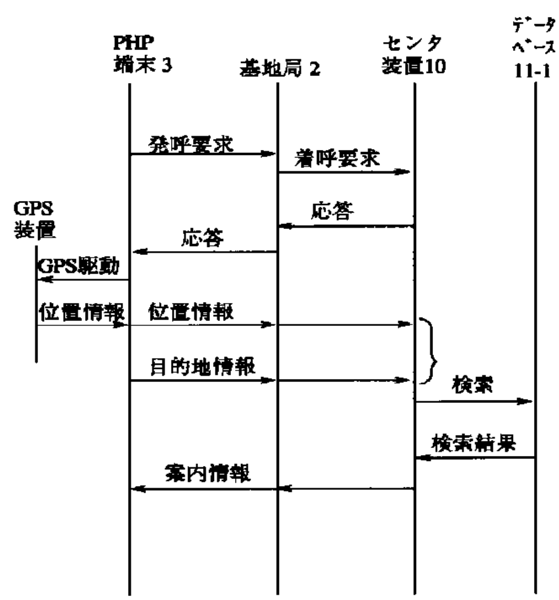
【図10】

実施例（5）における各部の動作を
説明するシーケンス図



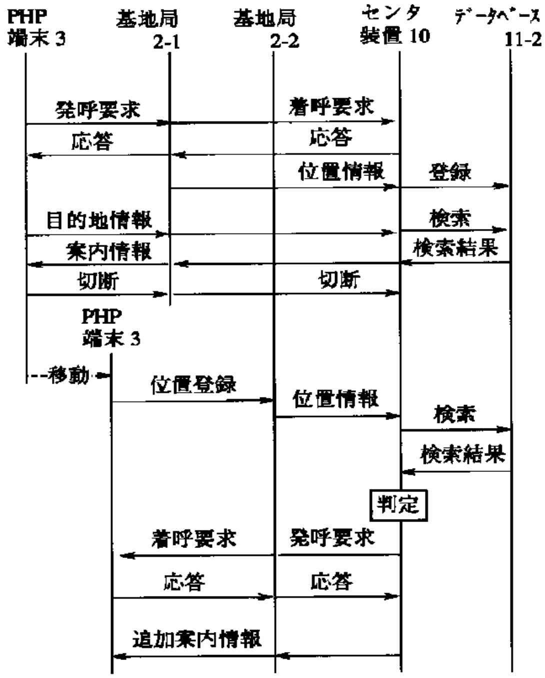
【図12】

実施例（6）における各部の動作を
説明するシーケンス図



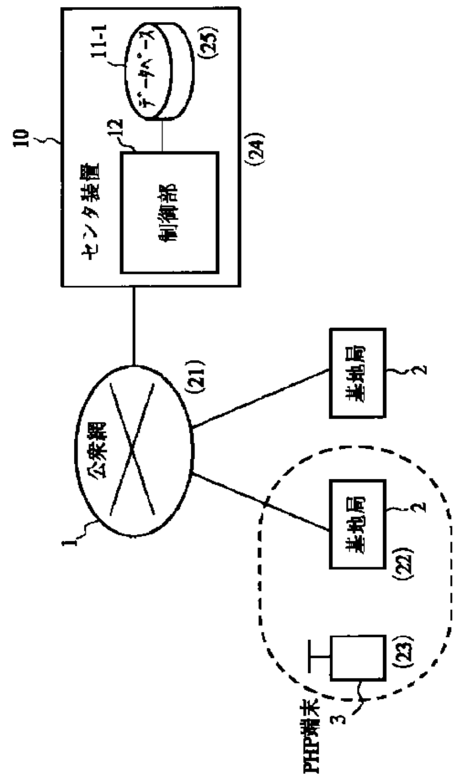
【図８】

実施例(4)における各部の動作を
説明するシーケンス図



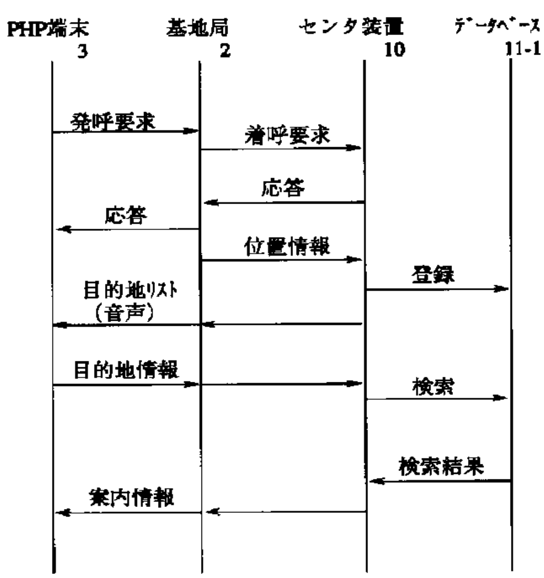
【図９】

本発明の実施例（5）を示す図



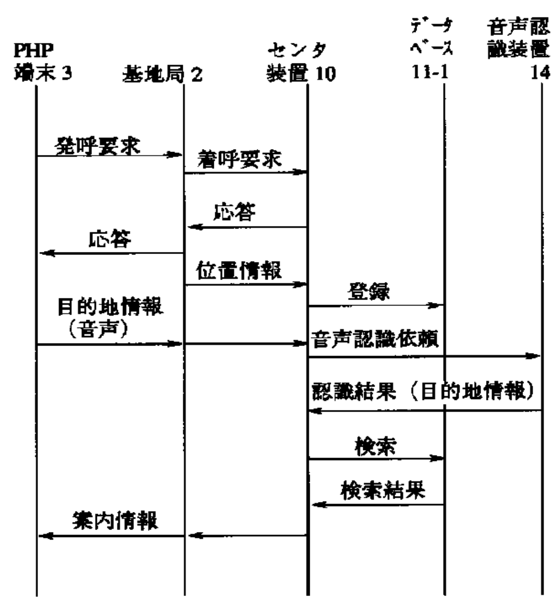
【図１４】

実施例(7)における各部の動作を
説明するシーケンス図



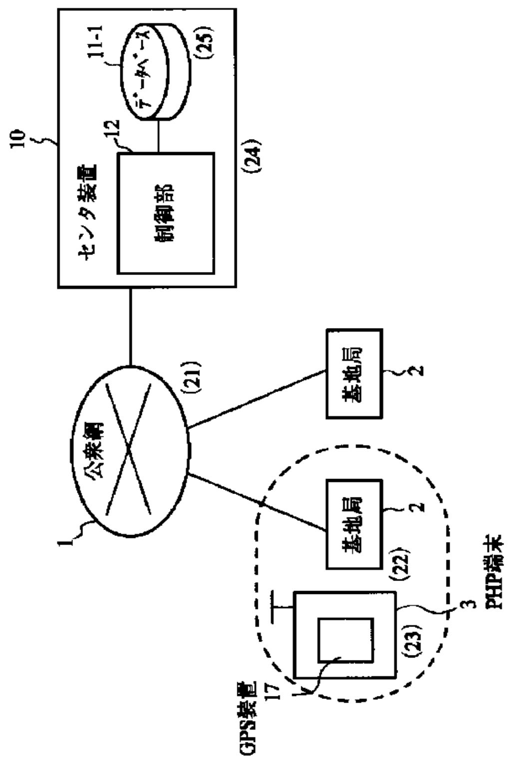
【図１６】

実施例(8)における各部の動作を
説明するシーケンス図



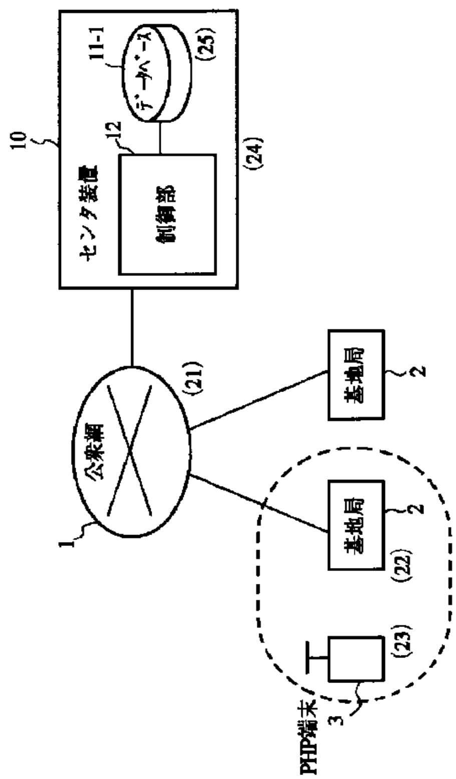
【図１１】

本発明の実施例(6)を示す図



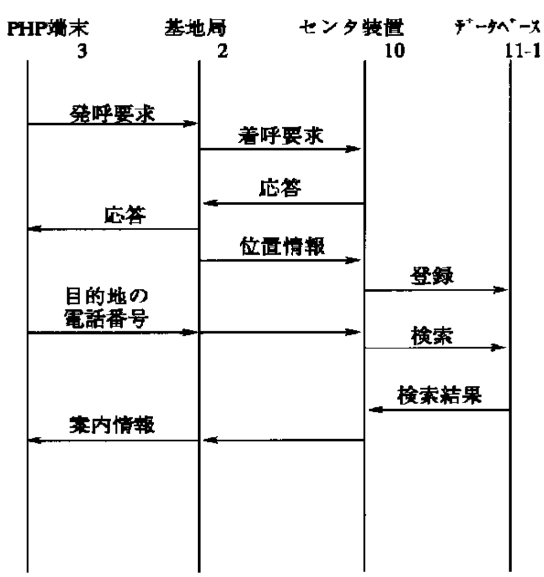
【図１３】

本発明の実施例(7)を示す図



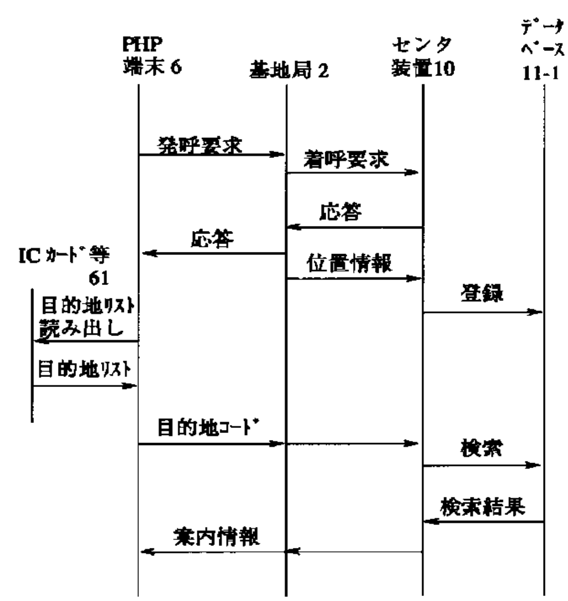
【図１８】

実施例(9)における各部の動作を説明するシーケンス図



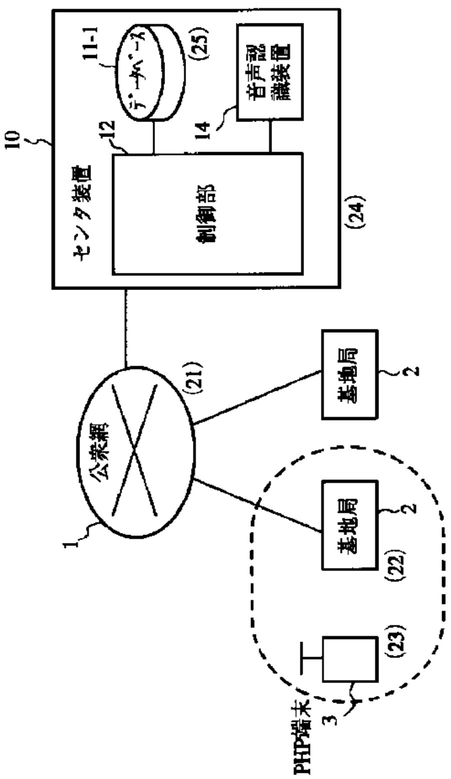
【図２０】

実施例(10)における各部の動作を説明するシーケンス図



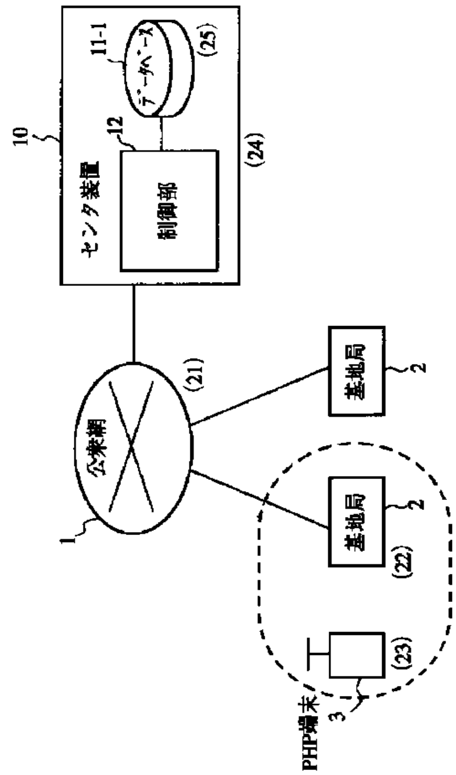
【図15】

本発明の実施例（8）を示す図



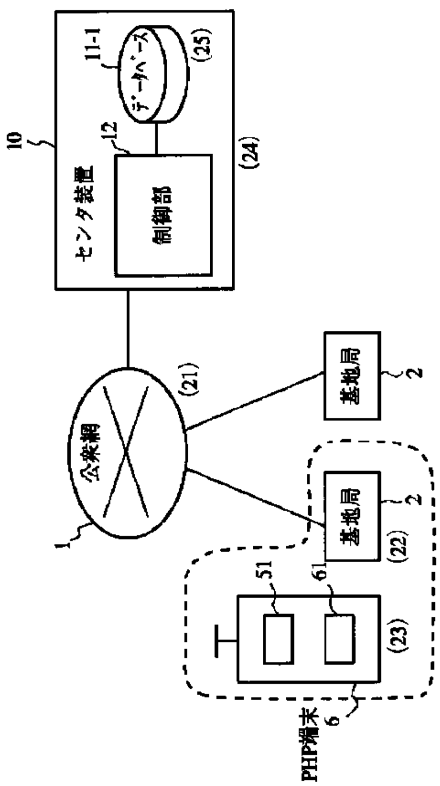
【図17】

本発明の実施例（9）を示す図



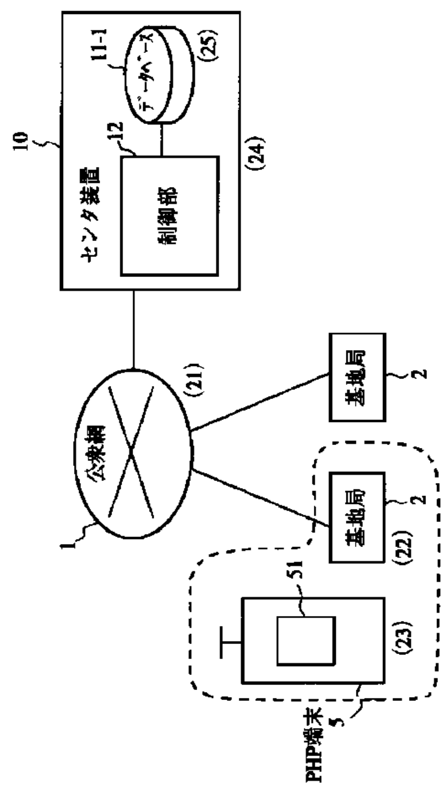
【図19】

本発明の実施例（10）を示す図



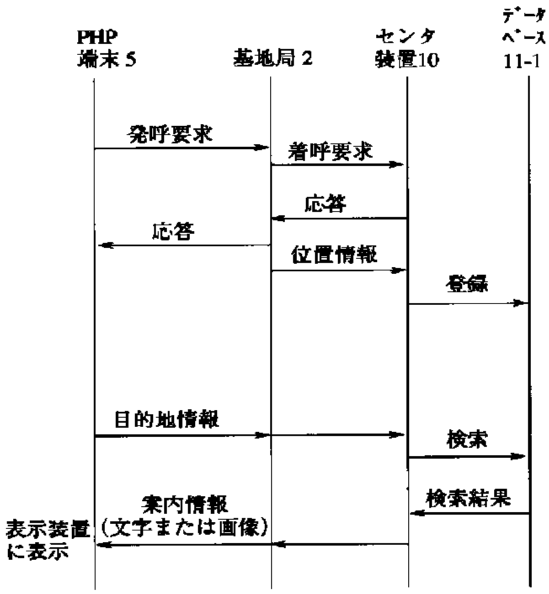
【図21】

本発明の実施例（11）を示す図



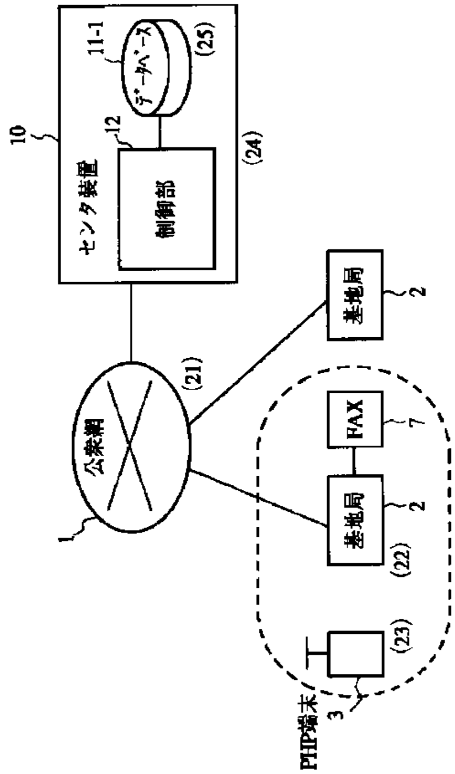
【図22】

実施例(11)における各部の動作を
説明するシーケンス図



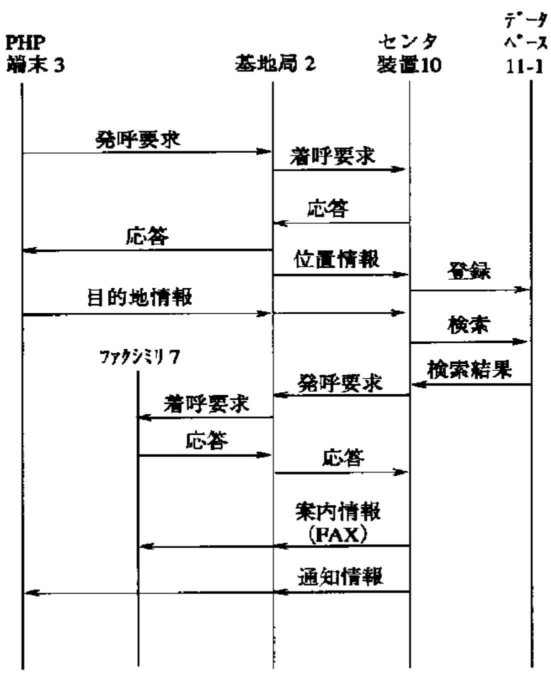
【図23】

本発明の実施例(12)を示す図



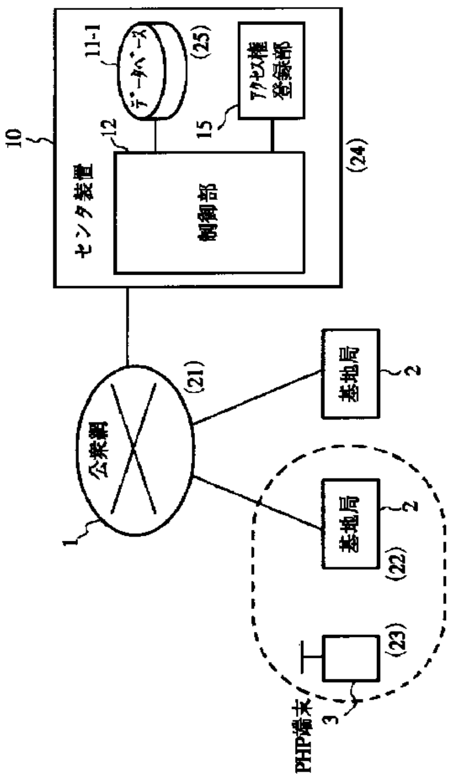
【図24】

実施例(12)における各部の動作を
説明するシーケンス図



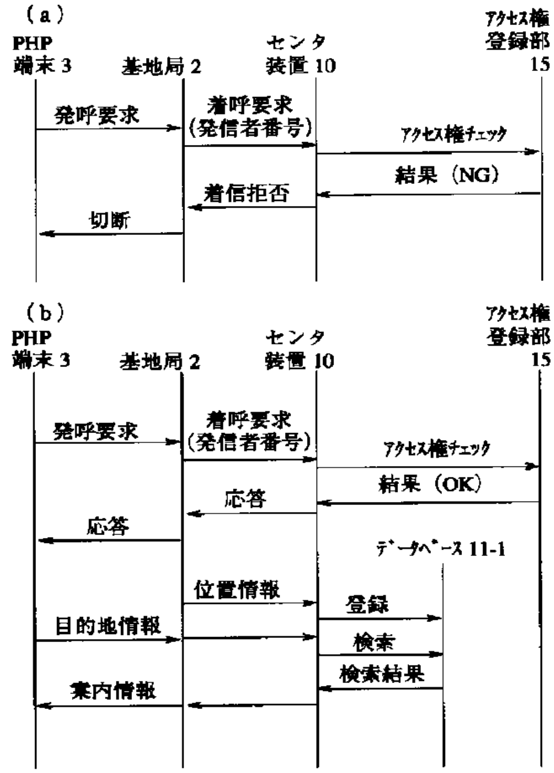
【図25】

本発明の実施例（13）を示す図



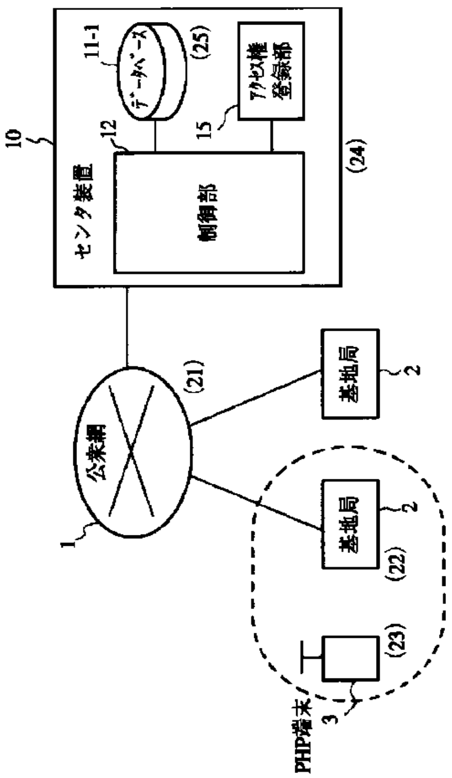
【図26】

実施例（13）における各部の動作を説明するシーケンス図



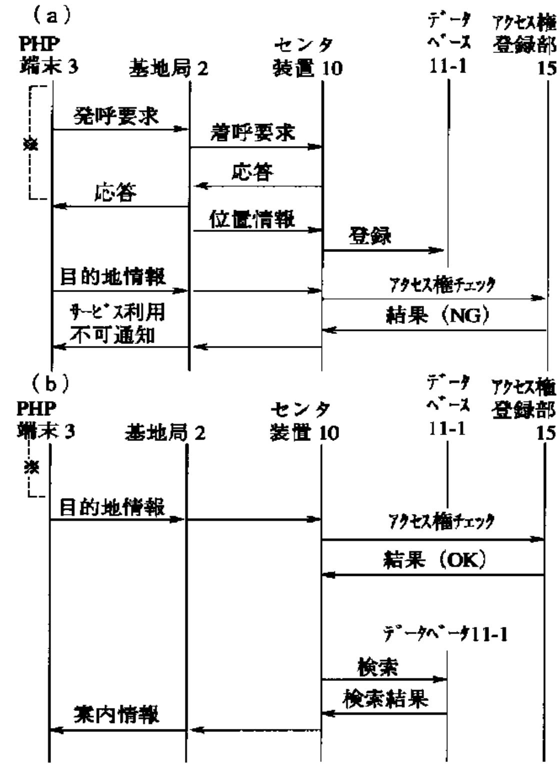
【図27】

本発明の実施例（14）を示す図



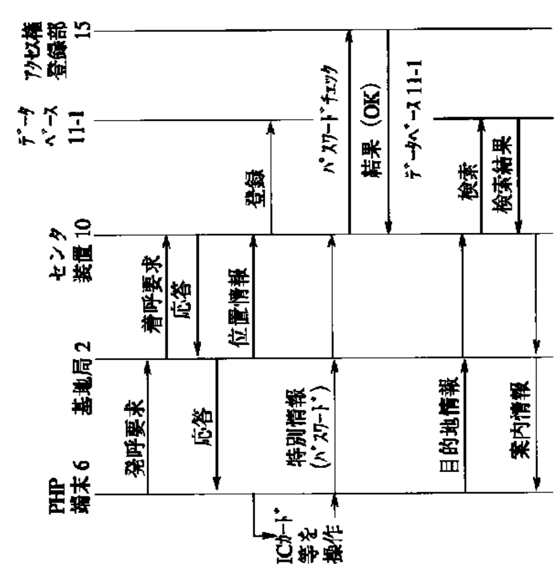
【図28】

実施例（14）における各部の動作を
説明するシーケンス図



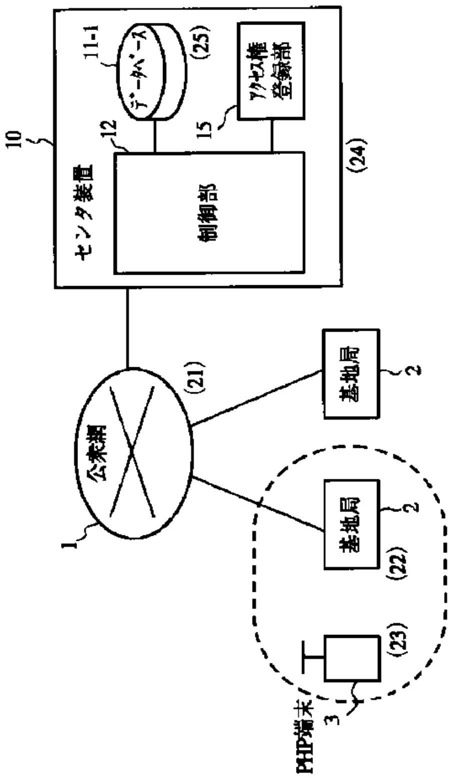
【図32】

実施例（16）における各部の動作を
説明するシーケンス図



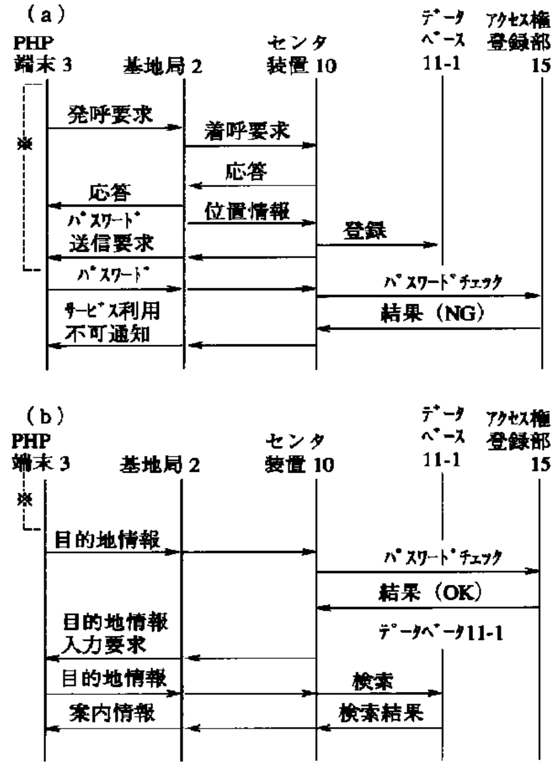
【図29】

本発明の実施例（15）を示す図



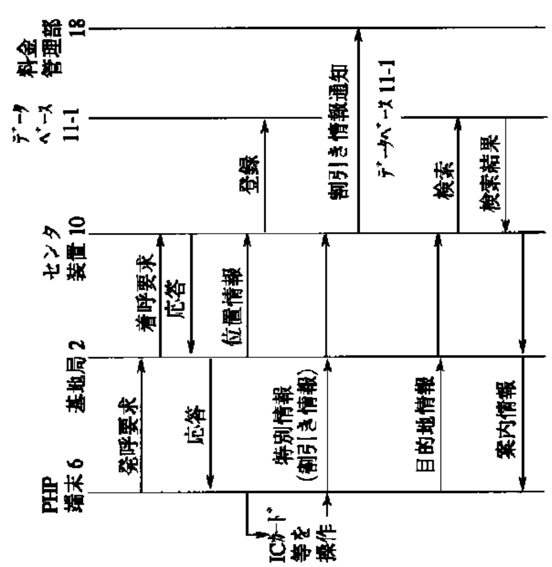
【図30】

実施例（15）における各部の動作を説明するシーケンス図



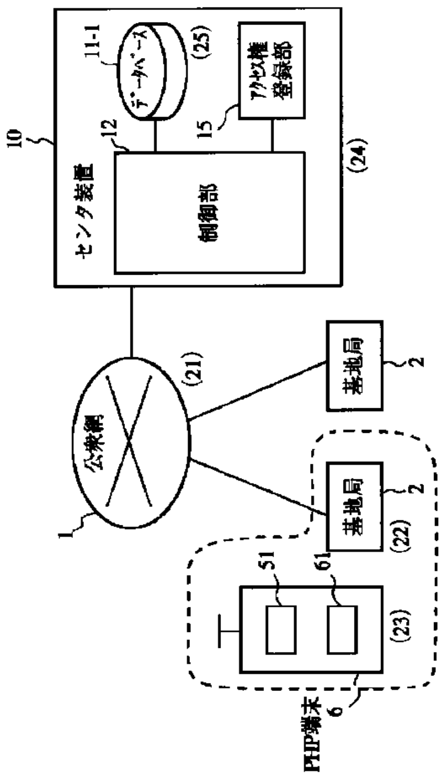
【図34】

実施例（17）における各部の動作を説明するシーケンス図



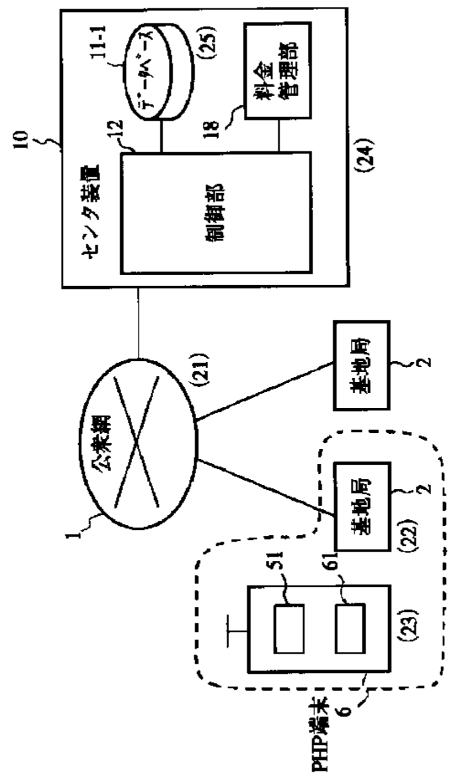
【図３１】

本発明の実施例（16）を示す図



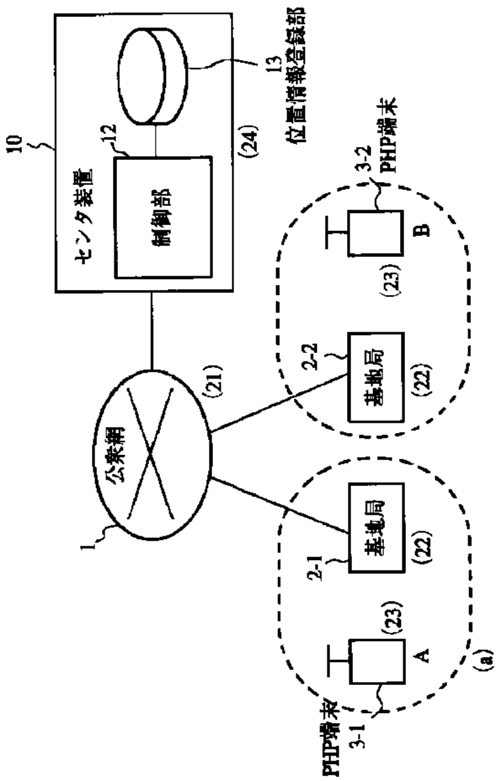
【図３３】

本発明の実施例（17）を示す図



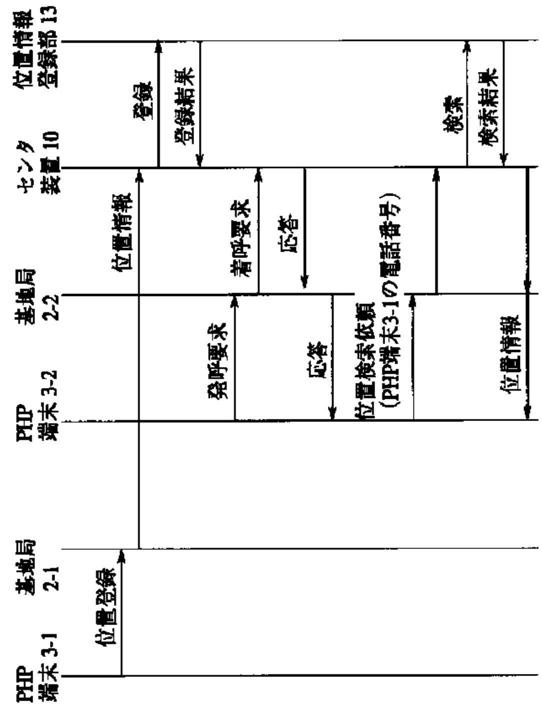
【図３５】

本発明の実施例（18）を示す図



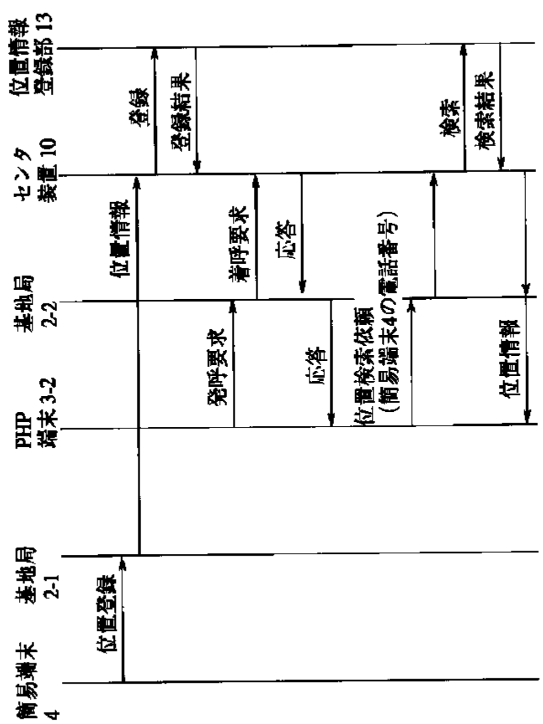
【図３６】

実施例（18）における各部の動作を説明するシーケンス図



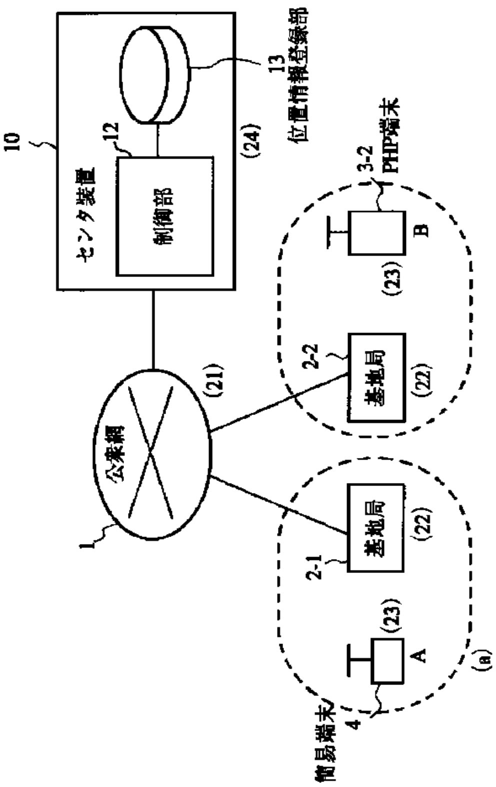
【図３８】

実施例（19）における各部の動作を説明するシーケンス図



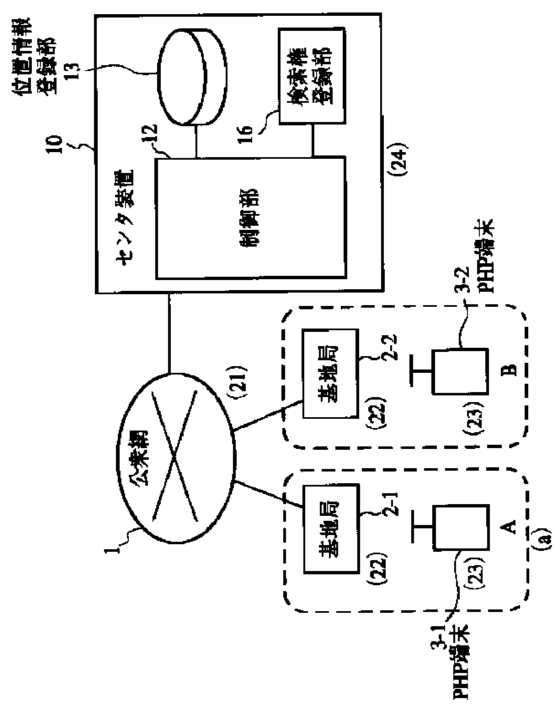
【図37】

本発明の実施例（19）を示す図



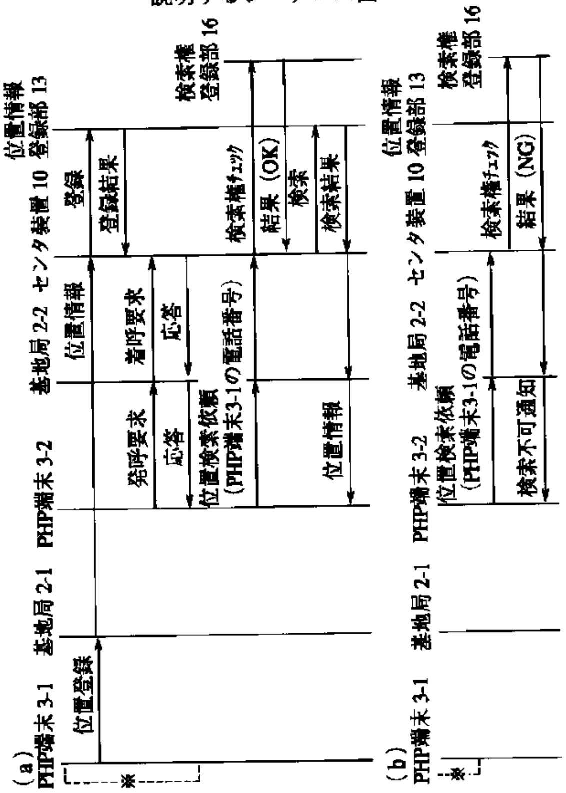
【図39】

本発明の実施例（20）を示す図



【図40】

実施例(20)における各部の動作を
説明するシーケンス図



Espacenet

Bibliographic data: JP2000091982 (A) — 2000-03-31

RADIO QUALITY DETERIORATION PREVENTING METHOD FOR CDMA MOBILE RADIO COMMUNICATION SYSTEM, AND CDMA MOBILE RADIO COMMUNICATION SYSTEM

Inventor(s): HATA HIDEO + (HATA HIDEO)

Applicant(s): NEC CORP + (NEC CORP)

Classification: - international: ***H04B17/00; H04B7/26; H04J13/00; H04W24/00; H04W24/04; H04W88/02;*** (IPC1-7): H04B17/00; H04B7/26; H04J13/00

- cooperative:

Application number: JP19980270501 19980909

Priority number(s): JP19980270501 19980909

Also published as: JP3549745 (B2)

Abstract of JP2000091982 (A)

PROBLEM TO BE SOLVED: To prevent the radio quality from deteriorating by continuously monitoring the output information of a mobile device and forcibly stopping the radio communication of faulty mobile device sending an abnormal output automatically or manually by a service engineer if the faulty mobile device is detected. SOLUTION: A base station controller 13 which has received mobile device fault detection alarm signals from base stations 12a to 12n transfers a message to base station maintenance controllers 14a to 14k. The base station maintenance controllers 14a to 14k sends a mobile device fault detection alarm report out to a total maintenance monitor device 19.; A base station position information data server 16 retrieves the position of specified base station information and a subscriber characteristic identification information data server 18 retrieves specified subscriber information from a data base and reports it to the total maintenance monitor device 19. After fault information is recorded, the total maintenance monitor device 19 sends a specific MS transmission indication instruction to the base station maintenance

controllers 14a to 14k under automatic control or manual control.

(19)日本国特許庁（ＪＰ）　　(12) **公開特許公報**（Ａ）　　(11)特許出願公開番号
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（P2000－91982A）
(43)公開日　平成12年３月31日(2000.3.31)

(51)Int.Cl.⁷	識別記号	ＦＩ		テーマコード*(参考)
Ｈ０４Ｂ　7/26		Ｈ０４Ｂ　7/26	Ｋ	５Ｋ０２２
17/00		17/00	Ｄ	５Ｋ０４２
Ｈ０４Ｊ　13/00		7/26	Ｓ	５Ｋ０６７
		Ｈ０４Ｊ　13/00	Ａ	

審査請求　有　　請求項の数11　ＦＤ　（全 11 頁）

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(22)出願日　平成10年９月９日(1998.9.9)

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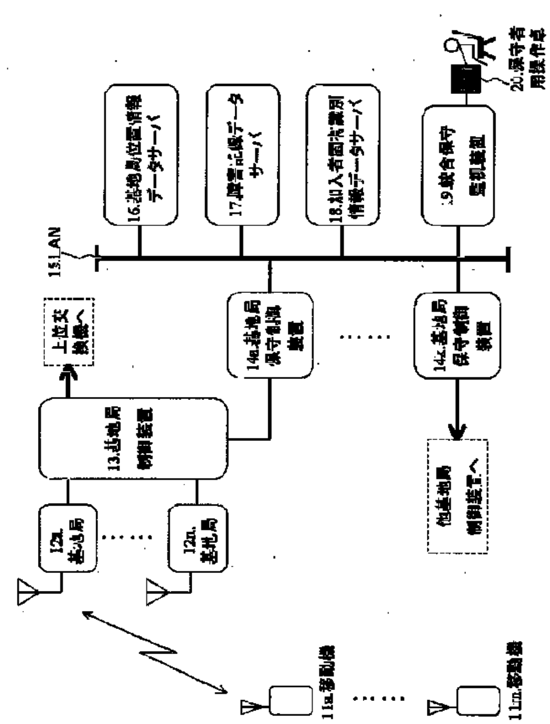
最終頁に続く

(54)【発明の名称】　ＣＤＭＡ移動無線通信システムにおける無線品質劣化防止方法及びＣＤＭＡ移動無線通信システム

(57)【要約】
【課題】無線送信出力最適制御機能が故障した移動機がシステム内に存在するかを常に監視し、存在した場合には故障移動機の送信出力を基地局が強制停止させ、システム内の無線品質の劣化を防止するＣＤＭＡ移動無線通信システムの無線品質劣化防止方法及びＣＤＭＡ移動無線通信システムを提供する点にある

【解決手段】図１に示すように、本実施の形態に係るＣＤＭＡ移動無線通信システムは、基地局制御装置１３と基地局１２ａ～１２ｎと基地局保守制御装置１４ａ～１４ｋと移動機１１ａ～１１ｍと基地局位置情報データサーバ１６と障害記録データサーバ１７と加入者固有識別情報データサーバ１８と統合保守監視装置１９とで概略構成される。



【特許請求の範囲】

【請求項１】　ＣＤＭＡ移動無線通信システムにおける無線品質劣化防止方法であって、
移動機の出力情報を継続して監視し、異常な出力を発している故障した移動機を検出した場合、
自動または保守者による手動制御により前記移動機の無線送信を強制的に停止させることを特徴とする、ＣＤＭＡ移動無線通信システムにおける無線品質劣化防止方法。

【請求項２】　基地局は、故障した前記移動機に対する送信停止指令を出し、
故障した前記移動機からの受信信号が停止したかを確認し、
故障した前記移動機からの受信信号の停止が確認できなかった時、故障した前記移動機の電波停止処理部の不具合により停波できない状態であると認識し、
前記基地局から故障している前記移動機に送信している電波を強制的に停止することを特徴とする請求項１記載の、ＣＤＭＡ移動無線通信システムにおける無線品質劣化防止方法。

【請求項３】　受信部は全移動機から送信された拡散信号をアンテナを介して受信し、
逆拡散部は受信された前記拡散信号を各移動機に割り当てられた拡散コードにより逆拡散処理し、
ＳＩＲ検出部にて各拡散コードに対するＳＩＲを検出し、
Ｅｂ／Ｉｏ算出部にて各移動機のＥｂ／Ｉｏを算出し、
誤差検出部は、前記ＳＩＲ又は前記Ｅｂ／Ｉｏと制御目標値との誤差を検出し、
移動機出力監視部は、前記誤差が許容範囲内であるか判定し、
一定時間以上に渡り前記誤差が許容範囲外を継続した場合に移動機の障害と判断し、
上位の基地局制御装置に移動機障害検出アラーム報告を送ることを特徴とする請求項１又は２に記載の、ＣＤＭＡ移動無線通信システムにおける無線品質劣化防止方法。

【請求項４】　前記基地局制御装置は基地局保守制御装置に対し前記移動機障害検出アラーム報告を転送し、
前記基地局保守制御装置は前記移動機障害検出アラーム報告を正常に受信した場合、移動機障害検出アラーム受信完了報告を前記基地局制御装置に送信し、
前記基地局制御装置は前記基地局保守制御装置から通知された前記移動機障害検出アラーム受信完了報告を前記基地局に転送し、
前記基地局保守制御装置は統合保守監視装置に前記移動機障害検出アラーム報告を送出し、
前記統合保守監視装置は前記移動機障害検出アラーム報告を受信後、基地局位置情報データサーバへ基地局位置問合せ要求を送出し、加入者固有識別情報データサーバへ加入者情報問合せ要求を送出し、
前記基地局位置情報データサーバは指定された基地局情報から位置をデータベースから検索して詳細な位置情報を基地局位置報告にて前記統合保守監視装置へ報告し、
加入者固有識別情報データサーバは指定された加入者固有識別情報から住所と氏名と連絡先と電話番号等の加入者情報を前記データベースから検索して加入者情報報告で統合保守監視装置へ報告し、
前記統合保守監視装置は、前記基地局位置報告と前記加入者情報報告とを受信した時、コンソール画面に移動機障害検出と前記基地局位置情報と前記加入者情報とを警告音と共に表示することにより保守者に対し通知し、
自動制御又は保守者による手動制御で前記統合保守監視装置から指定ＭＳ送信停止指令を前記基地局保守制御装置に対し送信し、
前記指定ＭＳ送信停止指令を前記基地局保守制御装置と前記基地局制御装置とへ転送して基地局に通知し、
前記指定ＭＳ送信停止指令を受信した前記基地局は、指定された移動機に対し送信停止指令を行うことを特徴とする請求項１乃至３のいずれかに記載の、ＣＤＭＡ移動無線通信システムにおける無線品質劣化防止方法。

【請求項５】　前記基地局は送信停止を確認した時、送信停止確認報告を前記基地局制御装置と前記基地局保守制御装置とへ転送して前記統合保守監視装置に通知することを特徴とする請求項１乃至４のいずれかに記載の、ＣＤＭＡ移動無線通信システムにおける無線品質劣化防止方法。

【請求項６】　前記基地局制御装置が前記基地局保守制御装置から通知された前記移動機障害検出アラーム受信完了報告を前記基地局に転送し、
前記基地局にて設定された移動機障害検出アラーム受信完了報告待ちタイマがタイムアウトした場合は、個別にパラメータにて設定されたリトライ回数だけ再送を行うことを特徴とする請求項１乃至５のいずれかに記載の、ＣＤＭＡ移動無線通信システムにおける無線品質劣化防止方法。

【請求項７】　前記指定ＭＳ送信停止指令を受信した前記基地局は、指定された移動機に対し送信停止指令を行い、
送信停止できなかった場合、前記統合保守管理装置は強制的に該当移動機との通信に使用していた無線回線資源の解放を行うよう基地局に指示し、指定された前記移動機との通信を強制解放し、
前記統合保守管理装置は強制解放を確認した時、送信停止確認報告を前記基地局制御装置と前記基地局保守制御装置とへ転送して前記統合保守監視装置に通知することを特徴とする請求項１乃至６のいずれかに記載の、ＣＤＭＡ移動無線通信システムにおける無線品質劣化防止方法。

【請求項８】　請求項１乃至７のいずれかに記載のＣＤ

ＭＡ移動無線通信システムにおける無線品質劣化防止方法が実行可能なプログラムが記載された記憶媒体。

【請求項９】　システム内の移動機を監視するＣＤＭＡ移動無線通信システムであって、
故障した移動機をリアルタイムで検出し強制的に無線送信停止させたこと記録する記録手段と、
該記録手段を必要により検索できる検索手段とを備えたことを特徴とする、ＣＤＭＡ移動無線通信システム。

【請求項１０】前記記録手段には加入者情報や障害検出時刻や障害検出場所が同時に記録されていることを特徴とする請求項９記載の、ＣＤＭＡ移動無線通信システム。

【請求項１１】　システム内の移動機を監視するＣＤＭＡ移動無線通信システムであって、
保守者の操作により保守監視制御され、システム内の全装置に指示情報を送ることができる統合保守監視装置と、
システム内でパワーコントロールされた複数の移動機と、
前記移動機と無線回線で接続された基地局と、
各基地局に対する保守制御を行う基地局保守制御装置と、
前記基地局保守制御装置と前記基地局との間で情報の授受をする基地局制御装置と、
システム内にて稼働している全基地局の位置をデータベース化し所有している基地局位置情報データサーバと、
基地局障害情報や移動機障害情報を記録する障害記録データサーバと、
加入者の個人情報が移動機固有識別情報とリンクしてデータベース化された加入者固有識別情報データサーバとを備えたことを特徴とする、ＣＤＭＡ移動無線通信システム。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、ＣＤＭＡ移動無線通信システムにおいて、特にシステム運用中にパワーコントロール機能が故障した移動機を検出、強制通信停止することによるＣＤＭＡ移動無線通信システムにおける無線品質劣化防止方法及びＣＤＭＡ移動無線通信システムに属する。

【０００２】

【従来の技術】従来、ＣＤＭＡ（Code Division Multiple Access）移動無線通信システムでは、同一の周波数帯に複数の信号が共存するため、基地局における全移動機からの受信レベルを各々一定にする必要（遠近問題）から、この遠近問題を解決するために、ＣＤＭＡ移動無線通信システムにおいては基地局と移動機共に無線送信出力最適制御（パワーコントロール）が行われており、前記問題を解決しシステム内の無線品質を一定に保つことがおこなわれており、基地局が移動機の異常を検出した場合は、その移動機に対し送信停止をさせるような信号を送出し電波出力を停止または抑制することが行われている。（特開平７－３８４５２）

【発明が解決しようとする課題】しかしながら、従来技術には以下に掲げる問題点があった。無線送信出力最適制御（パワーコントロール）機能が故障し最大出力となっている移動機が存在した場合、システム内の無線品質の著しい劣化を発生させる恐れがあるということである。

【０００３】その理由は、基地局の近くにおいて前記故障した移動機が最大出力にて送信した場合、基地局においては他の移動機からの受信が十分にできなくなり、遠近問題が解決できないという問題点があった。

【０００４】また、基地局が移動機の異常を検出した場合は、その移動機に対し送信停止をさせるような信号を送出し電波出力を停止または抑制することが行われているが、その制御部分にも不具合があった場合には、異常出力のまま通信が継続されるという問題点があった。

【０００５】本発明は斯かる問題点を鑑みてなされたものであり、その目的とするところは、無線送信出力最適制御機能が故障した移動機がシステム内に存在するかを常に監視し、存在した場合には故障移動機の送信出力を基地局が強制停止させ、システム内の無線品質の劣化を防止するＣＤＭＡ移動無線通信システムの無線品質劣化防止方法及びＣＤＭＡ移動無線通信システムを提供する点にある。

【０００６】

【課題を解決するための手段】請求項１記載の本発明の要旨は、ＣＤＭＡ移動無線通信システムにおける無線品質劣化防止方法であって、移動機の出力情報を継続して監視し、異常な出力を発している故障した移動機を検出した場合、自動または保守者による手動制御により前記移動機の無線送信を強制的に停止させることを特徴とする、ＣＤＭＡ移動無線通信システムにおける無線品質劣化防止方法に存する。請求項２記載の本発明の要旨は、基地局は、故障した前記移動機に対する送信停止指令を出し、故障した前記移動機からの受信信号が停止したかを確認し、故障した前記移動機からの受信信号の停止が確認できなかった時、故障した前記移動機の電波停止処理部の不具合により停波できない状態であると認識し、前記基地局から故障している前記移動機に送信している電波を強制的に停止することを特徴とする請求項１記載の、ＣＤＭＡ移動無線通信システムにおける無線品質劣化防止方法に存する。請求項３記載の本発明の要旨は、受信部は全移動機から送信された拡散信号をアンテナを介して受信し、逆拡散部は受信された前記拡散信号を各移動機に割り当てられた拡散コードにより逆拡散処理し、ＳＩＲ検出部にて各拡散コードに対するＳＩＲを検出し、Ｅｂ／Ｉｏ算出部にて各移動機のＥｂ／Ｉｏを算出し、誤差検出部は、前記ＳＩＲ又は前記Ｅｂ／Ｉｏと

制御目標値との誤差を検出し、移動機出力監視部は、前記誤差が許容範囲内であるか判定し、一定時間に以上前記誤差が許容範囲外を継続した場合に移動機の障害と判断し、上位の基地局制御装置に移動機障害検出アラーム報告を送ることを特徴とする請求項１又は２に記載の、ＣＤＭＡ移動無線通信システムにおける無線品質劣化防止方法に存する。請求項４記載の本発明の要旨は、前記基地局制御装置は基地局保守制御装置に対し前記移動機障害検出アラーム報告を転送し、前記基地局保守制御装置は前記移動機障害検出アラーム報告を正常に受信した場合、移動機障害検出アラーム受信完了報告を前記基地局制御装置に送信し、前記基地局制御装置は前記基地局保守制御装置から通知された前記移動機障害検出アラーム受信完了報告を前記基地局に転送し、前記基地局保守制御装置は統合保守監視装置に前記移動機障害検出アラーム報告を送出し、前記統合保守監視装置は前記移動機障害検出アラーム報告を受信後、基地局位置情報データサーバへ基地局位置問合せ要求を送出し、加入者固有識別情報データサーバへ加入者情報問合せ要求を送出し、前記基地局位置情報データサーバは指定された基地局情報から位置をデータベースから検索して詳細な位置情報を基地局位置報告にて前記統合保守監視装置へ報告し、加入者固有識別情報データサーバは指定された加入者固有識別情報から住所と氏名と連絡先と電話番号等の加入者情報を前記データベースから検索して加入者情報報告で統合保守監視装置へ報告し、前記統合保守監視装置は、前記基地局位置報告と前記加入者情報報告とを受信した時、コンソール画面に移動機障害検出と前記基地局位置情報と前記加入者情報とを警告音と共に表示することにより保守者に対し通知し、自動制御又は保守者による手動制御で前記統合保守監視装置から指定ＭＳ送信停止指令を前記基地局保守制御装置に対し送信し、前記指定ＭＳ送信停止指令を前記基地局保守制御装置と前記基地局制御装置とへ転送して基地局に通知し、前記指定ＭＳ送信停止指令を受信した前記基地局は、指定された移動機に対し送信停止指令を行うことを特徴とする請求項１乃至３のいずれかに記載の、ＣＤＭＡ移動無線通信システムにおける無線品質劣化防止方法に存する。　請求項５記載の本発明の要旨は、前記基地局制御装置は基地局保守制御装置に対し前記移動機障害検出アラーム報告を転送し、前記基地局保守制御装置は前記移動機障害検出アラーム報告を正常に受信した場合、移動機障害検出アラーム受信完了報告を前記基地局制御装置に送信し、前記基地局制御装置は前記基地局保守制御装置から通知された前記移動機障害検出アラーム受信完了報告を前記基地局に転送し、前記基地局保守制御装置は統合保守監視装置に前記移動機障害検出アラーム報告を送出し、前記統合保守監視装置は前記移動機障害検出アラーム報告を受信後、基地局位置情報データサーバへ基地局位置問合せ要求を送出し、加入者固有識別情報データサーバへ加入者情報問合せ要求を送出し、前記基地局位置情報データサーバは指定された基地局情報から位置をデータベースから検索して詳細な位置情報を基地局位置報告にて前記統合保守監視装置へ報告し、加入者固有識別情報データサーバは指定された加入者固有識別情報から住所と氏名と連絡先と電話番号等の加入者情報を前記データベースから検索して加入者情報報告で統合保守監視装置へ報告し、前記統合保守監視装置は、前記基地局位置報告と前記加入者情報報告とを受信した時、コンソール画面に移動機障害検出と前記基地局位置情報と前記加入者情報とを警告音と共に表示することにより保守者に対し通知し、自動制御又は保守者による手動制御で前記統合保守監視装置から指定ＭＳ送信停止指令を前記基地局保守制御装置に対し送信し、前記指定ＭＳ送信停止指令を前記基地局保守制御装置と前記基地局制御装置とへ転送して基地局に通知し、前記指定ＭＳ送信停止指令を受信した前記基地局は、指定された移動機に対し送信停止指令を行うことを特徴とする請求項１乃至３のいずれかに記載の、ＣＤＭＡ移動無線通信システムにおける無線品質劣化防止方法に存する。請求項６記載の本発明の要旨は、前記基地局制御装置が前記基地局保守制御装置から通知された前記移動機障害検出アラーム受信完了報告を前記基地局に転送し、前記基地局にて設定された移動機障害検出アラーム受信完了報告待ちタイマがタイムアウトした場合は、個別にパラメータにて設定されたリトライ回数だけ再送を行うことを特徴とする請求項１乃至５のいずれかに記載の、ＣＤＭＡ移動無線通信システムにおける無線品質劣化防止方法に存する。請求項７記載の本発明の要旨は、前記指定ＭＳ送信停止指令を受信した前記基地局は、指定された移動機に対し送信停止指令を行い、送信停止できなかった場合、前記統合保守管理装置は強制的に該当移動機との通信に使用していた無線回線資源の解放を行うよう基地局に指示し、指定された前記移動機との通信を強制解放し、前記統合保守管理装置は強制解放を確認した時、送信停止確認報告を前記基地局制御装置と前記基地局保守制御装置とへ転送して前記統合保守監視装置に通知することを特徴とする請求項１乃至６のいずれかに記載の、ＣＤＭＡ移動無線通信システムにおける無線品質劣化防止方法に存する。請求項８記載の本発明の要旨は、請求項１乃至７のいずれかに記載のＣＤＭＡ移動無線通信システムにおける無線品質劣化防止方法が実行可能なプログラムが記載された記憶媒体に存する。請求項９記載の本発明の要旨は、システム内の移動機を監視するＣＤＭＡ移動無線通信システムであって、故障した移動機をリアルタイムで検出し強制的に無線送信停止させたこと記録する記録手段と、該記録手段を必要により検索できる検索手段とを備えたことを特徴とする、ＣＤＭＡ移動無線通信システムに存する。

請求項１０記載の本発明の要旨は、前記記録手段には加入者情報や障害検出時刻や障害検出場所が同時に記録

されていることを特徴とする請求項９記載の、ＣＤＭＡ移動無線通信システムに存する。請求項１１記載の本発明の要旨は、システム内の移動機を監視するＣＤＭＡ移動無線通信システムであって、保守者の操作により保守監視制御され、システム内の全装置に指示情報を送ることができる統合保守監視装置と、システム内でパワーコントロールされた複数の移動機と、前記移動機と無線回線で接続された基地局と、各基地局に対する保守制御を行う基地局保守制御装置と、前記基地局保守制御装置と前記基地局との間で情報の授受をする基地局制御装置と、システム内にて稼働している全基地局の位置をデータベース化し所有している基地局位置情報データサーバと、基地局障害情報や移動機障害情報を記録する障害記録データサーバと、加入者の個人情報が移動機固有識別情報とリンクしてデータベース化された加入者固有識別情報データサーバとを備えたことを特徴とする、ＣＤＭＡ移動無線通信システムに存する。

【０００７】なお、本発明において「ＳＩＲ」とは、Signal to Interference Ratio（信号対干渉比）を意味する。

【０００８】本発明において「Ｅｂ／Ｉｏ」とは１ビットあたりのエネルギー対干渉比を意味する。

【０００９】本発明において「ＭＳ」とはMobile Station（移動機）を意味する。

【００１０】

【発明の実施の形態】以下、本発明の実施の形態を図面に基づいて詳細に説明する。図１に示すように、本実施の形態に係るＣＤＭＡ移動無線通信システムは、基地局制御装置１３と基地局１２ａ～１２ｎと基地局保守制御装置１４ａ～１４ｋと移動機１１ａ～１１ｍと基地局位置情報データサーバ１６と障害記録データサーバ１７と加入者固有識別情報データサーバ１８と統合保守監視装置１９とで概略構成される。

【００１１】移動機１１ａ～１１ｍは基地局１２ａ～１２ｎと無線回線で接続されており、ＣＤＭＡ無線方式による信号の送受信が行われる。各基地局１２ａ～１２ｎは基地局制御装置１３に接続されている。また、このシステム内には複数の基地局制御装置１３を有し、各々の基地局制御装置１３には、基地局保守制御装置１４ａ～１４ｋが接続されており各基地局に対する保守制御を行う。

【００１２】基地局保守制御装置１４ａ～１４ｋは、Local Area Network１５（以下LANと称す）によって代表されるネットワークに接続され、このＬＡＮ１５上には、基地局位置情報データサーバ１６と障害記録データサーバ１７と加入者固有識別情報データサーバ１８と統合保守監視装置１９とが接続されており、各情報の記録手段と記録された前記情報の検索手段となる。統合保守監視装置１９には、保守者用操作卓２０が接続されており、必要な保守監視制御を行ったり、本システム内の各種保守情報を得ることが可能である。

【００１３】基地局位置情報データサーバ１６は、ＣＤＭＡ移動無線通信システム内にて稼働している全基地局の位置をデータベース化し所有しており、ＬＡＮ１５上の別装置から個別に要求された指定基地局の位置情報を提供することができる。

【００１４】障害記録データサーバ１７は、基地局障害情報や移動機障害情報を記録するためのデータサーバであり、本発明においては故障した移動機の加入者情報や位置情報などを記録する装置である。加入者固有識別情報データサーバ１８は、各加入者の個人情報が移動機固有識別情報とリンクされたデータベースであり、別装置から個別に要求された指定固有識別情報から個人情報（住所、氏名、連絡先、電話番号等）を提供することができる。

【００１５】統合保守監視装置１９は、ＬＡＮ１５に接続されているすべての装置を適切に制御し、本発明の目的である「無線送信出力最適制御（パワーコントロール）機能が故障した移動機がシステム内に存在するかを常に監視し、存在した場合には故障移動機の送信出力を停止させ、システム内の無線品質の劣化を防止する」ことを実現するための中央指令制御装置である。

【００１６】保守者２０は、保守者用操作卓２０を必要により操作し、障害記録データサーバ１７に記録された障害情報を検索することができる。

【００１７】図２に基地局受信系制御ブロック図を示す。基本動作は以下の通りである。アンテナ２１は受信部２２に接続され、全移動機から送信された拡散信号を受信する。逆拡散部２３では、受信された信号を各移動機に割り当てられた拡散コードにより逆拡散処理する。ＳＩＲ検出部２４にて各拡散コードに対するＳＩＲを検出し、Ｅｂ／Ｉｏ算出部２５にて各移動機のＥｂ／Ｉｏを算出し、これらの受信信号から得られたデータ（各ＳＩＲまたは各Ｅｂ／Ｉｏ）は誤差検出部２６に引き渡され、算出した各ＳＩＲまたは各Ｅｂ／Ｉｏと制御目標値に対しての誤差を検出する。

【００１８】移動機出力監視部２７では、検出された各誤差が許容範囲内であるか判定する。この時、一定時間に渡り許容範囲外である場合が継続した場合、上位の基地局保守制御装置に対し移動機障害検出アラーム信号を送出する。

【００１９】図３に誤差信号から移動機障害検出アラームを送出するまでのフローチャートを示す。ｘ台の移動機が同時に該当基地局と通信している場合を想定する。各移動機から送信された拡散信号を基地局にて受信し、各ＳＩＲまたは各Ｅｂ／Ｉｏから誤差信号δ１～δｘまでを検出した後、本誤差検出フローにて処理される。

【００２０】フロー３２にて、カウンタｉを１にセットする。

【００２１】フロー３３にて、誤差信号δｉの絶対値が

制御目標許容値αを以下であるか判定する。

【００２２】この時、許容範囲内であった場合は、フロー３４にてカウンタｉをインクリメントする。

【００２３】フロー３５にて、ｉがｘを越えていないかを判定する。越えていない場合は、フロー３３から順に繰り返す。

【００２４】ここで、誤差信号δｉが許容範囲αを越えていたことをフロー３３で検出された場合を考える。

【００２５】許容範囲αを超えていた場合はフロー３６へ遷移する。

【００２６】基地局のパワーコントロール部にて該当移動機に対して送信出力低下指示を連続して行っているにもかかわらず、β回連続して許容範囲オーバが発生しているか判定する。具体的には、β回分の該当移動機に対する｜δｉ｜の変動をチェックし、送信出力低下できる環境であるにもかかわらず出力低下されないと判断した時、β回連続して許容範囲オーバしたと判定する。

【００２７】β回連続して誤差信号δｉが許容範囲αをオーバしたと判定された時、フロー３７にて移動機障害検出アラームを上位の基地局保守制御装置に対し送出する。なお、移動機障害検出アラーム信号には、出力異常と検出された移動機の固有識別情報と検出された基地局の識別情報が付加される。また、その後フロー３８へ遷移する。

【００２８】β回連続して誤差信号δｉが許容範囲αをオーバしたと判定されなかった場合、フロー３４へ遷移する。

【００２９】フロー３５にてカウンタｉがｘを越えた場合、フロー３８にて次タイミングにおける誤差信号を要求し、フロー３１へ遷移する。

【００３０】以下、上記フローが継続される。

【００３１】図４に移動機障害検出アラーム発生から、移動機送信停止までの制御シーケンスを示す。基地局より移動機障害検出アラーム報告を受信した基地局制御装置は基地局保守制御装置に対しメッセージを転送する。

【００３２】基地局保守制御装置は該当メッセージを正常に受信した場合、移動機障害検出アラーム受信完了報告を基地局制御装置に送信する。

【００３３】基地局制御装置は基地局保守制御装置から通知される移動機障害検出アラーム受信完了報告を基地局に転送する。この時、基地局にて設定された移動機障害検出アラーム受信完了報告待ちタイマがタイムアウトした場合は、個別にパラメータにて設定されたリトライ回数だけ再送を行う。

【００３４】基地局保守制御装置は統合保守監視装置に対し、移動機障害検出アラーム報告を送出する。

【００３５】統合保守監視装置は移動機障害検出アラーム報告を受信後、基地局位置情報データサーバへ基地局位置問合せ要求を送出し、加入者固有識別情報データサーバへ加入者情報問合せ要求を送出する。

【００３６】基地局位置情報データサーバは指定された基地局情報から位置をデータベースから検索し、より具体的な位置情報を基地局位置報告で統合保守監視装置へ報告する。

【００３７】加入者固有識別情報データサーバは指定された加入者固有識別情報から加入者情報（住所、氏名、連絡先、電話番号など）をデータベースから検索し、加入者情報報告で統合保守監視装置へ報告する。

【００３８】統合保守監視装置は、基地局位置報告と加入者情報報告を共に受信した時、コンソール画面に移動機障害検出したことを警告音と共に表示し、保守者に対し通知する。この時、基地局位置情報と加入者情報も共に表示する。

【００３９】同時に統合保守監視装置は障害記録サーバに対し障害情報記録指示メッセージを送出する。

【００４０】障害記録データサーバは、障害記録指令にて通知された基地局位置情報と加入者情報をタイムスタンプと共に記録する。

【００４１】障害情報の記録が完了した後、自動制御または保守者による手動制御により、統合保守監視装置から指定ＭＳ送信停止指令が基地局保守制御装置に対し送信される。

【００４２】本メッセージは基地局保守制御装置と基地局制御装置を転送され、基地局に通知される。

【００４３】指定ＭＳ送信停止指令を受信した基地局は、配下にて通信している該当移動機に対し送信停止指令を行い、該当移動機からの受信信号が停止したかの確認をする。

【００４４】この時の確認方法は、第１に「該当移動機と無線上での同期はずれが一定時間継続したかどうかの確認」と第２に「該当移動機のＥｂ／Ｉｏが一定時間継続して検出不能となったかどうかの確認」等である。

【００４５】該当移動機からの受信信号の停止が確認できなかった時、移動機の電波停止処理部の不具合により停波できない状態であると認識し、通信に使用中の基地局から送信している電波を強制的に停止する。

【００４６】基地局から、移動局に対して強制的に通信の停止をさせることができる理由は、無線通信において、移動機から基地局への送信と基地局から移動機への送信が常に行われており、お互いが相手の送信した電波を監視し通信が継続されているか認識している。ところが、基地局からの送信が突然停止されると、移動機では通信が継続されていないと認識し、復旧動作を行うようになっており、復旧できない場合には通常の切断処理を伴って通信の停止を行うことができる。従って、移動機における電波停止処理部が故障しており、基地局から通知される電波停止指示に対し正常に停止動作が行えなくても、基地局からの送信を強制停止させることで、通常の切断処理によって電波を停止させることが可能である。さらに、通信が開始できるということは通信制御処

理部には不具合がないと認められるため、通常の切断処理は正常に動作できる状態にあると判断できると考える。

【００４７】基地局は送信停止が確認された、または強制解放したことを確認した時、送信停止確認報告を送信する。

【００４８】本メッセージは基地局制御装置と基地局保守制御装置に転送され、統合保守監視装置に通知される。

【００４９】統合保守監視装置は、送信停止確認報告を受信後、強制送信停止履歴記録指令を障害記録データサーバに対し送信する。

【００５０】障害記録データサーバは本指令を受信後、該当移動機に対し強制送信停止したことを記録する。これら記録されたすべてのデータは、保守者によって容易に検索することが可能である。

【００５１】実施の形態に係るＣＤＭＡ移動無線通信システムは上記の如く構成されているので、以下に掲げる効果を奏する。ＣＤＭＡ移動無線通信システムは、数多くの移動機が収容された基地局内において干渉波をいかに低減させ無線品質を安定させるかが大きな課題であるが、本発明により送信異常の移動機を検出した場合には該当移動機に対し強制的に送信停止をさせることが可能であり干渉波を的確に低減させることにより無線品質の劣化を防止できる。

【００５２】また、ＣＤＭＡ移動無線通信システムにおいて、遠近問題を解決するために送信出力最適制御（パワーコントロール）機能を必ず備えており、パワーコントロールするために必要な各移動機のＳＩＲやＥｂ／Ｉｏを常に算出しているが、本発明ではこの各移動機のＳＩＲまたはＥｂ／Ｉｏを常時監視することにより、送信異常の移動機を検出することにより、専用の新しい検出回路を必要としないため、装置構成を大きくしなくても済む。

【００５３】また、基地局位置情報データサーバ、障害記録データサーバ、加入者固有識別情報データサーバ等を有し、これらの検索ができることにより、障害時に迅速な対応ができる。

【００５４】

【発明の効果】本発明は以上のように構成されているので、以下に掲げる効果を奏する。第１の効果は、ＣＤＭＡ移動無線通信システムにおける無線品質の劣化を防止することができることにある。その理由は、ＣＤＭＡ移動無線通信システムの場合、数多くの移動機が収容された基地局内において干渉波をいかに低減させ無線品質を安定させるかが大きな課題であるが、本発明により送信異常の移動機を検出した場合には該当移動機に対し強制的に送信停止をさせることが可能であり干渉波を的確に低減させることが可能であるためである。

【００５５】第２の効果は、専用の新しい検出回路を必要としないため、装置構成を大きくしなくても済むことである。その理由は、ＣＤＭＡ移動無線通信システムにおいて、遠近問題を解決するために送信出力最適制御（パワーコントロール）機能を必ず備えており、パワーコントロールするために必要な各移動機のＳＩＲやＥｂ／Ｉｏを常に算出しているが、本発明ではこの各移動機のＳＩＲまたはＥｂ／Ｉｏを常時監視することにより、送信異常の移動機を検出できるためである。

【００５６】第３の理由は、移動機の故障を確認した時、迅速に移動機の解放をすることができる。その理由は、基地局位置情報データサーバ、障害記録データサーバ、加入者固有識別情報データサーバ等のデータベースを検索することで、速やかに移動機の特定ができるからである。

【図面の簡単な説明】

【図１】本発明の実施の形態に係るＣＤＭＡ移動無線通信システムネットワーク構成図である。

【図２】図１の基地局受信系制御ブロック図である。

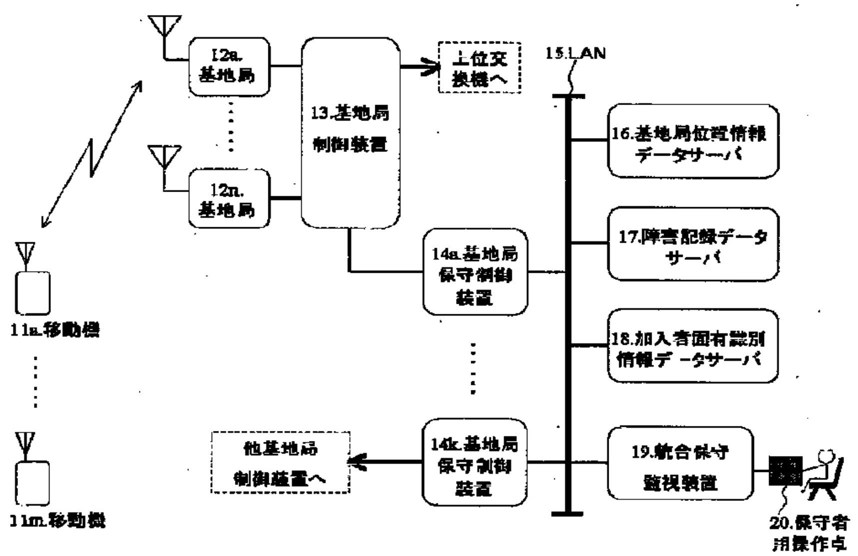
【図３】図１の障害アラーム検出のフローチャートである。

【図４】図１の制御シーケンス図である。

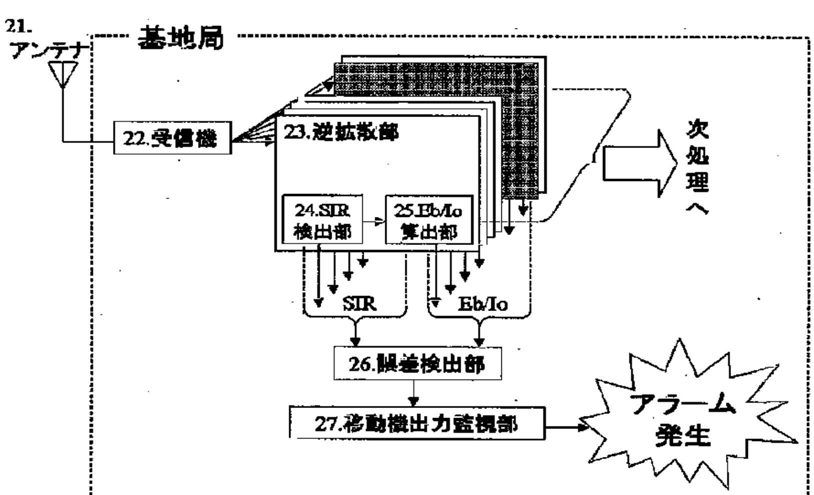
【符号の説明】

１１ａ～１１ｍ　移動機
１２ａ～１２ｎ　基地局
１３　基地局制御装置
１４ａ～１４ｋ　基地局保守監視装置
１５　ＬＡＮ
１６　基地局位置情報データサーバ
１７　障害記録データサーバ
１８　加入者固有識別情報データサーバ
１９　統合保守監視装置
２０　保守者用操作卓
２１　アンテナ
２２　受信機
２３　逆拡散部
２４　ＳＩＲ検出部
２５　Ｅｂ／Ｉｏ算出部
２６　誤差検出部
２７　移動機出力監視部

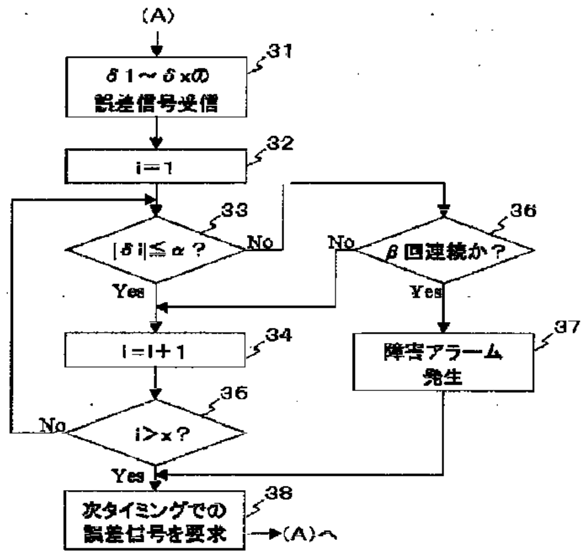
【図1】


12a.
基地局
12n.
基地局
13.基地局
制御装置
上位交
換機へ
15.LAN
16.基地局位置情報
データサーバ
17.障害記録データ
サーバ
18.加入者固有識別
情報データサーバ
19.統合保守
監視装置
20.保守者
用操作卓
14a.基地局
保守制御
装置
14k.基地局
保守制御
装置
他基地局
制御装置へ
11a.移動機
11m.移動機

【図2】


21.
アンテナ
基地局
22.受信機
23.逆拡散部
24.SIR
検出部
25.Eb/Io
算出部
SIR
Eb/Io
26.誤差検出部
27.移動機出力監視部
次
処
理
へ
アラーム
発生

【図3】



x:現在通信している総移動機台数

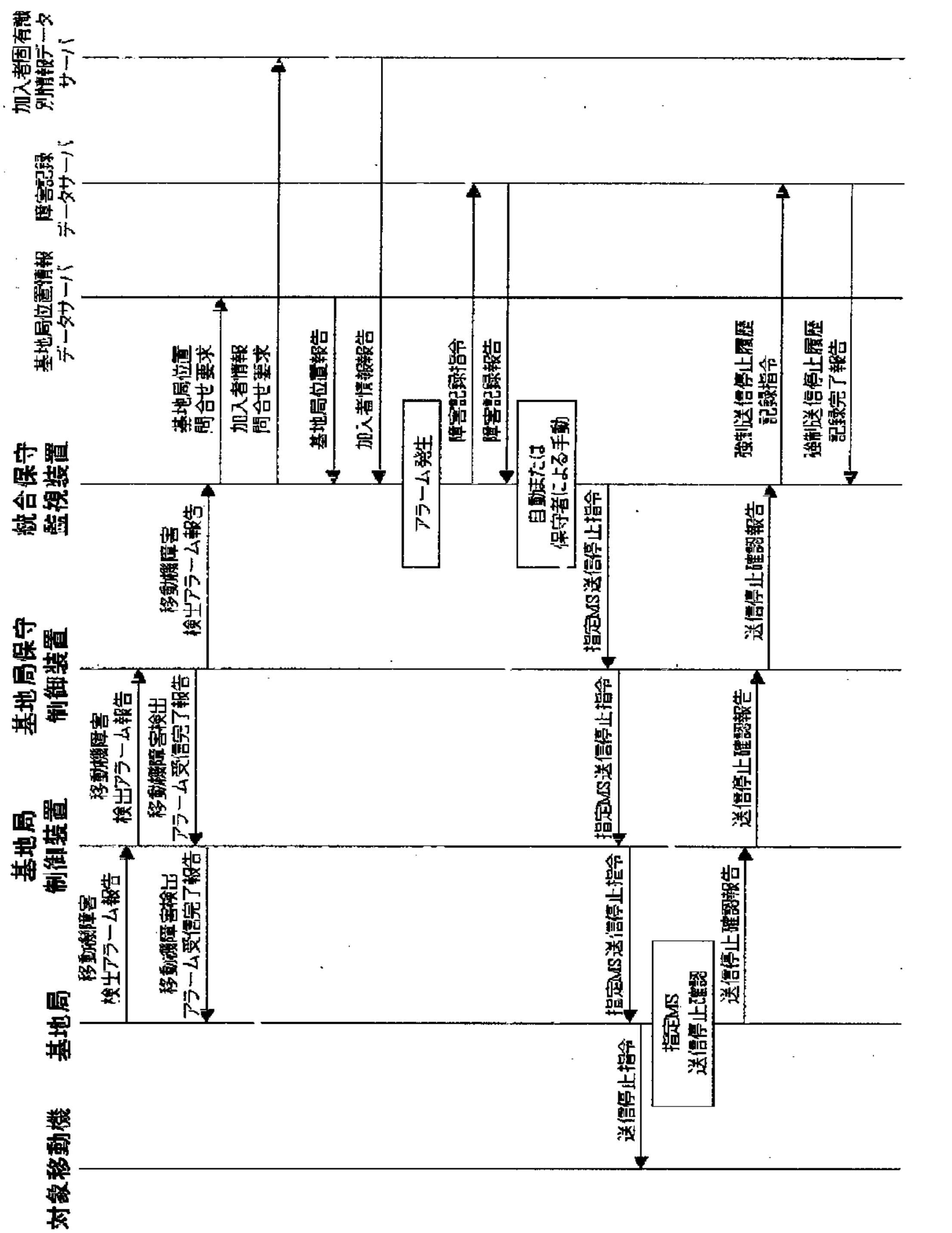
i:任意カウンタ

α:制御目標許容値

β:連続回数検出カウンタ

δ1～δx:x台分の誤差信号

【図4】


対象移動機
基地局
基地局制御装置
基地局保守制御装置
統合保守監視装置
基地局位置情報データサーバ
障害記録データサーバ
加入者固有識別情報データサーバ
移動機障害検出アラーム報告
移動機障害検出アラーム受信完了報告
基地局位置問合せ要求
加入者情報問合せ要求
基地局位置報告
加入者情報報告
アラーム発生
障害記録指令
障害記録報告
自動または保守者による手動
指定MS送信停止指令
送信停止指令
指定MS送信停止確認
送信停止確認報告
強制送信停止履歴記録指令
強制送信停止履歴記録完了報告

フロントページの続き

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NA01
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DD26 DD27 DD43 DD44 EE02
EE10 EE16 FF18 FF20 FF23
GG08 GG09 GG11 GG22 HH17
HH22 HH23 HH28 JJ53 JJ66
LL01 LL05 LL14

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Bibliographic data: JPH1127729 (A) — 1999-01-29

MOBILE COMMUNICATION SYSTEM, ITS PORTABLE INFORMATION TERMINAL AND COMMUNICATION CONTROLLER

Inventor(s): HIGUCHI GOJI ± (HIGUCHI GOJI)

Applicant(s): SANYO ELECTRIC CO ± (SANYO ELECTRIC CO LTD)

Classification: **- international:** ***G06F13/00; G06F3/00; H04W16/18; H04W4/02;*** (IPC1-7): G06F13/00; G06F3/00; H04Q7/34; H04Q7/38
- cooperative:

Application number: JP19970176186 19970701

Priority number(s): JP19970176186 19970701

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Abstract of JPH1127729 (A)

PROBLEM TO BE SOLVED: To provide a mobile communication system by which information relating to places with a poor radio wave status is collected and such places are reported in advance to a portable information terminal based on the collected information. SOLUTION: A portable information terminal 10 is provided with a current location detection section 13 that detects a current location, a location information processing section 14 that sends location information at start of communication, and a message notice section 16 that receives information related to a radio wave status at a current position.; A communication controller 20 is provided with a database 24 that stores the location information and information denoting the quality of radio wave status in cross reference with the location information, a location information extract section 21 that extracts the location information from the received radio wave and stores it in the database 24, an interrupt processing section 22 that monitors the communication status and stores the information denoting a poor radio wave status to the database 24 in cross reference with the location information, a radio wave state discrimination section 23 that discriminates the propriety of the radio wave

status corresponding to the extracted location information, and a message notice processing section 25 that sends the information relating to the radio wave status to the portable information terminal 10.

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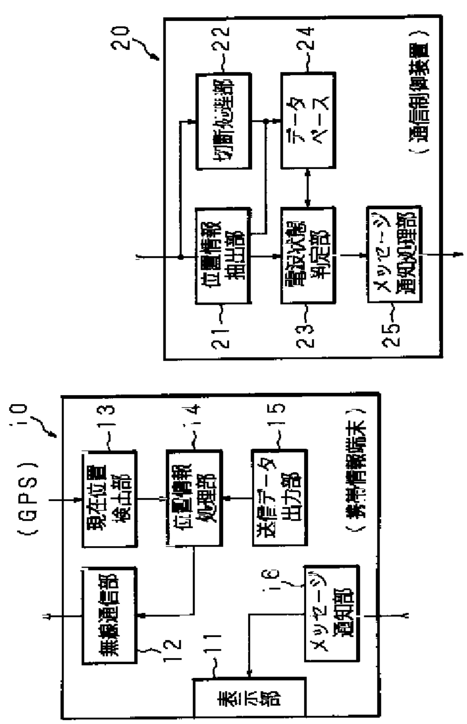
(54)【発明の名称】　モバイルコミュニケーションシステム，その携帯情報端末及び通信制御装置

(57)【要約】

【課題】　携帯電話機，PHS 等と接続された、またはそれ自体が移動体通信の機能を有する携帯タイプのコンピュータシステムによるモバイルコミュニケーションシステムにおいては、電波状態の良否が重要な問題である。

【解決手段】　携帯情報端末10は、現在位置を検出する現在位置検出部13と、位置情報を通信開始時に送信する位置情報処理部14と、現在位置の電波状態に関する情報を受信するメッセージ通知部16とを備え、通信制御装置20は、位置情報とその位置情報に対応付けて電波状態の良否を示す情報とを記憶するデータベース24と、受信電波から位置情報を抽出してデータベース24に記憶させる位置情報抽出部21と、通信状態を監視し、電波状態が不良であることを示す情報を位置情報に対応付けてデータベース24に記憶させる切断処理部22と、抽出された位置情報に対応する電波状態の良否を判定する電波状態判定部23と、電波状態に関する情報を携帯情報端末10へ送信するメッセージ通知処理部25とを備える。



【特許請求の範囲】

【請求項１】　携帯情報端末と、携帯情報端末との間で通信を行なう通信制御装置とを含むモバイルコミュニケーションシステムにおいて、

前記携帯情報端末は、現在位置を検出する現在位置検出手段と、該現在位置検出手段が検出した現在位置に関する位置情報を通信開始時に送信する位置情報送信手段と、前記通信制御装置から現在位置の電波状態に関する情報を受信するメッセージ通知手段とを備え、

前記通信制御装置は、位置情報とその位置情報に対応付けて電波状態の良否を示す情報とを記憶する位置情報記憶手段と、前記携帯情報端末からの受信電波から位置情報を抽出して前記位置情報記憶手段に記憶させる位置情報抽出手段と、前記携帯情報端末との通信状態を監視し、通信切断時に電波状態が不良であることを示す情報を前記位置情報抽出手段が抽出した位置情報に対応付けて前記位置情報記憶手段に記憶させる切断処理手段と、前記位置情報抽出手段が抽出した位置情報に対応する電波状態の良否を前記位置情報記憶手段の記憶内容に従って判定する電波状態判定手段と、該電波状態判定手段が判定した電波状態に関する情報を前記携帯情報端末へ送信するメッセージ通知手段とを備えたことを特徴とするモバイルコミュニケーションシステム。

【請求項２】　現在位置を検出する現在位置検出手段と、該現在位置検出手段が検出した現在位置に関する位置情報を通信開始時に送信する位置情報送信手段と、現在位置の電波状態に関する情報を受信するメッセージ通知手段とを備えたことを特徴とする携帯情報端末。

【請求項３】　位置情報とその位置情報に対応付けて電波状態の良否を示す情報とを記憶する位置情報記憶手段と、通信相手からの受信電波から位置情報を抽出して前記位置情報記憶手段に記憶させる位置情報抽出手段と、前記通信相手との通信状態を監視し、通信切断時に電波状態が不良であることを示す情報を前記位置情報抽出手段が抽出した位置情報に対応付けて前記位置情報記憶手段に記憶させる切断処理手段と、前記位置情報抽出手段が抽出した位置情報に対応する電波状態の良否を前記位置情報記憶手段の記憶内容に従って判定する電波状態判定手段と、該電波状態判定手段が判定した電波状態に関する情報を前記通信相手へ送信するメッセージ通知手段とを備えたことを特徴とする通信制御装置。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明はモバイルコミュニケーションシステム、即ち移動体通信、たとえば携帯電話機，PHS(Personal Handy-phone System)等と携帯タイプのコンピュータシステムとを接続して、またはそれ自体が移動体通信の機能を有する携帯タイプのコンピュータシステムによるコミュニケーションシステムに関する。

【０００２】

【従来の技術】携帯電話機，PHS(Personal Handy-phone System)等と携帯タイプのコンピュータシステムとを接続して、またはそれ自体が移動体通信の機能を有する携帯タイプのコンピュータシステムによるモバイルコミュニケーションシステムにおいては、無線方式の通信を行なうため、電波状態が不良の場所では通信が切断される場合があった。簡単な電子メールの送信中であれば、通信が切断されても再送信は容易であるが、画像のようなサイズの大きい、即ち送受信に長時間を要するデータの送受信中に通信が切断されると、再度最初から長時間をかけて再通信する必要が生じる。また、一時的な電波状態の不良が原因で通信が切断された場合には再通信が可能であるが、その場所が恒常的に電波状態が不良の場所である場合には再送信自体が困難である。

【０００３】このような事情から、たとえばOracle社が開発したモバイルエージェントでは、データ通信が切断された場合にはその時点の状態を記憶しておき、通信が再接続した時点で先にデータ通信が切断された時点の状態からデータ通信を再開するようにしている。

【０００４】

【発明が解決しようとする課題】しかし、上述のような従来技術では、電波状態が不良の場所に居たのでは、データ通信を再開すること自体が困難である。

【０００５】本発明はこのような事情に鑑みてなされたものであり、電波状態が不良の場所に関する情報を収集することが可能であり、またその収集した情報に基づいて電波状態が不良の場所を携帯情報端末へ予め通知し得るモバイルコミュニケーションシステムの提供を目的とする。

【０００６】

【課題を解決するための手段】本発明に係るモバイルコミュニケーションシステムは、携帯情報端末と、携帯情報端末との間で通信を行なう通信制御装置とを含むモバイルコミュニケーションシステムであって、携帯情報端末は、現在位置を検出する現在位置検出手段と、この現在位置検出手段が検出した現在位置に関する位置情報を通信開始時に送信する位置情報送信手段と、通信制御装置から現在位置の電波状態に関する情報を受信するメッセージ通知手段とを備え、通信制御装置は、位置情報とその位置情報に対応付けて電波状態の良否を示す情報とを記憶する位置情報記憶手段と、携帯情報端末からの受信電波から位置情報を抽出して位置情報記憶手段に記憶させる位置情報抽出手段と、携帯情報端末との通信状態を監視し、通信切断時に電波状態が不良であることを示す情報を位置情報抽出手段が抽出した位置情報に対応付けて位置情報記憶手段に記憶させる切断処理手段と、位置情報抽出手段が抽出した位置情報に対応する電波状態の良否を位置情報記憶手段の記憶内容に従って判定する電波状態判定手段と、この電波状態判定手段が判定した電波状態に関する情報を携帯情報端末へ送信するメッセ

ージ通知手段とを備えたことを特徴とする。

【０００７】本発明のモバイルコミュニケーションシステムでは、携帯情報端末においては、現在位置検出手段が現在位置を検出し、その現在位置に関する位置情報を通信開始時に位置情報送信手段が通信制御装置へ送信する。一方、通信制御装置においては、位置情報抽出手段が携帯情報端末からの受信電波から位置情報を抽出して位置情報記憶手段に記憶させ、切断処理手段が携帯情報端末との通信状態を監視し、通信切断時に電波状態が不良であることを示す情報を位置情報抽出手段が抽出した位置情報に対応付けて位置情報記憶手段に記憶させ、電波状態判定手段が位置情報抽出手段が抽出した位置情報に対応する電波状態の良否を位置情報記憶手段の記憶内容に従って判定し、メッセージ通知手段が電波状態判定手段が判定した電波状態に関する情報を携帯情報端末へ送信する。そして、この通信制御装置から送信された電波状態に関する情報を携帯情報端末のメッセージ通知手段が受信する。

【０００８】また本発明に係る携帯情報端末は、現在位置を検出する現在位置検出手段と、この現在位置検出手段が検出した現在位置に関する位置情報を通信開始時に送信する位置情報送信手段と、現在位置の電波状態に関する情報を受信するメッセージ通知手段とを備えたことを特徴とする。

【０００９】このような本発明の携帯情報端末では、現在位置検出手段が現在位置を検出し、この現在位置検出手段が検出した現在位置に関する位置情報を通信開始時に位置情報送信手段が送信し、メッセージ通知手段が現在位置の電波状態に関する情報を受信する。

【００１０】更に本発明に係る通信制御装置は、位置情報とその位置情報に対応付けて電波状態の良否を示す情報とを記憶する位置情報記憶手段と、通信相手からの受信電波から位置情報を抽出して位置情報記憶手段に記憶させる位置情報抽出手段と、通信相手との通信状態を監視し、通信切断時に電波状態が不良であることを示す情報を位置情報抽出手段が抽出した位置情報に対応付けて位置情報記憶手段に記憶させる切断処理手段と、位置情報抽出手段が抽出した位置情報に対応する電波状態の良否を位置情報記憶手段の記憶内容に従って判定する電波状態判定手段と、この電波状態判定手段が判定した電波状態に関する情報を通信相手へ送信するメッセージ通知手段とを備えたことを特徴とする。

【００１１】またこのような本発明の通信制御装置では、位置情報抽出手段が通信相手からの受信電波から位置情報を抽出して位置情報記憶手段に記憶させ、切断処理手段が通信相手との通信状態を監視し、通信切断時に電波状態が不良であることを示す情報を位置情報抽出手段が抽出した位置情報に対応付けて位置情報記憶手段に記憶させ、電波状態判定手段が位置情報抽出手段が抽出した位置情報に対応する電波状態の良否を位置情報記憶手段の記憶内容に従って判定し、この電波状態判定手段が判定した電波状態に関する情報をメッセージ通知手段が通信相手へ送信する。

【００１２】

【発明の実施の形態】以下、本発明をその実施の形態を示す図面に基づいて詳述する。図１は本発明に係るモバイルコミュニケーションシステム（以下、本システムと言う）の一構成例を示すブロック図である。

【００１３】本システムは、大きくは携帯情報端末10と通信制御装置20とに別れている。携帯情報端末10は、たとえば携帯電話機，PHS(Personal Handy-phone System)等と携帯タイプのコンピュータシステムとを接続したシステム、またはそれ自体が移動体通信の機能を有する携帯タイプのコンピュータシステムである。また、通信制御装置20は、複数の携帯情報端末10と無線方式で通信可能なたとえば制御局内のサーバ等である。

【００１４】携帯情報端末10は、種々の情報を表示するためのたとえば液晶表示装置を利用した表示部11と、携帯電話機，PHS 等の移動体通信のシステムを利用して通信制御装置20と通信を行なう無線通信部12と、たとえばGPS(Grobal Positioning System)からの電波を受信して携帯情報端末10自身の現在位置を検出する現在位置検出部13と、本来の送信されるべきデータを出力する送信データ出力部15と、現在位置検出部13により得られた現在位置のデータ（以下、位置情報と言う）を送信データ出力部15から出力される本来の送信データに付加して無線通信部12から送信させる位置情報送信手段としての位置情報処理部14と、通信制御装置20から送信されたメッセージを受信した場合にそれを表示部11に表示出力することにより通知するメッセージ通知部16とを含んでいる。

【００１５】一方、通信制御装置20は、携帯情報端末10の無線通信部12から送信される電波による通信を受信してそれに含まれる位置情報を抽出して位置情報記憶手段としてのデータベース24に蓄積する位置情報抽出部21と、携帯情報端末10からの通信状態を監視し、通信が切断された場合にその時点で位置情報抽出部21が抽出している位置情報に対して電波状態が不良であることを示す情報を付加してデータベース24に蓄積させる切断処理部22と、位置情報抽出部21が抽出した位置情報に対応する電波状態の情報をデータベース24から読み出して携帯情報端末10に対してメッセージを通知するメッセージ通知処理部25とを含んでいる。

【００１６】従って、携帯情報端末10から電波を受信した場合には、まず位置情報抽出部21により位置情報が抽出されてデータベース24に蓄積され、それに対応する電波状態の情報が電波状態判定部23によりデータベース24から読み出され、電波状態が不良である場合にはメッセージ通知処理部25により携帯情報端末10へ所定のメッセージが送信される。

【００１７】また、通信が切断された場合には、切断処

理部22によってそのことが抽出され、データベース24には位置情報抽出部21が抽出した位置情報に電波状態が不良であることを示す情報が付加されてデータベース24に蓄積される。このような処理が多数の携帯情報端末10からの受信の都度反復されることにより、データベース24には多数の位置情報が蓄積されると共に、通信が切断された場合には位置情報に電波状態が不良であることを示す情報が付加されて蓄積される。

【００１８】このような構成の本システムの動作について、図２及び図３のフローチャートを参照して説明する。まず、携帯情報端末10の通信開始時の動作について図２のフローチャートを参照して説明する。

【００１９】携帯情報端末10は、通信制御装置20との接続が確認されると（ステップS11 で”YES ”）、現在位置検出部13が現在位置を検出する（ステップS12)。この現在位置検出部13による現在位置の検出は、前述した如く、たとえば GPSを利用することにより容易に可能である。次に、送信データ出力部15から本来送信されるべきデータが出力されると、位置情報処理部14は現在位置検出部13が検出している現在位置のデータ、即ち位置情報を付加し（ステップS13)、無線通信部12から送信させる（ステップS14)。

【００２０】次に、通信制御装置20の動作について図３のフローチャートを参照して説明する。通信制御装置20は、携帯情報端末10との接続が確認されると（ステップS21で”YES ”）、携帯情報端末10から受信した電波から位置情報を位置情報抽出部21が抽出してデータベース24に蓄積する（ステップS22)。そして、電波状態判定部23は位置情報抽出部21が抽出した位置情報に基づいて電波状態判定部23が携帯情報端末10の現在位置の電波状態をデータベース24を検索することにより判定する（ステップS23)。

【００２１】電波状態判定部23によるデータベース24の検索の結果、携帯情報端末10の現在位置が電波状態のが不良の場所であると判明した場合には（ステップS24 で”YES ”）、メッセージ通知処理部25が所定のメッセージを携帯情報端末10へ送信する（ステップS24)。図４の模式図にこのメッセージの一例を示す。この例では、携帯情報端末10の表示部11に「現在位置では電波状態が良くないので、200m先の東京駅の前で送信して下さい。」というメッセージが通信制御装置20のメッセージ通知処理部25から送信され、携帯情報端末10のメッセージ通知部16により受信されて表示部に表示される（ステップS25)。

【００２２】一方、携帯情報端末10の現在位置が電波状態が不良の場所ではない場合には（ステップS24 で”NO”）、通信制御装置20は通常の受信処理を行なう（ステップS26，S28）。但し、この受信処理中においては、切断処理部22が携帯情報端末10からの受信電波の状態を常時監視しており、通信が切断された場合には（ステップS26 で”YES ”）、切断処理部22は携帯情報端末10の位置情報にその位置が電波状態が不良の場所であることを示す情報（切断情報）を付加してデータベース24に蓄積する（ステップS27)。このような切断処理部22による通信状態の監視が受信処理の終了まで行なわれる（ステップS29)。

【００２３】以上のように、本システムでは、携帯情報端末10が通信を開始する際にまず現在位置を示す位置情報を送信し、通信制御装置20側でデータベース24に蓄積されている情報を検索してそこが電波状態が不良の場所であるか否かを調べる。そして、携帯情報端末10の現在位置が電波状態が不良の場所である場合には、通信制御装置20から携帯情報端末10に対して電波状態が良好な場所への移動を勧告するメッセージが送信される。更に、通信が行なわれている間に通信が切断された場合には、携帯情報端末10の現在位置が電波状態が不良の場所であることがデータベース24に蓄積される。

【００２４】従って、通信制御装置20には多数の携帯情報端末10からの位置情報が得られ、またそれぞれの位置情報に対応した実際の通信状態の監視結果が得られることにより、多数の場所の電波状態の良否がデータベース24に蓄積されることになる。そして、電波状態が不良の場所において携帯情報端末10からの通信が開始されると、図４の模式図に示されているようなメッセージが通信制御装置20から携帯情報端末10へ送信されてその表示部11に表示されるので、携帯情報端末10のユーザは現在位置の近傍で電波状態の良い場所へ直ちに移動することが可能になる。

【００２５】なお、上述の実施の形態においては、現在位置検出部13は GPSからの電波を利用して携帯情報端末10の現在位置を検出するようにしているが、これに限られるものではなく、他の種々の手法により携帯情報端末10の現在位置を検出することが可能である。

【００２６】

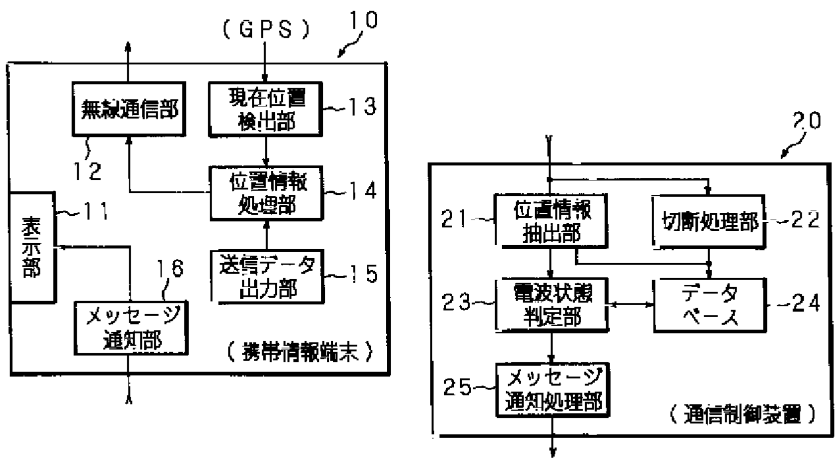
【発明の効果】以上に詳述したように本発明によれば、通信制御装置では、携帯情報端末からの通信接続の都度、位置情報を収集することが出来ると共に、通信状態を監視することによりその位置の電波状態の良否に関する情報を蓄積する。そして、携帯情報端末に対して、通信開始時に携帯情報端末の現在位置の電波状態の良否を調べ、不良である場合には近傍の電波状態の良い場所の情報を送信するので、携帯情報端末のユーザは電波状態が不良である場合には直ちに電波状態の良い場所へ移動して通信を行なうことが可能になる。従って、通信切断を予め回避することが可能になるので、モバイルコミュニケーションシステムの利用効率が向上する。

【図面の簡単な説明】

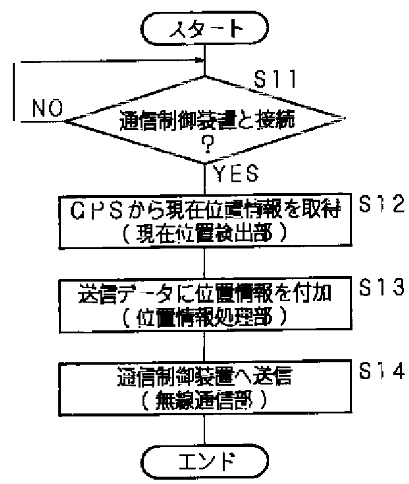
【図１】本発明に係る携帯情報端末及び通信制御装置により構成されるモバイルコミュニケーションシステムの一構成例を示すブロック図である。

【図２】本発明の携帯情報端末の通信開始時の動作を示すフローチャートである。
【図３】本発明の通信制御装置の動作を示すフローチャートである。
【図４】本発明の通信制御装置から送信されて携帯情報端末に表示される電波状態不良時のメッセージの一例を示す模式図である。
【符号の説明】
10　携帯情報端末
11　表示部
12　無線通信部
13　現在位置検出部
14　位置情報処理部
15　送信データ出力部
16　メッセージ通知部
20　通信制御装置
21　位置情報抽出部
22　切断処理部
23　電波状態判定部
24　データベース
25　メッセージ通知処理部

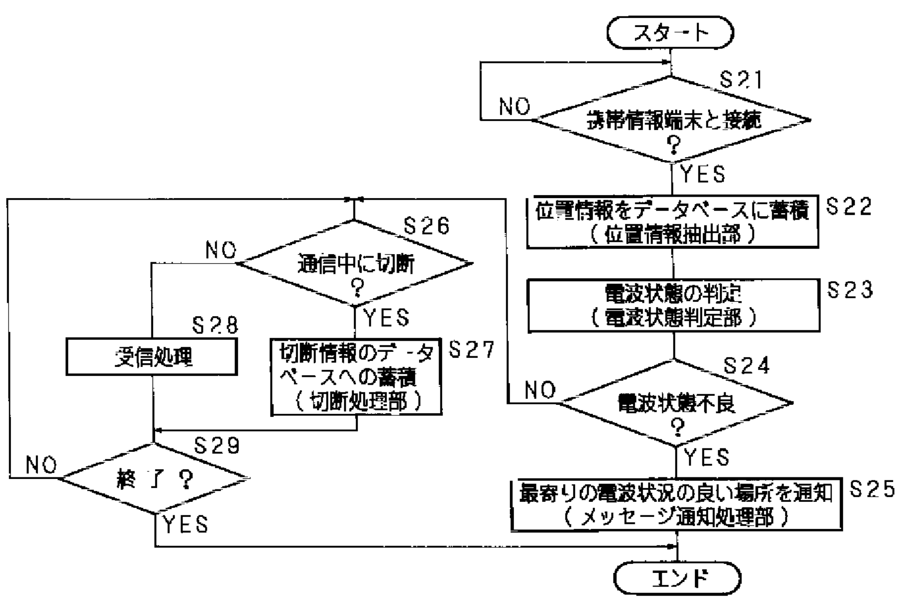
【図１】



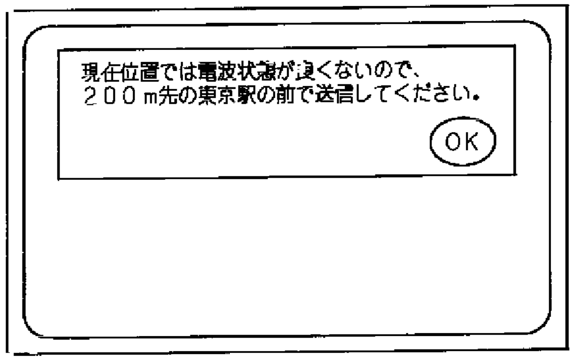
【図２】



【図３】



【図４】



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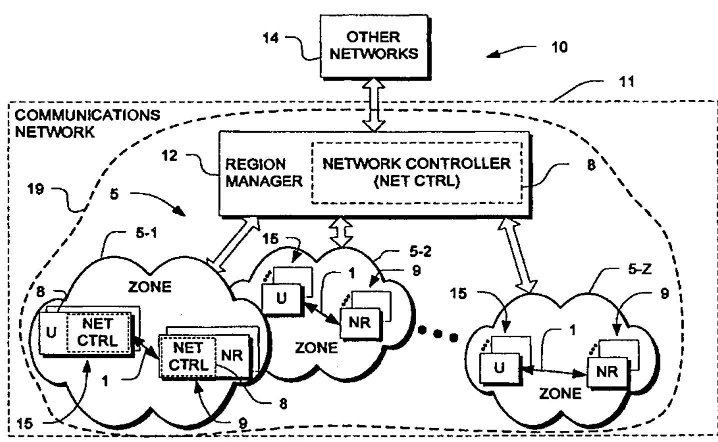

(57) Abstract

A method and apparatus for control of network resources in communications networks based upon the time and locations that communication events occur, the time and locations that communication resources are available and the transmission characteristics at selected times and locations. This invention predicts spatial locations where and times when usage requests can be serviced in a network. A network controller is provided for the network that operates to determine and control the location/time distribution of use requests for resources, the location/time distribution of available resources, and the location/time transmission characteristics in a manner that enhances system performance. The network controller has one or more components, for example communication controllers, a network operating system and network applications. The network controller is located, for example, in a region manager but can be distributed over the network. The network controller obtains and stores knowledge over time (both current and a priori) that is useful in dynamically optimizing system performance.

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METHOD AND APPARATUS FOR NETWORK CONTROL IN COMMUNICATIONS NETWORKS

Background of the Invention

The present invention relates to the field of wireless communications networks and more specifically to methods and apparatus for control of network resources in communications networks based upon the times that and locations at which communication events occur and at which communication resources are available.

Wireless networks

Wireless communications networks utilize network resources in an environment where the demand for and the availability of those communication resources is variable over time and with location. Also, the transmission characteristics of wireless communications networks frequently change over time and with location. The combined effects of changes in use requests, resource availability, transmission characteristics and other factors dynamically affect system performance where system performance includes reliability, efficiency and availability.

Wireless communications networks have many different characteristics and are described, for example, as being single-directional or bi-directional (with balanced or unbalanced traffic in the different directions), simultaneous or non-simultaneous, ground-limited or non-ground-limited and voice or data or combined voice and data. Wireless communications networks employ many types of communication protocols including multiple access protocols such as frequency division (FDMA), code division (CDMA) and space division (SDMA).

Wireless communications networks utilize many different network resources including antennas, transmitters, receivers, spectrum, channels, switches, links and so forth. Wireless networks have interfaces to other systems such as the public switched telephone network (PSTN).

Cellular Networks

Cellular networks are wireless communications networks that "reuse" frequency and other radio frequency (RF) resources within zones or cells to provide wireless communication to users such as cellular phones, computers and other electronic devices. Each cell covers a small geographic area and collectively a group of adjacent cells covers a larger geographic region. Each cell has a fraction of the total amount of the RF spectrum or other resource available to support cellular users. Cells are of different sizes (for example, macro-cell or micro-cell).

The actual shapes and sizes of cells are complex functions of the terrain, the man-made environment, the quality of communication and the user capacity required. Cells are connected to each other via land lines or microwave links and to the public-switched telephone network (PSTN) through telephone switches that are adapted for mobile communication. The switches provide for the hand-off (hand-over) of users from cell to cell as mobile users move between cells.

In conventional cellular networks, each cell has a base station with RF transmitters and RF receivers co-sited for transmitting and receiving communications to and from cellular users in the cell. The base station transmits forward channel communications to users and receives reverse channel communications from users in the cell.

The forward and reverse channel communications use separate channel resources, such as frequency bands or spreading codes, so that simultaneous transmissions in both directions are possible. With separate frequency bands, the operation is referred to as frequency division duplex (FDD) signaling. In time division duplex (TDD) signaling, the forward and reverse channels take turns using the same frequency band. In code division duplex (CDD), the signaling is spread across a wide spectrum of frequencies and the signals are distinguished by different codes.

The base station in addition to providing RF connectivity to users also provides connectivity to a Mobile Telephone Switching Office (MTSO) or Mobile Switching Center (MSC). In a typical cellular system, one or more MTSO' s (MSC' s) will be used over the covered region. Each MTSO (MSC) can service a number of base stations (which are also known as Base Transceiver Stations (BTS)) and associated cells in the cellular system and supports switching operations for routing calls between other systems (such as the PSTN) and the cellular system or for routing calls within the cellular system.

Base stations are typically controlled from the MTSO by means of a Base Station Controller (BSC). The BSC assigns RF carriers or other resources to support calls, coordinates the handoff of mobile users between base stations, and monitors and reports on the status of base stations. The number of base stations controlled by a single MTSO depends upon the traffic at each base station, the cost of interconnection between the MTSO and the base stations, the topology of the service area and other similar factors.

A handoff is a communication transfer for a particular user from one base station in one cell to another base station in another call. A handoff between base stations occurs, for example, when a mobile user travels from a first cell to an adjacent second call. Handoffs also occur to relieve the load on a base station that has exhausted its traffic-carrying capacity or where poor quality communication is occurring. During the handoff in conventional cellular networks, there may be a transfer period of time during which the forward and reverse communications to the mobile user are severed with the base station for the first cell and are not yet established with the second cell.

Cellular Architectures

In wireless networks, both physical channels and logical channels exist where logical channels carry signaling data or user data that is mapped onto physical channels. In cellular networks, traffic channels are logical channels for user data and are distinguished from control channels that are logical channels for network management messages, maintenance, operational tasks and other control information used to move traffic data reliably and efficiently in the system. In general, the term channels refers to logical channels unless the context indicates otherwise and those logical channels are understood to be mapped to physical channels. The control channels process the access requests of mobile users.

Conventional cellular implementations employ one of several techniques to allocate RF resources from cell to cell over the cellular domain. Since the power at a receiver of a radio signal fades as the distance between transmitter and receiver increases, power fading is relied upon to enable RF resource reuse in cellular networks. In a cellular system, potentially interfering transmitters that are far enough away from a particular receiver, and which transmit with acceptable transmission parameters, do not unacceptably interfere with reception at the particular receiver.

In a frequency division multiple access (FDMA) system, a communications channel consists of an assigned frequency and bandwidth (carrier). If a carrier is in use in a given cell, it can only be reused in other cells sufficiently separated from the given cell so that the other cell signals do not significantly interfere with the carrier in the given cell. The determination of how far away reuse cells must be and of what constitutes significant interference are implementation-specific details.

In a time division multiple access (TDMA) system, time is divided into time slots of a specified duration. Time slots are grouped into frames and the homologous time slots in each frame are assigned to the same channel. It is common practice to refer to the set of homologous time slots over all frames as a time slot. Typically, each logical channel is assigned a time slot or slots on a common carrier band. The radio transmissions carrying the communications over each logical channel are thus discontinuous in time. The radio transmitter is *on* during the time slots allocated to it and is *off* during the time slots not allocated to it. Each separate radio transmission which occupies a single time slot is called a burst. Each TDMA implementation defines one or more burst structures. Typically, there are at least two burst structures, namely, a first one for the user access request to the system, and a second one for routine communications once a user has been registered. Strict timing must be maintained in TDMA systems to prevent the bursts comprising one logical channel from interfering with the bursts comprising other logical channels in adjacent time slots.

One example of a TDMA system is a GSM system. In GSM systems, in addition to traffic channels, there are four different classes of control channels, namely, broadcast channels, common control channels, dedicated control channels, and associated control channels that are used in connection with access processing and user registration.

In a code division multiple access (CDMA) system, the RF transmissions are forward channel communications and reverse channel communications that are spread over a wide spectrum (spread spectrum) with unique spreading codes. The RF receptions in such a system distinguish the emissions of a particular transmitter from those of many others in the same spectrum by processing the whole occupied spectrum in careful time coincidence. The desired signal in an emission is recovered by de-spreading the signal with a copy of the spreading code in the receiving correlator while all other signals remain fully spread and are not subject to demodulation.

In wide band CDMA, different bandwidths may be employed. For example, a relatively narrowband signal (compared with the entire band available for the channel) may be used at some times for a lower data rate transfer and a wider band may be employed at other times for a higher bandwidth a higher date rate where the bandwidth is dynamically controlled.

The CDMA forward physical channel transmitted from a base station in a cell site is a forward waveform that includes individual logical channels that are distinguished from each other by their spreading codes (and are not separated in frequency or time as is the case with GSM). The forward waveform includes a pilot channel, a synchronization channel and traffic channels. Timing is critical for proper de-spreading and demodulation of CDMA signals and the mobile users employ the pilot channel to synchronize with the base station so the users can recognize any of the other channels. The synchronization channel contains information needed by mobile users in a CDMA system including the system identification number (SID), access procedures and precise time-of-day information.

Spread spectrum communication protocols include but are not limited to CDMA as well as Frequency Hopping and Time Hopping techniques. Frequency Hopping involves the partitioning of the frequency bandwidth into smaller frequency components, which a channel then uses by hopping from one frequency component to another in an essentially random manner. Interchannel distortion acts essentially as Gaussian white noise across time for each channel. Time Hopping involves a time division scheme wherein each channel starts and stops at differing time slots in an essentially random fashion. Again, interchannel distortion acts essentially as Gaussian white noise across time for each channel.

Many cellular networks are inherently space division multiple access (SDMA) systems in which each cell occupies and operates in a zone within a larger region. Also, cell sectoring, microcells and narrow beam antennas all employ spatial divisions that are useful in optimizing the reuse of RF resources.

Space Diversity

The combining of signals from a single source that are received at multiple spaced-apart antennas is called space diversity. Micro-diversity is one form of space diversity that exists when two or more receiving antennas are located in close proximity to each other (within a distance of several meters for example) and where each antenna receives the signals from the single source. In micro-diversity systems, the received signals from the common source are processed and combined to form an improved quality resultant signal for that single source. Micro-diversity is effective against Rayleigh or Rician fading or similar disturbances. The terminology micro-diverse locations means, therefore, the locations of antennas that are close together and that are only separated enough to be effective against Rayleigh or Rician fading or similar disturbances. The signal processing for micro-diverse locations can occur at a single physical location and hence micro-diversity processing need not adversely impact reverse channel bandwidth requirements.

Macro-diversity is another form of space diversity that exists when two or more receiving antennas are located far apart from each other (at a distance much greater than several meters, for example, several kilometers) and where each antenna receives the signals from the single source. In macro-diversity systems, the received signals from the single source are processed and combined to form an improved quality resultant signal for that single source. The terminology macro-diversity means that the antennas are far enough apart to have de-correlation between the mean signal levels for signals from the single source. The terminology macro-diverse locations means, therefore, the locations of antennas that are far enough apart to achieve that de-correlation. Macro-diversity processing involves forwarding of signals to a common processing location and hence consumes communication bandwidth.

The mean signal levels in macro-diversity systems are de-correlated because each separate signal path has unique propagation properties that diminish the signal strength. The propagation properties in each path are different from those in each other signal path. These unique propagation properties vary with distances above Rayleigh or Rician fading distances and are due to terrain effects, signal blocking by structures or vegetation and other similar environmental factors. Fading due to such factors is referred to as shadow fading. De-correlation distances for shadow fading may be just above Rayleigh fading distances and may be as large as several kilometers.

User Location In Cellular Networks

In cellular networks, equipment and functions are distributed over zones, cells, and other coverage areas. In order to control and operate cellular networks efficiently, information about the location of active users in the system is increasingly important.

In conventional cellular networks, the user location information that has been used has included the cell, or sector of a cell, in which a user is located. The location of a user in a cellular system is important because of the fading of signals as a function of the distance of a receiver from a transmitter. Although increases in broadcast power can be used at greater distances between broadcasters and receivers, such increases tend to cause reception interference by other receivers and hence tend to reduce the user capacity of the system. Accordingly, cellular networks balance RF resources in order to optimize parameters that efficiently establish good system performance. The problems associated with changing times and locations that communication events occur and the times and locations that communication resources are available have created a need for improved methods and apparatus for use in wireless mobile communication systems.

In order to improve system performance, a need exists for improved communication controls that account for location/time distributions of changes in user demand for resources, resource availability, transmission characteristics and other factors.

Summary of the Invention

The present invention is a method and apparatus for network control in communications networks. The communications network has one or more communications zones with users and network resources in each zone communicating in channels using messages. The channels are carried by data links between the users and network resources.

Communications in the network are controlled by a network controller that includes network applications for controlling the communications among users and network resources as a function of system parameters, network stores for storing information including system parameters, a network operating system for integrating the operation of the network applications and the network controller, and network processors for processing the network applications and other components of the network operating system.

The network controller controls the users and network resources based upon the times, locations and conditions of communication events.

In a wireless system embodiment, the present invention uses historical and current information, including system parameters, about the wireless network to predict a spatial location where and when mobile wireless users can be connected for high quality data sessions.

The invention makes advantageous use of knowledge of the actual transport layer over space, the current location and vector of the mobile user, either predictive or "planned" information regarding the future path of the mobile user, the "backlog" of stored transactions in the network and their priorities, and the size and nature of the information to be transferred.

The invention is particularly useful when relatively large data structures are to transmitted to and from wireless users. Since large data structures cannot conventionally be transferred when the bit error rate (BER) is high without lowering spectral efficiency, the present invention chooses times, locations and conditions where low BER exists so as to enhance the transfer of the data. The present invention also employs intelligent queuing to further enhance the performance.

The invention is applied to all forms of wireless illumination, regardless of antenna aperture and is particularly meaningful where there is large variation. The use of "smart" (beam steered) antennas increases frequency re-use on the downlink in the presence of reliable spatial prediction. The asymmetry in data sessions usually means more data is transmitted to the mobile user than from it.

A network controller is provided that operates to determine and control the location/time distribution of user requests for resources, the location/time distribution of available resources, and the location/time transmission characteristics. The network controller obtains and stores knowledge over time (both current and *a priori*) that is useful in dynamically optimizing system performance.

In one embodiment of the invention, the wireless users are mobile and have locations in the zone that can change from time to time. The data transfer characteristics of wireless users are a function of their location and provide unreliable data transfer at specific locations and/or times. The network controller senses when a wireless user is at a specific location and the communication system adjusts to prevent unreliable data transfers at that specific location and time so as to cause a reliable data transfer at other locations or times.

The foregoing and other objects, features and advantages of the invention will be apparent from the following detailed description in conjunction with the drawings.

Brief Description of the Drawings

FIG. 1 depicts a communications system for communications in a region, formed by a number of zones, and controlled by a region manager and network controllers.

FIG. 2 depicts further details of the FIG. 1 system.

FIG. 3 depicts the a block diagram representation of the network controller of FIG. 1.

FIG. 4 depicts a block diagram representation of the network controller of FIG. 3 in distributed form.

FIG. 5 depicts the communications system of FIG. 1 and FIG. 2 where the users are cellular users communicating with communication resources that include a zone manager for broadcasting communications to the cellular users and that include macro-diverse collectors for receiving user communications for forwarding to the zone manger.

FIG. 6 depicts a representation of multiple zones using the macro-diverse collectors of FIG. 5 and forming a cluster of zones in a cellular system.

FIG. 7 depicts a block diagram representation of a typical one of the zones of the FIG. 6 system.

FIG. 8 depicts a block diagram representation of the users, micro-diverse collectors and an aggregator for the communications system of FIG. 5.

FIG. 9 depicts a block diagram representation of a space/time data multiplexer for the communications system of FIG 5.

FIG. 10 depicts a representation of a data message transmitted in the communications system of FIG 5.

FIG. 11 depicts a representation of the wireless data link transmission characteristic during the transmission of the data message of FIG. 10.

FIG. 12 depicts a representation of the modification of the transmission of the data message of FIG. 10 to compensate for the data link transmission characteristic of FIG. 11.

FIG. 13 depicts a representation of the modification of the data link transmission characteristic of FIG. 11 to accommodate the data message of FIG. 10.

FIG. 14 depicts the architecture of the network operating system component of the network controller of FIG. 3.

FIG. 15 depicts a server network controller and a client network controller of the FIG. 3 type connected together for distributed interaction under control of a distributed network operating system.

Detailed Description of the Invention

Communications System -- FIG. 1

FIG. 1 depicts a communications system 10 including a communications network 11 and other networks 14 such as the PSTN. The communications network 11 operates for communications in a region 19, formed by a number of zones 5, including the zones 5-1, ..., 5-Z, controlled by a region manager 12 including a network controller (NET CTRL) 8. The zones 5 include users (U) 15 and network resources (NR) 9 which are connected by data links 1 that enable the users 15 and network resources 9 to actively communicate over channels. The users 15 and network resources 9 also include network controllers 8 that cooperate with the network controller 8 in the region manger 12. Since the users 15 and network resources 9 are distributed over the region 19, their included network controllers 8 are distributed at different locations in the region 19.

The region 19 and the zones 5 are within the universal spatial domain which for generality is defined by three-dimensional coordinate systems so that the term location refers to places in the spatial domain that have space coordinates within a three-dimensional coordinate system. The spatial domain is typically partitioned into regions, such as region 19 and the zones (cells) 5, so that scarce resources (for example, channel frequencies or other reusable phenomena) from one zone can be reused in other zones. In this manner, the scarce resource is conserved while communications capabilities are extended throughout the spatial domain and particularly in the present example throughout the region 19. A typical communications network 11 has users 15 in motion at many different locations in region 19 and the term motion refers to the relative movement of users 15 with respect to network resources 9.

In FIG. 1, the users 15 are any users of network resources 9 and are, for example, wireless phones, computers and other wireless devices in the communications network 11. The network resources 9 are, for example, broadcasters, receivers, signal processors and other communications devices useful for communications with users in region 19. The users 15 and the network resources 9 may include both receive-related and transmit-related components that can be integrated into a single combined component or may be present as separate components and, when separate, the components may or may not be physically proximate and may or may not be of different numbers.

In FIG. 1, any ones of the users 15 may be active or inactive at any given time. Each active user 15 typically engages in bidirectional communications with network resources 9, which in turn typically act to interconnect to one or more other users 15 located either within or external to the communications network 11. The bidirectional communications between two or more users 15 or to other users in the communications system 10 may be simultaneous or non-simultaneous.

The data links 1 in FIG. 1 include components for the direct and logical interconnection of network resources 9 and users 15 and these components exhibit capacities and levels of utilization that may change as a function of time, location and other system parameters. In some instances, the data link components may reach full capacity or may become disconnected directly or logically from particular network resources 9 or users 15. Furthermore, the data links 1 typically exhibit background noise, co-channel and adjacent channel interference, fading and other variations due to changes in the system. The changes in the system include changes in the number of active users 7, changes in the number of network resources 9, changes in background noise, changes due to local phenomena, changes in attenuation and signal propagation, changes in weather conditions, changes in the relative distance of users 15 and groups of users 15 relative to network resources 9.

The data link 1 between the users 15 and the network resources 9 can be characterized as wireline or wireless or characterized as a combination of wireline and wireless. Wireline links include wires and fiber optic and support any of a variety of communications protocols including fibre channel, wavelength division multiple access and orthogonal waveform techniques.

The network controllers 8 operate to determine and control the location/time distribution of communications to service the needs of users 15 based upon the location/time distribution of available network resources 9 and the location/time distribution of transmission characteristics of channels between the users 15 and the network resources 9. The network controllers 8 use the location and time information obtained and may rely upon the history of prior conditions and information to predict conditions that will improve system performance. The network controllers 8 obtain and store information that is useful in dynamically optimizing system performance.

When the communications network 11 of FIG. 1 is ground-based and the users 15 are mobile telephone users, the system operation typically includes handoffs (handovers) between neighboring zones 5 particularly when a mobile user 15 travels from one zone 5 to another zone 5. In typical environments, noise, fading and high Bit Error Rates (BER) are present that can cause dropped calls. In such an environment, the present invention schedules the times and locations for communications in order to improve communications reliability and reduce losses and dropped calls due to noise, fading, high BER or other phenomena.

The FIG. 1 system supports data communications that operate to transfer data messages having message transmission durations in data sessions. Data sessions for transferring data messages can consist of multiple transmission segments. Data messages from or to users 15 can be sent using multiple network resources 9 at different times and locations. For each data session, a determination is made as to where, when and how the data message is to be transferred considering system parameters such as sustainable bandwidth and communication reliability.

Some embodiments of the communications network 11 have a disproportionate amount of traffic in the forward (downlink) direction from network resources 9 to users 15 relative to the reverse (uplink) direction from users 15 to network resources 9.

Some embodiments of the communications network 11 experience wide variations in directional gain, loss and interference from their components. In such embodiments, typically one or more users 15 request data sessions within a common period of time. Prediction as to when and where to start these data sessions with the goal of improving resource allocation improves overall communication reliability and availability. In other embodiments, such as traffic surveillance and weather surveillance systems, a disproportionate amount of data is needed from particular user locations relative to all user locations which are available to provide data.

From time to time, the availability of network resources 9 to serve the needs of users 15 changes. Further, the data links 1 over which communications occur typically have characteristics that change as a function of time and as a function of where users 15 and network resources 9 are located at different times. The combined effects of changes in service needs, resource availability, transmission characteristics and other parameters of the communication network 11 are dynamically changing and affect the overall system performance. System performance includes reliability, efficiency, availability and other factors.

In FIG. 1, each user 15 operates as function of network parameters that affect system performance in the communications system 10 and the communications network 11. For example, a user performance parameter, $U(\alpha, \sigma, \lambda, \tau)$, is a function of a link parameter, α, a signal parameter, σ, a location parameter, λ, and a time parameter, τ. The link parameter, α, is a parameter that indicates properties of the RF spectrum resource that is reused such as frequency in an FDMA protocol or spreading codes or frequencies in CDMA protocol. In wide band CDMA (W-CDMA), spreading codes or frequencies are the resource where the spreading codes are more efficiently used, but the clock speeds are higher in order to accommodate the wider spectrum. The signal parameter, σ, is a parameter that indicates the quality of the RF signal such as power or bit error rate (BER). The location parameter, λ, is a parameter that indicates a location in the region 19 and is typically measured in *x, y, z* or $r(\theta)$ coordinates. The time parameter, τ, is real time, for example.

Each network resource 9 operates as a function of the network parameters. For example, the resource parameter, $R(\alpha, \sigma, \lambda, \tau)$, is a function of the resources available to service users with the link parameters, α, the signal parameters, σ, the location parameters, λ, and the time parameters, τ, for each of the users 15 and collectively for all of the users 15 of network 11.

The network 11 as a whole operates as a function of the network parameters. For example, a system parameter, $S(\alpha, \sigma, \lambda, \tau)$, is a function of all or some subset of the users 15 needing service, is a function of the network resources 9 available to provide service considering the link parameters, α, the signal parameters, σ, the location parameters, λ, and the time parameters, τ, for all of the users 15 and the network resources 9.

The parameters $U(\alpha, \sigma, \lambda, \tau)$, $R(\alpha, \sigma, \lambda, \tau)$ and $S(\alpha, \sigma, \lambda, \tau)$ or any components thereof or statistical values derived therefrom, at any particular time, τ=t, are determined from time to time and are stored in a history store for use in predicting performance from time to time.

Communication events are events measured or determined, at event sample times (τ= 1, 2, ..., T), during communications in the network 11. For each event sample time, the parameters $U(\alpha, \sigma, \lambda, \tau)$, $R(\alpha, \sigma, \lambda, \tau)$ and $S(\alpha, \sigma, \lambda, \tau)$ are determined. In one embodiment, communications with mobile users 15 are processed to detect the users' locations λ in the region 19 and for those locations the parameters $U(\alpha, \sigma, \lambda, \tau)$, $R(\alpha, \sigma, \lambda, \tau)$ and $S(\alpha, \sigma, \lambda, \tau)$ and/or statistical values derived therefrom (generically "sampled parameters") are determined. The sampled parameters for $U(\alpha, \sigma, \lambda, \tau)$ are stored as a function of λ and $R(\alpha, \sigma, \lambda, \tau)$ and $S(\alpha, \sigma, \lambda, \tau)$ to create a stored data map for the communication region 19. After a statistically significant number of events are stored for a particular location, selected new communication events are processed with reference to the stored map in the history store. For example, for a selected communication event, the location

λ_t of the communicating user 15 is determined, the map from the history store is interrogated for the location λ_t, and the parameters U(α, σ, λ, τ), R(α, σ, λ, τ) and S(α, σ, λ, τ) are analyzed. If communication performance is predicted to be improvable, selected components of the parameters U(α, σ, λ, τ), R(α, σ, λ, τ) and S(α, σ, λ, τ) are modified so as to improve system performance.

The stored parameters can be processed in many different ways. For example, a sequence of location parameters for a user 15 are processed to yield user vector information including both the direction and speed of travel of the user. Such user vector information is useful in predicting the future path of the user. Speed is important at times because in some cases bad quality can be tolerated while at other times it cannot as a function of speed. For example, if a user is a vehicle moving fast through a location with bad quality, a data message burst or segment may not be affected by the location. Alternatively, if the location with bad quality is at a stop light where the moving vehicle stops for an extended period to wait for the light to change, the data message may be materially affected. Speed as a function of location is an important system parameter for this and other examples. Speed is determined for a user using a speed network application.

In the present invention, the network controllers 8 distributed throughout the region 19 cooperate to detect, measure and process the network parameters and control the users 15 and network resources 9 to improve and optimize system performance.

Wireless Communications Network -- FIG. 2

In FIG. 2, an embodiment of the communications network 11 of FIG. 1 is shown with users 15 and network resources 9 in region 19 including the zones 5. The users 15 are typically wireless mobile users such as mobile telephones, portable computers and other electronic devices. The users 15 include the users 15-1, ..., 15-W, located in a zone 5-1. The network resources 9 are typical resources such as broadcasters, receivers and signal processors useful in communicating with wireless mobile users 15. The network resources 9 include the network resources

9-1, ..., 9-R located in zone 5-1. The users 15 and network resources 9 are connected by data links 1, including the data links {1-(1,1)... 1-(1,R)} ... and the data links ...{1-(W,1) ... 1-(W,R)}. Each of the zones 5-1, 5-2, ..., 5-Z in region 19 include users, network resources and data links like those in the zone 5-1 and are under control of a region manager 12 and the network controllers 8 for controlling communications in the region.

The wireless communications network 11 of FIG. 2 supports communications that operate to transfer messages having message transmission durations in message sessions. Message sessions can consist of multiple transmission segments. Messages can be sent using multiple network resources 9 at different times and different locations 23 in region 19. For example, a mobile wireless user 15-1 can receive a message at a particular user location 23-1 in zone 5-1, at another location 23-2 in zone 5-1 (to which the user 15-1 moves within a period of time) or to still another location outside of zone 5-1, for example, location 23-3 in zone 5-Z (to which the user 15-1 moves within another period of time). For each message session, a determination is made as to where, when and how the message is to be transferred considering system performance parameters.

The control of the communications in the communication network 11 of FIG. 2 relies upon the operation of the network controllers 8 including the region network controller 8 in the region manager 12 and the zone network controllers 8 in the zones 5.

Network Controller -- FIG. 3

In FIG. 3, a block diagram representation of the network controllers 8 of FIG. 1 and FIG. 2 is shown. The network controllers 8 utilize historical and current spatial and temporal information about the network 11 to determine where, when and how to service the communications needs of users 15. The network controller 8 in FIG. 3 includes network applications 31, a network operating system 32, network processors 33 and network stores 34.

The network applications 31 are computer software or other control logic for controlling the communications between users 15 and network resources 9. The network applications 31 are executed in conjunction with the network operating system 32 and network processors 33 based upon spatial, temporal and other information generated and stored in the network stores 34.

In FIG. 3, the network operating system 32 is a control program, control logic or other means which integrates the operation of the network applications 31, the network processors 33 and the network stores 34. The network operating system 32 maintains a User List, a Net Resources List, a Network Processors List, a Network Stores List and runs processes for scheduling and otherwise servicing the network applications 31.

In FIG. 3, the network processors 33 are general-purpose or special-purpose digital processors for executing the control algorithms of the network operating system 32 and the network applications 31 and for accessing the network stores 34.

In FIG. 3, the network stores 34 are data stores for storing the information used in controlling the communications between users and network resources. The network stores 34 are of the type accessible by general-purpose or special-purpose digital processors for storing control programs and/or control logic of the network operating system 32, the network applications 31 and the system parameters, models and other data of the communications network 11.

The control information used by the network controllers 9 includes the location parameter λ, the link parameter α, the quality parameter σ and the time τ. Additional parameters determined as a function of location and/or time include traffic statistics such as calls started, calls ongoing, calls terminated, hand-offs accepted and rejected and call setups attempted and rejected. Further parameters include user data such as user location, velocity, equipment and historical travel patterns. Still further information includes environmental conditions due, for example, to weather (such as rain, hurricanes, tornados and fog); due to events (such as sporting and other events with large crowds that concentrate users) and due to time-of-day patterns (such as daily commutes). Further parameters include message information including type, size and priority. Further parameters include data link and channel information such as bandwidth requirements, transfer time restrictions and transmission power. In general, the control information used by the network controllers 9 includes any data that is useful in predicting user communications needs and the availability of resources to meet those needs.

The network controller 8 of FIG. 3 obtains the parameter data and processes the data for storage in network stores 34. The network controller 8 uses the stored information to allocate communication resources 9 for servicing the users 15.

Many different network applications 31 are present for execution by network controllers 8 to obtain and process parameters and control information transfers. In general, the network applications 31 include utility applications that are executed to provide information for determining and processing the system parameters and include output applications for controlling operations that provide an out put. Output applications include transfer applications for the transfer of information to and from users using network resources. The utility applications include, for example, a location application for determining the location λ of users 15 and network resources 9, a link application for determining links α, a quality application for determining the quality σ of signals and a time application for coordinating time τ.

Further examples of utility applications include model applications for processing the system parameters and other information to form models and data maps. Models generated from the history data are used to predict spatial and/or temporal changes for one or more parameters used for resource allocation. Models are generated in some embodiments based upon generalized pattern matching without any direct correlation to theoretical user models while in other embodiments the patterns are correlated to a theoretical user model.

The present invention includes a number of transfer applications which are active in transferring information to and from users. A data multiplexer application is one example of a transfer application in which a data message is transferred to a particular user from one or more of the network resources in a data session. In the data multiplexer application, the network controllers 8 determine if the data session for transferring the data message can be completed in a single transmission segment or whether multiple transmission segments are required using multiple network resources at different times and locations. The network controllers executing the data multiplexer determine where, when and how the data message is to be transferred considering the system parameters.

Another example of a transfer application is a priority application where, for example, the first of a number of emergency E911 calls from one location are given priority but subsequent E911 calls from that location are given lower priority than E911 calls from other locations.

Distributed Network Controller -- FIG. 4

FIG. 4 depicts a block diagram representation of the network controller 8 of FIG. 3 in distributed form. Each of the components of the network controller 8 of FIG. 3 are distributed among the users 7, the network resources 9 and the region manager 12. Specifically, the network applications 31 are distributed as network applications modules 31-1, 31-2, ..., 31-A, the network operating system 32 is distributed as network operating system modules 32-1, 32-2, ..., 32-N, the network processors 33 are distributed as network processor modules 33-1, 33-2, ..., 33-P, and network stores 34 are distributed as network stores modules 34-1, 34-2, ..., 34-S. Each of the modules of FIG. 4 can be located in different users 15 and/or network resources 9, but they all operate together logically to carry out their respective functions.

Asymmetrical Cellular System -- FIG. 5

In FIG. 5, one embodiment of the present invention is implemented in an asymmetrical wireless network having multiple collectors 45 in a network resource

9. The asymmetrical wireless network of FIG. 5 is of the type described in the above-identified US Patent 5,715,516.

In FIG. 5, a zone 5-1 of the type described in connection with the wireless communication network 11 of FIG. 1 and FIG. 2 provides communication to users 15 that are wireless users 15 including users 15-1, ..., 15-W. The wireless user 15-1, by way of example, has multiple reverse data links 1_1, ..., 1_{Nc} that connect to multiple collectors 45-1, ..., 45-Nc which in turn connect the reverse channels to zone manager 20. Each of the collectors 45-1, ..., 45-Nc and the zone manager 20 are a network resource 9 as described in connection with FIG. 1 and FIG. 2 and collectively they are combined network resource 9'. The zone manager 20 connects the channels to the users 15-1, ..., 15-W. The wireless users 15, the collectors 45 and the zone manager 20 include network controllers 8 of the distributed form of FIG. 4 for controlling the wireless communications in the zone 5-1. The network controllers 8 function, in one example, to determine which one or more of the collectors 45-1, ..., 45-Nc are active for particular ones of the users 5-1, ..., 15-W in connection with execution of a network application and at different times and locations of the users 15.

Multiple Zone Asymmetrical Cellular Network-- FIG. 6

In FIG. 6, one embodiment of the present invention is implemented in an asymmetrical wireless network of the FIG. 5 type having multiple zones 5, including the zones 5-1, 5-2, ..., 5-6, where each zone has multiple collectors 45 including collectors C1, C2, C3 and C4. The collectors 45 are network resources 9 as described in connection with FIG 5. The asymmetrical wireless multiple zone network of FIG. 6 is of the type described in FIG. 5 and the above-identified US Patent 5,715,516. While the zones of FIG. 6 have been schematically represented as triangles that collectively form a hexagon, zones are frequently irregular in shape and FIG. 6 is only intended to be schematic in nature. Reference is made to the above-identified application entitled METHOD AND APPARATUS FOR COLLECTOR ARRAYS OF DIRECTIONAL ANTENNAS CO-LOCATED

WITH ZONE MANAGERS IN WIRELESS COMMUNICATIONS SYSTEMS in which an actual embodiment of zones with irregular shapes is shown.

In FIG. 6, the zones 5 are like a zone 5-1 of FIG. 5 and a zone 5 hereinafter described in connection with FIG. 7. Each of the zones 5-2, ..., 5-6 includes users 15 like those for zones 5 and 5-1. The zone 5-1 includes a C2 collector 45 that operates, at times determined by the network controllers 8, together with the collectors C1 and C3 where collectors C1 and C3 also operate, at times determined by the network controllers 8, with zone 5-2 together with collector C4.

In FIG. 6, the cellular system is shown having zone managers 20-1, ..., 20-6 of which zone manager 20-1 is typical. The zone managers 20 have broadcasters 16-1, ..., 16-6, where broadcaster 16-1 is typical, that broadcast forward channel (FC) communications to multiple users 15 in one or more of the zones 5-1, ..., 5-6. The zone managers 20 are network resources 9 as described in connection with FIG 5.

In FIG. 6, each of the users 15 transmits reverse channel (RC) communications to one or more of multiple collectors 45 including collectors C1, C2, C3 and C4, which in turn forward the reverse channel communications to aggregators 17-1, ..., 17-6, where aggregator 17-1 is typical. The zone managers 20 can be located at a base station that is configured in a number of different ways. In one configuration determined by the network controllers 8, each broadcaster broadcasts forward channel communications in a different one of six sectors in six different frequency ranges corresponding to the zones 5-1, 5-2, ..., 5-6. The users 15 in the different zones transmit in reverse channels on corresponding frequency ranges to the various collectors operating in their broadcast ranges and the collectors in turn forward reverse channel communications to a corresponding one of the aggregators 17. In another configuration determined by the network controllers 8, all of the zones use the same frequency ranges and no sectorization is employed and in such an embodiment one or more zone managers may be employed. In general, regardless of the configuration, some collector sites are associated with collectors for several zones. For example, C3 services users in two zones, 5-1 and 5-2. The backhaul link from C3 to the aggregator 17-1 is shared by users from zones 5-1 and 5-2.

In one embodiment in order to conserve bandwidth, the confidence metric bandwidth for one zone is at times reduced in order to permit an increase in the bandwidth of another zone where the zones are sharing reverse channel communication bandwidth from common associated collectors, like collectors C1 and C3 in the example described. Bandwidth control algorithms are stored and executed in each collector. Further, the zone manager 20 of FIG. 8 communicates with the processors 42 of FIG. 8 over remote interfaces when adjustments, such as for bandwidth balancing, are required. The implementation of the bandwidth control is through a bandwidth network application.

In FIG. 6, the region manager 12 controls the bandwidth allocation of the zone managers 20-1, ..., 20-6 for the contiguous zones 5-1, ..., 5-6 and for other zones which may or may not be contiguous to the zones 5-1, ..., 5-6.

Cellular System -- FIG. 7

In FIG. 7, a cellular system is shown having a zone manager 20 that includes broadcaster (B)16, aggregator (A)17 and network controller (NET CTRL) 8. The broadcaster 16 broadcasts forward channel (FC) communications from broadcaster 16 to multiple users 15 including users U1, U2, ..., UU located within a broadcaster zone 5 designated by the dashed-line triangle. The users 15 can be at fixed locations or can be mobile. Each of the multiple users 15 transmits reverse channel (RC) communications to one or more of multiple collectors 45 including collectors C1, C2, and C3 which, when active, in turn forward the reverse channel communications to aggregator 17 in zone manager 20. The broadcaster 16, the aggregator 17 and the network controller 8-0 can be co-sited or at different locations. The determination of which ones of the collectors 45 are active for any particular user 15 is under control of network controller 8-0. Network controller 8-0 operates to select active collectors based upon bandwidth availability, signal quality and other system parameters. For purposes of explanation in this application, it is assumed that collectors C1, C2 and C3 have been selected for user U1.

Each of the users 15 has a receiver for receiving broadcasts on the forward channels from the broadcaster 16. Also, each of the users 15 has a transmitter that transmits on reverse channels to the collectors 45. The collectors 45 are sited at macro-diverse locations relative to each other generally within broadcaster zone 5. Therefore, multiple copies of macro-diverse reverse channel communications are received at the aggregator 17 for each user 15.

In the FIG. 7 system, when any user 15 is turned from *off* to *on* in zone 5, an access protocol is followed in order that the user becomes recognized and registered for operations in the system. First, an orientation procedure is followed by user 15 to orient the user to zone manager 20 and any connected network such as the Public switched telephone network (PSTN). The user 15 receives access synchronization signals from the broadcaster 16.

When a user 15 is turned from *off* to *on* in a broadcaster zone 5 and the orientation procedure has been followed, the user 15 sends access request bursts on an access reverse channel. Each burst includes a predetermined access request sequence of bits.

The collectors 45, distributed at macro-diverse locations, are time synchronized and receive the reverse channel signals with access request bursts from the users 15. The access requests from the users received at the macro-diverse collectors 45 are processed and forwarded to an aggregator 17 for final user registration processing.

In FIG. 7, the U1 user $15\text{-}1_1$ is typical and receives forward channel (FC) communications including access sychronization information from broadcaster 16. The user $15\text{-}1_1$ also forwards user-to-collector reverse channel communications ($^{u/c}$RC) including user access requests to each of the collectors 45 and particularly to the active collectors C1, C2 and C3. Each of the active collectors C1, C2 and C3 for user $15\text{-}1_1$ forwards collector-to-aggregator reverse channel communications ($^{c/a}RC1$) to aggregator 17. The reverse channel communications from the U1 user $15\text{-}1_1$ include the user-to-collector communication $^{u/c}RC1$ and the collector-to-aggregator communication $^{c/a}RC1$, the user-to-collector communication $^{u/c}RC2$ and the collector-to-aggregator communication $^{c/a}RC2$ and the user-to-collector communication $^{u/c}RC3$ and the collector-to-aggregator communication $^{c/a}RC3$. Each of the other users U2, ..., UU in FIG. 7 has similar forward channel communications that include access synchronization signals and reverse channel communications that include user access requests.

In FIG. 7, the U1 users $15\text{-}1_1$, ..., $15\text{-}1_{u1}$ are all located in a subzone bounded by the collector C1 and the arc 5_1 and hence are in close proximity to the collector C1. Because of the close proximity, the signal strength of the reverse channel transmissions from the U1 users $15\text{-}1_1$, ..., $15\text{-}1_{u1}$ to collector C1 is normally high. Similarly, the U2 users $15\text{-}2_1$, ..., $15\text{-}2_{u2}$ are all located in a subzone bounded by the collector C2 and the arc 5_2 and hence are in close proximity to the collector C2. Because of the close proximity, the signal strength of the reverse channel transmissions from the U2 users $15\text{-}2_1$, ..., $15\text{-}2_{u2}$ to collector C2 is normally high. The U3 users $15\text{-}3_1$, ..., $15\text{-}3_{u3}$ are all located in a subzone bounded by the collector C3 and the arc 5_3 and hence are in close proximity to the collector C3. The signal strength of the reverse channel transmissions from the U3 users $15\text{-}3_1$, ..., $15\text{-}3_{u3}$ to collector C3 is normally high.

In FIG. 7, the central subzone 5_c generally bounded by the arcs 5_1, 5_2 and 5_3 are relatively far from the collectors C1, C2 and C3 so that the reverse channel signal strength from all of the UU users $15\text{-}U_1$, ..., $15\text{-}U_{uU}$ in this region to each of the collectors C1, C2 and C3 is normally weaker than for users closer to the collectors in the subzones 5_1, 5_2 and 5_3.

The forward and reverse channel communications of FIG. 7 in the present invention apply to any digital radio signal system including, for example, TDMA, CDMA (including W-CDMA), SDMA and FDMA systems. If the digital radio signals of any particular system are not inherently burst structured, then some arbitrary partitioning of time into intervals may be used for processing in accordance with the present invention.

Multiple-Collector Configuration -- FIG. 8

In FIG. 8, a plurality of collectors 45-1, ..., 45-Nc, like the collectors 45 in FIG.5, each are network resources, available under control of network controllers 8, to receive reverse channel communications from users 15-1, ..., 15-U. For each selected user 15, the selected ones of the collectors 45-1, ..., 45-Nc each process the received signals all representing the same communication from the user 15. When more than one of the collectors 45 is selected, these communications have macro-diversity because of the macro distances separating the collectors 45 of FIG. 7. These communications include spatially macro-diverse data bursts, ${}^{1}B_p$, ..., ${}^{Nc}B_p$, and corresponding processed confidence metric vectors ${}^{1}CM_p$, ..., ${}^{Nc}CM_p$ that are forwarded to the aggregator 17 in formatted form designated as ${}^{1}B_p/{}^{1}CM_p/{}^{1}M/{}^{1}CC$, ..., ${}^{Nc}B_p/\ {}^{Nc}CM_p/\ {}^{Nc}M/\ {}^{Nc}CC$. The aggregator 17 combines the spatially diverse data bursts ${}^{1}B_p$, ..., ${}^{Nc}B_p$, and corresponding confidence metric vectors ${}^{1}CM_p$, ..., ${}^{Nc}CM_p$ to form a final single representation of the data burst, B_f, with a corresponding final confidence metric vector, CM_f. The aggregator 17 may use the measurement signals ${}^{1}M$,..., ${}^{Nc}M$ and control signals ${}^{1}CC$, ... ${}^{Nc}CC$ in selecting or processing the data bursts ${}^{1}B_p$, ..., ${}^{Nc}B_p$, and/or the corresponding confidence metric vectors ${}^{1}CM_p$, ..., ${}^{Nc}CM_p$. For example, if a particular burst is associated with a poor quality signal, the particular burst may be excluded from the aggregation. The quality of a signal is measured in one example based on the channel model attenuation estimate.

In FIG. 8, the collectors 45-1, ..., 45-Nc include RF subsystems 43-1, ..., 43-Nc which have two or more micro-diversity receive antennas 48-1, ..., 48-N_a. The antennas 48-1, ..., 48-N_a each receives the transmitted signals from each one of a plurality of users 15-1, ..., 15-U. Each representation of a received signal from a single user that is received by the RF subsystems 43-1, ..., 43-Nc connects in the form of a burst of data to the corresponding one of the signal processors 42-1, ..., 42-Nc. The received data bursts from the antennas 48-1, ..., 48-N_a are represented as ${}^{1}B_r$, ..., ${}^{Na}B_r$. The signal processors 42-1, ..., 42-Nc process the plurality of received bursts for a single user to form single processed bursts, ${}^{1}B_p$, ..., ${}^{Nc}B_p$, representing the signals from the single user. The processed bursts, ${}^{1}B_p$, ..., ${}^{Nc}B_p$, have corresponding confidence metric vectors, ${}^{1}CM_p$, ${}^{2}CM_p$, ..., ${}^{Nc}CM_p$, representing the reliability of each bit of the data bursts. Each processed burst has the bits β_{p1}, β_{p2}, ..., β_{pB} and the processed confidence metric vector, CM_p, has the corresponding processed confidence metrics cm_{p1}, cm_{p2}, ..., cm_{pB}. Measurement signals, ${}^{1}M$, ..., ${}^{Nc}M$, are formed that measure the power or other characteristics of the signal. The processed bursts, the confidence metric vectors, and the measurements connect to the interface units 46-1, ..., 46-Nc which format those signals and transmit or otherwise connect them as reverse channel signals to the aggregator 17.

In FIG. 8, the signal processors 42-1, ..., 42-Nc receive timing information that permits collector signals from each collector to be time synchronized with signals from each of the other collectors. For example, each collector may have a global positioning system (GPS) receiver (not shown) for receiving a time synchronization signal. Alternatively, or in addition, the zone manager 20 of FIG. 7 can broadcast or otherwise transmit time synchronization information. The signal processors 42-1, ..., 42-Nc provide time stamps in collector control signals ${}^{1}CC$, ..., ${}^{Nc}CC$ that are forwarded from interface units 46-1, ..., 46-Nc as part of the reverse channel signals to the aggregator 17.

In FIG. 8, a block diagram representation of the aggregator 17 is shown. The aggregator 17 includes a receive/format group 66 which operates to receive and format signals transmitted by the collectors 45. The received signals ${}^{1}B_p/{}^{1}CM_p/{}^{1}M/{}^{1}CC$, ${}^{2}B_p/{}^{2}CM_p/{}^{2}M/{}^{2}CC$, ..., ${}^{Nc}B_p/{}^{Nc}Cm_p/{}^{Nc}M/{}^{Nc}CC$, after formatting are connected to the signal processor 67 which processes the received signals for macro-diversity combining. The format group 66 uses the time stamp and other control code (CC) information to align the signals from different collectors for the same user. More specifically, the unit 66 for each one or more bursts compares and aligns the time stamps from the control fields ^{1}CC, ^{2}CC, ..., ^{Nc}CC so that the corresponding data, confidence metric and measurement signals from different collectors, for the same common burst from a user are aligned.

The signal processor 67 for the aggregator 17 processes the burst signals from each user and the N_c representations of the reverse channel signal from the user as received through the N_c active collectors 45 under control of the network control 8 in aggregator 17. The network control 8 in aggregator 17 can use the signal processor 67 as the network processor 33 (see FIG. 3). The signal processor 67 functions, among other things, to generate BER signals and communicates them to the network controller 8. The N_c data, metric and measurement values for a single user include the data and processed confidence metric pairs [$^{1}B_b$, ^{1}CM], [$^{2}B_b$, $^{2}CM_p$] , ..., [$^{Nc}B_b$, $^{Nc}CM_p$] and the measurement values s, ^{1}M, ^{2}M, ..., ^{Nc}M. The processed confidence metrics, $^{1}CM_p$, $^{2}CM_p$, ..., $^{Nc}CM_p$ are processed to form the aggregator processed confidence metrics, $^{1}CM_{pp}$, $^{2}CM_{pp}$, ..., $^{Nc}CM_{pp}$.

Communications Network Operation

The communications network 11 of FIG. 1 and FIG. 2 operates with many network applications 31 as explained with reference to FIG. 3 and FIG. 4. The network applications 31 include a number of transfer applications some of which are listed in the following LIST 1.

LIST 1 TRANSFER APPLICATIONS	
Application Name	Application Operation
Resend Application	Resend entire Data Message upon detection of high BER
Segmented Resend Application	Partition Data Messages into segments, record which segments arrive with BER above and which segments arrive with BER below BER_T and resend only segments when BER is above BER_T.
Error-Correcting Application	Send Data Messages with error correction codes and correct detected errors.
Segmented Error-Correcting Application	Predict which segments will encounter BER above BER_T and send those segments with error-correcting codes.
Data Multiplexer Application	Predict locations where transfer in one or more segments can occur and send Data Message when user is at those locations using either a single-segment transfer or a multi-segment transfer.
Multi-User Broadcast Application	Multiple users receive a broadcast of the same data message, each transfer to a user potentially using a different one of the other transfer applications as a function of system parameters.

The present invention operates, in one example, where a data message is transferred using a selected one of the transfer applications of LIST 1. The decision as to which transfer application to employ is made consulting the network stores 34 to determine if a history of similar transfers is stored including the availability of resources from the resource parameter, R(α, σ, λ, τ), the particular characteristics for the particular user from the user parameter U(α, σ, λ, τ), and the conditions of the system from the system parameter S(α, σ, λ, τ). For example, if the history store for the particular user at the particular location, using selected data links and other resources for the current time of transmission, and the system load and priority determined by the system parameter indicates that a data multiplexer application is the desirable transfer application to select, then the data message is sent using the data multiplexer application. In general, the decision of which data transfer application and its transfer algorithm is to be used is based upon minimizing the load on system resources.

The load on system resources varies as a function of the network transfer application selected. The resend application is more inefficient the greater the frequency that the BER is above BER_T for a data message since more resources must be used for transferring resend traffic. The segmented resend application can have increased efficiency relative to the resend application but it is also is ineffective in high BER environments. The error-correcting application burdens the transmissions with extra error-correcting bits. While the segmented error-correcting application increases efficiency relative to the unsegmented error-correcting application, one of the other transfer applications may still be required when uncorrectable segments are present. The data multiplexer application is efficient and usually requires a minimum of resources relative to other network applications 31 that also achieve reliable message delivery.

The quality of received signals as measured, for example, by BER is a function of many different parameters in the communications network 11. Also, the value for BER_T can vary depending on the network application 31 being executed, the communication protocol, the types of data transferred and other system parameters.

<u>Data Multiplexer Application--FIG. 9</u>

FIG. 9 depicts a block diagram representation of a data multiplexer application 31-1 together with utility applications 31-0. The utility applications 31-0 are applications 31 of the network controllers 8 of FIG. 3 and FIG. 4 and are used to support the data multiplexer application 31-1 and other network operations. The data multiplexer application 31-1 and the utility applications 31-0 are executed by the network processors 33 of FIG. 3 and FIG. 4.

The data multiplexer application 31-1 functions to determine when some portions of a data message are likely to exhibit excessive errors during the data session as compared to how a data message otherwise would be transmitted over a data link absent the intervention of the network controllers. Such errors occur when the BER for messages over the data link is high. In one execution, the data message is broken into segments and each segment is sent only when the BER is low. In another execution, the transmission characteristics (TC) of the data link are modified to reduce BER to an acceptable level so that the data message can be sent without need for segmentation. In still additional executions, a combination of segmentation and transmission modification are used.

The data multiplexer application 31-1 includes a parameter module 25, a link module 26, a transfer module 27 and a message module 28. The message module 28 functions to supply and control the data message identifying the properties of the message including the source of the message, the destination of the message, the length of the message and segmentation boundaries within the message. The link module 26 identifies the particular network resources that establish a data link between the source and destination identified in the data message module and the transmission characteristics of the data link. The transfer module 27 controls the transmission of the data message over the channel and selected data link, determines start and stop times of the data message and any segments that may be required. The parameter module 25 determines and processes the system parameters that are used in controlling the transfer.

In the data multiplexer application, the system parameters include the current location, λ_c, of the destination user, the projected location, λ_p, of the destination user, the current signal quality, σ_c, of the data link between the user at the current location and the network resource, the projected signal quality, σ_p, of the data link between a user at the projected location and the network resource and the current time, τ_c, when the destination user is at the current location and the projected, τ_p, when the destination user will be at the projected location. The system parameters are determined and controlled in cooperation with the utility applications 31-0 of FIG. 9.

In FIG. 9, the utility applications 31-0 support the operation of the data multiplexer application in the following way. The location utility application operates to use location algorithms to periodically, at a location sampling rate, identify the current location, λ_c, of the destination user.

Referring to FIG. 7, the location algorithm operates, for example, to select three or more collectors 45 (collectors C1, C2 and C3) that are time synchronized and measures the time difference of arrival of the reverse channel signals from a destination user such as user $15\text{-}1_1$. Since the collectors 45 are at known locations, the locations of users can be accurately determined at the aggregator 17, for example.

Each current location is stored together with the time of the sample in a current data table. Concurrently with each location measurement, a quality utility application measures the current signal quality, σ_c, at each current location and stores the data in the current data table. A quality-history utility application processes all the current data tables for each user to build a quality-history data map of the zone with signal quality versus location for each data link separately or in combination when aggregation of signals is employed. Each new sample of data is combined with a weighting algorithm with the data stored in the quality-history store. The weighting in one example uses the number of samples used to generate the data in the quality-history store as the weight for the data in the quality-history store and the weight for each new sample is a weight of 1.

A speed network application determines the speed of a user, for example, by determining the rate of change of the locations in the current data table.

Although locations of users are important, network applications can also determine locations of elements or conditions within the communications network. In some cases, the locations and patterns of "interferers" may be of interest. Interferers can be moving and, include by way of example, climate conditions such as heavy fog, rush-hour high usage areas in CDMA and other systems and microwave blasts. In general, any of such conditions in a communications network can be located using a condition network application.

A speed network application determines the speed of users, for example, by determining the rate of change of the locations in the current data table for each user.

A path-history utility application processes all the current data tables for each user to build a path-history data map of the zone with current location versus projected location. The path-history algorithm functions to analyze the entire sequence of locations in the current data table for fits of similar sequences of locations in a path-history store. When more than one path in the path-history store correlates against the current sequence, branch locations in paths are recorded identifying possible alternate future paths. For each stored path, a range of path traversal rates are stored as a function of location, time and date.

In one data multiplexer application, a data message is to be transferred from a particular user, such as user 15-1 in FIG. 2, to one or more of the network resources during a data session. In the data multiplexer application, the network controllers 8 determine if the data session for transferring the data message can complete in a single transmission segment or whether multiple transmission segments are required. The data message from user 15-1 can be sent using multiple network resources 9 at different times and locations and a determination is made as to where, when and how the data message is to be transferred considering the system parameters. For example, the data message can be commenced by network resources 9-1 when the user 15-1 is at location 23-1, thereafter may be suspended for a time until user 15-1 moves to location 23-2 and the data message continues from network resource 9-R and still further may continue to completion only when user 15-1 is at location 23-3 in zone 5-Z.

Data Multiplexer Example-- FIG. 10 to FIG. 13.

In FIG. 10, the data message DM that extends from t=2 to t=12 is to be transmitted in a data session having one or more segments. By way of example, assume the data message of FIG. 10 is to be transferred from the user $15\text{-}1_1$ of FIG. 7 to the aggregator 17 in zone manager 20. In the example, assume the user $15\text{-}1_1$ is moving on a path 71 starting at a location $\lambda_{t=p}$ prior to the current location $\lambda_{t=2}$ and projected to travel to the location $\lambda_{t=20}$.

To transfer the data message of FIG. 10 from user $15\text{-}1_1$ to the aggregator 17 in zone manager 20 using network resources which include the collector C1, C2 and C3, the network controllers 8 determine if the data session for transferring the data message can be completed in a single transmission segment or whether multiple transmission segments are warranted. The network controllers 8 include the network controller 8-0 in zone manager 20 and the network controllers 8-1, 8-2 and 8-3 in the collectors C1, C2 and C3, respectively.

To determine if multiple segments are warranted, the network controllers 8 determine the projected transmission characteristic of the data link over the projected travel path of the user $15\text{-}1_1$ from the current time t=2 at least until t=12 and in the present example until t=20 using the utility applications 31-0 of FIG. 9. In FIG. 7, the prior path of the user $15\text{-}1_1$ from $\lambda_{t=p}$ to the current location at $\lambda_{t=2}$ is recorded in the current data table. The prior path data for user $15\text{-}1_1$ is detected by operation of the collectors C1, C2 and C3 transmitting location information to the aggregator 17. The prior path data in the current data table is analyzed against the path-history store data to determine the projected path of the user $15\text{-}1_1$ between the location $\lambda_{t=2}$ and location $\lambda_{t=20}$.

As shown in FIG. 11, the transmission characteristic of the wireless data link from user $15\text{-}1_1$ is estimated to have a high BER that is above the threshold

BER_T between t=9 until about t=14 and hence, between t=9 until about t=14, the data message of FIG. 10 cannot be reliably transmitted over the projected path of user $15\text{-}1_1$ unless some adjustment is made.

As shown in FIG. 12, the present invention in one embodiment makes an adjustment and transmits the data message of FIG. 10 in two segments, a first segment between t=2 and t=8 and a second segment between t=16 and t=20. The first and second segments are present when the BER is below the threshold BER_T.

In FIG. 9, the link module 26 processes the link data α that determines and controls what data links are available and active. The transfer module 27 receives the data message from the message module 28 and in the present example breaks the data message for transmission into two segments. The parameter module 25 processes system parameters including the quality parameter σ for the current data table and projects the transmission characteristics of FIG. 11 that determine projected excessive BER from about t=9 to about t=15.

The following TABLE 1 is a current data table for the user system parameters $U(\alpha,\sigma,\lambda,\tau)$ for the data multiplexer application of FIG. 9 when only the wireless data link $\alpha={}^{u/c}RC1$ between the user $15\text{-}1_1$ and the collector C1 in FIG. 7 is used for data transfer. Note that the measured current data quality parameter σ of TABLE 1 tracks the estimated transfer characteristic of FIG. 11 so that error free transfer of the data message of FIG. 10 is achieved with effective use of bandwidth in the two segments of FIG. 12.

TABLE 1		
Time τ	Location λ	Link $\alpha={}^{u/c}RC1$ Quality σ
t=p	$\lambda_{t=p}$	2.5
t=p+1	$\lambda_{t=p+1}$	3.5
	• • •	
t=0	$\lambda_{t=0}$	3.0
t=2	$\lambda_{t=2}$	2.5
	• • •	
t=8	$\lambda_{t=8}$	4.0
t=10	$\lambda_{t=10}$	6.5
t=12	$\lambda_{t=12}$	10.0
	• • •	
t=16	$\lambda_{t=16}$	3.0
t=18	$\lambda_{t=18}$	1.5
t=20	$\lambda_{t=20}$	1.5

The following TABLE 2 is a current data table for the user system parameter $U(\alpha,\sigma,\lambda,\tau)$ for the data multiplexer application of FIG. 9 when the wireless data links $\alpha={}^{u/c}RC1$, $\alpha={}^{u/c}RC2$ and $\alpha={}^{u/c}RC3$ between the user $15\text{-}1_1$ and the collector C1, the collector C2 and the collector C3, respectively, in FIG. 7 are available for data transfer of the data message of FIG. 10. In the TABLE 2 example, the network controllers determined that the data message of FIG. 10 can be transmitted in a single segment if the quality of the data link between user $15\text{-}1_1$ and collector C1 is improved at least between t=8 to t=16. To improve the quality, the confidence metric processing for ${}^{1}CM_{p}$ in the collector 45-1 of FIG. 8 is adjusted. The result of the adjustment reduces the BER below the threshold BER_T as shown by the broken line in FIG. 13.

Note that the measured current data quality parameter σ_1 of TABLE 2 is below the threshold BER_T for the entire period t=2 to t=12 so that error free transfer of the data message of FIG. 10 is achieved in one segment from t=2 to t=12.

Note that the measured current data quality parameters σ_1, σ_2 and σ_3 of TABLE 2 (which for purposes of the present example are assumed to be the same as the estimated values) indicate that other mechanisms for error free transfer of the FIG. 10 data message are available to the network controllers 8. For example, during the period from t=8 to t=16 when the quality of σ_1 is bad, the quality of σ_3 is uniformly good and below the threshold BER_T. Accordingly, the network controllers 8 can operate to select one portion of the data message of FIG. 10 over the data link $\alpha={}^{u/c}RC1$ from t=2 to t=8 and the other portion of the message over the data link $\alpha={}^{u/c}RC3$ from t=8 to t=12. As a further alternative, aggregation of the signals is possible from all of the data links $\alpha={}^{u/c}RC1$, $\alpha={}^{u/c}RC2$ and $\alpha={}^{u/c}RC3$

between the user $15\text{-}1_1$ and the collector C1, the collector C2 and the collector C3, respectively, as forwarded to the aggregator 17.

TABLE 2				
Time τ	Location λ	Link $\alpha={}^{u/c}RC1$ Quality σ_1	Link $\alpha={}^{u/c}RC2$ Quality σ_2	Link $\alpha={}^{u/c}RC3$ Quality σ_3
t=p	$\lambda_{t=p}$	2.5	5.5	5.5
t=p+1	$\lambda_{t=p+1}$	3.5	5.0	5.0
		• • •		
t=0	$\lambda_{t=0}$	3.0	4.5	5.5
t=2	$\lambda_{t=2}$	2.5	5.5	5.5
		• • •		
t=8	$\lambda_{t=8}$	4.0	6.0	3.5
t=10	$\lambda_{t=10}$	4.5	5.0	3.5
t=12	$\lambda_{t=12}$	5.0	5.5	2.5
t=14	$\lambda_{t=14}$	4.5	5.0	3.5
t=16	$\lambda_{t=16}$	3.0	5.5	4.5
t=18	$\lambda_{t=18}$	1.5	3.5	4.5
t=20	$\lambda_{t=20}$	1.5	2.5	4.0

The decision as to which particular resources and methods are employed for each data message is a function of the quality of the history data in the history stores and the efficient allocation of resources among users competing for system resources. The utility applications 31-0 include a resource application that operates to determine resource parameters, R(α, σ, λ, τ), as a function of the resources available to service users with the link parameters, α, the signal parameters, σ, the location parameters, λ, and the time parameters, τ, for each of the users 15 and collectively for all of the users 15 of network 11.

The network 11 as a whole operates as a function of the network parameters. For example, a system parameter, S(α, σ, λ, τ), is a function of all or some subset of the users 15 needing service and is a function of the network resources 9 available to provide service considering the link parameters, α, the signal parameters, σ, the location parameters, λ, and the time parameters, τ, for all of the users 15 and the network resources 9.

The network controllers 8 are distributed in FIG. 7 in the manner indicated in FIG. 4. In FIG. 7, the network controller 8-0 in the zone manager 20 is a server network controller or a client network controller depending, among other things, on the direction of data transfer and the other network controllers 8-1, 8-2 and 8-3 in the collectors C1, C2 and C3 are client network controllers or server network controllers depending, among other things, on the direction of data transfer.

The distributed components of network controller 8-0 include the FIG. 3 components, namely, server network applications 31, server network operating system 32, server network processors 33 and server network stores 34. The server network stores 34 include the current data store for storing data of the TABLE 1 and TABLE 2 type, a quality-history store, a path-history store, a program store for storing the network operating system 32 and network applications 31. The server network applications 31 include the transfer applications, such as the data multiplexer application, and utility applications. The utility applications include a resource application that operates to determine resource parameters, R(α, σ, λ, τ) which among other things identifies the collectors (C1, C2 and C3) available, operational features of the collectors (for example, confidence metric parameters, micro-diversity, aggregation and non-aggregation modes, location and time off-sets from server time, current users and channel assignments) and the features of the zone manager (for example, confidence metric parameters, the presence of micro-diversity and the number of micro-diverse antennas for collectors, aggregation and non-aggregation modes, location and time off-sets from other zone managers and the current user load for the channels in use). The utility applications include system parameter, S(α, σ, λ, τ), application for keeping track of the users 15 needing service and the network resources made available to provide service. The server network operating system 32 includes a scheduler task for scheduling the operations of the network applications 31 and the other operations of the network controller 8. The server network processors 33 are any one or more processors for executing the network applications 31 and the network operating system 32. In general, the server network applications 31, server network operating system 32, server network processors 33 and server network stores 34 within the network controller 8-0 of FIG. 7 correspond to the components of modules 31-1, 32-1, 33-1 and 34-1 with reference to FIG. 3.

The distributed components of network controllers 8-1, 8-2 and 8-3 in a conceptually simple embodiment are substantially identical to those in the network controller 8-0 except that they are made to function as clients or servers, the opposite as the functioning of controller 8-0 depending on the network application and other factors. With reference to FIG. 4 and FIG. 7, a network controller 8-1 for collector C1 includes the distributed components 31-2, 32-2, 33-2 and 34-2 ,a network controller 8-2 for collector C2 includes the distributed components 31-3, 32-3, 33-3 and 34-3 (not explicitly shown in FIG. 4) and a network controller 8-3 for collector C3 includes the distributed components 31-4, 32-4, 33-4 and 34-4 (not explicitly shown in FIG. 4). In actual practice, however, the requirements of the network controllers 8-1, 8-2 and 8-3 are generally less so that for economy, only a subset of the components of the network controller 8-0 need be mirrored in the network controllers 8-1, 8-2 and 8-3.

Network Operating System – FIG. 14

In FIG. 14, the architecture of the network operating system 32 of FIG. 3 is shown and is that of a real-time operating system with the conventional structure, features and capabilities of such operating systems. The architecture is different in that it is a wireless operating system in that components of the operating system are interconnected over wireless links in a communications network. In addition to the conventional structure, features and capabilities, the network operating system 32 includes in one embodiment the communications architecture of the following TABLE 3.

TABLE 3

Network Operating System
- Scheduler Task
- Synchronizer Task
- Priority Task
- Conventional Tasks

Network Applications

- Output Applications
  - Data Transfer
  - Multipoint Data Transfer
  - E911
  - User Location Report
  - Operation And Maintenance Reports

- Utility Applications
  - User Location Detect And Location Store Update
  - User Direction and Rate of Travel
  - Network Resources Assignment and Control
  - Link Quality Detect And Quality-History Store Update
  - User Path Detect And Path-History Store Update
  - Channel Assignment And Control
  - Channel Handover
  - Network Resources Selection (Broadcasters/Collectors)

Referring to TABLE 3, FIG. 3 and FIG. 14, the network operating system 32, in addition to conventional tasks 84, includes, for example, a scheduler task 81, a synchronizer task 80 and a priority task 82. The scheduler task 81 functions to schedule execution of the network applications 31. The synchronizer task 80 functions to synchronize the server execution with the client execution. The priority task 82 functions to control the prioritization of scheduled executions of network applications 31 and detects and responds to high priority events and the network applications that are affected. Each instance (for example, a server instance and a client instance) of the network operating system of FIG. 14 can be executed on one or more of the network processors 33 as indicated in FIG. 3 and in FIG. 4.

Referring to FIG. 14, an embodiment of the network operating system 32-1 is shown that can be both a server instance and a client instance of the network operating system. The network operating system 32-1 includes conventional tasks 84, scheduler task 81, a synchronizer task 80 and a priority task 82. The scheduler task 81 schedules conventional tasks 84 and network applications 31 requiring execution. The network applications 31 requiring execution are stored in the network operating system (NOS) queues 83 including the priority queue 83-1, the repeat queue 83-2 and the demand queue 83-3. The demand queue 83-2 queues output applications that are added to the demand queue by the queue load 89. The queue load 89 is supplied by network applications from various sources including internally generated requests from the network operating system 32-1 at input 88 and by network applications detected by the channel analyzer 85. The channel analyzer 85 functions to monitor activity on the channels to detect output applications that require scheduling. The repeat queue 83-2 queues utility applications that are repeatedly executed to keep the system parameters and other information current. The priority queue 83-1 queues priority applications that need priority attention as determined by the priority task 82. The priority task 82 monitors the activity of the queue load 89 to detect high priority applications, such as E911 applications, and grants such applications priority to the scheduler task 81.

Scheduled tasks from the scheduler task 81 are then synchronized in the synchronizer task 80 to insure coordination between client and server embodiments of the network operating system 32.

Server/Client Architecture – FIG. 15

In FIG. 15, a server network controller 8-0 and a client network controller 8-1 of the type described in connection with FIG. 3 with a network processor 33 and network stores 34. The network stores 34 include the network operating system 32 and network applications 31 including output applications and utility applications.

The manner in which the network controllers 8-0 and 8-1 operate in connection with the data multiplexer application of FIG. 9 is as follows assuming that the data message of FIG. 10 is to be transferred from a zone manager 20 to a user 15 (the opposite direction to that previously described) under control of the server network controller 8-0 and the client network controller 8-1 of FIG. 15.

In FIG. 15, two instances of the network operating system 32-1 of FIG. 14 are invoked, one for the network controller 8-0 having modules with subscripts ZM and one for the network controller 8-1 having modules with subscripts U1. Referring to FIG. 9 and FIG. 15, the network controller 8-0 includes, for example, message module 28, MM_{ZM}, transfer module 27, TM_{ZM}, link module 26, LM_{ZM}, and parameter module 25, PM_{ZM}. Referring to FIG. 9 and FIG. 15, the network controller 8-1 includes, for example, the message module 28, MM_{U1}, transfer module 27, TM_{U1}, link module 26, LM_{U1}, and parameter module 25, PM_{U1}.

The module, MM_{ZM}, includes, for example, a Server_ID, a Client_ID, DataMessage_ID and a DataMessage_Length and places through the queue load 89 of FIG. 14 the transfer application for the data message on the demand queue 83-3. The module LM_{ZM} includes, for example, a Server_ID, a Client_ID, a DataMessage_ID, a Channel_ID and a Link_ID for identifying the channel and link over which the data message is to be sent. The module PM_{ZM} includes, for example, a Server_ID, a Client_ID, a DataMessage_ID, a Channel_ID, a Link_ID and user parameters P_{U1} for the particular data link between user 15 and zone manager 20. The parameter processing, relying on utility applications, determines the current location, λ_c of U1, the estimated path of U1 and where on the estimated path the transfer characteristic, TC, is less than BER_T. The module TM_{ZM} includes, for example, a Server_ID, a Client_ID, a DataMessage_ID, a Channel_ID and a Link_ID. The module TM_{ZM}, for locations on the estimated path of U1 where TC is less than BER_T, partitions the Data Message into one or more segments. For transfer of the data message, the module TM_{ZM} issues a Message_TransferMethod (one of the transfer applications of LIST1 and in the present example Data Multiplexer), Message_Length, No_Segments, Message_Start, intermediate segment messages, if any, and Message_End. The intermediate segment messages include Segment1_Start, Segment1_End, Segment2_Start, Segment2_End, ..., SegmentL_Start, SegmentL_End. Assuming that the FIG. 12 segmentation is employed, the module TM_{ZM} issues a Message_TransferMethod (Data Multiplexer), Message_Length (10), No_Segments (2), Message_Start (t=2), Segment1_Start (t=2), Segment1_End (t=8), Segment2_Start (t=16), Segment2_-End (t=20) and Message_End (t=20).

The module, MM_{U1}, receives a Server_ID, a Client_ID, DataMessage_ID and a DataMessage_Length and places on the priority queue 83-1 through the queue load 89 and priority task 82 of FIG. 14 a transfer application to control receipt of the data message. The module LM_{U1} receives a Server_ID, a Client_ID, a DataMessage_ID, a Channel_ID and a Link_ID for identifying the channel and link over which the data message is being sent. The module PM_{U1} receives a Server_ID, a Client_ID, a DataMessage_ID, a Channel_ID, a Link_ID and, assuming in the embodiment described that the user has the capability to calculate BER, calculates user parameters P_{U1} including the actual BER for the transfer of the data message over the particular data link between user 15 and zone manager 20. The parameter processing determines when the transfer characteristic, TC, is less than BER_T during the data message transfer. The module TM_{U1} receives a Server_ID, a Client_ID, a DataMessage_ID, a Channel_ID and a Link_ID. The module TM_{U1}, for locations on the estimated path of U1 where TC is greater than BER_T, determines if the Data Message segments are active, that a Segment_Start has been received and a Segment_End has not. During transfer of the data message, the module TM_{U1} looks for a Message_TransferMethod, Message_-Length, No_Segments, Message_Start, intermediate segment messages, if any, and Message_End. With the FIG. 12 segmentation, the module TM_{U1} receives a Message_TransferMethod (Data Multiplexer), Message_Length (10), No_Segments (2), Message_Start (t=2), Segment1_Start (t=2), Segment1_End (t=8), Segment2_Start (t=16), Segment2_End (t=20) and Message_End (t=20).

In embodiments where the users have the ability to detect BER, if any high BER error condition is detected during any one of the segments, the error condition is reported by the client network controller 8-1 to the server network controller 8-0 for appropriate resend or other operation.

During a high BER period such as between t=10 and t=14 in FIG. 11 for example, communications over the channel may be lost such that the channel needs to be reestablished. Upon reestablishment of the channel, only unsent segments need to be sent, for example the segment from t=16 to t=20 in FIG. 12 in the example described.

While the invention has been particularly shown and described with reference to preferred embodiments thereof it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

Claims

1. A communications network for communications in one or more communications zones comprising:

a plurality of users in said communication zones, each user for communicating over channels using messages,

a plurality of communication resources for said communication zones, said communication resources for communications with said users over said channels,

a plurality of links for connecting said users to corresponding communication resources for transferring said messages over said channels,

network controller means including,

network applications for controlling the communications among users and network resources as a function of system parameters including a location parameter,

network stores for storing information including system parameters,

a network operating system for integrating the operation of the network applications and the network controller means,

network processors for processing the network applications and the network operating system to control communications among users and network resources.

2. The communications network of Claim 1 wherein said network controller means has network controller components distributed at multiple locations in the communications network.

3. The communications network of Claim 2 wherein said network controller components include server components and client components that cooperate in a server/client relationship to control communications among users and network resources.

4. The communications network of Claim 1 wherein,

said links include wireless data links having from time to time transfer characteristics that exhibit changes that affect the quality of transfers of said messages,

said system parameters include quality parameters that represent the quality of transfers over said wireless data links,

said network applications include a transfer application for controlling the scheduling of the transfer of said messages to adjust for changes in said transfer characteristics.

5. The communications network of Claim 4 wherein quality is measured as a bit error rate.

6. The communications network of Claim 1 wherein,

said network applications include utility applications and one or more output applications.

7. The communications network of Claim 5 wherein said output applications include a data multiplexer application.

8. The communications network of Claim 7 wherein said data multiplexer application includes a message module for providing messages, a link module for controlling links for transferring said messages, a parameter module for processing system parameters to determine specific locations of users where said messages with high quality can be transmitted over the established links, and a transfer module for transferring said messages at said locations of users.

9. The communications network of Claim 7 wherein said data multiplexer application partitions data messages into segments and controls the times when and locations where said segments are transferred.

10. The communications network of Claim 7 wherein said data multiplexer application partitions a data message having a message length, Message_-Length, into a number of segments, No_Segments, where the data message is transmitted with a message start time indicator, Message_Start and is terminated with a message stop time indicator, Message_Stop, and wherein one or more segments 1, 2, ..., L between Message_Start and Message_Stop are sent with segment start and stop indicators Segment1_Start, Segment1_End; Segment2_Start, Segment2_End; ..., SegmentL_Start, SegmentL_End whereby each of said one or more segments is transferred at said specific locations of users where said messages with high quality can be transmitted.

11. The communications network of Claim 6 wherein said utility applications include a location application for determining the locations of users.

12. The communications network of Claim 6 wherein said utility applications include a speed application for determining the speeds of users.

13. The communications network of Claim 6 wherein said utility applications include a system application that operates to determine system parameters, $S(\alpha, \sigma, \lambda, \tau)$.

14. The communications network of Claim 13 wherein said system application determines the location of interferers in the communications network.

15. The communications network of Claim 6 wherein said utility applications include a bandwidth application for determining bandwidth allocation in the communications network.

16. The communications network of Claim 6 wherein said utility applications include a resource application that operates to determine resource parameters, $R(\alpha, \sigma, \lambda, \tau)$.

17. The communications network of Claim 16 wherein said resource application identifies collectors and operational features of the collectors used in transferring messages.

18. The communications network of Claim 16 wherein said resource application identifies zone managers and operational features of zone managers used in connection with transferring messages.

19. The communications network of Claim 6 wherein said utility applications include a confidence metric application for determining confidence metric parameters in the communications network.

20. The communications network of Claim 1 wherein,

said network stores include a quality store for storing quality parameters for locations within said region to indicate the quality of communications at said locations,

said network controller includes a transfer application that compares the current location of said user with locations in said location store to detect the stored quality of communications at said current location.

21. The communications network of Claim 1 wherein,

said network stores include a path store for storing path information identifying paths of locations within said region followed by users,

said network controller includes a network application for predicting a path of future locations of a particular user and comparing said future locations with locations in said quality store to detect the stored quality of communications at said future,

said network controller includes a transfer application that permits data transfers at ones of said future locations as a function of the stored quality of communications at said future locations.

22. The communications network of Claim 21 wherein,

said network controller includes a utility application for updating said quality store for locations at which the quality of communications are detected.

23. The communications network of Claim 1 wherein,

said users are mobile and have locations that can change from time to time,

said transfer characteristics are a function of said locations and where for specific locations the transfer characteristics exhibit low quality,

said network controller includes a transfer application that adjusts said communications network to prevent transfers of said messages when said transfer characteristics exhibit low quality and said particular user is at said specific locations.

24. The communications network of Claim 1 wherein said network controller includes server components and client components that cooperate in a server/client relationship to control communications among users and network resources.

25. The communications network of Claim 1 wherein,

said users are mobile and capable of traveling in a broadcaster zone, each of said users including user receiver means for receiving forward channel communications and including transmitter means for transmitting reverse channel communications,

said communications resources include,

broadcaster means having a broadcaster transmitter for broadcasting said forward channel communications in said broadcaster zone,

collector means including collector receiver means active to receive said reverse channel communications for ones of said plurality of users,

aggregator means for receiving said collector reverse channel communications from said collector means.

26. The communication system of Claim 25 wherein said collector receiver means includes micro-diverse antenna.

27. The communication system of Claim 25 wherein said collector means includes a plurality of macro-diverse collectors.

28. The communication system of Claim 25 wherein said forward channel communications and said reverse channel communications have a TDMA protocol.

29. The communication system of Claim 25 wherein said forward channel communications and said reverse channel communications have a CDMA protocol.

30. The communication system of Claim 25 wherein said forward channel communications and said reverse channel communications have a wide band CDMA protocol.

31. The communication system of Claim 25 wherein said forward channel communications and said reverse channel communications have a SDMA protocol.

32. The communication system of Claim 25 wherein said forward channel communications and said reverse channel communications have a FDMA protocol.

33. The communications network of Claim 25 wherein said network controller components include server components and client components that cooperate in a server/client relationship to control communications among users and network resources and wherein, dependant on the direction of data transfer, said collector means can function as a server or a client and wherein said aggregator means can function as a client or a server.

34. The communications network of Claim 1 wherein said network operating system includes queues for queuing network applications to be executed, a scheduler task for scheduling network applications in said queues and a synchronizer task for synchronizing scheduled tasks.

35. The communications network of Claim 34 wherein said network operating system includes a priority task recognizing high priority network applications for priority scheduling by said scheduling task.

36. The communications network of Claim 1 wherein said system parameters include a user performance parameter, $U(\alpha, \sigma, \lambda, \tau)$ for indicating properties of a user where α is link parameter that indicates properties of an RF spectrum resource that is reused by different resources in the communications network , σ is a signal parameter that indicates the quality of an RF signal, λ is a location parameter that indicates a location in a communication zone, and τ is a time parameter.

37. The communications network of Claim 1 wherein said network operating system includes,

queues for queuing network applications to be executed including a priority queue for queuing high priority network applications, a repeat queue for storing utility applications, and a demand queue for queuing output applications,

a scheduler task for scheduling network applications in said queues,

a synchronizer task for synchronizing scheduled tasks,

a priority task for recognizing high priority network applications and for queuing said high priority network applications in said priority queue for priority scheduling by said scheduling task,

a queue load for queuing network applications in said queues, said queue load responsive to a channel analyzer for queuing network applications active on a channel that require execution and responsive to an internal input for queuing network applications identified by the network operating system as requiring execution.

38. The communications network of Claim 1 wherein a plurality of said communications zones are present where said zones overlap in communications coverage for users in a region and wherein communications in said region are under control of a region manager where said region manager includes a region

network controller for communicating with said network controller means for each of said zones.

39. In a communications network for communications in one or more communications zones with a plurality of users in said communication zones, each user for communicating over channels using messages, with a plurality of communication resources for said communication zones, said communication resources for communications with said users over said channels, with a plurality of links for connecting said users to corresponding communication resources for transferring said messages over said channels, a method of controlling the communications network comprising:

controlling with network applications the communications among users and network resources as a function of system parameters including a location parameter,

storing in network stores information including system parameters,

integrating with a network operating system the operation of the network applications, the users and the communication resources,

processing in network processors the network applications and the network operating system to control communications among users and network resources.

40. The communications method of Claim 39 having network controller components including network applications, network stores, network operating system components and network processors distributed at multiple locations in the communications network.

41. The communications method of Claim 40 wherein said network controller components include server components and client components that cooperate in a server/client relationship to control communications among users and network resources.

42. The communications method of Claim 39 wherein,

said links include wireless data links having from time to time transfer characteristics that exhibit changes that affect the quality of transfers of said messages,

said system parameters include quality parameters that represent the quality of transfers over said wireless data links,

said network applications include a transfer application for controlling the scheduling of the transfer of said messages to adjust for changes in said transfer characteristics.

43. The communications method of Claim 42 wherein quality is measured as a bit error rate.

44. The communications method of Claim 39 wherein,

said network applications include utility applications and one or more output applications.

45. The communications method of Claim 44 wherein said output applications include a data multiplexer application.

46. The communications method of Claim 45 wherein said data multiplexer application includes a message module for providing messages, a link module for controlling links for transferring said messages, a parameter module for processing system parameters to determine specific locations of users where said messages with high quality can be transmitted over the established links, and a transfer module for transferring said messages at said locations of users.

47. The communications method of Claim 45 wherein said data multiplexer application partitions a data message having a message length, Message_-Length, into a number of segments, No_Segments, where the data message is transmitted with a message start time indicator, Message_Start and is terminated with a message stop time indicator, Message_Stop, and wherein one or more segments 1, 2, ..., L between Message_Start and Message_Stop are sent with segment start and stop indicators Segment1_Start, Segment1_End; Segment2_Start, Segment2_End; ..., SegmentL_Start, SegmentL_End whereby each of said one or more segments is transferred at said specific locations of users where said messages with high quality can be transmitted.

48. The communications method of Claim 44 wherein said utility applications include a location application for determining the locations of users.

49. The communications method of Claim 48 wherein,

said network stores include a quality store for storing quality parameters for locations within said region that exhibit poor quality communications,

said network controller includes a transfer application that compares the current location of said user with locations in said location store to detect locations that exhibit poor quality communications.

50. The communications method of Claim 48 wherein,

said network stores include a path store for storing path information identifying paths of locations within said region followed by users,

said network controller includes a network application for predicting a path of future locations of a particular user and comparing said future locations with locations in said quality store to detect future locations that are likely to exhibit poor quality communications, said network controller includes a transfer application that permits data transfers at ones of said future locations that are not likely to exhibit poor quality communications.

51. The communications method of Claim 50 wherein,

said network controller includes a utility application for updating said quality store for locations at which poor quality communications are detected.

52. The communications method of Claim 48 wherein,

said users are mobile and have locations that can change from time to time,

said transfer characteristics are a function of said locations and where for specific locations the transfer characteristics exhibit low quality,

said network controller includes a transfer application that adjusts said communications network to prevent transfers of said messages when said transfer characteristics exhibit low quality and said particular user is at said specific locations.

53. The communications method of Claim 48 wherein said network controller includes server components and client components that cooperate in a server/client relationship to control communications among users and network resources.

54. The communications method of Claim 48 wherein,

said users are mobile and capable of traveling in a broadcaster zone, each of said users including user receiver means for receiving forward channel communications and including transmitter means for transmitting reverse channel communications,

said communications resources include,

broadcaster means having a broadcaster transmitter for broadcasting said forward channel communications in said broadcaster zone,

collector means including collector receiver means active to receive said reverse channel communications for ones of said plurality of users,

aggregator means for receiving said collector reverse channel communications from said collector means.

55. The communications method of Claim 48 wherein said network operating system includes,

queues for queuing network applications to be executed including a priority queue for queuing high priority network applications, a repeat queue for storing utility applications, and a demand queue for queuing output applications,

a scheduler task for scheduling network applications in said queues,

a synchronizer task for synchronizing scheduled tasks,

a priority task for recognizing high priority network applications and for queuing said high priority network applications in said priority queue for priority scheduling by said scheduling task,

a queue load for queuing network applications in said queues, said queue load responsive to a channel analyzer for queuing network applications active on a channel that require execution and responsive to an internal input for queuing network applications identified by the network operating system as requiring execution.

56. The communications method of Claim 48 wherein a plurality of said communications zones are present where said zones overlap in communications coverage for users in a region and wherein communications in said region are under control of a region manager where said region manager includes a region network controller for communicating with said network controller means for each of said zones.

FIG. 1

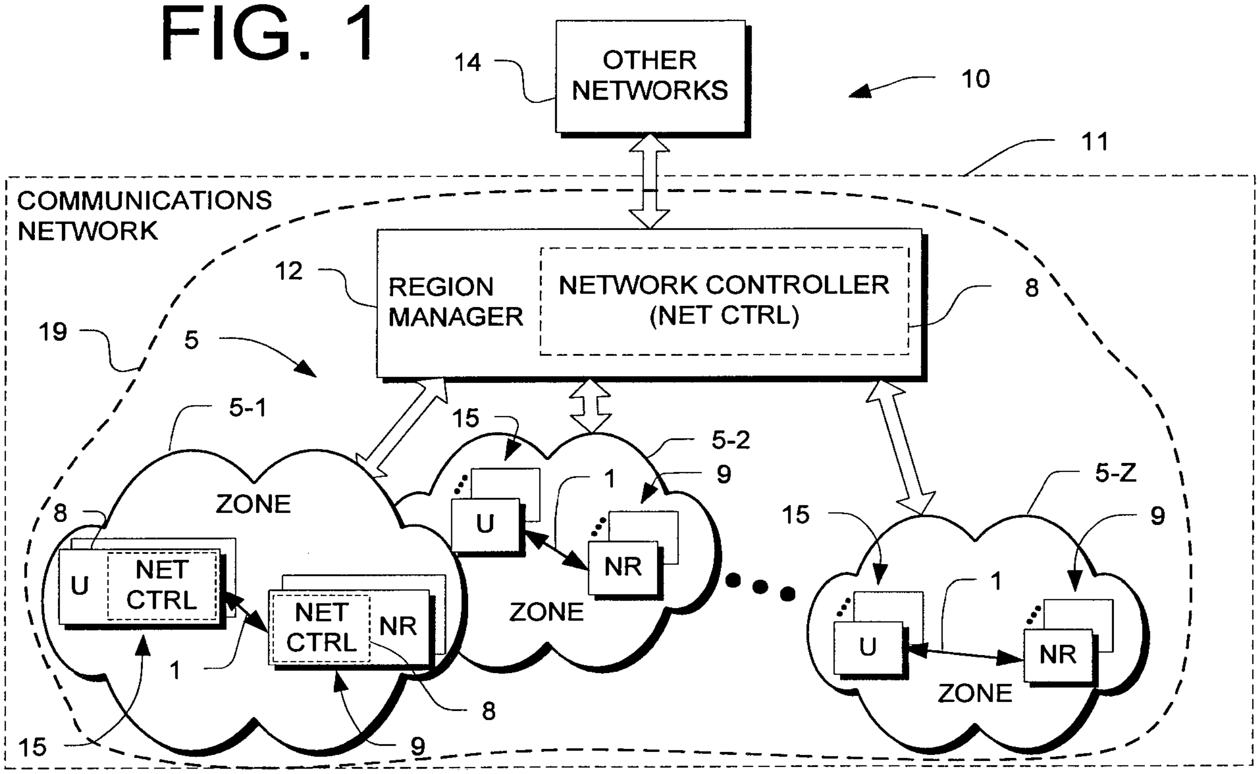
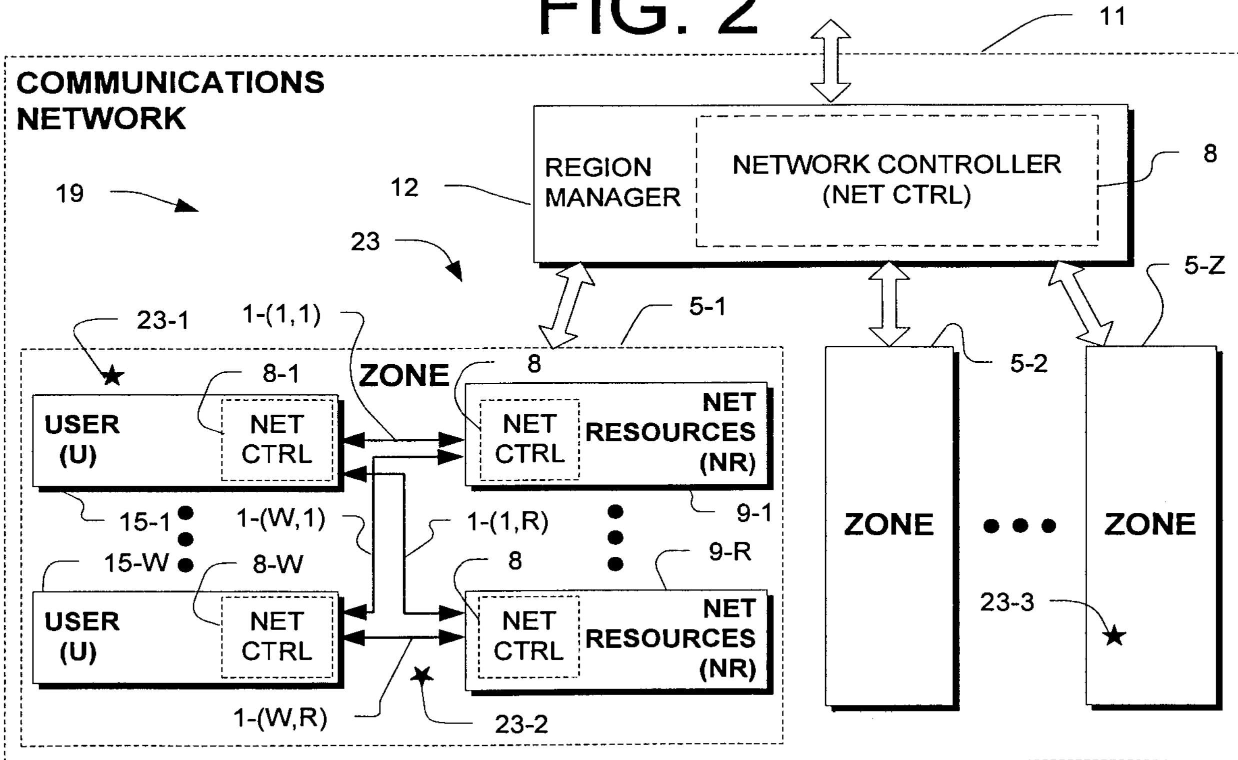
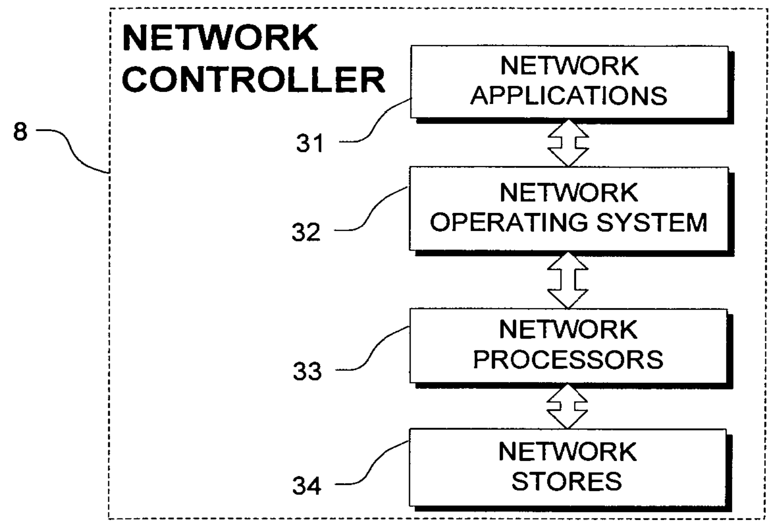

14
OTHER NETWORKS
10
11
COMMUNICATIONS NETWORK
12
REGION MANAGER
NETWORK CONTROLLER (NET CTRL)
8
19
5
5-1
15
5-2
1
9
5-Z
ZONE
8
U
NET CTRL
NET CTRL
NR
U
NR
ZONE
15
9
1
U
NR
ZONE
1
8
15
9

FIG. 2


11
COMMUNICATIONS NETWORK
19
12
REGION MANAGER
NETWORK CONTROLLER (NET CTRL)
8
23
5-Z
23-1
1-(1,1)
5-1
8-1
ZONE
8
5-2
USER (U)
NET CTRL
NET CTRL
NET RESOURCES (NR)
15-1
1-(W,1)
1-(1,R)
9-1
15-W
8-W
8
9-R
ZONE
ZONE
USER (U)
NET CTRL
NET CTRL
NET RESOURCES (NR)
23-3
1-(W,R)
23-2


NETWORK CONTROLLER
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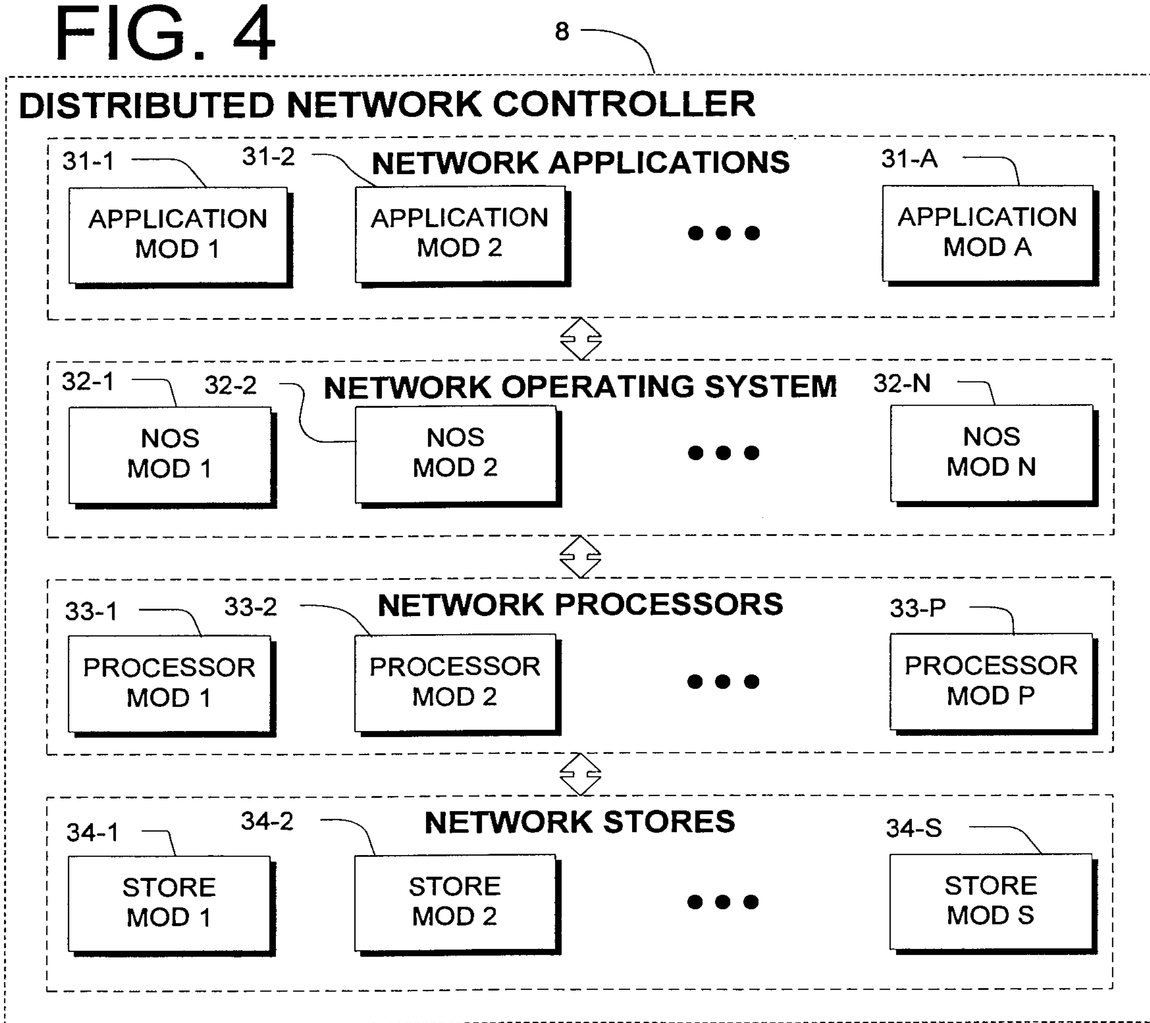
31
NETWORK APPLICATIONS
32
NETWORK OPERATING SYSTEM
33
NETWORK PROCESSORS
34
NETWORK STORES

FIG. 3

FIG. 4


8
DISTRIBUTED NETWORK CONTROLLER
NETWORK APPLICATIONS
31-1
31-2
31-A
APPLICATION MOD 1
APPLICATION MOD 2
APPLICATION MOD A
NETWORK OPERATING SYSTEM
32-1
32-2
32-N
NOS MOD 1
NOS MOD 2
NOS MOD N
NETWORK PROCESSORS
33-1
33-2
33-P
PROCESSOR MOD 1
PROCESSOR MOD 2
PROCESSOR MOD P
NETWORK STORES
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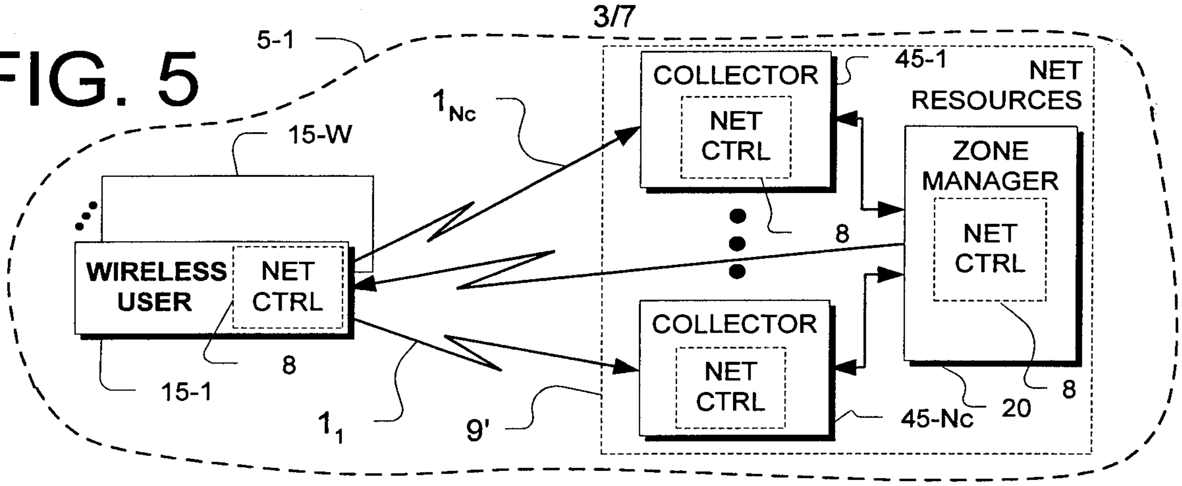
34-2
34-S
STORE MOD 1
STORE MOD 2
STORE MOD S

FIG. 5


5-1
1Nc
15-W
COLLECTOR
NET CTRL
45-1
NET RESOURCES
ZONE MANAGER
NET CTRL
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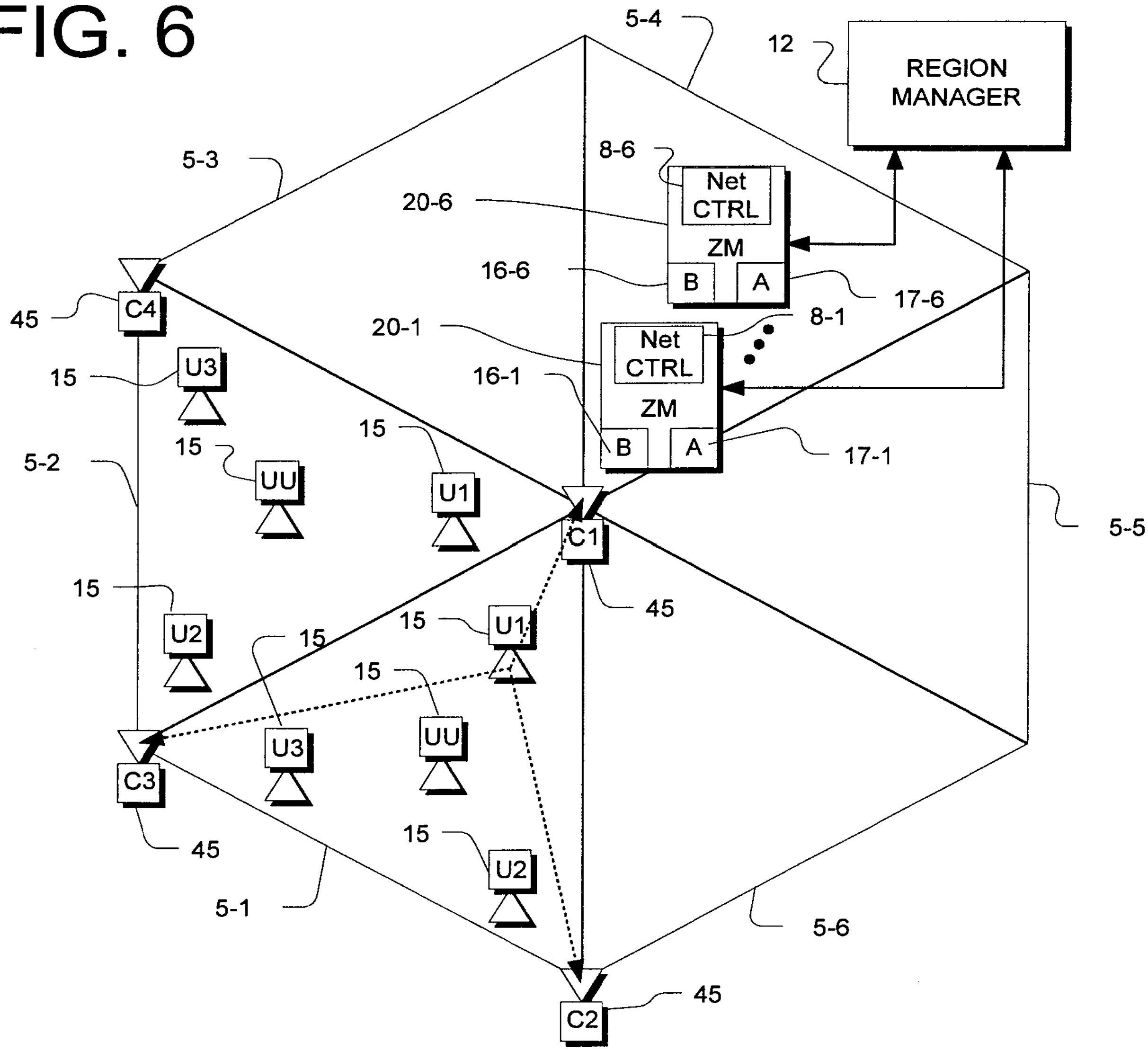
WIRELESS USER
NET CTRL
8
15-1
11
9'
COLLECTOR
NET CTRL
45-Nc
20
8

FIG. 6


5-4
12
REGION MANAGER
5-3
8-6
Net CTRL
20-6
ZM
16-6
B
A
17-6
45
C4
20-1
Net CTRL
8-1
15
U3
16-1
ZM
5-2
15
UU
15
U1
B
A
17-1
C1
5-5
45
15
U2
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C3
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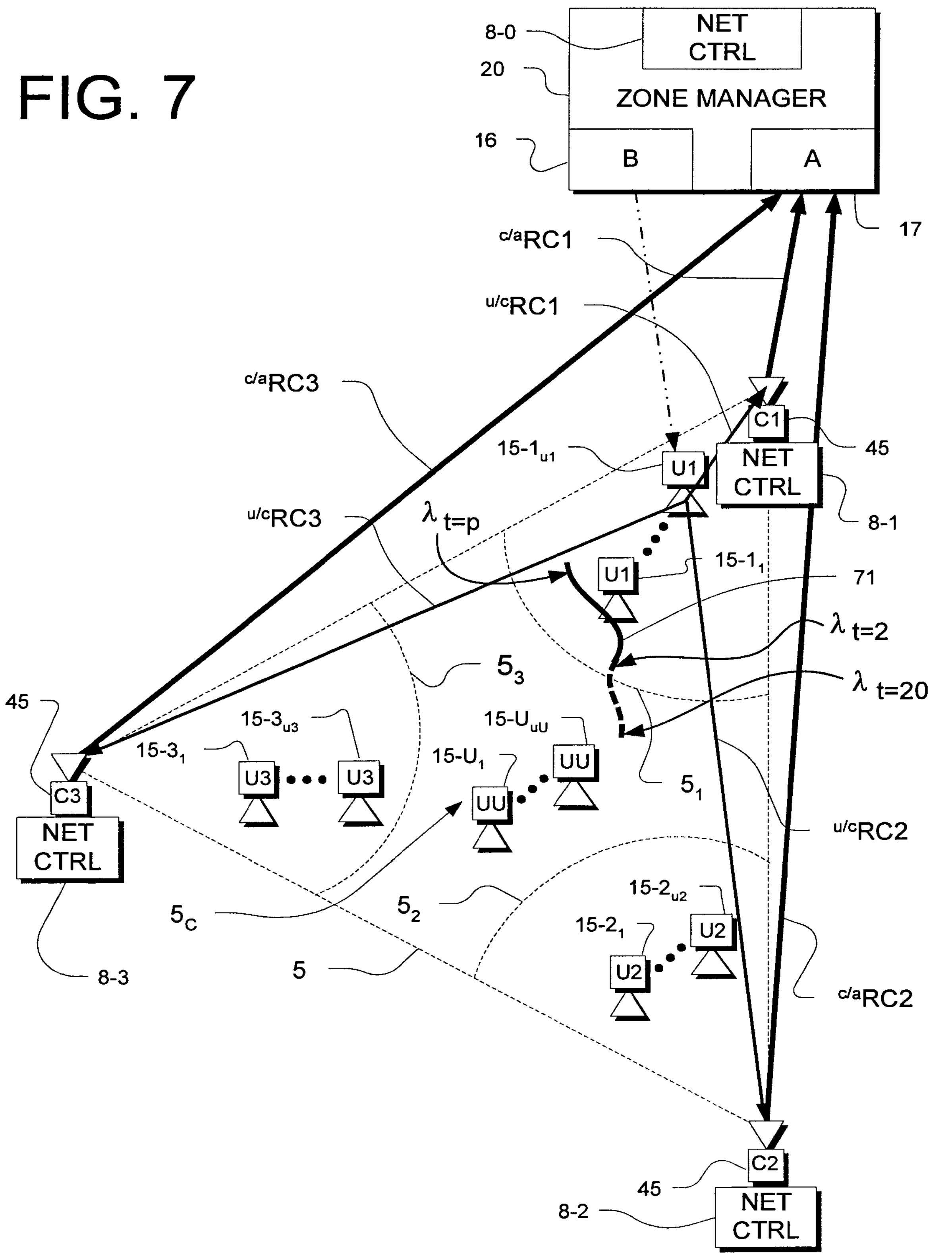
U2
5-1
5-6
C2
45

FIG. 7



NET CTRL
8-0
20
ZONE MANAGER
16
B
A
17
c/aRC1
u/cRC1
c/aRC3
u/cRC3
15-1u1
U1
C1
45
NET CTRL
8-1
λ t=p
15-11
71
λ t=2
λ t=20
53
51
45
15-3u3
15-Uuu
15-31
U3
U3
15-U1
UU
UU
C3
NET CTRL
u/cRC2
5C
52
15-2u2
15-21
U2
U2
8-3
5
c/aRC2
C2
45
8-2
NET CTRL

FIG. 8

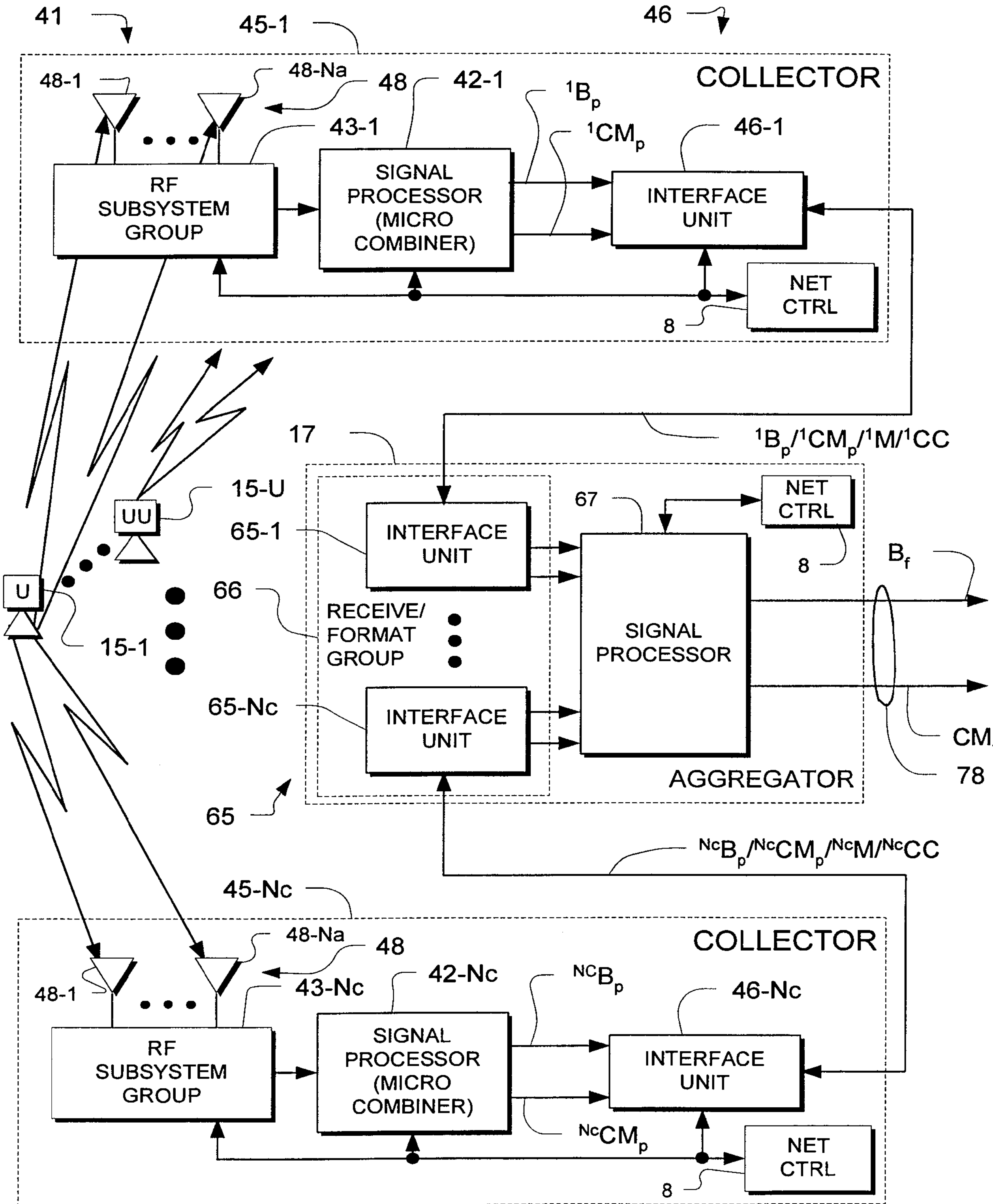

41
45-1
46
COLLECTOR
48-1
48-Na
48
42-1
^1B_p
^1CM_p
46-1
43-1
RF SUBSYSTEM GROUP
SIGNAL PROCESSOR (MICRO COMBINER)
INTERFACE UNIT
NET CTRL
8
$^1B_p/^1CM_p/^1M/^1CC$
17
15-U
UU
65-1
INTERFACE UNIT
67
NET CTRL
8
B_f
U
66
RECEIVE/ FORMAT GROUP
15-1
SIGNAL PROCESSOR
65-Nc
INTERFACE UNIT
CM_f
78
AGGREGATOR
65
$^{Nc}B_p/^{Nc}CM_p/^{Nc}M/^{Nc}CC$
45-Nc
COLLECTOR
48-Na
48
48-1
43-Nc
42-Nc
$^{NC}B_p$
46-Nc
RF SUBSYSTEM GROUP
SIGNAL PROCESSOR (MICRO COMBINER)
INTERFACE UNIT
$^{Nc}CM_p$
NET CTRL
8

FIG. 9

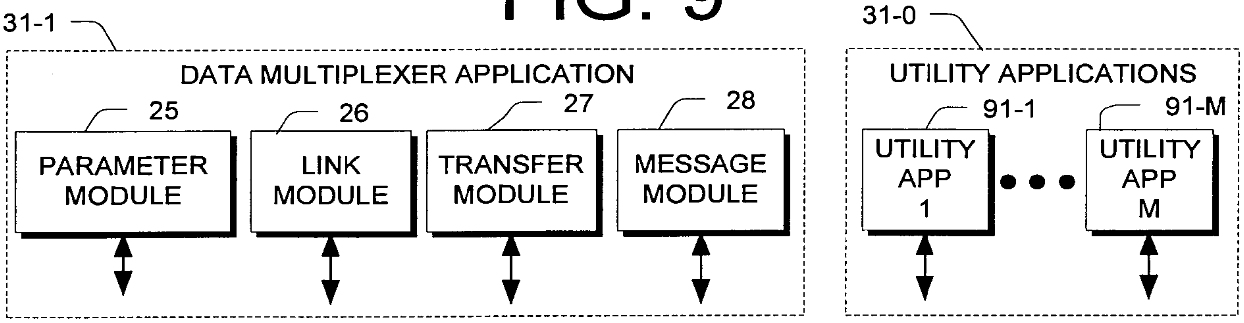


FIG. 10

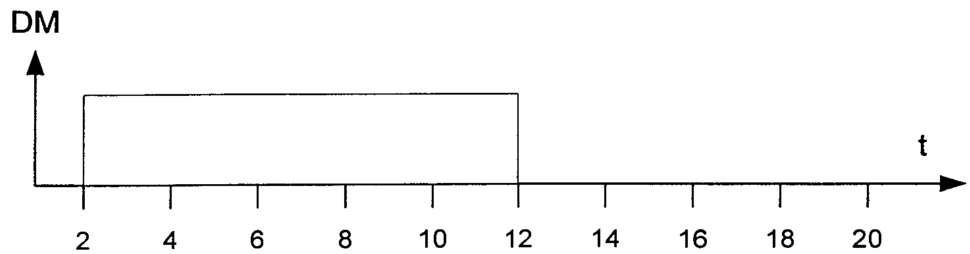


FIG. 11

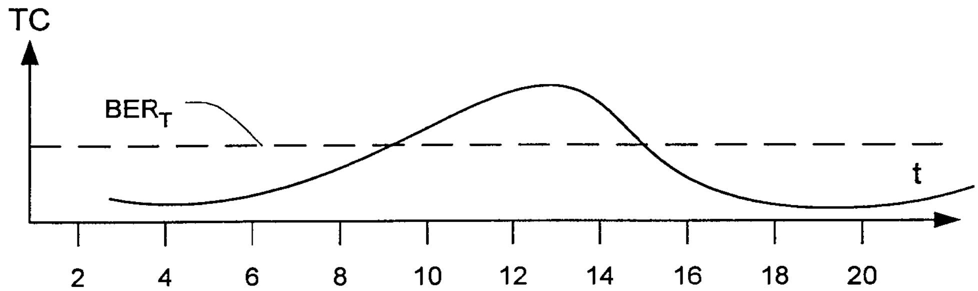


FIG. 12

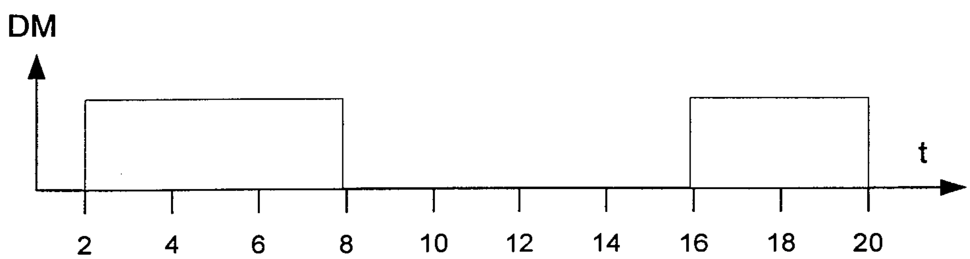


FIG. 13

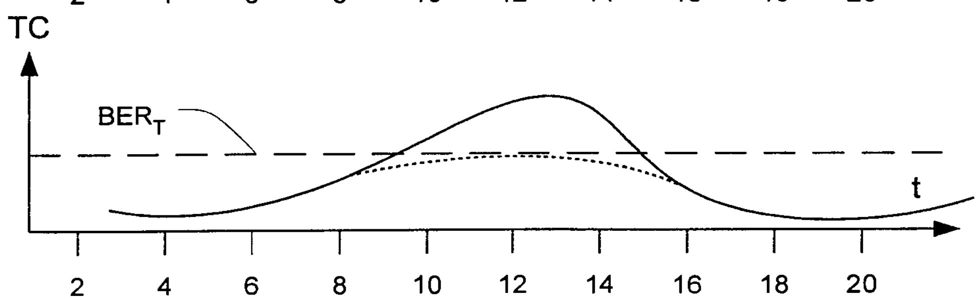


FIG. 14

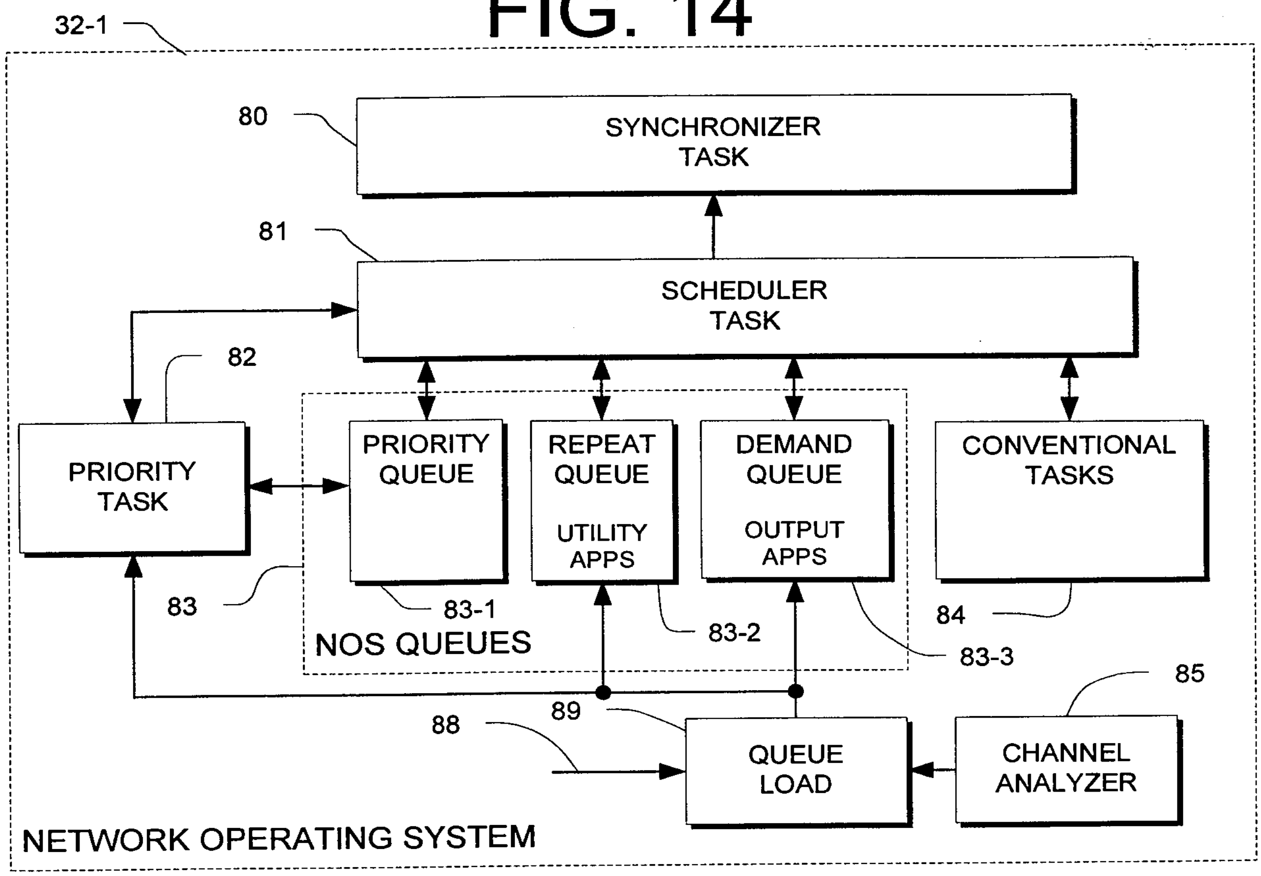
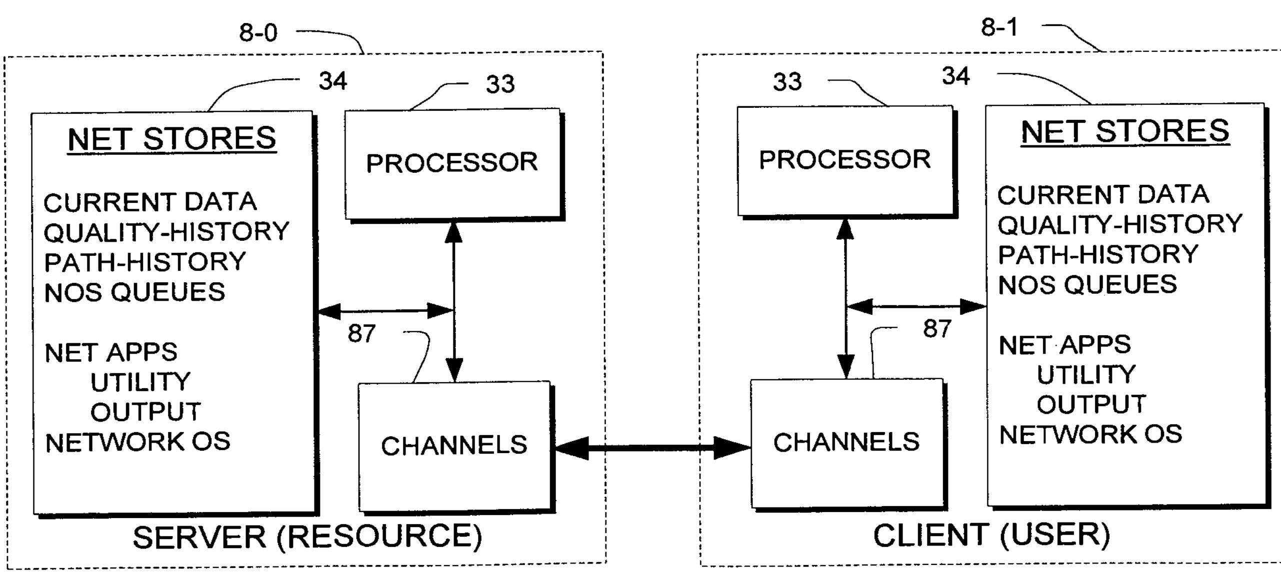

32-1
80
SYNCHRONIZER TASK
81
SCHEDULER TASK
82
PRIORITY TASK
PRIORITY QUEUE
REPEAT QUEUE
UTILITY APPS
DEMAND QUEUE
OUTPUT APPS
CONVENTIONAL TASKS
83
83-1
83-2
83-3
84
NOS QUEUES
85
88
89
QUEUE LOAD
CHANNEL ANALYZER
NETWORK OPERATING SYSTEM

FIG. 15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34
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NET STORES
CURRENT DATA
QUALITY-HISTORY
PATH-HISTORY
NOS QUEUES
NET APPS
UTILITY
OUTPUT
NETWORK OS
PROCESSOR
87
CHANNELS
SERVER (RESOURCE)
8-1
33
34
PROCESSOR
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CURRENT DATA
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PATH-HISTORY
NOS QUEUES
87
NET APPS
UTILITY
OUTPUT
NETWORK OS
CHANNELS
CLIENT (USER)

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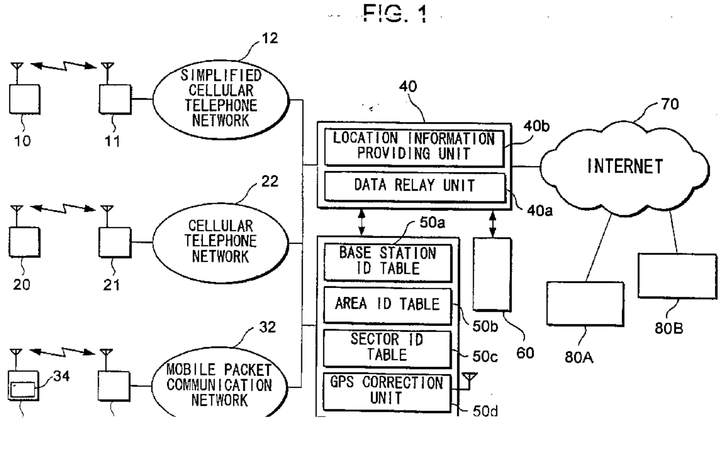
(54) **METHOD AND APPARATUS FOR SUBMITTING POSITION INFORMATION**

(57) The present invention aims to provide a common platform for providing location information, which provision corresponds to network integration.

In the present invention, a location information providing unit 40b of a gateway server 40 obtains from a position measuring center 50 location information of cellular devices 10, 20, and 30, which are each generated in different representational formats each, converts the obtained location information into representational formats which IP servers 80A, 80B, ··· are capable of handling, via a location information converting device 60, and notifies the location information following conversion to the IP servers 80A, 80B, ···.

FIG. 1



EP 1 126 376 A1

Description

Technical Field

[0001] The present invention relates to a location information notifying method and a location information notifying apparatus for notifying location information of a mobile communication terminal.

Background Art

[0002] Mobile communication networksfor mobile terminals such as cellular telephones are capable of obtaining the current position of a mobile communication terminal. In recent years, various types of systems for performing information providing services using location information obtained by such mobile communication networks have been proposed. For example with PHS (Personal Handy-phone System) networks, it is possible to determine within which base station wireless zone a mobile communication terminal is currently used, and a system for providing a position tracking service using this location information is known.

[0003] Also, a system wherein a GPS (Global Positioning System) isinstalled for mobile communication terminals and location information obtained by the GPS is used for a service has also been proposed.

[0004] The obtained location information of the mobile communication terminal differs in representational format according to the position detection method employed by the mobile communication network. For example, with a PHS network, the location information isidentification information (hereafter referred to as "base station ID") for identifying base stations managing wireless zones where mobile communication terminals are used, and with GPS, the location information is in the format of latitude and longitude, obtained by measuring the positions of mobile communication terminals.

[0005] On the other hand, the representational format for the desired location information, the precision thereof, and communication protocol differ between the computer systems which use such location information and provide various types of services.

[0006] For example, there may be cases wherein handling of the location information in the latitude-and-longitude representational format is desired by the computer system application, or there may be cases wherein obtaining the location information in the representational format corresponding to administrative district is desired. Also, for example, computer systems which provide position tracking services require relatively high-precision location information, but computer systems which provide weather forecast information at the location of where the mobile communication terminal require only relatively low-precision location information. Further, even in the event that the representational format of the location information is the same for the mobile communication terminal side and the computer system side, the method for obtainingthe location information by the computer systems differs according to the communication protocol which the application of the computer system supports.

[0007] Thus, as long as the representational formats and communication protocols for location information differ according to the mobile communication network and the computer using the location information, services dealing with network integration, which have been rapidly progressing in recent years, cannot be provided.

Disclosure of Invention

[0008] According to one aspect of the present invention, the position of a mobile communication terminal is detected and location information is generated, following which, in the event of notifying a first computer of location information, the representational format of the location information at the time of generating the location information is converted into a first representational format which the first computer is capable of handling, and on the other hand, in the event of notifying a second computer of location information, the representational format of the location information at the time of generating the location information is converted into a second representational format which the second computer is capable of handling, and notification is made. Thus, a common platform for providing location information dealing with integration of networks from the perspective of representation format of location information, can be provided.

[0009] According to another aspect of the present invention, following detection of the position of the mobile communication terminal, the computer generates and notifies location informationhaving a precision which the computer requires. Thus, a common platform for providing location information dealing with integration of networks from the perspective of precision of location information, can be provided.

[0010] Also, according to another aspect of the present invention, the position of the mobile communication terminal is detected and location information is generated, and the location information is added to data transmitted from the mobile communication terminal to the computer, thereby notifying the computer of the location information. Thus, location information of the mobile communication terminal can be supplied to various computers in a form not dependent on the specifications of the mobile communication terminal.

[0011] Also, according to another aspect of the present invention, upon receiving a request signal from the computer requesting obtaining of the location information of the mobile communication terminal, the position of the mobile communication terminal is detected in response to this request signal and location information is generated, and this location information is notified to the computer. Thus, the location information of the mobile communication terminal can be supplied to various computers as a standard interface protocol, in a form not dependent on the specifications of the mobile communication terminal.

Brief Description of the Drawings

[0012] Fig. 1 is a block diagram illustrating the configuration of the overall network for executing the location information notifying method according to a first embodiment of the present invention.
[0013] Fig. 2 is a block diagram illustrating the configuration of a simplified cellular telephone according to this embodiment.
[0014] Fig. 3 is a block diagram illustrating the configuration of a cellular telephone provided with a GPS receiver, according to this embodiment.
[0015] Fig. 4 is a format diagram illustrating an example of a simplified cellular telephone network conversion table according to this embodiment.
[0016] Fig. 5 is a format diagram illustrating an example of a cellular telephone network conversion table according to this embodiment.
[0017] Fig. 6 is a format diagram illustrating an example of a mobile packet communication network conversion table according to this embodiment.
[0018] Fig. 7 is a format diagram illustrating an example of a latitude and longitude receiver list table according to this embodiment.
[0019] Fig. 8 is a flowchart illustrating the operation of the location information providing unit of a gateway server according to this embodiment.
[0020] Fig. 9 is a flowchart illustrating the operation of the location information providing unit of a gateway server according to a variation of this embodiment.
[0021] Fig. 10 is a block diagram illustrating the configuration of the overall network for executing the location information notifying method according to a second embodiment of the present invention.
[0022] Fig. 11 is a format diagram illustrating an example of an area ID conversion table according to this embodiment.
[0023] Fig. 12 is a format diagram illustrating an example of a sector ID conversion table according to this embodiment.
[0024] Fig. 13 is a format diagram illustrating an example of a location information precision table according to this embodiment.
[0025] Fig. 14 is a flowchart illustrating the operation of the location information providing unit of a gateway server according to this embodiment.
[0026] Fig. 15 is a block diagram illustrating the configuration of the overall mobile communication system for executing the location information notifying method according to a third embodiment of the present invention.
[0027] Fig. 16 is a format diagram illustrating an example of HTML-format sub-menu data which the IP server transmits to a mobile station, according to this embodiment.
[0028] Fig. 17 is a diagram of a screen displayed at the mobile station based on the HTML-format sub-menu data shown in Fig. 11, according to this embodiment.
[0029] Fig. 18 is a block diagram illustrating the configuration of a gateway server according to this embodiment.
[0030] Fig. 19 is a format diagram illustrating an example of the storage contents of an IP information database provided in the gateway server according to this embodiment.
[0031] Fig. 20 is a format diagram illustrating an exanple of the storage contents of a region code table provided in the gateway server according to this embodiment.
[0032] Fig. 21 is a format diagram illustrating an example of the storage contents of a positional relation information database provided in the IP server according to this embodiment.
[0033] Figs. 22A and 22B constitute a flowchart illustrating the flow of operations in a mobile communication system in a first specific example of this embodiment.
[0034] Fig. 23 is a format diagram illustrating an example of the sorage contents of an in-zone information table provided in an exchange station according to this embodiment.
[0035] Fig. 24 is a format diagram illustrating an example of the storage contents of a position registration database within a home memory according to this embodiment.
[0036] Fig. 25 is a format diagram illustrating an example of the storage contents of an ID database provided in the gateway server according to this embodiment.
[0037] Figs. 26A and 26B constitute a flowchart illustrating the flow of operation of the mobile communication system according to a second specific example according to this embodiment.
[0038] Fig. 27 is a flowchart illustrating the flow of operation of the mobile communication system according to the second specific example according to this embodiment.
[0039] Fig. 28 is a format diagram illustrating an example of the storage contents of the database provided in the gateway server according to this embodiment.
[0040] Fig. 29 is a format diagram illustrating an example of the storage contents of a database provided in the gateway server according to this embodiment.

Best Mode for Carrying Out the Invention

[0041] Embodiments of the present invention will be described with reference to the drawings.
[0042] In the following, a description will be given forthe following three embodiments.
[0043] First embodiment: An embodiment wherein a mobile communication terminal can notify of location information to a computer, even in the event that the representational format of location information differs be-

tween the mobile communication terminal and the computer;

[0044] Second embodiment: An embodiment wherein a mobile communication terminal notifies to a computer of location information at a precision desired by the computer; and

[0045] Third embodiment: An embodiment wherein a mobile communication terminal notifies to various servers of location information as a standard interface protocol, while maintaining security of the location information of the mobile communication terminal.

[0046] Note, however, that these first through third embodiments are nomore than examples, and that the present invention can take on various embodiments within the scope of the technical concept thereof.

A: First embodiment

[0047] With the first embodiment of the present invention, an embodiment will be described wherein a mobile communication terminal can notify location information to a computer, even in the event that the representational format of the location information differs between the mobile communication terminal and the computer.

A-1: Configuration of the first embodiment

[0048] First, the configuration of the first embodiment will be described.

(1) Overall configuration of the network

[0049] Fig. 1 is a block diagram illustrating the overall configuration of a network relating to the embodiment. In this figure, reference numeral 10 denotes a simplified cellular telephone (mobile communication terminal) served by a simplified cellular telephone network 12 (mobile communication network) called a PHS (Personal Handy-phone System). The simplified cellular telephone 10 can receive PHS telephone communication services by performing wireless communication with a base station 11 of the simplified cellular telephone network 12.

[0050] Reference numeral 20 denotes a cellular telephone (mobile communication terminal)served by a cellular telephone network 22 (mobile communication network) such as a PDC (Personal Digital Cellular)network. The cellular telephone 20 can receive cellular telephone servicessuch as the PDC service by performing wireless communication with a base station 21 of the cellular telephone network 22. The above simplified cellular telephone network 12 and cellular telephone network 22 are connected by a gateway device not shown here, so that call connections can be made between them.

[0051] Reference numeral 30 denotes a cellular telephone (mobile communication terminal)served by a mobile packet communication network 32 (mobile communication network). The cellular telephone 30 can receive packet communication services by performing wireless communication with a base station 31 of the mobile packet communication network 32. The cellular telephone 30 is provided with a GPS receiver 34, and is capable of performing measurementsto obtain location informationrepresenting latitude and longitude. In the following description, in cases where the above simplified cellular telephone 10, cellular telephone 20, and cellular telephone 30 are to be collectively referred to, these will be referred to as cellular telephones 10, 20, and 30.

[0052] Reference numeral 40 denotes a gateway server, which relays data communications between the mobile packet communication network 30 and the Internet 70 or other external networks. This gateway server 40 is provided with a data relay unit 40a for handling the above data communication relayingand a location information providing unit 40b (first location information notifying unit) for notifying location information of the above-described cellular telephones 10, 20, and 30 to computers such as IP (Information Provider) servers 80A, 80B, etc., connected to the Internet 70. This location information providing unit 40b is provided with a latitude and longitude receiver list table which is described herein below.

[0053] Reference numeral 50 denotes a position measurement center (first location information generating unit), which obtains and stores location information for the cellular telephones 10, 20, and 30. For example, the simplified cellular telephone network 12 is arranged so as to be able to determine wireless zone of the base station 11 in which each simplified cellular telephone 10 currently exists. The position measurement center 50 obtains the determination results from the simplified cellular telephone network 12, correlates the identification information of each simplified cellular telephone 10 and the identification information of the base station 11 (i.e., base station ID) by which the cellular telephone is served, and stores the correlated information in a base station ID table 50a.

[0054] The cellular telephone network 22 is arranged so as to be able to determine service area in which each cellular telephone 20 currently exists. A service area is a region which includes a predetermined number of wireless zones of the base station 21. The position measurement center 50 obtains the determination results from the cellular telephone network 22, correlates the identification information of each cellular telephone 20 and the identification information of the service area (i.e., area ID)in which the cellular telephone is currently located and stores the correlated information in an area ID table 50b.

[0055] The mobile packet communication network 32 is arranged so as to be able to determine sector of the wireless zones of the base station 31 in which each cellular telephone 30 currently exists. The wireless zone of the base station 31 is divided into partial regions by the directional antennas of the base station and each partial region is called as a sector. The position measurement center 50 obtains the determination results from the mobile packet communication network 32, correlates the identification information of each cellular telephone 30 and the identification information of the sector (i.e., sector ID) in which the cellular telephone exists, and stores the correlated information in a sector ID table 50c.

[0056] Further, the position measurement center 50 is provided with a GPS correction unit 50d for performing correction processing on the measurement values of the cellular telephone 30 by the D (differential) -GPS method. The GPS correction unit 50d obtains GPS measurement values of the cellular telephone 30 via the mobile packet communication network 32, and corrects the obtained GPS measurement values based on the GPS measurement margin of error held within itself. The latitude and longitude information as a result of the correction is stored in a latitude and longitude table (not shown) within the GPS correction unit 50d, in such a manner so as to be correlated with the identification information of the cellular telephones 30.

[0057] As described above, according to the present embodiment, the location information of the cellular telephones 10, 20, and 30 is obtained from the networks 12, 22, and 32, in representational formats which are all different from each other.

[0058] Reference numeral 60 denotes a location informationconverting device (location information representation converting unit) which performs conversion of the location information. This location information converting device 60 converts the location information of the cellular telephones 10, 20, and 30 obtained from the networks 12, 22, and 32 with differing representational formats into location information with a representational format which can be handled by the computers such as the IP servers 80A, 80B, etc., connected to the Internet 70, based on a location information conversion table described herein below. Due to this location information converting device 60, the computers requesting location information can receive supply of location information of the cellular telephones 10, 20, and 30, without taking the difference in representational format into consideration.

[0059] The IP servers 80A and 80B which have obtained location information provide position-related information relating to the location information to the cellular telephones 10, 20, and 30.

(2) Configuration of the cellular telephones

[0060] Next, the configuration of the cellular telephones 10,, 20, and 30, will be described.

[0061] Fig. 2 is a block diagram illustrating the configuration of the simplified cellular telephone 10. In the figure, the simplified cellular telephone 10 comprises a control unit 10A, a wireless unit 10B, and a user interface unit 10C, which are mutually connected by a bus.

[0062] The control unit 10A is made up of a CPU, memory, etc., and controls each of the units of the simplified cellular telephone 10. The wireless unit 10B performs wireless communication of audio signals and various types of control signals with the base station 11, thereby enabling wireless calls. The user interface unit 10C is made up of a microphone and speaker for providing audio input and output for calls, an operating panel for dialing operations, a liquid crystal display unit, and so forth.

[0063] The configuration of the cellular telephone 20 is the same as the configuration shown in Fig. 2, so description thereof will be omitted.

[0064] Fig. 3 is a block diagram illustrating the configuration of the cellular telephone 30. In the figure, the cellular telephone 30 comprises a control unit 30A, a wireless unit 30B, a user interface unit 30C, and a GPS receiver 34, mutually connected by a bus.

[0065] This cellular telephone 30 differs from the other cellular telephones 10 and 20 in that what is sent by wireless communication is not so-called voice calls, but packet data communication, and in that a GPS receiver 34 is provided. The GPS receiver 34 measures latitude and longitude which indicates the position of the cellular telephone 30, based on signals received from a satellite (not shown). The measured values of the latitude and longitude are transmitted by the wireless unit 30B, sent to the position measurement center 50 via the mobile packet communication network 32 as described above, and subjected to D-GPS correction.

(3) Configuration of the location information conversion table

[0066] Next, various types of location information conversion tables provided in the location information converting device 60 will be described with reference to Fig. 4 through Fig. 6.

[0067] Fig. 4 is a format diagram illustrating an example of a simplified cellular telephone network conversion table. As shown in the figure, the conversion table holds in a correlated manner the base station ID which is used as location information in the simplified cellular telephone network 12 and information such as latitude and longitude (X, Y) or administrative district (1-1-1, Toranomon, Minato-ku) and the like, which can be handled as location informationby computers such as the IP servers 80A and 80B and the like.

[0068] Fig. 5 is a format diagram illustrating an example of a cellular telephone network conversion table. As shown in the figure, the conversion table holds in a correlated manner the area ID which is used as location information in the cellular telephone network 22 and information such as latitude and longitude (X, Y) or administrative district (1-1-1,Toranomon, Minato-ku) and the like, which can be handled as location information by computers such as the IP servers 80A and 80B and the like.

[0069] Fig. 6 is a format diagram illustrating an example of a mobile packet communication network conversion table. As shown in the figure, the conversion table holds in a correlated manner the sector ID which isused as location information in the mobile packet communication network 32 and information such as latitude and longitude (X, Y) or administrative district (1-1-1, Toranomon, Minato-ku) and the like, which can be handled as location informationby computers such as the IP servers 80A and 80B and the like.

(4) Configuration of latitude and longitude receiver list table

[0070] Next, the configuration of the latitude and longitide receiver list table provided in the location information providing unit 40b of the gateway server 40 will be described with reference to Fig. 7.

[0071] Fig. 7 is a format diagram illustrating an example of a latitude and longitude receiver list table. As shown in the figure, the latitude and longitude receiver list table holds a list of computers which can handle latitude and longitude as location information. In this example, they are the IP servers 80A, 80F, 80K ···. Though not shown in Fig. 1, each of the IP servers 80F and 80K are computers connected to the Internet 70.

[0072] In the event of providing location information to computers listed in this latitude and longitude receiver list table, the location information providing unit 40b supplies the latitude and longitude information obtained by making reference to the latitude and longitude table (not shown) within the GPS correction unit 50d as is to the computer which requested it, without passing through the location information converting device 60.

A-2: Operation of the first embodiment

[0073] Next, the operation of the embodiment with the above-described configuration will be described.

[0074] Fig. 8 is a flowchart illustrating the operation of the location information providing unit 40b of the gateway server 40. With reference to this flowchart, the following is a description of operations, according to an example of notifying the location information of the cellular telephone 30 to the IP server 80B.

[0075] First, upon a request signal requesting the location information of the cellular telephone 30 being transmitted from the IP server 80B to the gateway server 40, the processing of the location information providing unit 40b proceeds to step S1. At step S1, the location information providing unit 40b receives the above request signal via the data relay unit 40a. Contained in this request signal is identification information of the IP server 80B which is the requester of the location information and identification information of the cellular telephone 30 regarding which location information is being requested, and the location information providing unit 40b detects these pieces of identification information from the request signal.

[0076] Next, the processing of the location information providing unit 40b proceeds to step S2. In step S2, the location information providing unit 40b locates information regarding the IP server 80B amongthe latitude and longitude receiver list table shown in Fig. 7using the identification information of the IP server 80B contained in the request signal as a search key, and determines whether or not this IP server 80B is on the latitude and longitude receiver list. In the example shown in Fig. 7, the IP server 80B is not on the list, so the result of the determination is "No".

[0077] Next, the processing of the location information providing unit 40b proceeds to step S3. In step S3, the location information providing unit 40b specifies the identification information of the cellular telephone 30, and makes a request to the position measurement center 50 for the location information of the cellular telephone 30. Upon receiving this request, the position measurement center 50 locates information regardingthe specified the cellular telephone 30 amongthe sector ID table 50c using the identification information of the telephone as a search key, reads out the sector ID which is the location information of the cellular telephone 30, and provides this to the location information providing unit 40b. Thus, the location information providing unit 40b obtains the sector ID as the location information of the cellular telephone 30.

[0078] Next, the processing of the location information providing unit 40b proceeds to step S4. In step S4, the location information providing unit 40b specifies the obtained sector ID and the identification information of the IP server 80B, and orders the location information converting device 60 to convert the location information. Upon receiving this orders, the location information converting device 60 makes reference to the mobile packet communication network conversion table shown in Fig. 6, with the specified sector ID and the identification information of the IP server 80B as a search key. Thus, the location information converting device 60 reads out from the mobile packet communication network conversion table the location information corresponding to the sector ID of the administrative district in the representational format which the IP server 80B is capable of handling, and supplies this to the location information providing unit 40b.

[0079] Next, the processing of the location information providing unit 40b proceeds to step S5. In step S5, the location information providing unit 40b obtains the location information of the cellular telephone 30, which has been converted into the administrative district representational format, from the location information converting device 60.

[0080] Next, the processing of the location information providing unit 40b proceeds to step S6. In step S6, the location information providing unit 40b sends the obtained location information of the cellular telephone 30 out onto the Internet 70, with the identification information of the IP server 80B specified as the destination address.

[0081] Thus, the IP server 80B can obtain the location information of the cellular telephone 30 in an administrative district representational format which can be handled by the server 80B.

[0082] On the other hand, in the above example, in the event that notification of the location information of the cellular telephone 30 is to be made to the IP server 80A for example, the IP server 80A is registered in the latitude and longitude receiver list table shown in Fig. 7, so the result of the determination at step S2 is "Yes". In this case, the processing of the location information providing unit 40b proceeds to step S7. In step S7, the location information providing unit 40b specifies the identification information of the cellular telephone 30, and requests the latitude and longitude information of the cellular telephone 30 from the GPS correction unit 50d of the position measurement center 50. Upon receiving this request, the GPS correction unit 50d makes reference to the above latitude and longitude table with the identification information of the specified cellular telephone 30 as a search key, and reads out the latitude and longitude information as the location information of the cellular telephone 30. Then the latitude and longitude information is supplied to the location information providing unit 40b. Upon obtaining the latitude and longitude information as the location information of the cellular telephone 30, the location information providing unit 40b proceeds to step S6, and transmits the obtained latitude and longitude information to the IP server 80A.

[0083] Also, though operation examples have been described wherein the location information of the cellular telephone 30 is notified to the IP servers 80B or 80A, the basic operation is the same in cases wherein the requester of the location information is another computer, or in cases wherein the cellular device the location information of which is requested belongs to another network, with only the tables to which reference is made changing to those corresponding to identification information of these. However, in the event that there is a request from a computer which handles provision of latitude and longitude, for location information (latitude and longitude information) specifying the identification information of a cellular device not provided with a GPS receiver, the latitude and longitude information of this cellular device cannot be obtained even by making reference to the above latitude and longitude table. In this case, latitude and longitude information cannot be provided, and an error notification is made the requesting computer, to that effect.

[0084] Thus, according to the first embodiment of the present invention, the computers can obtain location information without taking differences in representational formats into consideration, even in cases wherein the representational formats of location information differ according to cellular devices belonging to different networks and further even in cases wherein the representational formats which the computers requesting the location information of the cellular devices can handle differ. That is to say, according to this first embodiment, it can be said that a common platform for location information notification can be provided.

A-3: Modifications of first embodiment

[0085] As already mentioned, the present invention is not restricted to the above embodiment; rather, various modifications may be made. For example, the following modification may be made with the first embodiment.

(1) Arrangement of the network

[0086] The arrangement of the network is not restricted to that shown in Fig. 1. For example, the mobile communication networks which are connected are not restricted to the networks 12, 22, and 32; rather, any of these may be omitted, or alternately, other communication networks may be further connected.

[0087] For example, the above-described cellulartelephone network 32 may be a fixed communication network, and the cellular telephone 30 may be a fixed communication terminal or a portable communication terminal connected to the fixed communication network.

[0088] Also, with regard to networks to which computers such as the IP servers or the like are connected, the network is not restricted to the Internet; rather, intranets, dedicated lines, or other networks may serve.

[0089] Further, the form of nodes on the network are not restricted to the gateway server 40, position measurement center 50, and location information converting device 60, shown in Fig. 1; rather, which functions to assign to which node is determined arbitrarily. For example, all of the functions of these nodes 40 through 60 may be handled by the gateway server 40, or the location information providing unit 40b may be configured as a separate node. Also, an arrangement may be made wherein the position measurement center 50 notifies the location information of the cellular telephones 10 through 30 to the cellular telephones 10 through 30, with the cellular telephones 10 through 30 themselves functioning as the location information providing unit 40b of the gateway server 40, and the location information converting device 60.

(2) Notification of latitude and longitude information

[0090] With the first embodiment, in the event that there is a request from a computer which is to be provided with latitude and longitude, for location information (latitude and longitude information) of cellular telephones 10, 20, and 30 which are not provided with GPS receivers, an error notification is made to the requesting computer, that latitude and longitude information cannot be provided.

[0091] However, the invention is not restricted to such an arrangement; rather, an arrangement may be made wherein in the event that latitude and longitude information cannot be obtained by GPS, the location information providing unit 40b provides to the computer latitude and longitude information obtained by making reference to the tables 50a through 50c.

[0092] Fig. 9 is a flowchart illustrating the operation of the location information providing unit 40b of the gateway server 40 in such an arrangement. With reference to this flowchart, the following is a description of the operation, according to an example in which the location information of a cellular telephone 20 which is not provided with a GPS receiver is notified, to the IP server 80A which can handle location information in the latitude and longitude representational format.

[0093] First, upon a request signal requesting location information of the cellular telephone 20 being transmitted from the IP server 80A to the gateway server 40, the processing of the location information providing unit 40b proceeds to step S11. In step S11, the location information providing unit 40b receives the above request signal via the data relay unit 40a. Contained in this request signal is the identification information of the IP server 80A which is the requester of the location information and identification information of the cellular telephone 20 regarding which location information is being requested, and the location information providing unit 40b detects these pieces of identification information from the request signal.

[0094] Next, the processing of the location information providing unit 40b proceeds to step S12. In step S12, the location information providing unit 40b specifically indicates the identification information of the cellular telephone 20, and requests location information for the cellular telephone 20 from the position measuring center 50. Upon receiving this request, the position measuring center 50 makes reference to the area ID table 50b with the identification information of the specifically indicated cellular telephone 20 as a search key, reads out the area ID as the location information of the cellular telephone 20, and supplies this to the location information providing unit 40b. Thus, the location information providing unit 40b obtains the area ID as the location information of the cellular telephone 20.

[0095] Next, the processing of the location information providing unit 40b proceeds to step S13. In step S13, the location information providing unit 40b specifically indicates the obtained area ID and the identification information of the IP server 80A, and orders the location information converting device 60 to convert the location information. Upon receiving this order, the location information converting device 60 makes reference to the cellular telephone network conversion table shown in Fig. 5, with the specifically indicated area ID and the identification information of the IP server 80A as a search key. Thus, the location information converting device 60 reads out the latitude and longitude location information corresponding to the area ID which is the representational format which the IP server 80A is capable of handling, and supplies this to the location information providing unit 40b.

[0096] Next, the processing of the location information providing unit 40b proceeds to step S14. In step S14, the location information providing unit 40b obtains from the location information converting device 60 the location information of the cellular telephone 20 which has been converted into the latitude and longitude representational format.

[0097] Next, the processing of the location information providing unit 40b proceeds to step S15. In step S15, the location information providing unit 40b sends the obtained location information of the cellular telephone 20 out onto the Internet 70, with the identification information of the IP server 80A specified as the destination address.

[0098] Thus, the IP server 80A can obtain the location information of the cellular telephone 20 which is not provided with a GPS receiver, in a latitude and longitude representational format which it is capable of handling.

(3) Arrangement for operation of location information notification

[0099] With the first embodiment, the arrangement was such that location information notification is performed in response to location information requests from the side of computers such as the IP servers 80A and 80B, but the invention is not restricted to this; rather, an arrangement may be made wherein, for example, the gateway server 40 notifies location information to the IP servers 80A and 80B in response to a notification request from a cellular device, or wherein the gateway server 40 arbitrarily notifies location information to the IP servers 80A and 80B.

(4) Receiver of location information notification

[0100] With the first embodiment, the example is a case in which notifying the location information of the cellular devices 10, 20, and 30, is notified to computers such as IP servers connected to networks outside the networks 12, 22, and 32, but the invention is not restricted to such; rather, an arrangement may be made wherein, instead of the location information of the cellular devices being notified to the cellular devices 10, 20, and 30 themselves, the location information thereof is notified to other cellular devices. Further, notification may be made to predetermined nodes within the networks 12, 22, and 32, instead of the cellular devices 10, 20, and 30. That is to say, the terminology "predetermined computer" within the scope of the Claims is a concept encompassing these cellular devices and nodes within the networks.

B: Second embodiment

[0101] Next, as a second embodiment of the present invention, an arrangement wherein notification is made of location information at a precision desired by a computer is given. The present embodiment will be described with an example wherein the location information of the cellular telephone 30 (mobile communication terminal) contained in the mobile packet communication network 32 (mobile communication network) according to the first embodiment is notified to a computer.

B-1: Configuration of second embodiment

(1) First, the configuration of the second embodiment will be described.

[0102] Fig. 10 is a block diagram illustrating the overall configuration of a network relating to the second embodiment. In this figure, the configurations which are the same as those in the above-described first embodiment will be denoted with the same reference numerals, and the description thereof will be omitted. The second embodiment differs from the first embodiment with regard to the functions of the position measurement center 51 (second location information generating unit), location information converting device 61 (second location information generating unit), and location information providing unit 40c (second location information notifying unit), and description will be made below accordingly.

[0103] As described above, the position measurement center 51 correlates the identification information of the cellular telephone 30 and the sector ID of the service area where the cellular telephone 30 exists, and stores this in the sector ID table 50c. Further, the position measurement center 51 obtains the area ID of the service area where the cellular telephone 30 exists, and correlates the identification information of the cellular telephone 30with the area ID of the service area where the cellular telephone 30 exists, and stores the correlation in the area ID table. Obtaining of this area ID is performed by correlating each sector ID and area ID of service areas containing the sector IDs beforehand.

[0104] The location information converting device 61 converts the location information of the cellular telephone 30 into location information with a precision desired by the computers of IP servers 90A through 90C connected to the Internet, based on the location information conversion table described herein below. Due to the location information converting device 61, each computer requesting obtaining of location information can receive location information of the cellular telephone 30, without taking into consideration differences in precision with which it desires.

[0105] Then, the IP servers 90A through 90C, upon having obtained location information, provide the position related information relating to the location information to the cellular telephone 30.

(2) Configuration of location information conversion table

[0106] Next, the various types of location information conversion tables provided in the location information converting device 61 will be described with reference to Fig. 11 and Fig. 12.

[0107] Fig. 11 is a format diagram illustrating an example of a low-precision conversion table. As shown in the figure, the low-precision conversion table holds, in a correlated manner, the area ID (e.g., AREA001), and the region name of the service area indicated by the area ID (e.g., East Tokyo).

[0108] Fig. 12 is a format diagram illustrating an example of a medium-precision conversion table. As shown in the figure, the conversion table holds, in a correlated manner, the sector ID (e.g., SEC001), and the region name of the sector which the sector ID indicates (e.g., 1 Chome, Toranomon, Minato-ku, Tokyo).

(3) Configuration of the location information providing unit 40c

[0109] Next, with reference to Fig. 13, the configuration of the location information precision table provided in the location information providing unit 40c of the gateway server 40 will be described.

[0110] Fig. 13 is a format diagram illustrating an example of the location information precision table. As shown in the figure, the location information precision table holds information relating to the precision of the location information required by the computers such as the IP servers 90A, 90B, 90C, and so forth.

[0111] In this example, the IP server 90A is a server which performs, for example, route navigation serves to a destination point for the user or position tracking services, and accordingly requires high-precision location information with a margin of error around 10 meters. This high-precision location information is equivalent to the location information obtained by the GPS receiver 34 provided in the cellular telephone 30.

[0112] The IP server 90B is a server which provides, for example, town information for the area of town where the user is, and accordingly requires medium-precision location information with a margin of error of around several hundred meters. This medium-precision location information is equivalent to the location information based on the sector ID of the sector where the cellular telephone 30 exists.

[0113] The IP server 90C is a server which, for example, provides weather forecast information for the region where the user is, and accordingly only needs to obtain low-precision location information with a margin of error of around several kilometers to several tens of kilometers. This low-precision location information is equivalent to the location information based on the area ID of the service area where the cellular telephone 30 exists.

[0114] In the event that location information is to be provided to a computer listed in this location information precision table, the location information providing unit 40c specifies one of the precisions, high-precision through low-precision, held in a manner correlated with the computer, and orders the location information converting device 60 to perform location information conversion.

B-2: Operation of second embodiment

[0115] Next, the operation of the second embodiment with the above-described configuration will be described.

[0116] Fig. 14 is a flowchart illustration the operation of the location information providing unit 40c of the gateway server 40. With reference to this flowchart, the following is a description of the operation, according to an example of the location information providing unit 40c notifying the location information of the cellular telephone 30 to the IP server 90A.

[0117] First, upon a request signal requesting the location information of the cellular telephone 30 being transmitted from the IP server 90A to the gateway server 40, the processing of the location information providing unit 40c proceeds to step Sa1. At step Sa1, the location information providing unit 40c receives the above request signal via the data relay unit 40a. Contained in this request signal is the identification information of the IP server 90A which is the requester of the location information and identification information of the cellular telephone 30 regarding which location information is being requested, and the location information providing unit 40c detects these pieces of identification information from out of the request signal.

[0118] Next, the processing of the location information providing unit 40c proceeds to step Sa2. In step Sa2, the location information providing unit 40c specifies the identification information of the cellular telephone 30, and makes a request to the position measurement center 51 for the location information of the cellular telephone 30. Upon receiving this request, the position measurement center 51 makes reference to the sector ID table 50c with the identification information of the specified cellular telephone 30 as a search key, and reads out the sector ID which as location information of the cellular telephone 30. Then, this sector ID is supplied to the location information providing unit 40c. Thus, the location information providing unit 40c obtains the sector ID as the location information of the cellular telephone 30.

[0119] Next, the processing of the location information providing unit 40c proceeds to step Sa3. In step Sa3, the location information providing unit 40c makes reference to the location information precision table shown as an example in Fig. 13 with the identification information of the IP server 90A contained in the request signal as a search key, thereby obtaining the precision of the location information required by the IP server 90A.

[0120] Next, the processing of the location information providing unit 40c proceeds to step Sa4. In step Sa4, the location information providing unit 40c makes reference to the precision of the location information obtained in step Sa2 and the precision of the location information obtained in step Sa3, and determines whether or not conversion of location information is necessary. Specifically, in the event that the precision of the location information of the cellular telephone 30 obtained from the position measurement center 51 is the same precision or a higher precision than that needed by the IP server 90A, a determination is made that there is no need to convert the location information. On the other hand, in the event that the precision of the location information of the cellular telephone 30 obtained from the position measurement center 51 is the a lower precision than that needed by the IP server 90A, determination is made that it is necessary to convert the location information.

[0121] Here, while the precision of the location information of the cellular telephone 30 obtained from the position measurement center 51 is medium-precision, the precision needed by the IP server 90A is high-precision, so determination is made that conversion of location information is necessary, and the flow proceeds along "Yes".

[0122] Next, the processing of the location information providing unit 40c proceeds to step Sa5. In step Sa5, the location information providing unit 40c specifies the identification information of the cellular telephone 30 and the precision of location information needed by the IP server 90A (high-precision), and orders the location information converting device 61 to convert the location information. Upon receiving this order, the location information converting device 61 specifies the identification information of the cellular telephone 30 and requests high-precision location information (latitude and longitude information) of the cellular telephone 30 from the GPS correction unit 50d of the position measurement center 51. Upon receiving this request, the GPS correction unit 50d makes reference to the latitude and longitude table (not shown) with the identification information of the specified cellular telephone 30 as a search key, thereby reading out the latitude and longitude information which is the location information of the cellular telephone 30. Then, the latitude and longitude information is supplied from the position measurement center 51 to the location information converting device 61.

[0123] Next, the processing of the location information providing unit 40c proceeds to step Sa6. In step Sa6, the location information providing unit 40c obtains the high-precision location information from the location information converting device 61.

[0124] Further, the processing of the location informationproviding unit 40c proceeds to step Sa7, sends the high-precision location information of the cellular telephone 30 out onto the Internet 70, with the identification information of the IP server 90A specified as the destination address.

[0125] Thus, the IP server 90A can obtain location information of the cellular telephone 30 at the precision which it needs.

[0126] On the other hand, in the above example, in the event for example of notifying the location information of the cellular telephone 30 to the IP server 90B, the precision of the location information obtained from the position measurement center 51 in step Sa2 matches the precision of the location information required by the IP server 90B, so the result of the determination in step Sa4 is "No". In this case, the processing of the location information providing unit 40c proceeds to step Sa7, and sends the location information of the cellular telephone 30 obtained from the position measurement center 51 to the IP server 90B, without change.

[0127] Thus, according to the second embodiment of the present invention, even in the event that the precision of the location information needed by the computers differs, the computers can obtain location information without taking into consideration such difference in precision, thereby allowing a common platform for location information notification to be provided.

B-3: Modifications of second embodiment

[0128] As already mentioned, the present invention is not restricted to the above second embodiment; rather, various modifications may be made. For example, the following modification may be made with the second embodiment.

(1) Arrangement of the network

[0129] The arrangement of the network is not restricted to that shown in Fig. 10.

[0130] For example, the above-described cellular telephone netwrk 32 may be a fixed communication network, and the cellular telephone 30 may be a fixed communication terminal or a portable communication terminal connected to the fixed communication network.

[0131] Also, with regard to networks to which computers such as IP servers or the like are connected, the network is not restricted to the Internet; rather, intranets, dedicated lines, or other networks may serve.

(2) Arrangement of nodes on network

[0132] Further, the arrangement of nodes on the network are not restricted to the cellular telephone 30, gateway server 40, position measurement center 51, and location information converting device 61, as with the second embodiment; rather, which functions to assign to which node is determined arbitrarily. For example, all of the functions of the nodes 40, 51, and 61 may be handled by the gateway server 40, or a location information providing unit 40c may be configured as a separate node.

[0133] Also, an arrangement may be made wherein the cellular telephone 30 functions as the location information providing unit 40c of the gateway server 40, and the location information converting device 61. This arrangement will be described below.

[0134] In addition to the GPS receiver 34, the cellular telephone 30 is provided with a location information receiving unit (not shown). This location information receiving unit requests transmission of location information of itself to the mobile packet communication network 32, and is provided with functions for receiving location information transmitted from the network 32. The location information transmitted from the network 32 is location information of medium-precision based on the sector ID or low-precision based on the area ID.

[0135] First, the cellular telephone 30 transmits a request signal requesting a route navigation service to the IP server 90A. In response to this request signal, the IP server 90A notifies the precision of the location information which it needs (e.g., high-precision location information) to the cellular telephone 30.

[0136] In response to this notification, the cellular telephone 30 obtains its own location information. The default operation of this location information obtaining is to obtain the location information with high-precision of latitude and longitude by the cellular telephone 30 instructing the GPS receiver 34.

[0137] Next, the cellular telephone 30 converts the location information based on the precision notified from the IP server 90A. Here, the notified precision is high-precision of latitude and longitude, so the location information obtained from the GPS receiver 34 is notified to the IP server 90A without converting the latitude and longitude location information.

[0138] On the other hand, in the above example, in the event that the cellular telephone 30 requests a weather forecast from the IP server 90C, the precision of the location information specified by the IP server 90C is low-precision, so the cellular telephone 30 sends a request to the mobile packet communication network 32 and obtains low-precision location information, which is transmitted to the IP server 90C.

(3) Arrangement for operation of location information notification

[0139] With the second embodiment, the arrangement was such that location information notification is performed in response to location information requests from the side of computers such as the IP servers 90A through 90C and so forth, but the invention is not restricted to this; rather, an arrangement may be made wherein, for example, notification is made in response to notification requests from the cellular telephone 30, or wherein the gateway server 40 arbitrarily notifies.

(4) Location information notification receiver

[0140] With the second embodiment, the example is a case wherein the location information of the cellular telephone 30 is notified to computers such as IP servers 90A through 90C and the like connected to networks outside the mobile packet communication network 32, but the invention is not restricted to such; rather, an arrangement may be made wherein the location information of the cellular telephone 30 is notified to another cellular telephone (not shown). Further, notification may be made to predetermined nodes within the mobile packet communication network 32, rather than to another cellular telephone. That is to say, the terminology "predetermined computer" within the scope of the Claims is a concept encompassing these other cellular telephones and nodes within the mobile packet communication network 32.

C: Third embodiment

[0141] Next, with the third embodiment of the present invention, an arrangement will be described wherein the location information is notified to various servers as a standard interface protocol, while maintaining security of the location information of the mobile communication terminal.

[0142] As for specific examples of this third embodiment, there are 1: a first specific example wherein location information is notified to the server along with data signals transmitted from a mobile station; and 2: a second specific example wherein location information is notified to the server in response to requests from the server; these will now be described in order.

C-1: First specific example

C-1-1 Configuration of first specific example

[0143] First, the configuration of the first specific example will be described.

(1) Configuration of the overall system

[0144] Fig. 15 is a block diagram illustrating the configuration of the overall mobile communication system relating to the first specific example.

[0145] This mobile communication system comprises a mobile station 100, mobile telephone network 200, mobile packet communication network 300, Internet 400, IP servers 500A, 500B, and so forth. In this first specific example, the above mobile packet communication network 300 and mobile telephone network 200 will be collectively referred to as a mobile communication network.

[0146] The mobile station 100 (mobile communication terminal) is a mobile communication terminal such as a cellular telephone or aPHS, and receives call services of the mobile telephone network 200 and packet communication services of the mobile packet communication network 300. The mobile station 100 comprises an audio input/output unit for allowing the user to make voice calls, a wireless unit for performing wireless communication with the base station of the mobile communication network, an information display unit configured of a liquid crystal panel or the like, an operating unit where information input operations such as numerical input and character input and the like is performed, and a built-in micro-computer for controlling each unit.

[0147] Also, the mobile station 100 is provided with document data viewing software (a so-called browser), so as to display an interactive screen based on HTML (HyperText Markup Language) format data (hereafter referred to as HTML data) supplied from an information provider (hereafter abbreviated as IP) via the mobile packet communication network 300.

[0148] The mobile telephone network 200 (mobile communication network) is a communication network for providing communication services to the mobile station 100, and the mobile station 100 can receive call services via this mobile telephone network 200, or via the network 200 and a fixed telephone network (not shown).

[0149] The mobile telephone network 200 is configured of a base station 210, exchange station 220, home memory 230, and communication lines and the like connecting these.

[0150] A large number of the base stations 210 are set up within the call service area at predetermined intervals, and a base station ID is provided for each base station 210. The base stations 210 perform wireless communication with the mobile stations 100 existing within the various wireless zones. The exchange station 220 contains multiple base stations 210, and performs exchanging processing of the communication lines of the mobile stations 100 existing within the wireless zones of the base stations. This exchange station 220 has an in-zone information table 221 for obtaining the mobile stations 100 existing within the wireless zones of the base stations 210 which it contains.

[0151] The home memory 230 has registered therein various information such as subscriber information, position registration information, billing information, etc., as a database. The position registration information is information indicating the areas within the network to which the mobile stations 100 belong, and this is stored in the position registration database 231.

[0152] The mobile packet communication network 300 is a communication network for providing packet communication services to the mobile station 100, and is configured of the above base station 210, exchange station 220, home memory 230, etc., and further packet subscriber processing devices 310, gateway server 320, and communication lines connecting these. The packet subscriber processing devices 310 are computer systems included in the above exchange station 220 regarding the device configuration thereof, and each has a unique packet subscriber processing device ID. The packet subscriber processing devices 310 receive packet exchange requests from the mobile stations 100, confirm the validity of the received packet exchange requests, and perform processing for relaying the packet exchange, and so forth.

[0153] The gateway server 320 is a computer system provided in a mobile packet gateway relay exchange station (not shown) for mutual connection of the mobile packet communication network 300 with other networks such as the Internet 400 and the like, and intermediates data exchange between networks while converting differing communication protocols between the multiple networks. Specifically, the gateway server 320 performs mutual conversion between the transfer protocol of the mobile packet communication network 300 and TCP/IP which is the standard communication protocol of the Internet 400.

[0154] Further, the gateway server 320 holds main menu screen data for showing menus for the various services provided to the users of the mobile stations 100 by the IP servers 500A, 500B, ··· and so forth, and the data is transmitted to a mobile station 100 in response to a request from the mobile station 100. This main menu screen data is HTML format data, and URLs including the host names of the IP servers 500A, 500B, ··· for executing the services corresponding to the menu items, are embedded in the main menu items.

[0155] Further, the gateway server 320 further is provided with functions for generating location information indicating the position of the mobile station 100. With the present embodiment, the gateway server 320 generates location information of the mobile station 100 by analyzing inbound signals transmitted from the mobile station 100 to the IP servers 500A, 500B, ···. Also, location information can be generated using the above-described in-zone information table 221 or the position registration database 231, but such techniques will not be used with this first specific example; these techniques will be used with a second specific example described herein below. The configuration of the gateway server 320 and details of the location information generating operations thereof will be described later.

[0156] The IP servers 500A, 500B, ··· are server systems run by the IPs, and send information out onto the Internet 400, to be provided to the users as HTML format data. In this first specific example, the IP servers 500A, 500B, ··· are servers for providing to the mobile station 100 position related information according to the position of the mobile station 100, and are provided with position related information databases 510A, 510B, ··· which store various types of position related information. The IP servers 500A, 500B, ··· search the position related information databases 510A, 510B, ··· based on the location information of the mobile station 100 notified from the gateway server 320, and transmit the position related information obtained as a result of the search to the mobile station 100 via the Internet 400 or the like.

[0157] Further, the IP servers 500A, 500B, ··· store HTML format sub-menu screen data for showing the user menus for services which it performs, and when the mobile station 100 accesses the IP servers 500A, 500B, ···, the stored sub-menu screens are transmitted to the mobile station 100.

[0158] Now, a description regarding the configuration of HTML data, which is the sub-menu screen data, will be given.

[0159] Fig. 16 is a diagram illustrating anexample of HTML format sub-menu screen data which the IP servers 500A, 500B, ··· transmit to the mobile station 100, and Fig. 17 is a diagram of the sub-menu screen displayed on the mobile station 100 based on the screen data.

[0160] As shown in Fig. 11, sub-menu items include, for example, "restaurant information", "movie theater information", "museum information", "registration of tracking information provision", and so forth.

[0161] Of these sub-menu items, "restaurant information", "movie theater information", and "museum information" are for providing restaurant information and the like to the user of the mobile station 100, according to the location information of the mobile station 100. Each sub-menu item has a corresponding hypertext link text string embedded therein.

[0162] For example, in the event that the user selects "Restaurant information" from the sub-menu screen shown in Fig. 17, the hypertext link text string "http://xxx.co.jp/cgibin/restaurant.cgi?area=NULLAREA" (see Fig. 16) which is embedded in "restaurant information" is transmitted from the mobile station 100 to one of the IP servers 500A, 500B, ··· indicated by the host name "xxx.co.jp", via the gateway server 320 and the like.

[0163] A predetermined data string "NULLAREA" is included at the end of the hypertext link text string, and this data string "NULLAREA" will be substituted with the location information of the mobile station 100 at the gateway server 320 and transmitted to the IP servers 500A, 500B, ··· indicated by the host name, and hereafter will be referred to as "location information substituting data string".

[0164] Now, the service contents of "Registration of tracking information provision" shown in Fig. 16 and the hypertext link text string "http://xxx.co.jp/cgi-bin/pushregist.cgi?uid=NULLID" embedded therein will be described in the second specific example described herein below.

(2) Configuration of gateway server 320

[0165] Next, the configuration of the gateway server 320 will be described.

[0166] Fig. 18 is a block diagram illustrating the configuration ofthe gateway server 320.

[0167] The gateway server 320 is made up of an interface unit 321 (receiving unit and transmitting unit), subscriber information managing unit 322, data distribution managing unit 323 (third location information notifying unit, receiving unit, transmitting unit, detecting unit, substituting unit, notification permission/non-permission determining unit, inquiry unit, determining unit, and error signal transmitting unit), IP server information managing unit 324 (disclosure information storing unit), location information generating unit 325 (third location information generating unit), and a bus 326 and the like mutually connecting these.

[0168] The interface unit 321 functions as an interface between networks, such as performing protocol conversion between other networks such as the mobile packet communication network 300 and the Internet 400.

[0169] The subscriber information managing unit 322 stores and manages subscriber information which is obtained by making reference to the above-described home memory 230.

[0170] The data distribution managing unit 323 manages data distribution processing between mobile stations 100, between a mobile station 100 and another network such as the Internet 400, or between a mobile station 100 and the IP servers 500A, 500B, ···, and the like, and also functions to substitute a predetermined data string detected in data transmitted from the mobile station 100 with location information of the mobile station 100, as described later. Further, the data distribution managing unit 323 stores the above-described main menu screen data, and transmits the screen data to the mobile station 100 in response to request signals from the mobile station 100. In addition to "position related information services" for providing position related information relating to the position of the mobile station 100, the main menu items also include a "news distribution service" which performs news distribution, and so forth.

[0171] Now, there are two methods for the mobile station 100 to access the IP servers 500A, 500B, ···,: a method for the user to select a desired main menu item from the main menu screen displayed on the mobile station 100, and a method for the user to use the keypad of the mobile station 100 to directly input the URL of the desired IP servers 500A, 500B, ···.

[0172] First, in the event of the user selecting a main menu item from the main menu screen displayed on the mobile station 100, the arrangement is such that, upon the mobile station 100 transmitting a request signal containing a URL embedded in that main menu item to the gateway server 320, the data distribution managing unit 323 of the gateway server 320 accesses one of the IP servers 500A, 500B, ··· based on the host name of the URL contained in the received request signal.

[0173] Also, in the event of the user directly inputting the URL of the IP servers 500A, 500B, ··· which the user desires to access to the mobile station 100, the arrangement is such that, upon the mobile station 100 transmitting a request signal containing the input URL to the gateway server 320, the data distribution managing unit 323 of the gateway server 320 accesses one of the IP servers 500A, 500B, ··· based on the host name of the URL contained in the received request signal.

[0174] Once the mobile station 100 accesses one of the IP servers 500A, 500B, ··· by one of the above methods, the IP server 500A, 500B, ··· transmits a stored submenu screen to the mobile station 100, as described above.

[0175] The IP server information managing unit 324 is provided with an IP information database 327 which stores information relating to the IP servers 500A, 500B, ···, and performs registration, updating, etc., of this information. The above data distribution managing unit 323 makes reference to this IP information database 327, and transmits the location information of the mobile station 100 to the IP servers 500A, 500B, ···. The configuration of this IP information database 327 will be described later.

[0176] The location information generating unit 325 generates location information of the mobile station 100 as described below.

[0177] Inbound signals transmitted from the mobile station 100 to the IP servers 500A, 500B, ··· contain for example, URLs for the IP servers 500A, 500B, ··· which are the destinations of the signals, the mobile station ID of the originating mobile station 100, and so forth. Further, in the process of the inbound signals being relayed by the devices within the mobile communication network, the ID of each device is added to the signal. That is to say, following transmission of this inbound signal from the mobile station 100, reception at the base station 210 adds the base station ID of the base station, and further, reception at the packet subscriber processing device 310 adds the packet subscriber processing device ID of the packet subscriber processing device 310.

[0178] Accordingly, when the inbound signal transmitted from the mobile station 100 is received by the gateway server 320, the signal contains the URL of one of the destination IP servers 500A, 500B, ···, the mobile station ID, a base station ID, and a packet subscriber processing device ID. The location information generating unit 325 can determine in which base station 210 wireless zone which mobile station 100 exists, by analyzing the ID information and so forth.

[0179] The location information generating unit 325 is provided with, in a correlated manner, a region code table 328, storing base station IDs and region codes of regions where the base stations of the base station IDs are located. The location information generating unit 325 searches the region code table 328 with the base station ID of the zone where the mobile station 100 exists as a search key, and the region code obtained as the result thereof and the mobile station ID of the above mobile station 100 are taken as the location information of the mobile station 100.

(3) Configuration of IP information database 327

[0180] Next, the configuration of the IP information database 327 provided in the IP server information managing unit 324 will be described.

[0181] Fig. 19 shows a data format diagram of the IP information database 327.

[0182] As shown in the figure, for each "IP server name", information such as "host name", "service name", "location information disclosure flag", "user consent flag", and so forth, is stored in the IP information database 327 for each server.

[0183] The location information disclosure flag is set to ON regarding an IP server 500 for which the location information of the mobile station 100 is disclosed (i.e., an IP server 500 capable of obtaining the location information of the mobile station 100).

[0184] For example, in the figure, the IP server 500A and IP server 500B are IP servers for providing position related information providing services, and the IP server 500B is an IP server for performing wide-area information providing services.

[0185] Now, wide-area information means information which is not specific to a particular region, and wide-area information providing services are services providing wide-area information to the mobile station 100 which are not dependent on the location information of the mobile station 100. An example of wide-area information providing services is nationwide news distribution services and so forth. On the other hand, position related information providing services are services for providing information relating to a particular region based on the position of the mobile station 100, such as services for providing restaurant information and so forth, as described above.

[0186] Accordingly, as shown in the figure, the IP server 500A and the IP server 500B are IP servers capable of obtaining location information (i.e., the IP server 500A and IP server 500B receive disclosure of location information), so the location information disclosure flag is set to ON. On the other hand, the IP server 500C is a server which does not obtain location information of the mobile station 100 (i.e., the IP server 500C does not receive disclosure of location information), so the location information disclosure flag is set to OFF.

[0187] Of the IP servers 500 which are the object of disclosure of the location information of the mobile station 100, the user consent flag is set to ON regarding the IP servers 500 which need the consent of the user of the mobile station 100 when disclosing the location information.

[0188] There are cases wherein the user does not want his/her own location information to be known, and, in such cases, this user consent flag has been provided in order to prevent the location information of the mobile station 100 from the disclosed to the IP servers 500A, 500B, ···, against the will of the user.

[0189] Accordingly, even with IP servers 500 which receive disclosure of location information, there are IP servers which can unconditionally (i.e., without the consent of the user) obtain location information of the mobile station 100 (the IP server 500B shown in the figure) and IP servers which can obtain location information only with consent of the user (the IP server 500A shown in the figure).

[0190] Now, there is no flag information or the like to serve as such disclosure standards for IP servers 500 not registered in the IP information database 327, but the gateway server 320 determines that the location information disclosure flag is set to OFF for such IP servers 500 not registered in the IP information database 327 (i.e., not to receive disclosure of location information).

(4) Configuration of region code table 328

[0191] Next, the region code table 328 in the location information generating unit 325 will be described.

[0192] Fig. 20 is a data format diagram for the region code table 328.

[0193] This region code table 328 stores in a corresponding manner a "base station ID" which can be obtained as information indicating position within the mobile communication network, and a "region code" which IP servers 500A, 500B, ··· set up outside the network can obtain as information indicating position.

[0194] For example, the base station ID group "BS001-BS005" shown in the figure is approximately equivalent to the area of 1-Chome, Shibuyaku, Tokyo, and accordingly a region code "CODE001" indicating 1-Chome, Shibuya-ku, Tokyo, is stored corresponding to this base station group.

(5) Configuration of position related information database 510

[0195] Next, the configuration of the position related information databases 510A, 510B, ···, provided in the IP servers 500A, 500B, ···, will be described, with the position related information database 510A as an example.

[0196] Fig. 21 is a format diagram of the position related information database 510A.

[0197] This position related information database 510A stores a "region code" for each region, and "region name" and "position related information" corresponding to each region code.

[0198] Now various standards may be conceived for sectioning the regions, such as by administrative district such as town and city names, by postal code, by latitude and longitude, etc. In the figure, region code "CODE001" indicates "1-Chome, Shibuya-ku", which is an administrative district, and information such as "buildings" in "1-Chome, Shibuyaku" like "restaurants", "movie theaters", "museums", and "addresses", "telephone numbers", "events", and so forth, are stored in the position related information database 510A.

C-1-2: Operation of the first specific example

[0199] Next, the operation of the first specific example with the above configuration will be described with reference to the flowchart shown in Figs. 22A and 22B.

[0200] First, the user selects a desired main menu item from the main menu screen displayed on the mobile station 100, or the user directly inputs the URL of a desired IP server 500A, 500B, ··· to the mobile station 100, thereby accessing an IP server 500A, 500B, ··· (here, the IP server 500A (host name: xxx.co.jp)). Next, the IP server 500A transmits the stored sub-menu screen data (e.g., the screen data illustrated in Fig. 16) to the mobile station 100 via the gateway server 320, and the mobile station 100 receives and displays this, thereby starting the processing shown in the figure.

[0201] Once the user selects a desired menu item from the sub-menu screen displayed on the mobile station 100 (e.g., "restaurant information" shown in Fig. 17), in step SP1, the mobile station 100 transmits to the gateway server 320 a request signal containing "http://xxx.co.jp/cgibin/restaurant.cgi?area=NULLAREA", which is embedded in the selected menu item.

[0202] In step SP3, the gateway server 320 receives the request signal via the base station 210 and the like.

[0203] In step SP5, the gateway server 320 determines whether or not the location information substitution data string "NULLAREA" is included in the hyperlink text string in the received request signal. In the event that the result of the determination is "No" (i.e., in the event that there is no location information substitution data string), the flow proceeds to step SP7, the gateway server 320 accesses one of the IP servers 500A, 500B, ···, based on the host name contained in the hyperlink text string in the received request signal, and subsequently performs data relay processing between the mobile station 100 and the IP servers 500A, 500B, ···, following the operations made by the user.

[0204] On the other hand, in the event that the result of the determination in step SP5 is "Yes" (i.e., in the event that there is a location information substitution data string), the flow proceeds to step SP9, the gateway server 320 makes reference to the host name contained in the hyperlink text string, and determines whether or not the IP server 500A indicated by the host name is to receive disclosure of location information. As described above, this determination is made by making reference to the setting state (ON or OFF) of the location information disclosure flag within the IP information database 327.

[0205] In the event that the result of the determination in step SP9 is OFF (i.e., in the event that the IP server 500A is not the object of disclosure of location information), the flow proceeds to step SP11, and the gateway server 320 transmits a transmission impossible notification to the mobile station 100 to the effect that location information cannot not be transmitted to the IP server 500A.

[0206] Then, in step SP13, the mobile station 100 receives the transmission impossible notification, and notifies this to the user by displaying it on the liquid crystal display. On the other hand, in the event that the result of the determination in step SP9 is ON (i.e., in the event that the IP server 500A is to receive disclosure of location information), the flow proceeds to step SP15, and the gateway server 320 determines whether or not the consent of the user of the mobile station 100 is necessary when disclosing location information to the IP server 500A. As described above, this determination is made by making reference to the setting state (ON or OFF) of the user consent flag within the IP information database 327.

[0207] In the event that the result of the determination in step SP15 is OFF (i.e., in the event that user consent is unnecessary), the flow proceeds to step SP17.

[0208] On the other hand, in the event that the result of the determination in step SP15 is ON (i.e., in the event that user consent is necessary), the flow proceeds to step SP19, and the gateway server 320 transmits to the mobile station 100 input screen data for obtaining consent from the user for transmitting location information.

[0209] Then, in step SP21, the mobile station 100 receives and interpretsthe input screen data, and displays it on the liquid crystal display.

[0210] In step SP23, the mobile station 100 accepts input regarding permission/non-permission of consent from the user.

[0211] In step SP25, the mobile station 100 transmits the input information input by the user to the gateway server 320.

[0212] In step SP27, the gateway server 320 receives the input information.

[0213] Then, in step SP29, the input information relating to permission/non-permission of consent is interpreted, and determination is made regarding whether or not the location information may be transmitted to the IP server 500A.

[0214] In the event that the result of the determination is "No" (i.e., in the event that location information may not be transmitted to the IP server 500A), the flow proceeds to step SP31, and the gateway server 320 transmits a transmission impossible notification to the mobile station 100 to the effect that location information cannot be transmitted to the mobile station 100.

[0215] Then, in step SP33, the mobile station 100 receives the transmission impossible notification, and display this on the liquid crystal display. The user can view the display to confirm that location information was not transmitted.

[0216] On the other hand, in the event that the result of the determination in step S29 is "Yes" (i.e., in the event that location information may be transmitted to the IP server 500A), the flow proceeds to step SP17, and the gateway server 320 generates location information of the mobile station 100. That is, as described above, the gateway server 320 first extracts the base station ID contained in the request signal, searches the region code table 328 with the extracted base station ID as a search key, obtains the region code (which is "CODE001" here) corresponding to the base station ID, and uses the region code as the location information of the mobile station 100.

[0217] In step SP35, the gateway server 320 substitutes the location information substitution data string "NULLAREA" within the request signal with the location information "CODE001" of the mobile station 100, and transmits the hyperlink text string including the substituted location information, i.e., "http://xxx.co.jp/cgi-bin/restaurant.cgi?area=CODE001", as the request signal, to the IP server 500A based on the host name "xxx.co.jp".

[0218] In step SP37, the IP server 500A activates a position related information application in response to the received request signal. Then, position related information (restaurant information) corresponding to the location information (CODE001) received from the gateway server 320 is obtained from the position related information database 510A, and the above position related information is transmitted via the Internet 400 to the mobile station 100 based on the mobile station ID contained in the request signal.

[0219] Subsequently, the mobile station 100 receives and displays the position related information via the gateway server 320, thereby achieving the objective aim of the user at this time.

C-2: Second specific example

[0220] Next, as a second specific example of the third embodiment, an example will be described wherein location information of the mobile station 100 is notified to the IP servers 500A, 500B, ···, in response to requests from the IP servers 500A, 500B, ···.

C-2-1: Configuration of second specific example

[0221] With the second specific example, as described above, location information of the mobile station 100 is generated using the in-zone information table 221 of the exchange station 220 and the position registration database 231 of the home memory 230. Accordingly, in the following, the configuration of the in-zone information table 221 and the position registration database 231 will be described in detail, and further, description will be made regarding how the second specific example differs from the first specific example. Incidentally, other configurations are the same as those of the first specific example, and accordingly description thereof will be omitted.

(1) Configuration of in-zone information table 221 of exchange station 220

[0222] Fig. 23 is a format diagram illustrating an example of the stored contents of the in-zone information table 221.

[0223] As shown in the figure, the in-zone information table 221 stores a "base station ID" for each base station 210 contained in the exchange station 220, and a "mobile station ID" of the mobile station 100 used in a wireless zone of the base station 210 indicated by the base station ID (generally, the telephone No. of the mobile station 100 is used). Hereafter, information made up of the mobile station ID and base station ID will be referred to as in-zone information.

[0224] For example, this shows that there are three mobile stations 100 represented by the mobile station IDs "MS09011111111", "MS09011111122", and "MS09011111130" existing in the wireless zone of the base station ID "BS001" shown in the figure. Also, there are no mobile stations 100 in the wireless zone of the base station ID "BS002", and there is one mobile station 100 represented by the mobile station ID "MS09011111140" existing in the wireless zone of the base station 210 of the base station ID "BS003".

[0225] When the mobile stations 100 move between the wireless zones of the base stations 210, processing for switching over to communication channels unique to each base station is performed between the mobile stations 100 and exchange stations 220 (a so-called hand-over), and the in-zone information of the above in-zone information table 221 are updated at the timing of this hand-over.

[0226] Each exchange station 220 makes reference to this in-zone information table 221 and manages communication processing between the base stations 210 and mobile stations 100.

(2) Configuration of the position registration database 231 of the home memory 230

[0227] Fig. 24 is a format diagram illustrating an example of the stored contents of the position registration database 231.

[0228] Now, an area made up of the wireless zones of multiple base stations 210 contained in one exchange station 220 will be referred to as a "position registration area" (or general calling area). This position registration area is a unit of position registration of the mobile stations 100 performed within a mobile communication network, and the exchange station 220 performs general calling of the mobile stations 100 in units thereof. Also, each position registration area is provided with a position registration area ID.

[0229] As shown in the figure, the position registration database 231 stores each "mobile station ID" and the "position registration area ID" of the position registration areas where each mobile station exists, in an associated manner. Information made up of this "mobile station ID" and "position registration area ID" will be called position registration information.

[0230] For example, in the figure, this shows that the mobile station 100 represented by the mobile station ID "MS09011111111" exists in the position registration area represented by the position registration area ID "AREA0001".

(3) Configuration of IP servers 500A, 500B, ···

[0231] The IP servers 500A, 500B, ··· store sub-menu screens, as in the above-described first specific example, but the configuration of the hyperlink text string embedded in the sub-menu items used in the second specific example differ from those of the first specific example.

[0232] Now, the configuration of the hyperlink text-string according to the second specific example will be described with reference to Fig. 16 and Fig. 17.

[0233] The "registration of tracking information provision" shown in Fig. 16 and Fig. 17 is a menu item for registering the mobile station 100 which is to be tracked, with the IP servers 500A, 500B, ··· for performing services such as, for example, periodically tracking the position of the mobile station 100.

[0234] Specifically, registering the ID of the mobile station with the IP servers 500A, 500B, ··· using the "registration of tracking information provision" causes the IP servers 500A, 500B, ··· to periodically inquire regarding location information of the mobile station 100 indicated by the registered ID to the gateway server 320, and obtain location information.

[0235] As shown in Fig. 16, the hyperlink text string "http://xxx.co.jp/cgibin/pushregist.cgi?ID=NULLID" is embedded in the menu item "registration of tracking information provision", with the data string "NULLID" included at the end of the hyperlink text string.

[0236] When the user selects "registration of tracking information provision" from the sub-menu screen shown in Fig. 17, a request signal containing the hyperlink text string "http://xxx.co.jp/cgi-bin/pushregist.cgi?ID=NULLID" is transmitted from the mobile station 100 to the gateway server 320, and at this time the predetermined data string "NULLID" is substituted with the ID of the mobile station 100 at the gateway server 320 and is transmitted to the IP servers 500A, 500B, ··· indicated by the host name. This predetermined data string "NULLID" will hereafter be referred to as "mobile station ID substituting data string".

[0237] The ID of the mobile station 100 substituted at this time is not the above-described mobile station ID made up of the telephone number of the mobile station 100, but rather is an ID uniquely determined between the gateway server 320 and IP servers 500A, 500B, ··· (hereafter called pseudo ID).

[0238] The substituted pseudo ID is temporarily stored in the IP servers 500A, 500B, ···, and the IP servers 500A, 500B, ··· are arranged so as to transmit the location information request which specified that pseudo ID to the gateway server 320.

(4) Configuration of the gateway server 320

[0239] Next, the configuration of the gateway server 320 will be described.

[0240] The gateway server 320 is made up of the interface unit 321 (receiving unit) described in the first specific example, subscriber information managing unit 322, data distribution managing unit 323 (receiving unit, fourth location information notifying unit, detecting unit, substituting unit, identification information adding unit, notification permission/non-permission determining unit, inquiry unit, determining unit, and error signal transmitting unit), IP server information managing unit 324 (disclosure information storing unit), location information generating unit 325 (fourth location information generating unit), and a mobile station ID table for converting mobile station IDs into pseudo IDs.

[0241] Fig. 25 is a format diagram illustrating an example of he stored contents of the mobile station ID table.

[0242] As shown in the figure, the mobile station ID table stores a "mobile station ID" and a corresponding "pseudo ID". For example, the mobile station ID "MS09011111111" corresponds to the pseudo ID "00ZDGVXAKLLG"

[0243] Upon detecting the mobile station ID substituting data string from the request signal received from the mobile station 100, the data distribution managing unit 323 of the gateway server 320 searches the mobile station ID table with the mobile station ID contained in the signal as a search key, substitutes the obtained pseudo ID with the mobile station ID substituting data string, and transmits this to one of the IP servers 500A, 500B, ···.

[0244] On the other hand, the pseudo ID transmitted to the IP servers 500A, 500B, ··· is temporarily stored within the server as described above, and a location information request with the pseudo ID specified above is transmitted from the IP servers 500A, 500B, ··· to the gateway server 320.

[0245] Then, the location information generating unit 325 of the gateway server 320 which has received the location information generating request generates location information of the specified mobile station 100. Now, the location information generating unit 325 does not generate location information using the base station ID within the inbound signal from the mobile station 100 and so forth, as with the above-described first specific example, but rather generates location information by making reference to the above-described position registration database 231 and in-zone information table 221. The details of the operation of generating location information with the gateway server 320 will be described later.

C-2-2: Operation of second specific example

[0246] Next, the operation of the second specific example with the above configuration will be described with reference to the flowchart shown in Figs. 26A, 26B and 27.

[0247] First, the user selects a desired main menu item from the main menu screen displayed on the mobile station 100, or the user directly inputs the URL of a desired IP server 500A, 500B, ··· to the mobile station 100, thereby accessing an IP server 500A, 500B, ··· (here, the IP server 500A (host name: xxx.co.jp)). Next, the IP server 500A transmits the stored sub-menu screen data (e.g., the screen data illustrated in Fig. 16) to the mobile station 100 via the gateway server 320, and the mobile station 100 receives and displays this, thereby starting the processing shown in the figure.

[0248] Once the user selects a desired menu item from the sub-menu screen displayed on the mobile station 100 (e.g., "registration of position tracking information" shown in Fig. 17), in step SP51, the mobile station 100 transmits a request signal containing the hyperlink text string "http://xxx.co.jp/cgi-bin/pushregist.cgi?ID=NULLID" embedded in the selected menu item and mobile station ID (e.g., "MS09011111111") to the gateway server 320.

[0249] In step SP53, the gateway server 320 receives the request signal.

[0250] In step SP55, the gateway server 320 determines whether or not the mobile station ID substitution data string "NULLID" is included in the received request signal.

[0251] In the event that the result of the determination is "No" (i.e., in the event that there is no mobile station ID substitution data string), the flow proceeds to step SP57, the gateway server 320 accesses one of the IP servers 500A, 500B, ···, based on the host name contained in the hyperlink text string in the received request signal, and subsequently performs data relay processing between the mobile station 100 and the IP servers 500A, 500B, ···, following the operations made by the user.

[0252] On the other hand, in the event that the result of the determination in step SP55 is "Yes" (i.e., in the event that there is a mobile station ID substitution data string), the flow proceeds to step SP59, the gateway server 320 searches the mobile station ID table, and obtains the pseudo ID of the mobile station 100 ("00ZDGVXAKLLG" shown in Fig. 25).

[0253] In step SP61, the gateway server 320 substitutes the mobile station ID substitution data string "NULLID" in the hyperlink text string within the request signal with the pseudo ID "00ZDGVXAKLLG", and transmits the hyperlink text string containing the substituted pseudo ID "http://xxx.co.jp/cgi-bin/pushregist.cgi?ID=00ZDGVXAKLLG" and the like as a request signal to the IP server 500A based on the host name "xxx.co.jp".

[0254] In step SP63, the IP server 500A receives and interprets the request signal, and stores the pseudo ID "00ZDGVXAKLLG" contained in the request signal as a mobile station which is to have position tracking performed thereon.

[0255] In step SP65, the IP server 500A specifies the stored pseudo ID "00ZDGVXAKLLG" and periodically transmits location information requests to the gateway server 320.

[0256] In step SP67, the gateway server 320 receives the location information request from the IP server 500A. Then, the gateway server 320 searches the mobile station ID table with the specified pseudo ID "00ZDGVXAKLLG" as a search key, and obtains the corresponding mobile station ID "MS09011111111".

[0257] In step SP69, the gateway server 320 determines whether or not the IP server 500A which has transmitted the location information request is to have the location information thereof disclosed. As described in the first specific example, this determination is made by making reference to the setting state (ON or OFF) of the location information disclosure flag within the IP information database 327.

[0258] In the event that the result of the determination in step SP69 is OFF (i.e., in the event that the IP server 500A is not to be subjected to disclosure of location information), the flow proceeds to step SP71, and the gateway server 320 transmits to the mobile station 100 a transmission impossible notification to the effect that location information cannot be transmitted to the IP server 500A. Then, in step SP73, the IP server 500A receives the transmission impossible notification.

[0259] On the other hand, in the event that the result of the determination in step SP69 is ON (i.e., in the event that the IP server 500A is to be subjected to disclosure of location information), the flow proceeds to step SP75, and the gateway server 320 determines whether or not the consent of the user of the mobile station 100 is necessary when transmitting location information to the IP server 500A. As described in the first specific example, this determination is made by making reference to the setting state (ON or OFF) of the user consent flag within the IP information database 327.

[0260] In the event that the result of the determination in step SP75 is OFF (i.e., in the event that user consent is unnecessary), the flow proceeds to step SP77 in Fig. 27.

[0261] On the other hand, in the event that the result of the determination in step SP75 is ON (i.e., in the event that user consent is necessary), the flow proceeds to step SP79, and the gateway server 320 transmits input screen data for obtaining consent from the user for transmitting location information to the mobile station 100 indicated by the mobile station ID "MS09011111111".

[0262] Then, in step SP81, the mobile station 100 receives and interprets the input screen data, and displays it on the liquid crystal display.

[0263] In step SP83, the mobile station 100 accepts input regarding permission/non-permission of consent from the user.

[0264] In step SP85, the mobile station 100 transmits the input information input by the user to the gateway server 320, and in step SP87, the gateway server 320 receives the input information.

[0265] Next, in step SP89 shown in Fig. 27, the gateway server 320 interprets the input information relating to permission/non-permission of consent, and makes a determination regarding whether or not the location information may be transmitted to the IP server 500A.

[0266] In the event that the result of the determination is "No" (i.e, in the event that location information may not be transmitted to the IP server 500A), the flow proceeds to step SP91, and the gateway server 320 transmits a transmission impossible notification to the mobile station 100 to the effect that location information cannot be transmitted to the IP server 500A.

[0267] Then, in step SP93, the IP server 500A receives the transmission impossible notification.

[0268] Alternatively, in the event that the result of the determination in step SP89 is "Yes" (i.e., in the event that location information may be transmitted to the IP server 500A), the flow proceeds to step SP77, and the gateway server 320 generates location information of the mobile station 100, as described next.

[0269] First, the gateway server 320 searches the position registration database 231 with the mobile station ID as a search key, and obtains the corresponding position registration area ID. The mobile station 100 exists within the position registration area indicated by the position registration area ID obtained here.

[0270] Next, the gateway server 320 accesses the in-zone information table 221 provided in the exchange station 220 indicated by the obtained position registration area ID, searches with the mobile station ID as the search key, and obtains the corresponding base station ID.

[0271] Then, the gateway server 320 searches the region code table 328 with the obtained base station ID as a search key, obtains the corresponding region code, and takes this as the location information of the mobile station 100.

[0272] In step SP95, the gateway server 320 transmits to the IP server 500A the generated location information, as the location information of the mobile station 100 indicated by the pseudo ID "00ZDGVXAKLLG".

[0273] In step SP97, the IP server 500A receives the location information of the mobile station 100, and transmits position related information to the mobile station 100, as appropriate, in response to the received location information.

[0274] With the above-described first and second specific examples of the third embodiment, predetermined data strings decided upon between the gateway server 320 and the IP servers 500A, 500B, ···, are to be substituted with location information and mobile station IDs, so location information can be notified to the IP server 500 in a form not dependent on the specifications of the mobile station 100.

[0275] Also, the gateway server 320 determines whether or not notification of location information is permissible, based on disclosure standard information such as the location information disclosure flag and the like, so security regarding the location information of the mobile station 100 is secured.

C-3: Modifications of third embodiment

[0276] As already described, the present invention is not restricted to the above third embodiment, rather, various modifications may be made. For example, the following modifications may be made with the first and second specific examples of the third embodiment.

(1) Arrangement of IP servers 500A, 500B ···

[0277] With the first and second specific examples described above, the IP servers 500A, 500B ··· are connected to the gateway server 320 via the Internet 400, but the invention is not necessarily restricted to such a connection arrangement.

[0278] For example, the IP servers 500A, 500B ··· may be connected to the gateway server 320 via dedicated lines, or may be provided within the mobile communication network.

[0279] Also, though with the first and second specific examples the IP servers 500A, 500B ··· have functions of providing some sort of information to the mobile station 100, the invention is not restricted to this and these may just be computers.

[0280] For example, in the second specific example, the IP server 500 may periodically obtain the location information of the mobile station 100 and provided the location information obtained as the result thereof to a predetermined information processing device (e.g., an administration center or the like which performs operational administration of vehicles in which mobile stations 100 are mounted), or the IP server 500 may simply accumulate the obtained location information without making output to other terminals.

(2) Arrangement of location information substitution data string or mobile station ID substitution data string

[0281] In the first and second specific examples described above, the location information substitution data string "NULLAREA" or mobile station ID substitution data string "NULLID" were added to the end of the hyperlink text string contained in the request signal. However, this arrangement is not essential, and including the above substitution data strings at predetermined positions within the request signal transmitted from the mobile station 100 suffices. Also, the data string does not need to be the text strings "NULLAREA" and "NULLID";

these may be other text strings instead.

(3) Arrangement of location information description format

[0282] Also, in the first and second specific examples described above, location information can be supplied to various IP servers by converting the predetermined text string determined beforehand into location information.

[0283] However, the invention is not restricted to this, and matching the description format for location information between the mobile stations 100 and the IP servers 500A, 500B ··· will suffice. That is to say, the IP servers 500A, 500B ··· may notify the mobile stations 100 of the location information description format beforehand, such that the mobile stations 100 describe the location information based on the notified format, and transmit this to the IP servers 500A, 500B ···.

[0284] An example ofthe notification processing of the above location information description format is as follows. First, the IP servers 500A, 500B ··· describe the description format of location information within a predetermined file, add a specific suffix to a file indicating that the file specifies the location information description format, and send this to the mobile stations 100. The mobile stations 100 make reference to the file and obtain the location information description format.

(4) Arrangement of location information generation

[0285] In the first and second specific examples described above, the mobile communication network including the gateway server 320 generated the location information of the mobile stations 100; however, the invention is not restricted to such, and location information of mobile stations 100 generated by other means may be notified to the IP servers 500A, 500B ···.

[0286] The following is a description of a specific example of other means for generating location information of a mobile station 100.

[0287] For example, the user may input location information to the mobile station 100 by operating the keys himself/herself.

[0288] First, the data distribution managing unit 323 (input screen transmitting unit and specified location information receiving unit) of the gateway server 320 transmits specified location information input screen data for inputting user-specified location information, along with input screen data for inquiring of consent for transmitting the location information, to the mobile station 100.

[0289] The mobile station 100 interprets the received specified location information input screen data and displays this on the liquid crystal display. The user inputs more specific location information to the specified location information input screen data displayed on the mobile station 100, such as the position with respect to a certain building like "East entrance of station A", or the "address" itself of the location of the user.

[0290] The mobile station 100 then transmits the specified location information input by the user to the gateway server 320. The gateway server 320 transmits the specified location information received from the mobile station 100 to the IP servers 500A, 500B ··· along with the location information generated by its location information generating unit 325.

[0291] In the event that the notified location information is detailed, the IP servers 500A, 500B ··· can correspondingly provide detailed and precise position related information.

[0292] Also, the mobile station 100 may be provided with a measuring unit (position measuring unit) such as GPS or the like.

[0293] The mobile station 100 measures the position of the mobile station 100 with the above position measuring unit and transmits the obtained position measurement information to the data distribution managing unit 323 (position measurement information receiving unit) of the gateway server 320.

[0294] The gateway server 320 transmits only location information generated by the location information generating unit 325 to the IP servers 500A, 500B ··· with regard to mobile stations 100 not provided with the above position measuring means, and transmits the position measurement information received from the mobile station 100 in addition to the location information generated by the location information generating unit 325 to the IP servers 500A, 500B ··· with regard to mobile stations 100 provided with the above position measuring means.

[0295] Now, the operation for the gateway server 320 to transmit the location information and position measurement information to the IP servers 500A, 500B ··· will be described in detail.

[0296] The position related information which is transmitted from the gateway server 320 to the IP servers 500A, 500B ··· is made up of an 8-character text string.

[0297] Of the 8-character text string, the four upper characters indicate the location information generated by the location information generating unit 325, and the four lower characters indicate the position measurement information measured by the position measurement means. Further, in the event that measurement by the position measurement means is impossible, or in the event that the mobile station 100 is not provided with position measuring means, the 4-character text string "0000" indicates that position measurement information does not exist.

[0298] For example, regarding location information of a mobile station 100 not provided with position measuring means, in the event that the location information generated by the gateway server 320 is "1-Chome, Shibuyaku, Tokyo" (which is represented by the text string "C49D"), the 8-character text string is "C49D0000".

[0299] On the other hand, regarding location information of a mobile station 100 provided with position measuring means, in the event that the location information generated by the gateway server 320 is "1-Chome, Shibuyaku, Tokyo", and the position measurement information generated by the position measuring means is "1-1 1-Chome, Shibuyaku, Tokyo", the text string "7236" representing "1-1" is inserted in to the lower four characters, so the 8-character text string is "C49D7236".

[0300] Generally, using position measuring means such as GPS allows positions to be measured in a more detailed manner than the location information generated by the mobile communication network. Accordingly, in the event the above-described 8-character text string configuration is employed, the IP servers 500A, 500B ··· would only refer to the upper four characters of the 8-character text string in the event that only general position related information is to be provided to the user, and would make reference to the lower four characters in the event of providing detailed position related information, which is to say that the location information reference operation can be changed according to the level of position related information to be provided to the mobile stations 100.

[0301] Further, in the event that the lower four characters are "0000" (i.e., there is no position measurement information), and in the event that the IP servers 500A, 500B ··· determine that more detailed location information is necessary, the gateway server 320 may be requested to transmit input screen data to the mobile station 100 for the user to input detailed location information.

[0302] Thus, the IP servers 500A, 500B ··· would change the location information referring operation as appropriate, so the gateway server 320 does not need to perform the determination processing and the like regarding whether to transmit general location information or detailed location information to the IP servers 500A, 500B ···.

(5) Operation of the gateway server 320 and IP servers 500A, 500B ··· in the event of not disclosing location information

[0303] In the above-described first specific example, in the event that the location information of the mobile station 100 is not disclosed to the IP servers 500A, 500B ···, the gateway server 320 transmits a location information transmission impossible notification to the mobile station 100, but the invention is not restricted to this, and the transmission impossible notification may be transmitted to the IP servers 500A, 500B ··· to be accessed.

[0304] Then, upon receiving the transmission impossible notification, the IP servers 500A, 500B ··· transmit screen data to the effect that location information cannot be obtained (hereafter referred to as error screen data) to the mobile station 100, and the mobile station 100 displays the error screen.

[0305] Then, the above-described transmission impossible notification may be transmitted from the gateway server 320 to the both the mobile station 100 and the IP servers 500A, 500B ···.

[0306] Further, various arrangements may be conceived for the arrangement of the above transmission impossible notification, as described below. For example, in the above first specific example, an arrangement may be made wherein, even in the event that the location information may not be transmitted, the gateway server 320 transmits a request signal to the IP servers 500A, 500B ··· containing the location information substitution data string "NULLAREA" within the hyperlink text string of the IP servers 500A, 500B ···. Then, upon detecting the location information substitution data string "NULLAREA" within the request signal, the IP servers 500A, 500B ··· interpret the location information substitution data string to mean that location information may not be transmitted.

[0307] Then, in the event that location information may not be transmitted, the gateway server 320 may replace the location information substitution data string "NULLAREA" with a predetermined keyword indicating that transmission is impossible (hereafter referred to as error keyword) and transmit it to the IP servers 500A, 500B ···.

[0308] Further, an arrangement may be made wherein link information to a site which provides error screen data displayed on the mobile station 100 may be inserted within this error keyword, so that the error screen data is transmitted from the site to the mobile station 100.

[0309] Such arrangements may be similarly applied to the second specific example, as well.

(6) Types of information serving as location information disclosure standards

[0310] With the above first and second specific examples, the gateway server 320 performs a determination of whether location information may or may not be disclosed to the IP servers 500A, 500B ···, by making reference to the IP information database 327. This IP information database 327 had been set with location information disclosure flags and user consent flags, but information serving as disclosure standards is not necessarily limited to this flag information alone; rather, various arrangements may be conceived, as described below.

[0311] For example, IP servers 500A, 500B ··· to which location information for each mobile station 100 is to be disclosed may be set.

[0312] Fig. 28 is a data format diagram of a database provided in the gateway server 320 in such a case.

[0313] As shown in the figure, this database (disclosure information storing unit) has an "IP server name" registered for each "mobile station ID" to which location information is to be disclosed.

[0314] For example, the location information of the mobile station ID "MS0901111111" shown in the figure permits disclosure to "IP servers 500A, 500D, 500H ···". The user of the mobile station 100 notifies the IP server name to which disclosure is to be performed to the communications company operating the mobile communication network beforehand, and the communications company registers in this database the IP server names to be disclosed based on this notification. The gateway server 320 makes reference to this database and determines whether or not location information can be disclosed.

[0315] That is to say, disclosure standards for each IP server 500A, 500B ··· are set for each mobile station 100, unlike the arrangement in the above first and second specific examples wherein a uniform location information disclosure standard is set for all of the IP servers 500A, 500B ···.

[0316] Also, specific mobile stations 100 may be set such that the location information thereof is not disclosed at all.

[0317] Fig. 29 is a data format diagram of a database provided in the gateway server 320 in such a case.

[0318] As shown in the figure, the mobile station ID of a mobile station 100 which does not disclose location information is registered in this database (terminal information storing unit). In the event that the user does not want to disclose his/her own location information to any server at all, notification to this effect is made to the communications company operating the mobile communication network beforehand, and, based on this notification, the communications company registers this mobile station ID to this database. The gateway server 320 makes reference to this database and determines whether or not location information can be disclosed.

[0319] Providing various disclosure standards as described above allows various user needs to be met, such as notifying only a specific IP server 500 of location information, or not wanting location information to be known at all.

(7) Types of information serving as location information disclosure standards

[0320] While the first and second specific examples invdved using mobile stations such as cellular telephones and PHSs and the like, the invention is not restricted to this, and mobile communication terminals such asPDAs (Personal digital Assistants) may be used, as long as they are provided with functions for performing wireless communication of data with the base station 210 of the mobile communication network.

(8) Description language for data

[0321] With the first and second specific examples, data was exchanged between the gateway server 320 and IP servers 500A, 500B ···, and the mobile stations 100 in the HTML format, but the invention is not restricted to this, and other description languages such, for example, as XML (Extensible Markup Language) may be used.

Claims

1. A location information notifying method for notifying a predetermined computer of location information of a mobile communication terminal obtained on a mobile communication network which contains mobile communication terminals capable of wireless communication, said computer to which said location information is notified being a plurality of computers including a first computer capable of handling said location information in a first representational format and a second computer capable of handling said location information in a second representational format, said location information notifying method comprising:

   a location information generating step of detecting the position of said mobile communication terminal and generating the location information thereof;
   a location information converting step wherein, in the event of notifying said location information to said first computer, said location information is converted from an original representational format into said first representational format, and in the event of making notification of location information to said second computer, said location information is converted from said original representational format into said second representational format; and
   a location information notifying step of notifying said computers of said location information with the representational format thereof converted.

2. A location information notifying method according to Claim 1, wherein said mobile communication network comprises a plurality of mobile communication networks including a first mobile communication network and a second mobile communication network with differing representational formats for location information generated thereby;

   wherein said location information generating step generates, on one hand, the location information of a mobile communication terminal belonging to said first mobile communication network in a third representational format, and, on the other hand generates the location information of a mobile communication terminal belonging to said second mobile communication network in a fourth representational format;
   and wherein, in the event of notifying said loca-

tion information of said mobile communication terminal belonging to said first mobile communication network to said computers, said location information is converted in said location information converting step from said third representational format into a representational format which said computers are capable of handling, and on the other hand, in the event of notifying said location information of said mobile communication terminal belonging to said second mobile communication network to said computers, said location information is converted in said location information converting step converts from said fourth representational format into a representational format which said computers are capable of handling.

3. A location information notifying method according to Claim 1, wherein said first and said second representational formats are one of:

a format representing latitude and longitude information; and
a format representing an administrative district.

4. A location information notifying method according to Claim 2, wherein said third or said fourth representational formats are one of:

a format representing identification information provided to base stations of said mobile communication network;
a format representing identification information provided to wireless communication zones of a predetermined number of said base stations;
a format representing identification information provided to partial areas of wireless zones of said base stations; and
a format representing latitude and longitude.

5. A location information notifying method for notifying a predetermined computer of location information of a mobile communication terminal obtained on a mobile communication network which contains mobile communication terminals capable of wireless communication, said location information notifying method comprising:

a location information generating step of detecting the position of said mobile communication terminal and generating location information with a precision needed by said computer; and
a location information notifying step of notifying said computer of said generated location information.

6. A location information notifying method according toClaim 5, wherein said location information with a precision needed by said computer includes one of:

location information representing latitude and longitude information; and
location information representing an administrative district.

7. A location information notifying method for notifying a predetermined computer of location information of a mobile communication terminal obtained on a mobile communication network which contains mobile communication terminals capable of wireless communication, said location information notifying method comprising:

a location information generating step of detecting the position of said mobile communication terminal and generating location information; and
a location information notifying step of notifying said computer of said generated location information by adding said generated location information to data transmitted from said mobile communication terminal to said computer.

8. A location information notifying method according to Claim 7, wherein said location information notifying step includes:

a step of notifying to said mobile communication terminal the adding method of said location information from said computer, and notifying said generated location information after said notified adding method.

9. A location information notifying method according to Claim 7, further comprising:

a step of detecting a predetermined data sequence within data transmitted from said mobile communication terminal to said computer; and
a step of substituting said predetermined data sequence with said location information and transmitting to said computer.

10. A location information notifying method according to Claim 9, wherein said predetermined data sequence is contained within data transmitted from said computer to said mobile communication terminal;

and wherein said location information notifying step detects said data sequence in the process of said mobile communication terminal returning data transmitted from said computer, and substitutes this with said location information.

11. A location information notifying method for notifying a predetermined computer of location information of a mobile communication terminal obtained on a mobile communication network which contains mobile communication terminals capable of wireless communication, said location information notifying method comprising:

a step of receiving from said computer a request signal requesting location information of said mobile communication terminal;
a location information generating step of detecting the position of said mobile communication terminal in response to said request signal and generating location information; and
a location information notifying step of notifying said generated location information to said computer.

12. A location information notifying method according to Claim 11, further comprising:

an identification information adding step of adding identification information of said mobile communication terminal to said data transmitted from said mobile communication terminal to said computer, and transmitting to said computer;
wherein said location information generating step determines the mobile communication terminal for which said location information to be generated and generates said location information, based on said identification information contained in said request signal from said computer.

13. A location information notifying method according to Claim 12, wherein said identification information adding step comprises:

a step of detecting predetermined data sequence within data transmitted from said mobile communication terminal to said computer; and
a step for substituting said predetermined data sequence with said identification information.

14. A location information notifying method according to Claim 13, wherein said predetermined data sequence is contained within the data transmitted from said computer to said mobile communication terminal;

and wherein said identification information adding step detects said data sequence in the process of said mobile communication terminal returning the data transmitted from said computer, and substituting this with said identification information.

15. A location information notifying method according to either Claim 7 or 11, further comprising:

a notification permission/non-permission determining step of determining whether or not said location information may be notified to said computer;
wherein said location information notifying step notifies said location information based on the determination result in said notification permission/non-permission determining step.

16. A location information notifying method according to Claim 15, wherein disclosure information regarding whether or not a computer is to have said location information disclosed thereto is stored in predetermined storing means beforehand;

and wherein said notification permission/non-permission determining step makes said determination by referring to said disclosure information stored by said storing means with regard to said computer which is to have said location information disclosed thereto.

17. A location information notifying method according to Claim 16, wherein said disclosure information is stored in said predetermined storing means beforehand for each mobile communication terminal;

and wherein said notification permission/non-permission determining step makes said determination by referring to said disclosure information stored by said storing means with regard to said computer which is to have said location information disclosed thereto.

18. A location information notifying method according to Claim 15, wherein said notification permission/non-permission determining step comprises:

a step of making an inquiry to said mobile communication terminal regarding whether or not said location information may be notified to said computer; and
a step of making said determination based on response information from said mobile communication terminal to said inquiry.

19. A location information notifying method according to Claim 15, wherein terminal information, relating to whether or not said location information may be disclosed outside of said mobile communication network with regard to a mobile communication terminal, is stored in predetermined storage means beforehand;

and wherein said notification permission/non-permission determining step makes said determination by referring to terminal information stored in said storage means with regard to said mobile communication terminal relating to said location information of which notification is to be made.

20. A location information notifying method according to Claim 15, further comprising an error signal transmitting step of, in the event that it has been determined that transmission is not permissible in said notification permission/non-permission determination step, transmitting a transmission error signal to said mobile communication terminal or said computer to the effect that said location information may not be notified.

21. A location information notifying method according to either Claim 7 or 11, further comprising:

an input screen transmitting step of transmitting input screen data for inputting to said mobile communication terminal specified location information which the user of said mobile communication terminal can specify; and
a specified location information receiving step of receiving from said mobile communication terminal said specified location information input by said user;
wherein said location information notifying step notifies said computer of said specified location information received in said specified location information receiving step, along with said location information generated in said location information generating step.

22. A location information notifying method according to either Claim 7 or 11, wherein said mobile communication terminal comprises position measuring means for measuring its own position;

wherein said location information notifying method comprises a measured location information receiving step of receiving from said mobile communication terminal measured location information relating to the position of said mobile communication terminal measured by said position measuring means;
and wherein said location information notifying step notifies said computer of said measured location information received in said measured location information receiving step, along with said location information generated in said location information generating step.

23. A location information notifying method according to any of the Claims 1, 5, 7, or 11, wherein said computer is an information providing server for providing said mobile communication terminal with position-related information relating to the position of said mobile communication terminal.

24. A location information notifying method according to any one of the Claims 1, 5, 7, and 11, wherein said mobile communication terminal is a cellular phone which performs wireless telephone communication.

25. A location information notifying apparatus for notifying a predetermined computer of location information of a mobile communication terminal obtained on a mobile communication network which contains mobile communication terminals capable of wireless communication, said computer to which said location information is notified being a plurality of computers including a first computer capable of handling said location information in a first representational format and a second computer capable of handling said location information in a second representational format, said location information notifying apparatus comprising:

a first location information generating unit for detecting the position of said mobile communication terminal and generating the location information thereof;
a location information representational format converting unit which, in the event of notifying said location information to said first computer, converts said location information from said representational format which is generated into said first representational format, and in the event of notifying said location information to said second computer, said location information is converted from said generated representational format into said second representational format; and
a first location information notifying unit for notifying said computer of said location information with the representational format thereof converted.

26. A location information notifying apparatus according to Claim 25, wherein said mobile communication network comprises a plurality of mobile communication networks including a first mobile communication network and a second mobile communication network with differing representational formats for location information generated thereby;

wherein said first location information generating unit generates, on one hand, the location information of a mobile communication terminal belonging to said first mobile communication network in a third representational format, and, on the other hand, generates the location information of a mobile communication terminal belonging to said second mobile communication network in a fourth representational format;
and wherein, in the event of notifying said location information of said mobile communication

terminal belonging to said first mobile communication network to said computer, said location information representation converting unit converts said location information from said third representational format into a representational format which said computer is capable of handling, and on the other hand, in the event of notifying said location information of said mobile communication terminal belonging to said second mobile communication network to said computer, said location information representation converting unit converts said location information from said fourth representational format into a representational format which said computer is capable of handling.

27. A location information notifying apparatus according to Claim 25, wherein said first and said second representational formats are one of:

a format representing latitude and longitude information; and
a format representing an administrative district.

28. A location information notifying apparatus according to Claim 26, wherein said third and said fourth representational formats are one of:

a format representing identification information provided to lase stations of said mobile communication network;
a format representing identification information provided to wireless communication zones of a predetermined number of said base stations;
a format representing identification information provided to patial areas of wireless zones of said base stations; and
a format representing latitude and longitude.

29. A location information notifying apparatus for notifying a predetermined computer of location information of a mobile communication terminal obtained on a mobile communication network which contains mobile communication terminals capable of wireless communication, said location information notifying apparatus comprising:

a second location information generating unit for detecting the position of said mobile communication terminal and generating location information with a precision needed by said computer; and
a second position notifying unit for notifying said computer of said generated location information.

30. A location information notifying apparatus according to Claim 29, wherein said location information with a precision needed by said computer includes one of:

location information representing latitude and longitude information; and
location information representing administrative distric.

31. A location information notifying apparatus for notifying a predetermined computer of location information of a mobile communication terminal obtained on a mobile communication network which contains mobile communication terminals capable of wireless communication, said location information notifying apparatus comprising:

a third location information generating unit for detecting the position of said mobile communication terminal and generating location information; and
a third location information notifying unit for transmitting said computer of said generated location information by adding said generated location information to data transmitted from said mobile communication terminal to said computer.

32. A location information notifying apparaus according to Claim 31, wherein said third location information notifying unit comprises:

a receiving unit for receiving notification indicating the adding method of said generated location information added to said data from said computer; and
a transmitting unit for adding said generated location information to said data by said method and transmitting.

33. A location information notifying apparatus according to Claim 31, wherein said third location information notifying unit comprising:

a detecting unit for detecting a predetermined data sequence within data transmitted from said mobile communication terminal to said computer; and
a substituting unit for substituting said predetermined data sequence with said location information and transmitting this to said computer.

34. A location information notifying apparatus according to Claim 33, wherein said predetermined data sequence is contained within data transmitted from said computer to said mobile communication terminal;

and wherein said third location information notifying unit detects said data sequence in the process of said mobile communication terminal returning the data transmitted from said computer, and substitutes this with said location information.

35. A location information notifying apparatus according to Claim 31, further comprising:

a notification permission/non-permission determining unit for determining whether or not said location information may be notified to said computer;
wherein said third location information notifyingunit notifies said location information based on the determination result from said notification permission/non-permission determining unit.

36. A location information notifying apparatus according to Claim 35, comprising a disclosure information storing unit for storing therein disclosure information regarding whether or not said computer is to have said location information disclosed thereto;
wherein said notification permission/non-permission determining unit makes said determination by referring to said disclosure information stored by said disclosure information storing unit with regard to said computer which is to have said location information disclosed thereto.

37. A location information notifying apparatus according to Claim 36, wherein said disclosure information storing unit stores said disclosure information for each mobile communication terminal;
and wherein said notification permission/non-permission determining unit makes said determination by referring to said disclosure information stored by said disclosure information storing unit with regard to said computer which is to have said location information disclosed thereto.

38. A location information notifying apparatus according to Claim 35, wherein said notification permission/non-permission determining unit comprises:

an inquiry unit for making an inquiry to said mobile communication terminal regarding whether or not said location information may be notified to said computer; and
a determining unit for making said determination basedon response information from said mobile communication terminal to said inquiry.

39. A location information notifying apparatus according to Claim 35, comprising a terminal information storing unit for storing terminal information relating to whether or not said location information may be disclosed outside of said mobile communication network with regard to a mobile communication terminal;
wherein said notification permission/non-permission determining unit makes said determination by referring to said terminal information stored in terminal information storing unit, regarding said mobile communication terminal relating to said location information of which notification is to be made.

40. A location information notifying apparatus according to Claim 35, comprising an error signal transmitting unit for, in the event that it has been determined that transmission is not permissible by said notification permission/non-permission determining unit transmitting a transmission error signal to said mobile communication terminal or said computer to the effect that said location information may not be notified.

41. A location information notifying apparatus according to Claim 31, comprising:

an input screen transmitting unit for transmitting input screen data for inputting to said mobile communication terminal specified location information which the user of said mobile communication terminal can specify; and
a specified location information receiving unit for receiving from said mobile communication terminal said specified location information input by said user;
wherein said third location information notifying unit notifies said computer of said specified location information received by said specified location information receiving unit, along with said location information generated by said third location information generating unit.

42. A location information notifying apparatus according to Claim 31, wherein said mobile communication terminal comprises a position measuring unit for measuring its own position;

wherein said location information notifying apparatus comprises a measured location information receiving unit for receiving from said mobile communication terminal measured location information relating to the position of said mobile communication terminal measured by said position measuring unit;
and wherein said location information notifying unit notifies said computer of said measured location information received by said measured location information receiving unit, along with said location information generated by said location information generating unit.

43. A location information notifying apparatus for notifying a predetermined computer of location information of a mobile communication terminal obtained on a mobile communication network which contains mobile communication terminals capable of wireless communication, said location information notifying apparatus comprising:

a receiving unit for receiving a request signal from said computer requesting location information of said mobile communication terminal;
a fourth location information generating unit for detecting the position of said mobile communication terminal in response to said request signal and generating location information; and
a fourth location information notifying unitfor notifying said generated location information to said computer.

44. A location information notifying apparatus according to Claim 43, further comprising:

an identification information adding unit for adding identification information of said mobile communication terminal to said data transmitted from said mobile communication terminal to said computer, and transmitting this to said computer;
wherein said fourth location information generating unit determines the mobile communication terminal for which location information is to be generated and generates said location information, based on said identification information contained in said request signal from said computer.

45. A location information notifying apparatus according to Claim 44, wherein said identification information adding unit comprises:

a detecting unit for detecting predetermined data sequences within data transmitted from said mobile communication terminal to said computer; and
a substituting unit for substituting said predetemined data sequence with said identification information.

46. A location information notifying apparatus according to Claim 45, wherein said predetermined data sequence is contained within the data transmitted from said computer to said mobile communication terminal;

and wherein said identification information adding unit detects said data sequence in the process of said mobile communication terminal returning data transmitted from said computer, and substitutes this with said information.

47. A location information notifying apparatus according to Claim 43, further comprising:

a notification permission/non-permission determining unit for determining whether or not said location information may be notified to said computer;
wherein said fourth location information notifying unit transmits said location information based on the determination result from said notification permission/non-permission determining unit.

48. A location information notifying apparatus according to Claim 47, comprising a disclosure information storing unit for storing therein disclosure information regarding whether or not a computer is to have said location information disclosed thereto;

wherein said notification permission/non-permission determining unit makes said determination by referring to said disclosure information stored by said disclosure information storing unit with regard to said computer which is to have said location information disclosed thereto.

49. A location information notifying apparatus according to Clam 48, wherein said disclosure information storing unit stores said disclosure information for each mobile communication terminal;

and wherein said notification permission/non-permission determining unit makes said determination by referring to said disclosure information stored by said disclosure information storing unit with regard to said computer which is to have said location information disclosed thereto.

50. A location information notifying apparatus according to Claim 47, wherein said notification permission/non-permission determining unit comprises:

an inquiry unit for making inquiry to said mobile communication terminal regarding whether or not said location information may be notified to said computer; and
a determining unit for making said determination based on response information from said mobile communication terminal to said inquiry.

51. A location information notifying apparatus according to Claim 47, comprising a terminal information storing unit for storing terminal information relating to whether or not said location information may be disclosed outside of said mobile communication network with regard to a mobile communication terminal;

wherein said notification permission/non-permission determining unit makes said determination by referring to terminal information stored in said terminal information storing unit, regarding said mobile communication terminal relating to said location information of which notification is to be made.

52. A location information notifying apparatus according to Claim 47, comprising an error signal transmitting unit for transmitting, in the event that it has been determined that transmission us not permissible has been made by said permission/non-permission determining unit, a transmission error signal to said mobile communication terminal or said computer to the effect that said location information may not be notified.

53. A location information notifying apparatus according to Claim 43, comprising:

an input screen transmitting unit for transmittingto said mobile communication terminal input screen data for inputting specified location information which the user of said mobile communication terminal can specify; and
a specified location information receiving unit for receiving from said mobile communication terminal said specified location information input by said user;
wherein said fourth location information notifying unit notifies said computer of said specified location information received by said specified location information receiving unit, along with said location information generated by said fourth location information generating unit.

54. A location information notifying apparatus according to Claim 43, wherein said mobile communication terminal comprises a position measuring unit for measuring its own position;

wherein said location information notifying apparatus comprises a measured location information receiving unit for receiving from said mobile communication terminal measured location information relating to the position of said mobile communication terminal measured by said position measuring unit;
and wherein said fourth location information notifying unit notifies said computer of said measured location information received by said measured location information receiving unit, along with said location information generated by said fourth location information generating unit.

55. A location information notifying apparatus according to any one of the Claims 25, 29, 31, and 43, wherein said computer is an information providing server for providing said mobile communication terminal with position-related information relating to the position of said mobile communication terminal.

56. A location information notifying apparatus according to any one of the Claims 25, 29, 31, and 43, wherein said mobile communication terminal is a cellular phone which performs wireless telephone communication.

FIG. 1

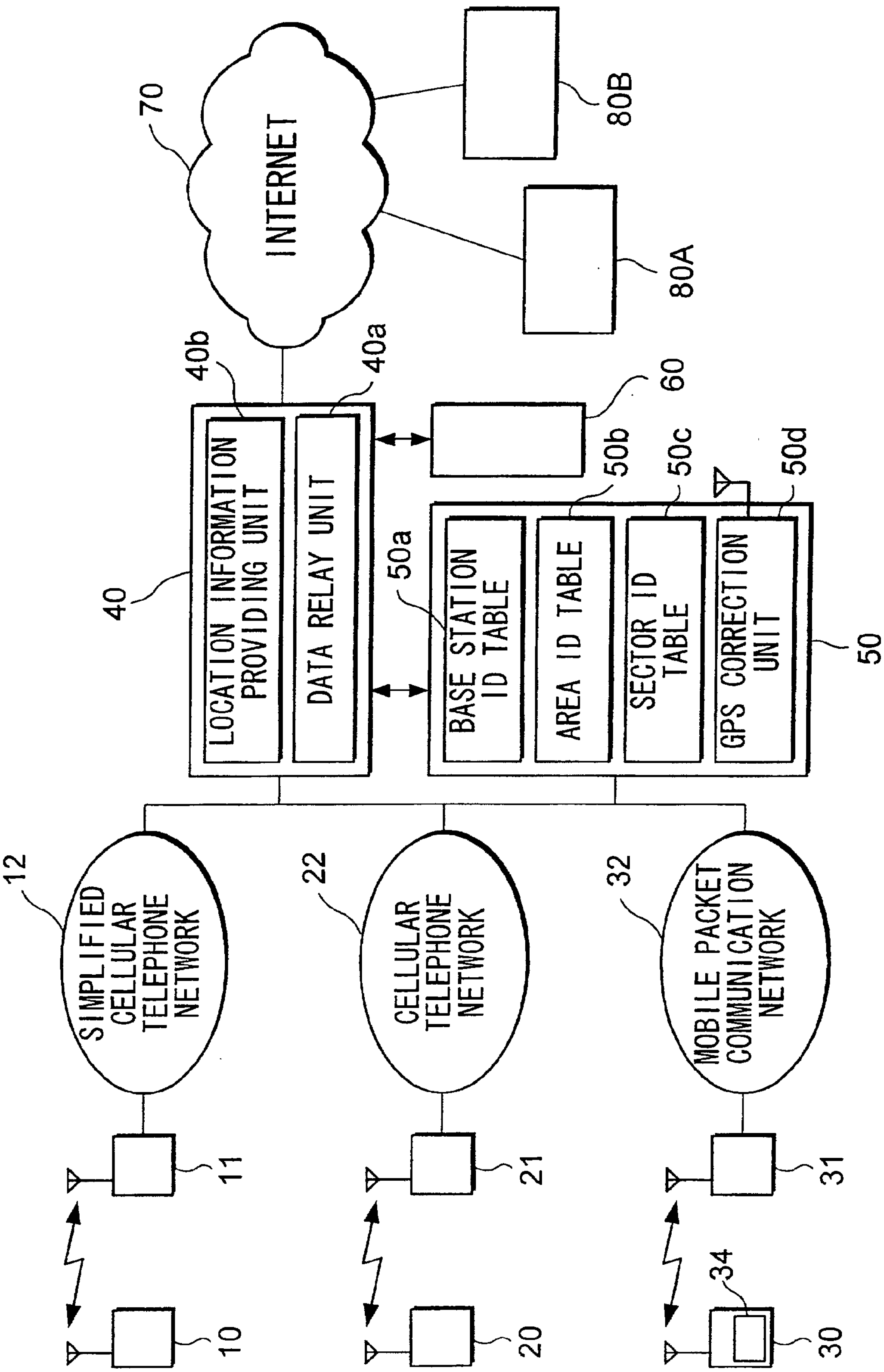

70
INTERNET
80B
80A
40b
40a
40
LOCATION INFORMATION PROVIDING UNIT
DATA RELAY UNIT
60
50a
50b
50c
50d
BASE STATION ID TABLE
AREA ID TABLE
SECTOR ID TABLE
GPS CORRECTION UNIT
50
12
SIMPLIFIED CELLULAR TELEPHONE NETWORK
22
CELLULAR TELEPHONE NETWORK
32
MOBILE PACKET COMMUNICATION NETWORK
11
21
31
10
20
34
30

FIG. 2

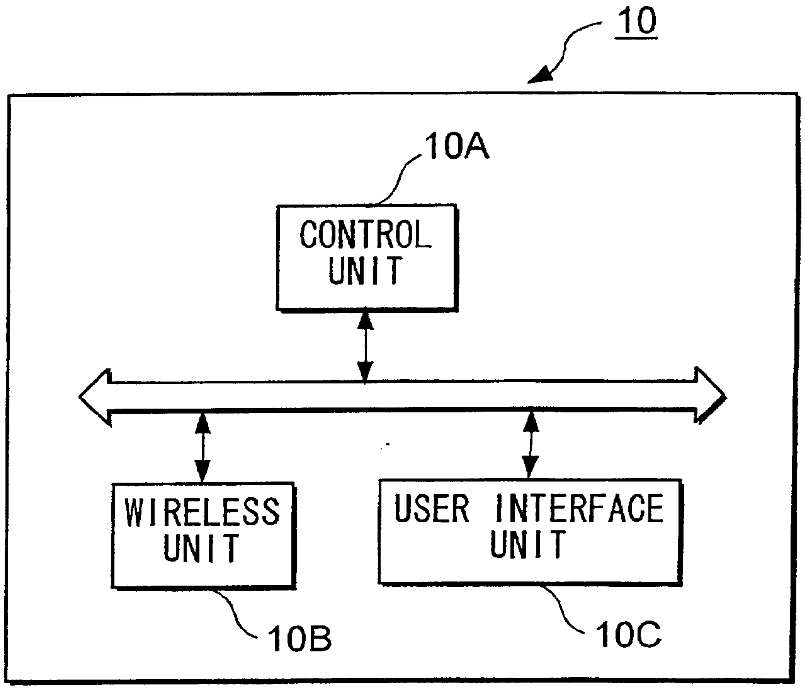

10
10A
CONTROL UNIT
WIRELESS UNIT
USER INTERFACE UNIT
10B
10C

FIG. 3

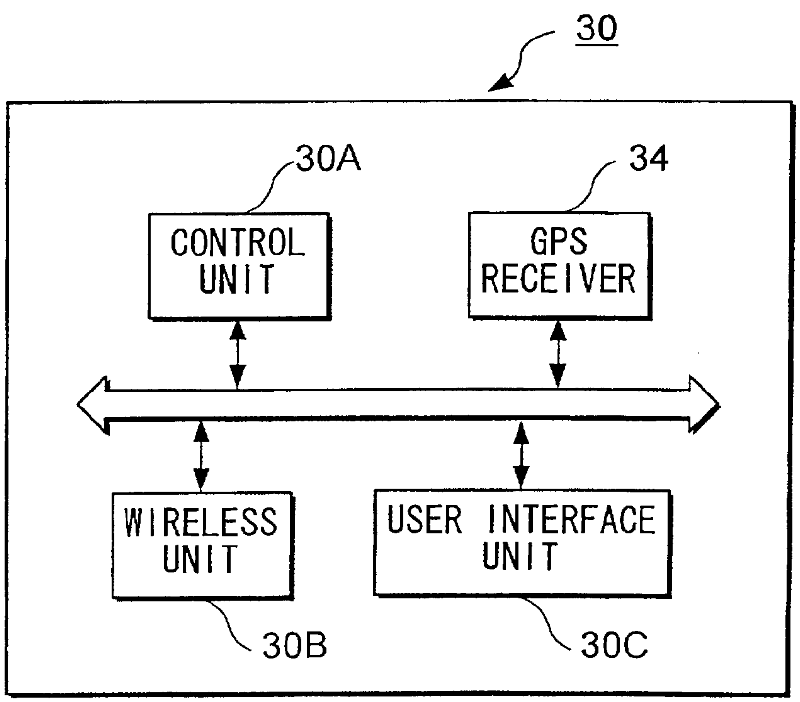

30
30A
34
CONTROL UNIT
GPS RECEIVER
WIRELESS UNIT
USER INTERFACE UNIT
30B
30C

FIG. 4

BASE STATION ID	IP SERVER 80A	IP SERVER 80B	.....
BS0011	X , Y	1-1-1 TORANOMON, MINATO-KU	.....
⋮	⋮	⋮	

FIG. 5

AREA ID	IP SERVER 80A	IP SERVER 80B	.....
AREA001	X , Y	1-1-1 TORANOMON, MINATO-KU	.....
⋮	⋮	⋮	

FIG. 6

SECTOR ID	IP SERVER 80A	IP SERVER 80B	.....
SEC001	X , Y	1-1-1 TORANOMON, MINATO-KU	.....
⋮	⋮	⋮	

FIG. 7

LATITUDE AND LONGITUDE RECEIVERS
IP SERVER 80A
IP SERVER 80F
IP SERVER 80K
⋮

FIG. 8

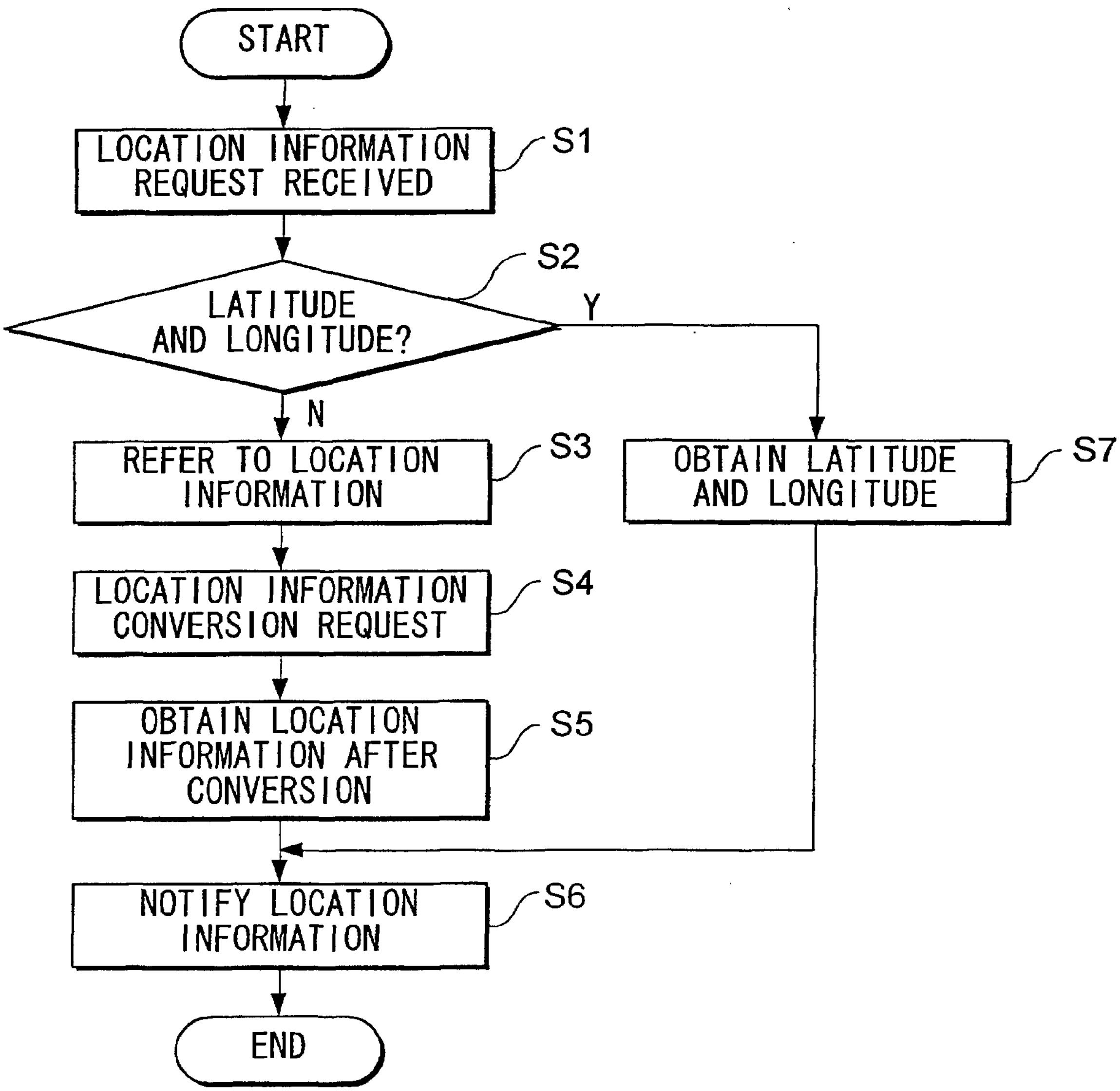

START
LOCATION INFORMATION REQUEST RECEIVED
S1
LATITUDE AND LONGITUDE?
S2
Y
N
REFER TO LOCATION INFORMATION
S3
OBTAIN LATITUDE AND LONGITUDE
S7
LOCATION INFORMATION CONVERSION REQUEST
S4
OBTAIN LOCATION INFORMATION AFTER CONVERSION
S5
NOTIFY LOCATION INFORMATION
S6
END

FIG. 9

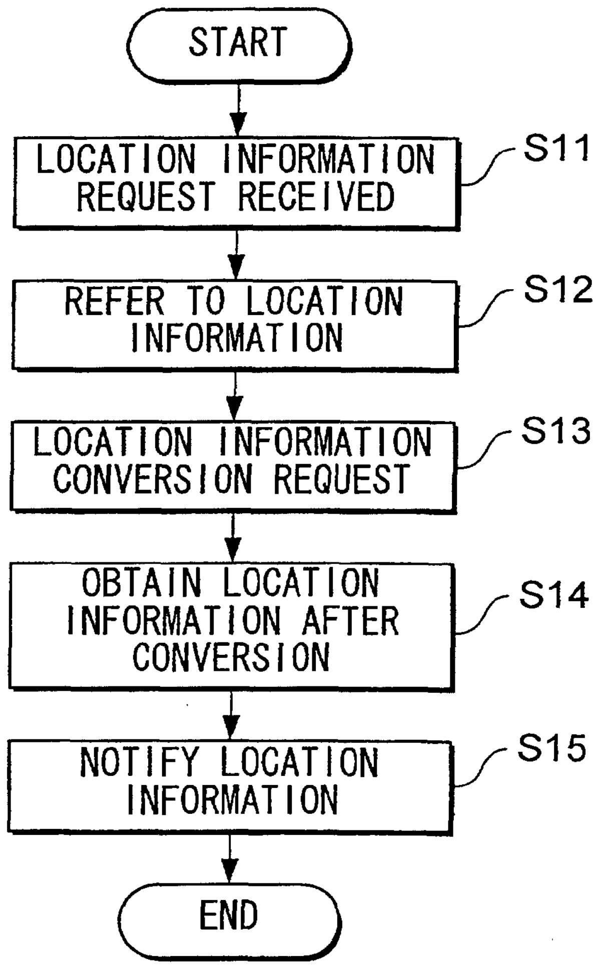

START
LOCATION INFORMATION REQUEST RECEIVED
S11
REFER TO LOCATION INFORMATION
S12
LOCATION INFORMATION CONVERSION REQUEST
S13
OBTAIN LOCATION INFORMATION AFTER CONVERSION
S14
NOTIFY LOCATION INFORMATION
S15
END

FIG. 10

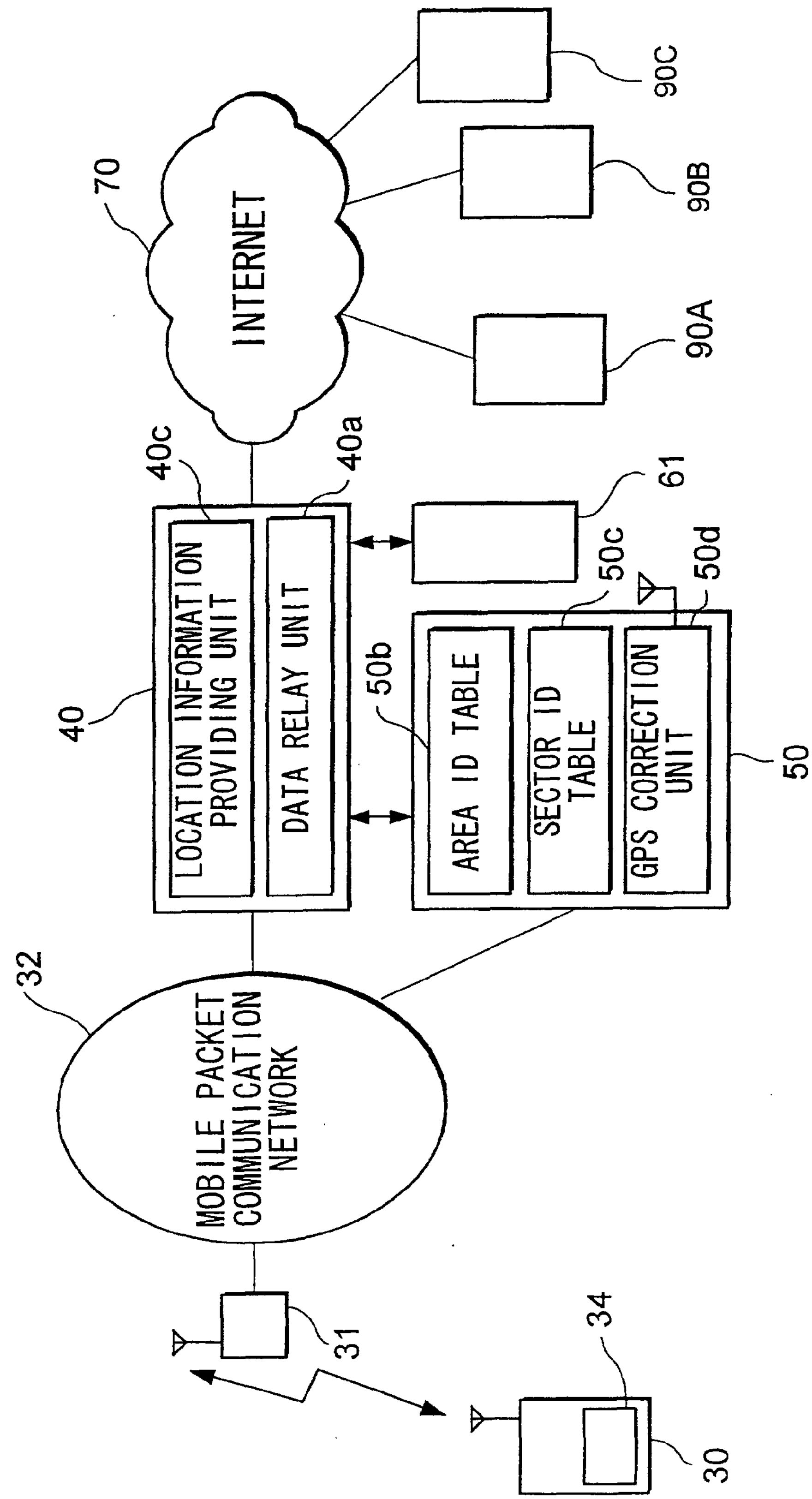

70
INTERNET
90A
90B
90C
40
40c
40a
LOCATION INFORMATION PROVIDING UNIT
DATA RELAY UNIT
61
50
50b
50c
50d
AREA ID TABLE
SECTOR ID TABLE
GPS CORRECTION UNIT
32
MOBILE PACKET COMMUNICATION NETWORK
31
34
30

FIG. 11

AREA ID	REGION NAME
AREA001	EAST TOKYO
⋮	⋮

FIG. 12

SECTOR ID	REGION NAME
SEC001	1-CHOME, TORANOMON, MINATO-KU, TOKYO
⋮	⋮

FIG. 13

IP SERVER NAME	LOCATION INFORMATION PRECISION
IP SERVER 90A	HIGH-PRECISION
IP SERVER 90B	MEDIUM-PRECISION
IP SERVER 90C	MEDIUM-PRECISION
⋮	⋮

FIG. 14

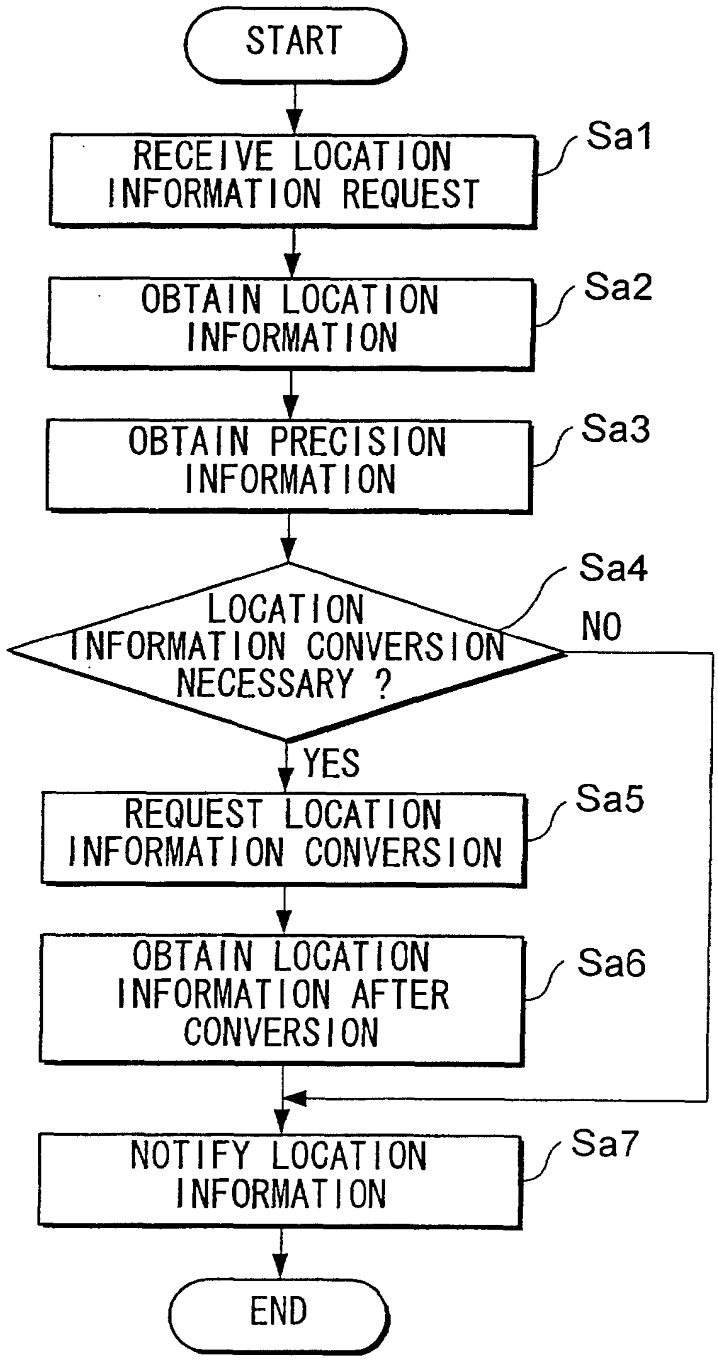

START
RECEIVE LOCATION INFORMATION REQUEST
Sa1
OBTAIN LOCATION INFORMATION
Sa2
OBTAIN PRECISION INFORMATION
Sa3
LOCATION INFORMATION CONVERSION NECESSARY ?
Sa4
NO
YES
REQUEST LOCATION INFORMATION CONVERSION
Sa5
OBTAIN LOCATION INFORMATION AFTER CONVERSION
Sa6
NOTIFY LOCATION INFORMATION
Sa7
END

FIG. 15

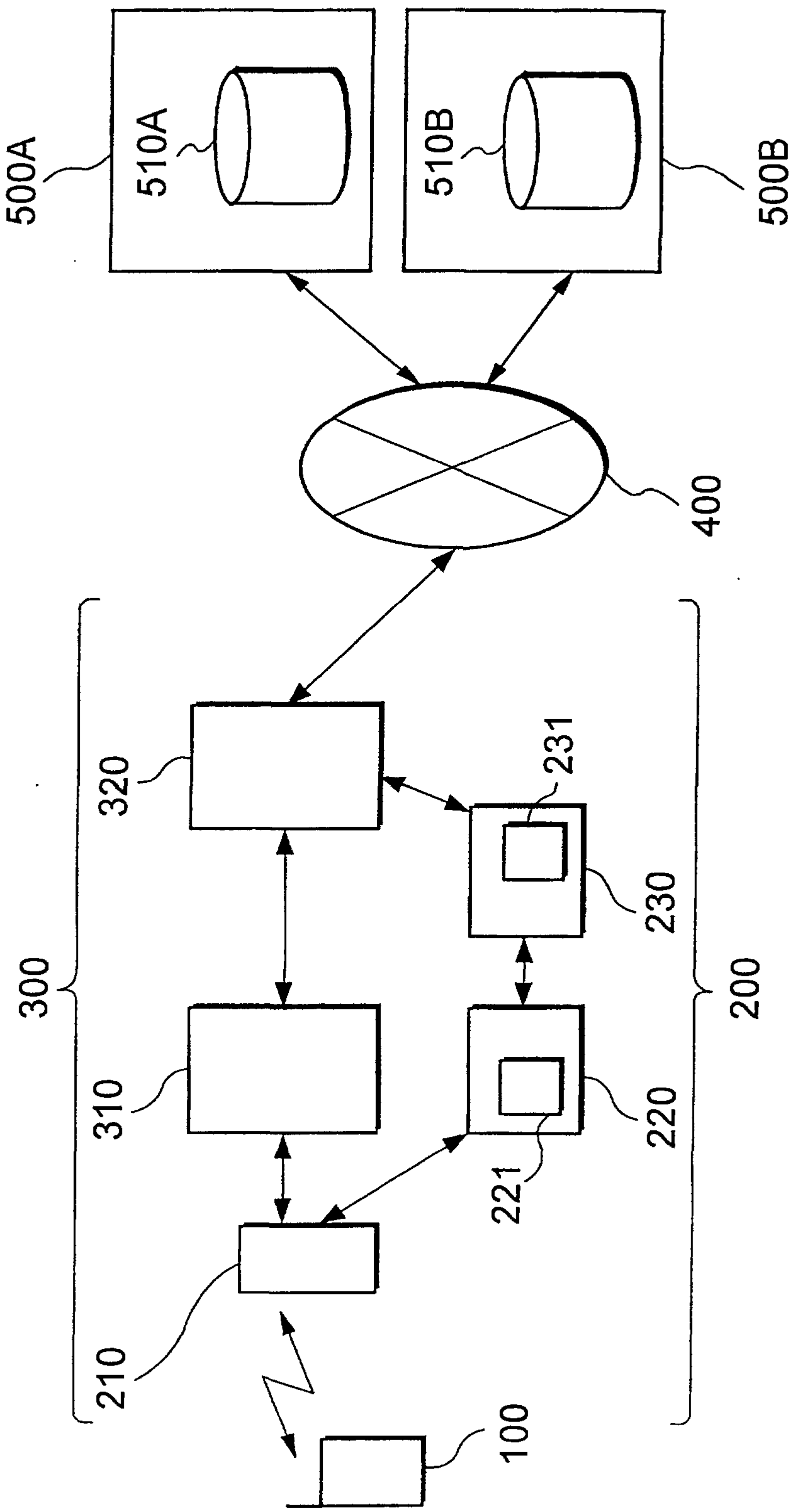


FIG. 16

```
<HTML>
<TITLE>SHOP INFORMATION IN YOUR VICINITY</TITLE>
<BODY>
ALLOW ME TO PROVIDE YOU WITH VARIOUS SHOP INFORMATION IN YOUR VICINITY.<BR>

<A HREF="http://xxx.co.jp/cgi-bin/restaurant.cgi?area=NULLAREA">RESTAURANT INFORMATION</A><BR>
<A HREF="http://xxx.co.jp/cgi-bin/movie.cgi?area=NULLAREA">MOVIE THEATER INFORMATION</A><BR>
<A HREF="http://xxx.co.jp/cgi-bin/artmuseum.cgi?area=NULLAREA">MUSEUM INFORMATION</A><BR>
<BR>
<A HREF="http://xxx.co.jp/cgi-bin/pushregist.cgi?uid=NULLID">REGISTRATION OF TRACKING INFORMATION
PROVISION</A><BR>
<A HREF="http://xxx.co.jp/about.html">ABOUT THIS SERVICE</A><BR>
</BODY>
</HTML>
```

FIG. 17

ALLOW ME TO PROVIDE YOU WITH VARIOUS SHOP INFORMATION IN YOUR VICINITY.

RESTAURANT INFORMATION

MOVIE THEATER INFORMATION

MUSEUM INFORMATION

REGISTRATION OF TRACKING INFORMATION PROVISION

ABOUT THIS SERVICE

FIG. 18

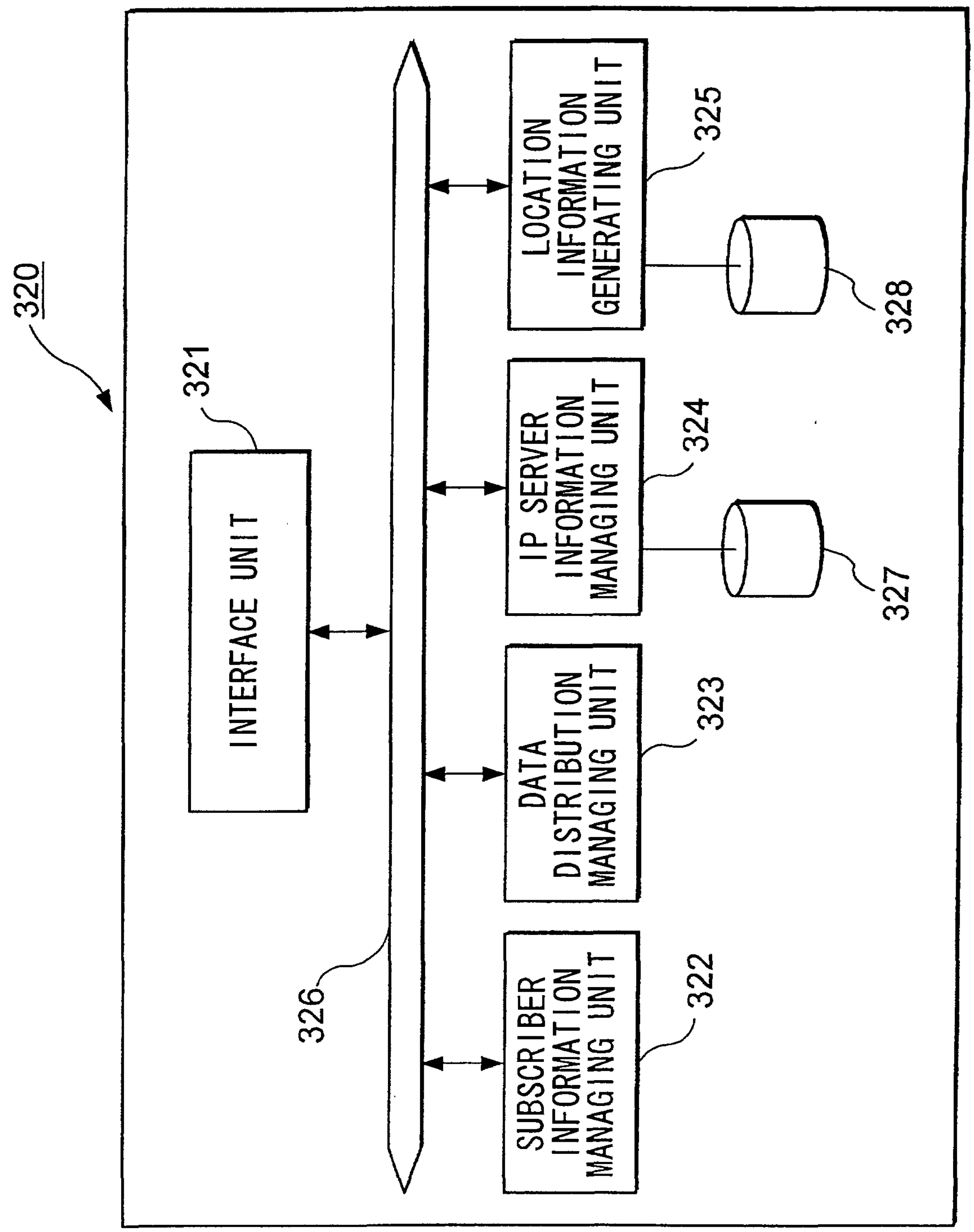

320
321
INTERFACE UNIT
326
SUBSCRIBER INFORMATION MANAGING UNIT
322
DATA DISTRIBUTION MANAGING UNIT
323
IP SERVER INFORMATION MANAGING UNIT
324
327
LOCATION INFORMATION GENERATING UNIT
325
328

FIG. 19

IP SERVER NAME	HOST NAME	SERVICE NAME	LOCATION INFORMATION DISCLOSURE FLAG	USER CONSENT FLAG
IP SERVER 500A	xxx.co.jp	POSITION RELATED INFORMATION PROVIDING SERVICE	ON	ON
IP SERVER 500B	yyy.co.jp	POSITION RELATED INFORMATION PROVIDING SERVICE	ON	OFF
IP SERVER 500C	zzz.co.jp	WIDE-AREA INFORMATION PROVIDING SERVICE	OFF	—
...	...	...	...	...
...	...	...	...	...
...	...	...	...	...
...	...	...	...	...
...	...	...	...	...

FIG. 20

BASE STATION ID	REGION CODE
BS001 ~ BS005	CODE001
......	......
......	......
......	......
......	......
......	......

FIG. 21

REGION CODE	REGION NAME	POSITION RELATED INFORMATION				
		BUILDING NAME	ADDRESS	TELEPHONE NUMBER	EVENT	OTHER INFORMATION
CODE001	1-CHOME, SHIBUYA-KU	RESTAURANT A	···	···	···	···
		···	···	···	···	···
		MOVIE THEATER B	···	···	···	···
		···	···	···	···	···
		MUSEUM C	···	···	···	···
		···	···	···	···	···
···	···	···	···	···	···	···
···	···	···	···	···	···	···
···	···	···	···	···	···	···
···	···	···	···	···	···	···
···	···	···	···	···	···	···
···	···	···	···	···	···	···

FIG. 22A

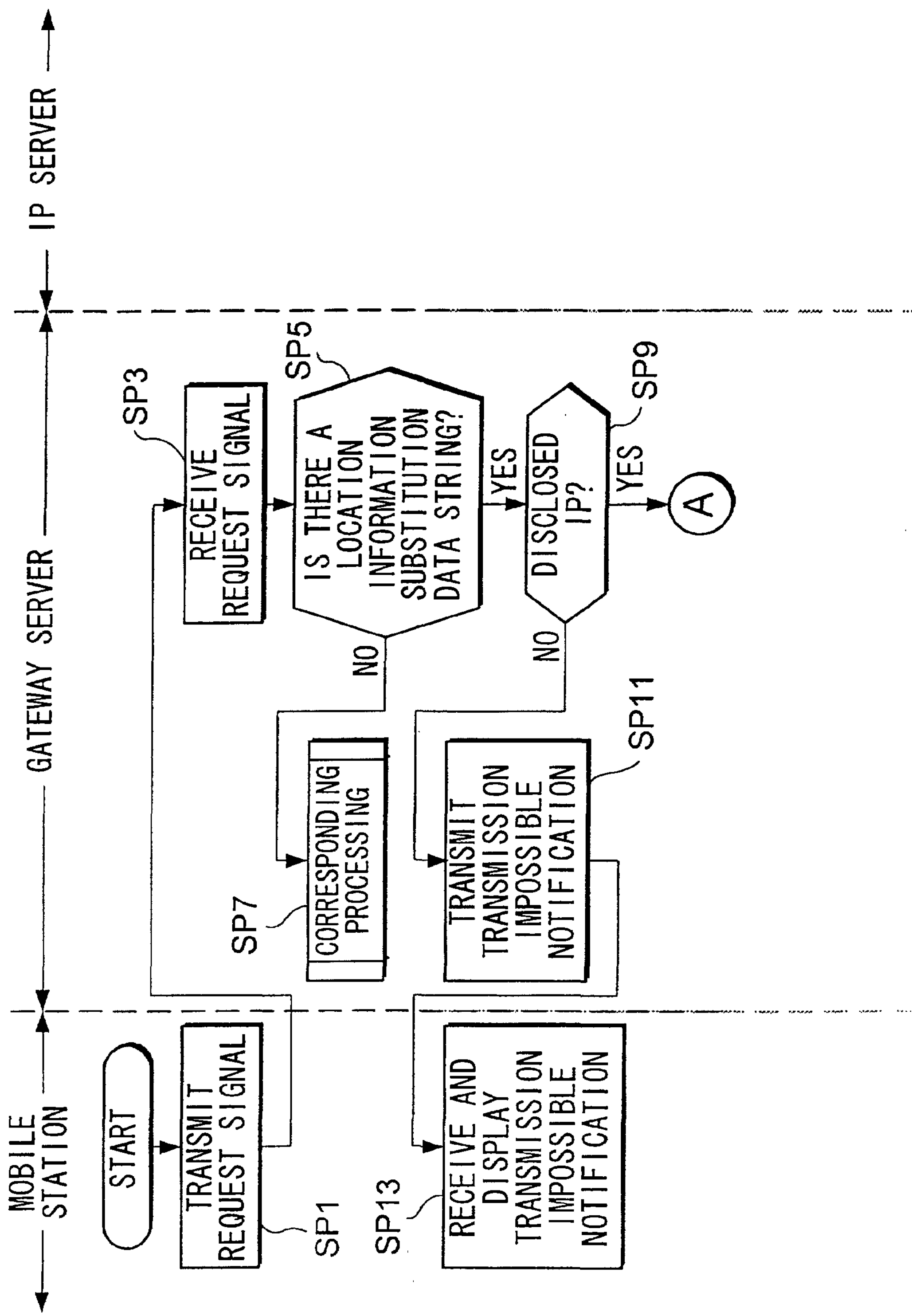

MOBILE STATION
GATEWAY SERVER
IP SERVER
START
TRANSMIT REQUEST SIGNAL
SP1
RECEIVE REQUEST SIGNAL
SP3
IS THERE A LOCATION INFORMATION SUBSTITUTION DATA STRING?
SP5
YES
NO
CORRESPONDING PROCESSING
SP7
DISCLOSED IP?
SP9
YES
NO
A
TRANSMIT TRANSMISSION IMPOSSIBLE NOTIFICATION
SP11
RECEIVE AND DISPLAY TRANSMISSION IMPOSSIBLE NOTIFICATION
SP13

FIG. 22B

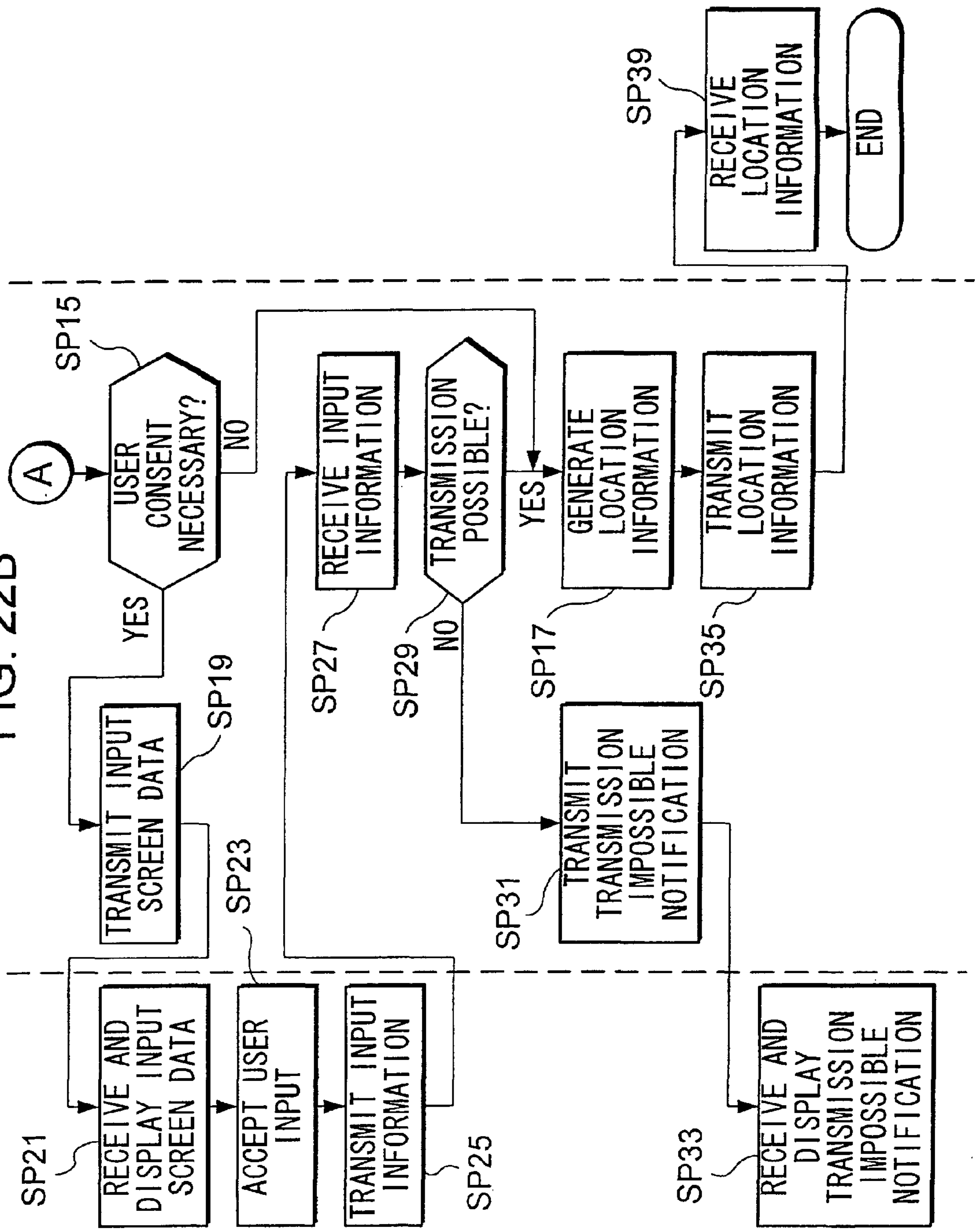

A
USER CONSENT NECESSARY?
SP15
YES
NO
TRANSMIT INPUT SCREEN DATA
SP19
RECEIVE AND DISPLAY INPUT SCREEN DATA
SP21
ACCEPT USER INPUT
SP23
TRANSMIT INPUT INFORMATION
SP25
RECEIVE INPUT INFORMATION
SP27
TRANSMISSION POSSIBLE?
SP29
YES
NO
GENERATE LOCATION INFORMATION
SP17
TRANSMIT LOCATION INFORMATION
SP35
TRANSMIT TRANSMISSION IMPOSSIBLE NOTIFICATION
SP31
RECEIVE AND DISPLAY TRANSMISSION IMPOSSIBLE NOTIFICATION
SP33
RECEIVE LOCATION INFORMATION
SP39
END

FIG. 23

BASE STATION ID	MOBILE STATION ID
BS001	MS09011111111
	MS09011111122
	MS09011111130
BS002	—
BS003	MS09011111140
...	...
...	...
...	...
...	...

FIG. 24

MOBILE STATION ID	POSITION REGISTRATION AREA ID
MS09011111111	AREA0001
MS09011111112	AREA0011
MS09011111113	AREA0050
...	...
...	...
...	...
...	...
...	...
...	...

FIG. 25

MOBILE STATION ID	PSEUDO ID
MS09011111111	00ZDGVXAKLLG
...	...
...	...
...	...
...	...
...	...
...	...

FIG. 26A

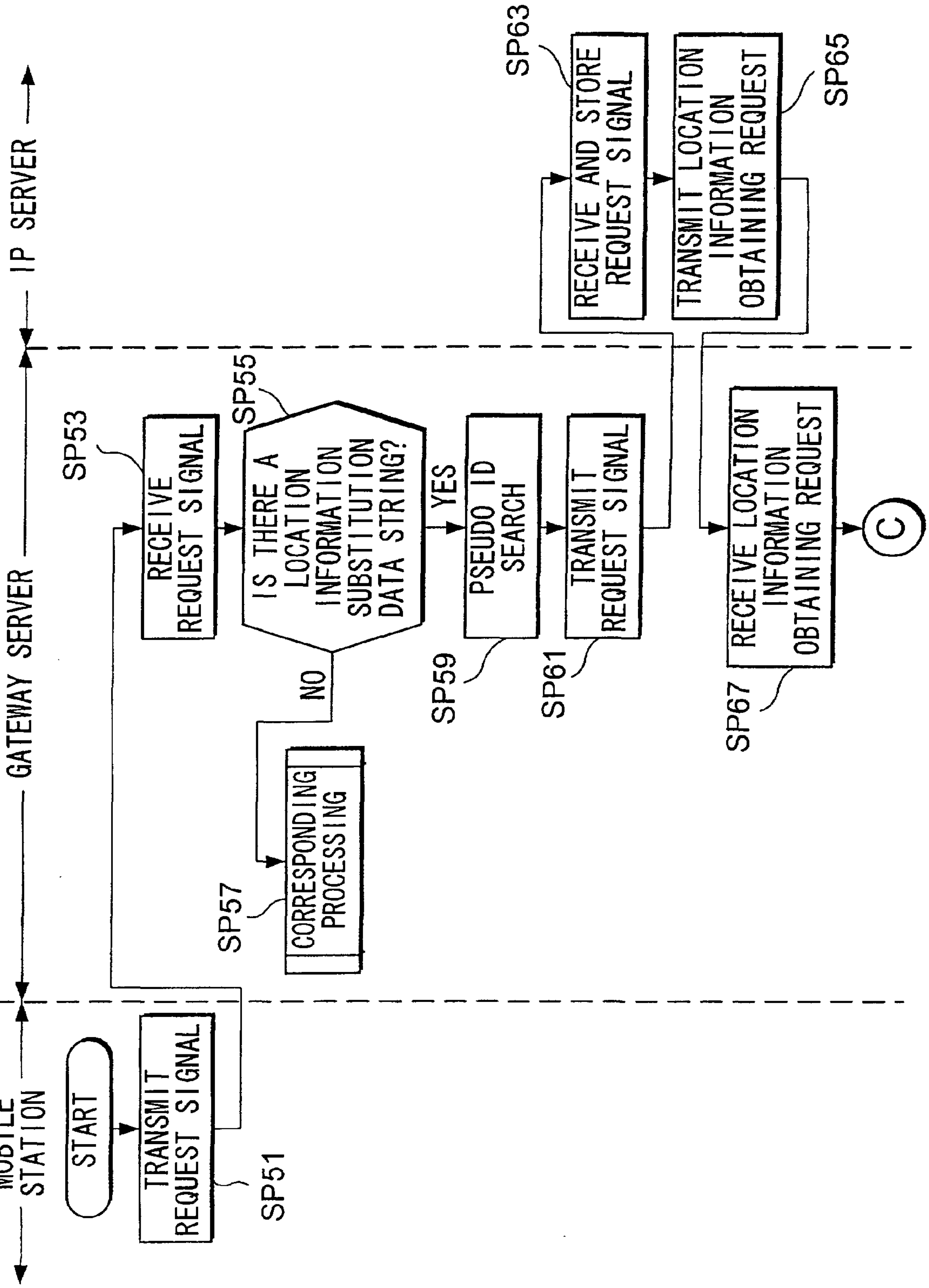

MOBILE STATION
GATEWAY SERVER
IP SERVER
START
TRANSMIT REQUEST SIGNAL
SP51
RECEIVE REQUEST SIGNAL
SP53
IS THERE A LOCATION INFORMATION SUBSTITUTION DATA STRING?
SP55
YES
NO
CORRESPONDING PROCESSING
SP57
PSEUDO ID SEARCH
SP59
TRANSMIT REQUEST SIGNAL
SP61
RECEIVE AND STORE REQUEST SIGNAL
SP63
TRANSMIT LOCATION INFORMATION OBTAINING REQUEST
SP65
RECEIVE LOCATION INFORMATION OBTAINING REQUEST
SP67
C

FIG. 26B

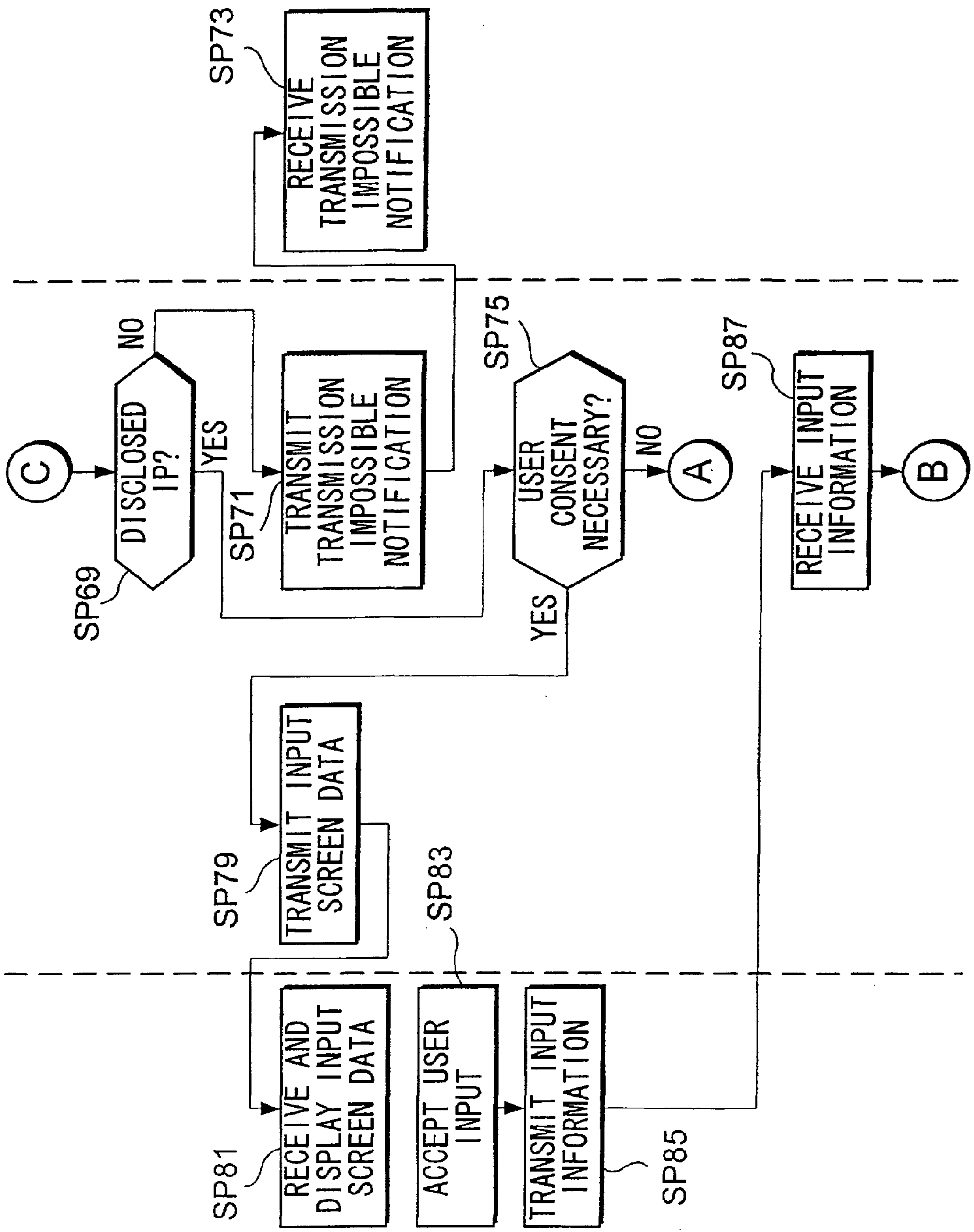

C
DISCLOSED IP?
SP69
YES
NO
TRANSMIT TRANSMISSION IMPOSSIBLE NOTIFICATION
SP71
RECEIVE TRANSMISSION IMPOSSIBLE NOTIFICATION
SP73
USER CONSENT NECESSARY?
SP75
NO
A
YES
TRANSMIT INPUT SCREEN DATA
SP79
RECEIVE AND DISPLAY INPUT SCREEN DATA
SP81
ACCEPT USER INPUT
SP83
TRANSMIT INPUT INFORMATION
SP85
RECEIVE INPUT INFORMATION
SP87
B

FIG. 27

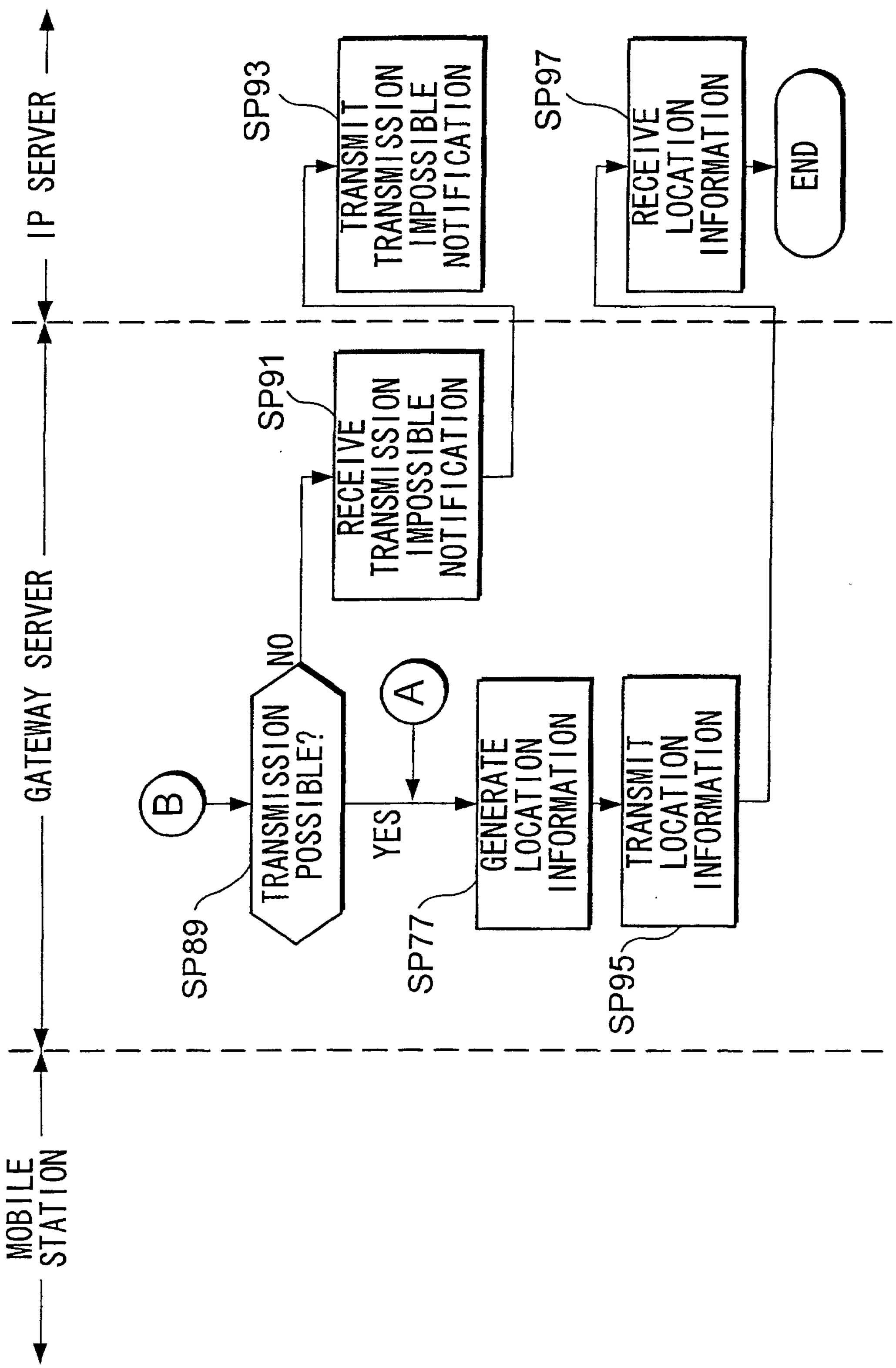

MOBILE STATION
GATEWAY SERVER
IP SERVER
B
SP89
TRANSMISSION POSSIBLE?
YES
NO
A
SP77
GENERATE LOCATION INFORMATION
SP95
TRANSMIT LOCATION INFORMATION
SP91
RECEIVE TRANSMISSION IMPOSSIBLE NOTIFICATION
SP93
TRANSMIT TRANSMISSION IMPOSSIBLE NOTIFICATION
SP97
RECEIVE LOCATION INFORMATION
END

FIG. 28

MOBILE STATION ID	LOCATION INFORMATION DISCLOSURE IP SERVER
MS09011111111	IP SERVER 500A
	IP SERVER 500B
	IP SERVER 500H
	....
MS09011111112	IP SERVER 500D
	IP SERVER 500M
	....
....	....

FIG. 29

ID OF MOBILE STATIONS WHICH DO NOT DISCLOSE LOCATION INFORMATION
MS09011111122
MS09011155555
....
....
....
....

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP00/05142

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[7] G06F13/00, H04Q7/34, G01S5/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl[7] G06F13/00, H04Q7/34, G01S5/14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Toroku Jitsuyo Shinan Koho	1994-2000
Kokai Jitsuyo Shinan Koho	1971-2000	Jitsuyo Shinan Toroku Koho	1996-2000

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP, 10-170625, A (Nippon Telegr. & Teleph. Corp. <NTT>), 26 October, 1998 (26.10.98) (Family: none)	1,5,11,25 29,43
X	JP, 63-199528, A (Nippon Telegr. & Teleph. Corp. <NTT>), 18 August, 1988 (18.08.88) (Family: none)	1,5,11,25 29,43
X	JP, 3-120995, A (Hitachi, Ltd.), 23 May, 1991 (23.05.91) (Family: none)	11,15-17,19 43,47-49,51
X	JP, 6-165246, A (NTT Ido Tsushinmo K.K.), 10 June, 1994 (10.06.94) (Family: none)	11,12,15-17, 19,22,23,43 44,47-49,51 54,55
Y		1,5,25,29
X	GB, 2322248, A (Fujitsu Limited), 08 October, 1997 (08.10.97)	11,22,24,43 54,56
Y	& CN, 1190183, A & JP, 10-281801, A	1,2,4,5,25 26,28,29

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search 13 September, 2000 (13.09.00)	Date of mailing of the international search report 26 September, 2000 (26.09.00)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP00/05142

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP, 5-102906, A (Nippon Telegr. & Teleph. Corp. <NTT>), 23 April, 1993 (23.04.93) (Family: none)	11,22,23,24 43,54,55,56 1,5,25,29
Y	JP, 11-51678, A (Honda Motor Co., Ltd.), 26 February, 1999 (26.02.99) (Family: none)	12,15-19,21 35-39,41,44 47-51,53
Y	JP, 9-153054, A (NEC Corporation), 10 June, 1997 (10.06.97) (Family: none)	7,11,31,43
Y	JP, 10-148542, A (Canon Inc.), 02 June, 1998 (02.06.98) (Family: none)	21,22,41,42 53,54
Y A	JP, 11-178047, A (Canon Inc.), 02 July, 1999 (02.07.99) (Family: none)	3,6,27,30 1,11,22,25 42,43,54
Y A	JP, 11-94923, A (Canon Inc.), 09 April, 1999 (09.04.99) (Family: none)	1,5,25,29 3,6,27,30
Y	JP, 10-191409, A (Uniden K.K.), 21 July, 1998 (21.07.98) (Family: none)	1,2,25,26
A	JP, 8-289355, A (NEC Corporation), 01 November, 1996 (01.11.96) (Family: none)	3,6,27,30
A	JP, 9-172672, A (NEC Corporation), 1997 June, 1997 (30.06.97)(Family: none)	4,28
A	JP, 11-41276, A (Sony Corp.), 12 February, 1999 (12.02.99)(Family: none)	8-10,13,14, 32-34,45,46
A	JP, 4-213258, A (Nippon Telegr. & Teleph. Corp.<NTT>), 04 August, 1992 (04.08.92), (Family: none)	9,10,13,14,33, 34,45,46
A	JP, 10-171727, A (Nippon Telegr. & Teleph. Corp.<NTT>), 26 June, 1998 (26.06.98) (Family: none)	9,10,13,14,33, 34,45,46

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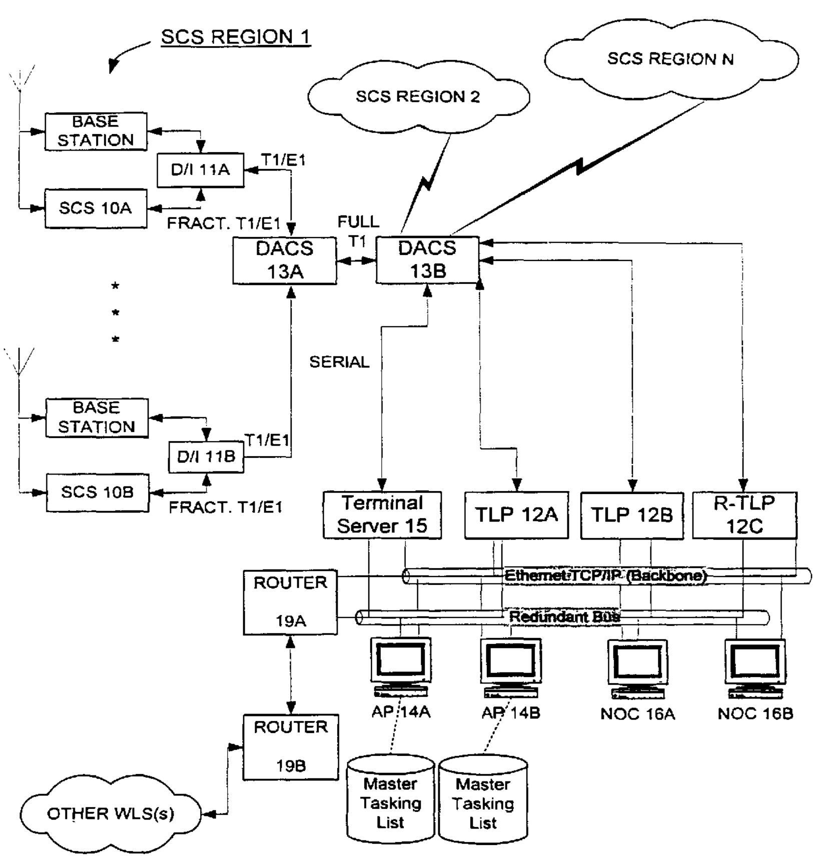
(81) **Designated States** (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) **Designated States** (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European

[Continued on next page]

(54) Title: MODIFIED TRANSMISSION METHOD FOR IMPROVING ACCURACY FOR E-911 CALLS



(57) Abstract: A wireless location system for providing an accurate location for a mobile unit comprises a signal collection system (10), a TDOA location processor (12), an application processor (14) and a network operation console (16). The location determination process uses a modification of the transmission parameters in order to minimize the interference in the wireless location system.

WO 01/76093 A1

patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:
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— *of inventorship (Rule 4.17(iv)) for US only*

Published:
— *with international search report*
— *with amended claims*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

MODIFIED TRANSMISSION METHOD FOR IMPROVING ACCURACY FOR E-911 CALLS

CROSS REFERENCE TO RELATED APPLICATIONS

This is a continuation-in-part of U.S. Patent Application Serial No. 09/227,764, filed on January 8, 1999, entitled "Calibration for Wireless Location System."

FIELD OF THE INVENTION

The present invention relates generally to methods and apparatus for locating wireless transmitters, such as those used in analog or digital cellular systems, personal communications systems (PCS), enhanced specialized mobile radios (ESMRs), and other types of wireless communications systems. This field is now generally known as wireless location, and has application for Wireless E9-1-1, fleet management, RF optimization, and other valuable applications.

BACKGROUND OF THE INVENTION

Early work relating to the present invention has been described in U.S. Patent Number 5,327,144, July 5, 1994, "Cellular Telephone Location System," which discloses a system for locating cellular telephones using novel time difference of arrival (TDOA) techniques. Further enhancements of the system disclosed in the '144 patent are disclosed in U.S. Patent Number 5,608,410, March 4, 1997, "System for Locating a Source of Bursty Transmissions." Both patents are owned by the assignee of the current invention, and both are incorporated herein by reference. The present inventors have continued to develop significant enhancements to the original inventive concepts and have developed techniques to further improve the accuracy of Wireless Location Systems while significantly reducing the cost of these systems.

Over the past few years, the cellular industry has increased the number of air interface protocols available for use by wireless telephones, increased the number of frequency bands in which wireless or mobile telephones may operate, and expanded the number of terms that refer or relate to mobile telephones to include "personal communications services", "wireless", and others. The air interface protocols now include AMPS, N-AMPS, TDMA, CDMA, GSM,TACS, ESMR, GPRS, EDGE, and others. The changes in terminology and increases in the number of air interfaces do not change the basic principles and inventions discovered and enhanced by the inventors. However, in keeping with the current terminology of the industry, the inventors now call the system described herein a *Wireless Location System*.

The inventors have conducted extensive experiments with the Wireless Location System technology disclosed herein to demonstrate both the viability and value of the technology. For example, several experiments were conducted during several months of 1995 and 1996 in the cities of Philadelphia and Baltimore to verify the system's ability to mitigate multipath in large urban environments. Then, in 1996 the inventors constructed a system in Houston that was used to test the technology's effectiveness in that area and its ability to interface directly with E9-1-1 systems. Then, in 1997, the system was tested in a 350 square mile area in New Jersey and was used to locate real 9-1-1 calls from real people in trouble. Since that time, the system test has been expanded to include 125 cell sites covering an area of over 2,000 square miles. During all of these tests, techniques discussed and disclosed herein were tested for effectiveness and further developed, and the system has been demonstrated to overcome the limitations of other approaches that have been proposed for locating wireless telephones. Indeed, as of December, 1998, no other Wireless Location System has been installed anywhere else in the world that is capable of locating live 9-1-1 callers. The innovation of the Wireless Location System disclosed herein has been acknowledged in the wireless industry by the extensive amount of media coverage given to the system's capabilities, as well as by awards. For example, the prestigious Wireless Appy Award was granted to the system by the Cellular Telephone Industry Association in October, 1997, and the Christopher Columbus Fellowship Foundation and Discover Magazine found the Wireless Location System to be one of the top 4 innovations of 1998 out of 4,000 nominations submitted.

The value and importance of the Wireless Location System has been acknowledged by the wireless communications industry. In June 1996, the Federal Communications Commission issued requirements for the wireless communications industry to deploy location systems for use in locating wireless 9-1-1 callers, with a deadline of October 2001. The location of wireless E9-1-1 callers will save response time, save lives, and save enormous costs because of reduced use of emergency responses resources. In addition, numerous surveys and studies have concluded that various wireless applications, such as location sensitive billing, fleet management, and others, will have great commercial values in the coming years.

Background on Wireless Communications Systems

There are many different types of air interface protocols used for wireless communications systems. These protocols are used in different frequency bands, both in the U.S. and internationally. The frequency band does not impact the Wireless Location System's effectiveness at locating wireless telephones.

All air interface protocols use two types of "channels". The first type includes control channels that are used for conveying information about the wireless telephone or transmitter, for initiating or terminating calls, or for transferring bursty data. For example, some types of short messaging services transfer data over the control channel. In different air interfaces, control channels are known by different terminology, but the use of the control channels in each air interface is similar. Control channels generally have identifying information about the wireless telephone or transmitter contained in the transmission. Control channels also include various data transfer protocols that are not voice specific – these include General Packet Radio Service (GPRS), Enhanced Data rate for GSM Evolution (EDGE), and Enhanced GPRS (EGPRS).

The second type includes voice channels that are typically used for conveying voice communications over the air interface. These channels are only used after a call has been set up using the control channels. Voice channels will typically use dedicated resources within the wireless communications system whereas control channels will use shared resources. This distinction will generally make the use of control channels for wireless location purposes more cost effective than the use of voice channels, although there are some applications for which regular location on the voice channel is desired. Voice channels generally do not have identifying information about the wireless telephone or transmitter in the transmission. Some of the differences in the air interface protocols are discussed below:

AMPS – This is the original air interface protocol used for cellular communications in the U.S. In the AMPS system, separate dedicated channels are assigned for use by control channels (RCC). According to the TIA/EIA Standard IS-553A, every control channel block must begin at cellular channel 333 or 334, but the block may be of variable length. In the U.S., by convention, the AMPS control channel block is 21 channels wide, but the use of a 26-channel block is also known. A reverse voice channel (RVC) may occupy any channel that is not assigned to a control channel. The control channel modulation is FSK (frequency shift keying), while the voice channels are modulated using FM (frequency modulation).

N-AMPS – This air interface is an expansion of the AMPS air interface protocol, and is defined in EIA/TIA standard IS-88. The control channels are substantially the same as for AMPS, however, the voice channels are different. The voice channels occupy less than 10 KHz of bandwidth, versus the 30 KHz used for AMPS, and the modulation is FM.

TDMA – This interface is also known D-AMPS, and is defined in EIA/TIA standard IS-136. This air interface is characterized by the use of both frequency and time separation. Control channels are known as Digital Control Channels (DCCH) and are transmitted in bursts in timeslots assigned for use by DCCH. Unlike AMPS, DCCH may be assigned anywhere in the frequency band, although there are generally some frequency assignments that are more attractive than others based upon the use of probability blocks. Voice channels are known as Digital Traffic Channels (DTC). DCCH and DTC may occupy the same frequency assignments, but not the same timeslot assignment in a given frequency assignment. DCCH and DTC use the same modulation scheme, known as $\pi/4$ DQPSK (differential quadrature phase shift keying). In the cellular band, a carrier may use both the AMPS and TDMA protocols, as long as the frequency assignments for each protocol are kept separated. A carrier may also aggregate digital channels together to support higher speed data transfer protocols such as GPRS and EDGE.

CDMA – This air interface is defined by EIA/TIA standard IS-95A. This air interface is characterized by the use of both frequency and code separation. However, because adjacent cell sites may use the same frequency sets, CDMA is also characterized by very careful power control. This careful power control leads to a situation known to those skilled in the art as the near-far problem, which makes wireless location difficult for most approaches to function properly. Control channels are known as Access Channels, and voice channels are known as Traffic Channels. Access and Traffic Channels may share the same frequency band, but are separated by code. Access and Traffic Channels use the same modulation scheme, known as OQPSK. CDMA can support higher speed data transfer protocols by aggregating codes together.

GSM - This air interface is defined by the international standard Global System for Mobile Communications. Like TDMA, GSM is characterized by the use of both frequency and time separation. The channel bandwidth is 200 KHz, which is wider than the 30 KHz used for TDMA. Control channels are known as Standalone Dedicated Control Channels (SDCCH), and are transmitted in bursts in timeslots assigned for use by SDCCH. SDCCH may be assigned anywhere in the frequency band. Voice channels are known as Traffic Channels (TCH). SDCCH and TCH may occupy the same frequency assignments, but not the same timeslot assignment in a given frequency assignment. SDCCH and TCH use the same modulation scheme, known as GMSK. GSM can also support higher data transfer protocols such as GPRS and EGPRS.

Within this specification the reference to any one of the air interfaces shall automatically refer to all of the air interfaces, unless specified otherwise. Additionally, a reference to control channels or voice channels shall refer to all types of control or voice channels, whatever the preferred terminology for a particular air interface. Finally, there are many more types of air interfaces used throughout the world, and there is no intent to exclude any air interface from the inventive concepts described within this specification. Indeed, those skilled in the art will recognize other interfaces used elsewhere are derivatives of or similar in class to those described above.

The preferred embodiments of the inventions disclosed herein have many advantages over other techniques for locating wireless telephones. For example, some of these other techniques involve adding GPS functionality to telephones, which requires that significant changes be made to the telephones. The preferred embodiments disclosed herein do not require such changes.

SUMMARY OF THE INVENTION

The accuracy of the location estimate of a Wireless Location System is dependent, in part, upon both the transmitted power of the wireless transmitter and the length in time of the transmission from the wireless transmitter. In general, higher power transmissions and transmissions of greater transmission length can be located with better accuracy by the Wireless Location System than lower power and shorter transmissions. Wireless communications systems generally limit the transmit power and transmission length of wireless transmitters in order to minimize interference within the communications system and to maximize the potential capacity of the system.

An inventive method disclosed herein meets the conflicting needs of both systems by enabling the wireless communications system to minimize transmit power and length while enabling improved location accuracy for certain types of calls, such as wireless 9-1-1 calls. This method comprises the following steps: a wireless transmitter receives normal transmission parameters from a base station; the user of the wireless transmitter initiates a call on the wireless transmitter by dialing a sequence of digits and pressing "SEND" or "YES"; a processor within the wireless transmitter compares the dialed sequence of digits with one or more trigger events stored within the wireless transmitter; if the dialed sequence of digits does not match the trigger event, then the wireless transmitter uses the normal transmission parameters in making the call; and if the dialed sequence of digits matches the trigger event, then the wireless transmitter uses a modified transmission sequence.

Other features and advantages of the invention are disclosed below.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1 and 1A schematically depict a Wireless Location System in accordance with the present invention.

Figure 2 schematically depicts a Signal Collection System (SCS) 10 in accordance with the present invention.

Figure 2A schematically depicts a receiver module 10-2 employed by the Signal Collection System.

Figures 2B and 2C schematically depict alternative ways of coupling the receiver module(s) 10-2 to the antennas 10-1.

Figure 2C-1 is a flowchart of a process employed by the Wireless Location System when using narrowband receiver modules.

Figure 2D schematically depicts a DSP module 10-3 employed in the Signal Collection System in accordance with the present invention.

Figure 2E is a flowchart of the operation of the DSP module(s) 10-3, and Figure 2E-1 is a flowchart of the process employed by the DSP modules for detecting active channels.

Figure 2F schematically depicts a Control and Communications Module 10-5 in accordance with the present invention.

Figures 2G-2J depict aspects of the presently preferred SCS calibration methods. Figure 2G is a schematic illustration of baselines and error values used to explain an external calibration method in accordance with the present invention. Figure 2H is a flowchart of an internal calibration method. Figure 2I is an exemplary transfer function of an AMPS control channel and Figure 2J depicts an exemplary comb signal.

Figures 2K and 2L are flowcharts of two methods for monitoring performance of a Wireless Location System in accordance with the present invention.

Figure 3 schematically depicts a TDOA Location Processor 12 in accordance with the present invention.

Figure 3A depicts the structure of an exemplary network map maintained by the TLP controllers in accordance with the present invention.

Figures 4 and 4A schematically depict different aspects of an Applications Processor 14 in accordance with the present invention.

Figure 5 is a flowchart of a central station-based location processing method in accordance with the present invention.

Figure 6 is a flowchart of a station-based location processing method in accordance with the present invention.

Figure 7 is a flowchart of a method for determining, for each transmission for which a location is desired, whether to employ central or station-based processing.

Figure 8 is a flowchart of a dynamic process used to select cooperating antennas and SCS's 10 used in location processing.

Figure 9 is diagram that is referred to below in explaining a method for selecting a candidate list of SCS's and antennas using a predetermined set of criteria.

Figures 10A and 10B are flowcharts of alternative methods for increasing the bandwidth of a transmitted signal to improve location accuracy.

Figures 11A-11C are signal flow diagrams and Figure 11D is a flowchart, and they are used to explain an inventive method for combining multiple statistically independent location estimates to provide an estimate with improved accuracy.

Figures 12A and 12B are a block diagram and a graph, respectively, for explaining a bandwidth synthesis method.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The Wireless Location System (Wireless Location System) operates as a passive overlay to a wireless communications system, such as a cellular, PCS, or ESMR system, although the concepts are not limited to just those types of communications systems. Wireless communications systems are generally not suitable for locating wireless devices because the designs of the wireless transmitters and cell sites do not include the necessary functionality to achieve accurate location. Accurate location in this application is defined as accuracy of 100 to 400 feet RMS (root mean square). This is distinguished from the location accuracy that can be achieved by existing cell sites, which is generally limited to the radius of the cell site. In general, cell sites are not designed or programmed to cooperate between and among themselves to determine wireless transmitter location. Additionally, wireless transmitters such as cellular and PCS telephones are designed to be low cost and therefore generally do not have locating capability built-in. The Wireless Location System is designed to be a low cost addition to a wireless communications system that involves minimal changes to cell sites and no changes at all to standard wireless transmitters. The Wireless Location System is passive because it does not contain transmitters, and therefore cannot cause interference of any kind to the wireless communications system. The Wireless Location System uses only its own specialized receivers at cell sites or other receiving locations.

Overview of Wireless Location System (Wireless Location System)

As shown in Figure 1, the Wireless Location System has four major kinds of subsystems: the Signal Collection Systems (SCS's) 10, the TDOA Location Processors (TLP's) 12, the Application Processors (AP's) 14, and the Network Operations Console (NOC) 16. Each SCS is responsible for receiving the RF signals transmitted by the wireless transmitters on both control channels and voice channels. In general, each SCS is preferably installed at a wireless carrier's cell site, and therefore operates in parallel to a base station. Each TLP 12 is responsible for managing a network of SCS's 10 and for providing a centralized pool of digital signal processing (DSP) resources that can be used in the location calculations. The SCS's 10 and the TLP's 12 operate together to determine the location of the wireless transmitters, as will be discussed more fully below. Digital signal processing is the preferable manner in which to process radio signals because DSP's are relatively low cost, provide consistent performance, and are easily re-programmable to handle many different tasks. Both the SCS's 10 and TLP's 12 contain a significant amount of DSP resources, and the software in these systems can operate dynamically to determine where to perform a particular processing function based upon tradeoffs in processing time, communications time, queuing time, and cost. Each TLP 12 exists centrally primarily to reduce the overall cost of implementing the Wireless Location System, although the techniques discussed herein are not limited to the preferred architecture shown. That is, DSP resources can be relocated within the Wireless Location System without changing the basic concepts and functionality disclosed.

The AP's 14 are responsible for managing all of the resources in the Wireless Location System, including all of the SCS's 10 and TLP's 12. Each AP 14 also contains a specialized database that contains "triggers" for the Wireless Location System. In order to conserve resources, the Wireless Location System can be programmed to locate only certain pre-determined types of transmissions. When a transmission of a pre-determined type occurs, then the Wireless Location System is triggered to begin location processing. Otherwise, the Wireless Location System may be programmed to ignore the transmission. Each AP 14 also contains applications interfaces that permit a variety of applications to securely access the Wireless Location System. These applications may, for example, access location records in real time or non-real time, create or delete certain type of triggers, or cause the Wireless Location System to take other actions. Each AP 14 is also capable of certain post-processing functions that allow the AP 14 to combine a number of location records to generate extended reports or analyses useful for applications such as traffic monitoring or RF optimization.

The NOC 16 is a network management system that provides operators of the Wireless Location System easy access to the programming parameters of the Wireless Location System. For example, in some cities, the Wireless Location System may contain many hundreds or even thousands of SCS's 10. The NOC is the most effective way to manage a large Wireless Location System, using graphical user interface capabilities. The NOC will also receive real time alerts if certain functions within the Wireless Location System are not operating properly. These real time alerts can be used by the operator to take corrective action quickly and prevent a degradation of location service. Experience with trials of the Wireless Location System show that the ability of the system to maintain good location accuracy over time is directly related to the operator's ability to keep the system operating within its predetermined parameters.

Readers of U.S. Patents 5,327,144 and 5,608,410 and this specification will note similarities between the respective systems. Indeed, the system disclosed herein is significantly based upon and also significantly enhanced from the system described in those previous patents. For example, the SCS 10 has been expanded and enhanced from the Antenna Site System described in 5,608,410. The SCS 10 now has the capability to support many more antennas at a single cell site, and further can support the use of extended antennas as described below. This enables the SCS 10 to operate with the sectored cell sites now commonly used. The SCS 10 can also transfer data from multiple antennas at a cell site to the TLP 12 instead of always combining data from multiple antennas before transfer. Additionally, the SCS 10 can support multiple air interface protocols thereby allowing the SCS 10 to function even as a wireless carrier continually changes the configuration of its system.

The TLP 12 is similar to the Central Site System disclosed in 5,608,410, but has also been expanded and enhanced. For example, the TLP 12 has been made scaleable so that the amount of DSP resources required by each TLP 12 can be appropriately scaled to match the number of locations per second required by customers of the Wireless Location System. In order to support scaling for different Wireless Location System capacities, a networking scheme has been added to the TLP 12 so that multiple TLP's 12 can cooperate to share RF data across wireless communication system network boundaries. Additionally, the TLP 12 has been given control means to determine the SCS's 10, and more importantly the antennas at each of the SCS's 10, from which the TLP 12 is to receive data in order to process a specific location. Previously, the Antenna Site Systems automatically forwarded data to the Central Site System, whether requested or not by the Central Site System. Furthermore, the SCS 10 and TLP 12 combined have been designed with additional means for removing multipath from the received transmissions.

The Database Subsystem of the Central Site System has been expanded and developed into the AP 14. The AP 14 can support a greater variety of applications than previously disclosed in 5,608,410, including the ability to post-process large volumes of location records from multiple wireless transmitters. This post-processed data can yield, for example, very effective maps for use by wireless carriers to improve and optimize the RF design of the communications systems. This can be achieved, for example, by plotting the locations of all of the callers in an area and the received signal strengths at a number of cell sites. The carrier can then determine whether each cell site is, in fact, serving the exact coverage area desired by the carrier. The AP 14 can also now store location records anonymously, that is, with the MIN and/or other identity information removed from the location record, so that the location record can be used for RF optimization or traffic monitoring without causing concerns about an individual user's privacy.

As shown in Figure 1A, a presently preferred implementation of the Wireless Location System includes a plurality of SCS regions each of which comprises multiple SCS's 10. For example, "SCS Region 1" includes SCS's 10A and 10B (and preferably others, not shown) that are located at respective cell sites and share antennas with the base stations at those cell sites. Drop and insert units 11A and 11B are used to interface fractional T1/E1 lines to full T1/E1 lines, which in turn are coupled to a digital access and control system (DACS) 13A. The DACS 13A and another DACS 13B are used in the manner described more fully below for communications between the SCS's 10A, 10B, etc., and multiple TLP's 12A, 12B, etc. As shown, the TLP's are typically collocated and interconnected via an Ethernet network (backbone) and a second, redundant Ethernet network. Also coupled to the Ethernet networks are multiple AP's 14A and 14B, multiple NOC's 16A and 16B, and a terminal server 15.

Routers 19A and 19B are used to couple one Wireless Location System to one or more other Wireless Location System(s).

Signal Collection System 10

Generally, cell sites will have one of the following antenna configurations: (i) an omnidirectional site with 1 or 2 receive antennas or (ii) a sectored site with 1, 2, or 3 sectors, and with 1 or 2 receive antennas used in each sector. As the number of cell sites has increased in the U.S. and internationally, sectored cell sites have become the predominant configuration. However, there are also a growing number of micro-cells and pico-cells, which can be omnidirectional. Therefore, the SCS 10 has been designed to be configurable for any of these typical cell sites and has been provided with mechanisms to employ any number of antennas at a cell site.

The basic architectural elements of the SCS 10 remain the same as for the Antenna Site System described in 5,608,410, but several enhancements have been made to increase the flexibility of the SCS 10 and to reduce the commercial deployment cost of the system. The most presently preferred embodiment of the SCS 10 is described herein. The SCS 10, an overview of which is shown in Figure 2, includes digital receiver modules 10-2A through 10-2C; DSP modules 10-3A through 10-3C; a serial bus 10-4, a control and communications module 10-5; a GPS module 10-6; and a clock distribution module 10-7. The SCS 10 has the following external connections: power, fractional T1/E1 communications, RF connections to antennas, and a GPS antenna connection for the timing generation (or clock distribution) module 10-7. The architecture and packaging of the SCS 10 permit it to be physically collocated with cell sites (which is the most common installation place), located at other types of towers (such as FM, AM, two-way emergency communications, television, etc.), or located at other building structures (such as rooftops, silos, etc.).

Timing Generation

The Wireless Location System depends upon the accurate determination of time at all SCS's 10 contained within a network. Several different timing generation systems have been described in previous disclosures, however the most presently preferred embodiment is based upon an enhanced GPS receiver 10-6. The enhanced GPS receiver differs from most traditional GPS receivers in that the receiver contains algorithms that remove some of the timing instability of the GPS signals, and guarantees that any two SCS's 10 contained within a network can receive timing pulses that are within approximately ten nanoseconds of each other. These enhanced GPS receivers are now commercially available, and further reduce some of the time reference related errors that were observed in previous implementations of wireless location systems. While this enhanced GPS receiver can produce a very accurate time reference, the output of the receiver may still have an unacceptable phase noise. Therefore, the output of the receiver is input to a low phase noise, crystal oscillator-driven phase locked loop circuit that can now produce 10 MHz and one pulse per second (PPS) reference signals with less than 0.01 degrees RMS of phase noise, and with the pulse output at any SCS 10 in a Wireless Location System network within ten nanoseconds of any other pulse at another SCS 10. This combination of enhanced GPS receiver, crystal oscillator, and phase locked loop is now the most preferred method to produce stable time and frequency reference signals with low phase noise.

The SCS 10 has been designed to support multiple frequency bands and multiple carriers with equipment located at the same cell site. This can take place by using multiple receivers internal to a single SCS chassis, or by using multiple chassis each with separate receivers. In the event that multiple SCS chassis are placed at the same cell site, the SCS's 10 can share a single timing generation/clock distribution circuit 10-7 and thereby reduce overall system cost. The 10 MHz and one PPS output signals from the timing generation circuit are amplified and buffered internal to the SCS 10, and then made available via external connectors. Therefore a second SCS can receive its timing from a first SCS using the buffered output and the external connectors. These signals can also be made available to base station equipment collocated at the cell site. This might be useful to the base station, for example, in improving the frequency re-use pattern of a wireless communications system.

Receiver Module 10-2 (Wideband Embodiment)

When a wireless transmitter makes a transmission, the Wireless Location System must receive the transmission at multiple SCS's 10 located at multiple geographically dispersed cell sites. Therefore, each SCS 10 has the ability to receive a transmission on any RF channel on which the transmission may originate. Additionally, since the SCS 10 is capable of supporting multiple air interface protocols, the SCS 10 also supports multiple types of RF channels. This is in contrast to most current base station receivers, which typically receive only one type of channel and are usually capable of receiving only on select RF channels at each cell site. For example, a typical TDMA base station receiver will only support 30 KHz wide channels, and each receiver is programmed to receive signals on only a single channel whose frequency does not change often (i.e. there is a relatively fixed frequency plan). Therefore, very few TDMA base station receivers would receive a transmission on any given frequency. As another example, even though some GSM base station receivers are capable of frequency hopping, the receivers at multiple base stations are generally not capable of simultaneously tuning to a single frequency for the purpose of performing location processing. In fact, the receivers at GSM base stations are programmed to frequency hop to avoid using an RF channel that is being used by another transmitter so as to minimize interference.

The SCS receiver module 10-2 is preferably a dual wideband digital receiver that can receive the entire frequency band and all of the RF channels of an air interface. For cellular systems in the U.S., this receiver module is either 15 MHz wide or 25 MHz wide so that all of the channels of a single carrier or all of the channels of both carriers can be received. This receiver module has many of the characteristics of the receiver previously described in Patent Number 5,608,410, and Figure 2A is a block diagram of the currently preferred embodiment. Each receiver module contains an RF tuner section 10-2-1, a data interface and control section 10-2-2 and an analog to digital conversion section 10-2-3. The RF tuner section 10-2-1 includes two full independent digital receivers (including Tuner #1 and Tuner #2) that convert the analog RF input from an external connector into a digitized data stream. Unlike most base station receivers, the SCS receiver module does not perform diversity combining or switching. Rather, the digitized signal from each independent receiver is made available to the location processing. The present inventors have determined that there is an advantage to the location processing, and especially the multipath mitigation processing, to independently process the signals from each antenna rather than perform combining on the receiver module.

The receiver module 10-2 performs, or is coupled to elements that perform, the following functions: automatic gain control (to support both nearby strong signals and far away weak signals), bandpass filtering to remove potentially interfering signals from outside of the RF band of interest, synthesis of frequencies needed for mixing with the RF signals to create an IF signal that can be sampled, mixing, and analog to digital conversion (ADC) for sampling the RF signals and outputting a digitized data stream having an appropriate bandwidth and bit resolution. The frequency synthesizer locks the synthesized frequencies to the 10 MHz reference signal from the clock distribution/timing generation module 10-7 (Figure 2). All of the circuits used in the receiver module maintain the low phase noise characteristics of the timing reference signal. The receiver module preferably has a spurious free dynamic range of at least 80 dB.

The receiver module 10-2 also contains circuits to generate test frequencies and calibration signals, as well as test ports where measurements can be made by technicians during installation or troubleshooting. Various calibration processes are described in further detail below. The internally generated test frequencies and test ports provide an easy method for engineers and technicians to rapidly test the receiver module and diagnose any suspected problems. This is also especially useful during the manufacturing process.

One of the advantages of the Wireless Location System described herein is that no new antennas are required at cell sites. The Wireless Location System can use the existing antennas already installed at most cell sites, including both omni-directional and sectored antennas. This feature can result in significant savings in the installation and maintenance costs of the Wireless Location System versus other approaches that have been described in the prior art. The SCS's digital receivers 10-2 can be connected to the existing antennas in two ways, as shown in Figures 2B and 2C, respectively. In Figure 2B, the SCS receivers 10-2 are connected to the existing cell site multi-coupler or RF splitter. In this manner, the SCS 10 uses the cell site's existing low noise pre-amplifier, band pass filter, and multi-coupler or RF splitter. This type of connection usually limits the SCS 10 to supporting the frequency band of a single carrier. For example, an A-side cellular carrier will typically use the band pass filter to block signals from customers of the B-side carrier, and vice versa.

In Figure 2C, the existing RF path at the cell site has been interrupted, and a new pre-amplifier, band pass filter, and RF splitter has been added as part of the Wireless Location System. The new band pass filter will pass multiple contiguous frequency bands, such as both the A-side and B-side cellular carriers, thereby allowing the Wireless Location System to locate wireless transmitters using both cellular systems but using the antennas from a single cell site. In this configuration, the Wireless Location System uses matched RF components at each cell site, so that the phase versus frequency responses are identical. This is in contrast to existing RF components, which may be from different manufacturers or using different model numbers at various cell sites. Matching the response characteristics of RF components reduces a possible source of error for the location processing, although the Wireless Location System has the capability to compensate for these sources of error. Finally, the new pre-amplifier installed with the Wireless Location System will have a very low noise figure to improve the sensitivity of the SCS 10 at a cell site. The overall noise figure of the SCS digital receivers 10-2 is dominated by the noise figure of the low noise amplifiers. Because the Wireless Location System can use weak signals in location processing, whereas the base station typically cannot process weak signals, the Wireless Location System can significantly benefit from a high quality, very low noise amplifier.

In order to improve the ability of the Wireless Location System to accurately determine TDOA for a wireless transmission, the phase versus frequency response of the cell site's RF components are determined at the time of installation and updated at other certain times and then stored in a table in the Wireless Location System. This can be important because, for example, the band pass filters and/or multi-couplers made by some manufacturers have a steep and non-linear phase versus frequency response near the edge of the pass band. If the edge of the pass band is very near to or coincident with the reverse control or voice channels, then the Wireless Location System would make incorrect measurements of the transmitted signal's phase characteristics if the Wireless Location System did not correct the measurements using the stored characteristics. This becomes even more important if a carrier has installed multi-couplers and/or band pass filters from more than one manufacturer, because the characteristics at each site may be different. In addition to measuring the phase versus frequency response, other environmental factors may cause changes to the RF path prior to the ADC. These factors require occasional and sometimes periodic calibration in the SCS 10.

Alternative Narrowband Embodiment of Receiver Module 10-2

In addition or as an alternative to the wideband receiver module, the SCS 10 also supports a narrowband embodiment of the receiver module 10-2. In contrast to the wideband receiver module that can simultaneously receive all of the RF channels in use by a wireless communications system, the narrowband receiver can only receive one or a few RF channels at a time. For example, the SCS 10 supports a 60 KHz narrowband receiver for use in AMPS/TDMA systems, covering two contiguous 30 KHz channels. This receiver is still a digital receiver as described for the wideband module, however the frequency synthesizing and mixing circuits are used to dynamically tune the receiver module to various RF channels on command. This dynamic tuning can typically occur in one millisecond or less, and the receiver can dwell on a specific RF channel for as long as required to receive and digitize RF data for location processing.

The purpose of the narrowband receiver is to reduce the implementation cost of a Wireless Location System from the cost that is incurred with wideband receivers. Of course, there is some loss of performance, but the availability of these multiple receivers permits wireless carriers to have more cost/performance options. Additional inventive functions and enhancements have been added to the Wireless Location System to support this new type of narrowband receiver. When the wideband receiver is being used, all RF channels are received continuously at all SCS's 10, and subsequent to the transmission, the Wireless Location System can use the DSP's 10-3 (Figure 2) to dynamically select any RF channel from the digital memory. With the narrowband receiver, the Wireless Location System must ensure *a priori* that the narrowband receivers at multiple cell sites are simultaneously tuned to the same RF channel so that all receivers can simultaneously receive, digitize and store the same wireless transmission. For this reason, the narrowband receiver is generally used only for locating voice channel transmissions, which can be known *a priori* to be making a transmission. Since control channel transmissions can occur asynchronously at any time, the narrowband receiver may not be tuned to the correct channel to receive the transmission.

When the narrowband receivers are used for locating AMPS voice channel transmissions, the Wireless Location System has the ability to temporarily change the modulation characteristics of the AMPS wireless transmitter to aid location processing. This may be necessary because AMPS voice channels are only FM modulated with the addition of a low level supervisory tone known as SAT. As is known in the art, the Cramer-Rao lower bound of AMPS FM modulation is significantly worse than the Manchester encoded FSK modulation used for AMPS reverse channels and "blank and burst" transmissions on the voice channel. Further, AMPS wireless transmitters may be transmitting with significantly reduced energy if there is no modulating input signal (i.e., no one is speaking). To improve the location estimate by improving the modulation characteristics without depending on the existence or amplitude of an input modulating signal, the Wireless Location System can cause an AMPS wireless transmitter to transmit a "blank and burst" message at a point in time when the narrowband receivers at multiple SCS's 10 are tuned to the RF channel on which the message will be sent. This is further described later.

The Wireless Location System performs the following steps when using the narrowband receiver module (see the flowchart of Figure 2C-1):

a first wireless transmitter is *a priori* engaged in transmitting on a particular RF channel;

the Wireless Location System triggers to make a location estimate of the first wireless transmitter (the trigger may occur either internally or externally via a command/response interface);

the Wireless Location System determines the cell site, sector, RF channel, timeslot, long code mask, and encryption key (all information elements may not be necessary for all air interface protocols) currently in use by the first wireless transmitter;

the Wireless Location System tunes an appropriate first narrowband receiver at an appropriate first SCS 10 to the RF channel and timeslot at the designated cell site and sector, wherein appropriate typically means both available and collocated or in closest proximity;

the first SCS 10 receives a time segment of RF data, typically ranging from a few microseconds to tens of milliseconds, from the first narrowband receiver and evaluates the transmission's power, SNR, and modulation characteristics;

if the transmission's power or SNR is below a predetermined threshold, the Wireless Location System waits a predetermined length of time and then returns to the above third step (where the Wireless Location System determines the cell site, sector, etc.);

if the transmission is an AMPS voice channel transmission and the modulation is below a threshold, then the Wireless Location System commands the wireless communications system to send a command to the first wireless transmitter to cause a "blank and burst" on the first wireless transmitter;

the Wireless Location System requests the wireless communications system to prevent hand-off of the wireless transmitter to another RF channel for a predetermined length of time;

the Wireless Location System receives a response from the wireless communications system indicating the time period during which the first wireless transmitter will be prevented from handing-off, and if commanded, the time period during which the wireless communications system will send a command to the first wireless transmitter to cause a "blank and burst";

the Wireless Location System determines the list of antennas that will be used in location processing (the antenna selection process is described below);

the Wireless Location System determines the earliest Wireless Location System timestamp at which the narrowband receivers connected to the selected antennas are available to begin simultaneously collecting RF data from the RF channel currently in use by the first wireless transmitter;

based upon the earliest Wireless Location System timestamp and the time periods in the response from the wireless communications system, the Wireless Location System commands the narrowband receivers connected to the antennas that will be used in location processing to tune to the cell site, sector, and RF channel currently in use by the first wireless transmitter and to receive RF data for a predetermined dwell time (based upon the bandwidth of the signal, SNR, and integration requirements);

the RF data received by the narrowband receivers are written into the dual port memory;

location processing on the received RF data commences, as described in Patent Nos. 5,327,144 and 5,608,410 and in sections below;

the Wireless Location System again determines the cell site, sector, RF channel, timeslot, long code mask, and encryption key currently in use by the first wireless transmitter;

if the cell site, sector, RF channel, timeslot, long code mask, and encryption key currently in use by the first wireless transmitter has changed between queries (i.e. before and after gathering the RF data) the Wireless Location System ceases location processing, causes an alert message that location processing failed because the wireless transmitter changed transmission status during the period of time in which RF data was being received, and re-triggers this entire process;

location processing on the received RF data completes in accordance with the steps described below.

The determination of the information elements including cell site, sector, RF channel, timeslot, long code mask, and encryption key (all information elements may not be necessary for all air interface protocols) is typically obtained by the Wireless Location System through a command / response interface between the Wireless Location System and the wireless communications system.

The use of the narrowband receiver in the manner described above is known as random tuning because the receivers can be directed to any RF channel on command from the system. One advantage to random tuning is that locations are processed only for those wireless transmitters for which the Wireless Location System is triggered. One disadvantage to random tuning is that various synchronization factors, including the interface between the wireless communications system and the Wireless Location System and the latency times in scheduling the necessary receivers throughout the system, can limit the total location processing throughput. For example, in a TDMA system, random tuning used throughout the

Wireless Location System will typically limit location processing throughput to about 2.5 locations per second per cell site sector.

Therefore, the narrowband receiver also supports another mode, known as automatic sequential tuning, which can perform location processing at a higher throughput. For example, in a TDMA system, using similar assumptions about dwell time and setup time as for the narrowband receiver operation described above, sequential tuning can achieve a location processing throughput of about 41 locations per second per cell site sector, meaning that all 395 TDMA RF channels can be processed in about 9 seconds. This increased rate can be achieved by taking advantage of, for example, the two contiguous RF channels that can be received simultaneously, location processing all three TDMA timeslots in an RF channel, and eliminating the need for synchronization with the wireless communications system. When the Wireless Location System is using the narrowband receivers for sequential tuning, the Wireless Location System has no knowledge of the identity of the wireless transmitter because the Wireless Location System does not wait for a trigger, nor does the Wireless Location System query the wireless communications system for the identity information prior to receiving the transmission. In this method, the Wireless Location System sequences through every cell site, RF channel and time slot, performs location processing, and reports a location record identifying a time stamp, cell site, RF channel, time slot, and location. Subsequent to the location record report, the Wireless Location System and the wireless communications system match the location records to the wireless communications system's data indicating which wireless transmitters were in use at the time, and which cell sites, RF channels, and time slots were used by each wireless transmitter. Then, the Wireless Location System can retain the location records for wireless transmitters of interest, and discard those location records for the remaining wireless transmitters.

Digital Signal Processor Module 10-3

The SCS digital receiver modules 10-2 output a digitized RF data stream having a specified bandwidth and bit resolution. For example, a 15 MHz embodiment of the wideband receiver may output a data stream containing 60 million samples per second, at a resolution of 14 bits per sample. This RF data stream will contain all of the RF channels that are used by the wireless communications system. The DSP modules 10-3 receive the digitized data stream, and can extract any individual RF channel through digital mixing and filtering. The DSP's can also reduce the bit resolution upon command from the Wireless Location System, as needed to reduce the bandwidth requirements between the SCS 10 and TLP 12. The Wireless Location System can dynamically select the bit resolution at which to forward digitized baseband RF data, based upon the processing requirements for each location. DSP's are used for these functions to reduce the systemic errors that can occur from mixing and filtering with analog components. The use of DSP's allows perfect matching in the processing between any two SCS's 10.

A block diagram of the DSP module 10-3 is shown is Figure 2D, and the operation of the DSP module is depicted by the flowchart of Figure 2E. As shown in Figure 2D, the DSP module 10-3 comprises the following elements: a pair of DSP elements 10-3-1A and 10-3-1B, referred to collectively as a "first" DSP; serial to parallel converters 10-3-2; dual port memory elements 10-3-3; a second DSP 10-3-4; a parallel to serial converter; a FIFO buffer; a DSP 10-3-5 (including RAM) for detection, another DSP 10-3-6 for demodulation, and another DSP 10-3-7 for normalization and control; and an address generator 10-3-8. In a presently preferred embodiment, the DSP module 10-3 receives the wideband digitized data stream (Figure 2E, step S1), and uses the first DSP (10-3-1A and 10-3-1B) to extract blocks of channels (step S2). For example, a first DSP programmed to operate as a digital drop receiver can extract four blocks of channels, wherein each block includes at least 1.25 MHz of bandwidth. This bandwidth can include 42 channels of AMPS or TDMA, 6 channels of GSM, or 1 channel of CDMA. The DSP does not require the blocks to be contiguous, as the DSP can independently digitally tune to any set of RF channels within the bandwidth of the wideband digitized data stream. The DSP can also perform wideband or narrow band energy detection on all or any of the channels in the block, and report the power levels by channel to the TLP 12 (step S3). For example, every 10 ms, the DSP can perform wideband energy detection and create an RF spectral map for all channels for all receivers (see step S9). Because this spectral map can be sent from the SCS 10 to the TLP 12 every 10 ms via the communications link connecting the SCS 10 and the TLP 12, a significant data overhead could exist. Therefore, the DSP reduces the data overhead by companding the data into a finite number of levels. Normally, for example, 84 dB of dynamic range could require 14 bits. In the companding process implemented by the DSP, the data is reduced, for example, to only 4 bits by selecting 16 important RF spectral levels to send to the TLP 12. The choice of the number of levels, and therefore the number of bits, as well as the representation of the levels, can be automatically adjusted by the Wireless Location System. These adjustments are performed to maximize the information value of the RF spectral messages sent to the TLP 12 as well as to optimize the use of the bandwidth available on the communications link between the SCS 10 and the TLP 12.

After conversion, each block of RF channels (each at least 1.25 MHz) is passed through serial to parallel converter 10-3-2 and then stored in dual port digital memory 10-3-3 (step S4). The digital memory is a circular memory, which means that the DSP module begins writing data into the first memory address and then continues sequentially until the last memory address is reached. When the last memory address is reached, the DSP returns to the first memory address and continues to sequentially write data into memory. Each DSP module typically contains enough memory to store several seconds of data for each block of RF channels to support the latency and queuing times in the location process.

In the DSP module, the memory address at which digitized and converted RF data is written into memory is the time stamp used throughout the Wireless Location System and which the location processing references in determining TDOA. In order to ensure that the time stamps are aligned at every SCS 10 in the Wireless Location System, the address generator 10-3-8 receives the one pulse per second signal from the timing generation/clock distribution module 10-7 (Figure 2). Periodically, the address generator at all SCS's 10 in a Wireless Location System will simultaneously reset themselves to a known address. This enables the location processing to reduce or eliminate accumulated timing errors in the recording of time stamps for each digitized data element.

The address generator 10-3-8 controls both writing to and reading from the dual port digital memory 10-3-3. Writing takes places continuously since the ADC is continuously sampling and digitizing RF signals and the first DSP (10-3-1A and 10-3-1B) is continuously performing the digital drop receiver function. However, reading occurs in bursts as the Wireless Location System requests data for performing demodulation and location processing. The Wireless Location System may even perform location processing recursively on a single transmission, and therefore requires access to the same data multiple times. In order to service the many requirements of the Wireless Location System, the address generator allows the dual port digital memory to be read at a rate faster than the writing occurs. Typically, reading can be performed eight times faster than writing.

The DSP module 10-3 uses the second DSP 10-3-4 to read the data from the digital memory 10-3-3, and then performs a second digital drop receiver function to extract baseband data from the blocks of RF channels (step S5). For example, the second DSP can extract any single 30 KHz AMPS or TDMA channel from any block of RF channels that have been digitized and stored in the memory. Likewise, the second DSP can extract any single GSM channel. The second DSP is not required to extract a CDMA channel, since the channel bandwidth occupies the full bandwidth of the stored RF data. The combination of the first DSP 10-3-1A, 10-3-1B and the second DSP 10-3-4 allows the DSP module to select, store, and recover any single RF channel in a wireless communications system. A DSP module typically will store four blocks of channels. In a dual-mode AMPS/TDMA system, a single DSP module can continuously and simultaneously monitor up to 42 analog reverse control channels, up to 84 digital control channels, and also be tasked to monitor and locate any voice channel transmission. A single SCS chassis will typically support up to three receiver modules 10-2 (Figure 2), to cover three sectors of two antennas each, and up to nine DSP modules (three DSP modules per receiver permits an entire 15 MHz bandwidth to be simultaneously stored into digital memory). Thus, the SCS 10 is a very modular system than can be easily scaled to match any type of cell site configuration and processing load.

The DSP module 10-3 also performs other functions, including automatic detection of active channels used in each sector (step S6), demodulation (step S7), and station based location processing (step S8). The Wireless Location System maintains an active map of the usage of the RF channels in a wireless communications system (step S9), which enables the Wireless Location System to manage receiver and processing resources, and to rapidly initiate processing when a particular transmission of interest has occurred. The active map comprises a table maintained within the Wireless Location System that lists for each antenna connected to an SCS 10 the primary channels assigned to that SCS 10 and the protocols used in those channels. A primary channel is an RF control channel assigned to a collocated or nearby base station which the base station uses for communications with wireless transmitters. For example, in a typical cellular system with sectored cell sites, there will be one RF control channel frequency assigned for use in each sector. Those control channel frequencies would typically be assigned as primary channels for a collocated SCS 10.

The same SCS 10 may also be assigned to monitor the RF control channels of other nearby base stations as primary channels, even if other SCS's 10 also have the same primary channels assigned. In this manner, the Wireless Location System implements a system demodulation redundancy that ensures that any given wireless transmission has an infinitesimal probability of being missed. When this demodulation redundancy feature is used, the Wireless Location System will receive, detect, and demodulate the same wireless transmission two or more times at more than one SCS 10. The Wireless Location System includes means to detect when this multiple demodulation has occurred and to trigger location processing only once. This function conserves the processing and communications resources of the Wireless Location System, and is further described below. This ability for a single SCS 10 to detect and demodulate wireless transmissions occurring at cell sites not collocated with the SCS 10 permits operators of the Wireless Location System to deploy more efficient Wireless Location System networks. For example, the Wireless Location System may be designed such that the Wireless Location System uses much fewer SCS's 10 than the wireless communications system has base stations.

In the Wireless Location System, primary channels are entered and maintained in the table using two methods: direct programming and automatic detection. Direct programming comprises entering primary channel data into the table using one of the Wireless Location System user interfaces, such as the Network Operations Console 16 (Figure 1), or by receiving channel assignment data from the Wireless Location System to wireless communications system interface. Alternatively, the DSP module 10-3 also runs a background process known as automatic detection in which the DSP uses spare or scheduled processing capacity to detect transmissions on various possible RF channels and then attempt to demodulate those transmissions using probable protocols. The DSP module can then confirm that the primary channels directly programmed are correct, and can also quickly detect changes made to channels at base station and send an alert to the operator of the Wireless Location System.

The DSP module performs the following steps in automatic detection (see Figure 2E-1):

- for each possible control and/or voice channel which may be used in the coverage area of the SCS 10, peg counters are established (step S7-1);
- at the start of a detection period, all peg counters are reset to zero (step S7-2);
- each time that a transmission occurs in a specified RF channel, and the received power level is above a particular pre-set threshold, the peg counter for that channel is incremented (step S7-3);
- each time that a transmission occurs in a specified RF channel, and the received power level is above a second particular pre-set threshold, the DSP module attempts to demodulate a certain portion of the transmission using a first preferred protocol (step S7-4);
- if the demodulation is successful, a second peg counter for that channel is incremented (step S7-5);
- if the demodulation is unsuccessful, the DSP module attempts to demodulate a portion of the transmission using a second preferred protocol (step S7-6);
- if the demodulation is successful, a third peg counter for that channel is incremented (step S7-7);
- at the end of a detection period, the Wireless Location System reads all peg counters (step S7-8); and
- the Wireless Location System automatically assigns primary channels based upon the peg counters (step S7-9).

The operator of the Wireless Location System can review the peg counters and the automatic assignment of primary channels and demodulation protocols, and override any settings that were performed automatically. In addition, if more than two preferred protocols may be used by the wireless carrier, then the DSP module 10-3 can be downloaded with software to detect the additional protocols. The architecture of the SCS 10, based upon wideband receivers 10-2, DSP modules 10-3, and downloadable software permits the Wireless Location System to support multiple demodulation protocols in a single system. There is a significant cost advantage to supporting multiple protocols within the single system, as only a single SCS 10 is required at a cell site. This is in contrast to many base station architectures, which may require different transceiver modules for different modulation protocols. For example, while the SCS 10 could support AMPS, TDMA, and CDMA simultaneously in the same SCS 10, there is no base station currently available that can support this functionality.

The ability to detect and demodulate multiple protocols also includes the ability to independently detect the use of authentication in messages transmitted over the certain air interface protocols. The use of authentication fields in wireless transmitters started to become prevalent within the last few years as a means to reduce the occurrence of fraud in wireless communications systems. However, not all wireless transmitters have implemented authentication. When authentication is used, the protocol generally inserts an additional field into the transmitted message. Frequently this field is inserted between the identity of the wireless transmitter and the dialed digits in the transmitted message. When demodulating a wireless transmission, the Wireless Location System determines the number of fields in the transmitted message, as well as the message type (i.e. registration, origination, page response, etc.). The Wireless Location System demodulates all fields and if extra fields appear to be present, giving consideration to the type of message transmitted, then the Wireless Location System tests all fields for a trigger condition. For example, if the dialed digits "911" appear in the proper place in a field, and the field is located either in its proper place without authentication or its proper place with authentication, then the Wireless Location System triggers normally. In this example, the digits "911" would be required to appear in sequence as "911" or "*911", with no other digits before or after either sequence. This functionality reduces or eliminates a false trigger caused by the digits "911" appearing as part of an authentication field.

The support for multiple demodulation protocols is important for the Wireless Location System to successfully operate because location processing must be quickly triggered when a wireless caller has dialed "911". The Wireless Location System can trigger location processing using two methods: the Wireless Location System will independently demodulate control channel transmissions, and trigger location processing using any number of criteria such as dialed digits, or the Wireless Location System may receive triggers from an external source such as the carrier's wireless communications system. The present inventors have found that independent demodulation by the SCS 10 results in the fastest time to trigger, as measured from the moment that a wireless user presses the "SEND" or "TALK" (or similar) button on a wireless transmitter.

Control and Communications Module 10-5

The control and communications module 10-5, depicted in Figure 2F, includes data buffers 10-5-1, a controller 10-5-2, memory 10-5-3, a CPU 10-5-4 and a T1/E1 communications chip 10-5-5. The module has many of the characteristics previously described in Patent Number 5,608,410. Several enhancements have been added in the present embodiment. For example, the SCS 10 now includes an automatic remote reset capability, even if the CPU on the control and communications module ceases to execute its programmed software. This capability can reduce the operating costs of the Wireless Location System because technicians are not required to travel to a cell site to reset an SCS 10 if it fails to operate normally. The automatic remote reset circuit operates by monitoring the communications interface between the SCS 10 and the TLP 12 for a particular sequence of bits. This sequence of bits is a sequence that does not occur during normal communications between the SCS 10 and the TLP 12. This sequence, for example, may consist of an all ones pattern. The reset circuit operates independently of the CPU so that even if the CPU has placed itself in a locked or other non-operating status, the circuit can still achieve the reset of the SCS 10 and return the CPU to an operating status.

This module now also has the ability to record and report a wide variety of statistics and variables used in monitoring or diagnosing the performance of the SCS 10. For example, the SCS 10 can monitor the percent capacity usage of any DSP or other processor in the SCS 10, as well as the communications interface between the SCS 10 and the TLP 12. These values are reported regularly to the AP 14 and the NOC 16, and are used to determine when additional processing and communications resources are required in the system. For example, alarm thresholds may be set in the NOC to indicate to an operator if any resource is consistently exceeding a preset threshold. The SCS 10 can also monitor the number of times that transmissions have been successfully demodulated, as well as the number of failures. This is useful in allowing operators to determine whether the signal thresholds for demodulation have been set optimally.

This module, as well as the other modules, can also self-report its identity to the TLP 12. As described below, many SCS's 10 can be connected to a single TLP 12. Typically, the communications between SCS's 10 and TLP's 12 is shared with the communications between base stations and MSC's. It is frequently difficult to quickly determine exactly which SCS's 10 have been assigned to particular circuits. Therefore, the SCS 10 contains a hard coded identity, which is recorded at the time of installation. This identity can be read and verified by the TLP 12 to positively determine which SCS 10 has been assigned by a carrier to each of several different communications circuits.

The SCS to TLP communications supports a variety of messages, including: commands and responses, software download, status and heartbeat, parameter download, diagnostic, spectral data, phase data, primary channel demodulation, and RF data. The communications protocol is designed to optimize Wireless Location System operation by minimizing the protocol overhead and the protocol includes a message priority scheme. Each message type is assigned a priority, and the SCS 10 and the TLP 12 will queue messages by priority such that a higher priority message is sent before a lower priority message is sent. For example, demodulation messages are generally set at a high priority because the Wireless Location System must trigger location processing on certain types of calls (i.e., E9-1-1) without delay. Although higher priority messages are queued before lower priority messages, the protocol generally does not preempt a message that is already in transit. That is, a message in the process of being sent across the SCS 10 to TLP 12 communications interface will be completed fully, but then the next message to be sent will be the highest priority message with the earliest time stamp. In order to minimize the latency of high priority messages, long messages, such as RF data, are sent in segments. For example, the RF data for a full 100-millisecond AMPS transmission may be separated into 10-millisecond segments. In this manner, a high priority message may be queued in between segments of the RF data.

Calibration and Performance Monitoring

The architecture of the SCS 10 is heavily based upon digital technologies including the digital receiver and the digital signal processors. Once RF signals have been digitized, timing, frequency, and phase differences can be carefully controlled in the various processes. More importantly, any timing, frequency, and phase differences can be perfectly matched between the various receivers and various SCS's 10 used in the Wireless Location System. However, prior to the ADC, the RF signals pass through a number of RF components, including antennas, cables, low noise amplifiers, filters, duplexors, multi-couplers, and RF splitters. Each of these RF components has characteristics important to the Wireless Location System, including delay and phase versus frequency response. When the RF and analog components are perfectly matched between the pairs of SCS's 10, such as SCS 10A and SCS 10B in Figure 2G, then the effects of these characteristics are automatically eliminated in the location processing. But when the characteristics of the components are not matched, then the location processing can inadvertently include instrumental errors resulting from the mismatch. Additionally, many of these RF components can experience instability with power, time, temperature, or other factors that can add instrumental errors to the determination of location. Therefore, several inventive techniques have been developed to calibrate the RF components in the Wireless Location System and to monitor the performance of the Wireless Location System on a regular basis. Subsequent to calibration, the Wireless Location System stores the values of these delays and phases versus frequency response (i.e. by RF channel number) in a table in the Wireless Location System for use in correcting these instrumental errors. Figures 2G-2J are referred to below in explaining these calibration methods.

External Calibration Method

Referring to Figure 2G, the timing stability of the Wireless Location System is measured along baselines, wherein each baseline is comprised of two SCS's, 10A and 10B, and an imaginary line (A - B) drawn between them. In a TDOA / FDOA type of Wireless Location System, locations of wireless transmitters are calculated by measuring the differences in the times that each SCS 10 records for the arrival of the signal from a wireless transmitter. Thus, it is important that the differences in times measured by SCS's 10 along any baseline are largely attributed to the transmission time of the signal from the wireless transmitter and minimally attributed to the variations in the RF and analog components of the SCS's 10 themselves. To meet the accuracy goals of the Wireless Location System, the timing stability for any pair of SCS's 10 are maintained at much less than 100 nanoseconds RMS (root mean square). Thus, the components of the Wireless Location System will contribute less than 100 feet RMS of instrumentation error in the estimation of the location of a wireless transmitter. Some of this error is allocated to the ambiguity of the signal used to calibrate the system. This ambiguity can be determined from the well-known Cramer-Rao lower bound equation. In the case of an AMPS reverse control channel, this error is approximately 40 nanoseconds RMS. The remainder of the error budget is allocated to the components of the Wireless Location System, primarily the RF and analog components in the SCS 10.

In the external calibration method, the Wireless Location System uses a network of calibration transmitters whose signal characteristics match those of the target wireless transmitters. These calibration transmitters may be ordinary wireless telephones emitting periodic registration signals and/or page response signals. Each usable SCS-to-SCS baseline is preferably calibrated periodically using a calibration transmitter that has a relatively clear and unobstructed path to both SCS's 10 associated with the baseline. The calibration signal is processed identically to a signal from a target wireless transmitter. Since the TDOA values are known *a priori*, any errors in the calculations are due to systemic errors in the Wireless Location System. These systemic errors can then be removed in the subsequent location calculations for target transmitters.

Figure 2G illustrates the external calibration method for minimizing timing errors. As shown, a first SCS 10A at a point "A" and a second SCS 10A at a point "B" have an associated baseline A-B. A calibration signal emitted at time T_0 by a calibration transmitter at point "C" will theoretically reach first SCS 10A at time $T_0 + T_{AC}$. T_{AC} is a measure of the amount of time required for the calibration signal to travel from the antenna on the calibration transmitter to the dual port digital memory in a digital receiver. Likewise, the same calibration signal will reach second SCS 10B at a theoretical time $T_0 + T_{BC}$. Usually, however, the calibration signal will not reach the digital memory and the digital signal processing components of the respective SCS's 10 at exactly the correct times. Rather, there will be errors e1 and e2 in the amount of time (T_{AC}, T_{BC}) it takes the calibration signal to propagate from the calibration transmitter to the SCS's 10, respectively, such that the exact times of arrival are actually $T_0 + T_{AC} + e1$ and $T_0 + T_{BC} + e2$. Such errors will be due to some extent to delays in the signal propagation through the air, i.e., from the calibration transmitter's antenna to the SCS antennas; however, the errors will be due primarily to time varying characteristics in the SCS front end components. The errors e1 and e2 cannot be determined *per se* because the system does not know the exact time (T_0) at which the calibration signal was transmitted. The system can, however, determine the error in the *difference* in the time of arrival of the calibration signal at the respective SCS's 10 of any given pair of SCS's 10. This TDOA error value is defined as the difference between the measured TDOA value and the theoretical TDOA value τ_0, wherein τ_0 is the theoretical differences between the theoretical delay values T_{AC} and T_{BC}. Theoretical TDOA values for each pair of SCS's 10 and each calibration transmitter are known because the positions of the SCS's 10 and calibration transmitter, and the speed at which the calibration signal propagates, are known. The measured TDOA baseline ($TDOA_{A-B}$) can be represented as $TDOA_{A-B} = \tau_0 + \in$, wherein $\in = e1 - e2$. In a similar manner, a calibration signal from a second calibration transmitter at point "D" will have associated errors e3 and e4. The ultimate value of $\in$ to be subtracted from TDOA measurements for a target transmitter will be a function (e.g., weighted average) of the $\in$ values derived for one or more calibration transmitters. Therefore, a given TDOA measurement ($TDOA_{measured}$) for a pair of SCS's 10 at points "X" and "Y" and a target wireless transmitter at an unknown location will be corrected as follows:

$$TDOA_{X-Y} = TDOA_{measured} - \in$$

$$\in = k1\in1 + k2\in2 + \ldots. kN\in N,$$

where k1, k2, etc., are weighting factors and ∈1, ∈2, etc., are the errors determined by subtracting the measured TDOA values from the theoretical values for each calibration transmitter. In this example, error value ∈1 may the error value associated with the calibration transmitter at point "C" in the drawing. The weighting factors are determined by the operator of the Wireless Location System, and input into the configuration tables for each baseline. The operator will take into consideration the distance from each calibration transmitter to the SCS's 10 at points "X" and "Y", the empirically determined line of sight from each calibration transmitter to the SCS's 10 at points "X" and "Y", and the contribution that each SCS "X" and "Y" would have made to a location estimate of a wireless transmitter that might be located in the vicinity of each calibration transmitter. In general, calibration transmitters that are nearer to the SCS's 10 at points "X" and "Y" will be weighted higher than calibration transmitters that are farther away, and calibration transmitters with better line of sight to the SCS's 10 at points "X" and "Y" will be weighted higher than calibration transmitters with worse line of sight.

Each error component e1, e2, etc., and therefore the resulting error component ∈, can vary widely, and wildly, over time because some of the error component is due to multipath reflection from the calibration transmitter to each SCS 10. The multipath reflection is very much path dependent and therefore will vary from measurement to measurement and from path to path. It is not an object of this method to determine the multipath reflection for these calibration paths, but rather to determine the portion of the errors that are attributable to the components of the SCS's 10. Typically, therefore, error values e1 and e3 will have a common component since they relate to the same first SCS 10A. Likewise, error values e2 and e4 will also have a common component since they relate to the second SCS 10B. It is known that while the multipath components can vary wildly, the component errors vary slowly and typically vary sinusoidally. Therefore, in the external calibration method, the error values ∈ are filtered using a weighted, time-based filter that decreases the weight of the wildly varying multipath components while preserving the relatively slow changing error components attributed to the SCS's 10. One such exemplary filter used in the external calibration method is the Kalman filter.

The period between calibration transmissions is varied depending on the error drift rates determined for the SCS components. The period of the drift rate should be much longer than the period of the calibration interval. The Wireless Location System monitors the period of the drift rate to determine continuously the rate of change, and may periodically adjust the calibration interval, if needed. Typically, the calibration rate for a Wireless Location System such as one in accordance with the present invention is between 10 and 30 minutes. This corresponds well with the typical time period for the registration rate in a wireless communications system. If the Wireless Location System were to determine that the calibration interval must be adjusted to a rate faster than the registration rate of the wireless communications system, then the AP 14 (Figure 1) would automatically force the calibration transmitter to transmit by paging the transmitter at the prescribed interval. Each calibration transmitter is individually addressable and therefore the calibration interval associated with each calibration transmitter can be different.

Since the calibration transmitters used in the external calibration method are standard telephones, the Wireless Location System must have a mechanism to distinguish those telephones from the other wireless transmitters that are being located for various application purposes. The Wireless Location System maintains a list of the identities of the calibration transmitters, typically in the TLP 12 and in the AP 14. In a cellular system, the identity of the calibration transmitter can be the Mobile Identity Number, or MIN. When the calibration transmitter makes a transmission, the transmission is received by each SCS 10 and demodulated by the appropriate SCS 10. The Wireless Location System compares the identity of the transmission with a pre-stored tasking list of identities of all calibration transmitters. If the Wireless Location System determines that the transmission was a calibration transmission, then the Wireless Location System initiates external calibration processing.

Internal Calibration Method

In addition to the external calibration method, it is an object of the present invention to calibrate all channels of the wideband digital receiver used in the SCS 10 of a Wireless

Location System. The external calibration method will typically calibrate only a single channel of the multiple channels used by the wideband digital receiver. This is because the fixed calibration transmitters will typically scan to the highest-power control channel, which will typically be the same control channel each time. The transfer function of a wideband digital receiver, along with the other associated components, does not remain perfectly constant, however, and will vary with time and temperature. Therefore, even though the external calibration method can successfully calibrate a single channel, there is no assurance that the remaining channels will also be calibrated.

The internal calibration method, represented in the flowchart of Figure 2H, is particularly suited for calibrating an individual first receiver system (i.e., SCS 10) that is characterized by a time- and frequency-varying transfer function, wherein the transfer function defines how the amplitude and phase of a received signal will be altered by the receiver system and the receiver system is utilized in a location system to determine the location of a wireless transmitter by, in part, determining a difference in time of arrival of a signal transmitted by the wireless transmitter and received by the receiver system to be calibrated and another receiver system, and wherein the accuracy of the location estimate is dependent, in part, upon the accuracy of TDOA measurements made by the system. An example of a AMPS RCC transfer function is depicted in Figure 2I, which depicts how the phase of the transfer function varies across the 21 control channels spanning 630 KHz.

Referring to Figure 2H, the internal calibration method includes the steps of temporarily and electronically disconnecting the antenna used by a receiver system from the receiver system (step S-20); injecting an internally generated wideband signal with known and stable signal characteristics into the first receiver system (step S-21); utilizing the generated wideband signal to obtain an estimate of the manner in which the transfer function varies across the bandwidth of the first receiver system (step S-22); and utilizing the estimate to mitigate the effects of the variation of the first transfer function on the time and frequency measurements made by the first receiver system (step S-23). One example of a stable wideband signal used for internal calibration is a comb signal, which is comprised of multiple individual, equal-amplitude frequency elements at a known spacing, such as 5 KHz. An example of such a signal is shown in Figure 2I.

The antenna must be temporarily disconnected during the internal calibration process to prevent external signals from entering the wideband receiver and to guarantee that the receiver is only receiving the stable wideband signal. The antenna is electronically disconnected only for a few milliseconds to minimize the chance of missing too much of a signal from a wireless transmitter. In addition, internal calibration is typically performed immediately after external calibration to minimize the possibility that the any component in the SCS 10 drifts during the interval between external and internal calibration. The antenna is disconnected from the wideband receiver using two electronically controlled RF relays (not shown). An RF relay cannot provide perfect isolation between input and output even when in the "off" position, but it can provide up to 70 dB of isolation. Two relays may be used in series to increase the amount of isolation and to further assure that no signal is leaked from the antenna to the wideband receiver during calibration. Similarly, when the internal calibration function is not being used, the internal calibration signal is turned off, and the two RF relays are also turned off to prevent leakage of the internal calibration signals into the wideband receiver when the receiver is collecting signals from wireless transmitters.

The external calibration method provides an absolute calibration of a single channel and the internal calibration method then calibrates each other channel relative to the channel that had been absolutely calibrated. The comb signal is particularly suited as a stable wideband signal because it can be easily generated using a stored replica of the signal and a digital to analog converter.

External Calibration Using Wideband Calibration Signal

The external calibration method described next may be used in connection with an SCS 10 receiver system characterized by a time- and frequency-varying transfer function, which preferably includes the antennas, filters, amplifiers, duplexors, multi-couplers, splitters, and cabling associated with the SCS receiver system. The method includes the step of transmitting a stable, known wideband calibration signal from an external transmitter. The wideband calibration signal is then used to estimate the transfer function across a prescribed bandwidth of the SCS receiver system. The estimate of the transfer function is subsequently employed to mitigate the effects of variation of the transfer function on subsequent TDOA/FDOA measurements. The external transmission is preferably of short duration and low power to avoid interference with the wireless communications system hosting the Wireless Location System.

In the preferred method, the SCS receiver system is synchronized with the external transmitter. Such synchronization may be performed using GPS timing units. Moreover, the receiver system may be programmed to receive and process the entire wideband of the calibration signal only at the time that the calibration signal is being sent. The receiver system will not perform calibration processing at any time other than when in synchronization with the external calibration transmissions. In addition, a wireless communications link is used between the receiver system and the external calibration transmitter to exchange commands and responses. The external transmitter may use a directional antenna to direct the wideband signal only at the antennas of the SCS receiver system. Such as directional antenna may be a Yagi antenna (i.e. linear end-fire array). The calibration method preferably includes making the external transmission only when the directional antenna is aimed at the receiver system's antennas and the risk of multipath reflection is low.

Calibrating for Station Biases

Another aspect of the present invention concerns a calibration method to correct for station biases in a SCS receiver system. The "station bias" is defined as the finite delay between when an RF signal from a wireless transmitter reaches the antenna and when that same signal reached the wideband receiver. The inventive method includes the step of measuring the length of the cable from the antennas to the filters and determining the corresponding delays associated with the cable length. In addition, the method includes injecting a known signal into the filter, duplexor, multi-coupler, or RF splitter and measuring the delay and phase response versus frequency response from the input of each device to the wideband receiver. The delay and phase values are then combined and used to correct subsequent location measurements. When used with the GPS based timing generation described above, the method preferably includes correcting for the GPS cable lengths. Moreover, an externally generated reference signal is preferably used to monitor changes in station bias that may arise due to aging and weather. Finally, the station bias by RF channel and for each receiver system in the Wireless Location System is preferably stored in tabular form in the Wireless Location System for use in correcting subsequent location processing.

Performance Monitoring

The Wireless Location System uses methods similar to calibration for performance monitoring on a regular and ongoing basis. These methods are depicted in the flowcharts of Figure 2K and 2L. Two methods of performance monitoring are used: fixed phones and drive testing of surveyed points. The fixed phone method comprises the following steps (see Figure 2K):

standard wireless transmitters are permanently placed at various points within the coverage area of the Wireless Location System (these are then known as the fixed phones) (step S-30);

the points at which the fixed phones have been placed are surveyed so that their location is precisely known to within a predetermined distance, for example ten feet (step S-31);

the surveyed locations are stored in a table in the AP 14 (step S-32);

the fixed phones are permitted to register on the wireless communications system, at the rate and interval set by the wireless communications system for all wireless transmitters on the system (step S-33);

at each registration transmission by a fixed phone, the Wireless Location System locates the fixed phone using normal location processing (as with the calibration transmitters, the Wireless Location System can identify a transmission as being from a fixed phone by storing the identities in a table) (step S-34);

the Wireless Location System computes an error between the calculated location determined by the location processing and the stored location determined by survey (step S-35);

the location, the error value, and other measured parameters are stored along with a time stamp in a database in the AP 14 (step S-36);

the AP 14 monitors the instant error and other measured parameters (collectively referred to as an extended location record) and additionally computes various statistical values of the error(s) and other measured parameters (step S-37); and

if any of the error or other values exceed a pre-determined threshold or a historical statistical value, either instantaneously or after performing statistical filtering over a prescribed number of location estimates, the AP 14 signals an alarm to the operator of the Wireless Location System (step S-38).

The extended location record includes a large number of measured parameters usefully for analyzing the instant and historical performance of the Wireless Location System. These parameters include: the RF channel used by the wireless transmitter, the antenna port(s) used by the Wireless Location System to demodulate the wireless transmission, the antenna ports from which the Wireless Location System requested RF data, the peak, average, and variance in power of the transmission over the interval used for location processing, the SCS 10 and antenna port chosen as the reference for location processing, the correlation value from the cross-spectra correlation between every other SCS 10 and antenna used in location processing and the reference SCS 10 and antenna, the delay value for each baseline, the multipath mitigation parameters, and the residual values remaining after the multipath mitigation calculations. Any of these measured parameters can be monitored by the Wireless Location System for the purpose of determining how the Wireless Location System is performing. One example of the type of monitoring performed by the Wireless Location System may be the variance between the instant value of the correlation on a baseline and the historical range of the correlation value. Another may be the variance between the instant value of the received power at a particular antenna and the historical range of the received power. Many other statistical values can be calculated and this list is not exhaustive.

The number of fixed phones placed into the coverage area of the Wireless Location System can be determined based upon the density of the cell sites, the difficulty of the terrain, and the historical ease with which wireless communications systems have performed in the area. Typically the ratio is about one fixed phone for every six cell sites, however in some areas a ratio of one to one may be required. The fixed phones provide a continuous means to monitor the performance of the Wireless Location System, as well as the monitor any changes in the frequency plan that the carrier may have made. Many times, changes in the frequency plan will cause a variation in the performance of the Wireless Location System and the performance monitoring of the fixed phones provide an immediate indication to the Wireless Location System operator.

Drive testing of surveyed points is very similar to the fixed phone monitoring. Fixed phones typically can only be located indoors where access to power is available (i.e. the phones must be continuously powered on to be effective). To obtain a more complete measurement of the performance of the location performance, drive testing of outdoor test points is also performed. Referring to Figure 2L, as with the fixed phones, prescribed test points throughout the coverage area of the Wireless Location System are surveyed to within ten feet (step S-40). Each test point is assigned a code, wherein the code consists of either a "*" or a "#", followed by a sequence number (step S-41). For example, "*1001" through "*1099" may be a sequence of 99 codes used for test points. These codes should be sequences, that when dialed, are meaningless to the wireless communications system (i.e. the codes do not cause a feature or other translation to occur in the MSC, except for an intercept message). The AP 14 stores the code for each test point along with the surveyed location (step S-42). Subsequent to these initial steps, any wireless transmitter dialing any of the codes will be triggered and located using normal location processing (steps S-43 and S-44). The Wireless Location System automatically computes an error between the calculated location determined by the location processing and the stored location determined by survey, and the location and the error value are stored along with a time stamp in a database in the AP 14 (steps S-45 and S-46). The AP 14 monitors the instant error, as well as various historical statistical values of the error. If the error values exceed a pre-determined threshold or a historical statistical value, either instantaneously or after performing statistical filtering over a prescribed number of location estimates, the AP 14 signals an alarm to the operator of the Wireless Location System (step S-47).

TDOA Location Processor (TLP)

The TLP 12, depicted in Figures 1, 1A and 3, is a centralized digital signal processing system that manages many aspects of the Wireless Location System, especially the SCS's 10, and provides control over the location processing. Because location processing is DSP intensive, one of the major advantages of the TLP 12 is that the DSP resources can be shared among location processing initiated by transmissions at any of the SCS's 10 in a Wireless Location System. That is, the additional cost of DSP's at the SCS's 10 is reduced by having the resource centrally available. As shown in Figure 3, there are three major components of the TLP 12: DSP modules 12-1, T1/E1 communications modules 12-2 and a controller module 12-3.

The T1/E1 communications modules 12-2 provide the communications interface to the SCS's 10 (T1 and E1 are standard communications speeds available throughout the world). Each SCS 10 communicates to a TLP 12 using one or more DS0's (which are typically 56Kbps or 64 Kbps). Each SCS 10 typically connects to a fractional T1 or E1 circuit, using, e.g., a drop and insert unit or channel bank at the cell site. Frequently, this circuit is shared with the base station, which communicates with the MSC. At a central site, the DS0's assigned to the base station are separated from the DS0's assigned to the SCS's 10. This is typically accomplished external to the TLP 12 using a digital access and control system (DACS) 13A that not only separates the DS0's but also grooms the DS0's from multiple SCS's 10 onto full T1 or E1 circuits. These circuits then connect from the DACS 13A to the DACS 13B and then to the T1/E1 communications module on the TLP 12. Each T1/E1 communications module contains sufficient digital memory to buffer packets of data to and from each SCS 10 communicating with the module. A single TLP chassis may support one or more T1/E1 communications modules.

The DSP modules 12-1 provide a pooled resource for location processing. A single module may typically contain two to eight digital signal processors, each of which are equally available for location processing. Two types of location processing are supported: central based and station based, which are described in further detail below. The TLP controller 12-3 manages the DSP module(s) 12-1 to obtain optimal throughput. Each DSP module contains sufficient digital memory to store all of the data necessary for location processing. A DSP is not engaged until all of the data necessary to begin location processing has been moved from each of the involved SCS's 10 to the digital memory on the DSP module. Only then is a DSP given the specific task to locate a specific wireless transmitter. Using this technique, the DSP's , which are an expensive resource, are never kept waiting. A single TLP chassis may support one or more DSP modules.

The controller module 12-3 provides the real time management of all location processing within the Wireless Location System. The AP 14 is the top-level management entity within the Wireless Location System, however its database architecture is not sufficiently fast to conduct the real time decision making when transmissions occur. The controller module 12-3 receives messages from the SCS's 10, including: status, spectral energy in various channels for various antennas, demodulated messages, and diagnostics. This enables the controller to continuously determine events occurring in the Wireless Location System, as well as to send commands to take certain actions. When a controller module receives demodulated messages from SCS's 10, the controller module decides whether location processing is required for a particular wireless transmission. The controller module 12-3 also determines which SCS's 10 and antennas to use in location processing, including whether to use central based or station based location processing. The controller module commands SCS's 10 to return the necessary data, and commands the communications modules and DSP modules to sequentially perform their necessary roles in location processing. These steps are described below in further detail.

The controller module 12-3 maintains a table known as the Signal of Interest Table (SOIT). This table contains all of the criteria that may be used to trigger location processing on a particular wireless transmission. The criteria may include, for example, the Mobile Identity Number, the Mobile Station ID, the Electronic Serial Number, dialed digits, System ID, RF channel number, cell site number or sector number, type of transmission, and other types of data elements. Some of the trigger events may have higher or lower priority levels associated with them for use in determining the order of processing. Higher priority location triggers will always be processing before lower priority location triggers. However, a lower priority trigger that has already begun location processing will complete the processing before being assigned to a higher priority task. The master Tasking List for the Wireless Location System is maintained on the AP 14, and copies of the Tasking List are automatically downloaded to the Signal of Interest Table in each TLP 12 in the Wireless Location System. The full Signal of Interest Table is downloaded to a TLP 12 when the TLP 12 is reset or first starts. Subsequent to those two events, only changes are downloaded from the AP 14 to each TLP 12 to conserve communications bandwidth. The TLP 12 to AP 14 communications protocol preferably contains sufficient redundancy and error checking to prevent incorrect data from ever being entered into the Signal of Interest Table . When the AP 14 and TLP 12 periodically have spare processing capacity available, the AP 14 reconfirms entries in the Signal of Interest Table to ensure that all Signal of Interest Table entries in the Wireless Location System are in full synchronization.

Each TLP chassis has a maximum capacity associated with the chassis. For example, a single TLP chassis may only have sufficient capacity to support between 48 and 60 SCS's 10. When a wireless communications system is larger that the capacity of a single TLP chassis, multiple TLP chassis are connected together using Ethernet networking. The controller module 12-3 is responsible for inter-TLP communications and networking, and communicates with the controller modules in other TLP chassis and with Application Processors 14 over the Ethernet network. Inter-TLP communications is required when location processing requires the use of SCS's 10 that are connected to different TLP chassis. Location processing for each wireless transmission is assigned to a single DSP module in a single TLP chassis. The controller modules 12-3 in TLP chassis select the DSP module on which to perform location processing, and then route all of the RF data used in location processing to that DSP module. If RF data is required from the SCS's 10 connected to more that one TLP 12, then the controller modules in all necessary TLP chassis communicate to move the RF data from all necessary SCS's 10 to their respective connected TLP's 12 and then to the DSP module and TLP chassis assigned to the location processing. The controller module supports two fully independent Ethernet networks for redundancy. A break or failure in any one network causes the affected TLP's 12 to immediately shift all communications to the other network.

The controller modules 12-3 maintain a complete network map of the Wireless Location System, including the SCS's 10 associated with each TLP chassis. The network map is a table stored in the controller module containing a list of the candidate SCS/antennas that may be used in location processing, and various parameters associated with each of the SCS/antennas. The structure of an exemplary network map is depicted in Figure 3A. There is a separate entry in the table for each antenna connected to an SCS 10. When a wireless transmission occurs in an area that is covered by SCS's 10 communicating with more than one TLP chassis, the controller modules in the involved TLP chassis determine which TLP chassis will be the "master" TLP chassis for the purpose of managing location processing. Typically, the TLP chassis associated with the SCS 10 that has the primary channel assignment for the wireless transmission is assigned to be the master. However, another TLP chassis may be assigned instead if that TLP temporarily has no DSP resources available for location processing, or if most of the SCS's 10 involved in location processing are connected to another TLP chassis and the controller modules are minimizing inter-TLP communications. This decision making process is fully dynamic, but is assisted by tables in the TLP 12 that pre-determine the preferred TLP chassis for every primary channel assignment. The tables are created by the operator of the Wireless Location System, and programmed using the Network Operations Console.

The networking described herein functions for both TLP chassis associated with the same wireless carrier, as well as for chassis that overlap or border the coverage area between two wireless carriers. Thus it is possible for a TLP 12 belonging to a first wireless carrier to be networked and therefore receive RF data from a TLP 12 (and the SCS's 10 associated with that TLP 12) belonging to a second wireless carrier. This networking is particularly valuable in rural areas, wherein the performance of the Wireless Location System can be enhanced by deploying SCS's 10 at cell sites of multiple wireless carriers. Since in many cases wireless carriers do not colocate cell sites, this feature enables the Wireless Location System to access more geographically diverse antennas than might be available if the Wireless Location System used only the cell sites from a single wireless carrier. As described below, the proper selection and use of antennas for location processing can enhance the performance of the Wireless Location System.

The controller module 12-3 passes many messages, including location records, to the AP 14, many of which are described below. Usually, however, demodulated data is not passed from the TLP 12 to the AP 14. If, however, the TLP 12 receives demodulated data from a particular wireless transmitter and the TLP 12 identifies the wireless transmitter as being a registered customer of a second wireless carrier in a different coverage area, the TLP 12 may pass the demodulated data to the first (serving) AP 14A. This will enable the first AP 14A to communicate with a second AP 14B associated with the second wireless carrier, and determine whether the particular wireless transmitter has registered for any type of location services. If so, the second AP 14B may instruct the first AP 14A to place the identity of the particular wireless transmitter into the Signal of Interest Table so that the particular wireless transmitter will be located for as long as the particular wireless transmitter is in the coverage area of the first Wireless Location System associated with the first AP 14A. When the first Wireless Location System has detected that the particular wireless transmitter has not registered in a time period exceeding a pre-determined threshold, the first AP 14A may instruct the second AP 14B that the identity of the particular wireless transmitter is being removed from the Signal of Interest Table for the reason of no longer being present in the coverage area associated with the first AP 14A.

Diagnostic Port

The TLP 12 supports a diagnostic port that is highly useful in the operation and diagnosis of problems within the Wireless Location System. This diagnostic port can be accessed either locally at a TLP 12 or remotely over the Ethernet network connecting the TLP's 12 to the AP's. The diagnostic port enables an operator to write to a file all of the demodulation and RF data received from the SCS's 10, as well as the intermediate and final results of all location processing. This data is erased from the TLP 12 after processing a location estimate, and therefore the diagnostic port provides the means to save the data for later post-processing and analysis. The inventor's experience in operating large scale wireless location systems is that a very small number of location estimates can occasionally have very large errors, and these large errors can dominate the overall operating statistics of the Wireless Location System over any measurement period. Therefore, it is important to provide the operator with a set of tools that enable the Wireless Location System to detect and trap the cause of the very large errors to diagnose and mitigate those errors. The diagnostic port can be set to save the above information for all location estimates, for location estimates from particular wireless transmitters or at particular test points, or for location estimates that meet a certain criteria. For example, for fixed phones or drive testing of surveyed points, the diagnostic port can determine the error in the location estimate in real time and then write the above described information only for those location estimates whose error exceeds a predetermined threshold. The diagnostic port determines the error in real time by storing the surveyed latitude, longitude coordinate of each fixed phone and drive test point in a table, and then calculating a radial error when a location estimate for the corresponding test point is made.

Redundancy

The TLP's 12 implement redundancy using several inventive techniques, allowing the Wireless Location System to support an M plus N redundancy method. M plus N redundancy means that N redundant (or standby) TLP chassis are used to provide full redundant backup to M online TLP chassis. For example, M may be ten and N may be two.

First, the controller modules in different TLP chassis continuously exchange status and "heartbeat" messages at pre-determined time intervals between themselves and with every AP 14 assigned to monitor the TLP chassis. Thus, every controller module has continuous and full status of every other controller module in the Wireless Location System. The controller modules in different TLP chassis periodically select one controller module in one TLP 12 to be the master controller for a group of TLP chassis. The master controller may decide to place a first TLP chassis into off-line status if the first TLP 12A reports a failed or degraded condition in its status message, or if the first TLP 12A fails to report any status or heartbeat messages within its assigned and pre-determined time. If the master controller places a first TLP 12A into off-line status, the master controller may assign a second TLP 12B to perform a redundant switchover and assume the tasks of the off-line first TLP 12A. The second TLP 12B is automatically sent the configuration that had been loaded into the first TLP 12A; this configuration may be downloaded from either the master controller or from an AP 14 connected to the TLP's 12. The master controller may be a controller module on any one of the TLP's 12 that is not in off-line status, however there is a preference that the master controller be a controller module in a stand-by TLP 12. When the master controller is the controller module in a stand-by TLP 12, the time required to detect a failed first TLP 12A, place the first TLP 12A into off-line status, and then perform a redundant switchover can be accelerated.

Second, all of the T1 or E1 communications between the SCS's 10 and each of the TLP T1/E1 communications modules 12-2 are preferably routed through a high-reliability DACS that is dedicated to redundancy control. The DACS 13B is connected to every groomed T1/E1 circuit containing DS0's from SCS's 10 and is also connected to every T1/E1 communications module 12-2 of every TLP 12. Every controller module at every TLP 12 contains a map of the DACS 13B that describes the DACS' connection list and port assignments. This DACS 13B is connected to the Ethernet network described above and can be controlled by any of the controller modules 12-3 at any of the TLP's 12. When a second TLP 12 is placed into off-line status by a master controller, the master controller sends commands to the DACS 13B to switch the groomed T1/E1 circuit communicating with the first TLP 12A to a second TLP 12B which had been in standby status. At the same time, the AP 14 downloads the complete configuration file that was being used by the second (and now off-line) TLP 12B to the third (and now online) TLP 12C. The time from the first detection of a failed first TLP chassis to the complete switch-over and assumption of processing responsibilities by a third TLP chassis is typically less than few seconds. In many cases, no RF data is lost by the SCS's 10 associated with the failed first TLP chassis, and location processing can continue without interruption. At the time of a TLP fail-over when a first TLP 12A is placed into off-line status, the NOC 16 creates an alert to notify the Wireless Location System operator that the event has occurred.

Third, each TLP chassis contains redundant power supplies, fans, and other components. A TLP chassis can also support multiple DSP modules, so that the failure of a single DSP module or even a single DSP on a DSP module reduces the overall amount of processing resources available but does not cause the failure of the TLP chassis. In all of the cases described in this paragraph, the failed component of the TLP 12 can be replaced without placing the entire TLP chassis into off-line status. For example, if a single power supply fails, the redundant power supply has sufficient capacity to singly support the load of the chassis. The failed power supply contains the necessary circuitry to remove itself from the load of the chassis and not cause further degradation in the chassis. Similarly, a failed DSP module can also remove itself from the active portions of the chassis, so as to not cause a failure of the backplane or other modules. This enables the remainder of the chassis, including the second DSP module, to continue to function normally. Of course, the total processing throughput of the chassis is reduced but a total failure is avoided.

Application Processor (AP) 14

The AP 14 is a centralized database system, comprising a number of software processes that manage the entire Wireless Location System, provide interfaces to external users and applications, store location records and configurations, and support various application-related functionality. The AP 14 uses a commercial hardware platform that is sized to match the throughput of the Wireless Location System. The AP 14 also uses a commercial relational database system (RDBMS), which has been significantly customized to provide the functionality described herein. While the SCS 10 and TLP 12 preferably operate together on a purely real time basis to determine location and create location records, the AP 14 can operate on both a real time basis to store and forward location records and a non-real time basis to post-process location records and provide access and reporting over time. The ability to store, retrieve, and post-process location records for various types of system and application analysis has proven to be a powerful advantage of the present invention. The main collection of software processes is known as the ApCore, which is shown in Figure 4 and includes the following functions:

The AP Performance Guardian (ApPerfGuard) is a dedicated software process that is responsible for starting, stopping, and monitoring most other ApCore processes as well as ApCore communications with the NOC 16. Upon receiving a configuration update command from the NOC, ApPerfGuard updates the database and notifies all other processes of the change. ApPerfGuard starts and stops appropriate processes when the NOC directs the ApCore to enter specific run states, and constantly monitors other software processes scheduled to be running to restart them if they have exited or stopping and restarting any process that is no longer properly responding. ApPerfGuard is assigned to one of the highest processing priorities so that this process cannot be blocked by another process that has "run away". ApPerfGuard is also assigned dedicated memory that is not accessible by other software processes to prevent any possible corruption from other software processes.

The AP Dispatcher (ApMnDsptch) is a software process that receives location records from the TLP's 12 and forwards the location records to other processes. This process contains a separate thread for each physical TLP 12 configured in the system, and each thread receives location records from that TLP 12. For system reliability, the ApCore maintains a list containing the last location record sequence number received from each TLP 12, and sends this sequence number to the TLP 12 upon initial connection. Thereafter, the AP 14 and the TLP 12 maintain a protocol whereby the TLP 12 sends each location record with a unique identifier. ApMnDsptch forwards location records to multiple processes, including Ap911, ApDbSend, ApDbRecvLoc, and ApDbFileRecv.

The AP Tasking Process (ApDbSend) controls the Tasking List within the Wireless Location System. The Tasking List is the master list of all of the trigger criteria that determines which wireless transmitters will be located, which applications created the criteria, and which applications can receive location record information. The ApDbSend process contains a separate thread for each TLP 12, over which the ApDbSend synchronizes the Tasking List with the Signal of Interest Table on each TLP 12. ApDbSend does not send application information to the Signal of Interest Table , only the trigger criteria. Thus the TLP 12 does not know why a wireless transmitter must be located. The Tasking List allows wireless transmitters to be located based upon Mobile Identity Number (MIN), Mobile Station Identifier (MSID), Electronic Serial Number (ESN) and other identity numbers, dialed sequences of characters and / or digits, home System ID (SID), originating cell site and sector, originating RF channel, or message type. The Tasking List allows multiple applications to receive location records from the same wireless transmitter. Thus, a single location record from a wireless transmitter that has dialed "911" can be sent, for example, to a 911 PSAP, a fleet management application, a traffic management application, and to an RF optimization application.

The Tasking List also contains a variety of flags and field for each trigger criteria, some of which are described elsewhere in this specification. One flag, for example, specifies the maximum time limit before which the Wireless Location System must provide a rough or final estimate of the wireless transmitter. Another flag allows location processing to be disabled for a particular trigger criteria such as the identity of the wireless transmitter. Another field contains the authentication required to make changes to the criteria for a particular trigger; authentication enables the operator of the Wireless Location System to specify which applications are authorized to add, delete, or make changes to any trigger criteria and associated fields or flags. Another field contains the Location Grade of Service associated with the trigger criteria; Grade of Service indicates to the Wireless Location System the accuracy level and priority level desired for the location processing associated with a particular trigger criteria. For example, some applications may be satisfied with a rough location estimate (perhaps for a reduced location processing fee), while other applications may be satisfied with low priority processing that is not guaranteed to complete for any given transmission (and which may be pre-empted for high priority processing tasks). The Wireless Location System also includes means to support the use of wildcards for trigger criteria in the Tasking List. For example, a trigger criteria can be entered as "MIN = 215555****". This will cause the Wireless Location System to trigger location processing for any wireless transmitter whose MIN begins with the six digits 215555 and ends with any following four digits. The wildcard characters can be placed into any position in a trigger criteria. This feature can save on the number of memory locations required in the Tasking List and Signal of Interest Table by grouping blocks of related wireless transmitters together.

ApDbSend also supports dynamic tasking. For example, the MIN, ESN, MSID, or other identity of any wireless transmitter that has dialed "911" will automatically be placed onto the Tasking List by ApDbSend for one hour. Thus, any further transmissions by the wireless transmitter that dialed "911" will also be located in case of further emergency. For example, if a PSAP calls back a wireless transmitter that had dialed "911" within the last hour, the

Wireless Location System will trigger on the page response message from the wireless transmitter, and can make this new location record available to the PSAP. This dynamic tasking can be set for any interval of time after an initiation event, and for any type of trigger criteria. The ApDbSend process is also a server for receiving tasking requests from other applications. These applications, such as fleet management, can send tasking requests via a socket connection, for example. These applications can either place or remove trigger criteria. ApDbSend conducts an authentication process with each application to verify that that the application has been authorized to place or remove trigger criteria, and each application can only change trigger criteria related to that application.

The AP 911 Process (Ap911) manages each interface between the Wireless Location System and E9-1-1 network elements, such as tandem switches, selective routers, ALI databases and/or PSAPs. The Ap911 process contains a separate thread for each connection to a E9-1-1 network element, and can support more than one thread to each network element. The Ap911 process can simultaneously operate in many modes based upon user configuration, and as described herein. The timely processing of E9-1-1 location records is one of the highest processing priorities in the AP 14, and therefore the Ap911 executes entirely out of random access memory (RAM) to avoid the delay associated with first storing and then retrieving a location record from any type of disk. When ApMnDsptch forwards a location record to Ap911, Ap911 immediately makes a routing determination and forwards the location record over the appropriate interface to a E9-1-1 network element. A separate process, operating in parallel, records the location record into the AP 14 database.

The AP 14, through the Ap911 process and other processes, supports two modes of providing location records to applications, including E9-1-1: "push" and "pull" modes. Applications requesting push mode receive a location record as soon as it is available from the AP 14. This mode is especially effective for E9-1-1 which has a very time critical need for location records, since E9-1-1 networks must route wireless 9-1-1 calls to the correct PSAP within a few seconds after a wireless caller has dialed "911". Applications requesting pull mode do not automatically receive location records, but rather must send a query to the AP 14 regarding a particular wireless transmitter in order to receive the last, or any other location record, about the wireless transmitter. The query from the application can specify the last location record, a series of location records, or all location records meeting a specific time or other criteria, such as type of transmission. An example of the use of pull mode in the case of a "911" call is the E9-1-1 network first receiving the voice portion of the "911" call and then querying the AP 14 to receive the location record associated with that call.

When the Ap911 process is connected to many E9-1-1 networks elements, Ap911 must determine to which E9-1-1 network element to push the location record (assuming that "push" mode has been selected). The AP 14 makes this determination using a dynamic routing table. The dynamic routing table is used to divide a geographic region into cells. Each cell, or entry, in the dynamic routing table contains the routing instructions for that cell. It is well known that one minute of latitude is 6083 feet, which is about 365 feet per millidegree. Additionally, one minute of longitude is cosine(latitude) times 6083 feet, which for the Philadelphia area is about 4659 feet, or about 280 feet per millidegree. A table of size one thousand by one thousand, or one million cells, can contain the routing instructions for an area that is about 69 miles by 53 miles, which is larger than the area of Philadelphia in this example, and each cell could contain a geographic area of 365 feet by 280 feet. The number of bits allocated to each entry in the table must only be enough to support the maximum number of routing possibilities. For example, if the total number of routing possibilities is sixteen or less, then the memory for the dynamic routing table is one million times four bits, or one-half megabyte. Using this scheme, an area the size of Pennsylvania could be contained in a table of approximately twenty megabytes or less, with ample routing possibilities available. Given the relatively inexpensive cost of memory, this inventive dynamic routing table provides the AP 14 with a means to quickly push the location records for "911" calls only to the appropriate E9-1-1 network element.

The AP 14 allows each entry in dynamic routing to be populated using manual or automated means. Using the automated means, for example, an electronic map application can create a polygon definition of the coverage area of a specific E9-1-1 network element, such as a PSAP. The polygon definition is then translated into a list of latitude, longitude points contained within the polygon. The dynamic routing table cell corresponding to each latitude, longitude point is then given the routing instruction for that E9-1-1 network element that is responsible for that geographic polygon.

When the Ap911 process receives a "911" location record for a specific wireless transmitter, Ap911 converts the latitude, longitude into the address of a specific cell in the dynamic routing table. Ap911 then queries the cell to determine the routing instructions, which may be push or pull mode and the identity of the E9-1-1 network element responsible for serving the geographic area in which the "911" call occurred. If push mode has been selected, then Ap911 automatically pushes the location record to that E9-1-1 network element. If pull mode has been selected, then Ap911 places the location record into a circular table of "911" location records and awaits a query.

The dynamic routing means described above entails the use of a geographically defined database that may be applied to other applications in addition to 911, and is therefore supported by other processes in addition to Ap911. For example, the AP 14 can automatically determine the billing zone from which a wireless call was placed for a Location Sensitive Billing application. In addition, the AP 14 may automatically send an alert when a particular wireless transmitter has entered or exited a prescribed geographic area defined by an application. The use of particular geographic databases, dynamic routing actions, any other location triggered actions are defined in the fields and flags associated with each trigger criteria. The Wireless Location System includes means to easily manage these geographically defined databases using an electronic map that can create polygons encompassing a prescribed geographic area. The Wireless Location System extracts from the electronic map a table of latitude, longitude points contained with the polygon. Each application can use its own set of polygons, and can define a set of actions to be taken when a location record for a triggered wireless transmission is contained within each polygon in the set.

The AP Database Receive Process (ApDbRecvLoc) receives all location records from ApMnDsptch via shared memory, and places the location records into the AP location database. ApDbRecvLoc starts ten threads that each retrieve location records from shared memory, validate each record before inserting the records into the database, and then inserts the records into the correct location record partition in the database. To preserve integrity, location records with any type of error are not written into the location record database but are instead placed into an error file that can be reviewed by the Wireless Location System operator and then manually entered into the database after error resolution. If the location database has failed or has been placed into off-line status, location records are written to a flat file where they can be later processed by ApDbFileRecv.

The AP File Receive Process (ApDbFileRecv) reads flat files containing location records and inserts the records into the location database. Flat files are a safe mechanism used by the AP 14 to completely preserve the integrity of the AP 14 in all cases except a complete failure of the hard disk drives. There are several different types of flat files read by ApDbFileRecv, including Database Down, Synchronization, Overflow, and Fixed Error. Database Down flat files are written by the ApDbRecvLoc process if the location database is temporarily inaccessible; this file allows the AP 14 to ensure that location records are preserved during the occurrence of this type of problem. Synchronization flat files are written by the ApLocSync process (described below) when transferring location records between pairs of redundant AP systems. Overflow flat files are written by ApMnDsptch when location records are arriving into the AP 14 at a rate faster than ApDbRecvLoc can process and insert the records into the location database. This may occur during very high peak rate periods. The overflow files prevent any records from being lost during peak periods. The Fixed Error flat files contain location records that had errors but have now been fixed, and can now be inserted into the location database.

Because the AP 14 has a critical centralized role in the Wireless Location System, the AP 14 architecture has been designed to be fully redundant. A redundant AP 14 system includes fully redundant hardware platforms, fully redundant RDBMS, redundant disk drives, and redundant networks to each other, the TLP's 12, the NOC's 16, and external applications. The software architecture of the AP 14 has also been designed to support fault tolerant redundancy. The following examples illustrate functionality supported by the redundant AP's. Each TLP 12 sends location records to both the primary and the redundant AP 14 when both AP's are in an online state. Only the primary AP 14 will process incoming tasking requests, and only the primary AP 14 will accept configuration change requests from the NOC 16. The primary AP 14 then synchronizes the redundant AP 14 under careful control. Both the primary and redundant AP's will accept basic startup and shutdown commands from the NOC. Both AP's constantly monitor their own system parameters and application health and monitor the corresponding parameters for the other AP 14, and then decide which AP 14 will be primary and which will be redundant based upon a composite score. This composite score is determined by compiling errors reported by various processes to a shared memory area, and monitoring swap space and disk space. There are several processes dedicated to supporting redundancy.

The AP Location Synchronization Process (ApLocSync) runs on each AP 14 and detects the need to synchronize location records between AP's, and then creates "sync records" that list the location records that need to be transferred from one AP 14 to another AP 14. The location records are then transferred between AP's using a socket connection. ApLocSync compares the location record partitions and the location record sequence numbers stored in each location database. Normally, if both the primary and redundant AP 14 are operating properly, synchronization is not needed because both AP's are receiving location records simultaneously from the TLP's 12. However, if one AP 14 fails or is placed in an off-line mode, then synchronization will later be required. ApLocSync is notified whenever ApMnDsptch connects to a TLP 12 so it can determine whether synchronization is required.

The AP Tasking Synchronization Process (ApTaskSync) runs on each AP 14 and synchronizes the tasking information between the primary AP 14 and the redundant AP 14. ApTaskSync on the primary AP 14 receives tasking information from ApDbSend, and then sends the tasking information to the ApTaskSync process on the redundant AP 14. If the primary AP 14 were to fail before ApTaskSync had completed replicating tasks, then ApTaskSync will perform a complete tasking database synchronization when the failed AP 14 is placed back into an online state.

The AP Configuration Synchronization Process (ApConfigSync) runs on each AP 14 and synchronizes the configuration information between the primary AP 14 and the redundant AP

14. ApConfigSync uses a RDBMS replication facility. The configuration information includes all information needed by the SCS's 10, TLP's 12, and AP's 14 for proper operation of the Wireless Location System in a wireless carrier's network.

In addition to the core functions described above, the AP 14 also supports a large number of processes, functions, and interfaces useful in the operation of the Wireless Location System, as well as useful for various applications that desire location information. While the processes, functions, and interfaces described herein are in this section pertaining to the AP 14, the implementation of many of these processes, functions, and interfaces permeates the entire Wireless Location System and therefore their inventive value should be not read as being limited only to the AP 14.

Roaming

The AP 14 supports "roaming" between wireless location systems located in different cities or operated by different wireless carriers. If a first wireless transmitter has subscribed to an application on a first Wireless Location System, and therefore has an entry in the Tasking List in the first AP 14 in the first Wireless Location System, then the first wireless transmitter may also subscribe to roaming. Each AP 14 and TLP 12 in each Wireless Location System contains a table in which a list of valid "home" subscriber identities is maintained. The list is typically a range, and for example, for current cellular telephones, the range can be determined by the NPA/NXX codes (or area code and exchange) associated with the MIN or MSID of cellular telephones. When a wireless transmitter meeting the "home" criteria makes a transmission, a TLP 12 receives demodulated data from one or more SCS's 10 and checks the trigger information in the Signal of Interest Table . If any trigger criterion is met, the location processing begins on that transmission; otherwise, the transmission is not processed by the Wireless Location System.

When a first wireless transmitter not meeting the "home" criterion makes a transmission in a second Wireless Location System, the second TLP 12 in the second Wireless Location System checks the Signal of Interest Table for a trigger. One of three actions then occurs: (i) if the transmission meets an already existing criteria in the Signal of Interest Table , the transmitter is located and the location record is forwarded from the second AP 14 in the second Wireless Location System to the first AP 14 in the first Wireless Location System; (ii) if the first wireless transmitter has a "roamer" entry in the Signal of Interest Table indicating that the first wireless transmitter has "registered" in the second Wireless Location System but has no trigger criteria, then the transmission is not processed by the second Wireless Location System and the expiration timestamp is adjusted as described below; (iii) if the first wireless transmitter has no "roamer" entry and therefore has not "registered", then the demodulated data is passed from the TLP 12 to the second AP 14.

In the third case above, the second AP 14 uses the identity of the first wireless transmitter to identify the first AP 14 in the first Wireless Location System as the "home" Wireless Location System of the first wireless transmitter. The second AP 14 in the second Wireless Location System sends a query to the first AP 14 in the first Wireless Location System to determine whether the first wireless transmitter has subscribed to any location application and therefore has any trigger criteria in the Tasking List of the first AP 14. If a trigger is present in the first AP 14, the trigger criteria, along with any associated fields and flags, is sent from the first AP 14 to the second AP 14 and entered in the Tasking List and the Signal of Interest Table as a "roamer" entry with trigger criteria. If the first AP 14 responds to the second AP 14 indicating that the first wireless transmitter has no trigger criteria, then the second AP 14 "registers" the first wireless transmitter in the Tasking List and the Signal of Interest Table as a "roamer" with no trigger criteria. Thus both current and future transmissions from the first wireless transmitter can be positively identified by the TLP 12 in the second Wireless Location System as being registered without trigger criteria, and the second AP 14 is not required to make additional queries to the first AP 14.

When the second AP 14 registers the first wireless transmitter with a roamer entry in the Tasking List and the Signal of Interest Table with or without trigger criteria, the roamer entry is assigned an expiration timestamp. The expiration timestamp is set to the current time plus a predetermined first interval. Every time the first wireless transmitter makes a transmission, the expiration timestamp of the roamer entry in the Tasking List and the Signal of Interest Table is adjusted to the current time of the most recent transmission plus the predetermined first interval. If the first wireless transmitter makes no further transmissions prior to the expiration timestamp of its roamer entry, then the roamer entry is automatically deleted. If, subsequent to the deletion, the first wireless transmitter makes another transmission, then the process of registering occurs again.

The first AP 14 and second AP 14 maintain communications over a wide area network. The network may be based upon TCP/IP or upon a protocol similar to the most recent version of IS-41. Each AP 14 in communications with other AP's in other wireless location systems maintains a table that provides the identity of each AP 14 and Wireless Location System corresponding to each valid range of identities of wireless transmitters.

Multiple Pass Location Records

Certain applications may require a very fast estimate of the general location of a wireless transmitter, followed by a more accurate estimate of the location that can be sent subsequently. This can be valuable, for example, for E9-1-1 systems that handle wireless calls and must make a call routing decision very quickly, but can wait a little longer for a more exact location to be displayed upon the E9-1-1 call-taker's electronic map terminal. The Wireless Location System supports these applications with an inventive multiple pass location processing mode, described later. The AP 14 supports this mode with multiple pass location records. For certain entries, the Tasking List in the AP 14 contains a flag indicating the maximum time limit before which a particular application must receive a rough estimate of location, and a second maximum time limit in which a particular application must receive a final location estimate. For these certain applications, the AP 14 includes a flag in the location record indicating the status of the location estimate contained in the record, which may, for example, be set to first pass estimate (i.e. rough) or final pass estimate. The Wireless Location System will generally determine the best location estimate within the time limit set by the application, that is the Wireless Location System will process the most amount of RF data that can be supported in the time limit. Given that any particular wireless transmission can trigger a location record for one or more applications, the Wireless Location System supports multiple modes simultaneously. For example, a wireless transmitter with a particular MIN can dial "911". This may trigger a two-pass location record for the E9-1-1 application, but a single pass location record for a fleet management application that is monitoring that particular MIN. This can be extended to any number of applications.

Multiple Demodulation and Triggers

In wireless communications systems in urban or dense suburban areas, frequencies or channels can be re-used several times within relatively close distances. Since the Wireless Location System is capable of independently detecting and demodulating wireless transmissions without the aid of the wireless communications system, a single wireless transmission can frequently be detected and successfully demodulated at multiple SCS's 10 within the Wireless Location System. This can happen both intentionally and unintentionally. An unintentional occurrence is caused by a close frequency re-use, such that a particular wireless transmission can be received above a predetermined threshold at more than one SCS 10, when each SCS 10 believes it is monitoring only transmissions that occur only within the cell site collocated with the SCS 10. An intentional occurrence is caused by programming more than one SCS 10 to detect and demodulate transmissions that occur at a particular cell site and on a particular frequency. As described earlier, this is generally used with adjacent or nearby SCS's 10 to provide system demodulation redundancy to further increase the probability that any particular wireless transmission is successful detected and demodulated.

Either type of event could potentially lead to multiple triggers within the Wireless Location System, causing location processing to be initiated several times for the same transmission. This causes an excess and inefficient use of processing and communications resources. Therefore, the Wireless Location System includes means to detect when the same transmission has been detected and demodulated more than once, and to select the best demodulating SCS 10 as the starting point for location processing. When the Wireless Location System detects and successfully demodulates the same transmission multiple times at multiple SCS/antennas, the Wireless Location System uses the following criteria to select the one demodulating SCS/antenna to use to continue the process of determining whether to trigger and possibly initiate location processing (again, these criteria may be weighted in determining the final decision): (i) an SCS/antenna collocated at the cell site to which a particular frequency has been assigned is preferred over another SCS/antenna, but this preference may be adjusted if there is no operating and on-line SCS/antenna collocated at the cell site to which the particular frequency has been assigned, (ii) SCS/antennas with higher average SNR are preferred over those with lower average SNR, and (iii) SCS/antennas with fewer bit errors in demodulating the transmission are preferred over those with higher bit errors. The weighting applied to each of these preferences may be adjusted by the operator of the Wireless Location System to suit the particular design of each system.

Interface to Wireless Communications System

The Wireless Location System contains means to communicate over an interface to a wireless communications system, such as a mobile switching center (MSC) or mobile positioning controller (MPC). This interface may be based, for example, on a standard secure protocol such as the most recent version of the IS-41 or TCP/IP protocols. The formats, fields, and authentication aspects of these protocols are well known. The Wireless Location System supports a variety of command / response and informational messages over this interface that are designed to aid in the successful detection, demodulation, and triggering of wireless transmissions, as well as providing means to pass location records to the wireless communications system. In particular, this interface provides means for the Wireless Location System to obtain information about which wireless transmitters have been assigned to particular voice channel parameters at particular cell sites. Example messages supported by the Wireless Location System over this interface to the wireless communications system include the following:

Query on MIN / MDN / MSID / IMSI / TMSI Mapping – Certain types of wireless transmitters will transmit their identity in a familiar form that can be dialed over the telephone network. Other types of wireless transmitters transmit an identity that cannot be dialed, but which is translated into a number that can be dialed using a table inside of the wireless communications system. The transmitted identity is permanent in most cases, but can also be temporary. Users of location applications connected to the AP 14 typically prefer to place triggers onto the Tasking List using identities that can be dialed. Identities that can be dialed are typically known as Mobile Directory Numbers (MDN). The other types of identities for which translation may be required includes Mobile Identity Number

(MIN), Mobile Subscriber Identity (MSID), International Mobile Subscriber Identity (IMSI), and Temporary Mobile Subscriber Identity (TMSI). If the wireless communications system has enabled the use of encryption for any of the data fields in the messages transmitted by wireless transmitters, the Wireless Location System may also query for encryption information along with the identity information. The Wireless Location System includes means to query the wireless communications system for the alternate identities for a trigger identity that has been placed onto the Tasking List by a location application, or to query the wireless communications system for alternate identities for an identity that has been demodulated by an SCS 10. Other events can also trigger this type of query. For this type of query, typically the Wireless Location System initiates the command, and the wireless communications system responds.

Query / Command Change on Voice RF Channel Assignment – Many wireless transmissions on voice channels do not contain identity information. Therefore, when the Wireless Location System is triggered to perform location processing on a voice channel transmission, the Wireless Location System queries the wireless communication system to obtain the current voice channel assignment information for the particular transmitter for which the Wireless Location System has been triggered. For an AMPS transmission, for example, the Wireless Location System preferably requires the cell site, sector, and RF channel number currently in use by the wireless transmitter. For a TDMA transmission, for example, the Wireless Location System preferably requires the cell site, sector, RF channel number, and timeslot currently in use by the wireless transmitter. Other information elements that may be needed includes long code mask and encryption keys. In general, the Wireless Location System will initiate the command, and the wireless communications system will respond. However, the Wireless Location System will also accept a trigger command from the wireless communications system that contains the information detailed herein.

The timing on this command / response message set is very critical since voice channel handoffs can occur quite frequently in wireless communications systems. That is, the Wireless Location System will locate any wireless transmitter that is transmitting on a particular channel – therefore the Wireless Location System and the wireless communications system must jointly be certain that the identity of the wireless transmitter and the voice channel assignment information are in perfect synchronization. The Wireless Location System uses several means to achieve this objective. The Wireless Location System may, for example, query the voice channel assignment information for a particular wireless transmitter, receive the necessary RF data, then again query the voice channel assignment information for that same wireless transmitter, and then verify that the status of the wireless transmitter did not change during the time in which the RF data was being collected by the Wireless Location System. Location processing is not required to complete before the second query, since it is only important to verify that the correct RF data was received. The Wireless Location System may also, for example, as part of the first query command the wireless communications system to prevent a handoff from occurring for the particular wireless transmitter during the time period in which the Wireless Location System is receiving the RF data. Then, subsequent to collecting the RF data, the Wireless Location System will again query the voice channel assignment information for that same wireless transmitter, command the wireless communications system to again permit handoffs for said wireless transmitter and then verify that the status of the wireless transmitter did not change during the time in which the RF data was being collected by the Wireless Location System.

For various reasons, either the Wireless Location System or the wireless communications system may prefer that the wireless transmitter be assigned to another voice RF channel prior to performing location processing. Therefore, as part of the command / response sequence, the wireless communications system may instruct the Wireless Location System to temporarily suspend location processing until the wireless communications system has completed a handoff sequence with the wireless transmitter, and the wireless communications system has notified the Wireless Location System that RF data can be received, and the voice RF channel upon which the data can be received. Alternately, the Wireless Location System may determine that the particular voice RF channel which a particular wireless transmitter is currently using is unsuitable for obtaining an acceptable location estimate, and request that the wireless communications system command the wireless transmitter to handoff. Alternately, the Wireless Location System may request that the wireless communications system command the wireless transmitter to handoff to a series of voice RF channels in sequence in order to perform a series of location estimates, whereby the Wireless Location System can improve upon the accuracy of the location estimate through the series of handoffs; this method is further described later.

The Wireless Location System can also use this command / response message set to query the wireless communications system about the identity of a wireless transmitter that had been using a particular voice channel (and timeslot, etc.) at a particular cell site at a particular time. This enables the Wireless Location System to first perform location processing on transmissions without knowing the identities, and then to later determine the identity of the wireless transmitters making the transmissions and append this information to the location record. This particular inventive feature enables the use of automatic sequential location of voice channel transmissions.

Receive Triggers – The Wireless Location System can receive triggers from the wireless communications system to perform location processing on a voice channel transmission without knowing the identity of the wireless transmitter. This message set bypasses the Tasking List, and does not use the triggering mechanisms within the Wireless Location System. Rather, the wireless communications system alone determines which wireless transmissions to locate, and then send a command to the Wireless Location System to collect RF data from a particular voice channel at a particular cell site and to perform location processing. The Wireless Location System responds with a confirmation containing a timestamp when the RF data was collected. The Wireless Location System also responds with an appropriate format location record when location processing has completed. Based upon the time of the command to Wireless Location System and the response with the RF data collection timestamp, the wireless communications system determines whether the wireless transmitter status changed subsequent to the command and whether there is a good probability of successful RF data collection.

Make Transmit – The Wireless Location System can command the wireless communications system to force a particular wireless transmitter to make a transmission at a particular time, or within a prescribed range of times. The wireless communications system responds with a confirmation and a time or time range in which to expect the transmission. The types of transmissions that the Wireless Location System can force include, for example, audit responses and page responses. Using this message set, the Wireless Location System can also command the wireless communications system to force the wireless transmitter to transmit using a higher power level setting. In many cases, wireless transmitters will attempt to use the lowest power level settings when transmitting in order to conserve battery life. In order improve the accuracy of the location estimate, the Wireless Location System may prefer that the wireless transmitter use a higher power level setting. The wireless communications system will respond to the Wireless Location System with a confirmation that the higher power level setting will be used and a time or time range in which to expect the transmission.

Delay Wireless Communications System Response to Mobile Access – Some air interface protocols, such as CDMA, use a mechanism in which the wireless transmitter initiates transmissions on a channel, such as an Access Channel, for example, at the lowest or a very low power level setting, and then enters a sequence of steps in which (i) the wireless transmitter makes an access transmission; (ii) the wireless transmitter waits for a response from the wireless communications system; (iii) if no response is received by the wireless transmitter from the wireless communications system within a predetermined time, the wireless transmitter increases its power level setting by a predetermined amount, and then returns to step (i); (iv) if a response is received by the wireless transmitter from the wireless communications system within a predetermined time, the wireless transmitter then enters a normal message exchange. This mechanism is useful to ensure that the wireless transmitter uses only the lowest useful power level setting for transmitting and does not further waste energy or battery life. It is possible, however, that the lowest power level setting at which the wireless transmitter can successfully communicate with the wireless communications system is not sufficient to obtain an acceptable location estimate. Therefore, the Wireless Location System can command the wireless communications system to delay its response to these transmissions by a predetermined time or amount. This delaying action will cause the wireless transmitter to repeat the sequence of steps (i) through (iii) one or more times than normal with the result that one or more of the access transmissions will be at a higher power level than normal. The higher power level may preferably enable the Wireless Location System to determine a more accurate location estimate. The Wireless Location System may command this type of delaying action for either a particular wireless transmitter, for a particular type of wireless transmission (for example, for all '911' calls), for wireless transmitters that are at a specified range from the base station to which the transmitter is attempting to communicate, or for all wireless transmitters in a particular area.

Send Confirmation to Wireless Transmitter – The Wireless Location System does not include means within to notify the wireless transmitter of an action because the Wireless Location System cannot transmit; as described earlier the Wireless Location System can only receive transmissions. Therefore, if the Wireless Location System desires to send, for example, a confirmation tone upon the completion of a certain action, the Wireless Location System commands the wireless communications system to transmit a particular message. The message may include, for example, an audible confirmation tone, spoken message, or synthesized message to the wireless transmitter, or a text message sent via a short messaging service or a page. The Wireless Location System receives confirmation from the wireless communications system that the message has been accepted and sent to the wireless transmitter. This command / response message set is important in enabling the Wireless Location System to support certain end-user application functions such as Prohibit Location Processing.

Report Location Records – The Wireless Location System automatically reports location records to the wireless communications system for those wireless transmitters tasked to report to the wireless communications system, as well as for those transmissions that the wireless communications system initiated triggers. The Wireless Location System also reports on any historical location record queried by the wireless communications system and which the wireless communications system is authorized to receive.

Monitor Internal Wireless Communications System Interfaces, State Table

In addition to this above interface between the Wireless Location System and the wireless communications system, the Wireless Location System also includes means to monitor existing interfaces within the wireless communications system for the purpose of intercepting messages important to the Wireless Location System for identifying wireless transmitters and the RF channels in use by these transmitters. These interfaces may include, for example, the "a-interface" and "a-bis interface" used in wireless communications systems employing the GSM air interface protocol. These interfaces are well-known and published in various standards. By monitoring the bi-directional messages on these interfaces between base stations (BTS), base station controllers (BSC), and mobile switching centers (MSC), and other points, the Wireless Location System can obtain the same information about the assignment of wireless transmitters to specific channels as the wireless communications system itself knows. The Wireless Location System includes means to monitor these interfaces at various points. For example, the SCS 10 may monitor a BTS to BSC interface. Alternately, a TLP 12 or AP 14 may also monitor a BSC where a number of BTS to BSC interfaces have been concentrated. The interfaces internal to the wireless communications system are not encrypted and the layered protocols are known to those familiar with the art. The advantage to the Wireless Location System to monitoring these interfaces is that the Wireless Location System may not be required to independently detect and demodulate control channel messages from wireless transmitters. In addition, the Wireless Location System may obtain all necessary voice channel assignment information from these interfaces.

Using these means for a control channel transmission, the SCS 10 receives the transmissions as described earlier and records the control channel RF data into memory without performing detection and demodulation. Separately, the Wireless Location System monitors the messages occurring over prescribed interfaces within the wireless communications system, and causes a trigger in the Wireless Location System when the Wireless Location System discovers a message containing a trigger event. Initiated by the trigger event, the Wireless Location System determines the approximately time at which the wireless transmission occurred, and commands a first SCS 10 and a second SCS 10B to each search its memory for the start of transmission. This first SCS 10A chosen is an SCS that is either collocated with the base station to which the wireless transmitter had communicated, or an SCS which is adjacent to the base station to which the wireless transmitter had communicated. That is, the first SCS 10A is an SCS which would have been assigned the control channel as a primary channel. If the first SCS 10A successfully determines and reports the start of the transmission, then location processing proceeds normally, using the means described below. If the first SCS 10A cannot successfully determine the start of transmission, then the second SCS 10B reports the start of transmission, and then location processing proceeds normally.

The Wireless Location System also uses these means for voice channel transmissions. For all triggers contained in the Tasking List, the Wireless Location System monitors the prescribed interfaces for messages pertaining to those triggers. The messages of interest include, for example, voice channel assignment messages, handoff messages, frequency hopping messages, power up / power down messages, directed re-try messages, termination messages, and other similar action and status messages. The Wireless Location System continuously maintains a copy of the state and status of these wireless transmitters in a State Table in the AP 14. Each time that the Wireless Location System detects a message pertaining to one of the entries in the Tasking List, the Wireless Location System updates its own State Table. Thereafter, the Wireless Location System may trigger to perform location processing, such as on a regular time interval, and access the State Table to determine precisely which cell site, sector, RF channel, and timeslot is presently being used by the wireless transmitter. The example contained herein described the means by which the Wireless Location System interfaces to a GSM based wireless communications system. The Wireless Location System also supports similar functions with systems based upon other air interfaces.

For certain air interfaces, such as CDMA, the Wireless Location System also keeps certain identity information obtained from Access bursts in the control channel in the State Table; this information is later used for decoding the masks used for voice channels. For example, the CDMA air interface protocol uses the Electronic Serial Number (ESN) of a wireless transmitter to, in part, determine the long code mask used in the coding of voice channel transmissions. The Wireless Location System maintains this information in the State Table for entries in the Tasking List because many wireless transmitters may transmit the information only once; for example, many CDMA mobiles will only transmit their ESN during the first Access burst after the wireless transmitter become active in a geographic area. This ability to independently determine the long code mask is very useful in cases where an interface between the Wireless Location System and the wireless communications system is not operative and/or the Wireless Location System is not able to monitor one of the interfaces internal to the wireless communications system. The operator of the Wireless Location System may optionally set the Wireless Location System to maintain the identity information for all wireless transmitters. In addition to the above reasons, the Wireless Location System can provide the voice channel tracking for all wireless transmitters that trigger location processing by calling "911". As described earlier, the Wireless Location System uses dynamic tasking to provide location to a wireless transmitter for a prescribed time after dialing "911", for example. By maintaining the identity information for all wireless transmitters in the State Table, the Wireless Location System is able to provide voice channel tracking for all transmitters in the event of a prescribed trigger event, and not just those with prior entries in the Tasking List.

Applications Interface

Using the AP 14, the Wireless Location System supports a variety of standards based interfaces to end-user and carrier location applications using secure protocols such as TCP/IP, X.25, SS-7, and IS-41. Each interface between the AP 14 and an external application is a secure and authenticated connection that permits the AP 14 to positively verify the identity of the application that is connected to the AP 14. This is necessary because each connected application is granted only limited access to location records on a real-time and/or historical basis. In addition, the AP 14 supports additional command / response, real-time, and post-processing functions that are further detailed below. Access to these additional functions also requires authentication. The AP 14 maintains a user list and the authentication means associated with each user. No application can gain access to location records or functions for which the application does not have proper authentication or access rights. In addition, the AP 14 supports full logging of all actions taken by each application in the event that problems arise or a later investigation into actions is required. For each command or function in the list below, the AP 14 preferably supports a protocol in which each action or the result of each is confirmed, as appropriate.

Edit Tasking List – This command permits external applications to add, remove, or edit entries in the Tasking List, including any fields and flags associated with each entry. This command can be supported on a single entry basis, or a batch entry basis where a list of entries is included in a single command. The latter is useful, for example, in a bulk application such as location sensitive billing whereby larger volumes of wireless transmitters are being supported by the external application, and it is desired to minimize protocol overhead. This command can add or delete applications for a particular entry in the Tasking List, however, this command cannot delete an entry entirely if the entry also contains other applications not associated with or authorized by the application issuing the command.

Set Location Interval – The Wireless Location System can be set to perform location processing at any interval for a particular wireless transmitter, on either control or voice channels. For example, certain applications may require the location of a wireless transmitter every few seconds when the transmitter is engaged on a voice channel. When the wireless transmitter make an initial transmission, the Wireless Location System initially triggers using a standard entry in the Tasking List. If one of the fields or flags in this entry specifies updated location on a set interval, then the Wireless Location System creates a dynamic task in the Tasking List that is triggered by a timer instead of an identity or other transmitted criteria. Each time the timer expires, which can range from 1 second to several hours, the Wireless Location System will automatically trigger to locate the wireless transmitter. The Wireless Location System uses its interface to the wireless communications system to query status of the wireless transmitter, including voice call parameters as described earlier. If the wireless transmitter is engaged on a voice channel, then the Wireless Location System performs location processing. If the wireless transmitter is not engaged in any existing transmissions, the Wireless Location System will command the wireless communications system to make the wireless transmitter immediately transmit. When the dynamic task is set, the Wireless Location System also sets an expiration time at which the dynamic task ceases.

End-User Addition / Deletion – This command can be executed by an end-user of a wireless transmitter to place the identity of the wireless transmitter onto the Tasking List with location processing enabled, to remove the identity of the wireless transmitter from the Tasking List and therefore eliminate identity as a trigger, or to place the identity of the wireless transmitter onto the Tasking List with location processing disabled. When location processing has been disabled by the end-user, known as Prohibit Location Processing then no location processing will be performed for the wireless transmitter. The operator of the Wireless Location System can optionally select one of several actions by the Wireless Location System in response to a Prohibit Location Processing command by the end user: (i) the disabling action can override all other triggers in the Tasking List, including a trigger due to an emergency call such as "911", (ii) the disabling action can override any other trigger in the Tasking List, except a trigger due to an emergency call such as "911", (iii) the disabling action can be overridden by other select triggers in the Tasking List. In the first case, the end-user is granted complete control over the privacy of the transmissions by the wireless transmitter, as no location processing will be performed on that transmitter for any reason. In the second case, the end-user may still receive the benefits of location during an emergency, but at no other times. In an example of the third case, an employer who is the real owner of a particular wireless transmitter can override an end-user action by an employee who is using the wireless transmitter as part of the job but who may not desire to be located. The Wireless Location System may query the wireless communications system, as described above, to obtain the mapping of the identity contained in the wireless transmission to other identities.

The additions and deletions by the end-user are effected by dialed sequences of characters and digits and pressing the "SEND" or equivalent button on the wireless transmitter. These sequences may be optionally chosen and made known by the operator of the Wireless Location System. For example, one sequence may be "*55 SEND" to disable location processing. Other sequences are also possible. When the end-user can dialed this prescribed sequence, the wireless transmitter will transmit the sequence over one of the prescribed control channels of the wireless communications system. Since the Wireless Location System independently detects and demodulates all reverse control channel transmissions, the Wireless Location System can independently interpret the prescribed dialed sequence and make the appropriate feature updates to the Tasking List, as described above. When the Wireless Location System has completed the update to the Tasking List, the Wireless Location System commands the wireless communications system to send a confirmation to the end-user. As described earlier, this may take the form of an audible tone, recorded or synthesized voice, or a text message. This command is executed over the interface between the Wireless Location System and the wireless communications system.

Command Transmit – This command allows external applications to cause the Wireless Location System to send a command to the wireless communications system to make a particular wireless transmitter, or group of wireless transmitters, transmit. This command may contain a flag or field that the wireless transmitter(s) should transmit immediately or at a prescribed time. This command has the effort of locating the wireless transmitter(s) upon command, since the transmissions will be detected, demodulated, and triggered, causing location processing and the generation of a location record. This is useful in eliminating or reducing any delay in determining location such as waiting for the next registration time period for the wireless transmitter or waiting for an independent transmission to occur.

External Database Query and Update – The Wireless Location System includes means to access an external database, to query the said external database using the identity of the wireless transmitter or other parameters contained in the transmission or the trigger criteria, and to merge the data obtained from the external database with the data generated by the Wireless Location System to create a new enhanced location record. The enhanced location record may then be forwarded to requesting applications. The external database may contain, for example, data elements such as customer information, medical information, subscribed features, application related information, customer account information, contact information, or sets of prescribed actions to take upon a location trigger event. The Wireless Location System may also cause updates to the external database, for example, to increment or decrement a billing counter associated with the provision of location services, or to update the external database with the latest location record associated with the particular wireless transmitter. The Wireless Location System contains means to performed the actions described herein on more than one external database. The list and sequence of external databases to access and the subsequent actions to take are contained in one of the fields contained in the trigger criteria in the Tasking List.

Random Anonymous Location Processing – The Wireless Location System includes means to perform large scale random anonymous location processing. This function is valuable to certain types of applications that require the gathering of a large volume of data about a population of wireless transmitters without consideration to the specific identities of the individual transmitters. Applications of this type include: RF Optimization, which enables wireless carriers to measure the performance of the wireless communications system by simultaneously determining location and other parameters of a transmission; Traffic Management, which enables government agencies and commercial concerns to monitor the flow of traffic on various highways using statistically significant samples of wireless transmitters travelling in vehicles; and Local Traffic Estimation, which enables commercial enterprises to estimate the flow of traffic around a particular area which may help determine the viability of particular businesses.

Applications requesting random anonymous location processing optionally receive location records from two sources: (i) a copy of location records generated for other applications, and (ii) location records which have been triggered randomly by the Wireless Location System without regard to any specific criteria. All of the location records generated from either source are forwarded with all of the identity and trigger criteria information removed from the location records; however, the requesting application(s) can determine whether the record was generated from the fully random process or is a copy from another trigger criteria. The random location records are generated by a low priority task within the Wireless Location System that performs location processing on randomly selected transmissions whenever processing and communications resources are available and would otherwise be unused at a particular instant in time. The requesting application(s) can specify whether the random location processing is performed over the entire coverage area of a Wireless Location System, over specific geographic areas such as along prescribed highways, or by the coverage areas of specific cell sites. Thus, the requesting application(s) can direct the resources of the Wireless Location System to those area of greatest interest to each application. Depending on the randomness desired by the application(s), the Wireless Location System can adjust preferences for randomly selecting certain types of transmissions, for example, registration messages, origination messages, page response messages, or voice channel transmissions.

Anonymous Tracking of a Geographic Group – The Wireless Location System includes means to trigger location processing on a repetitive basis for anonymous groups of wireless transmitters within a prescribed geographic area. For example, a particular location application may desire to monitor the travel route of a wireless transmitter over a prescribed period of time, but without the Wireless Location System disclosing the particular identity of the wireless transmitter. The period of time may be many hours, days, or weeks. Using the means, the Wireless Location System: randomly selects a wireless transmitter that initiates a transmission in the geographic area of interest to the application; performs location processing on the transmission of interest; irreversibly translates and encrypts the identity of the wireless transmitter into a new coded identifier; creates a location record using only the new coded identifier as an identifying means; forwards the location record to the requesting location application(s); and creates a dynamic task in the Tasking List for the wireless transmitter, wherein the dynamic task has an associated expiration time. Subsequently, whenever the prescribed wireless transmitter initiates transmission, the Wireless Location System shall trigger using the dynamic task, perform location processing on the transmission of interest, irreversibly translate and encrypt the identity of the wireless transmitter into the new coded identifier using the same means as prior such that the coded identifier is the same, create a location record using the coded identifier, and forward the location record to the requesting location application(s). The means described herein can be combined with other functions of the Wireless Location System to perform this type of monitoring use either control or voice channel transmissions. Further, the means described herein completely preserve the private identity of the wireless transmitter, yet enables another class of applications that can monitor the travel patterns of wireless transmitters. This class of applications can be of great value in determining the planning and design of new roads, alternate route planning, or the construction of commercial and retail space.

Location Record Grouping, Sorting, and Labeling – The Wireless Location System include means to post-process the location records for certain requesting applications to group, sort, or label the location records. For each interface supported by the Wireless Location System, the Wireless Location System stores a profile of the types of data for which the application is both authorized and requesting, and the types of filters or post-processing actions desired by the application. Many applications, such as the examples contained herein, do not require individual location records or the specific identities of individual transmitters. For example, an RF optimization application derives more value from a large data set of location records for a particular cell site or channel than it can from any individual location record. For another example, a traffic monitoring application requires only location records from transmitters that are on prescribed roads or highways, and additionally requires that these records be grouped by section of road or highway and by direction of travel. Other applications may request that the Wireless Location System forward location records that have been formatted to enhance visual display appeal by, for example, adjusting the location estimate of the transmitter so that the transmitter's location appears on an electronic map directly on a drawn road segment rather than adjacent to the road segment. Therefore, the Wireless Location System preferably "snaps" the location estimate to the nearest drawn road segment.

The Wireless Location System can filter and report location records to an application for wireless transmitters communicating only on a particular cell site, sector, RF channel, or group of RF channels. Before forwarding the record to the requesting application, the

Wireless Location System first verifies that the appropriate fields in the record satisfy the requirements. Records not matching the requirements are not forwarded, and records matching the requirements are forwarded. Some filters are geographic and must be calculated by the Wireless Location System. For example, the Wireless Location System can process a location record to determine the closest road segment and direction of travel of the wireless transmitter on the road segment. The Wireless Location System can then forward only records to the application that are determined to be on a particular road segment, and can further enhance the location record by adding a field containing the determined road segment. In order to determine the closest road segment, the Wireless Location System is provided with a database of road segments of interest by the requesting application. This database is stored in a table where each road segment is stored with a latitude and longitude coordinate defining the end point of each segment. Each road segment can be modeled as a straight or curved line, and can be modeled to support one or two directions of travel. Then for each location record determined by the Wireless Location System, the Wireless Location System compares the latitude and longitude in the location record to each road segment stored in the database, and determines the shortest distance from a modeled line connecting the end points of the segment to the latitude and longitude of the location record. The shortest distance is a calculated imaginary line orthogonal to the line connecting the two end points of the stored road segment. When the closest road segment has been determined, the Wireless Location System can further determine the direction of travel on the road segment by comparing the direction of travel of the wireless transmitter reported by the location processing to the orientation of the road segment. The direction that produces the smallest error with respect to the orientation of the road segments is then reported by the Wireless Location System.

Network Operations Console (NOC) 16

The NOC 16 is a network management system that permits operators of the Wireless Location System easy access to the programming parameters of the Wireless Location System. For example, in some cities, the Wireless Location System may contain many hundreds or even thousands of SCS's 10. The NOC is the most effective way to manage a large Wireless Location System, using graphical user interface capabilities. The NOC will also receive real time alerts if certain functions within the Wireless Location System are not operating properly. These real time alerts can be used by the operator to take corrective action quickly and prevent a degradation of location service. Experience with trials of the Wireless Location System show that the ability of the system to maintain good location accuracy over time is directly related to the operator's ability to keep the system operating within its predetermined parameters.

Location Processing

The Wireless Location System is capable of performing location processing using two different methods known as central based processing and station based processing. Both techniques were first disclosed in Patent Number 5,327,144, and are further enhanced in this specification. Location processing depends in part on the ability to accurately determine certain phase characteristics of the signal as received at multiple antennas and at multiple SCS's 10. Therefore, it is an object of the Wireless Location System to identify and remove sources of phase error that impede the ability of the location processing to determine the phase characteristics of the received signal. One source of phase error is inside of the wireless transmitter itself, namely the oscillator (typically a crystal oscillator) and the phase lock loops that allow the phone to tune to specific channels for transmitting. Lower cost crystal oscillators will generally have higher phase noise. Some air interface specifications, such as IS-136 and IS-95A, have specifications covering the phase noise with which a wireless telephone can transmit. Other air interface specifications, such as IS-553A, do not closely specify phase noise. It is therefore an object of the present invention to automatically reduce and/or eliminate a wireless transmitter's phase noise as a source of phase error in location processing, in part by automatically selecting the use of central based processing or station based processing. The automatic selection will also consider the efficiency with which the communications link between the SCS 10 and the TLP 12 is used, and the availability of DSP resources at each of the SCS 10 and TLP 12.

When using central based processing, the TDOA and FDOA determination and the multipath processing are performed in the TLP 12 along with the position and speed determination.

This method is preferred when the wireless transmitter has a phase noise that is above a predetermined threshold. In these cases, central based processing is most effective in reducing or eliminating the phase noise of the wireless transmitter as a source of phase error because the TDOA estimate is performed using a digital representation of the actual RF transmission from two antennas, which may be at the same SCS 10 or different SCS's 10. In this method, those skilled in the art will recognize that the phase noise of the transmitter is a common mode noise in the TDOA processing, and therefore is self-canceling in the TDOA determination process. This method works best, for example, with many very low cost AMPS cellular telephones that have a high phase noise. The basic steps in central based processing include the steps recited below and represented in the flowchart of Figure 6:

a wireless transmitter initiates a transmission on either a control channel or a voice channel (step S50);

the transmission is received at multiple antennas and at multiple SCS's 10 in the Wireless Location System (step S51);

the transmission is converted into a digital format in the receiver connected to each SCS/antenna (step S52);

the digital data is stored in a memory in the receivers in each SCS 10 (step S53);

the transmission is demodulated (step S54);

the Wireless Location System determines whether to begin location processing for the transmission (step S55);

if triggered, the TLP 12 requests copies of the digital data from the memory in receivers at multiple SCS's 10 (step S56);

digital data is sent from multiple SCS's 10 to a selected TLP 12 (step S57);

the TLP 12 performs TDOA, FDOA, and multipath mitigation on the digital data from pairs of antennas (step S58);

the TLP 12 performs position and speed determination using the TDOA data, and then creates a location record and forwards the location record to the AP 14 (step S59).

The Wireless Location System uses a variable number of bits to represent the transmission when sending digital data from the SCS's 10 to the TLP 12. As discussed earlier, the SCS receiver digitizes wireless transmissions with a high resolution, or a high number of bits per digital sample in order to achieve a sufficient dynamic range. This is especially required when using wideband digital receivers, which may be simultaneously receiving signals near to the SCS 10A and far from the SCS 10B. For example, up to 14 bits may be required to represent a dynamic range of 84 dB. Location processing does not always require the high resolution per digital sample, however. Frequently, locations of sufficient accuracy are achievable by the Wireless Location System using a fewer number of bits per digital sample. Therefore, to minimize the implementation cost of the Wireless Location System by conserving bandwidth on the communication links between each SCS 10 and TLP 12, the Wireless Location System determines the fewest number of bits required to digitally represent a transmission while still maintaining a desired accuracy level. This determination is based, for example, on the particular air interface protocol used by the wireless transmitter, the SNR of the transmission, the degree to which the transmission has been perturbed by fading and/or multipath, and the current state of the processing and communication queues in each SCS 10. The number of bits sent from the SCS 10 to the TLP 12 are reduced in two ways: the number of bits per sample is minimized, and the shortest length, or fewest segments, of the transmission possible is used for location processing. The TLP 12 can use this minimal RF data to perform location processing and then compare the result with the desired accuracy level. This comparison is performed on the basis of a confidence interval calculation. If the location estimate does not fall within the desired accuracy limits, the TLP 12 will recursively request additional data from selected SCS's 10. The additional data may include an additional number of bits per digital sample and/or may include more segments of the transmission. This process of requesting additional data may continue recursively until the TLP 12 has achieved the prescribed location accuracy.

There are additional details to the basic steps described above. These details are described in prior Patent Numbers 5,327,144 and 5,608,410 in other parts of this specification. One enhancement to the processes described in earlier patents is the selection of a single reference SCS/antenna that is used for each baseline in the location processing. In prior art, baselines were determined using pairs of antenna sites around a ring. In the present Wireless Location System, the single reference SCS/antenna used is generally the highest SNR signal, although other criteria are also used as described below. The use of a high SNR reference aids central based location processing when the other SCS/antennas used in the location processing are very weak, such as at or below the noise floor (i.e. zero or negative signal to noise ratio). When station based location processing is used, the reference signal is a re-modulated signal, which is intentionally created to have a very high signal to noise ratio, further aiding location processing for very weak signals at other SCS/antennas. The actual selection of the reference SCS/antenna is described below.

The Wireless Location System mitigates multipath by first recursively estimating the components of multipath received in addition to the direct path component and then subtracting these components from the received signal. Thus the Wireless Location System models the received signal and compares the model to the actual received signal and attempts to minimize the difference between the two using a weighted least square difference. For each transmitted signal x(t) from a wireless transmitter, the received signal y(t) at each SCS/antenna is a complex combination of signals:

$y(t) = \sum x\,(t - \tau_n)a_n\, e^{j\omega(t-\tau n)}$, for all n = 0 to N;

where x(t) is the signal as transmitted by the wireless transmitter;
a_n and τ_n are the complex amplitude and delays of the multipath components;
N is the total number of multipath components in the received signal; and
a_0 and τ_0 are constants for the most direct path component.

The operator of the Wireless Location System empirically determines a set of constraints for each component of multipath that applies to the specific environment in which each Wireless Location System is operating. The purpose of the constraints is to limit the amount of processing time that the Wireless Location System spends optimizing the results for each multipath mitigation calculation. For example, the Wireless Location System may be set to determine only four components of multipath: the first component may be assumed to have a time delay in the range τ_{1A} to τ_{1B}; the second component may be assumed to have a time delay in the range τ_{2A} to τ_{2B}; the third component may be assumed to have a time delay in the range τ_{3A} to τ_{3B}; and similar for the fourth component; however the fourth component is a single value that effectively represents a complex combination of many tens of individual (and somewhat diffuse) multipath components whose time delays exceed the range of the third component. For ease of processing, the Wireless Location System transforms the prior equation into the frequency domain, and then solves for the individual components such that a weighted least squares difference is minimized.

When using station based processing, the TDOA and FDOA determination and multipath mitigation are performed in the SCS's 10, while the position and speed determination are typically performed in the TLP 12. The main advantage of station based processing, as described in Patent Number 5,327,144, is reducing the amount of data that is sent on the communication link between each SCS 10 and TLP 12. However, there may be other advantages as well. One new objective of the present invention is increasing the effective signal processing gain during the TDOA processing. As pointed out earlier, central based processing has the advantage of eliminating or reducing phase error caused by the phase noise in the wireless transmitter. However, no previous disclosure has addressed how to eliminate or reduce the same phase noise error when using station based processing. The present invention reduces the phase error and increases the effective signal processing gain using the steps recited below and shown in Figure 6:

a wireless transmitter initiates a transmission on either a control channel or a voice channel (step S60);

the transmission is received at multiple antennas and at multiple SCS's 10 in the Wireless Location System (step S61);

the transmission is converted into a digital format in the receiver connected to each antenna (step S62);

the digital data is stored in a memory in the SCS 10 (step S63);

the transmission is demodulated (step S64);

the Wireless Location System determines whether to begin location processing for the transmission (step S65);

if triggered, a first SCS 10A demodulates the transmission and determines an appropriate phase correction interval (step S66);

for each such phase correction interval, the first SCS 10A calculates an appropriate phase correction and amplitude correction, and encodes this phase correction parameter and amplitude correction parameter along with the demodulated data (step S67);

the demodulated data and phase correction and amplitude correction parameters are sent from the first SCS 10A to a TLP 12 (step S68);

the TLP 12 determines the SCS's 10 and receiving antennas to use in the location processing (step S69);

the TLP 12 sends the demodulated data and phase correction and amplitude correction parameters to each second SCS 10B that will be used in the location processing (step S70);

the first SCS 10 and each second SCS 10B creates a first re-modulated signal based upon the demodulated data and the phase correction and amplitude correction parameters (step S71);

the first SCS 10A and each second SCS 10B performs TDOA, FDOA, and multipath mitigation using the digital data stored in memory in each SCS 10 and the first re-modulated signal (step S72);

the TDOA, FDOA, and multipath mitigation data are sent from the first SCS 10A and each second SCS 10B to the TLP 12 (step S73);

the TLP 12 performs position and speed determination using the TDOA data (step S74); and

the TLP 12 creates a location record, and forwards the location record to the AP 14 (step S75).

The advantages of determining phase correction and amplitude correction parameters are most obvious in the location of CDMA wireless transmitters based upon IS-95A. As is well known, the reverse transmissions from an IS-95A transmitter are sent using non-coherent modulation. Most CDMA base stations only integrate over a single bit interval because of the non-coherent modulation. For a CDMA Access Channel, with a bit rate of 4800 bits per second, there are 256 chips sent per bit, which permits an integration gain of 24 dB. Using the technique described above, the TDOA processing in each SCS 10 may integrate, for example, over a full 160 millisecond burst (196,608 chips) to produce an integration gain of 53 dB. This additional processing gain enables the present invention to detect and locate CDMA transmissions using multiple SCS's 10, even if the base stations collocated with the SCS's 10 cannot detect the same CDMA transmission.

For a particular transmission, if either the phase correction parameters or the amplitude correction parameters are calculated to be zero, or are not needed, then these parameters are not sent in order to conserve on the number of bits transmitted on the communications link between each SCS 10 and TLP 12. In another embodiment of the invention, the Wireless Location System may use a fixed phase correction interval for a particular transmission or for all transmissions of a particular air interface protocol, or for all transmissions made by a particular type of wireless transmitter. This may, for example, be based upon empirical data gathered over some period of time by the Wireless Location System showing a reasonable consistency in the phase noise exhibited by various classes of transmitters. In these cases, the SCS 10 may save the processing step of determining the appropriate phase correction interval.

Those skilled in the art will recognize that there are many ways of measuring the phase noise of a wireless transmitter. In one embodiment, a pure, noiseless re-modulated copy of the signal received at the first SCS 10A may be digitally generated by DSP's in the SCS, then the received signal may be compared against the pure signal over each phase correction interval and the phase difference may be measured directly. In this embodiment, the phase correction parameter will be calculated as the negative of the phase difference over that phase correction interval. The number of bits required to represent the phase correction parameter will vary with the magnitude of the phase correction parameter, and the number of bits may vary for each phase correction interval. It has been observed that some transmissions, for example, exhibit greater phase noise early in the transmission, and less phase noise in the middle of and later in the transmission.

Station based processing is most useful for wireless transmitters that have relatively low phase noise. Although not necessarily required by their respective air interface standards, wireless telephones that use the TDMA, CDMA, or GSM protocols will typically exhibit lower phase noise. As the phase noise of a wireless transmitter increases, the length of a phase correction interval may decrease and/or the number of bits required to represent the phase correction parameters increases. Station based processing is not effective when the number of bits required to represent the demodulated data plus the phase correction and amplitude parameters exceeds a predetermined proportion of the number of bits required to perform central based processing. It is therefore an object of the present invention to automatically determine for each transmission for which a location is desired whether to process the location using central based processing or station based processing. The steps in making this determination are recited below and shown in Figure 7:

a wireless transmitter initiates a transmission on either a control channel or a voice channel (step S80);

the transmission is received at a first SCS 10A (step S81);

the transmission is converted into a digital format in the receiver connected to each antenna (step S82);

the Wireless Location System determines whether to begin location processing for the transmission (step S83);

if triggered, a first SCS 10A demodulates the transmission and estimates an appropriate phase correction interval and the number of bits required to encode the phase correction and amplitude correction parameters (step S84);

the first SCS 10A then estimates the number of bits required for central based processing;

based upon the number of bits required for each respective method, the SCS 10 or the TLP 12 determine whether to use central based processing or station based processing to perform the location processing for this transmission (step S85).

In another embodiment of the invention, the Wireless Location System may always use central based processing or station based processing for all transmissions of a particular air interface protocol, or for all transmissions made by a particular kind of wireless transmitter.

This may, for example, be based upon empirical data gathered over some period of time by the Wireless Location System showing a reasonable consistency in the phase noise exhibited by various classes of transmitters. In these cases, the SCS 10 and/or the TLP 12 may be saved the processing step of determining the appropriate processing method.

A further enhancement of the present invention, used for both central based processing and station based processing, is the use of threshold criteria for including baselines in the final determination of location and velocity of the wireless transmitter. For each baseline, the Wireless Location System calculates a number of parameters that include: the SCS/antenna port used with the reference SCS/antenna in calculating the baseline, the peak, average, and variance in the power of the transmission as received at the SCS/antenna port used in the baseline and over the interval used for location processing, the correlation value from the cross-spectra correlation between the SCS/antenna used in the baseline and the reference SCS/antenna, the delay value for the baseline, the multipath mitigation parameters, the residual values remaining after the multipath mitigation calculations, the contribution of the SCS/antenna to the weighted GDOP in the final location solution, and a measure of the quality of fit of the baseline if included in the final location solution. Each baseline is included in the final location solution is each meets or exceeds the threshold criteria for each of the parameters described herein. A baseline may be excluded from the location solution if it fails to meet one or more of the threshold criteria. Therefore, it is frequently possible that the number of SCS/antennas actually used in the final location solution is less than the total number considered.

Previous Patent Numbers 5,327,144 and 5,608,410 disclosed a method by which the location processing minimized the least square difference (LSD) value of the following equation:

$$LSD = [Q_{12}(Delay\_T_{12}-Delay\_O_{12})^2+ Q_{13}(Delay\_T_{13}-Delay\_O_{13})^2+\ldots+ Q_{xy}(Delay\_T_{xy}-Delay\_O_{xy})^2$$

In the present implementation, this equation has been rearranged to the following form in order to make the location processing code more efficient:

$LSD = \Sigma (TDOA_{0i} - \tau_i + \tau_0)^2 w_i^2$; over all i=1 to N-1

where N = number of SCS/antennas used in the location processing;
$TDOA_{0i}$ = the TDOA to the i^{th} site from reference site 0;
τ_i = the theoretical line of sight propagation time from the wireless transmitter to the i^{th} site;
τ_0 = the theoretical line of sight propagation time from the transmitter to the reference; and
w_i = the weight, or quality factor, applied to the i^{th} baseline.

In the present implementation, the Wireless Location System also uses another alternate form of the equation that can aid in determining location solutions when the reference signal is not very strong or when it is likely that a bias would exist in the location solution using the prior form of the equation:

$LSD' = \Sigma (TDOA_{0i} - \tau_i)^2 w_i^2 - b^2 \Sigma w_i^2$; over all i=0 to N-1

Where N = number of SCS/antennas used in the location processing;
$TDOA_{0i}$ = the TDOA to the i^{th} site from reference site 0;
$TDOA_{00}$ = is assumed to be zero;
τ_i = the theoretical line of sight propagation time from the wireless transmitter to the i^{th} site;
b = a bias that is separately calculated for each theoretical point that minimizes LSD' at that theoretical point; and
w_i = the weight, or quality factor, applied to the i^{th} baseline.

The LSD' form of the equation offers an easier means of removing a bias in location solutions at the reference site by making w_0 equal to the maximum value of the other weights or basing w_0 on the relative signal strength at the reference site. Note that if w_0 is much larger than the other weights, then b is approximately equal to τ_0. In general, the weights, or quality factors are based on similar criteria to that discussed above for the threshold criteria in including baselines. That is, the results of the criteria calculations are used for weights and when the criteria falls below threshold the weight is then set to zero and is effectively not included in the determination of the final location solution.

Antenna Selection Process for Location Processing

Previous inventions and disclosures, such as those listed above, have described techniques in which a first, second, or possibly third antenna site, cell site, or base station are required to determine location. Patent number 5,608,410 further discloses a Dynamic Selection Subsystem (DSS) that is responsible for determining which data frames from which antenna site locations will be used to calculate the location of a responsive transmitter. In the DSS, if data frames are received from more than a threshold number of sites, the DSS determines which are candidates for retention or exclusion, and then dynamically organizes data frames for location processing. The DSS prefers to use more than the minimum number of antenna sites so that the solution is over-determined. Additionally, the DSS assures that all transmissions used in the location processing were received from the same transmitter and from the same transmission.

The preferred embodiments of the prior inventions had several limitations, however. First, either only one antenna per antenna site (or cell site) is used, or the data from two or four diversity antennas were first combined at the antenna site (or cell site) prior to transmission to the central site. Additionally, all antenna sites that received the transmission sent data frames to the central site, even if the DSS later discarded the data frames. Thus, some communications bandwidth may have been wasted sending data that was not used.

The present inventors have determined that while a minimum of two or three sites are required in order determine location, the actual selection of antennas and SCS's 10 to use in location processing can have a significant effect on the results of the location processing. In addition, it is advantageous to include the means to use more than one antenna at each SCS 10 in the location processing. The reason for using data from multiple antennas at a cell site independently in the location processing is that the signal received at each antenna is uniquely affected by multipath, fading, and other disturbances. It is well known in the field that when two antennas are separated in distance by more than one wavelength, then each antenna will receive the signal on an independent path. Therefore, there is frequently additional and unique information to be gained about the location of the wireless transmitter by using multiple antennas, and the ability of the Wireless Location System to mitigate multipath is enhanced accordingly.

It is therefore an object of the present invention to provide an improved method for using the signals received from more than one antenna at an SCS 10 in the location processing. It is a further object to provide a method to improve the dynamic process used to select the cooperating antennas and SCS's 10 used in the location processing. The first object is achieved by providing means within the SCS 10 to select and use any segment of data collected from any number of antennas at an SCS in the location processing. As described earlier, each antenna at a cell site is connected to a receiver internal to the SCS 10. Each receiver converts signals received from the antenna into a digital form, and then stores the digitized signals temporarily in a memory in the receiver. The TLP 12 has been provided with means to direct any SCS 10 to retrieve segments of data from the temporary memory of any receiver, and to provide the data for use in location processing. The second object is achieved by providing means within the Wireless Location System to monitor a large number of antennas for reception of the transmission that the Wireless Location System desires to locate, and then selecting a smaller set of antennas for use in location processing based upon a predetermined set of parameters. One example of this selection process is represented by the flowchart of Figure 8:

a wireless transmitter initiates a transmission on either a control channel or a voice channel (step S90);

the transmission is received at multiple antennas and at multiple SCS's 10 in the Wireless Location System (step S91);

the transmission is converted into a digital format in the receiver connected to each antenna (step S92);

the digital data is stored in a memory in each SCS 10 (step S93);

the transmission is demodulated at at least one SCS 10A and the channel number on which the transmission occurred and the cell site and sector serving the wireless transmitter is determined (step S94);

based upon the serving cell site and sector, one SCS 10A is designated as the 'primary' SCS 10 for processing that transmission (step S95);

the primary SCS 10A determines a timestamp associated with the demodulated data (step S96);

the Wireless Location System determines whether to begin location processing for the transmission (step S97);

if location processing is triggered, the Wireless Location System determines a candidate list of SCS's 10 and antennas to use in the location processing (step S98);

each candidate SCS/antenna measures and reports several parameters in the channel number of the transmission and at the time of the timestamp determined by the primary SCS 10A (step S99);

the Wireless Location System orders the candidate SCS/antennas using specified criteria and selects a reference SCS/antenna and a processing list of SCS/antennas to use in the location processing (step S100); and

the Wireless Location System proceeds with location processing as described earlier, using data from the processing list of SCS/antennas (step S101).

Selecting Primary SCS/Antenna

The process for choosing the 'primary' SCS/antenna is critical, because the candidate list of SCS's 10 and antennas 10-1 is determined in part based upon the designation of the primary SCS/antenna. When a wireless transmitter makes a transmission on a particular RF channel, the transmission frequently can propagate many miles before the signal attenuates below a level at which it can be demodulated. Therefore, there are frequently many SCS/antennas capable of demodulating the signal. This especially occurs is urban and suburban areas where the frequency re-use pattern of many wireless communications systems can be quite dense. For example, because of the high usage rate of wireless and the dense cell site spacing, the present inventors have tested wireless communications systems in which the same RF control channel and digital color code were used on cell sites spaced about one mile apart. Because the Wireless Location System is independently demodulating these transmissions, the Wireless Location System frequently can demodulate the same transmission at two, three, or more separate SCS/antennas. The Wireless Location System detects that the same transmission has been demodulated multiple times at multiple SCS/antennas when the Wireless Location System receives multiple demodulated data frames sent from different SCS/antennas, each with a number of bit errors below a predetermined bit error threshold, and with the demodulated data matching within an acceptable limit of bit errors, and all occurring within a predetermined interval of time.

When the Wireless Location System detects demodulated data from multiple SCS/antennas, it examines the following parameters to determine which SCS/antenna shall be designated the primary SCS: average SNR over the transmission interval used for location processing, the variance in the SNR over the same interval, correlation of the beginning of the received transmission against a pure pre-cursor (i.e. for AMPS, the dotting and Barker code), the number of bit errors in the demodulated data, and the magnitude and rate of change of the SNR from just before the on-set of the transmission to the on-set of the transmission, as well as other similar parameters. The average SNR is typically determined at each SCS/antenna either over the entire length of the transmission to be used for location processing, or over a shorter interval. The average SNR over the shorter interval can be determined by performing a correlation with the dotting sequence and/or Barker code and/or sync word, depending on the particular air interface protocol, and over a short range of time before, during, and after the timestamp reported by each SCS 10. The time range may typically be +/-200 microseconds centered at the timestamp, for example. The Wireless Location System will generally order the SCS/antennas using the following criteria, each of which may be weighted (multiplied by an appropriate factor) when combining the criteria to determine the final decision: SCS/antennas with a lower number of bit errors are preferred to SCS/antennas with a higher number of bit errors, average SNR for a given SCS/antenna must be greater than a predetermined threshold to be designated as the primary; SCS/antennas with higher average SNR are preferred over those with lower average SNR; SCS/antennas with lower SNR variance are preferred to those with higher SNR variance; and SCS/antennas with a faster SNR rate of change at the on-set of the transmission are preferred to those with a slower rate of change. The weighting applied to each of these criteria may be adjusted by the operator of the Wireless Location System to suit the particular design of each system.

The candidate list of SCS's 10 and antennas 10-1 are selected using a predetermined set of criteria based, for example, upon knowledge of the types of cell sites, types of antennas at the cell sites, geometry of the antennas, and a weighting factor that weights certain antennas more than other antennas. The weighting factor takes into account knowledge of the terrain in which the Wireless Location System is operating, past empirical data on the contribution of each antenna has made to good location estimates, and other factors that may be specific to each different WLS installation. In one embodiment, for example, the Wireless Location System may select the candidate list to include all SCS's 10 up to a maximum number of sites (max_number_of_sites) that are closer than a predefined maximum radius from the primary site (max_radius_from_primary). For example, in an urban or suburban environment, wherein there may be a large number of cell sites, the max_number_of_sites may be limited to nineteen. Nineteen sites would include the primary, the first ring of six sites surrounding the primary (assuming a classic hexagonal distribution of cell sites), and the next ring of twelve sites surrounding the first ring. This is depicted in Figure 9. In another embodiment, in a suburban or rural environment, max_radius_from_primary may be set to 40 miles to ensure that the widest possible set of candidate SCS/antennas is available. The Wireless Location System is provided with means to limit the total number of candidate SCS's 10 to a maximum number (max_number_candidates), although each candidate SCS may be permitted to choose the best port from among its available antennas. This limits the maximum time spent by the Wireless Location System processing a particular location. Max_number_candidates may be set to thirty-two, for example, which means that in a typical three sector wireless communications system with diversity, up to 32*6 = 192 total antennas could be considered for location processing for a particular transmission. In order to limit the time spent processing a particular location, the Wireless Location System is provided with means to limit the number of antennas used in the location processing to max_number_antennas_processed. Max_number_antennas_processed is generally less than max_number_candidates, and is typically set to sixteen.

While the Wireless Location System is provided with the ability to dynamically determine the candidate list of SCS's 10 and antennas based upon the predetermined set of criteria described above, the Wireless Location System can also store a fixed candidate list in a table. Thus, for each cell site and sector in the wireless communications system, the Wireless Location System has a separate table that defines the candidate list of SCS's 10 and antennas 10-1 to use whenever a wireless transmitter initiates a transmission in that cell site and sector. Rather than dynamically choose the candidate SCS/antennas each time a location request is triggered, the Wireless Location System reads the candidate list directly from the table when location processing is initiated.

In general, a large number of candidate SCS's 10 is chosen to provide the Wireless Location System with sufficient opportunity and ability to measure and mitigate multipath. On any given transmission, any one or more particular antennas at one or more SCS's 10 may receive signals that have been affected to varying degrees by multipath. Therefore, it is advantageous to provide this means within the Wireless Location System to dynamically select a set of antennas which may have received less multipath than other antennas. The Wireless Location System uses various techniques to mitigate as much multipath as possible from any received signal; however it is frequently prudent to choose a set of antennas that contain the least amount of multipath.

Choosing Reference and Cooperating SCS/Antennas

In choosing the set of SCS/antennas to use in location processing, the Wireless Location System orders the candidate SCS/antennas using several criteria, including for example: average SNR over the transmission interval used for location processing, the variance in the SNR over the same interval, correlation of the beginning of the received transmission against a pure pre-cursor (i.e. for AMPS, the dotting and Barker code) and/or demodulated data from the primary SCS/antenna, the time of the on-set of the transmission relative to the on-set reported at the SCS/antenna at which the transmission was demodulated, and the magnitude and rate of change of the SNR from just before the on-set of the transmission to the on-set of the transmission, as well as other similar parameters. The average SNR is typically determined at each SCS, and for each antenna in the candidate list either over the entire length of the transmission to be used for location processing, or over a shorter interval. The average SNR over the shorter interval can be determined by performing a correlation with the dotting sequence and/or Barker code and/or sync word, depending on the particular air interface protocol, and over a short range of time before, during, and after the timestamp reported by the primary SCS 10. The time range may typically be +/- 200 microseconds centered at the timestamp, for example. The Wireless Location System will generally order the candidate SCS/antennas using the following criteria, each of which may be weighted when combining the criteria to determine the final decision: average SNR for a given SCS/antenna must be greater than a predetermined threshold to be used in location processing; SCS/antennas with higher average SNR are preferred over those with lower average SNR; SCS/antennas with lower SNR variance are preferred to those with higher SNR variance; SCS/antennas with an on-set closer to the on-set reported by the demodulating SCS/antenna are preferred to those with an on-set more distant in time; SCS/antennas with a faster SNR rate of change are preferred to those with a slower rate of change; SCS/antennas with lower incremental weighted GDOP are preferred over those with higher incremental weighted GDOP, wherein the weighting is based upon estimated path loss from the primary SCS. The weighting applied to each of these preferences may be adjusted by the operator of the Wireless Location System to suit the particular design of each system. The number of different SCS's 10 used in the location processing is maximized up to a predetermined limit; the number of antennas used at each SCS 10 in limited to a predetermined limit; and the total number of SCS/antennas used is limited to max_number_antennas_processed. The SCS/antenna with the highest ranking using the above described process is designated as the reference SCS/antenna for location processing.

Best Port Selection Within an SCS 10

Frequently, the SCS/antennas in the candidate list or in the list to use in location processing will include only one or two antennas at a particular SCS 10. In these cases, the Wireless Location System may permit the SCS 10 to choose the "best port" from all or some of the antennas at the particular SCS 10. For example, if the Wireless Location System chooses to use only one antenna at a first SCS 10, then the first SCS 10 may select the best antenna port from the typical six antenna ports that are connected to that SCS 10, or it may choose the best antenna port from among the two antenna ports of just one sector of the cell site. The best antenna port is chosen by using the same process and comparing the same parameters as described above for choosing the set of SCS/antennas to use in location processing, except that all of the antennas being considered for best port are all in the same SCS 10. In comparing antennas for best port, the SCS 10 may also optionally divide the received signal into segments, and then measure the SNR separately in each segment of the received signal. Then, the SCS 10 can optionally choose the best antenna port with highest SNR either by (i) using the antenna port with the most segments with the highest SNR, (ii) averaging the SNR in all segments and using the antenna port with the highest average SNR, or (iii) using the antenna port with the highest SNR in any one segment.

Detection and Recovery From Collisions

Because the Wireless Location System will use data from many SCS/antenna ports in location processing, there is a chance that the received signal at one or more particular SCS/antenna ports contains energy that is co-channel interference from another wireless transmitter (i.e. a partial or full collision between two separate wireless transmissions has occurred). There is also a reasonable probability that the co-channel interference has a much higher SNR than the signal from the target wireless transmitter, and if not detected by the Wireless Location System, the co-channel interference may cause an incorrect choice of best antenna port at an SCS 10, reference SCS/antenna, candidate SCS/antenna, or SCS/antenna to be used in location processing. The co-channel interference may also cause poor TDOA and FDOA results, leading to a failed or poor location estimate. The probability of collision increases with the density of cell sites in the host wireless communications system, especially in dense suburban or rural environments where the frequencies are re-used often and wireless usage by subscribers is high.

Therefore, the Wireless Location System includes means to detect and recover from the types of collisions described above. For example, in the process of selecting a best port, reference SCS/antenna, or candidate SCS/antenna, the Wireless Location System determines the average SNR of the received signal and the variance of the SNR over the interval of the transmission; when the variance of the SNR is above a predetermined threshold, the Wireless

Location System assigns a probability that a collision has occurred. If the signal received at an SCS/antenna has increased or decreased its SNR in a single step, and by an amount greater than a predetermined threshold, the Wireless Location System assigns a probability that a collision has occurred. Further, if the average SNR of the signal received at a remote SCS is greater than the average SNR that would be predicted by a propagation model, given the cell site at which the wireless transmitter initiated its transmission and the known transmit power levels and antenna patterns of the transmitter and receive antennas, the Wireless Location System assigns a probability that a collision has occurred. If the probability that a collision has occurred is above a predetermined threshold, then the Wireless Location System performs the further processing described below to verify whether and to what extent a collision may have impaired the received signal at an SCS/antenna. The advantage of assigning probabilities is to reduce or eliminate extra processing for the majority of transmissions for which collisions have not occurred. It should be noted that the threshold levels, assigned probabilities, and other details of the collision detection and recovery processes described herein are configurable, i.e., selected based on the particular application, environment, system variables, etc., that would affect their selection.

For received transmissions at an SCS/antenna for which the probability of a collision is above the predetermined threshold and before using RF data from a particular antenna port in a reference SCS/antenna determination, best port determination or in location processing, the Wireless Location System preferably verifies that the RF data from each antenna port is from the correct wireless transmitter. This is determined, for example, by demodulating segments of the received signal to verify, for example, that the MIN, MSID, or other identifying information is correct or that the dialed digits or other message characteristics match those received by the SCS/antenna that initially demodulated the transmission. The Wireless Location System may also correlate a short segment of the received signal at an antenna port with the signal received at the primary SCS 10 to verify that the correlation result is above a predetermined threshold. If the Wireless Location System detects that the variance in the SNR over the entire length of the transmission is above a pre-determined threshold, the Wireless Location System may divide the transmission into segments and test each segment as described herein to determine whether the energy in that segment is primarily from the signal from the wireless transmitter for which location processing has been selected or from an interfering transmitter.

The Wireless Location System may choose to use the RF data from a particular SCS/antenna in location processing even if the Wireless Location System has detected that a partial collision has occurred at that SCS/antenna. In these cases, the SCS 10 uses the means described above to identify that portion of the received transmission which represents a signal from the wireless transmitter for which location processing has been selected, and that portion of the received transmission which contains co-channel interference. The Wireless Location System may command the SCS 10 to send or use only selected segments of the received transmission that do not contain the co-channel interference. When determining the TDOA and FDOA for a baseline using only selected segments from an SCS/antenna, the Wireless Location System uses only the corresponding segments of the transmission as received at the reference SCS/antenna. The Wireless Location System may continue to use all segments for baselines in which no collisions were detected. In many cases, the Wireless Location System is able to complete location processing and achieve an acceptable location error using only a portion of the transmission. This inventive ability to select the appropriate subset of the received transmission and perform location processing on a segment by segment basis enables the Wireless Location System to successfully complete location processing in cases that might have failed using previous techniques.

Multiple Pass Location Processing

Certain applications may require a very fast estimate of the general location of a wireless transmitter, followed by a more accurate estimate of the location that can be sent subsequently. This can be valuable, for example, for E9-1-1 systems that handle wireless calls and must make a call routing decision very quickly, but can wait a little longer for a more exact location to be displayed upon the E9-1-1 call-taker's electronic map terminal. The Wireless Location System supports these applications with an inventive multiple pass location processing mode.

In many cases, location accuracy is enhanced by using longer segments of the transmission and increasing the processing gain through longer integration intervals. But longer segments of the transmission require longer processing periods in the SCS 10 and TLP 12, as well as longer time periods for transmitting the RF data across the communications interface from the SCS 10 to the TLP 12. Therefore, the Wireless Location System includes means to identify those transmissions that require a fast but rough estimate of the location followed by more complete location processing that produces a better location estimate. The Signal of Interest Table includes a flag for each Signal of Interest that requires a multiple pass location approach. This flag specifies the maximum amount of time permitted by the requesting location application for the first estimate to be sent, as well as the maximum amount of time permitted by the requesting location application for the final location estimate to be sent. The Wireless Location System performs the rough location estimate by selecting a subset of the transmission for which to perform location processing. The Wireless Location System may choose, for example, the segment that was identified at the primary SCS/antenna with the highest average SNR. After the rough location estimate has been determined, using the methods described earlier, but with only a subset of the transmission, the TLP 12 forwards the location estimate to the AP 14, which then forwards the rough estimate to the requesting application with a flag indicating that the estimate is only rough. The Wireless Location System then performs its standard location processing using all of the aforementioned methods, and forwards this location estimate with a flag indicating the final status of this location estimate. The Wireless Location System may perform the rough location estimate and the final location estimate sequentially on the same DSP in a TLP 12, or may perform the location processing in parallel on different DSP's. Parallel processing may be necessary to meet the maximum time requirements of the requesting location applications. The Wireless Location System supports different maximum time requirements from different location applications for the same wireless transmission.

Very Short Baseline TDOA

The Wireless Location System is designed to operate in urban, suburban, and rural areas. In rural areas, when there are not sufficient cell sites available from a single wireless carrier, the Wireless Location System can be deployed with SCS's 10 located at the cell sites of other wireless carriers or at other types of towers, including AM or FM radio station, paging, and two-way wireless towers. In these cases, rather than sharing the existing antennas of the wireless carrier, the Wireless Location System may require the installation of appropriate antennas, filters, and low noise amplifiers to match the frequency band of the wireless transmitters of interest to be located. For example, an AM radio station tower may require the addition of 800 MHz antennas to locate cellular band transmitters. There may be cases, however, wherein no additional towers of any type are available at reasonable cost and the Wireless Location System must be deployed on just a few towers of the wireless carrier. In these cases, the Wireless Location System supports an antenna mode known as very short baseline TDOA. This antenna mode becomes active when additional antennas are installed on a single cell site tower, whereby the antennas are placed at a distance of less than one wavelength apart. This may require the addition of just one antenna per cell site sector such that the Wireless Location System uses one existing receive antenna in a sector and one additional antenna that has been placed next to the existing receive antenna. Typically, the two antennas in the sector are oriented such that the primary axes, or line of direction, of the main beams are parallel and the spacing between the two antenna elements is known with precision. In addition, the two RF paths from the antenna elements to the receivers in the SCS 10 are calibrated.

In its normal mode, the Wireless Location System determines the TDOA and FDOA for pairs of antenna that are separated by many wavelengths. For a TDOA on a baseline using antennas from two difference cell sites, the pairs of antennas are separated by thousands of wavelengths. For a TDOA on a baseline using antennas at the same cell site, the pairs of antennas are separated by tens of wavelengths. In either case, the TDOA determination effectively results in a hyperbolic line bisecting the baseline and passing through the location of the wireless transmitter. When antennas are separated by multiple wavelengths, the received signal has taken independent paths from the wireless transmitter to each antenna, including experiencing different multipath and Doppler shifts. However, when two antennas are closer than one wavelength, the two received signals have taken essentially the same path and experienced the same fading, multipath, and Doppler shift. Therefore, the TDOA and FDOA processing of the Wireless Location System typically produces a Doppler shift of zero (or near-zero) hertz, and a time difference on the order of zero to one nanosecond. A time difference that short is equivalent to an unambiguous phase difference between the signals received at the two antennas on the very short baseline. For example, at 834 MHz, the wavelength of an AMPS reverse control channel transmission is about 1.18 feet. A time difference of 0.1 nanoseconds is equivalent to a received phase difference of about 30 degrees. In this case, the TDOA measurement produces a hyperbola that is essentially a straight line, still passing through the location of the wireless transmitter, and in a direction that is rotated 30 degrees from the direction of the parallel lines formed by the two antennas on the very short baseline. When the results of this very short baseline TDOA at the single cell site are combined with a TDOA measurement on a baseline between two cell sites, the Wireless Location System can determine a location estimate using only two cell sites.

Bandwidth Monitoring Method For Improving Location Accuracy

AMPS cellular transmitters presently comprise the large majority of the wireless transmitters used in the U.S. and AMPS reverse voice channel transmissions are generally FM signals modulated by both voice and a supervisory audio tone (SAT). The voice modulation is standard FM, and is directly proportional to the speaking voice of the person using the wireless transmitter. In a typical conversation, each person speaks less that 35% of the time, which means that most of the time the reverse voice channel is not being modulated due to voice. With or without voice, the reverse channel is continuously modulated by SAT, which is used by the wireless communications system to monitor channel status. The SAT modulation rate is only about 6 KHz. The voice channels support in-band messages that are used for hand-off control and for other reasons, such as for establishing a 3-way call, for answering a second incoming call while already on a first call, or for responding to an 'audit' message from the wireless communications system. All of these messages, though carried on the voice channel, have characteristics similar to the control channel messages. These messages are transmitted infrequently, and location systems have ignored these messages and focused on the more prevalent SAT transmissions as the signal of interest.

In view of the above-described difficulties presented by the limited bandwidth of the FM voice and SAT reverse voice channel signals, an object of the present invention is to provide an improved method by which reverse voice channel (RVC) signals may be utilized to locate a wireless transmitter, particularly in an emergency situation. Another object of the invention is to provide a location method that allows the location system to avoid making location estimates using RVC signals in situations in which it is likely that the measurement will not meet prescribed accuracy and reliability requirements. This saves system resources and improves the location system's overall efficiency. The improved method is based upon two techniques. Figure 10A is a flowchart of a first method in accordance with the present invention for measuring location using reverse voice channel signals. The method comprises the following steps:

(i) It is first assumed that a user with a wireless transmitter wishes to be located, or wishes to have his location updated or improved upon. This may be the case, for example, if the wireless user has dialed "911" and is seeking emergency assistance. It is therefore also assumed that the user is coherent and in communication with a centrally located dispatcher.

(ii) When the dispatcher desires a location update for a particular wireless transmitter, the dispatcher sends a location update command with the identity of the wireless transmitter to the Wireless Location System over an application interface.

(iii) The Wireless Location System responds to the dispatcher with a confirmation that the Wireless Location System has queried the wireless communications system and has obtained the voice channel assignment for the wireless transmitter.

(iv) The dispatcher instructs the wireless user to dial a 9 or more digit number and then the "SEND" button. This sequence may be something like "123456789" or "911911911". Two functions happen to the reverse voice channel when the wireless user dial a sequence of at least 9 digits and then the "SEND" button. First, especially for an AMPS cellular voice channel, the dialing of digits causes the sending of dual tone multi-frequency (DTMF) tones over the voice channel. The modulation index of DTMF tones is very high and during the sending of each digit in the DTMF sequence will typically push the bandwidth of the transmitted signal beyond +/- 10 KHz. The second function occurs at the pressing of the "SEND" button. Whether or not the wireless user subscribes to 3-way calling or other special features, the wireless transmitter will send a message over the voice using a "blank and burst" mode where the transmitter briefly stops sending the FM voice and SAT, and instead sends a bursty message modulated in the same manner as the control channel (10 Kbits Manchester). If the wireless user dials less than 9 digits, the message will be comprised of approximately 544 bits. If the wireless user dials 9 or more digits, the message is comprised of approximately 987 bits.

(v) After notification by the dispatcher, the Wireless Location System monitors the bandwidth of the transmitted signal in the voice channel. As discussed earlier, when only the SAT is being transmitted, and even if voice and SAT are being transmitted, there may not be sufficient bandwidth in the transmitted signal to calculate a high quality location estimate. Therefore, the Wireless Location System conserves location processing resources and waits until the transmitted signal exceeds a predetermined bandwidth. This may be, for example, set somewhere in the range of 8 KHz to 12 KHz. When the DTMF dialed digits are sent or when the bursty message is sent, the bandwidth would typically exceed the predetermined bandwidth. In fact, if the wireless transmitter does transmit the DTMF tones during dialing, the bandwidth would be expected to exceed the predetermined bandwidth multiple times. This would provide multiple opportunities to perform a location estimate. If the DTMF tones are not sent during dialing, the bursty message is still sent at the time of pressing "SEND", and the bandwidth would typically exceed the predetermined threshold.

(vi) Only when the transmitted bandwidth of the signal exceeds the predetermined bandwidth, the Wireless Location System initiates location processing.

Figure 10B is a flowchart of another method in accordance with the present invention for measuring location using reverse voice channel signals. The method comprises the following steps:

(i) It is first assumed that a user with a wireless transmitter wishes to be located, or wishes to have their location updated or improved upon. This may be the case, for example, if the wireless user has dialed "911" and is seeking emergency assistance. It is assumed that the user may not wish to dial digits or may not be able to dial any digits in accordance with the previous method.

(ii) When the dispatcher desires a location update for a particular wireless transmitter user, the dispatcher sends a location update command to the Wireless Location System over an application interface with the identity of the wireless transmitter.

(iii) The Wireless Location System responds to the dispatcher with a confirmation.

(iv) The Wireless Location System commands the wireless communications system to make the wireless transmitter transmit by sending an "audit" or similar message to the wireless transmitter. The audit message is a mechanism by which the wireless communications system can obtain a response from the wireless transmitter without requiring an action by the end-user and without causing the wireless transmitter to ring or otherwise alert. The receipt of an audit message causes the wireless transmitter to respond with an "audit response" message on the voice channel.

(v) After notification by the dispatcher, the Wireless Location System monitors the bandwidth of the transmitted signal in the voice channel. As discussed earlier, when only the SAT is being transmitted, and even if voice and SAT are being transmitted, there may not be sufficient bandwidth in the transmitted signal to calculate a high quality location estimate. Therefore, the radio location conserves location processing resources and waits until the transmitted signal exceeds a predetermined bandwidth. This may be, for example, set somewhere in the range of 8 KHz to 12 KHz. When the audit response message is sent, the bandwidth would typically exceed the predetermined bandwidth.

(vi) Only when the transmitted bandwidth of the signal exceeds the predetermined bandwidth, the Wireless Location System initiates location processing.

<u>Estimate Combination Method For Improving Location Accuracy</u>

The accuracy of the location estimate provided by the Wireless Location System may be improved by combining multiple statistically-independent location estimates made while the wireless transmitter is maintaining its position. Even when a wireless transmitter is perfectly stationary, the physical and RF environment around a wireless transmitter is constantly changing. For example, vehicles may change their position or another wireless transmitter which had caused a collision during one location estimate may have stopped transmitting or changed its position so as to no longer collide during subsequent location estimates. The location estimate provided by the Wireless Location System will therefore change for each transmission, even if consecutive transmissions are made within a very short period of time, and each location estimate is statistically independent of the other estimates, particularly with respect to the errors caused by the changing environment.

When several consecutive statistically independent location estimates are made for a wireless transmitter that has not changed its position, the location estimates will tend to cluster about the true position. The Wireless Location System combines the location estimates using a weighted average or other similar mathematical construct to determine the improved estimate. The use of a weighted average is aided by the assignment of a quality factor to each independent location estimate. This quality factor may be based upon, for example, the correlation values, confidence interval, or other similar measurements derived from the location processing for each independent estimate. The Wireless Location System optionally uses several methods to obtain multiple independent transmissions from the wireless transmitter, including (i) using its interface to the wireless communications system for the Make Transmit command; (ii) using multiple consecutive bursts from a time slot based air interface protocol, such as TDMA or GSM; or (iii) dividing a voice channel transmission into multiple segments over a period of time and performing location processing independently for each segment. As the Wireless Location System increases the number of independent location estimates being combined into the final location estimate, it monitors a statistic indicating the quality of the cluster. If the statistic is below a prescribed threshold value, then the Wireless Location System assumes that the wireless transmitter is maintaining its position. If the statistic rises above the prescribed threshold value, the Wireless Location System assume that the wireless transmitter is not maintaining its position and therefore ceases to perform additional location estimates. The statistic indicating the quality of the cluster may be, for example, a standard deviation calculation or a root mean square (RMS) calculation for the individual location estimates being combined together and with respect to the dynamically calculated combined location estimate. When reporting a location record to a requesting application, the Wireless Location System indicates, using a field in the location record, the number of independent location estimate combined together to produce the reported location estimate.

Another exemplary process for obtaining and combining multiple location estimates will now be explained with reference to Figures 11A-11D. Figures 11A, 11B and 11C schematically depict the well-known "origination", "page response," and "audit" sequences of a wireless communications system. As shown in Figure 11A, the origination sequence (initiated by the wireless phone to make a call) may require two transmissions from the wireless transmitter, an "originate" signal and an "order confirmation" signal. The order confirmation signal is sent in response to a voice channel assignment from the wireless communications system (e.g., MSC). Similarly, as shown in Figure 11B, a page sequence may involve two transmissions from the wireless transmitter. The page sequence is initiated by the wireless communications system, e.g., when the wireless transmitter is called by another phone. After being paged, the wireless transmitter transmits a page response; and then, after being assigned a voice channel, the wireless transmitter transmits an order confirmation signal. The audit process, in contrast, elicits a single reverse transmission, an audit response signal. An audit and audit response sequence has the benefit of not ringing the wireless transmitter which is responding.

The manner in which these sequences may be used to locate a phone with improved accuracy will now be explained. According to the present invention, for example, a stolen phone, or a phone with a stolen serial number, is repeatedly pinged with an audit signal, which forces it to respond with multiple audit responses, thus permitting the phone to be located with greater accuracy. To use the audit sequence, however, the Wireless Location System sends the appropriate commands using its interface to the wireless communications system, which sends the audit message to the wireless transmitter. The Wireless Location System can also force a call termination (hang up) and then call the wireless transmitter back using the standard ANI code. The call can be terminated either by verbally instructing the mobile user to disconnect the call, by disconnecting the call at the landline end of the call, or by sending an artificial over-the-air disconnect message to the base station. This over-the-air disconnect message simulates the pressing of the "END" button on a mobile unit. The call-back invokes the above-described paging sequence and forces the phone to initiate two transmissions that can be utilized to make location estimates.

Referring now to Figure 11D, the inventive high accuracy location method will now be summarized. First, an initial location estimate is made. Next, the above-described audit or "hang up and call back" process is employed to elicit a responsive transmission from the mobile unit, and then a second location estimate is made. Whether the audit or "hang up and call back" process is used will depend on whether the wireless communications system and wireless transmitter have both implemented the audit functionality. Steps second and third steps are repeated to obtain however many independent location estimates are deemed to be necessary or desirable, and ultimately the multiple statistically-independent location estimates are combined in an average, weighted average, or similar mathematical construct to obtain an improved estimate. The use of a weighted average is aided by the assignment of a quality factor to each independent location estimate. This quality factor may be based upon a correlation percentage, confidence interval, or other similar measurements derived from the location calculation process.

Bandwidth Synthesis Method For Improving Location Accuracy

The Wireless Location System is further capable of improving the accuracy of location estimates for wireless transmitters whose bandwidth is relatively narrow using a technique of artificial bandwidth synthesis. This technique can applied, for example, to those transmitters that use the AMPS, NAMPS, TDMA, and GSM air interface protocols and for which there are a large number of individual RF channels available for use by the wireless transmitter. For exemplary purposes, the following description shall refer to AMPS-specific details; however, the description can be easily altered to apply to other protocols. This method relies on the principle that each wireless transmitter is operative to transmit only narrowband signals at frequencies spanning a predefined wide band of frequencies that is wider than the bandwidth of the individual narrowband signals transmitted by the wireless transmitter. This method also relies on the aforementioned interface between the Wireless Location System and the wireless communications system over which the WLS can command the wireless communications system to make a wireless transmitter handoff or switch to another frequency or RF channel. By issuing a series of commands, the Wireless Location System can force the wireless transmitter to switch sequentially and in a controlled manner to a series of RF channels, allowing the WLS effectively to synthesize a wider band received signal from the series of narrowband transmitted signals for the purpose of location processing.

In a presently preferred embodiment of the invention, the bandwidth synthesis means includes means for determining a wideband phase versus frequency characteristic of the transmissions from the wireless transmitter. For example, the narrowband signals typically have a bandwidth of approximately 20 KHz and the predefined wide band of frequencies spans approximately 12.5 MHz, which in this example, is the spectrum allocated to each cellular carrier by the FCC. With bandwidth synthesis, the resolution of the TDOA measurements can be increased to about 1/12.5 MHz; i.e., the available time resolution is the reciprocal of the effective bandwidth.

A wireless transmitter, a calibration transmitter (if used), SCS's 10A, 10B and 10C, and a TLP 12 are shown in Figure 12A. The location of the calibration transmitter and all three SCS's are accurately known *a priori*. Signals, represented by dashed arrows in Figure 12A, are transmitted by the wireless transmitter and calibration transmitter, and received at SCS's 10A, 10B and 10C, and processed using techniques previously described. During the location processing, RF data from one SCS (e.g. 10B) is cross-correlated (in the time or frequency domain) with the data stream from another SCS (e.g. 10C) separately for each transmitter and for each pair of SCS's 10 to generate TDOA estimates $TDOA_{23}$ and $TDOA_{13}$. An intermediate output of the location processing is a set of coefficients representing the complex cross-power as a function of frequency (e.g., R_{23}).

For example, if X(f) is the Fourier transform of the signal x(t) received at a first site and Y(f) is the Fourier transform of the signal y(t) received at a second site, then the complex cross-power $R(f)=X(f)Y^*(f)$, wherein Y^* is the complex conjugate of Y. The phase angle of R(f) at any frequency f equals the phase of X(f) minus the phase of Y(f). The phase angle of R(f) may be called the fringe phase. In the absence of noise, interference, and other errors, the fringe phase is a perfectly linear function of frequency within a (contiguous) frequency band observed; and slope of the line is minus the interferometric group delay, or TDOA; the intercept of the line at the band center frequency, equal to the average value of the phase of R(f), is called "the" fringe phase of the observation when reference is being made to the whole band. Within a band, the fringe phase may be considered to be a function of frequency.

The coefficients obtained for the calibration transmitter are combined with those obtained for the wireless transmitter and the combinations are analyzed to obtain calibrated TDOA measurements $TDOA_{23}$ and $TDOA_{13}$, respectively. In the calibration process, the fringe phase of the calibration transmitter is subtracted from the fringe phase of the wireless transmitter in order to cancel systematic errors that are common to both. Since each original fringe phase is itself the difference between the phases of signals received at two SCS's 10, the calibration process is often called *double-differencing* and the calibrated result is said to be *doubly-differenced.* TDOA estimate T-ij is a maximum-likelihood estimate of the time difference of arrival (TDOA), between sites i and j, of the signal transmitted by the wireless transmitter, calibrated and also corrected for multipath propagation effects on the signals. TDOA estimates from different pairs of cell sites are combined to derive the location estimate. It is well known that more accurate TDOA estimates can be obtained by observing a wider bandwidth. It is generally not possible to increase the "instantaneous" bandwidth of the signal transmitted by a wireless transmitter, but it is possible to command a wireless transmitter to switch from one frequency channel to another so that, in a short time, a wide bandwidth can be observed.

In a typical non-wireline cellular system, for example, channels 313-333 are control channels and the remaining 395 channels are voice channels. The center frequency of a wireless transmitter transmitting on voice RF channel number 1 (RVC 1) is 826.030 MHz and the center-to-center frequency spacing of successive channels of 0.030 MHz. The number of voice channels assigned to each cell of a typical seven-cell frequency-reuse block is about 57 (i.e., 395 divided by 7) and these channels are distributed throughout the 395-channel range, spaced every 7 channels. Note then that each cell site used in an AMPS system has channels that span the entire 12.5 MHz band allocated by the FCC. If, for example, we designate cells of each frequency set in a re-use pattern as cells "A" through "G", the channel numbers assigned to the "A" cell(s) might be 1, 8, 15, 22, ..., 309; the numbers of the channels assigned to the "B" cells are determined by adding 1 to the "A" channel numbers; and so on through G.

The method begins when the wireless transmitter has been assigned to a voice RF channel, and the Wireless Location System has triggered location processing for the transmissions from the wireless transmitter. As part of the location processing, the TDOA estimates $TDOA_{13}$ and $TDOA_{23}$ combined may have, for example, a standard deviation error of 0.5 microsecond. The method combining measurements from different RF channels exploits the relation between TDOA, fringe phase, and radio frequency. Denote the "true" value of the group delay or TDOA, i.e., the value that would be observed in the absence of noise, multipath, and any instrumental error, by τ; similarly, denote the true value of fringe phase by ϕ; and denote the radio frequency by f. The fringe phase ϕ is related to τ and f by:

$$\phi = -f\tau + n \qquad \text{(Eq. 1)}$$

where ϕ is measured in cycles, f in Hz and τ in seconds; and n is an integer representing the intrinsic integer-cycle ambiguity of a doubly-differenced phase measurement. The value of n is unknown *a priori* but is the same for observations at contiguous frequencies, i.e., within any one frequency channel. The value of n is generally different for observations at separated frequencies. τ can be estimated from observations in a single frequency channel is, in effect, by fitting a straight line to the fringe phase observed as a function of frequency within the channel. The slope of the best-fitting line equals minus the desired estimate of τ. In the single-channel case, n is constant and so Eq. 1 can be differentiated to obtain:

$$d\phi/df = -\tau \qquad \text{(Eq. 2).}$$

Independent estimates of τ are obtainable by straight-line fitting to the observations of ϕ vs. f separately for each channel, but when two separate (non-contiguous) frequency channels are observed, a single straight line will not generally fit the observations of ϕ vs. f from both channels because, in general, the integer n has different values for the two channels. However, under certain conditions, it is possible to determine and remove the difference between these two integer values and then to fit a single straight line to the entire set of phase data spanning both channels. The slope of this straight line will be much better determined because it is based on a wider range of frequencies. Under certain conditions, the uncertainty of the slope estimate is inversely proportional to the frequency span.

In this example, suppose that the wireless transmitter has been assigned to voice RF channel 1. The radio frequency difference between channels 1 and 416 is so great that initially the difference between the integers n_1 and n_{416} corresponding to these channels cannot be determined. However, from the observations in either or both channels taken separately, an initial TDOA estimate τ_0 can be derived. Now the Wireless Location System commands the wireless communications system to make the wireless transmitter to switch from channel 1 to channel 8. The wireless transmitter's signal is received in channel 8 and processed to update or refine the estimate τ_0. From τ_0, the "theoretical" fringe-phase ϕ_0 as a function of frequency can be computed, equal to $(-f\tau_0)$. The difference between the actually observed phase ϕ and the theoretical function ϕ_0 can be computed, wherein the actually observed phase equals the true phase within a very small fraction, typically 1/50th, of a cycle:

$$\phi\text{-}\phi_0 = -f\,(\tau\text{-}\tau_0) + n_1 \text{ or } n_8\text{, depending on the channel} \qquad \text{(Eq. 3)}$$

or

$$\Delta\phi = -\Delta f\tau\text{-}n_1 \text{ or } n_8\text{, depending on the channel} \qquad \text{(Eq. 4)}$$

where $\Delta\phi \equiv \phi-\phi_0$ and $\Delta\tau \equiv \tau-\tau_0$. Equation (4) is graphed in Figure 12B, depicting the difference, $\Delta\phi$, between the observed fringe phase ϕ and the value ϕ_0 computed from the initial TDOA estimate τ_0, versus frequency f for channels 1 and 8.

For the 20 KHz-wide band of frequencies corresponding to channel 1, a graph of $\Delta\phi$ vs. f is typically a horizontal straight line. For the 20 KHz-wide band of frequencies corresponding to channel 8, the graph of $\Delta\phi$ vs. f is also horizontal straight line. The slopes of these line segments are generally nearly zero because the quantity ($f\Delta\tau$) usually does not vary by a significant fraction of a cycle within 20 KHz, because $\Delta\tau$ is minus the error of the estimate τ_0. The magnitude of this error typically will not exceed 1.5 microseconds (3 times the standard deviation of 0.5 microseconds in this example), and the product of 1.5 microseconds and 20 KHz is under 4% of a cycle. In Figure 12B, the graph of $\Delta\phi$ for channel 1 is displaced vertically from the graph of $\Delta\phi$ for channel 8 by a relatively large amount because the difference between n_1 and n_8 can be arbitrarily large. This vertical displacement, or difference between the average values of $\Delta\phi$ for channels 1 and 8, will (with extremely high probability) be within ±0.3 cycle of the true value of the difference, n_1 and n_8, because the product of the maximum likely magnitude of $\Delta\tau$ (1.5 microseconds) and the spacing of channels 1 and 8 (210 KHz) is 0.315 cycle. In other words, the difference $n_1 - n_8$ is equal to the difference between the average values of $\Delta\phi$ for channels 1 and 8, rounded to the nearest integer. After the integer difference $n_1 - n_8$ is determined by this rounding procedure, the integer $\Delta\phi$ is added for channel 8 or subtracted from $\Delta\phi$ for channel 1. The difference between the average values of $\Delta\phi$ for channels 1 and 8 is generally equal to the error in the initial TDOA estimate, τ_0, times 210 KHz. The difference between the average values of $\Delta\phi$ for channels 1 and 8 is divided by 210 KHz and the result is added to τ_0 to obtain an estimate of τ, the true value of the TDOA; this new estimate can be significantly more accurate than τ_0.

This frequency-stepping and TDOA-refining method can be extended to more widely spaced channels to obtain yet more accurate results. If τ_1 is used to represent the refined result obtained from channels 1 and 8, τ_0 can be replaced by τ_1 in the just-described method; and the Wireless Location System can command the wireless communications system to make the wireless transmitter switch, e.g., from channel 8 to channel 36; then τ_1 can be used to determine the integer difference $n_8 - n_{36}$ and a TDOA estimate can be obtained based on the 1.05 MHz frequency span between channels 1 and 36. The estimated can be labeled τ_2; and the wireless transmitter switched, e.g., from channel 36 to 112, and so on. In principle, the full range of frequencies allocated to the cellular carrier can be spanned. The channel numbers (1, 8, 36, 112) used in this example are, of course, arbitrary. The general principle is that an estimate of the TDOA based on a small frequency span (starting with a single channel) is used to resolve the integer ambiguity of the fringe phase difference between more widely separated frequencies. The latter frequency separation should not be too large; it is limited by the uncertainty of the prior estimate of TDOA. In general, the worst-case error in the prior estimate multiplied by the frequency difference may not exceed 0.5 cycle.

If the very smallest (e.g., 210 KHz) frequency gap between the most closely spaced channels allocated to a particular cell cannot be bridged because the worst-case uncertainty of the single-channel TDOA estimate exceeds 2.38 microseconds (equal to 0.5 cycle divided by 0.210 MHz), the Wireless Location System commands the wireless communications system to force the wireless transmitter hand-off from one cell site to another (e.g. from one frequency group to another), such that the frequency step is smaller. There is a possibility of misidentifying the integer difference between the phase differences ($\Delta\phi$'s) for two channels, e.g., because the wireless transmitter moved during the handoff from one channel to the other. Therefore, as a check, the Wireless Location System may reverse each handoff (e.g., after switching from channel 1 to channel 8, switch from channel 8 back to channel 1) and confirm that the integer-cycle difference determined has precisely the same magnitude and the opposite sign as for the "forward" hand-off. A significantly nonzero velocity estimate from the single-channel FDOA observations can be used to extrapolate across the time interval involved in a channel change. Ordinarily this time interval can be held to a small fraction of 1 second. The FDOA estimation error multiplied by the time interval between channels must be small in comparison with 0.5 cycle. The Wireless Location System preferably employs a variety of redundancies and checks against integer-misidentification.

Directed Retry for 911

Another inventive aspect of the Wireless Location System relates to a "directed retry" method for use in connection with a dual-mode wireless communications system supporting at least a first modulation method and a second modulation method. In such a situation, the first and second modulation methods are assumed to be used on different RF channels (i.e. channels for the wireless communications system supporting a WLS and the PCS system, respectively). It is also assumed that the wireless transmitter to be located is capable of supporting both modulation methods, i.e. is capable of dialing

"911" on the wireless communications system having Wireless Location System support.

For example, the directed retry method could be used in a system in which there are an insufficient number of base stations to support a Wireless Location System, but which is operating in a region served by a Wireless Location System associated with another wireless communications system. The "first" wireless communications system could be a cellular telephone system and the "second" wireless communications system could be a PCS system operating within the same territory as the first system. According to the invention, when the mobile transmitter is currently using the second (PCS) modulation method and attempts to originate a call to 911, the mobile transmitter is caused to switch automatically to the first modulation method, and then to originate the call to 911 using the first modulation method on one of the set of RF channels prescribed for use by the first wireless communications system. In this manner, location services can be provided to customers of a PCS or like system that does is not served by its own Wireless Location System.

Modified Transmission Method for Improving Accuracy for E9-1-1 Calls

The accuracy of the location estimate of the Wireless Location System is dependent, in part, upon both the transmitted power of the wireless transmitter and the length in time of the transmission from the wireless transmitter. In general, higher power transmissions and transmissions of greater transmission length can be located with better accuracy by the Wireless Location System than lower power and shorter transmissions. These transmission characteristics of higher power and longer lengths are not attractive for wireless communications systems, however. Wireless communications systems generally limit the transmit power and transmission length of wireless transmitters in order to minimize interference within the communications system and to maximize the potential capacity of the system. The following method meets the conflicting needs of both systems by enabling the wireless communications system to minimize transmit power and length while enabling improved location accuracy for certain types of calls, such as wireless 9-1-1 calls.

The transmitted power and length of the transmission are typically controlled by the wireless communications system. That is, a wireless transmitter will receive parameters from the forward control channels of a base station in a wireless communications system, and the parameters will define power and transmission length for all phones and all wireless transmissions to that base station. By way of example, in an IS-136 (TDMA) type of system, the base station may set a parameter known as DMAC to 4, which defines the output power of a wireless transmitter's control channel transmission to be 8 dB less than full portable power, or approximately 100 mWatts. Further, the base station may set origination transmissions to have a length of 2 bursts, or 13.4 milliseconds, by minimizing the number of fields included in the transmission. For improved accuracy, the Wireless Location System would prefer transmissions of greater power, 600 mWatts for example, and lengths of 3 or more bursts, which can be achieved by enabling fields such as "Authentication", "Serial Number", or "Mobile Assisted Channel Allocation Report". AMPS, CDMA, GSM, and iDEN systems similarly have parameters controlling transmissions within those networks.

The following method can be used to improve the accuracy of specific types of calls from wireless transmitters, such as calls to "9-1-1". This might be important because, for example, particular types of calls might have greater accuracy requirements than other types of calls. Wireless calls to 9-1-1, for example, have very specific accuracy requirements defined by the Federal Communications Commission that may not apply to other types of calls. Therefore, this method is particularly inventive for wireless calls to 9-1-1 because in the United States, the FCC has mandated that "9-1-1" is the only number to call from wireless phones for emergencies. This mandated dialing sequence provides a consistent dialing sequence to use as a trigger for invoking this method for emergency calls. Previously, various states and cities had posted a wide variety of emergency numbers along highways.

There are two parts to this method to improve accuracy (i) processing logic within the wireless transmitter that detects one or more trigger events and causes a separate set of transmission parameters to be used, and (ii) processing logic with the Wireless Location System that detects the trigger event and processes the transmission using the different set of transmission parameters.

Within the wireless transmitter, the following steps are performed:

- a wireless transmitter listens to the forward control channels of a wireless communications system and receives the "normal" transmission parameters broadcast for use by all wireless transmitters;
- the user of a wireless transmitter initiates a call on the wireless transmitter by dialing a sequence of digits and pressing "SEND" or "YES";
- the processor within the wireless transmitter compares the dialed sequence of digits with one or more trigger events stored within the wireless transmitter (in this example, the trigger event may be "9-1-1" and/or variations such as "*9-1-1" or "#9-1-1");
- if the dialed sequence of digits does not match the trigger event, then the wireless transmitter uses the normal transmission parameters in making the call; and
- if the dialed sequence of digits matches the trigger event, then the wireless transmitter uses a modified transmission sequence.

The modified transmission sequence consists of one or more of the following steps:

- the wireless transmitter first examines the normal parameters broadcast on the forward channels by the base station to determine the normal power setting and normal fields to be included in the transmission;
- the wireless transmitter may increase its transmitted power by a predetermined amount over the power level setting in the normal parameters, up to the maximum power setting;
- the wireless transmitter may increase its transmitted power to the maximum power setting;
- the wireless transmitter may transmit an additional predetermined number of access probes (in the case of certain air interfaces such as CDMA) even after the base station has acknowledged receipt of the access probes to the wireless transmitter;
- the wireless transmitter may include additional fields, such as "Authentication", "Serial Number", or "Mobile Assisted Channel Allocation Report" fields, in the transmitted message even if these fields are not requested in the normal parameters broadcast on the forward channels by the base station;

the wireless transmitter may follow a transmitted message with one or more repeated registration messages, where each registration message may be of the normal length determined from the transmission parameters broadcast on the forward channels by the base station, or may be modified to a longer length by including additional fields, such as "Authentication", "Serial Number", "Mobile Assisted Channel Allocation Report", or "Capability Report" fields; or

the wireless transmitter may follow a transmitted message transmitted on a first one of a plurality of channels with one or more repeated registration messages transmitted on another second one of a plurality of channels, where each registration message may be of the normal length determined from the transmission parameters broadcast on the forward channels by the base station, or may be modified to a longer length by including additional fields, such as "Authentication", "Serial Number", "Mobile Assisted Channel Allocation Report", or "Capability Report" fields.

In one of the steps in modified transmission sequence, the wireless transmitter may follow a transmitted message transmitted on a first one of a plurality of channels with one or more repeated registration messages transmitted on another second one of a plurality of channels. The purpose of this step is to provide the Wireless Location System with transmissions of both longer length and on different frequencies. By observing transmissions at different frequencies, the Wireless Location System can potentially improve its location processing by better mitigating multipath and reducing noise due to interference. In selecting another second one of a plurality of channels, the wireless transmitter may modify its channel selection process by:

selecting another second channel in use by a second base station within listening range of the wireless transmitter and for which the wireless transmitter can receive the forward control channel broadcast by that second base station (the second base station may be the same as the first base station, or another sector of the first base station, or an entirely separate base station); or

selecting another second channel for which the wireless transmitter can detect no forward control channel activity by any base station (in this case, the wireless transmitter will transmit one or more registration messages without expecting any acknowledgement from the wireless communications system).

In some wireless communication systems, transmitted messages may follow one of several message encryption schemes defined in protocols such as TDMA, CDMA, or GSM. These encryption schemes are designed, in part, to prevent systems other than base stations from correctly interpreting the content of the messages transmitted by wireless transmitters. As a further step in this method, and in addition to the steps detailed above, the wireless transmitter may optionally deactivate encryption when a trigger event occurs and for all messages transmitted as part of the modified transmission sequence.

By using a trigger event as the only time in which the wireless transmitter modifies its transmission from the normal parameters broadcast by the base station, the wireless transmitter greater reduces the number of times in which the modified transmissions are used and therefore greater reduces the probability of increased interference to the wireless communications system caused by not using normal parameters. For example, this can be a significant advantage to increasing the location accuracy of 9-1-1 emergency calls, without measurable degradation to the remainder of a wireless network's call processing. While wireless 9-1-1 calls have great importance, the actual density of wireless 9-1-1 calls is very low when compared to all other calls in a wireless network. Across the U.S., there are an average of only 1.5 wireless 9-1-1 calls per cell site per day. Therefore, there is likely to be a very low incidence of interference to wireless networks caused by increased transmission power or transmission length during 9-1-1 calls. Even if an interference incident were caused by a phone using the methods of this invention, normal call processing within all existing air interface protocols provides for back-off and re-attempt by the phone receiving in the interference. Therefore, this method should never cause non-emergency call attempts to fail. While the above method has been described for calls using the dialed digits "9-1-1" and variations, the method can be applied to other types of triggered events as well. Finally, the trigger events may be permanently stored in the wireless transmitter, programmed by the user into the wireless transmitter, or broadcast by the wireless communications system for receipt by all wireless transmitters. Further, the actions to be taken during the modified transmission sequence may be permanently stored in the wireless transmitter, programmed by the user into the wireless transmitter, or broadcast by the wireless communications system for receipt by all wireless transmitters.

The Wireless Location System is capable of independently demodulating transmissions on multiple channels, and can therefore detect and process for location purposes the entirety of all messages sent from the wireless transmitter, including all of the modified transmission sequences described above. In most, if not all, cases the base station will ignore additional fields sent in a message by the wireless transmitter. Further, the additional registration messages will also have no effect on call processing by the base station. Therefore, the additional actions described above will have the primary effect of aiding the Wireless Location System in improving the accuracy of the location estimate without degrading the performance of the wireless communications system.

Conclusion

The true scope the present invention is not limited to the presently preferred embodiments disclosed herein. For example, the foregoing disclosure of a presently preferred embodiment of a Wireless Location System uses explanatory terms, such as Signal Collection System (SCS), TDOA Location Processor (TLP), Applications Processor (AP), and the like, which should not be construed so as to limit the scope of protection of the following claims, or to otherwise imply that the inventive aspects of the Wireless Location System are limited to the particular methods and apparatus disclosed. Moreover, as will be understood by those skilled in the art, many of the inventive aspects disclosed herein may be applied in location systems that are not based on TDOA techniques. For example, the processes by which the Wireless Location System uses the Tasking List, etc. can be applied to non-TDOA systems. In such non-TDOA systems, the TLP's described above would not be required to perform TDOA calculations. Similarly, the invention is not limited to systems employing SCS's constructed as described above, nor to systems employing AP's meeting all of the particulars described above. The SCS's, TLP's and AP's are, in essence, programmable data collection and processing devices that could take a variety of forms without departing from the inventive concepts disclosed herein. Given the rapidly declining cost of digital signal processing and other processing functions, it is easily possible, for example, to transfer the processing for a particular function from one of the functional elements (such as the TLP) described herein to another functional element (such as the SCS or AP) without changing the inventive operation of the system. In many cases, the place of implementation (i.e. the functional element) described herein is merely a designer's preference and not a hard requirement. Accordingly, except as they may be expressly so limited, the scope of protection of the following claims is not intended to be limited to the specific embodiments described above.

CLAIMS

What is claimed is:

1. A method for use in a Wireless Location System (WLS) in locating a mobile wireless transmitter, comprising the steps of:
   a) a wireless transmitter receives normal transmission parameters from a base station;
   b) the user of the wireless transmitter initiates a call on the wireless transmitter by dialing a sequence of digits and pressing "SEND" or "YES";
   c) a processor within the wireless transmitter compares the dialed sequence of digits with one or more trigger events stored within the wireless transmitter;
   d) if the dialed sequence of digits does not match the trigger event, then the wireless transmitter uses the normal transmission parameters in making the call; and
   e) if the dialed sequence of digits matches the trigger event, then the wireless transmitter uses a modified transmission sequence.
2. A method as recited in claim 1, wherein the modified transmission sequence comprises the wireless transmitter increasing its transmitted power by a predetermined amount over the power level setting in the normal parameters, up to a maximum power setting.
3. A method as recited in claim 1, wherein the modified transmission sequence comprises the wireless transmitter increasing its transmitted power to the maximum power setting.
4. A method as recited in claim 1, wherein the modified transmission sequence comprises the wireless transmitter transmitting an additional predetermined number of access probes even after the base station has acknowledged receipt of the access probes to the wireless transmitter.
5. A method as recited in claim 1, wherein the modified transmission sequence comprises the wireless transmitter including additional fields in the transmitted message even if these fields are not requested in the normal parameters broadcast on forward channels by the base station.

6. A method as recited in claim 1, wherein the modified transmission sequence comprises the wireless transmitter following a transmitted message with one or more repeated registration messages.
7. A method as recited in claim 1, wherein the modified transmission sequence comprises the wireless transmitter following a transmitted message transmitted on a first one of a plurality of channels with one or more repeated registration messages transmitted on another second one of a plurality of channels.
8. A method as recited in claim 5, wherein the additional field is an Authentication field.
9. A method as recited in claim 5, wherein the additional field is a Serial Number field.
10. A method as recited in claim 5, wherein the additional field is a Mobile Assisted Channel Allocation Report field.
11. A method as recited in claim 6, wherein the one or more repeated registration messages may be of the normal length determined from the transmission parameters broadcast on the forward channels by the base station.
12. A method as recited in claim 6, wherein the one or more repeated registration messages may be modified to a longer length by including additional fields.
13. A method as recited in claim 7, wherein the one or more repeated registration messages may be of the normal length determined from the transmission parameters broadcast on the forward channels by the base station.
14. A method as recited in claim 7, wherein the one or more repeated registration messages may be modified to a longer length by including additional fields.
15. A method as recited in claims 12 or 14, wherein the additional field is an Authentication field.
16. A method as recited in claims 12 or 14, wherein the additional field is a Serial Number field.
17. A method as recited in claims 12 or 14, wherein the additional field is a Mobile Assisted Channel Allocation Report field.

18. A method as recited in claims 12 or 14, wherein the additional field is a Capability Report field.

19. A method as recited in claim 7, wherein the second one of a plurality of channels is selected to be one in use by a second base station within listening range of the wireless transmitter and for which the wireless transmitter can receive the forward control channel broadcast by that second base station.

20. A method as recited in claim 7, wherein the second one of a plurality of channels is selected to be one for which the wireless transmitter can detect no forward control channel activity by any base station.

21. A method as recited in claim 19, wherein the second base station may be the same as the first base station, another sector of the first base station, or an entirely separate base station.

22. A method as recited in claim 20, wherein the wireless transmitter will transmit the one or more registration messages without expecting any acknowledgement from the wireless communications system.

23. A method as recited in claim 1, wherein the trigger events are permanently stored in the wireless transmitter.

24. A method as recited in claim 1, wherein the trigger events are programmed by the user into the wireless transmitter.

25. A method as recited in claim 1, wherein the trigger events are broadcast by the wireless communications system for receipt by a plurality of wireless transmitters.

26. A method as recited in claim 1, wherein the actions to be taken during the modified transmission sequence may be permanently stored in the wireless transmitter.

27. A method as recited in claim 1, wherein the actions to be taken during the modified transmission sequence are programmed by the user into the wireless transmitter.

28. A method as recited in claim 1, wherein the actions to be taken during the modified transmission sequence are broadcast by the wireless communications system for receipt by all wireless transmitters.

29. A method as recited in claim 1, wherein the trigger event includes the dialed digits "9-1-1" and/or variations such as "*9-1-1" or "#9-1-1".

30. A method as recited in claim 1, wherein the wireless transmitter deactivates encryption when a trigger event occurs.

31. A method as recited in claim 1, wherein the wireless transmitter deactivates encryption for all messages transmitted as part of the modified transmission sequence.

32. A wireless transmitter for use in a wireless communications system, capable of performing the following functions:

a) receiving normal transmission parameters from a base station;

b) initiating a call when a user of the wireless transmitter dials a sequence of digits and presses "SEND" or "YES";

c) comparing the dialed sequence of digits with one or more trigger events stored within the wireless transmitter;

d) using the normal transmission parameters in making the call if the dialed sequence of digits do not match the trigger event; and

e) using a modified transmission sequence if the dialed sequence of digits matches the trigger event.

33. A wireless transmitter as recited in claim 32, wherein the modified transmission sequence comprises the wireless transmitter increasing its transmitted power by a predetermined amount over the power level setting in the normal parameters, up to a maximum power setting.

34. A wireless transmitter as recited in claim 32, wherein the modified transmission sequence comprises the wireless transmitter increasing its transmitted power to the maximum power setting.

35. A wireless transmitter as recited in claim 32, wherein the modified transmission sequence comprises the wireless transmitter transmitting an additional predetermined number of access probes even after the base station has acknowledged receipt of the access probes to the wireless transmitter.

36. A wireless transmitter as recited in claim 32, wherein the modified transmission sequence comprises the wireless transmitter including additional fields in the transmitted message even if these fields are not requested in the normal parameters broadcast on forward channels by the base station.

37. A wireless transmitter as recited in claim 32, wherein the modified transmission sequence comprises the wireless transmitter following a transmitted message with one or more repeated registration messages.

38. A wireless transmitter as recited in claim 32, wherein the modified transmission sequence comprises the wireless transmitter following a transmitted message transmitted on a first one of a plurality of channels with one or more repeated registration messages transmitted on another second one of a plurality of channels.

39. A wireless transmitter as recited in claim 36, wherein the additional field is an Authentication field.

40. A wireless transmitter as recited in claim 36, wherein the additional field is a Serial Number field.

41. A wireless transmitter as recited in claim 36, wherein the additional field is a Mobile Assisted Channel Allocation Report field.

42. A wireless transmitter as recited in claim 36, wherein the one or more repeated registration messages may be of the normal length determined from the transmission parameters broadcast on the forward channels by the base station.

43. A wireless transmitter as recited in claim 37, wherein the one or more repeated registration messages may be modified to a longer length by including additional fields.

44. A wireless transmitter as recited in claim 38, wherein the one or more repeated registration messages may be of the normal length determined from the transmission parameters broadcast on the forward channels by the base station.

45. A wireless transmitter as recited in claim 38, wherein the one or more repeated registration messages may be modified to a longer length by including additional fields.

46. A wireless transmitter as recited in claims 43 or 45, wherein the additional field is an Authentication field.

47. A wireless transmitter as recited in claims 43 or 45, wherein the additional field is a Serial Number field.

48. A wireless transmitter as recited in claims 43 or 45, wherein the additional field is a Mobile Assisted Channel Allocation Report field.

49. A wireless transmitter as recited in claims 43 or 45, wherein the additional field is a Capability Report field.

50. A wireless transmitter as recited in claim 38, wherein the second one of a plurality of channels is selected to be one in use by a second base station within listening range of the wireless transmitter and for which the wireless transmitter can receive the forward control channel broadcast by that second base station.

51. A wireless transmitter as recited in claim 38, wherein the second one of a plurality of channels is selected to be one for which the wireless transmitter can detect no forward control channel activity by any base station.

52. A wireless transmitter as recited in claim 50, wherein the second base station may be the same as the first base station, another sector of the first base station, or an entirely separate base station.

53. A wireless transmitter as recited in claim 51, wherein the wireless transmitter will transmit the one or more registration messages without expecting any acknowledgement from the wireless communications system.

54. A wireless transmitter as recited in claim 32, wherein the trigger events are permanently stored in the wireless transmitter.

55. A wireless transmitter as recited in claim 32, wherein the trigger events are programmed by the user into the wireless transmitter.

56. A wireless transmitter as recited in claim 32, wherein the trigger events are broadcast by the wireless communications system for receipt by a plurality of wireless transmitters.

57. A wireless transmitter as recited in claim 32, wherein the actions to be taken during the modified transmission sequence may be permanently stored in the wireless transmitter.

58. A wireless transmitter as recited in claim 32, wherein the actions to be taken during the modified transmission sequence are programmed by the user into the wireless transmitter.

59. A wireless transmitter as recited in claim 32, wherein the actions to be taken during the modified transmission sequence are broadcast by the wireless communications system for receipt by all wireless transmitters.

60. A wireless transmitter as recited in claim 32, wherein the trigger event includes the dialed digits “9-1-1” and/or variations such as “*9-1-1” or “#9-1-1”.

61. A Wireless Location System capable of locating a wireless transmitter using a modified transmission sequence, wherein the modified transmission sequence comprises a message sent from the wireless transmitter using transmission parameters different from the normal transmission parameters broadcast on the forward control channel by the base stations in a wireless communications system.

AMENDED CLAIMS

[received by the International Bureau on 24 July 2001 (24.07.01);
original claims 29, 60 and 61 amended; new claims 62-83 added;
remaining claims unchanged (5 pages)]

29. A method as recited in claim 1, wherein the trigger event includes the dialed digits "9-1-1" and/or variations such as "*9-1-1" or "#9-1-1", or international equivalents thereof.

30. A method as recited in claim 1, wherein the wireless transmitter deactivates encryption when a trigger event occurs.

31. A method as recited in claim 1, wherein the wireless transmitter deactivates encryption for all messages transmitted as part of the modified transmission sequence.

32. A wireless transmitter for use in a wireless communications system, capable of performing the following functions:

   a) receiving normal transmission parameters from a base station;

   b) initiating a call when a user of the wireless transmitter dials a sequence of digits and presses "SEND" or "YES";

   c) comparing the dialed sequence of digits with one or more trigger events stored within the wireless transmitter;

   d) using the normal transmission parameters in making the call if the dialed sequence of digits do not match the trigger event; and

   e) using a modified transmission sequence if the dialed sequence of digits matches the trigger event.

33. A wireless transmitter as recited in claim 32, wherein the modified transmission sequence comprises the wireless transmitter increasing its transmitted power by a predetermined amount over the power level setting in the normal parameters, up to a maximum power setting.

34. A wireless transmitter as recited in claim 32, wherein the modified transmission sequence comprises the wireless transmitter increasing its transmitted power to the maximum power setting.

35. A wireless transmitter as recited in claim 32, wherein the modified transmission sequence comprises the wireless transmitter transmitting an additional predetermined number of access probes even after the base station has acknowledged receipt of the access probes to the wireless transmitter.

57. A wireless transmitter as recited in claim 32, wherein the actions to be taken during the modified transmission sequence may be permanently stored in the wireless transmitter.

58. A wireless transmitter as recited in claim 32, wherein the actions to be taken during the modified transmission sequence are programmed by the user into the wireless transmitter.

59. A wireless transmitter as recited in claim 32, wherein the actions to be taken during the modified transmission sequence are broadcast by the wireless communications system for receipt by all wireless transmitters.

60. A wireless transmitter as recited in claim 32, wherein the trigger event includes the dialed digits "9-1-1" and/or variations such as "*9-1-1" or "#9-1-1", or international equivalents thereof.

61. A wireless transmitter adapted to transmit a modified transmission sequence to facilitate location by a Wireless Location System, wherein the modified transmission sequence comprises a message sent from the wireless transmitter using transmission parameters different from the normal transmission parameters broadcast on a forward control channel by base stations in a wireless communications system.

62. A wireless transmitter as recited in claim 61, wherein the wireless transmitter is programmed to perform the following functions:

receiving the normal transmission parameters from a base station;

initiating a call when a user of the wireless transmitter dials a sequence of digits and presses a predefined button;

comparing the dialed sequence of digits with one or more trigger events stored within the wireless transmitter;

using the normal transmission parameters in making the call if the dialed sequence of digits do not match the trigger event; and

using the modified transmission sequence if the dialed sequence of digits matches the trigger event.

63. A wireless transmitter as recited in claim 61, wherein the modified transmission sequence comprises the wireless transmitter increasing its transmitted power by a predetermined amount over the power level setting in the normal parameters, up to a maximum power setting.

64. A wireless transmitter as recited in claim 63, wherein the modified transmission sequence comprises the wireless transmitter increasing its transmitted power to the maximum power setting.

65. A wireless transmitter as recited in claim 61, wherein the modified transmission sequence comprises the wireless transmitter transmitting an additional predetermined number of access probes after the base station has acknowledged receipt of the access probes to the wireless transmitter.

66. A wireless transmitter as recited in claim 61, wherein the modified transmission sequence comprises the wireless transmitter including at least one additional field in the transmitted message even if the additional field is not requested in the normal parameters broadcast on forward channels by the base station.

67. A wireless transmitter as recited in claim 61, wherein the modified transmission sequence comprises the wireless transmitter following a transmitted message with one or more repeated registration messages.

68. A wireless transmitter as recited in claim 61, wherein the modified transmission sequence comprises the wireless transmitter following a transmitted message transmitted on a first one of a plurality of channels with one or more repeated registration messages transmitted on a second one of the plurality of channels.

69. A wireless transmitter as recited in claim 66, wherein the additional field is an Authentication field.
70. A wireless transmitter as recited in claim 66, wherein the additional field is a Serial Number field.
71. A wireless transmitter as recited in claim 66, wherein the additional field is a Mobile Assisted Channel Allocation Report field.
72. A wireless transmitter as recited in claim 68, wherein the one or more repeated registration messages are of the normal length determined from the transmission parameters broadcast on the forward channels by the base station.
73. A wireless transmitter as recited in claim 68, wherein the one or more repeated registration messages are modified to a longer length by including additional fields.
74. A wireless transmitter as recited in claim 68, wherein the one or more repeated registration messages are of the normal length determined from the transmission parameters broadcast on the forward channels by the base station.
75. A wireless transmitter as recited in claim 68, wherein the second one of a plurality of channels is selected to be one in use by a second base station within listening range of the wireless transmitter and for which the wireless transmitter can receive the forward control channel broadcast by that second base station.
76. A wireless transmitter as recited in claim 68, wherein the second one of a plurality of channels is selected to be one for which the wireless transmitter can detect no forward control channel activity by any base station.
77. A wireless transmitter as recited in claim 61, wherein the trigger events are permanently stored in the wireless transmitter.
78. A wireless transmitter as recited in claim 61, wherein the trigger events are programmed by the user into the wireless transmitter.
79. A wireless transmitter as recited in claim 61, wherein the trigger events are broadcast by a wireless communications system for receipt by a plurality of wireless transmitters.
80. A wireless transmitter as recited in claim 61, wherein the actions to be taken during the modified transmission sequence are preprogrammed and permanently stored in the wireless transmitter.
81. A wireless transmitter as recited in claim 61, wherein the actions to be taken during the modified transmission sequence are programmed by the user into the wireless transmitter.

82. A wireless transmitter as recited in claim 61, wherein the actions to be taken during the modified transmission sequence are broadcast by the wireless communications system for receipt by all wireless transmitters.

83. A wireless transmitter as recited in claim 61, wherein the trigger event includes the dialed digits "9-1-1", or international equivalents thereof.

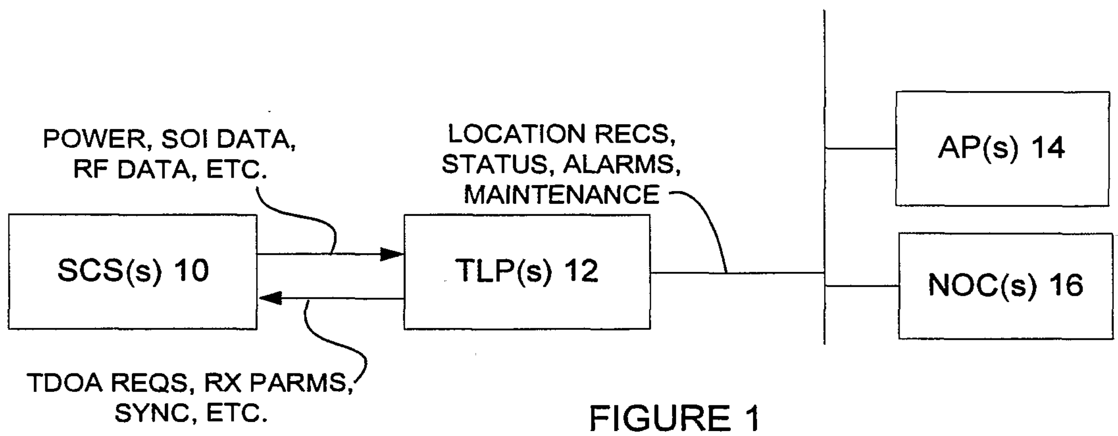

POWER, SOI DATA,
RF DATA, ETC.
LOCATION RECS,
STATUS, ALARMS,
MAINTENANCE
AP(s) 14
SCS(s) 10
TLP(s) 12
NOC(s) 16
TDOA REQS, RX PARMS,
SYNC, ETC.

FIGURE 1

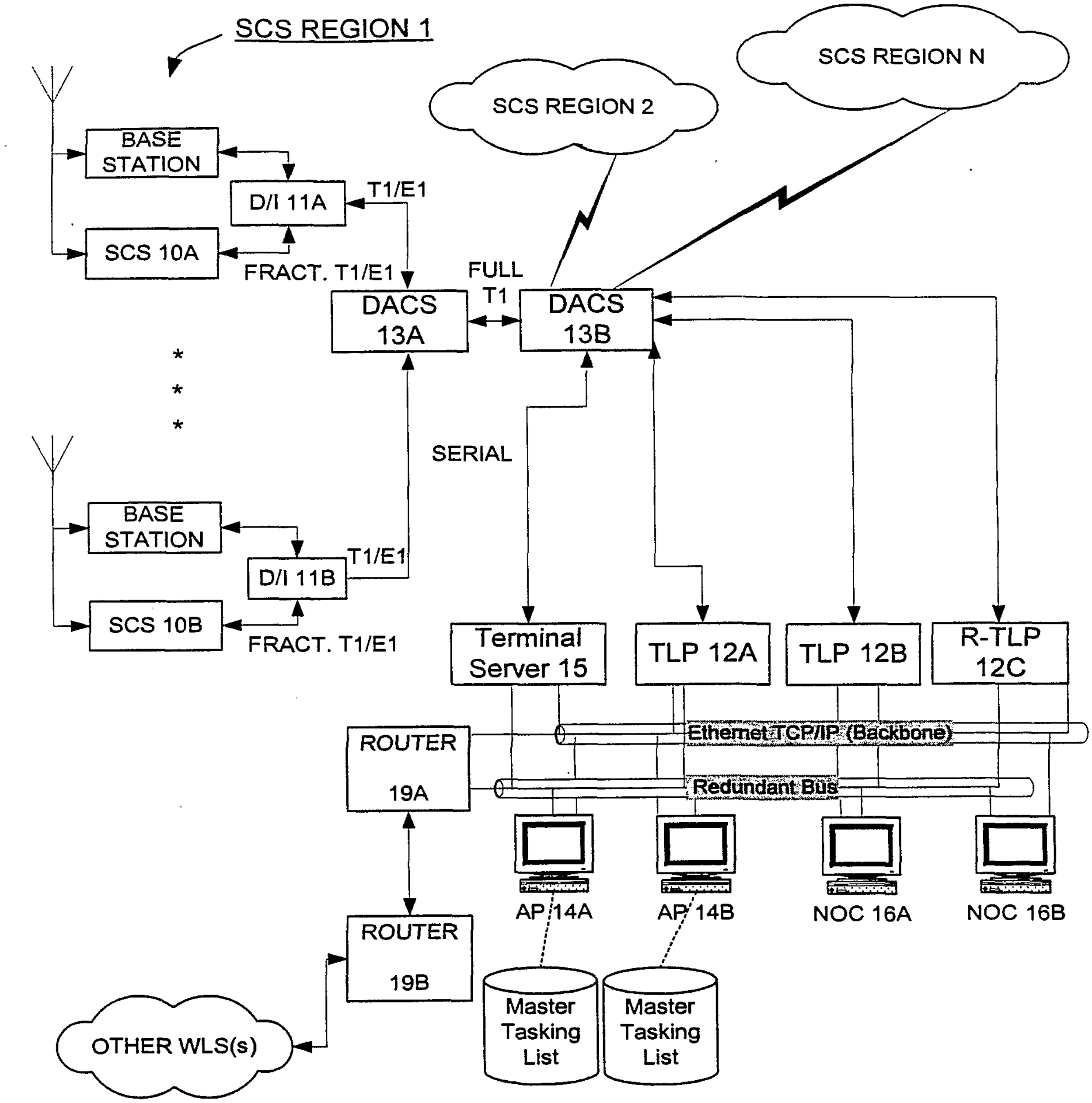

SCS REGION 1
SCS REGION 2
SCS REGION N
BASE STATION
D/I 11A
T1/E1
SCS 10A
FRACT. T1/E1
FULL T1
DACS 13A
DACS 13B
SERIAL
BASE STATION
D/I 11B
T1/E1
SCS 10B
FRACT. T1/E1
Terminal Server 15
TLP 12A
TLP 12B
R-TLP 12C
ROUTER 19A
Ethernet TCP/IP (Backbone)
Redundant Bus
AP 14A
AP 14B
NOC 16A
NOC 16B
ROUTER 19B
OTHER WLS(s)
Master Tasking List
Master Tasking List

FIGURE 1A

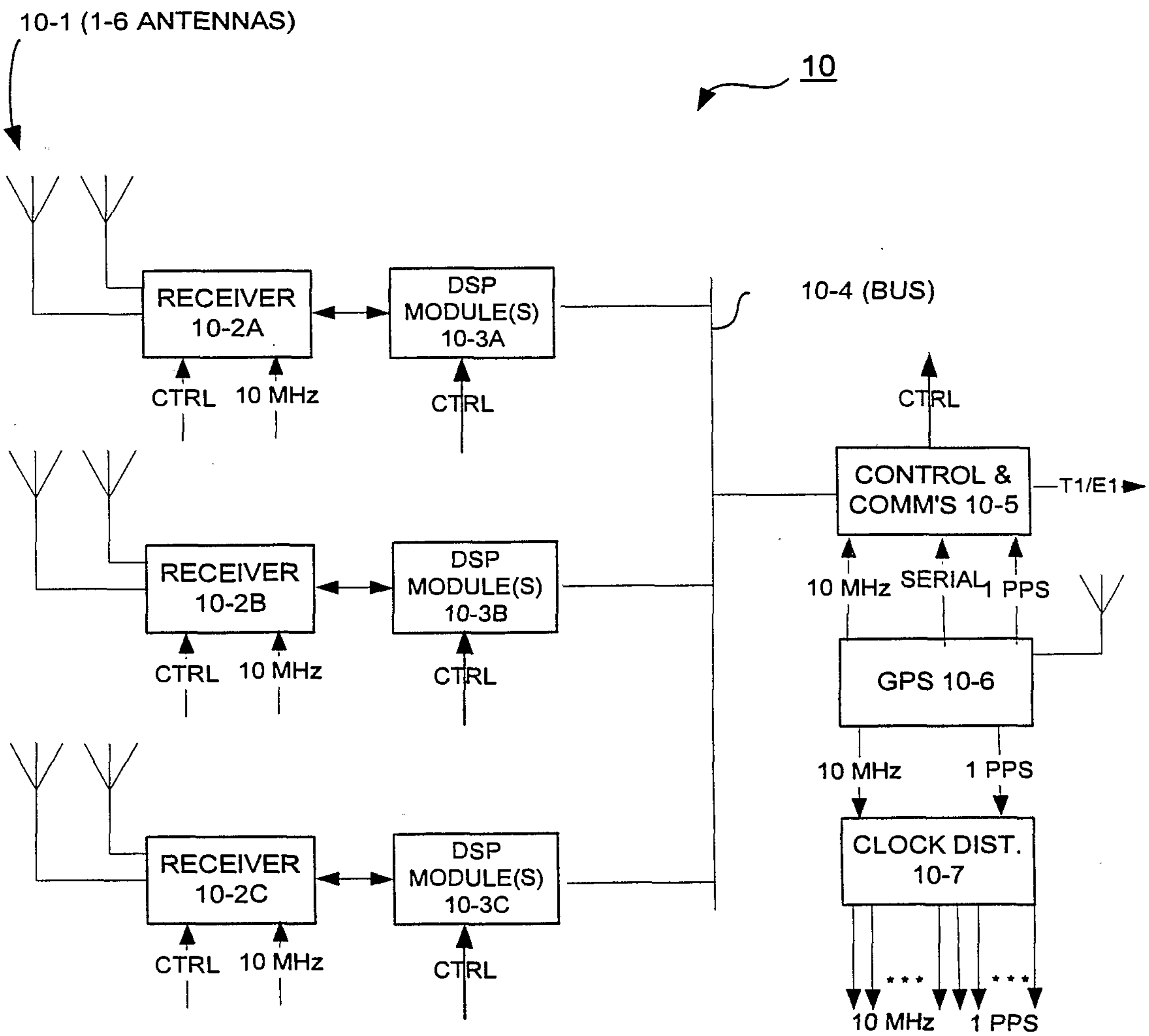

10-1 (1-6 ANTENNAS)
10
RECEIVER 10-2A
DSP MODULE(S) 10-3A
CTRL
10 MHz
CTRL
10-4 (BUS)
CTRL
CONTROL & COMM'S 10-5
T1/E1
10 MHz
SERIAL
1 PPS
GPS 10-6
10 MHz
1 PPS
CLOCK DIST. 10-7
10 MHz
1 PPS
RECEIVER 10-2B
DSP MODULE(S) 10-3B
CTRL
10 MHz
CTRL
RECEIVER 10-2C
DSP MODULE(S) 10-3C
CTRL
10 MHz
CTRL

FIGURE 2

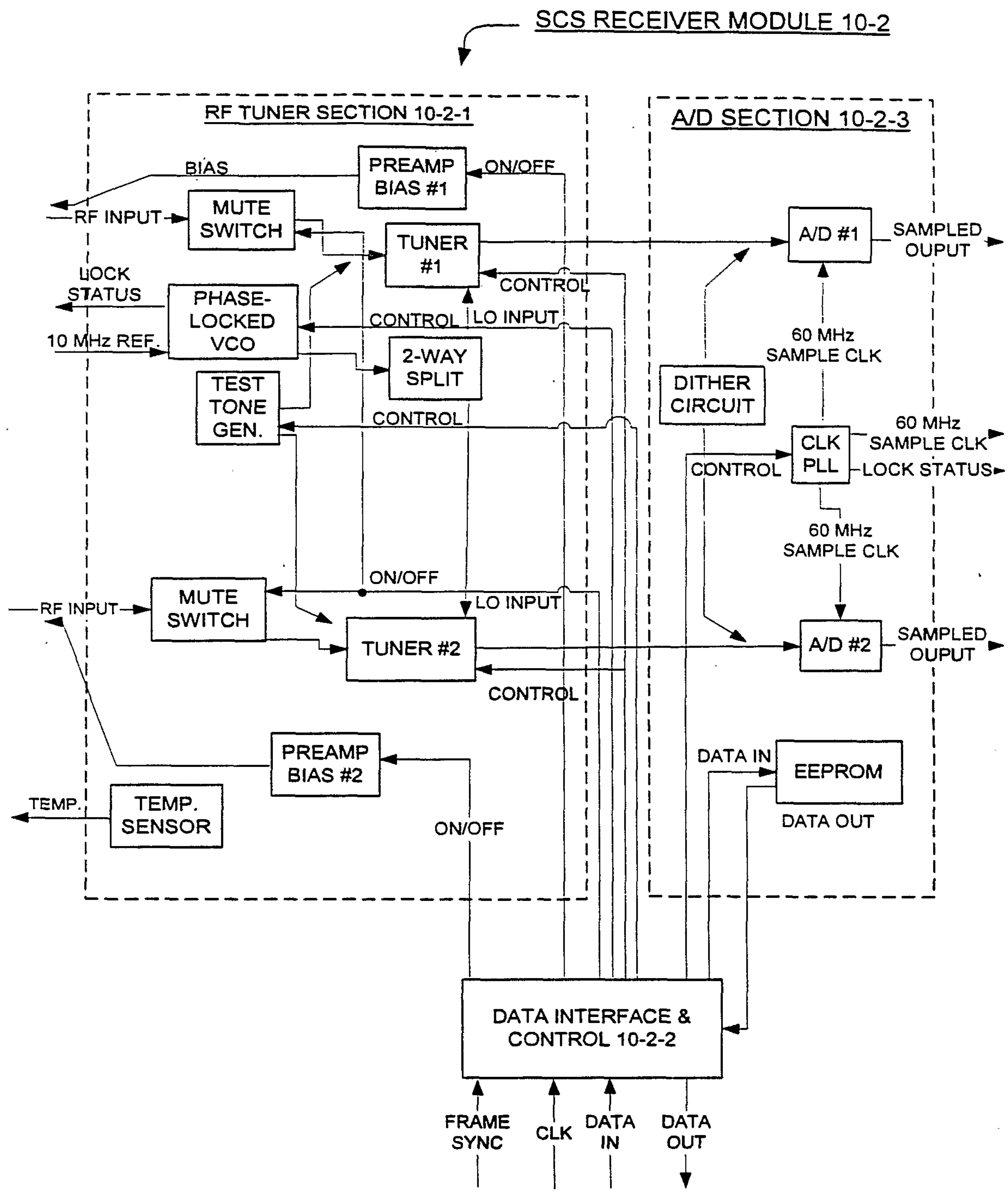

SCS RECEIVER MODULE 10-2
RF TUNER SECTION 10-2-1
A/D SECTION 10-2-3
BIAS
PREAMP BIAS #1
ON/OFF
RF INPUT
MUTE SWITCH
TUNER #1
LOCK STATUS
CONTROL
PHASE-LOCKED VCO
CONTROL
LO INPUT
10 MHz REF.
2-WAY SPLIT
TEST TONE GEN.
CONTROL
A/D #1
SAMPLED OUPUT
60 MHz SAMPLE CLK
DITHER CIRCUIT
CLK PLL
60 MHz SAMPLE CLK
LOCK STATUS
CONTROL
60 MHz SAMPLE CLK
ON/OFF
RF INPUT
MUTE SWITCH
LO INPUT
TUNER #2
CONTROL
A/D #2
SAMPLED OUPUT
PREAMP BIAS #2
DATA IN
EEPROM
DATA OUT
TEMP.
TEMP. SENSOR
ON/OFF
DATA INTERFACE & CONTROL 10-2-2
FRAME SYNC
CLK
DATA IN
DATA OUT

FIGURE 2A

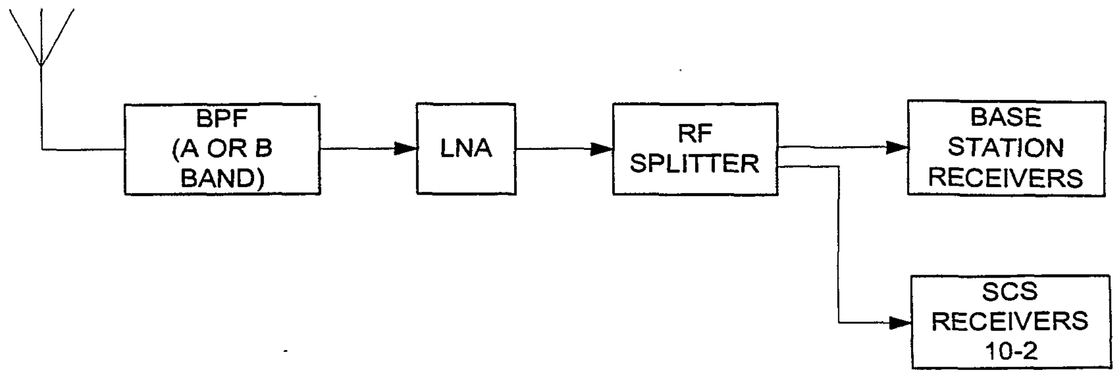


FIGURE 2B

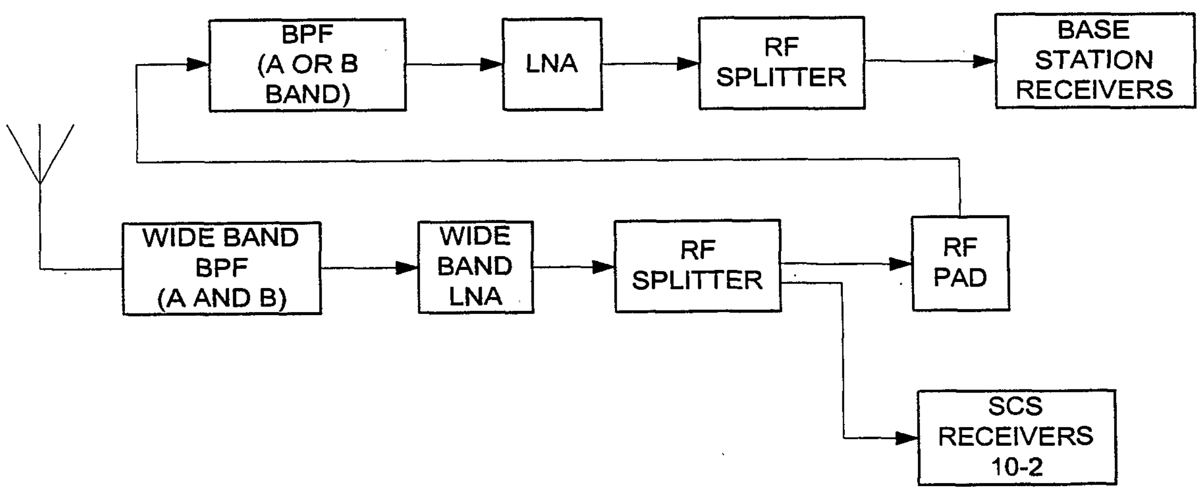


FIGURE 2C

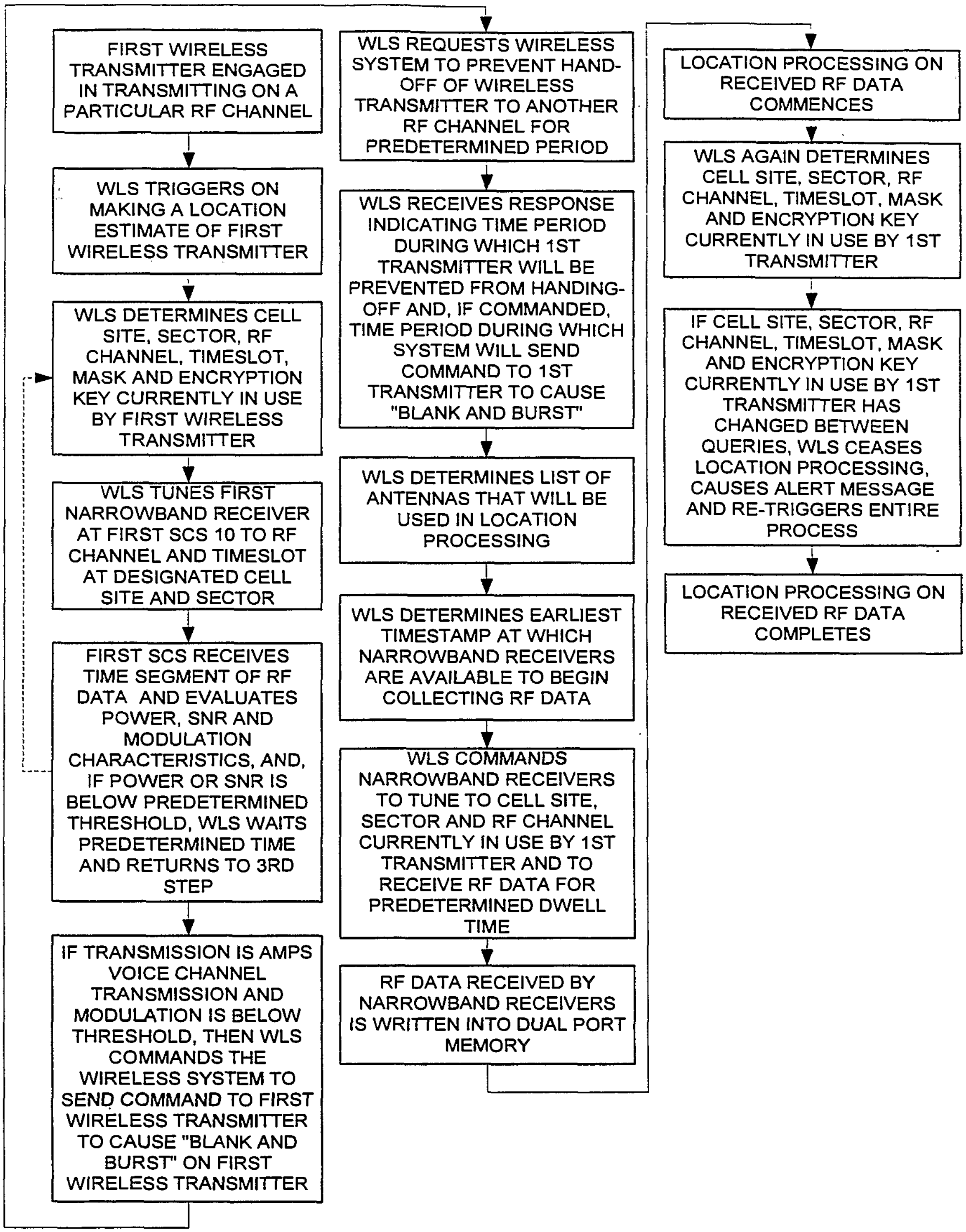

FIRST WIRELESS TRANSMITTER ENGAGED IN TRANSMITTING ON A PARTICULAR RF CHANNEL
WLS TRIGGERS ON MAKING A LOCATION ESTIMATE OF FIRST WIRELESS TRANSMITTER
WLS DETERMINES CELL SITE, SECTOR, RF CHANNEL, TIMESLOT, MASK AND ENCRYPTION KEY CURRENTLY IN USE BY FIRST WIRELESS TRANSMITTER
WLS TUNES FIRST NARROWBAND RECEIVER AT FIRST SCS 10 TO RF CHANNEL AND TIMESLOT AT DESIGNATED CELL SITE AND SECTOR
FIRST SCS RECEIVES TIME SEGMENT OF RF DATA AND EVALUATES POWER, SNR AND MODULATION CHARACTERISTICS, AND, IF POWER OR SNR IS BELOW PREDETERMINED THRESHOLD, WLS WAITS PREDETERMINED TIME AND RETURNS TO 3RD STEP
IF TRANSMISSION IS AMPS VOICE CHANNEL TRANSMISSION AND MODULATION IS BELOW THRESHOLD, THEN WLS COMMANDS THE WIRELESS SYSTEM TO SEND COMMAND TO FIRST WIRELESS TRANSMITTER TO CAUSE "BLANK AND BURST" ON FIRST WIRELESS TRANSMITTER
WLS REQUESTS WIRELESS SYSTEM TO PREVENT HAND-OFF OF WIRELESS TRANSMITTER TO ANOTHER RF CHANNEL FOR PREDETERMINED PERIOD
WLS RECEIVES RESPONSE INDICATING TIME PERIOD DURING WHICH 1ST TRANSMITTER WILL BE PREVENTED FROM HANDING-OFF AND, IF COMMANDED, TIME PERIOD DURING WHICH SYSTEM WILL SEND COMMAND TO 1ST TRANSMITTER TO CAUSE "BLANK AND BURST"
WLS DETERMINES LIST OF ANTENNAS THAT WILL BE USED IN LOCATION PROCESSING
WLS DETERMINES EARLIEST TIMESTAMP AT WHICH NARROWBAND RECEIVERS ARE AVAILABLE TO BEGIN COLLECTING RF DATA
WLS COMMANDS NARROWBAND RECEIVERS TO TUNE TO CELL SITE, SECTOR AND RF CHANNEL CURRENTLY IN USE BY 1ST TRANSMITTER AND TO RECEIVE RF DATA FOR PREDETERMINED DWELL TIME
RF DATA RECEIVED BY NARROWBAND RECEIVERS IS WRITTEN INTO DUAL PORT MEMORY
LOCATION PROCESSING ON RECEIVED RF DATA COMMENCES
WLS AGAIN DETERMINES CELL SITE, SECTOR, RF CHANNEL, TIMESLOT, MASK AND ENCRYPTION KEY CURRENTLY IN USE BY 1ST TRANSMITTER
IF CELL SITE, SECTOR, RF CHANNEL, TIMESLOT, MASK AND ENCRYPTION KEY CURRENTLY IN USE BY 1ST TRANSMITTER HAS CHANGED BETWEEN QUERIES, WLS CEASES LOCATION PROCESSING, CAUSES ALERT MESSAGE AND RE-TRIGGERS ENTIRE PROCESS
LOCATION PROCESSING ON RECEIVED RF DATA COMPLETES

FIGURE 2C-1

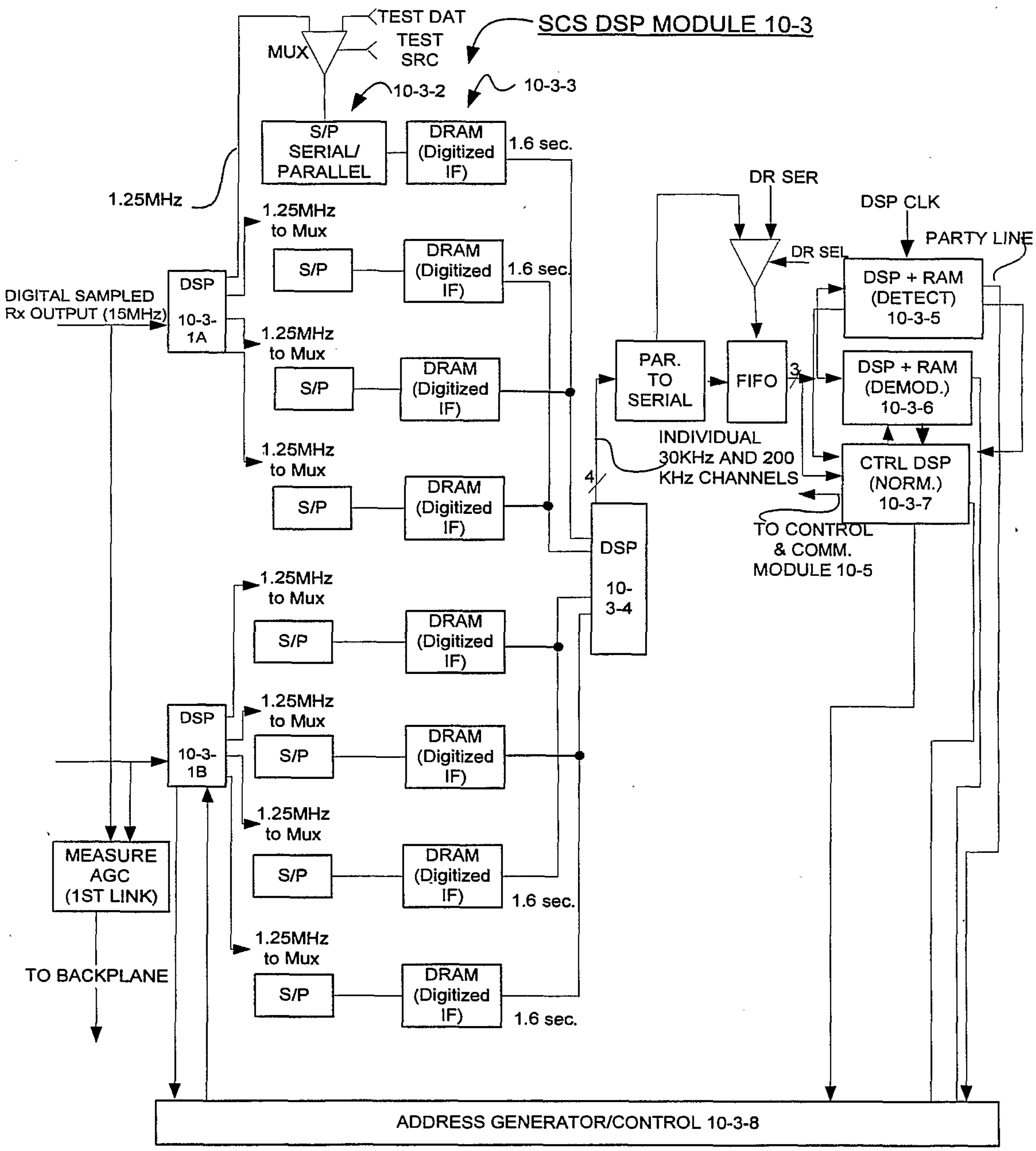

SCS DSP MODULE 10-3
TEST DAT
TEST SRC
MUX
10-3-2
10-3-3
S/P SERIAL/ PARALLEL
DRAM (Digitized IF)
1.6 sec.
1.25MHz
1.25MHz to Mux
S/P
DIGITAL SAMPLED Rx OUTPUT (15MHz)
DSP 10-3-1A
DR SER
DSP CLK
PARTY LINE
DR SEL
DSP + RAM (DETECT) 10-3-5
PAR. TO SERIAL
FIFO
DSP + RAM (DEMOD.) 10-3-6
INDIVIDUAL 30KHz AND 200 KHz CHANNELS
CTRL DSP (NORM.) 10-3-7
TO CONTROL & COMM. MODULE 10-5
DSP 10-3-4
DSP 10-3-1B
MEASURE AGC (1ST LINK)
TO BACKPLANE
ADDRESS GENERATOR/CONTROL 10-3-8

FIGURE 2D

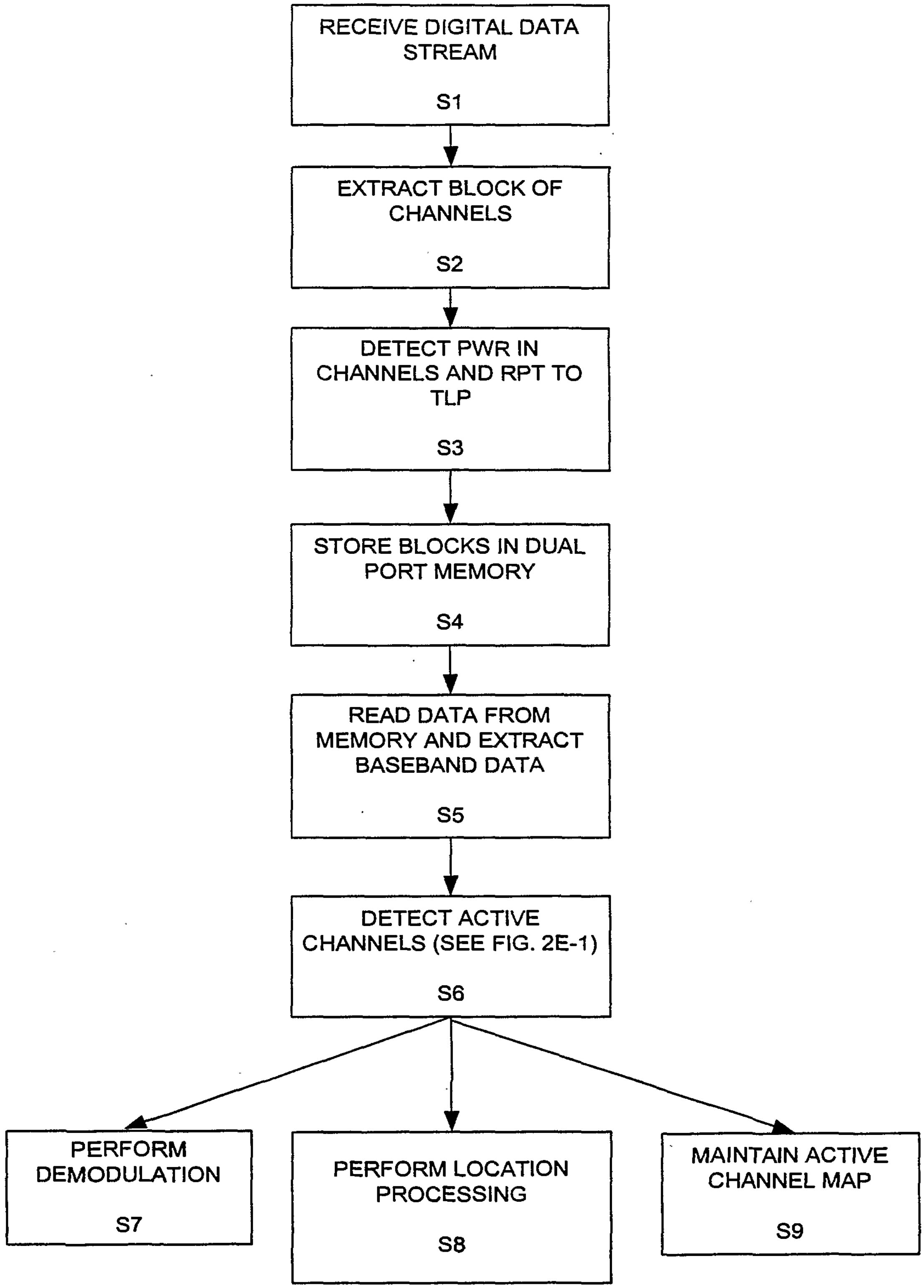

RECEIVE DIGITAL DATA STREAM
S1
EXTRACT BLOCK OF CHANNELS
S2
DETECT PWR IN CHANNELS AND RPT TO TLP
S3
STORE BLOCKS IN DUAL PORT MEMORY
S4
READ DATA FROM MEMORY AND EXTRACT BASEBAND DATA
S5
DETECT ACTIVE CHANNELS (SEE FIG. 2E-1)
S6
PERFORM DEMODULATION
S7
PERFORM LOCATION PROCESSING
S8
MAINTAIN ACTIVE CHANNEL MAP
S9

FIGURE 2E

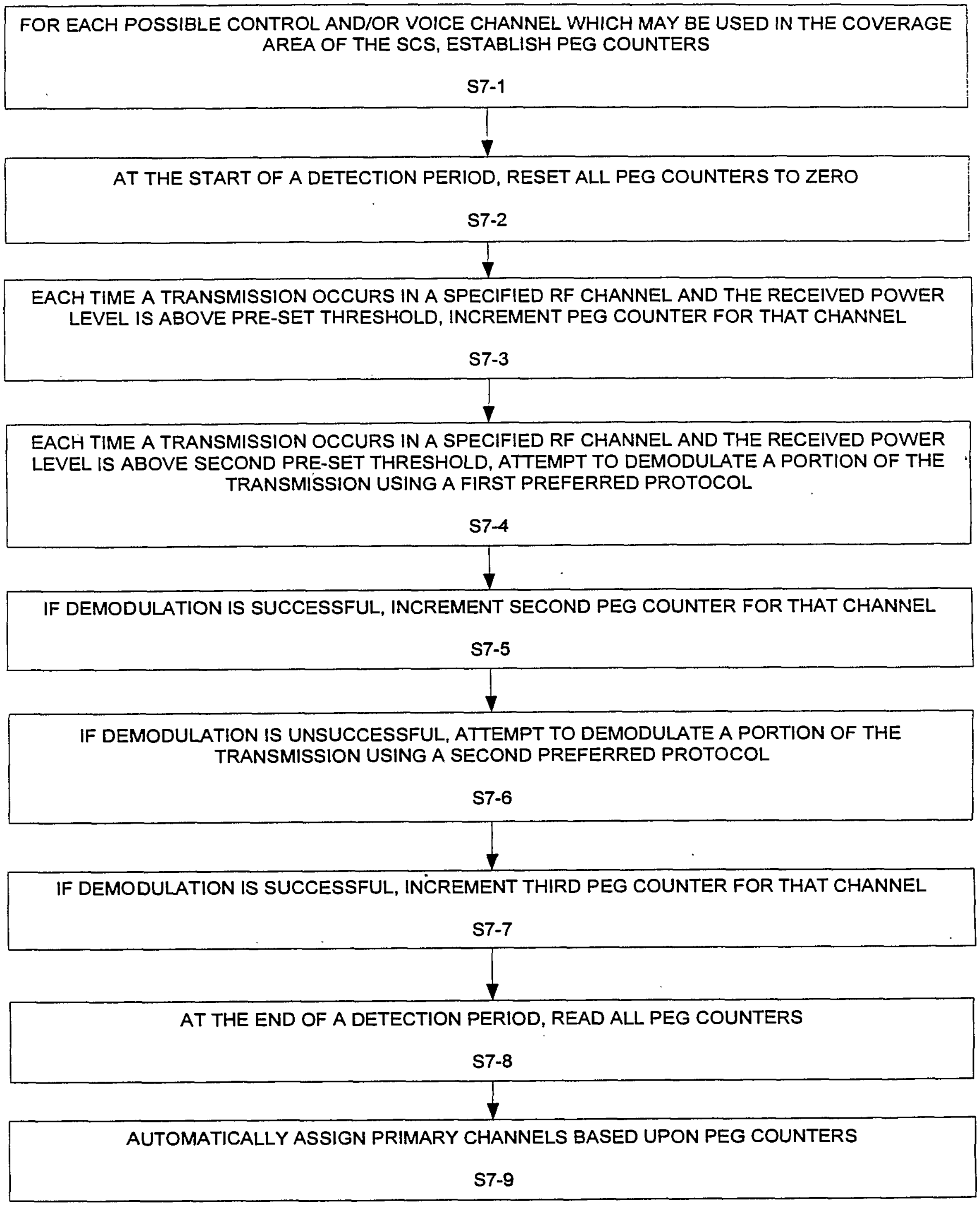

FOR EACH POSSIBLE CONTROL AND/OR VOICE CHANNEL WHICH MAY BE USED IN THE COVERAGE AREA OF THE SCS, ESTABLISH PEG COUNTERS
S7-1
AT THE START OF A DETECTION PERIOD, RESET ALL PEG COUNTERS TO ZERO
S7-2
EACH TIME A TRANSMISSION OCCURS IN A SPECIFIED RF CHANNEL AND THE RECEIVED POWER LEVEL IS ABOVE PRE-SET THRESHOLD, INCREMENT PEG COUNTER FOR THAT CHANNEL
S7-3
EACH TIME A TRANSMISSION OCCURS IN A SPECIFIED RF CHANNEL AND THE RECEIVED POWER LEVEL IS ABOVE SECOND PRE-SET THRESHOLD, ATTEMPT TO DEMODULATE A PORTION OF THE TRANSMISSION USING A FIRST PREFERRED PROTOCOL
S7-4
IF DEMODULATION IS SUCCESSFUL, INCREMENT SECOND PEG COUNTER FOR THAT CHANNEL
S7-5
IF DEMODULATION IS UNSUCCESSFUL, ATTEMPT TO DEMODULATE A PORTION OF THE TRANSMISSION USING A SECOND PREFERRED PROTOCOL
S7-6
IF DEMODULATION IS SUCCESSFUL, INCREMENT THIRD PEG COUNTER FOR THAT CHANNEL
S7-7
AT THE END OF A DETECTION PERIOD, READ ALL PEG COUNTERS
S7-8
AUTOMATICALLY ASSIGN PRIMARY CHANNELS BASED UPON PEG COUNTERS
S7-9

FIGURE 2E-1

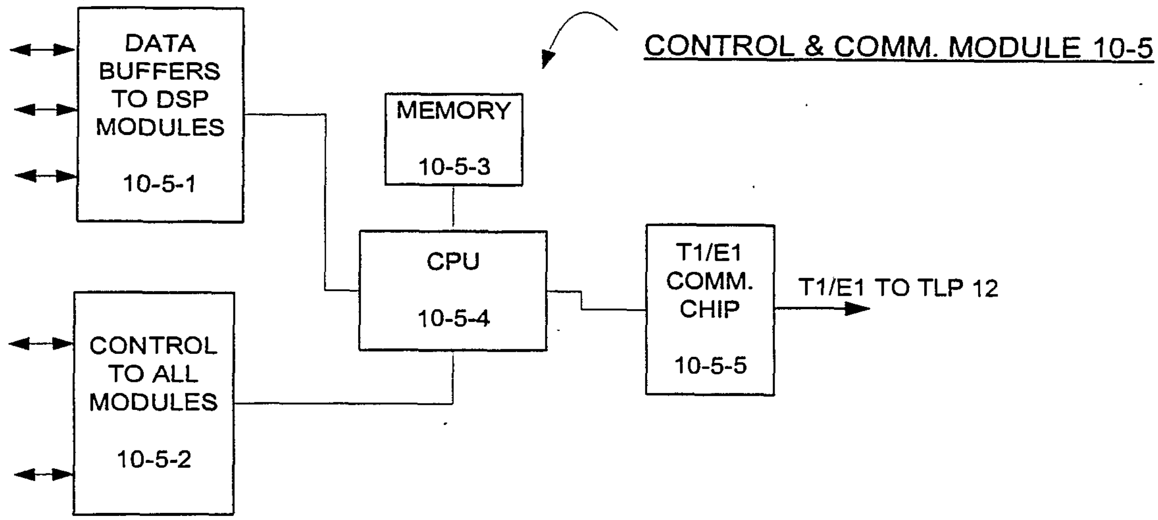


FIGURE 2F

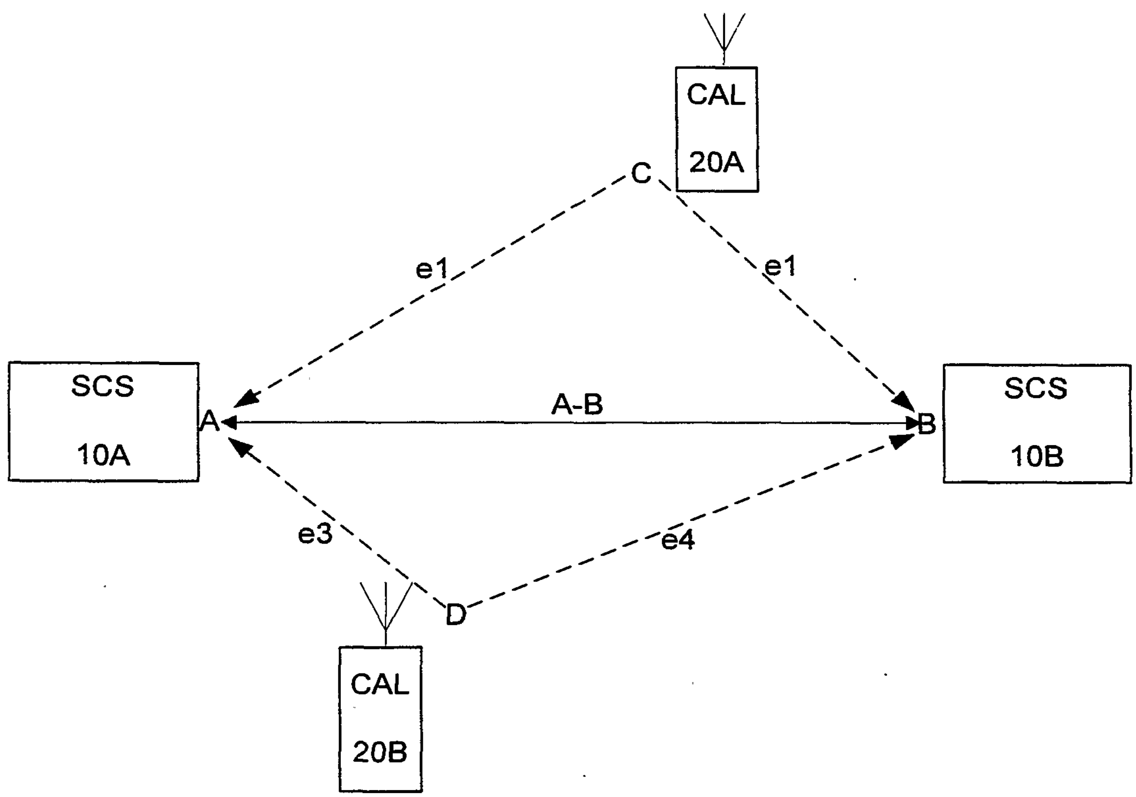


FIGURE 2G

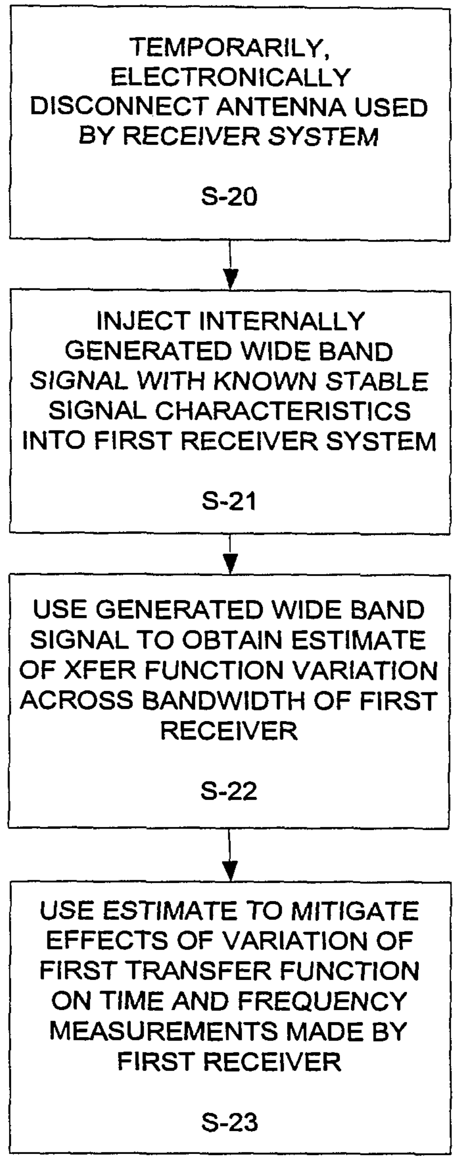

TEMPORARILY, ELECTRONICALLY DISCONNECT ANTENNA USED BY RECEIVER SYSTEM
S-20
INJECT INTERNALLY GENERATED WIDE BAND SIGNAL WITH KNOWN STABLE SIGNAL CHARACTERISTICS INTO FIRST RECEIVER SYSTEM
S-21
USE GENERATED WIDE BAND SIGNAL TO OBTAIN ESTIMATE OF XFER FUNCTION VARIATION ACROSS BANDWIDTH OF FIRST RECEIVER
S-22
USE ESTIMATE TO MITIGATE EFFECTS OF VARIATION OF FIRST TRANSFER FUNCTION ON TIME AND FREQUENCY MEASUREMENTS MADE BY FIRST RECEIVER
S-23

FIGURE 2H

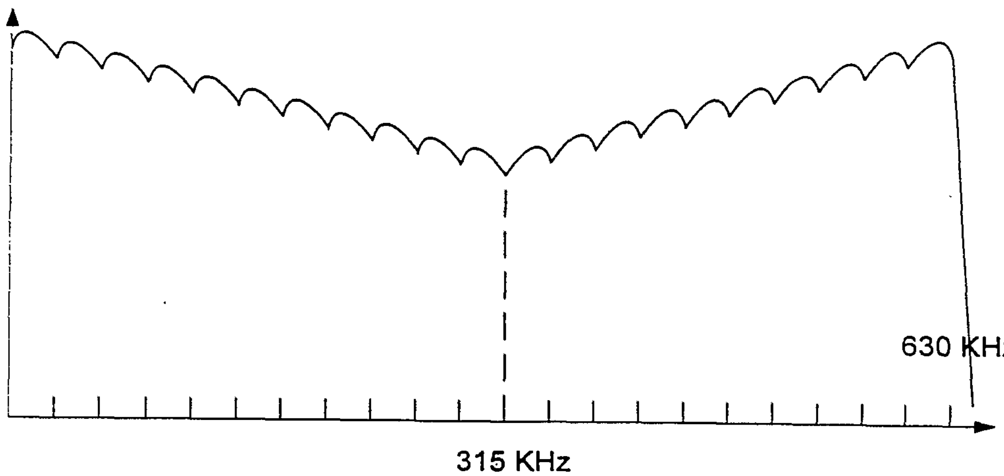


FIGURE 2I

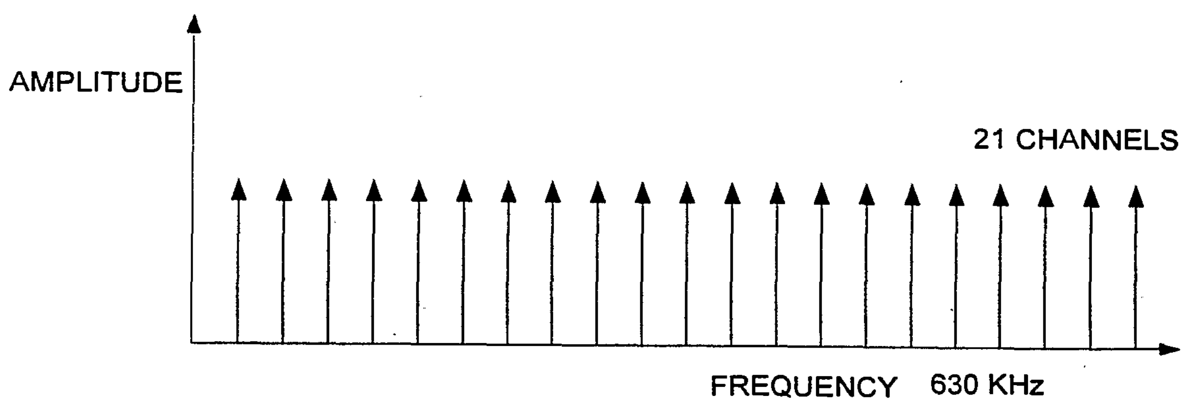


FIGURE 2J

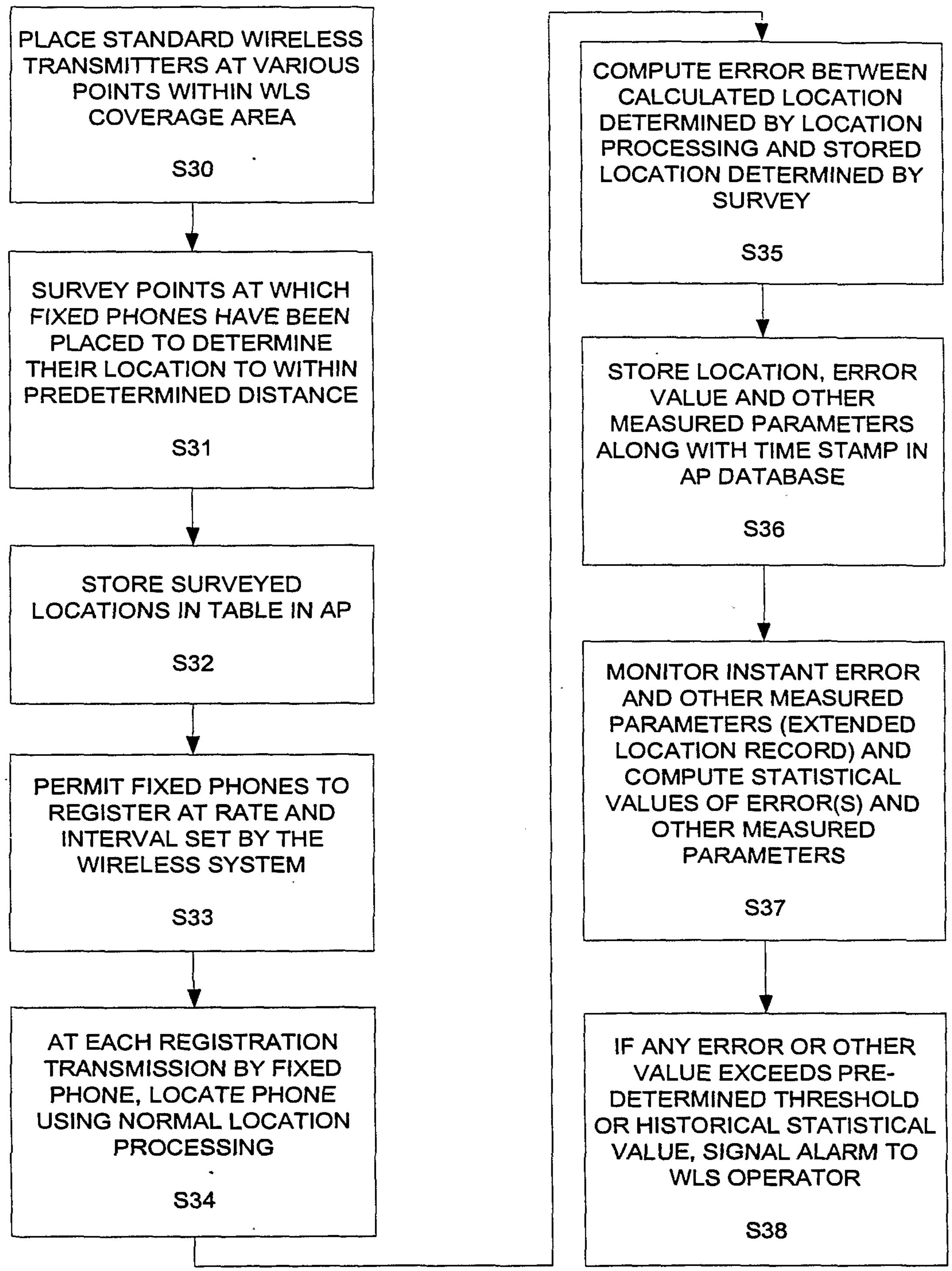

PLACE STANDARD WIRELESS TRANSMITTERS AT VARIOUS POINTS WITHIN WLS COVERAGE AREA
S30
SURVEY POINTS AT WHICH FIXED PHONES HAVE BEEN PLACED TO DETERMINE THEIR LOCATION TO WITHIN PREDETERMINED DISTANCE
S31
STORE SURVEYED LOCATIONS IN TABLE IN AP
S32
PERMIT FIXED PHONES TO REGISTER AT RATE AND INTERVAL SET BY THE WIRELESS SYSTEM
S33
AT EACH REGISTRATION TRANSMISSION BY FIXED PHONE, LOCATE PHONE USING NORMAL LOCATION PROCESSING
S34
COMPUTE ERROR BETWEEN CALCULATED LOCATION DETERMINED BY LOCATION PROCESSING AND STORED LOCATION DETERMINED BY SURVEY
S35
STORE LOCATION, ERROR VALUE AND OTHER MEASURED PARAMETERS ALONG WITH TIME STAMP IN AP DATABASE
S36
MONITOR INSTANT ERROR AND OTHER MEASURED PARAMETERS (EXTENDED LOCATION RECORD) AND COMPUTE STATISTICAL VALUES OF ERROR(S) AND OTHER MEASURED PARAMETERS
S37
IF ANY ERROR OR OTHER VALUE EXCEEDS PRE-DETERMINED THRESHOLD OR HISTORICAL STATISTICAL VALUE, SIGNAL ALARM TO WLS OPERATOR
S38

FIGURE 2K

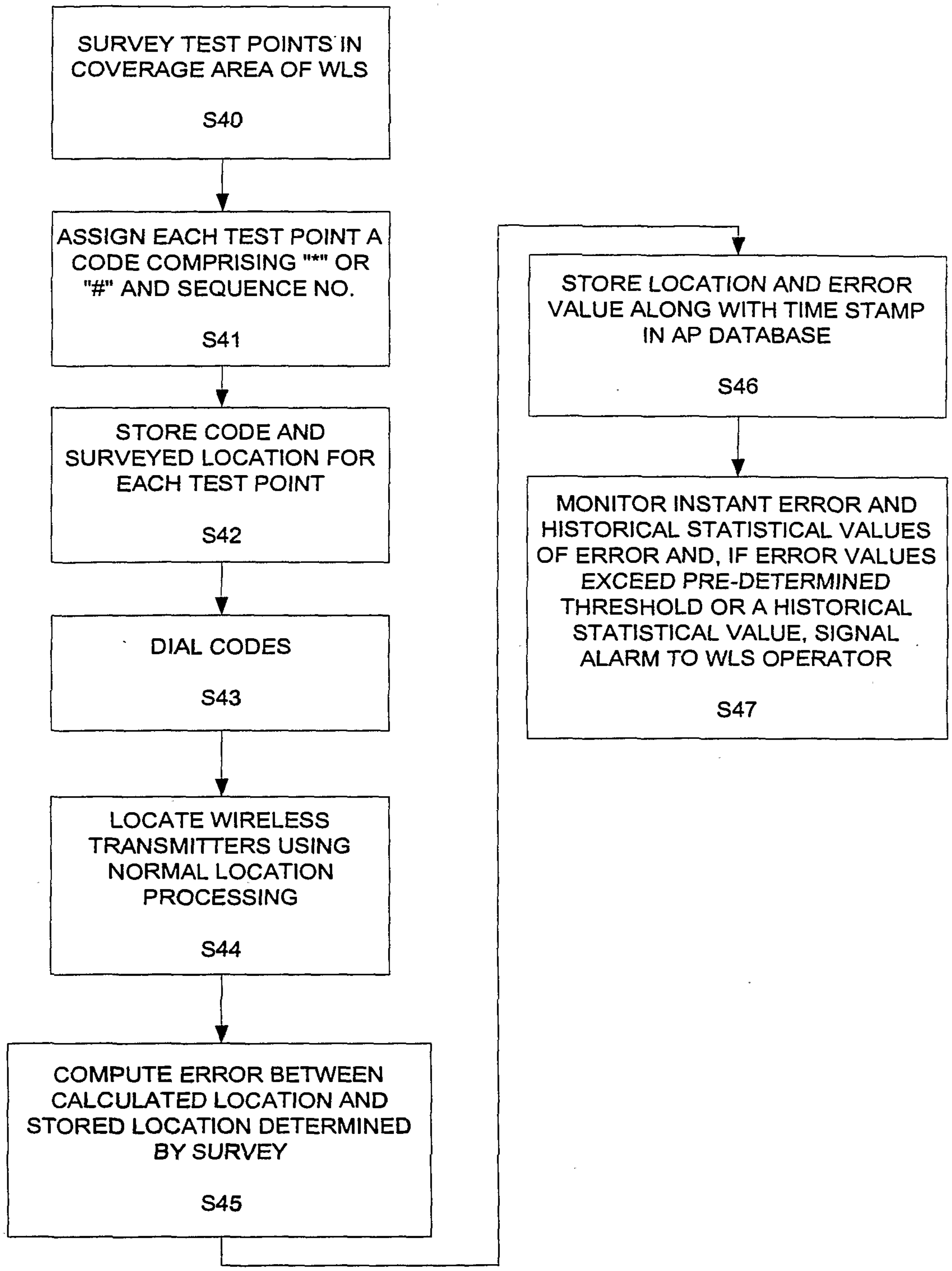

SURVEY TEST POINTS IN COVERAGE AREA OF WLS
S40
ASSIGN EACH TEST POINT A CODE COMPRISING "*" OR "#" AND SEQUENCE NO.
S41
STORE CODE AND SURVEYED LOCATION FOR EACH TEST POINT
S42
DIAL CODES
S43
LOCATE WIRELESS TRANSMITTERS USING NORMAL LOCATION PROCESSING
S44
COMPUTE ERROR BETWEEN CALCULATED LOCATION AND STORED LOCATION DETERMINED BY SURVEY
S45
STORE LOCATION AND ERROR VALUE ALONG WITH TIME STAMP IN AP DATABASE
S46
MONITOR INSTANT ERROR AND HISTORICAL STATISTICAL VALUES OF ERROR AND, IF ERROR VALUES EXCEED PRE-DETERMINED THRESHOLD OR A HISTORICAL STATISTICAL VALUE, SIGNAL ALARM TO WLS OPERATOR
S47

FIGURE 2L

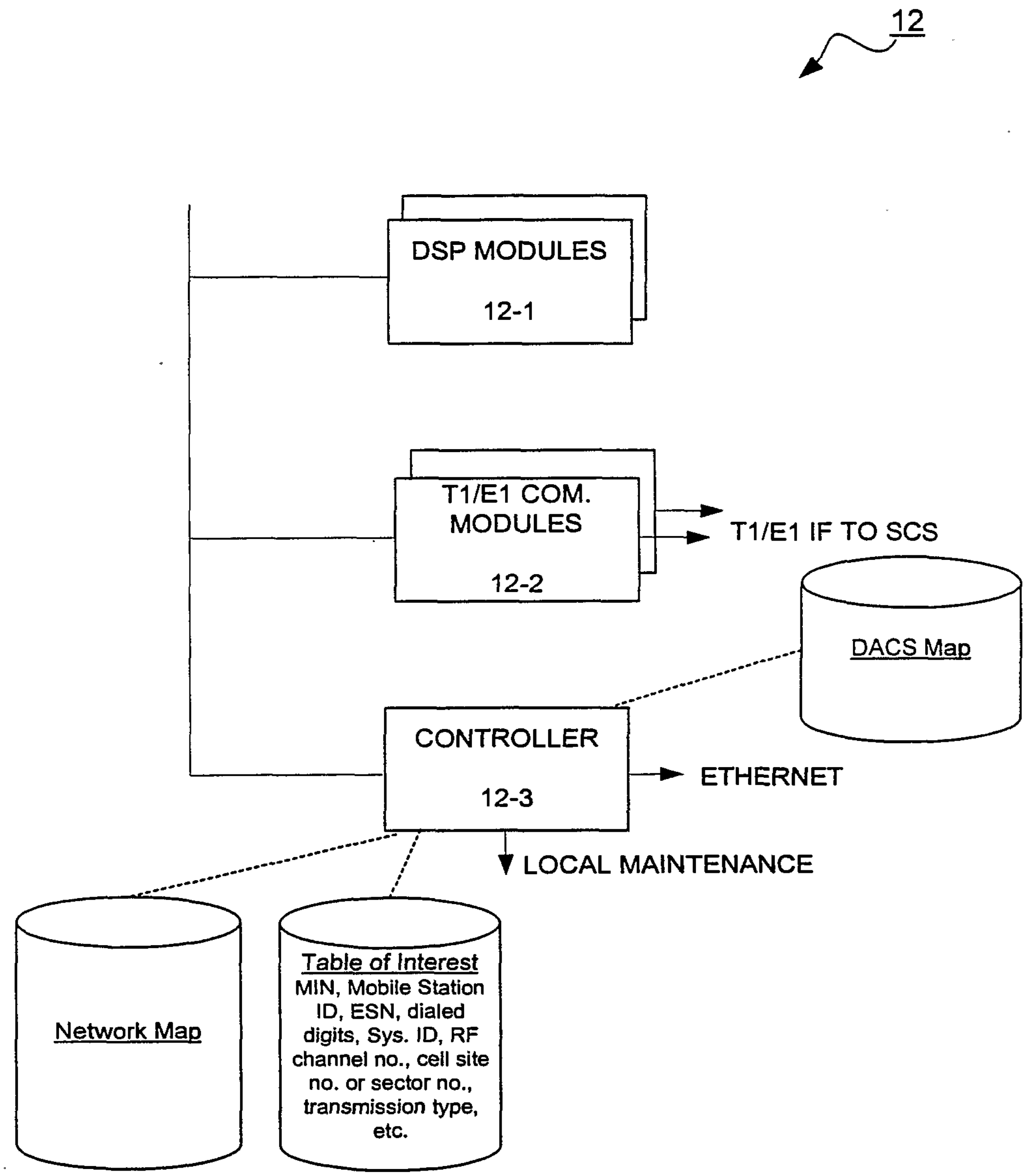
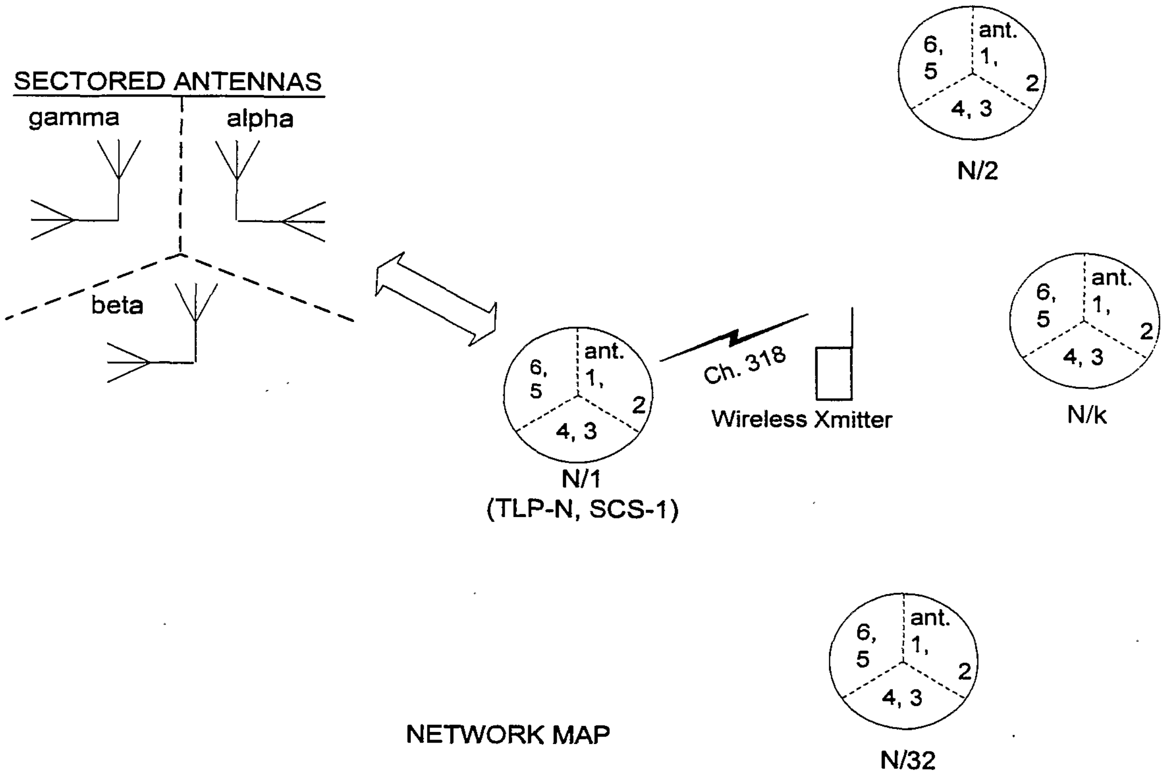
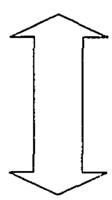

12
DSP MODULES
12-1
T1/E1 COM.
MODULES
12-2
T1/E1 IF TO SCS
DACS Map
CONTROLLER
12-3
ETHERNET
LOCAL MAINTENANCE
Network Map
Table of Interest
MIN, Mobile Station ID, ESN, dialed digits, Sys. ID, RF channel no., cell site no. or sector no., transmission type, etc.

FIGURE 3



NETWORK MAP



DYNAMIC COOPERATION TABLE

		Best Antenna Port
1	TLP 1/SCS 1	1 2 3 4 5 6
	1/2	4 3
	1/3	
	*	
	*	
	*	
	1/k	5 6 3 4
	*	
	*	
	*	
32	N/K	5 6

FIGURE 3A

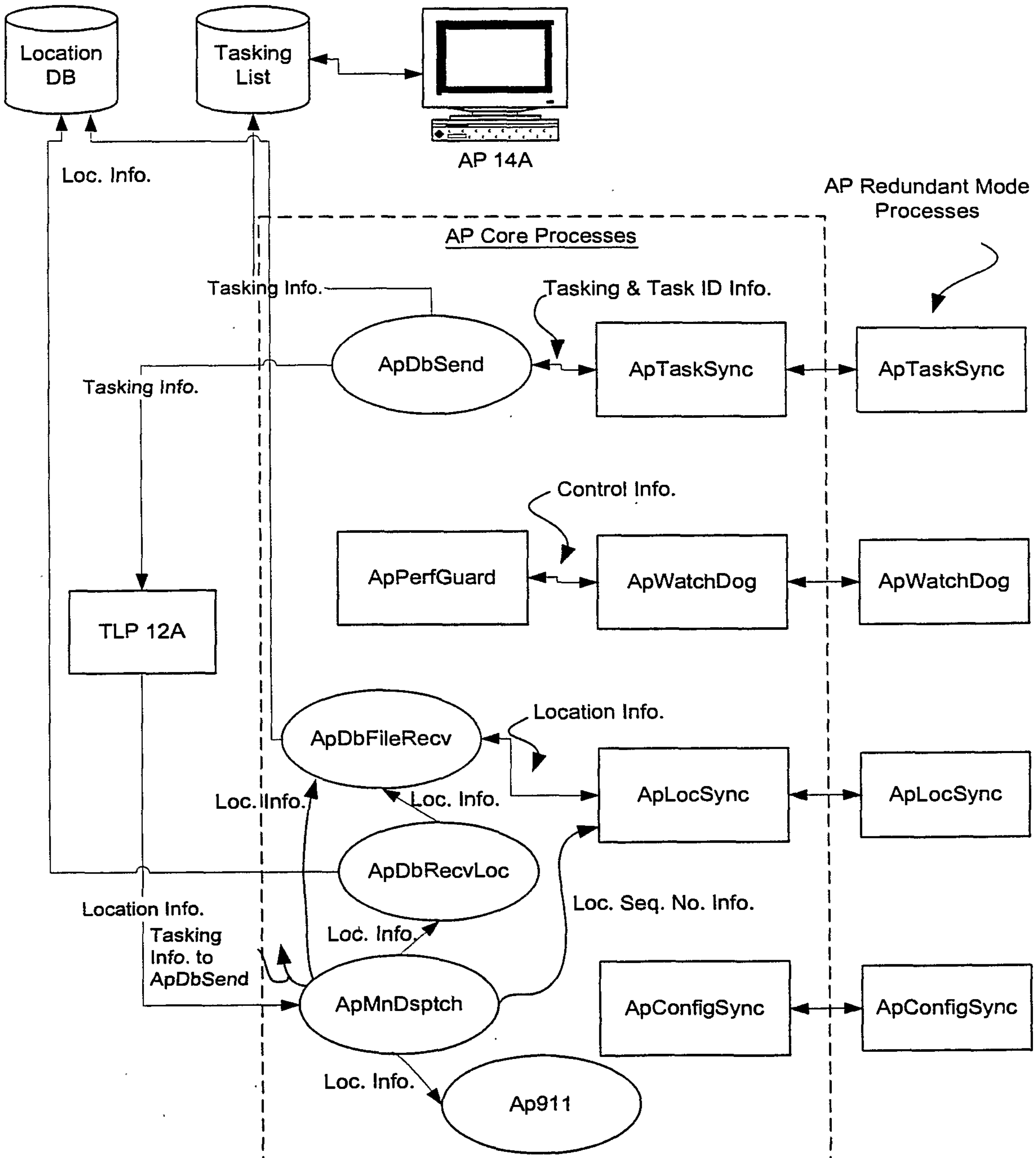

Location DB
Tasking List
AP 14A
Loc. Info.
AP Redundant Mode Processes
AP Core Processes
Tasking Info.
Tasking & Task ID Info.
ApDbSend
ApTaskSync
ApTaskSync
Tasking Info.
Control Info.
ApPerfGuard
ApWatchDog
ApWatchDog
TLP 12A
Location Info.
ApDbFileRecv
ApLocSync
ApLocSync
Loc. Info.
Loc. Info.
ApDbRecvLoc
Loc. Seq. No. Info.
Location Info.
Tasking Info. to ApDbSend
Loc. Info.
ApMnDsptch
ApConfigSync
ApConfigSync
Loc. Info.
Ap911

FIGURE 4

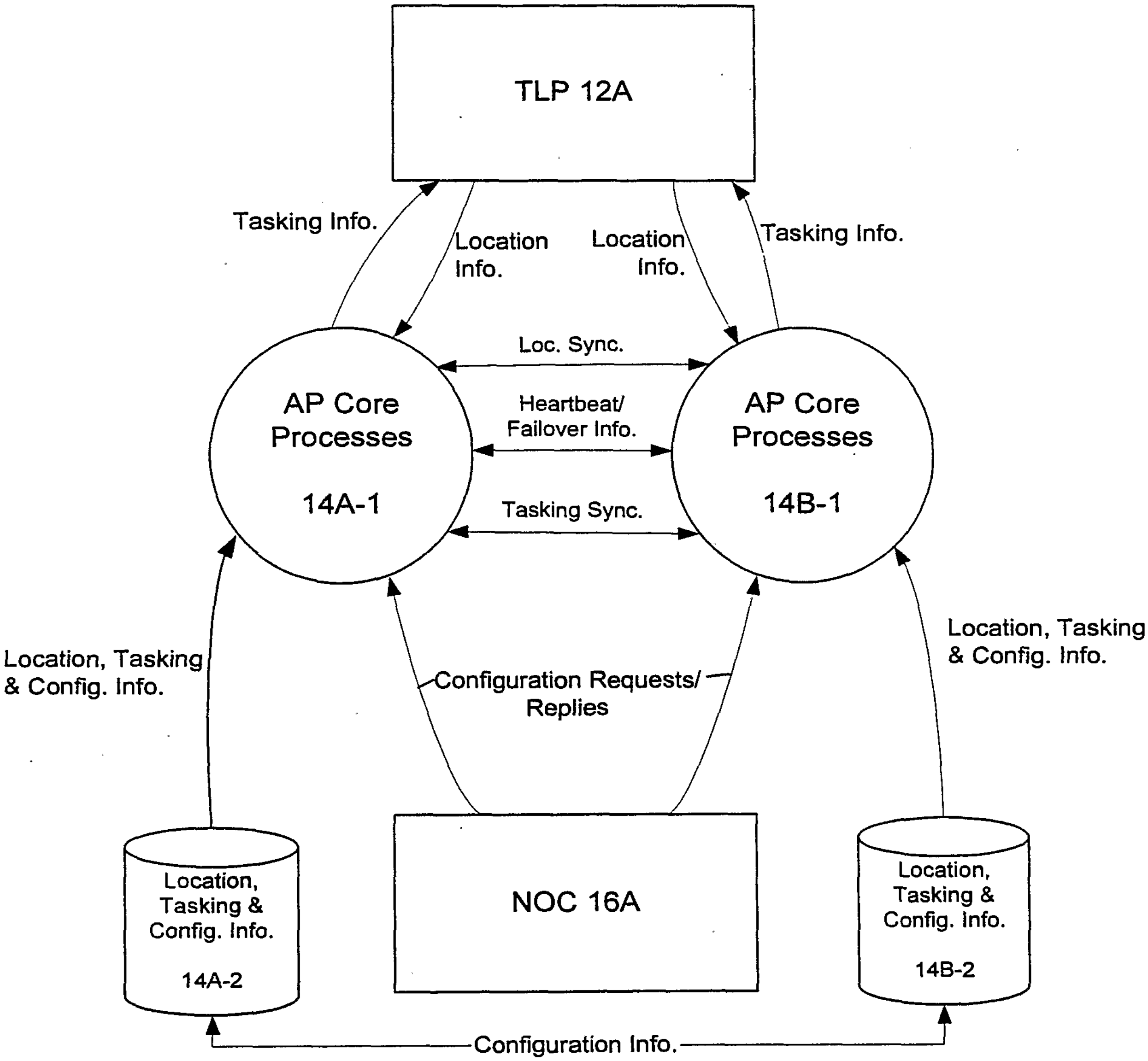

TLP 12A
Tasking Info.
Location Info.
Location Info.
Tasking Info.
Loc. Sync.
AP Core Processes
14A-1
Heartbeat/ Failover Info.
AP Core Processes
14B-1
Tasking Sync.
Location, Tasking & Config. Info.
Configuration Requests/ Replies
Location, Tasking & Config. Info.
Location, Tasking & Config. Info.
14A-2
NOC 16A
Location, Tasking & Config. Info.
14B-2
Configuration Info.

FIGURE 4A

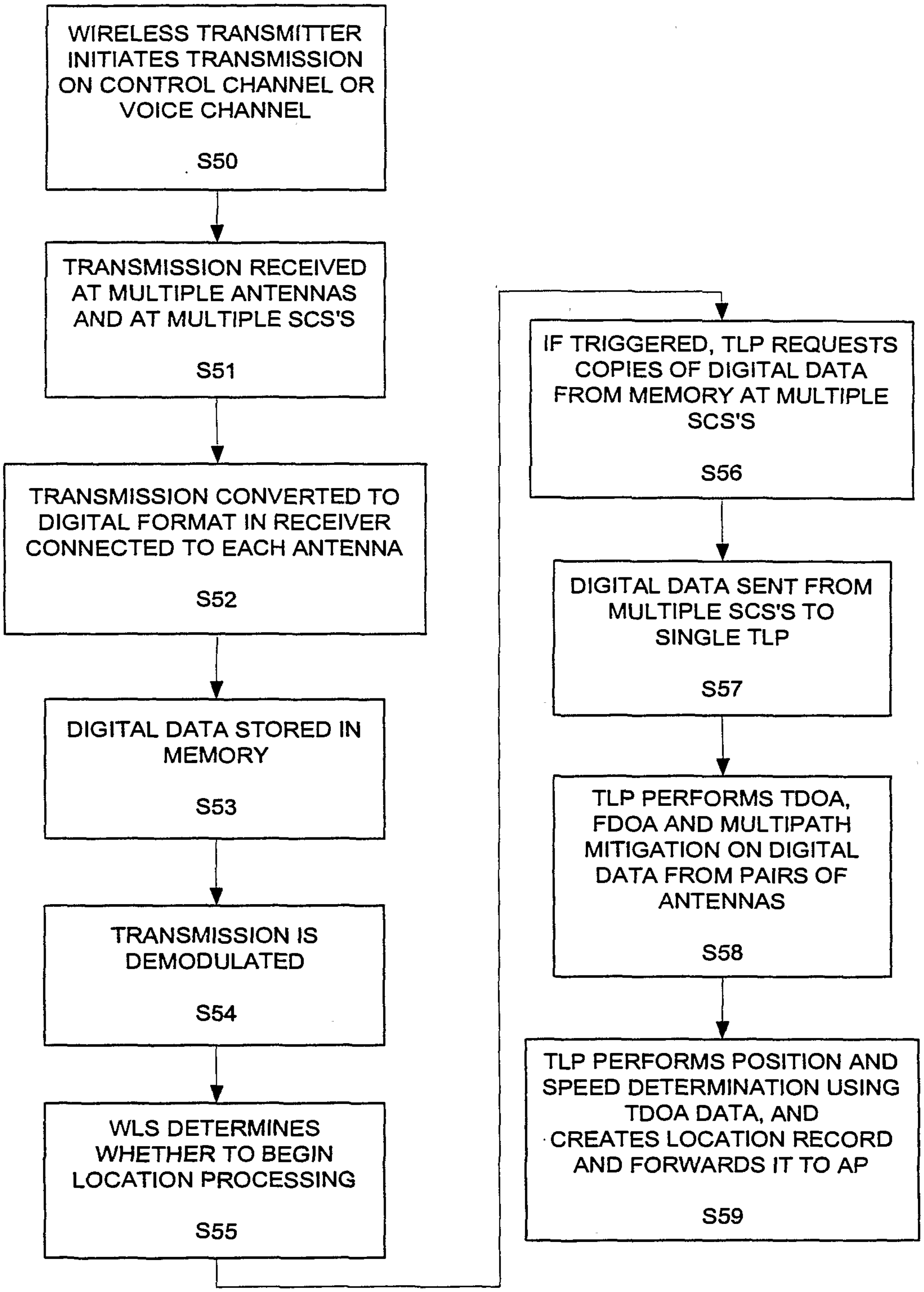

WIRELESS TRANSMITTER INITIATES TRANSMISSION ON CONTROL CHANNEL OR VOICE CHANNEL
S50
TRANSMISSION RECEIVED AT MULTIPLE ANTENNAS AND AT MULTIPLE SCS'S
S51
TRANSMISSION CONVERTED TO DIGITAL FORMAT IN RECEIVER CONNECTED TO EACH ANTENNA
S52
DIGITAL DATA STORED IN MEMORY
S53
TRANSMISSION IS DEMODULATED
S54
WLS DETERMINES WHETHER TO BEGIN LOCATION PROCESSING
S55
IF TRIGGERED, TLP REQUESTS COPIES OF DIGITAL DATA FROM MEMORY AT MULTIPLE SCS'S
S56
DIGITAL DATA SENT FROM MULTIPLE SCS'S TO SINGLE TLP
S57
TLP PERFORMS TDOA, FDOA AND MULTIPATH MITIGATION ON DIGITAL DATA FROM PAIRS OF ANTENNAS
S58
TLP PERFORMS POSITION AND SPEED DETERMINATION USING TDOA DATA, AND CREATES LOCATION RECORD AND FORWARDS IT TO AP
S59

FIGURE 5

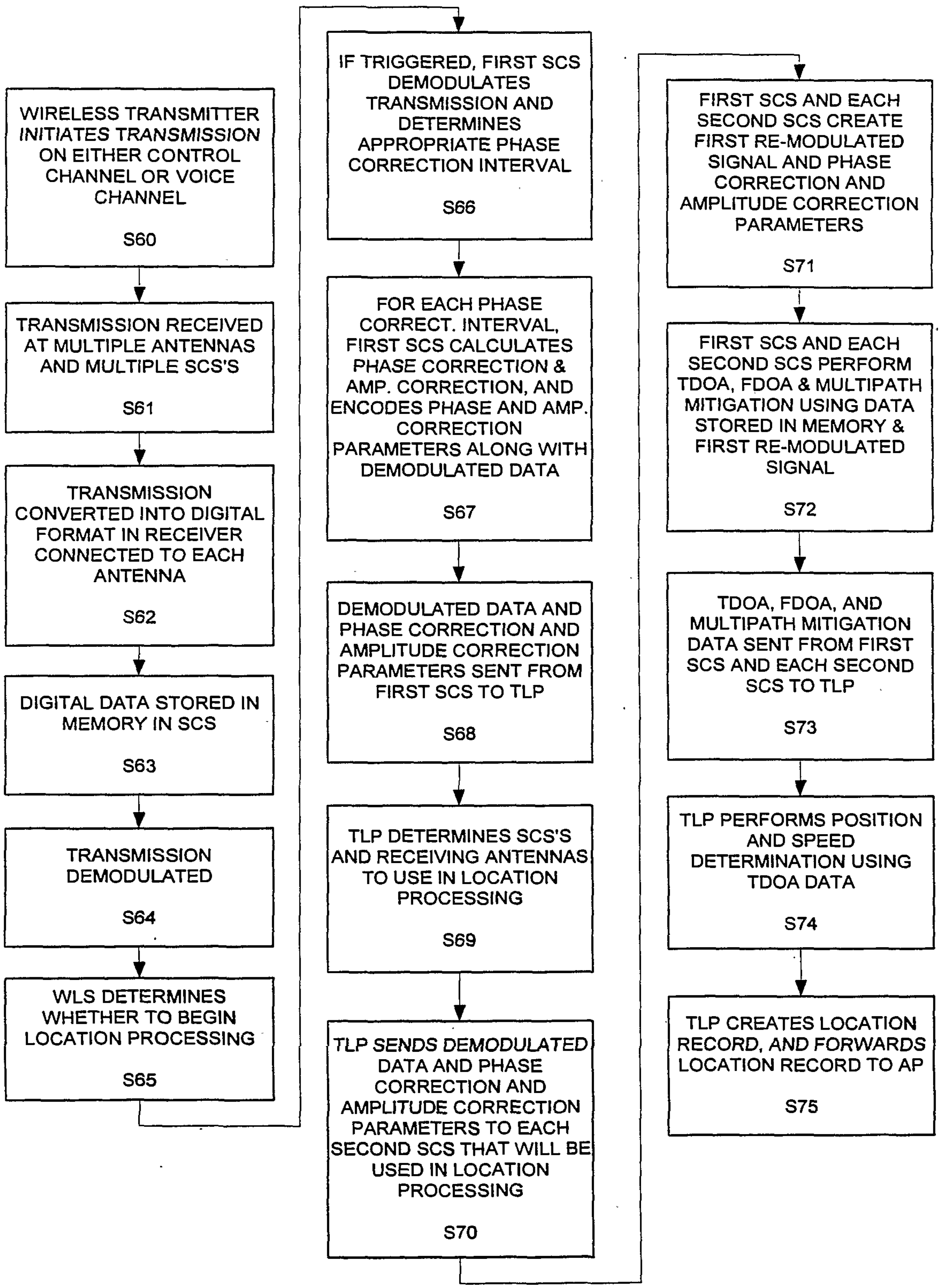

WIRELESS TRANSMITTER INITIATES TRANSMISSION ON EITHER CONTROL CHANNEL OR VOICE CHANNEL
S60
TRANSMISSION RECEIVED AT MULTIPLE ANTENNAS AND MULTIPLE SCS'S
S61
TRANSMISSION CONVERTED INTO DIGITAL FORMAT IN RECEIVER CONNECTED TO EACH ANTENNA
S62
DIGITAL DATA STORED IN MEMORY IN SCS
S63
TRANSMISSION DEMODULATED
S64
WLS DETERMINES WHETHER TO BEGIN LOCATION PROCESSING
S65
IF TRIGGERED, FIRST SCS DEMODULATES TRANSMISSION AND DETERMINES APPROPRIATE PHASE CORRECTION INTERVAL
S66
FOR EACH PHASE CORRECT. INTERVAL, FIRST SCS CALCULATES PHASE CORRECTION & AMP. CORRECTION, AND ENCODES PHASE AND AMP. CORRECTION PARAMETERS ALONG WITH DEMODULATED DATA
S67
DEMODULATED DATA AND PHASE CORRECTION AND AMPLITUDE CORRECTION PARAMETERS SENT FROM FIRST SCS TO TLP
S68
TLP DETERMINES SCS'S AND RECEIVING ANTENNAS TO USE IN LOCATION PROCESSING
S69
TLP SENDS DEMODULATED DATA AND PHASE CORRECTION AND AMPLITUDE CORRECTION PARAMETERS TO EACH SECOND SCS THAT WILL BE USED IN LOCATION PROCESSING
S70
FIRST SCS AND EACH SECOND SCS CREATE FIRST RE-MODULATED SIGNAL AND PHASE CORRECTION AND AMPLITUDE CORRECTION PARAMETERS
S71
FIRST SCS AND EACH SECOND SCS PERFORM TDOA, FDOA & MULTIPATH MITIGATION USING DATA STORED IN MEMORY & FIRST RE-MODULATED SIGNAL
S72
TDOA, FDOA, AND MULTIPATH MITIGATION DATA SENT FROM FIRST SCS AND EACH SECOND SCS TO TLP
S73
TLP PERFORMS POSITION AND SPEED DETERMINATION USING TDOA DATA
S74
TLP CREATES LOCATION RECORD, AND FORWARDS LOCATION RECORD TO AP
S75

FIGURE 6

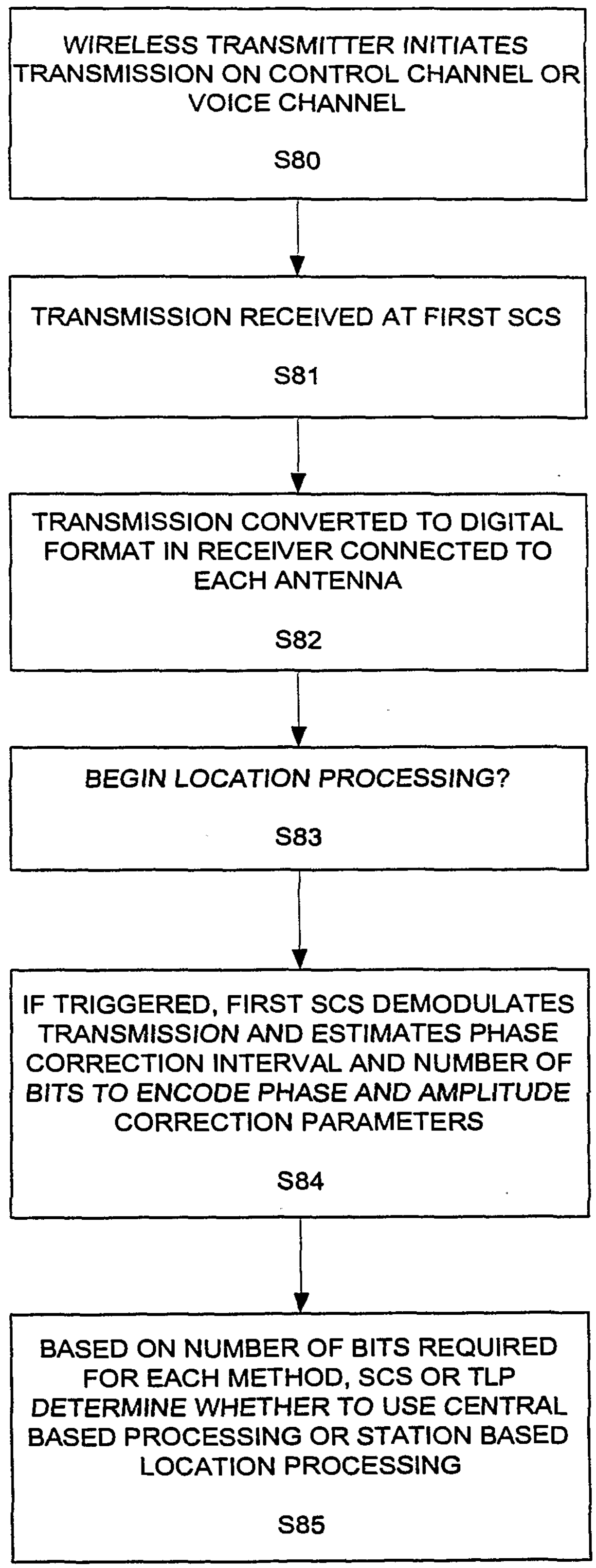

WIRELESS TRANSMITTER INITIATES TRANSMISSION ON CONTROL CHANNEL OR VOICE CHANNEL
S80
TRANSMISSION RECEIVED AT FIRST SCS
S81
TRANSMISSION CONVERTED TO DIGITAL FORMAT IN RECEIVER CONNECTED TO EACH ANTENNA
S82
BEGIN LOCATION PROCESSING?
S83
IF TRIGGERED, FIRST SCS DEMODULATES TRANSMISSION AND ESTIMATES PHASE CORRECTION INTERVAL AND NUMBER OF BITS TO ENCODE PHASE AND AMPLITUDE CORRECTION PARAMETERS
S84
BASED ON NUMBER OF BITS REQUIRED FOR EACH METHOD, SCS OR TLP DETERMINE WHETHER TO USE CENTRAL BASED PROCESSING OR STATION BASED LOCATION PROCESSING
S85

FIGURE 7

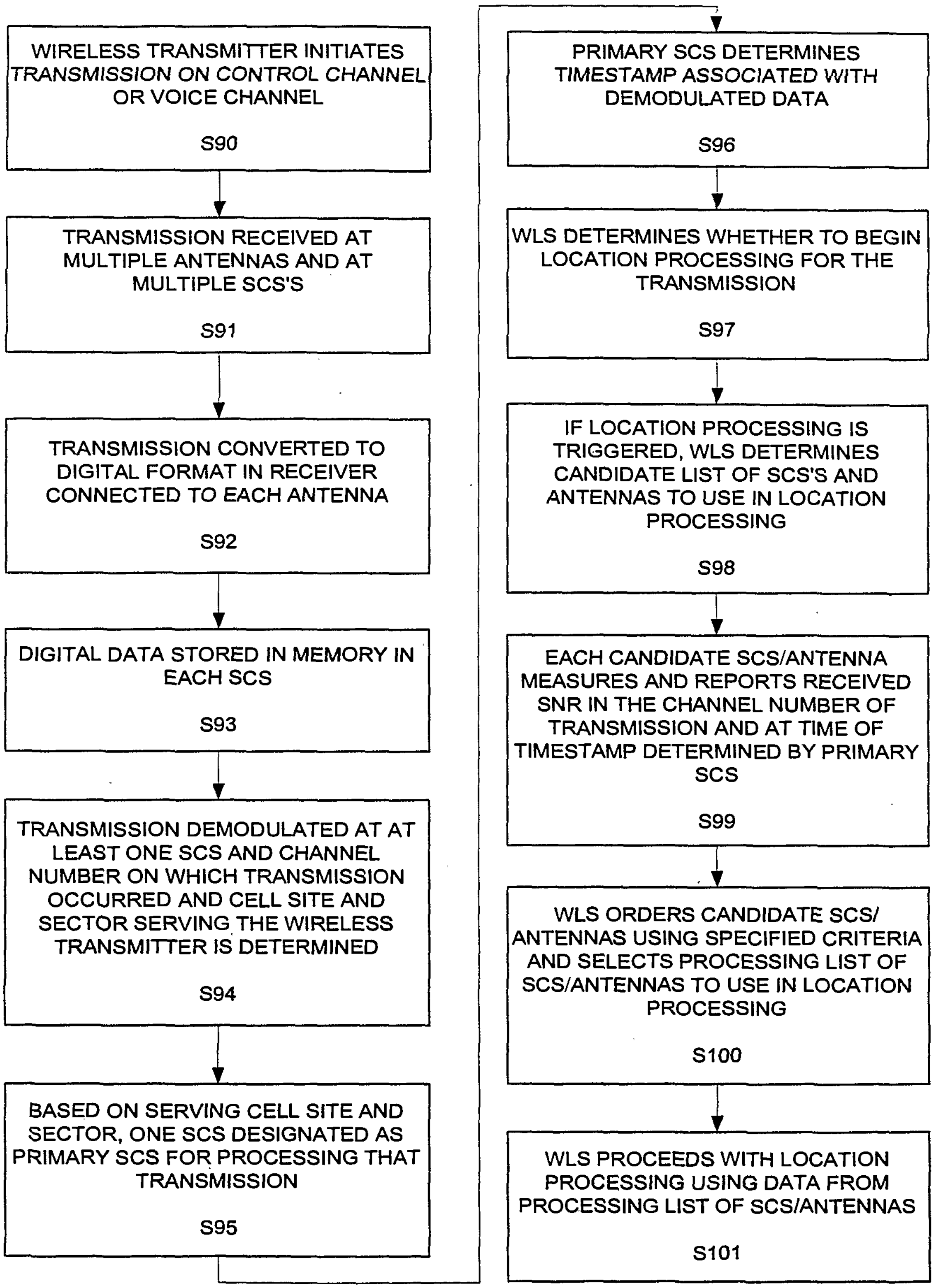

WIRELESS TRANSMITTER INITIATES TRANSMISSION ON CONTROL CHANNEL OR VOICE CHANNEL
S90
TRANSMISSION RECEIVED AT MULTIPLE ANTENNAS AND AT MULTIPLE SCS'S
S91
TRANSMISSION CONVERTED TO DIGITAL FORMAT IN RECEIVER CONNECTED TO EACH ANTENNA
S92
DIGITAL DATA STORED IN MEMORY IN EACH SCS
S93
TRANSMISSION DEMODULATED AT AT LEAST ONE SCS AND CHANNEL NUMBER ON WHICH TRANSMISSION OCCURRED AND CELL SITE AND SECTOR SERVING THE WIRELESS TRANSMITTER IS DETERMINED
S94
BASED ON SERVING CELL SITE AND SECTOR, ONE SCS DESIGNATED AS PRIMARY SCS FOR PROCESSING THAT TRANSMISSION
S95
PRIMARY SCS DETERMINES TIMESTAMP ASSOCIATED WITH DEMODULATED DATA
S96
WLS DETERMINES WHETHER TO BEGIN LOCATION PROCESSING FOR THE TRANSMISSION
S97
IF LOCATION PROCESSING IS TRIGGERED, WLS DETERMINES CANDIDATE LIST OF SCS'S AND ANTENNAS TO USE IN LOCATION PROCESSING
S98
EACH CANDIDATE SCS/ANTENNA MEASURES AND REPORTS RECEIVED SNR IN THE CHANNEL NUMBER OF TRANSMISSION AND AT TIME OF TIMESTAMP DETERMINED BY PRIMARY SCS
S99
WLS ORDERS CANDIDATE SCS/ ANTENNAS USING SPECIFIED CRITERIA AND SELECTS PROCESSING LIST OF SCS/ANTENNAS TO USE IN LOCATION PROCESSING
S100
WLS PROCEEDS WITH LOCATION PROCESSING USING DATA FROM PROCESSING LIST OF SCS/ANTENNAS
S101

FIGURE 8

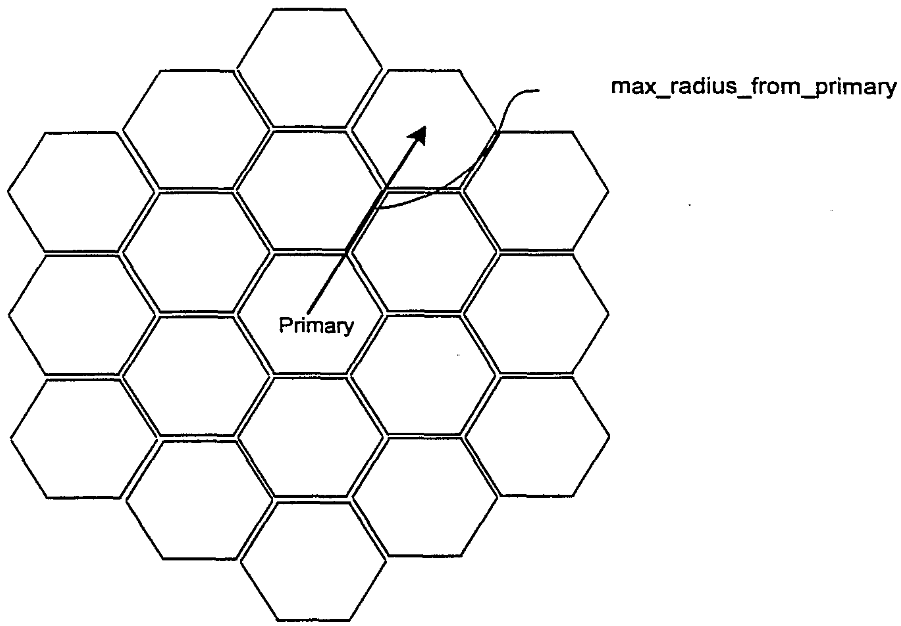


FIGURE 9

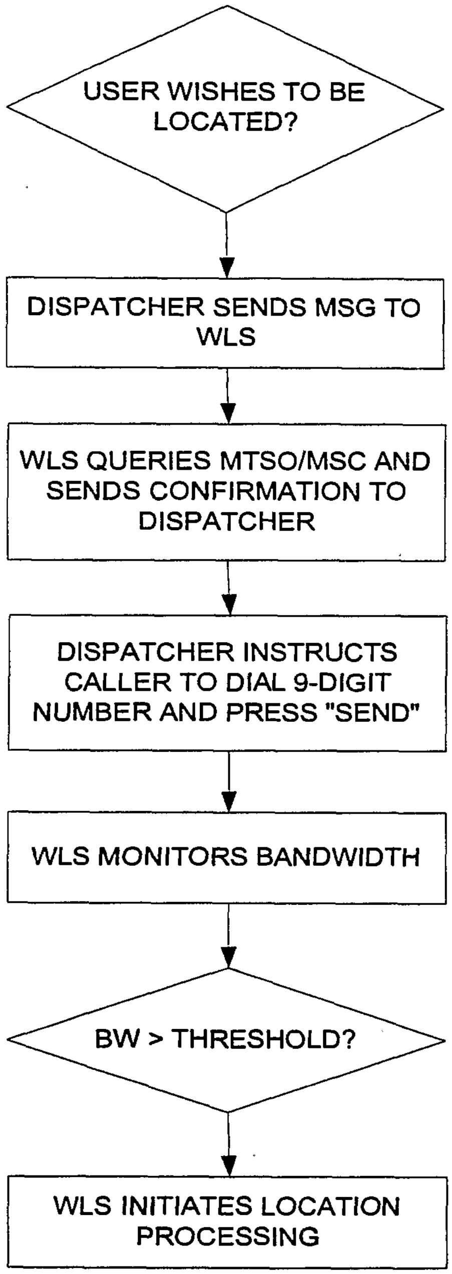


FIGURE 10A

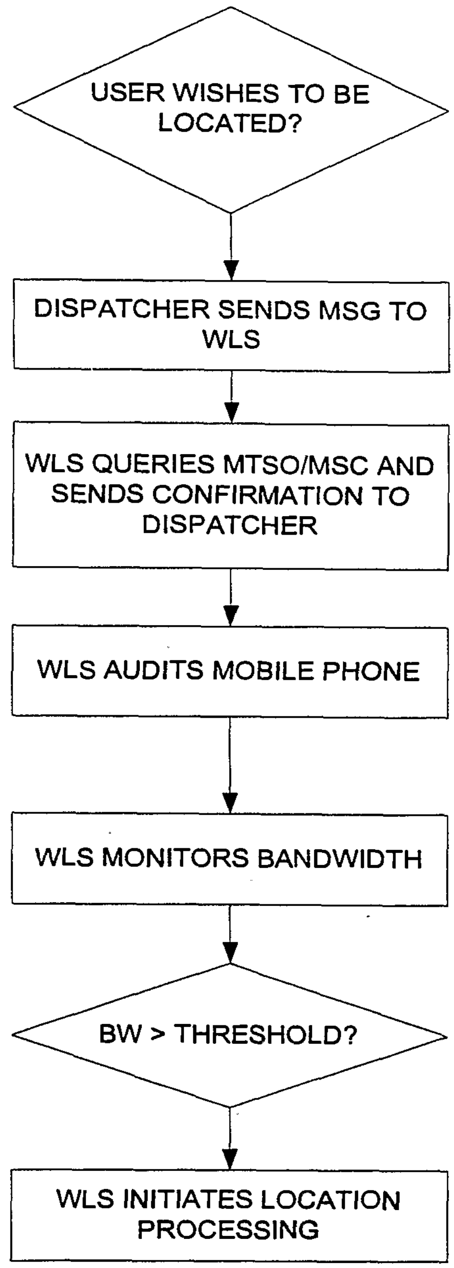


FIGURE 10B

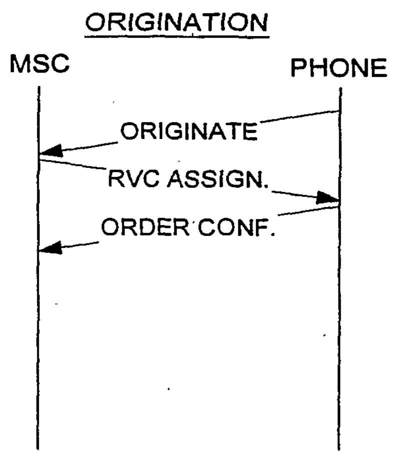


FIGURE 11A

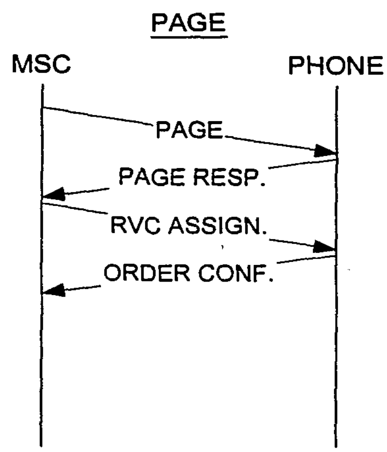


FIGURE 11B

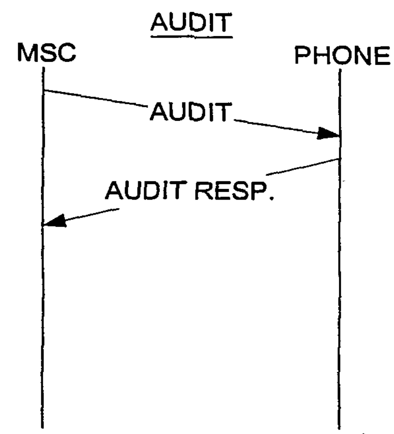


FIGURE 11C

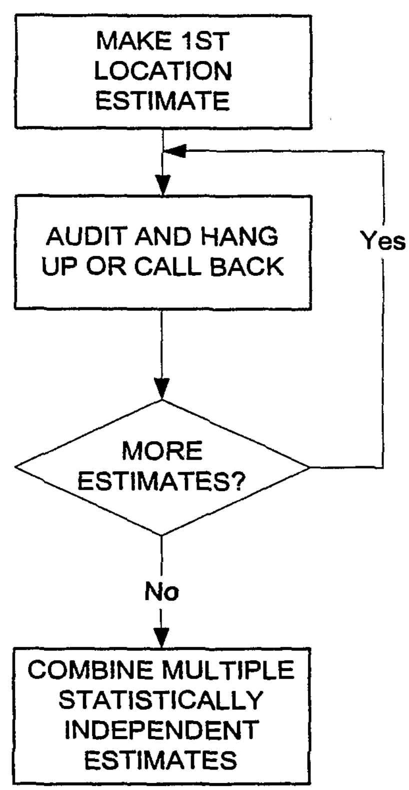


FIGURE 11D

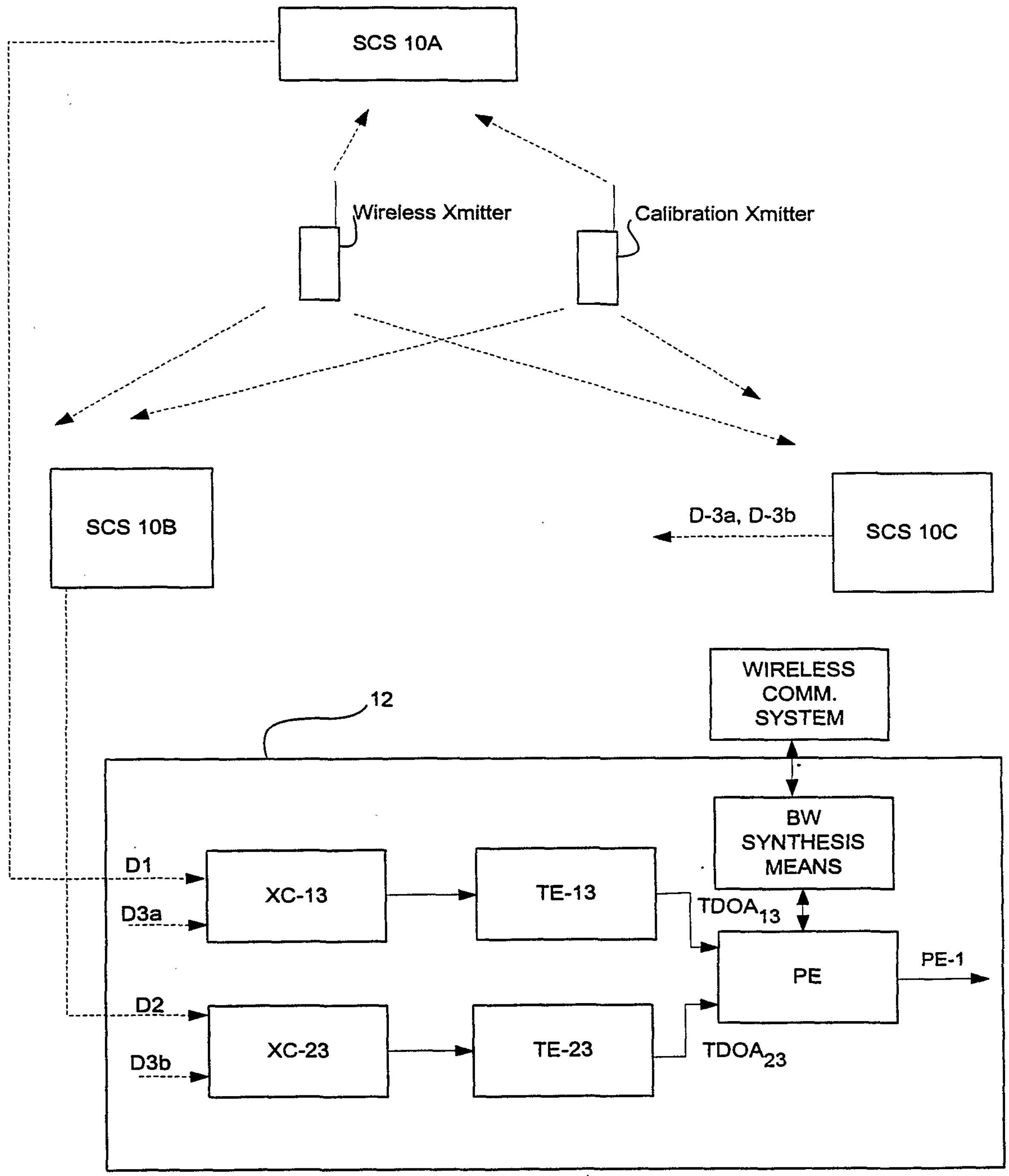

SCS 10A
Wireless Xmitter
Calibration Xmitter
SCS 10B
D-3a, D-3b
SCS 10C
12
WIRELESS COMM. SYSTEM
BW SYNTHESIS MEANS
D1
D3a
XC-13
TE-13
TDOA13
PE
PE-1
D2
D3b
XC-23
TE-23
TDOA23

FIGURE 12A

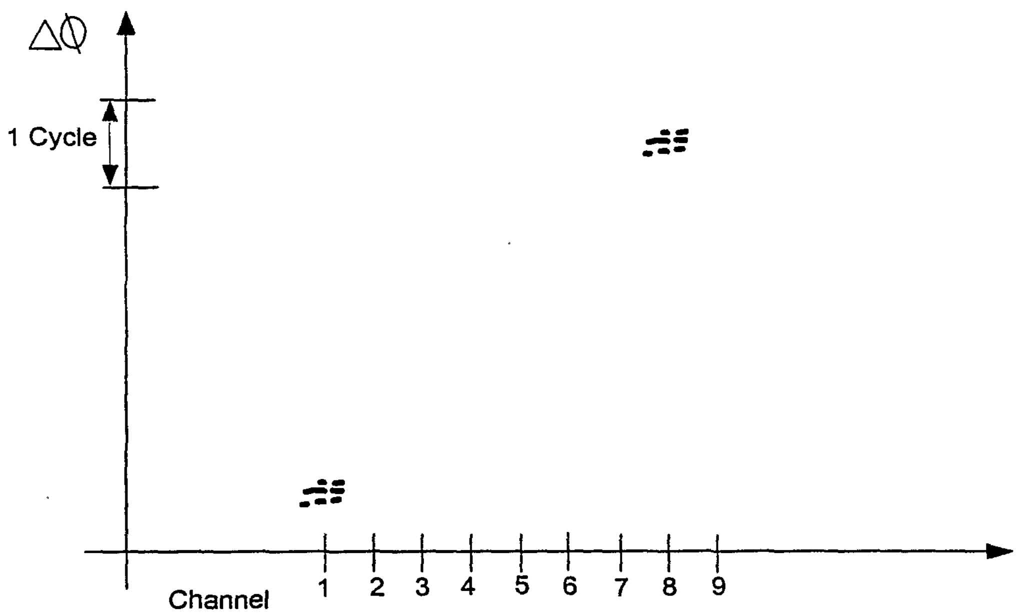


FIGURE 12B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/09078

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : H04B 7/00
US CL : 455/456
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 455/422, 456, 457, 522, 69

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,487,185 A (HALONEN) 23 JANUARY 1996, see, figures 1-3see column 2, lines	61

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"&" document member of the same patent family

Date of the actual completion of the international search
25 MAY 2001

Date of mailing of the international search report
18 JUN 2001

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THANH CONG LE
Telephone No. (703) 305-4819

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PCT

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(22) International Filing Date: 14 August 1989 (14.08.89)

(30) Priority data:
253,529 5 October 1988 (05.10.88) US

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(72) Inventors: SAGERS, Richard, Cameron ; 4112 Bristlecone Lane, Fort Worth, TX 76137 (US). WERNER, William, Dennis ; 2921 Creekwood Drive, Grapevine, TX 76051 (US). HALL, Scott, Maurice ; 4324 Crabapple Street, Fort Worth, TX 76137 (US).

(74) Agents: PARMELEE, Steven, G. et al.; Motorola, Inc., Intellectual Property Department, 1303 East Algonquin Road, Schaumburg, IL 60196 (US).

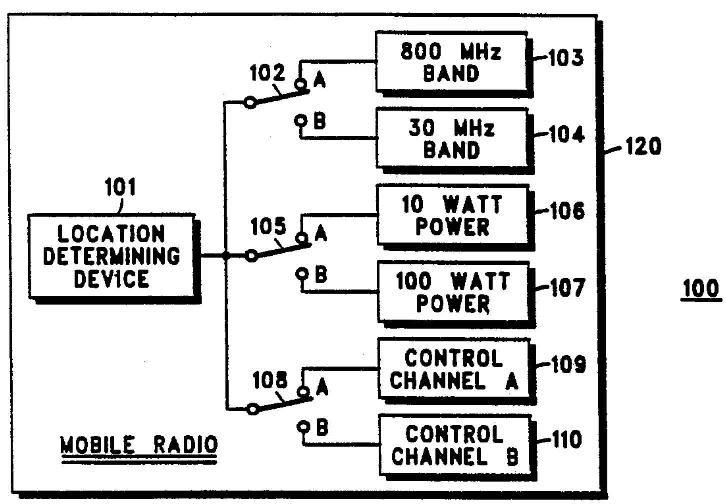
(81) Designated States: AT (European patent), AU, BE (European patent), BR, CH (European patent), DE (European patent), FR (European patent), GB (European patent), IT (European patent), JP, KR, LU (European patent), NL (European patent), SE (European patent).

Published
With international search report.

(54) Title: LOCATION-BASED ADAPTIVE RADIO CONTROL

(57) Abstract

A method (200) and apparatus (100) is provided for a radio having adjustable operating parameters to adjust at least one such adjustable operating parameter based on the current location of the radio. Operating parameters which may be so adjusted include, but are not limited to, the following: transmitting power (106, 107), operating channel, operating band (103, 104), modulation type, modulation index, frequency deviation, squelch setting, channel spacing, control channel (109, 110) (for trunked communications), noise blanker characteristic, and receive bandwidth. The location is determined by the radio (101).



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MW	Malawi
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NO	Norway
RO	Romania
SD	Sudan
SE	Sweden
SN	Senegal
SU	Soviet Union
TD	Chad
TG	Togo
US	United States of America

LOCATION-BASED ADAPTIVE RADIO CONTROL

Background of the Invention

This invention pertains to radios.

Two-way radios have a number of operating parameters including, but not limited to, transmitting power, operating frequencies (channel), operating band, modulation type, modulation index, frequency deviation, squelch setting, channel spacing, control channel (for trunked communications), noise blanker characteristic, and receive bandwidth. Of these parameters, some are fixed, while others may be, to some degree, variable. One example of a parameter which is usually, but not always, fixed is the modulation type, such as FM or AM. One example of a parameter which is usually, but not always, variable is the operating frequency or frequencies (channel).

At a given time, it may be desirable to adjust the operating parameters in response to the current operating environment to obtain optimum performance. For example, it may be desirable to minimize interference to other users.

A significant factor in determining the current optimum operating parameters is the geographic location of the radio. As an example, a particular radio operating in a densely-populated area, such as downtown

Los Angeles, California must contend with, among other factors, a relatively large number of other radios using the same frequency spectrum. As a result, the available frequencies (channels) may be limited. Also, the radio must limit its transmitting power to avoid interfering with neighboring users. On the other hand, if this identical radio were located in the middle of a sparsely-populated area, such as Death Valley, California, it would contend with few (if any) other radios using the same frequency spectrum. As a result, more channels are available and the transmitting power may be increased to achieve greater range without interfering with neighboring users.

For radios which are fixed in location, that is, non-mobile, usually there are few parameters, if any, which need to be varied during day-to-day operation. This is because the operating environment is relatively constant for the radio which is due, to a large extent, to the fact that the location of the radio is fixed.

For radios whose location is not fixed (that is, mobile), on the other hand, it is desirable for operating parameters to be adjusted whenever a change in the location of the radio causes the operating environment to change. For example, using our above example, if a mobile radio initially selects an operating frequency band and transmit power while it is located in downtown Los Angeles, the radio may need to periodically adjust (change) these frequency band and power settings as its location constantly changes during the course of its journey from the downtown area to a final destination of Death Valley. Moreover, it also may be advantageous to change other operating parameters during the course of such a journey.

Another situation where a mobile radio might need to adjust operating parameters based on its location arises in trunked radio systems. In such systems, many subscriber units share a fixed (and typically smaller) number of communication channels. In such systems, a common control station uses a control channel to allocate the shared channels amongst the subscriber units. When a subscriber wishes to place a call, it first tunes to the control channel and transmits a channel request message to the control station. Upon receipt of this message (and assuming an idle channel is available) the control station reserves, or assigns, an idle channel for the call. The control station then transmits the channel assignment information to the requesting subscriber via the control channel. Upon receipt of this channel assignment message, the requesting subscriber unit tunes to the assigned channel and proceeds to place its call.

A possible scenario which might arise in such trunked systems is a mobile subscriber unit which travels in geographic region A served by trunked system A with associated control channel A, and which mobile subscriber unit also travels in region B served by trunked system B with associated control channel B. With present trunked radio systems, no convenient mechanism exists to allow the subscriber unit to easily and readily change from one trunked system to another when travelling in this way.

In general, then, it is desirable for a mobile radio to have the ability to change operating parameters based on its current location. Given this fact, the question arises of how to effect the desired changes in the operating parameters. While it is obvious the human operator could manually adjust the operating parameters to obtain optimum performance, this could also prove to be risky. This is because, due to human error, the operator may be mistaken as to either the present location of the radio, or the current optimum operating parameters for the present location of the radio, or both.

Summary of the Invention

Therefore, it is an object of the present invention to vary one or more operating parameters of a mobile radio automatically, and without human intervention, based on the location of the radio. According to the invention, a method is provided, and an apparatus described, whereby one or more operating parameters of a mobile radio may be varied automatically, and without human intervention, based on the location of the radio.

Brief Description of the Drawings

Fig. 1 depicts the location-based adaptive radio control arrangement.

Fig. 2 depicts a flow diagram illustrating the steps of the invention.

Detailed Description of the Invention

The invention may be used with any location determining device or system (101), such as LORAN, satellite global positioning systems, or dead reckoning, and with any mobile radio having adjustable operating parameters. Such location determining systems are well understood and need not be described here in any further detail. (In the context of this invention, "mobile" refers to a non-fixed location radio, and includes both vehicle mounted and personally carried radios.)

The invention (100) is shown in Fig. 1.

Switch 1 (102) is arranged to select the operating frequency band of the radio. When switch 1 is in position designated "A", the radio operates on the 800 MHz band (103). When switch 1 is in the position designated "B", the radio operates on the 30 MHz band (104).

Switch 2 (105) is arranged to select the output power level of the transmitter. When switch 2 is in the position designated "A", the output power is 10 Watts (106). When switch 2 is in the position designated "B", the output power is 100 Watts (107).

Switch 3 (108) is arranged to select the control channel of the radio. When switch 3 is in the position designated "A", the control channel selected is channel A (109). When switch 3 is in position designated "B", the control channel selected is channel B (110).

The mobile radio (120) is equipped with a location determining device (101) which, in turn, is arranged to control the position of switch 1 (102), switch 2 (105), and switch 3 (108). In this embodiment, the location determining device (101) is capable of determining whether the radio is located in location A (the urban area) or location B (the rural area).

When the location determining device (101) determines the radio is located in location A, it causes switch 1 (102) to reside in position "A", thereby causing the radio to operate on the 800 MHz band. Also when the location determining device (101) determines the radio is located in location A, it causes switch 2 (105) to reside in position "A", thereby causing the radio to transmit at 10 Watts power output. Finally, when the location determining device (101) determines the radio is located in location A, it causes switch 3 (108) to also reside in position "A", thereby causing the radio to use channel A as a control channel.

When the location determining device (101) determines the radio is located in location B, it causes switch 1 (102) to reside in position "B", thereby causing the radio to operate on the 30 MHz band. Also when the location determining device (101) determines the radio is located in location B, it causes switch 2 (105) to reside in position "B", thereby causing the radio to transmit at 100 Watts power output. Finally, when the location determining device (101) determines the radio is located in location B, it causes switch 3 (108) to reside in position "B", thereby causing the radio to use channel B as a control channel.

Fig. 2 shows the flow diagram (200) of the steps of the invention.

The process starts with the radio determining its location (201). If the radio determines it is located in a first predetermined location, such as location A (the urban area), the radio operates on the 800 MHz band (202), adjusts the transmitter to 10 Watts of output power (203), and uses channel A as a control channel (204). The radio then returns (220) to its initial determining step (201), and makes a new determination of its location.

In this embodiment, if the radio determines it is located in location B (the rural area), the radio operates on the 30 MHz band (212), adjusts its transmitter to 100 Watts of output power (213), and uses channel B as a control channel (214). The radio then returns (220) to its initial determining step (201), and makes a new determination of its location.

What is claimed is:

CLAIMS:

1. A method for adjusting a radio comprising the steps of: in said radio:

(a) determining said radio's location; and,

(b) responsive to said determination, automatically adjusting at least one variable operating parameter.

2. A method for adjusting a radio, comprising the steps of: in said radio:

(a) determining when said radio is located within a predetermined region; and,

(b) responsive to said determination, automatically adjusting at least one variable operating parameter.

3. A method for adjusting a radio, comprising the steps of: in said radio:

(a) determining which of several predetermined regions said radio is located within; and,

(b) responsive to said determination, automatically adjusting at least one variable operating parameter.

4. A method for adjusting a radio, comprising the steps of:

(a) determining said radio's distance from at least one predetermined fixed point; and,

(b) responsive to said determination, automatically adjusting at least one variable operating parameter.

5. A radio having adjusting means, said adjusting means comprising:

means for determining said radio's location; and,

means responsive to said determining means for automatically adjusting at least one variable operating parameter.

6. A radio having adjusting means, said adjusting means comprising:

means for determining when said radio is located within a predetermined region; and,

means responsive to said determining means for automatically adjusting at least one variable operating parameter.

7. A radio having adjusting means, said adjusting means comprising:

means for determining which of several predetermined regions said mobile radio is located within; and,

means responsive to said determining means for automatically adjusting at least one variable operating parameter.

8. A radio having adjusting means, said adjusting means comprising:

means for determining said radio's distance from at least one predetermined fixed point; and,

means responsive to said determining means for automatically adjusting at least one variable operating parameter.

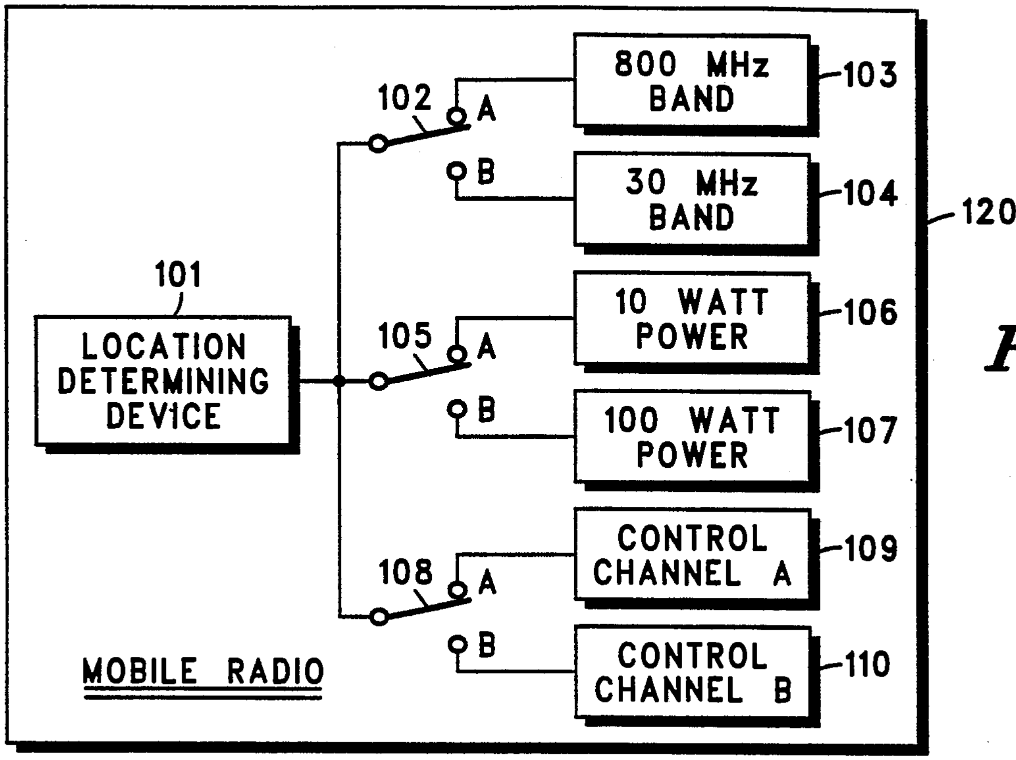
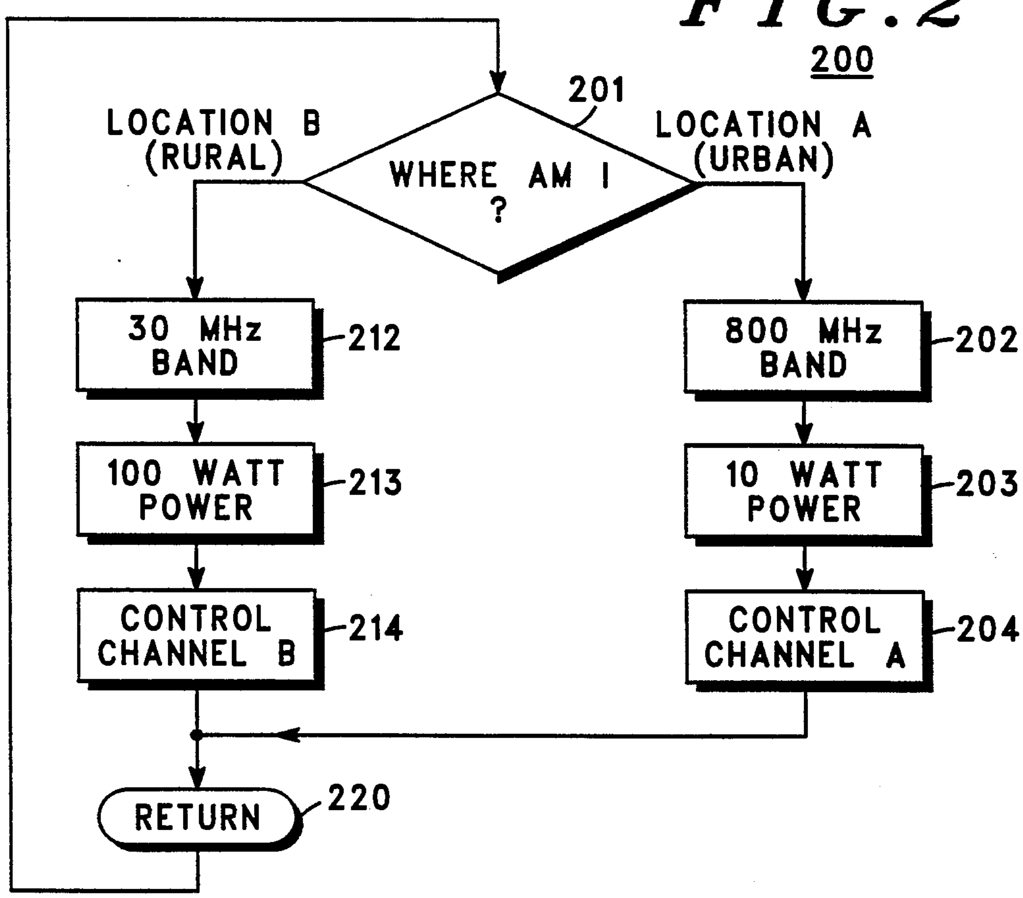


FIG.1

100

FIG.2

200



INTERNATIONAL SEARCH REPORT

International Application No. PCT/US89/03452

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl4 H04B 7/24
U.S. Cl. 455/33

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
U.S.	455: 33, 35, 62, 67, 54, 88, 89, 127, 166, 183, 184, 185, 186, 200, 212, 218, 221 342: 419, 457

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	US, A, 4,476,582 Strauss et al 09 October 1984, See the Figure and column 2, lines 39 to 68 and column 5, lines 3 to 16 and 44-61.	1-8
A	US, A, 4,550,443 Freeburg 29 October 1985.	1-8
A	US, A 4,765,753 Schmidt 23 August 1988	1-8
A	US, A, 3,906,166 Cooper et al. 16 September 1975.	1-8

* Special categories of cited documents: [10]

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
31 October 1989	29 NOV 1989
International Searching Authority	**Signature of Authorized Officer**
ISA/US	Ralph E. Smith

Form PCT/ISA/210 (second sheet) (Rev.11-87)

(12) UK Patent Application (19) GB (11) 2 252 475 (13) A

(43) Date of A publication 05.08.1992

(21) Application No 9123183.7

(22) Date of filing 01.11.1991

(30) Priority data
(31) 616457 (32) 21.11.1990 (33) US

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Motorola, European Intellectual Property Operations, Jays Close, Viables Industrial Estate, Basingstoke, Hants, RG22 4PD, United Kingdom

(51) INT CL^5
H04M 1/24, G06F 11/34

(52) UK CL (Edition K)
H4K KFF K1L
G4A AFMD
U1S S2215

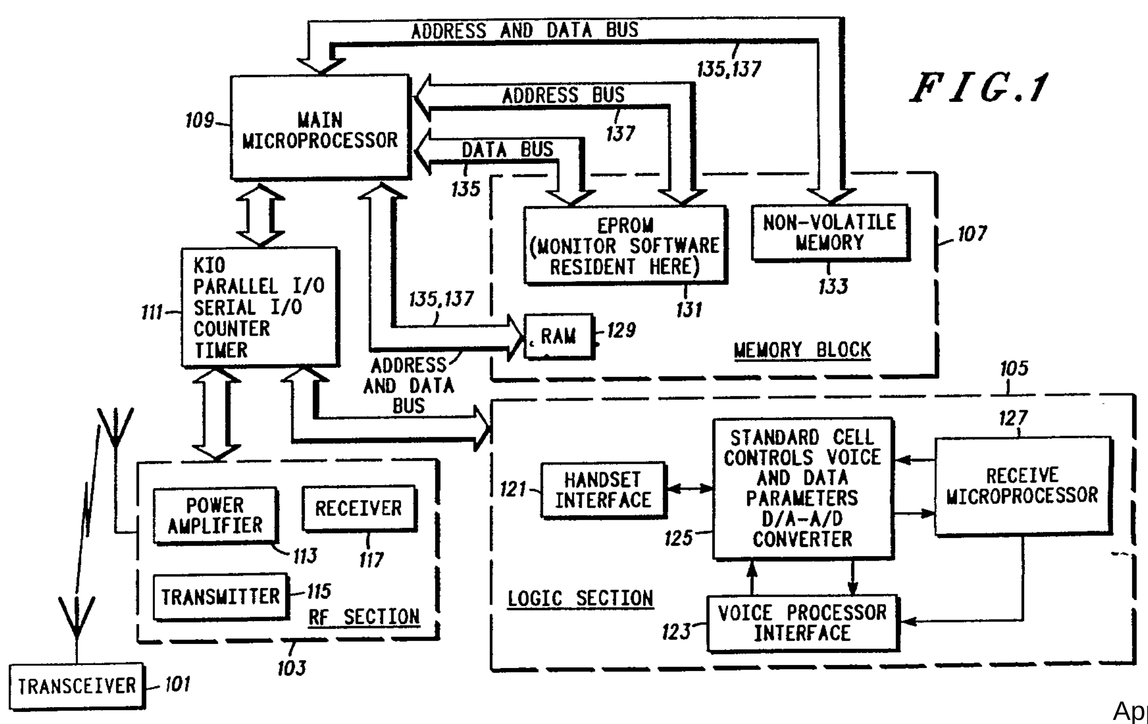
(56) Documents cited
GB 2246649 A GB 2176637 A GB 1459851 A
EP 0104886 A2

(58) Field of search
UK CL (Edition K) G4A AFMD, H4K KFF KTL KYX
INT CL^5 G06F 11/34, H04M 1/24 3/10 3/22

(54) **Recording error events particularly in radiotelephones**

(57) An error event is recorded by storing a counter value representing the number of times the error event has occurred and by storing a time related to the error event. In detail a method of recording an error event having one of a plurality of error types comprises determining a numeric error code related to the error type, in response to a trigger derived from the error event, calculating a memory location (133) correlated to the numeric error code, incrementing a counter value which represents the number of times the error type has occurred, and marking a time related to the error event. In a portable radiotelephone the counter value and the time marked are stored in a non-volatile memory location (133) so that an error history containing the frequency of an error type and the time of the latest occurence of the error type can be retrieved. The built in error record (133) assists diagnosis.

FIG.1



GB 2 252 475 A

1/3

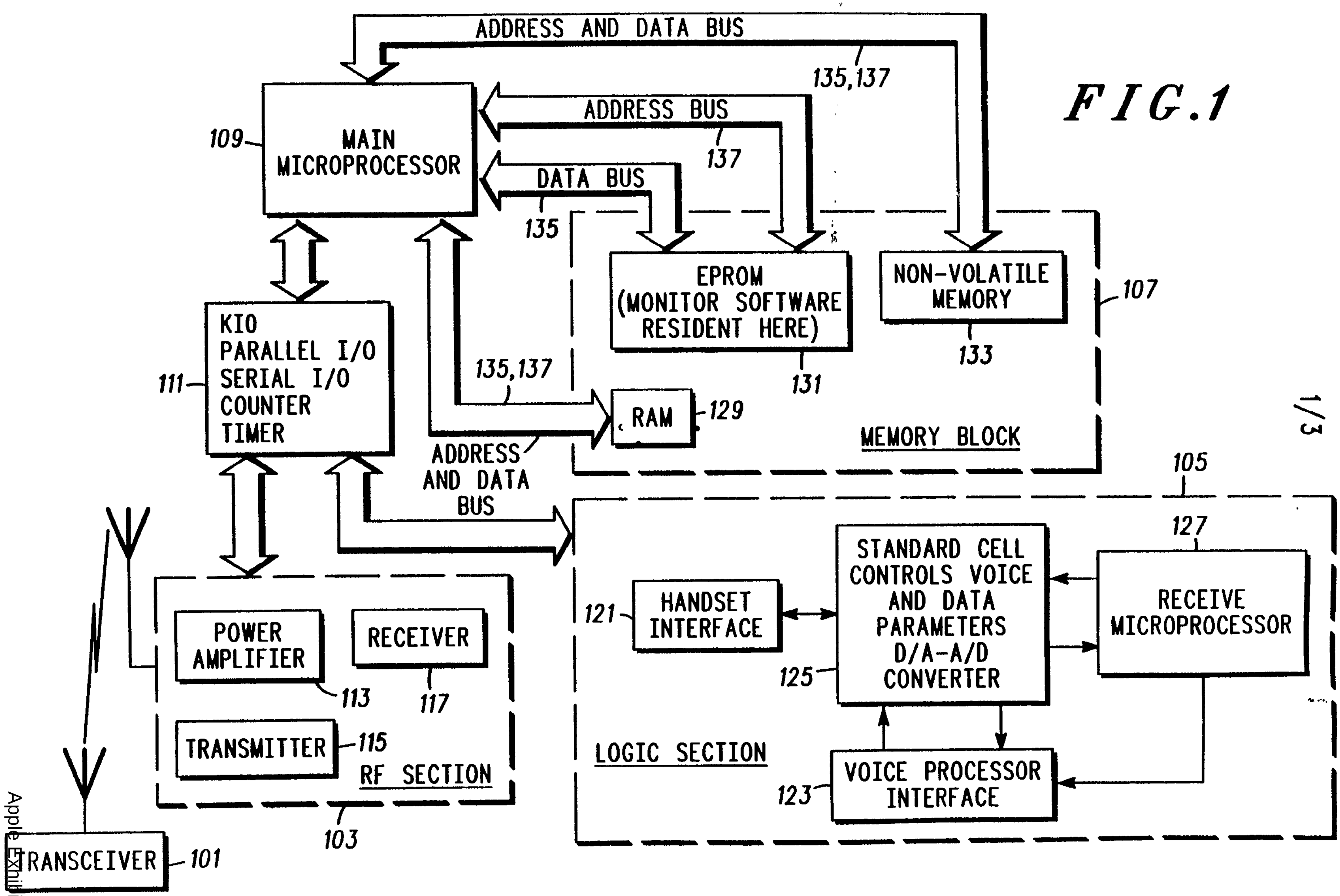

ADDRESS AND DATA BUS
135,137
ADDRESS BUS
137
DATA BUS
135
109
MAIN MICROPROCESSOR
EPROM (MONITOR SOFTWARE RESIDENT HERE)
131
NON-VOLATILE MEMORY
133
107
KIO
PARALLEL I/O
SERIAL I/O
COUNTER
TIMER
111
135,137
RAM
129
MEMORY BLOCK
ADDRESS AND DATA BUS
105
POWER AMPLIFIER
113
RECEIVER
117
TRANSMITTER
115
RF SECTION
103
HANDSET INTERFACE
121
STANDARD CELL CONTROLS VOICE AND DATA PARAMETERS D/A-A/D CONVERTER
125
RECEIVE MICROPROCESSOR
127
LOGIC SECTION
VOICE PROCESSOR INTERFACE
123
TRANSCEIVER
101

FIG.1

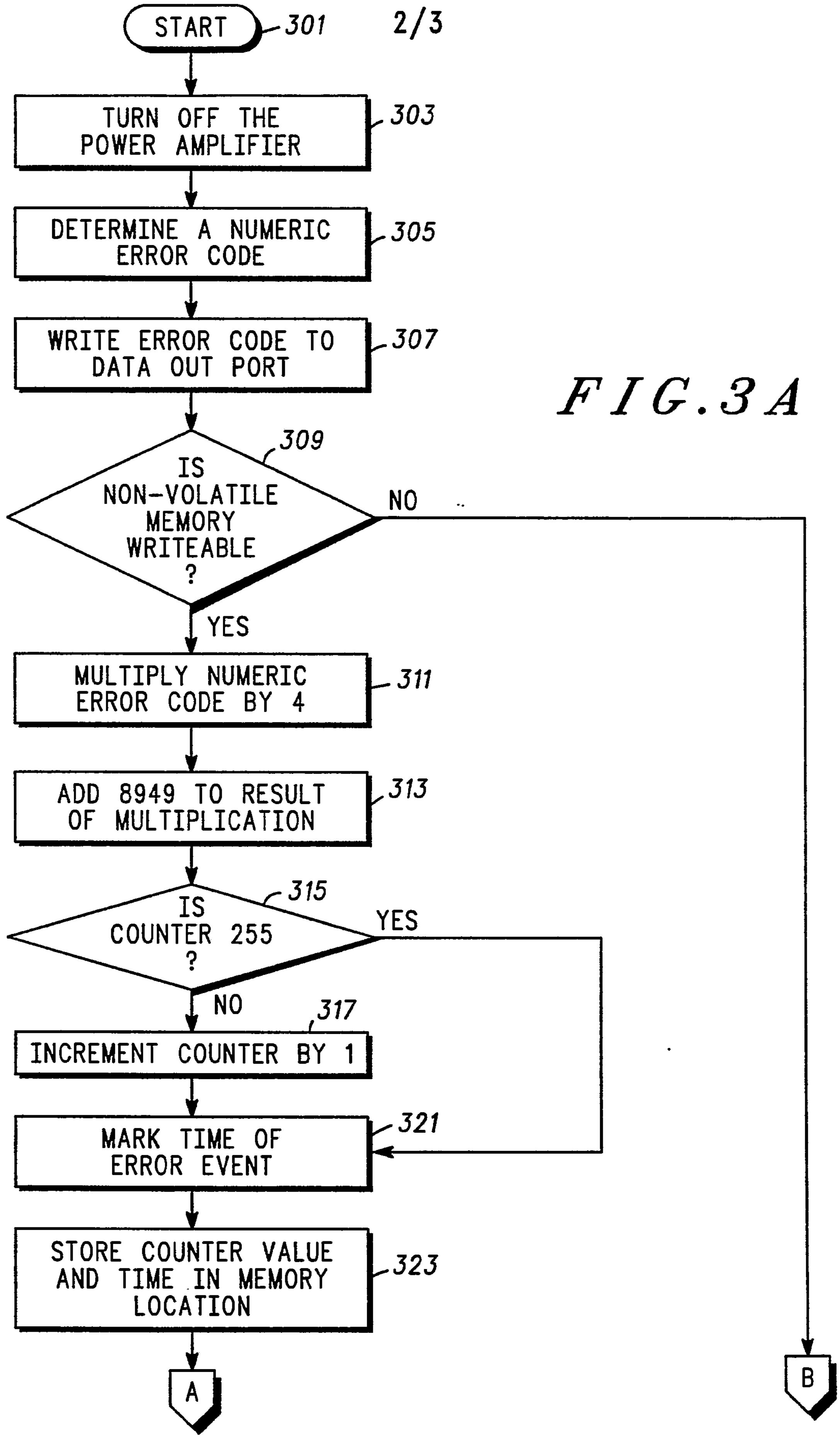

START
301
TURN OFF THE POWER AMPLIFIER
303
DETERMINE A NUMERIC ERROR CODE
305
WRITE ERROR CODE TO DATA OUT PORT
307
IS NON-VOLATILE MEMORY WRITEABLE ?
309
NO
YES
MULTIPLY NUMERIC ERROR CODE BY 4
311
ADD 8949 TO RESULT OF MULTIPLICATION
313
IS COUNTER 255 ?
315
YES
NO
INCREMENT COUNTER BY 1
317
MARK TIME OF ERROR EVENT
321
STORE COUNTER VALUE AND TIME IN MEMORY LOCATION
323
A
B

FIG.3A

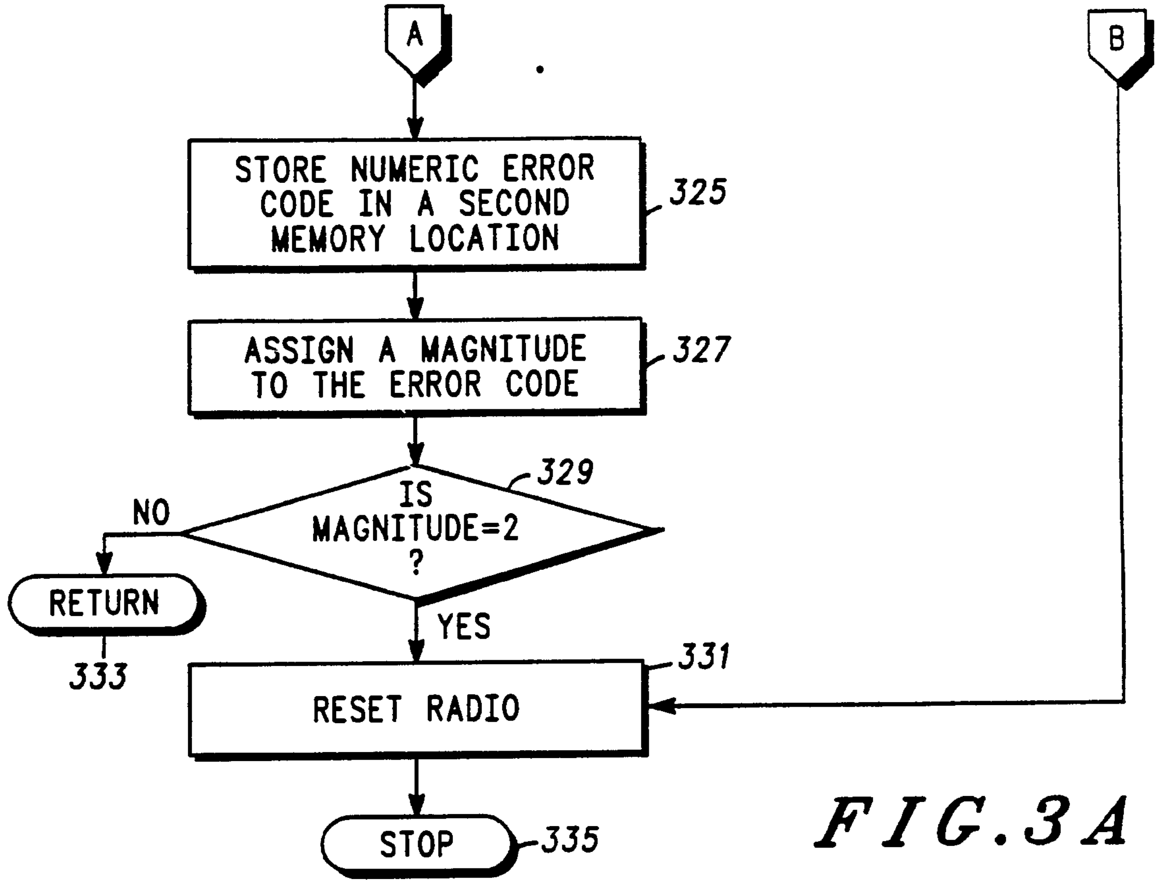
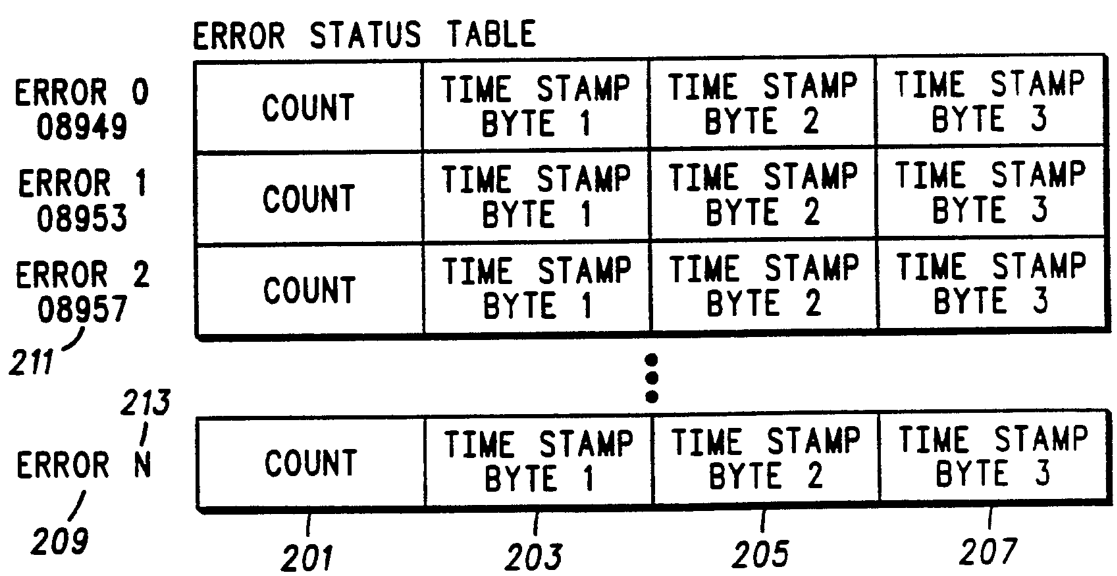

A
B
STORE NUMERIC ERROR CODE IN A SECOND MEMORY LOCATION
325
ASSIGN A MAGNITUDE TO THE ERROR CODE
327
IS MAGNITUDE=2 ?
329
NO
RETURN
333
YES
RESET RADIO
331
STOP
335

FIG. 3A

FIG. 2


ERROR STATUS TABLE
ERROR 0
08949
ERROR 1
08953
ERROR 2
08957
211
213
ERROR N
209
COUNT
TIME STAMP BYTE 1
TIME STAMP BYTE 2
TIME STAMP BYTE 3
201
203
205
207

Error Recording Method and Apparatus

Field of the Invention

This invention relates generally to data acquisition and more specifically to a method of and and an apparatus for data acquisition for use in diagnostics of mobile and portable radiotelephone equipment.

Background of the Invention

As electronic systems increase in complexity, they become more difficult for technicians to detect the cause of problems which may occur in the system. Therefore, there is a need for a comprehensive diagnostic system which includes a built-in error recording method and apparatus to assist the technicians in discovering problems.

Electronic systems typically contain a limited amount of diagnostic capability. There are two basic types of diagnostic systems. The first type of system has a large number of sensors in the system and can record a large amount of useful information, however, this system is usually external to the operational electronic system and only operates in the lab. It is very useful in making intelligent diagnoses of problems which occur in the testing environment. However, not all field problems can be reproduced in a testing environment, therefore, this system can not diagnose all of the problems which may exist.

The second type of diagnostic system is operable in the field. This system records only a limited amount of information, such as the latest type of error coded as a particular error code number. When the electronic system is returned to the laboratory because of a problem, the technician can access this error code. In a complex electronic system this error code, representing the latest type of error in time, is not always representative of the problem which had been occurring in the field. The technician has no way of knowing if this is the true problem and often spends hours tracking an incorrect problem.

Although these two diagnostic systems are well suited for their applications, when a complicated electronic system is returned to a technician frequently there is no communication between the user of the electronic system and the technician in the lab as to the problem which is occurring. This can be caused by language barriers as well as distance between the user and the technician. Therefore, there is a need for a comprehensible technique of automatically recording errors in the field so that the a technician can make a intelligent diagnosis of the problems which exist.

Summary of the Invention

The present invention encompasses a method of recording an error event having one of a plurality of error types, in response to a trigger derived from the error event. A numeric error code related to the error type is determined and in response to the trigger, a memory location correlated to the numeric error code is calculated. A counter value which represents the number of times the error type has occurred is incremented in response to the step of determining the numeric error code. A time related to the error event is marked. The counter value and the time is then stored in the memory location.

In one aspect the invention provides a method of recording an error event having one of a plurality of error types, in response to a trigger derived from the error event, the method comprising the steps of:

determining a numeric error code related to the error type;

calculating, in response to the trigger, a memory location correlated to said numeric error code;

incrementing a counter value which represents the number of times the error type has occurred and in response to said step of determining said numeric error code;

marking a time related to the error event; and storing said counter value and said time in said calculated memory location.

In another aspect, the invention provides a radiotelephone having a power amplifier, a non-volatile memory, a data output port and a microprocessor and an error event recorder responsive to a trigger derived from an error event having a plurality of error types, and including:

means for turning off, in response to the trigger, the power amplifier;

means for determining a numeric error code related to the error type;

means for multiplying said numeric error code by a first predetermined numeric value; and

means for adding a second predetermined numeric value to a result of said step of multiplying, thereby deriving a first location in the non-volatile memory.

means for incrementing a counter value which represents the number of times the error type has occurred and in response to said step of determing said numeric error code;

means for marking a time related to the error event; and

means for storing said counter value and said time in said first location in the non-volatile memory.

Brief Description of the Drawings

FIG. 1 is a block diagram of a radio frequency data transmission system which may utilize the current invention.

FIG. 2 is the format of data acquisition.

FIG. 3 is the process flow chart of acquiring and storing the data.

Description of a Preferred Embodiment

A radio telephone system conveying signals between a fixed site transceiver 101 and a portable transceiver 103 is shown in FIG. 1. The portable transceiver 103 is contained in a portable radiotelephone, such as model number TZ803 available from

Motorola, Inc.. The portable radiotelephone includes a logic section 105, a main microprocessor 109, a memory block 107 and killer input and output (KIO) controller 111, such as model number Z84C9008VEC available from Zilog.

The portable transceiver 103 is responsible for receiving and transmitting the signals between the fixed site transceiver 101 and the portable radiotelephone. The receiver 117 receives the signals from the fixed site transceiver 101 and distributes the received signals to the logic section 105. The main microprocessor 109 sends signals via the KIO controller 111 to the power amplifier 113, the power amplifier 113 amplifies the signals allowing the transmitter 115 to transmit to the fixed site transceiver 101.

The main microprocessor 109 is responsible for controlling the data paths of the receive signals and monitoring the portable radiotelephone for errors. Upon receiving signals from the transceiver 103, the KIO controller 111 transmits the received signals to the logic section 105. Within the logic section 105 a standard cell application specific integrated circuit (ASIC) 125 controls the voice and data parameters and also contains digital to analog converters and analog to digital converters for control signals to and from the power amplifier 113. The receive microprocessor 127, such as a model number 6805 available from Motorola, Inc., detects the received voice signals and data signals, transmitting the voice signals to the optional voice processor 123 and the data signals to the main processor 109. The optional voice processor interface block 123 is responsible for scrambling and unscrambling the voice signals for privacy. Then the voice signals are transferred to the handset interface 121. The handset interface 121 transfers the voice signals to the user of the portable radiotelephone. The handset interface 121 also receives voice signals from the user. This voice signals are transferred to the optional voice processor 123 for scrambling. These signals are transferred into the standard cell ASIC 125 which converts the voice signals to analog signals. The analog signals are sent back to the power amplifier 113 and the transmitter 115 for transmission back to the fixed site transceiver 101.

In the memory block 107 there is an EPROM 131 which contains call processing and error monitoring software. The error monitoring software is used by the main processor 109 to monitor the conditions and check for errors of the memory block 107, the logic section 105, the portable transceiver 103, the parallel and serial ports, the counters and the timers contained in the KIO 111. Upon finding an occurrence of an error event the monitoring software jumps to an error recording routine and stores the errors in the non-volatile memory 133 according to the method included in the invention .

The error recording routine stores related information in the non-volatile memory 133 according to the form described in FIG. 2. In the preferred embodiment, there are fifty-six error types which are checked by the monitoring software. Each error type has a distinct address location in the non-volatile memory 133. At each distinct location there are four bytes of information stored. The first byte 201 contains an 8 bit counter which represents the number of occurrences of this type of error up to a value of two-hundred-fifty-five occurrences. The next three bytes of information 203, 205, 207 contain a time stamp representing the time at which the last error type has occurred. The binary numbers stored in these three bytes 203, 205, 207 represent the number of minutes of operation of the portable radiotelephone since its release from the factory. The third byte 207 contains the most significant byte and the first byte 203 contains the least significant byte.

FIG. 3 is a process flow chart of the error recording routine which is activated after an error event has been found by the main monitoring routine. The first step of the routine 303 turns off the power amplifier to eliminate any possibility of undesired or improper transmissions. The second step 305 determines a numeric error code related to the error type. Next, the error code is written out serially to a data line which can be externally monitored at 307. This is done for testing purposes in the lab when the non-volatile memory 133 is not operational. Next, in block 309 the non-volatile memory 133 is checked to see if it is operational. If the non-volatile memory 133 is not operational then the radiotelephone is reset at 331 and the process is stopped at 335. If the non-volatile memory 133 is operational an address correlated to the error code is created for a location in the non-volatile memory 133. The first step in creating this address is to multiply the numeric error code by four at 311. The next step is to add the base address of 8949 to the result of the previous multiplication at 313. This multiplication and addition forms the non-volatile memory location address. Next, the value of the counter in byte 201 is compared to two-hundred-fifty-five at 315. This comparison is done to avoid incrementing the counter in byte 201 to zero, since two-hundred-fifty-five is the highest value which an eight bit counter can count. If the counter of byte 201 is equal to two-hundred-fifty-five, then the counter value is not changed. If the counter value is less than two-hundred-fifty-five, then it is incremented by one at 317. The counter value represents the number of times the error type determined at 305 has occurred. The time at which the error event occurred is marked at 321. Both the counter value and the marked time of the error are stored in the calculated memory location at 323. The numeric error code is stored in a second memory location which contains the latest error type at 325. Next, the type of error is assigned a magnitude at 327 by using the numeric error code as a pointer in a look-up table which contains the appropriate magnitude for the error. Then, the magnitude is compared at 329 to the number two. If the magnitude is less than two, the error is considered non-fatal and the program jumps to the main monitoring program and the operation of the radiotelephone is uninterrupted at 333. If the magnitude of the error is determined to be greater than two, the error is considered fatal and the entire radiotelephone is reset at 331.

The fifty-six addresses which are correlated to the error code form a table in the non-volatile memory 133. This table of the errors, containing the error type, the most current time of an occurence of the error type, and the number of occurrences of this error type, is available through the handset interface 121.

Claims

1. A method of recording an error event having one of a plurality of error types, in response to a trigger derived from the error event, the method comprising the steps of:

determining a numeric error code related to the error type;

calculating, in response to the trigger, a memory location correlated to said numeric error code;

incrementing a counter value which represents the number of times the error type has occurred and in response to said step of determining said numeric error code;

marking a time related to the error event; and

storing said counter value and said time in said calculated memory location.

2. A method of recording an error event in accordance with claim 1 further comprising the step of storing the error type in a second memory location.

3. A method of recording an error event in accordance with claim 1 further comprising the steps of:

assigning, in response to said step of storing, a magnitude to said error type; and

selecting a reset if said magnitude of said error type exceeds a predetermined magnitude.

4. A method of recording an error event in accordance with claim 3 further comprising the step of returning to a main program if said predetermined magnitude exceeds said magnitude of said error type.

5. A method of recording an error event as claimed in any preceding claim, in a radiotelephone having a power amplifier, a non-volatile memory, a data output port and a microprocessor, in response to a trigger derived from the error event, the method comprising:

turning off, in response to the trigger, the power amplifier;

determining a numeric error code related to the error type;

multiplying said numeric error code by a first predetermined numeric value; and

adding a second predetermined numeric value to a result of said step of multiplying, thereby deriving a first location in the non-volatile memory.

6. A method of recording an error event in accordance with claim 5 further comprising the step of writing, in response to the trigger, said numeric error code to the data output port.

7. A method of recording an error event in accordance with claim 5 further comprising the steps of:

determining, in response to the trigger, if the non-volatile memory will accept data; and

stopping, in response to a determination of no acceptance of data, the recording of the error event.

8. A radiotelephone having a power amplifier, a non-volatile memory, a data output port and a microprocessor and an error event recorder responsive to a trigger derived from an error event having a plurality of error types, and including:

means for turning off, in response to the trigger, the power amplifier;

means for determining a numeric error code related to the error type;

means for multiplying said numeric error code by a first predetermined numeric value; and

means for adding a second predetermined numeric value to a result of said step of multiplying, thereby deriving a first location in the non-volatile memory.

means for incrementing a counter value which represents the number of times the error type has occurred and in response to said step of determing said numeric error code;

means for marking a time related to the error event; and means for storing said counter value and said time in said first location in the non-volatile memory.

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Documents considered relevant following a search in respect of claims 1 TO 8

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
A,E	GB 2246649 A (GRANADA), Note page 4 lines 13-21	
A	GB 2176637 A (SONY), Note page 2 lines 6 to 19	
X	GB 1459851 (XEROX), Note page 11 line 38 to page 12 line 6	1
X	EP 0104886 A2 (XEROX), Note page 2 lines 1-12	1

Category	Identity of document and relevant passages	Relevant to claim(s)

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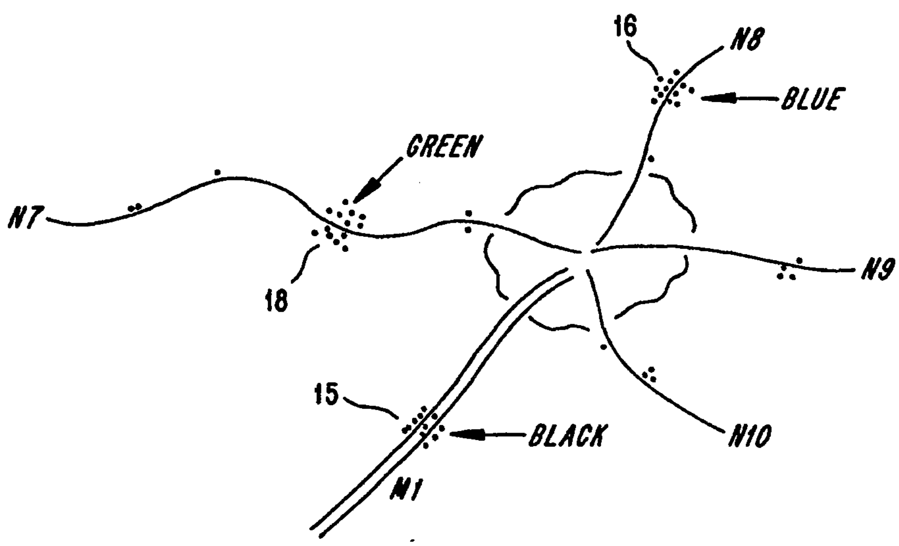

(57) Abstract

A method and system for automatically mapping areas of poor network coverage or high interference in a cellular network uses signal quality measures and mobile station location information. The system constructs a visual map that notes the locations of mobile stations when unacceptable base station–mobile station signal quality is reported. The visual map can be used for identifying areas of the network that may require remediation to ensure sufficient network coverage.

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Use of Mobile Locating and Power Control for Radio Network Optimization

BACKGROUND

The present invention is directed generally to radiocommunication systems and, more particularly, to techniques for identifying and mapping areas of poor signal quality in a CDMA radiocommunication system.

A mobile phone network conventionally consists of a plurality of base stations arranged in a pattern so as to define a plurality of overlapping cells which provide radiocommunication support in a geographic area. Base stations in the network are located so as to provide optimal coverage of the mobile phone service area. The transmission pattern of a geographic arrangement of network base stations typically looks like a honeycomb of cells. Each base station with omnidirectional transmission in the network serves a roughly circular area with a diameter ranging from a few hundred meters to several kilometers depending on population density. Additionally, base stations may have adaptive antennas that cover only narrow sectors, thus producing “sectored” cells instead of circular cells. The mobile phone network typically only has a specified number of frequencies available for use by mobile subscribers. Therefore, to maximize use of the specified number of frequencies while preventing interference between adjacent base stations, each base station supports different frequencies than its corresponding adjacent base stations. When a mobile subscriber moves to the edge of a cell associated with a current servicing base station the mobile subscriber can be "handed-off" to an adjacent base station so as to enable call quality and signal strength to be maintained at a predetermined level.

Traditionally, radio communication systems have employed either Frequency Division Multiple Access (FDMA) or Time Division Multiple Access (TDMA) to allocate access to available radio spectrum. Both methods attempt to ensure that no two potentially interfering signals occupy the same frequency at the same time. For example, FDMA assigns different signals to different frequencies. TDMA assigns different signals to different timeslots on the same frequencies. TDMA methods reduce adjacent channel interference through the use of synchronization circuitry which gates the reception of information to prescribed time intervals.

In contrast, Code Division Multiple Access (CDMA) systems allow interfering signals to share the same frequency at the same time. More specifically, CDMA systems "spread" signals across a common communication carrier by multiplying each signal with a unique spreading code sequence. The signals are then scrambled and transmitted on the common carrier in overlapping fashion as a composite signal. Each mobile receiver correlates the composite signal with a respective unique despreading code sequence, and thereby extracts the signal addressed to it.

The signals which are not addressed to a mobile receiver in CDMA assume the role of interference. To achieve reliable reception of a signal, the bit energy to interference ratio (Eb/Io) should be above a prescribed threshold for each mobile station. The bit energy of the signal is therefore adjusted to maintain the appropriate Eb/Io threshold level. However, increasing the energy associated with one mobile station increases the interference associated with other nearby mobile stations. As such, the radio communication system must strike a balance between the requirements of all mobile stations sharing the same common carrier. A steady state condition is reached when the Eb/Io requirements for all mobile stations within a given radio communication system are satisfied. Generally speaking, the balanced steady state may be achieved by transmitting to each mobile station using power levels which are neither too high nor too low. Transmitting messages at unnecessarily high levels raises interference experienced at each mobile receiver, and limits the number of signals which may be successfully communicated on the common channel (e.g. reduces system capacity).

In a conventional CDMA system such as, for example, a CDMA system using the IS-95 standard, power control commands are transmitted from the base station to a mobile station so that a constant bit energy to interference ratio is maintained for each received signal at the base station. To accomplish this reverse link power control, the base station sends a power control bit 800 times a second over the forward fundamental channel to the mobile station. This power control bit informs the mobile station whether the mobile station should raise or lower its transmission power level so as to maintain a constant Eb/Io at the base station. A transmitted power control bit with a value of 0 indicates that the mobile station should raise power. A transmitted power control bit with a value of 1 indicates that the mobile station should lower power. In response to the transmitted power control bit, the mobile station adjusts the transmission power by 1db increments on the reverse link. The base station then measures the Eb/Io ratio of the power adjusted reverse link signal and repeats the above process in an iterative fashion until the Eb/Io ratio reaches the specified level.

Measurement of the Eb/Io ratio provides an indication of either poor network coverage or high network interference conditions in a CDMA system. If poor network coverage exists at a given location of a mobile station then bit energy Eb will decrease (Io will not change if the number of users remains the same) and thus the Eb/Io ratio will likely decrease. Furthermore, if high interference exists at a given location, the interference Io will increase and thus the Eb/Io ratio will likely decrease. An increase in the interference Io generally implies that the number of mobiles has increased, since Io is composed of the normalized interference from mobile stations in the same cell, the interference from mobile stations in adjacent cells, and the background noise. The component of the interference due to same cell mobile stations will generally predominate.

Poor network coverage can occur due to a number of conditions including poor network planning, localized terrain features, shadowing due to obstacles (e.g., buildings, trees) in the path of the mobile station-base station connection, and "holes" in network coverage due to the phenomenon of "cell breathing." "Cell breathing" occurs when a mobile on the edge of a cell transmits close to its maximum power to overcome interference from other mobiles in the cell and to communicate with the base station. When new mobiles enter the cell and are allocated a channel they will raise the overall interference level. Thus, the mobile station at the cell edge will have to raise its power further to maintain the required signal to interference ratio at the base station. However, due to maximum power limitations, the mobile station at the cell edge is unable to raise its power any further. Thus, mobiles in this situation are either handed off to another cell or another frequency or the call is dropped. The net effect of this process is that the cell border effectively shrinks. This cell shrinking due to high load can cause coverage holes between cells.

High interference conditions can occur when there are a large number of users in a cell in a CDMA network. These large number of users produce an unstable state where any single user must increase power to overcome interference from surrounding users. The increase in power of any single user causes an increase in the overall level of interference, which further causes other users to also raise their power. This process can result in a rapidly escalating state of congestion. High interference conditions can be managed by the network by balancing the requirements of all mobile stations sharing the same common channel, as already discussed above. However, high data rate services that require the transmission of bursty packets of data over the air can cause localized interference conditions that cannot be adequately managed by the network.

Often, as noted above, high interference or poor coverage conditions can persist in certain localities of a CDMA network in-spite of the use of power control commands. These areas of persistent poor coverage or high interference can impair the quality of the mobile subscriber signal and also impair the ability of the network to avoid call dropping. In areas where poor coverage or high interference conditions exist, the quality of the phone signal will likely be degraded. Furthermore, in geographic areas of poor coverage or very high interference, the potential for call dropping exists.

Conventionally, network coverage and interference conditions are monitored through the performance of drive tests by network operator staff. To perform this monitoring, operator staff drive throughout the network and conduct and record call quality checks. This conventional monitoring technique, however, requires an inordinate amount of resources to survey the network. Such resources include extra monitoring equipment, extra staff to conduct the drive tests, and additional staff time to drive around and survey the network. Furthermore, the time delay between the actual time at which interference in a locality increases to a level that will have an adverse impact on call quality or system performance and the time taken to survey the network, tabulate the results, and implement changes in the network coverage, ensures a period of degraded performance to affected mobile subscribers.

Accordingly, it would be desirable to provide a technique for monitoring a cellular network that minimizes the time required to detect areas of poor network coverage or high interference and which further minimizes the necessity of operator intervention.

SUMMARY

These desirable characteristics and others are provided by the following exemplary embodiments of the invention.

According to one exemplary embodiment of the invention a method of constructing a data representation indicating a signal quality associated with a location of a mobile station in a radiocommunications network is provided. The method of this exemplary embodiment comprises the steps of: selectively adjusting uplink or downlink transmission power between said mobile station and said network using power control parameters; providing a location of said mobile station based on at least said power control parameters; selectively constructing a data representation indicating signal quality using said provided location and at least said power control parameters.

According to a second exemplary embodiment of the present invention a method of constructing a map of signal qualities associated with locations of mobile stations in a radiocommunications network is provided. The method of this exemplary embodiment comprises the steps of: a) selectively adjusting uplink or downlink transmission power between said mobile stations and said network using power control parameters; b) providing locations of each of said mobile stations based on at least said power control parameters; c) constructing data representations indicating said signal qualities using said provided locations of each of said mobile stations and at least said power control parameters; and d) selectively repeating steps a) through c) to construct a map of signal qualities throughout at least a portion of said network.

According to a third exemplary embodiment of the present invention a method of constructing a map of signal qualities associated with locations of mobile stations in a radiocommunications network is provided. The method of this exemplary embodiment comprises the steps of: a) providing at least one parameter indicative of a signal quality associated with a location of a mobile station, wherein said at least one parameter includes transmission power control parameters; b) comparing said at least one parameter with at least one criteria to provide a comparison result; c) initiating a positioning request from said network based on said comparison result; d) providing a location of said mobile station based on said positioning request; e) constructing a data representation indicating said signal quality using said at least one criteria and said location; and f) selectively repeating steps a) through e) to construct a map of signal qualities throughout at least a portion of said network.

BRIEF DESCRIPTION OF THE DRAWINGS

The objects and advantages of the invention will be understood by reading the following detailed description in conjunction with the drawings in which:

FIG. 1 represents an exemplary implementation of an apparatus for a cellular communications system according to the present invention;

FIG. 2 shows a diagram of a cellular system operating in accordance with exemplary embodiments of the present invention;

FIG. 3 shows a flow diagram of exemplary method steps of the present invention; and

FIG. 4 shows a network map indicating areas of deficient signal quality according to exemplary embodiments of the invention.

DETAILED DESCRIPTION

To provide some context within which to describe the present invention consider Figure 1, which represents a block diagram of an exemplary cellular mobile radiotelephone system, including an exemplary base station 110 and mobile station 120. The base station includes a control and processing unit 130 which is connected to the MSC 140 which in turn is connected to the PSTN (not shown). General aspects of the cellular radiotelephone system shown in Figure 1 are known in the art.

The base station 110 handles a plurality of traffic channels through a traffic channel transceiver 150, which is controlled by the control and processing unit 130. Also, each base station includes a pilot channel transceiver 160 for broadcasting pilot signals to mobile stations 120 in the network.

The mobile station 120 scans for pilot channels from one or more base stations using its traffic and pilot channel transceiver 170. Then, the processing unit 180 evaluates the received pilot signals to determine which base station is a suitable candidate to serve the mobile station 120. When the processing unit 180 selects the base station associated with the preferred pilot channel, the mobile station 120 demodulates the transmitted paging channel from that base station and then receives system parameter information from that base station.

In accordance with an exemplary embodiment of the invention, shown in Figure 1, mobile station position update information can be provided by the base station control and processing unit 130. This position update information can be calculated in any desired manner. For example, the position can be derived from a GPS receiver

220 located in the mobile station receiver 120. One skilled in the art will recognize, however, that various techniques for determining the location of a mobile station are known in the art, such as, for example, the technique disclosed in European Patent Application EP 0800319A1. If GPS is used to report the mobile station location, the mobile station can transmit position update information ("mobile position report") to the base station 110 in a regular periodic message that is either periodically transmitted or transmitted based on a positioning request from the network. In other positioning methods, however, the actual positioning determination is performed by the network and thus no position data needs to be transmitted over the air interface.

In exemplary embodiments of the invention, the position update information provided at the base station 110 is used in conjunction with the power control commands transmitted to the mobile station 120 to determine signal quality conditions. First, one or more interference determining algorithms are set in the operations and maintenance center (OMC) 1 shown in Figure 2. As described below in more detail, different algorithms can be used to identify signal quality conditions on the network map. The parameters for the different algorithms are then sent 2 to the prescribed base station controllers (BSC) 3 to be implemented within a supervisory functionality that is incorporated into each BSC. One skilled in the art will recognize, however, that the supervisory functionality could be incorporated into the processor of the mobile switching center (MSC) or a network node separate from either the BSC or the MSC.

As illustrated in the flow diagram of Figure 3, the BSC supervisory functionality (SF) first logs 4 the power control commands issued to mobile stations. Then, based on the power control commands or constant measurements of uplink power, the SF determines 5 the uplink power of the mobile stations. Subsequently, the SF determines signal quality conditions using a number of algorithms, as discussed further below, so as to invoke a positioning function that determines the mobile station's geographic position 6. The positioning function then requests the identity and location of the associated mobile station. In response to this request, the mobile station transmits location information (7, Fig. 2) to the BSC, in an exemplary embodiment wherein the mobile station includes a GPS receiver or some other locating mechanism. Alternatively, if the locating function 6 is performed by network components, then the positioning function requests the mobile station's current position from the system.

In the algorithm of one exemplary embodiment, an interference or poor coverage condition is identified by determining those mobile stations that are operating within a certain percentage of their transmission power ceilings 8. This could include operation at the mobile station's power ceiling. This operating status is indicative of an interference condition, a cell border, or a coverage hole, since the mobile station is likely to have been driven into a high power state due to the issuance of power control commands from the base station in attempts to overcome high interference conditions or poor coverage conditions.

In the algorithm of another exemplary embodiment, an interference or poor coverage condition is identified by analyzing the trend of the power transmission curve associated with each mobile station over time 9. When the slope of the power transmission curve is high, a large fluctuation in power is indicated which can correspond to increased interference. Therefore, the SF can calculate the slope of the power transmission curve over the current time interval and compare this to a specified threshold:

$$\frac{\Delta P}{\Delta t}(t = t_{\cup\odot\oplus\oplus\supset\sphericalangle\ominus}) \geq t_{\ni}$$

When the calculated slope of the power transmission curve exceeds the specified threshold value 10, the base station controller invokes the positioning function 6 to determine the mobile station's geographic position.

In the algorithm of an additional exemplary embodiment, the SF logs the signal interference level, measured at the base station, to produce an interference curve that permits discrimination between different signal quality conditions when the interference curve is compared with the power control curve. Using the slope of the logged interference curve and the slope of the power control curve, the SF can distinguish between low network coverage or high interference conditions. Under poor/low network coverage conditions the slope of the power control curve will decrease and the slope of the interference curve will maintain a substantially constant level (equivalent to $Eb\downarrow /Io\rightarrow =Eb/Io\downarrow$). Under high interference conditions the slope of the interference curve will increase while the slope of the power control curve will maintain a substantially constant level (equivalent to $Eb\rightarrow /Io\uparrow =Eb/Io\downarrow$). Under indeterminate poor signal quality conditions, the slope of the power control curve will decrease simultaneously with an increase in the slope of the interference curve (equivalent to $Eb\downarrow /Io\uparrow =Eb/Io\downarrow$).

In the algorithm of this exemplary embodiment, the SF distinguishes between poor coverage and high interference conditions by calculating the slope of the power control curve ($\Delta P/\Delta t$) and the slope of the interference curve ($\Delta Io/\Delta t$). These calculated slopes are then compared with a number of defined threshold values as shown in Figure 3. If the slope of the power control curve is decreasing at a rate greater than a defined threshold

($\Delta P/\Delta t<-t_{h3}$) and the slope of the interference curve is maintaining a substantially constant level ($|\Delta Io/\Delta t| <t_{h4}$) 20, then a low or poor coverage condition is indicated at the position of the mobile station. If the slope of the power control curve is maintaining a substantially constant level ($|\Delta P/\Delta t| <t_{h6}$), but the slope of the interference curve is increasing at a rate greater than a defined threshold ($\Delta Io/\Delta t>t_{h5}$) 21, then a high interference condition is indicated at the position of the mobile station. Also, if the slope of the power control curve decreases at a rate greater than a defined threshold ($\Delta P/\Delta t<-t_{h7}$) and the slope of the interference curve increases at a rate greater than a defined threshold ($\Delta Io/\Delta t >t_{h8}$) 22, then a poor signal quality condition of indeterminate cause exists. This indeterminate condition may either indicate low/poor network coverage or high interference. When poor coverage, high interference, or indeterminate poor signal quality conditions are indicated by the algorithm of this exemplary embodiment, the base station controller invokes the positioning function 6 to determine the mobile station's geographic location.

It is noted that the numerous comparisons of the interference curve slope ($\Delta Io/\Delta t$) with corresponding threshold values, discussed above and shown in Figure 3 at steps 20, 21, and 22, could each be replaced with, or used in combination with, an additional comparison between the interference level (Io) and corresponding thresholds. For example, the criterion $\Delta Io/\Delta t>t_{h5}$, shown in step 21 of Figure 3, could be replaced with an interference-to-threshold comparison $Io>t_{h9}$. $Io>t_{h9}$ could also be used as an additional criterion in combination with $\Delta Io/\Delta t>t_{h5}$. Use of an interference level criterion would thus provide an additional indicator of high interference in steps 20, 21, and 22 shown in Figure 3.

In an algorithm of a further exemplary embodiment, the SF analyzes the frame error rate of the uplink signal from the mobile station 11. In IS-95, for example, reverse link frames are sent every 20ms over the reverse fundamental channel. If the measured FER of these frames exceeds a specified threshold ($FER>t_{h2}$) 12 for a particular period of time, the SF will invoke the location function 6.

The different algorithms for determining signal quality conditions, discussed above, can be combined for use in an additional embodiment. This additional embodiment can make use of two or more of the signal quality measures shown in Figure 3 (8, 9, 11, 20, 21, or 22) to determine an overall signal quality value. For example, the positioning function could be invoked when the mobile station is transmitting within X% of its power ceiling <u>and</u> when the slope of the power transmission curve for that mobile is greater than a specified threshold. As an additional example, the positioning function could be invoked when the mobile station is transmitting within X% of its power ceiling <u>and</u> when the reverse link FER exceeds a specified threshold. One skilled in the art will recognize that any number of interference measures could be combined in one or more algorithms to determine the existence of poor signal quality conditions and, subsequently, determining the geographic position of the mobile station experiencing the poor signal quality condition.

After the positioning function determines the mobile station location, the BSC (3, Fig. 2) compiles the mobile station identification, signal quality measures, cell identification, and mobile station location information and transmits the information to the OMC (13, Fig. 2). A processor at the OMC operates upon the received data to construct a data representation 14 that indicates the signal quality measure and the associated mobile station location. This data representation can include translations of the different signal quality measures into different colored visual representations 17. For example, a FER greater than a first threshold could be represented as a green pixel or dot. Additionally, a FER greater than a second, higher threshold could be represented as a blue pixel or dot to indicate greater signal degradation. Over a period of time, a series of dots will accumulate in an area that is inadequately covered by the network. As the geographic illustration in Figure 4 shows, an accumulation of green dots 18 or blue dots 16 will clearly indicate areas of low or high signal quality. This application of color coding to provide a visual representation of signal quality could analogously be applied to any of the signal quality measures discussed above. Furthermore, the technique of color coding could be used to show the interference conditions encountered by the mobile station as the mobile station traverses the network map. Thus, using this technique, only one pixel would be associated with a given mobile station and the pixel would move on the visual representation of the network map as the mobile station moves, and may or may not change color, depending on the signal quality affecting conditions that are encountered.

The above exemplary embodiments all involve the reverse link from the mobile station to the base station. However, one skilled in the art will recognize that information on the forward link power control can also be used in a similar fashion to enable the mobile stations to raise or lower the power of the serving base station. This forward link power control is achieved by the mobile station informing the base station to adjust its power to maintain a specified FER on the forward channel received at the mobile station. Conventionally, this is accomplished using layer 3 commands that are not transmitted as often as specific power control commands (at present layer 3 power control messages are sent approximately a maximum of four times a second). Forward link power control using error indicator bits in the reverse link sent once every 20ms frame, has a maximum rate of 50Hz. However, in third generation systems, such as WCDMA or CDMA2000, fast power control on the forward link is anticipated.

Exemplary embodiments of the invention thus provide desirable techniques for automatically mapping areas of poor signal quality in a cellular network. Using mobile station positioning information, a visual map can be constructed for viewing in the operations and maintenance center that permits real time identification of areas of poor signal quality in the network that may require remediation. These techniques are advantageous in that they require minimal loading on current systems (i.e., provision of mobile station location data) and permit a reduction in resources and man-hours that were previously required to manually survey the network.

Although a number of embodiments are described herein for purposes of illustration, these embodiments are not meant to be limiting. Those skilled in the art will recognize modifications that can be made in the illustrated embodiment. Such modifications are meant to be covered by the spirit and scope of the appended claims.

What is Claimed is:

1. A method of constructing a data representation indicating a signal quality associated with a location of a mobile station in a radiocommunications network, comprising the steps of:

selectively adjusting uplink or downlink transmission power between said mobile station and said network using power control parameters;

providing a location of said mobile station based on at least said power control parameters; and

selectively constructing a data representation indicating said signal quality using said provided location and at least said power control parameters.

2. The method of claim 1, wherein said data representation is coded with a value derived from at least said power control parameters.

3. The method of claim 2, wherein said coded value represents color.

4. The method of claim 1, wherein said power control parameters indicate that said mobile station is transmitting within a percentage of a maximum power of said mobile station.

5. The method of claim 1, wherein said power control parameters indicate that said network is transmitting within a percentage of a specified maximum power.

6. The method of claim 1, wherein said mobile station location is provided based on one or more specified trends in said power control parameters.

7. The method of claim 1, wherein said location of said mobile station is provided based additionally on a forward link frame error rate associated with said mobile station.

8. The method of claim 1, wherein said location of said mobile station is provided additionally based on a reverse link frame error rate associated with said mobile station.

9. The method of claim 1, wherein said signal quality indicates poor network coverage.

10. The method of claim 1, wherein said signal quality indicates high signal interference.

11. The method of claim 1, wherein said mobile station location is provided based on one or more specified trends in said power control parameters and one or more trends in measured interference levels associated with said uplink or downlink.

12. A system for constructing a data representation indicating a signal quality associated with a location of a mobile station in a radiocommunications network comprising:

means for selectively adjusting uplink or downlink transmission power between said mobile station and said network using power control parameters;

means for providing a location of said mobile station based on at least said power control parameters; and

means for selectively constructing a data representation indicating said signal quality using said provided location and at least said power control parameters.

13. The system of claim 12, wherein said data representation is coded with a value derived from at least said power control parameters.

14. The system of claim 13, wherein said coded value represents color.

15. The system of claim 12, wherein said power control parameters indicate that said mobile station is transmitting within a percentage of a maximum power of said mobile station.

16. The system of claim 12, wherein said power control parameters indicate that said network is transmitting within a percentage of a specified maximum power.

17. The system of claim 12, wherein said mobile station location is provided based on one or more specified trends in said power control parameters.

18. The system of claim 12, wherein said location of said mobile station is provided based additionally on a forward link frame error rate associated with said mobile station.

19. The system of claim 12, wherein said location of said mobile station is provided additionally based on a reverse link frame error rate associated with said mobile station.

20. The system of claim 12, wherein said signal quality indicates poor network coverage.

21. The system of claim 12, wherein said signal quality indicates high signal interference.

22. The system of claim 12, wherein said mobile station location is provided based on one or more specified trends in said power control parameters and one or more trends in measured interference levels associated with said uplink or downlink.

23. A method of constructing a map of signal qualities associated with locations of mobile stations in a radiocommunications network comprising the steps of:

a) selectively adjusting uplink or downlink transmission power between said mobile stations and said network using power control parameters;

b) providing locations of each of said mobile stations based on at least said power control parameters;

c) constructing data representations indicating said signal qualities using said provided locations of each of said mobile stations and at least said power control parameters; and

d) selectively repeating steps a) through c) to construct a map of signal qualities throughout at least a portion of said network.

24. A method of constructing a data representation indicating a signal quality associated with a location of a mobile station in a radiocommunications network, comprising the steps of:

providing at least one parameter indicative of a signal quality associated with said location of said mobile station, wherein said at least one parameter includes transmission power control parameters;

comparing said at least one parameter with at least one criteria to provide a comparison result;

initiating a positioning request from said network based on said comparison result;

providing a location of said mobile station based on said positioning request; and

constructing a data representation indicating said signal quality using said at least one criteria and said location.

25. The method of claim 24, wherein said power control parameters control reverse link transmission power.

26. The method of claim 24, wherein said power control parameters control forward link transmission power.

27. The method of claim 24, wherein said comparison result indicates a trend of said power control parameters.

28. The method of claim 27, wherein said positioning request is initiated when said comparison result indicates one or more specified trends in said power control command parameters.

29. The method of claim 24, wherein said at least one parameter includes a forward link frame error rate.

30. The method of claim 24, wherein said at least one parameter includes a reverse link frame error rate.

31. The method of claim 24, wherein said comparison result indicates that said mobile station is transmitting within a percentage of a maximum power of said mobile station.

32. The method of claim 24, wherein said data representation is coded with a value derived from said comparison result.

33. The method of claim 32, wherein said coded value represents color.

34. The method of claim 24, wherein said signal quality indicates poor network coverage.

35. The method of claim 24, wherein said signal quality indicates high signal interference.

36. The method of claim 24, wherein said mobile station location is provided based on one or more specified trends in said power control parameters and one or more trends in measured interference levels associated with said uplink or downlink.

37. A method of constructing a map of signal qualities associated with locations of mobile stations in a radiocommunications network comprising the steps of:

a) providing at least one parameter indicative of a signal quality associated with a location of a mobile station, wherein said at least one parameter includes transmission power control parameters;

b) comparing said at least one parameter with at least one criteria to provide a comparison result;

c) initiating a positioning request from said network based on said comparison result;

d) providing a location of said mobile station based on said positioning request;

e) constructing a data representation indicating said signal quality using said at least one criteria and said location; and

f) selectively repeating steps a) through e) to construct a map of signal qualities throughout at least a portion of said network.

38. A method of constructing a map of signal qualities associated with locations of mobile stations in a radiocommunications network comprising the steps of:

a) selectively adjusting uplink or downlink transmission power between said mobile stations and said network using power control parameters;

b) providing locations of each of said mobile stations based on at least said power control parameters;

c) constructing data representations indicating said signal qualities using said provided locations of each of said mobile stations and at least said power control parameters; and

d) selectively repeating steps a) through c) to construct a map of signal qualities throughout at least a portion of said network.

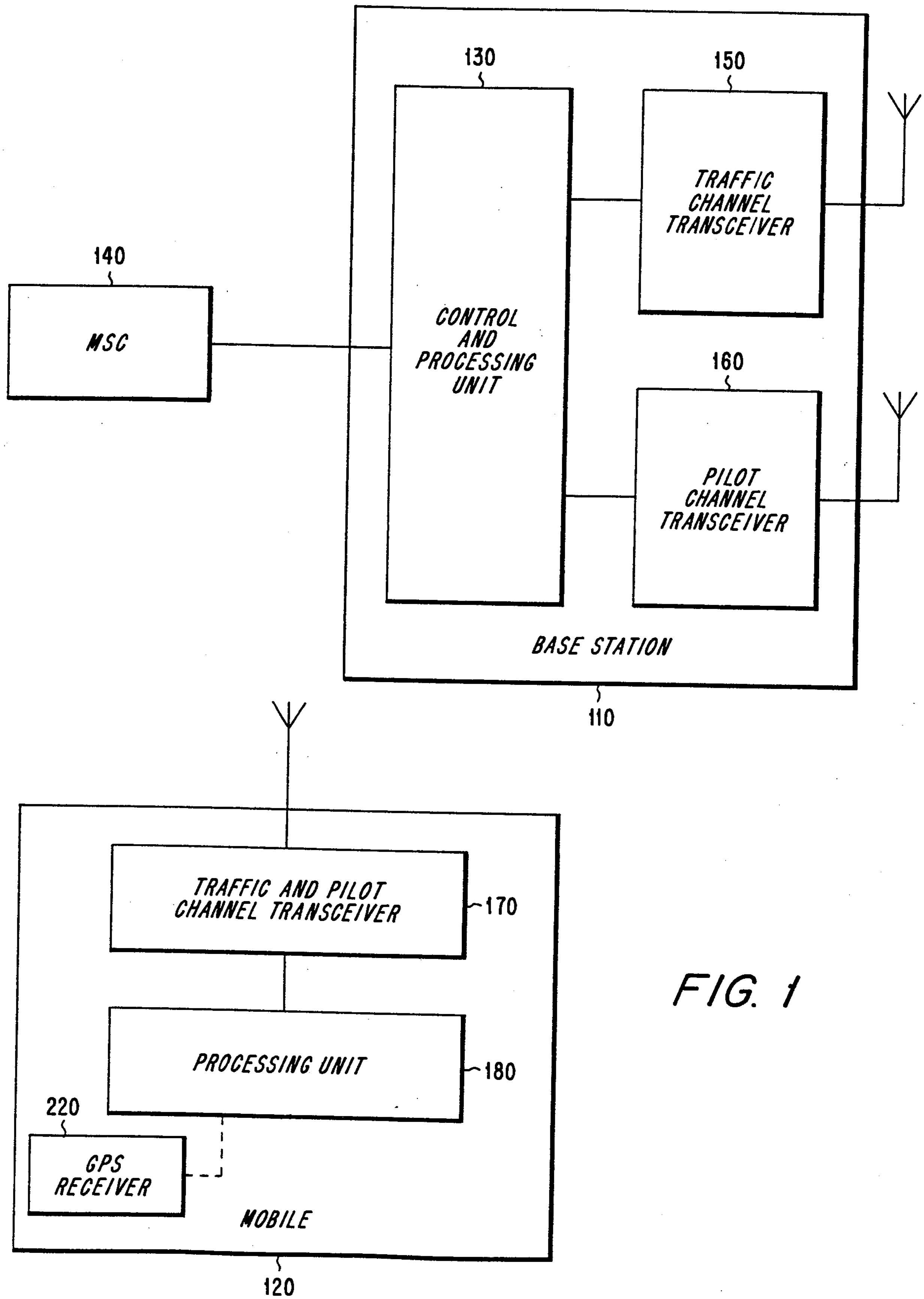
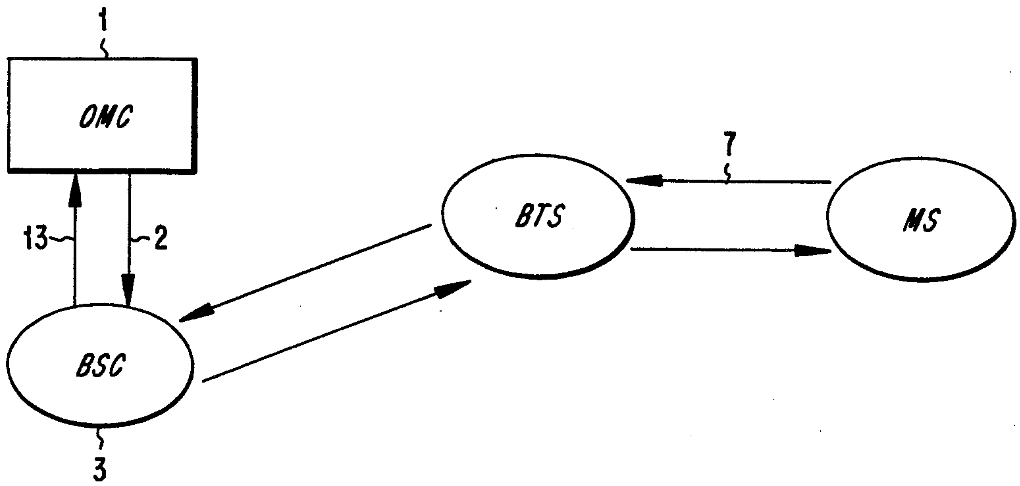

140
MSC
130
CONTROL AND PROCESSING UNIT
150
TRAFFIC CHANNEL TRANSCEIVER
160
PILOT CHANNEL TRANSCEIVER
BASE STATION
110
TRAFFIC AND PILOT CHANNEL TRANSCEIVER
170
PROCESSING UNIT
180
220
GPS RECEIVER
MOBILE
120

FIG. 1

FIG. 2



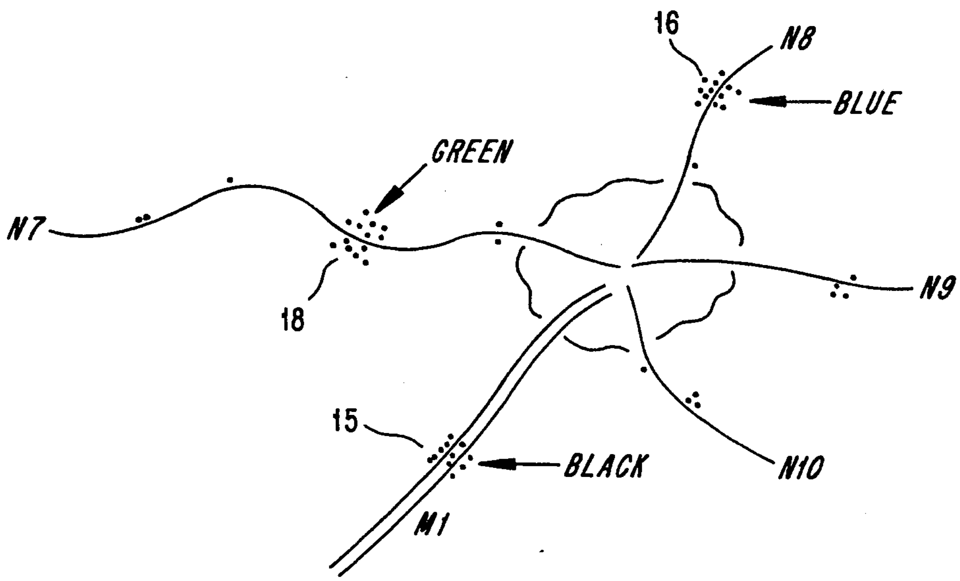


FIG. 4

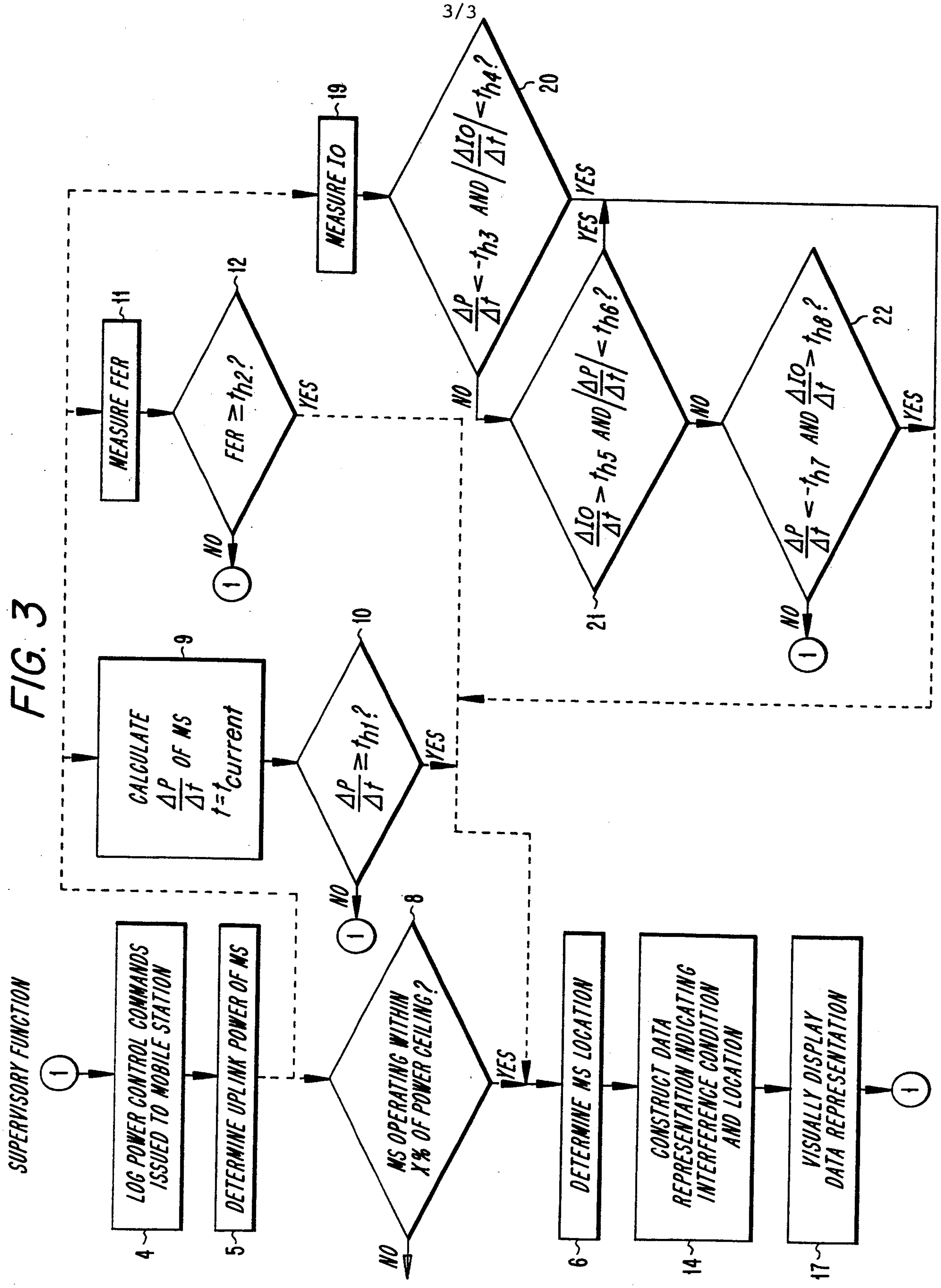

SUPERVISORY FUNCTION
1
LOG POWER CONTROL COMMANDS ISSUED TO MOBILE STATION
4
DETERMINE UPLINK POWER OF MS
5
MS OPERATING WITHIN X% OF POWER CEILING?
8
NO
YES
DETERMINE MS LOCATION
6
CONSTRUCT DATA REPRESENTATION INDICATING INTERFERENCE CONDITION AND LOCATION
14
VISUALLY DISPLAY DATA REPRESENTATION
17
CALCULATE ΔP/Δt OF MS t=t current
9
ΔP/Δt ≥ th1?
10
NO
YES
MEASURE FER
11
FER ≥ th2?
12
NO
YES
MEASURE IO
19
ΔP/Δt < -th3 AND |ΔIO/Δt| < th4?
20
NO
YES
ΔIO/Δt > th5 AND |ΔP/Δt| < th6?
21
NO
YES
ΔP/Δt < -th7 AND ΔIO/Δt > th8?
22
NO
YES

FIG. 3

INTERNATIONAL SEARCH REPORT

International Application No
PCT/SE 99/02000

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04Q7/34

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04Q H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 431 956 A (MOTOROLA INC) 12 June 1991 (1991-06-12) column 4, line 56 -column 8, line 47 claims 1-3,11-16 ---	1,2,4,5, 7-10,12, 13,15, 16, 18-21, 23-27, 29-32, 34,35, 37,38

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 January 2000	01/02/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Kokkoraki, A

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Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Interr ,nal Application No
PCT/SE 99/02000

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	LEJDAL J -O: "CELLO-a powerful operations tool for trouble-shooting in cellular systems" 38TH IEEE VEHICULAR TECHNOLOGY CONFERENCE: 'TELECOMMUNICATIONS FREEDOM - TECHNOLOGY ON THE MOVE' (CAT. NO.88CH2622-9), PHILADELPHIA, PA, USA, 15-17 JUNE 1988, pages 656-658, XP002111137 1988, New York, NY, USA, IEEE, USA the whole document -----	1,12,23, 24,37,38

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/SE 99/02000

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0431956 A	12-06-1991	US 5023900 A	11-06-1991
		US 5095500 A	10-03-1992

(12) UK Patent Application (19) GB (11) 2 357 010 (13) A

(43) Date of A Publication 06.06.2001

(21) Application No 9928546.2

(22) Date of Filing 02.12.1999

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(51) INT CL^7
H04Q 7/34

(52) UK CL (Edition S)
H4L LFMX L213

(56) Documents Cited
None

(58) Field of Search
UK CL (Edition R) **H4L LFMX**
INT CL^7 **H04Q 7/34**
On-Line - EPODOC, JAPIO, WPI

(54) Abstract Title
Error reporting in a mobile telecommunications network

(57) A method of reporting errors in a mobile telecommunications network comprising a core network 1 and a UMTS Terrestrial Radio Access Network (UTRAN) 4. The method comprises the steps of generating an error message at an error originating entity in one of the core network and the UTRAN, sending the error message to an error destination entity in the other of the core network and the UTRAN over an Iu interface, and, at each intermediate entity through which the error message passes, incrementing a distance counter contained in or accompanying the error message. The error destination entity is able to identify the error originating entity on the basis of the value of the distance counter contained in or accompanying the received error message. Alternatively, the error message may be accompanied by a code which identifies the originating entity.

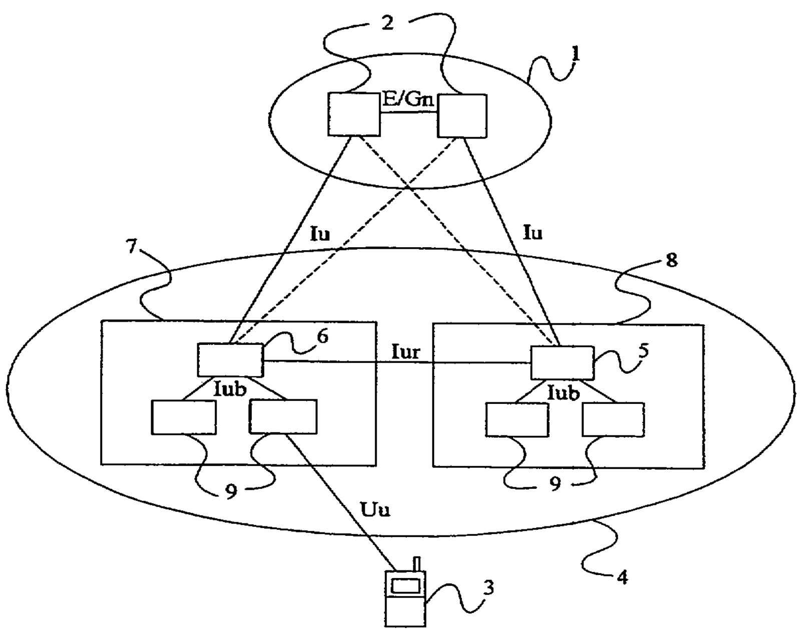

Figure 1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1995

GB 2 357 010 A

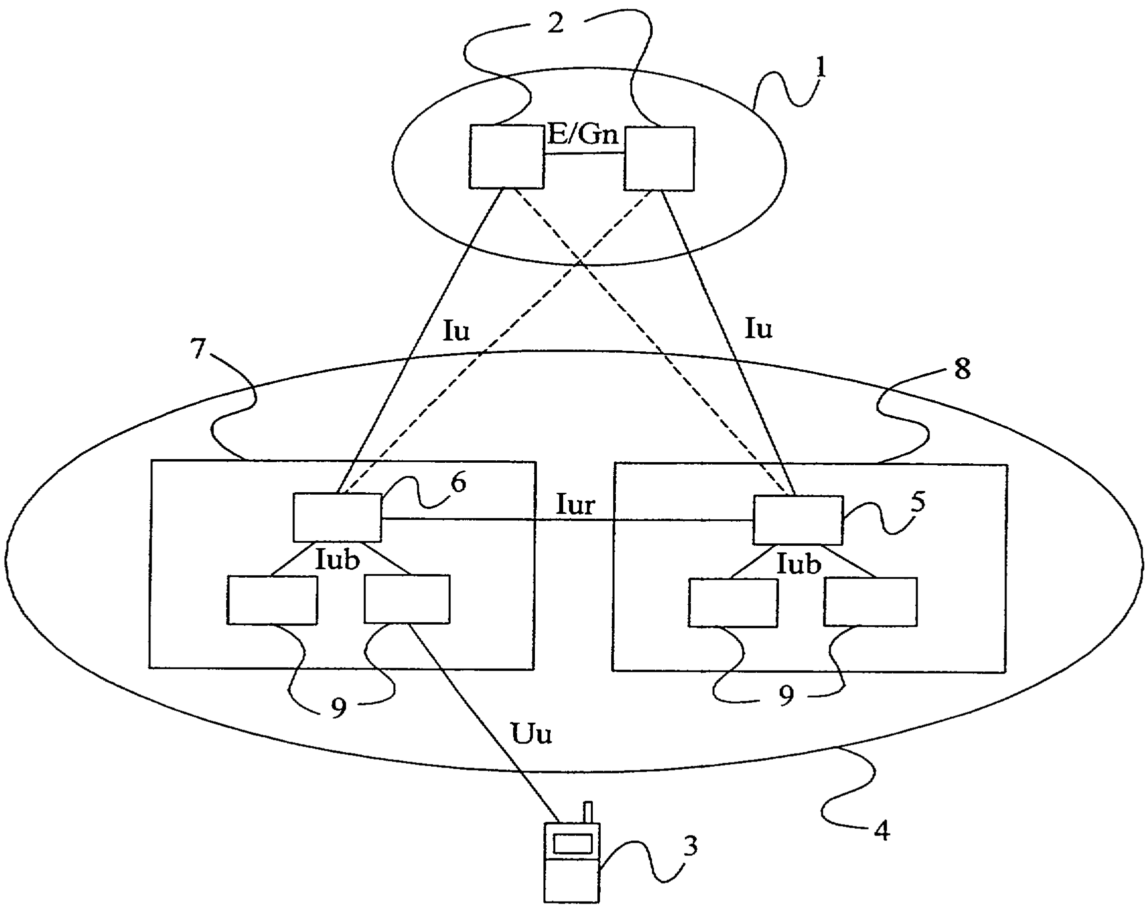

Figure 1

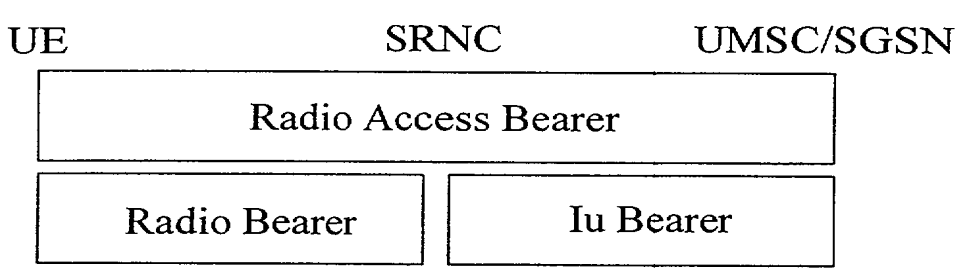

Figure 2

Bits								Number of Octets	
7	6	5	4	3	2	1	0		
PDU Type (=14)				Ack/Nack (=0)		PDU Type 14 Frame Number		1	Frame Control Part
Spare				Procedure Indicator (=3)				1	
Header CRC						Payload CRC		1	Frame Checksum Part
Payload CRC								1	
Error distance		Spare						2	Frame Payload Part
Cause value									

Figure 3

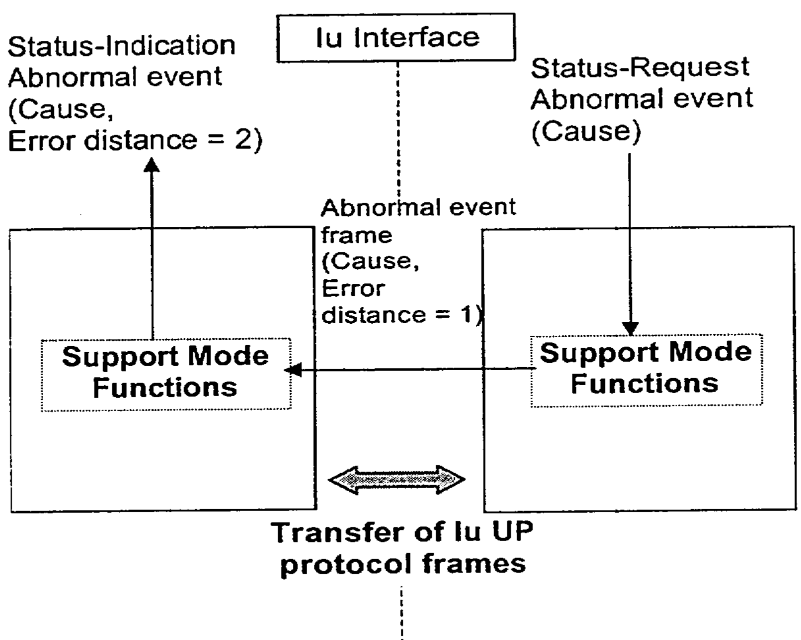

Figure 4

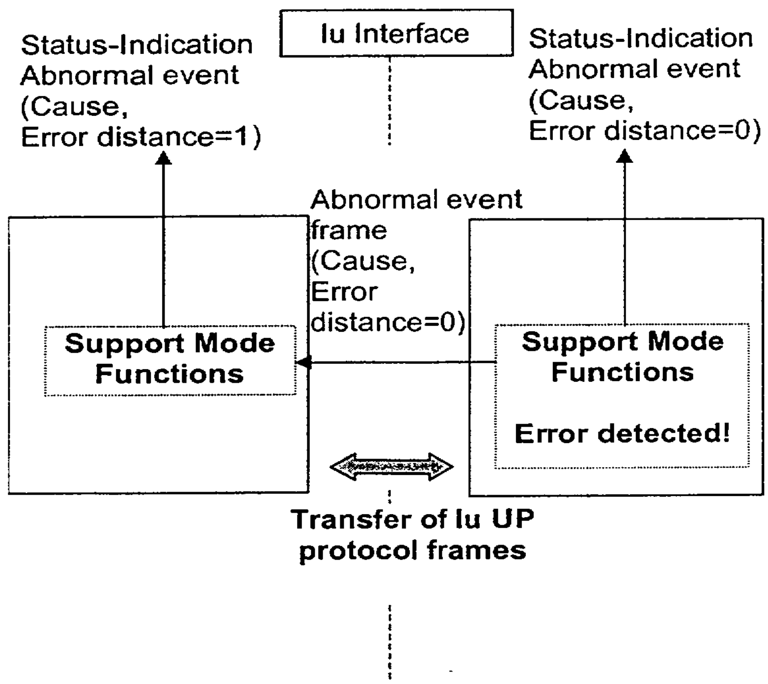
Iu Interface
Status-Indication
Abnormal event
(Cause,
Error distance=1)
Status-Indication
Abnormal event
(Cause,
Error distance=0)
Abnormal event
frame
(Cause,
Error
distance=0)
Support Mode
Functions
Support Mode
Functions
Error detected!
Transfer of Iu UP
protocol frames

Figure 5

Error Reporting in a Mobile Telecommunications Network

Field of the Invention

The present invention relates to error reporting in a mobile telecommunications network. More particularly, the invention relates to error reporting in the Iu User Plane (UP) between a Universal Mobile Telecommunications Network (UMTS) core network and a UMTS Terrestrial Radio Access Network (UTRAN).

Background to the Invention

Figure 1 illustrates schematically a part of a Universal Mobile Telecommunications System (UMTS) network. The network includes a core network part 1, which may be a network handling voice calls using UMTS Mobile-services Switching Centres (UMSCs) or may be a data network such as a General Packet Radio Service (GPRS) network including Serving GPRS Support Nodes (SGSNs). In Figure 1 the UMSCs and SGSNs are indicated generally with the reference numeral 2. A subscriber or User Equipment (UE) 3 is coupled to the core network 1 via an access network 4 referred to as a Universal Terrestrial Radio Access Network (UTRAN). More particularly, the UMSCs/SGSNs 2 are connected to Radio Network Controllers (RNCs) 5,6 of the UTRAN 4 over an interface referred to as the Iu interface.

Each RNC 5 forms part of a Radio Network Subsystem (RNSs) 7,8 which also comprises a set of Base Transceiver Stations 9 referred to in UMTS terminology as Node B's. The interface between a RNC 5,6 and a Node B 9 is known as the Iub interface. A Node B 9 provides the connection point for a UE 3 to the UTRAN 4, and the interface between the Node B 9 and the UE 3 is known as the Uu interface. The RNS (RNS 7 in Figure 1) which connects a UE 3 to the core network 1 at any given time is referred to as the Serving RNS (SRNS) for that particular UE 3.

Figure 2 illustrates in very general terms the bearer structure used by UTRAN to carry user data between the UE 3 and the core network 1. When it is required to establish a user plane connection, the responsible UMSC or SGSN 2 instructs the UTRAN 4 to establish a logical connection between the UMSC or SGSN 2 and the UE 3. This logical connection is referred to as a Radio Access Bearer (RAB). The established RAB inherits requirements of the requested UMTS service, e.g. Quality of Service, etc. Based on the inherited requirements of the RAB, the RNC 5,6 establishes user plane connections with the core network 1 (i.e. UMSC or SGSN 2) and with the UE 3. The connection between the RNC 5,6 and the core network 1 is referred to as the Iu bearer whilst the connection between the RNC 5,6 and the UE 3 is referred to as the Radio Bearer (RB). Both of these bearers represent further logical channels, with the RNC performing a mapping between them. The bearers themselves are mapped onto appropriate traffic channels for transmission over the respective interfaces (Iu and Uu).

In addition to carrying user data, the Iu bearer carries related control information between the UTRAN and the core network. Work is currently ongoing under the auspices of the European Telecommunications Standards Institute (ETSI) to specify the Iu User Plane (UP) protocol for carrying this control information. The specification is referred to as 25.415 and the current version is version 3.0.0 (1999-10). The current version of the Iu UP protocol does not deal with error handling, i.e. it does not provide for an "abnormal event" procedure. It is acknowledged that such a procedure is necessary to deal with errors such as might occur, for example, during a call initialisation stage.

Summary of the Invention

It is to be expected that ETSI will define as part of the 25.415 recommendation a set of error types, together with an Iu UP Packet Data Unit (PDU) format for conveying error messages between Iu entities (in the UTRAN and in the core network). It will be appreciated that an error message may pass through one or more intermediate entities on its journey between the originating entity and the terminating entity. A potential problem with such a solution however is that an entity receiving an error message may not know the source of an error message, even though it might know the error type and the identity of the last entity in the transmission path.

According to a first aspect of the present invention there is provided a method of reporting errors in a mobile telecommunications network comprising a core network and a UMTS Terrestrial Radio Access Network (UTRAN), the method comprising:

generating an error message at an error originating entity in one of the core network and the UTRAN;

sending the error message to an error destination entity in the other of the core network and the UTRAN over an Iu interface; and

at each intermediate entity through which the error message passes, incrementing a distance counter contained in or accompanying the error message,

wherein the error destination entity is able to identify the error originating entity on the basis of the value of the distance counter contained in or accompanying the received error message.

In certain embodiments of the present invention, error messages are sent between a UMTS Mobile Switching Centre (UMSC) of the core network and a Radio Network Controller (RNC) of the UTRAN. In other embodiments of the present invention, the error message may be sent between two RNCs, via the core network. The error message may be generated at either an Iu User Plane protocol instance or at an upper layer entity of the UMSC/RNC. Similarly, the message may be sent over the Iu interface to either an Iu User Plane protocol instance or upper layer entity of the receiving UMSC/RNC. Where the error message is generated by an upper layer entity, the message may be sent to a peer entity, over the Iu interface, via respective Iu User Plane protocol instances at the sending and receiving nodes (where the term "node" identifies either a UMSC or an RNC). Where the error message is generated by an Iu User Plane protocol instance, the error message may be sent to an upper layer entity of the same node, as well as over the Iu interface.

Preferably, the error message is incorporated into an abnormal event frame for sending over the Iu interface. The frame is constructed at the Iu interface of the node where the error message is generated. More preferably, the frame contains an error type identifier ("cause value") and said distance counter.

According to a second aspect of the present invention there is provided a mobile telecommunications network comprising a core network and a UMTS Terrestrial Radio Access Network (UTRAN) each comprising a number of nodes communicating over an Iu interface with nodes of the other network, wherein each node comprises:

means for generating error messages at an error originating entity;

means for sending error messages to an error destination entity in another node, and means for receiving error messages from an error generating entity in another entity, over an Iu interface; and

at least one intermediate entity through which error messages pass and which are arranged to increment a distance counter contained in or accompanying each error message,

wherein an error destination entity is able to identify the error originating entity on the basis of the value of the distance counter contained in or accompanying the received error message.

According to a second aspect of the present invention there is provided a method of reporting errors in a mobile telecommunications network comprising a core network and a UMTS Terrestrial Radio Access Network (UTRAN), the method comprising:

generating an error message at an error originating entity in one of the core network and the UTRAN;

constructing an abnormal event frame incorporating said error message and a code which identifies the location of said error originating entity; and

sending the error message to an error destination entity in the other of the core network and the UTRAN over an Iu interface,

wherein the error destination entity is able to identify the location of the error originating entity on the basis of said code contained in said abnormal event frame.

The method comprises constructing a second or modified abnormal event frame incorporating said error message and a code which identifies the location of said error originating entity, the first mentioned code identifying the originating entity as belonging to a different node than the destination entity, and the second mentioned code identifying the originating entity as belonging to the same node as the destination entity.

Brief Description of the Drawings

Figure 1 illustrates schematically a UMTS network;

Figure 2 illustrates schematically the bearer structure used in the UTRAN part of the UMTS network of Figure 1;

Figure 3 illustrates an Abnormal Event Packet Data Unit used in the network of Figure 1;

Figure 4 illustrates a portion of the network of Figure 1 in which an external error has arisen; and

Figure 5 illustrates a portion of the network of Figure 1 in which an internal error has arisen.

Detailed Description of a Preferred Embodiment

A typical UMTS network has been described above with reference to Figure 1, whilst the UTRAN bearer structure employed in such a network has been described with reference to Figure 2. The Iu bearer illustrated in Figure 2 terminates in the RNC and UMSC at so-called Iu User Plane protocol instances. Each of the Iu User Plane protocol instances communicate with upper layers of the same node, and in addition make use of a number of Iu UP functions.

Errors in the Iu User Plane (UP) can be classified as 'syntactical errors', 'semantical errors' or 'other errors'. A field in a message is defined to be syntactically incorrect if the field contains an unknown value defined as "reserved", or if its value part violates syntactic rules given in the specification of the value part. A message is defined to have semantically incorrect contents if it contains unexpected information which, possibly dependent on the state of the receiver, is in contradiction to the resources of the receiver and/or to the procedural part. Errors that are not seen as syntactical or semantical are defined as other errors. These errors include repeated failures of some procedures (e.g. Initialisation) and some error situations outside the Iu UP (e.g. initialisation failure at transcoder).

Error handling in the Iu User Plane (UP) is handled by an "abnormal event" procedure. This procedure makes use of an Iu UP frame which is sent over the Iu interface and which is referred to as an "abnormal event" frame. The abnormal event frame is illustrated in Figure 3 and contains a 'Cause value' which identifies the type of the error. The abnormal event frame also contains a field termed 'Error distance' which identifies the distance (from the receiving entity) to the entity reporting the abnormal event. The 'Error distance' is 0 when the error is originally sent. When an Abnormal event report is relayed forward, the 'Error distance' is incremented by one. The Error distance comprises two bits, and the four possible values are defined as follows:

0 - Reporting local error

1 - First forwarding of abnormal event report

2 - Second forwarding of abnormal event report

3 - Reserved for future use.

An abnormal event procedure can be triggered at an RNC or UMSC by; an error detected by one of the Iu UP functions (e.g. received frame format unknown), a request made by upper layers (e.g. Initialisation failure in transcoder), or an abnormal event frame sent over the Iu UP.

When an error is detected within an Iu UP function, one of the following actions is taken depending on the type of the error: (1) the error is reported to the upper layers (e.g. upper layer report to operation and maintenance level); (2) an abnormal event frame is sent over the Iu UP; (3) an abnormal event frame is sent over the Iu UP and the error is reported to the upper layers; or (4) no action is taken.

Considering now a specific example, when an Iu-UP-Status-Request indicating an abnormal event is received at an Iu User Plane protocol instance (of an RNC or UMSC) from the upper layers, an abnormal event frame should be sent over the Iu interface indicating the appropriate error type. When the abnormal event frame is received over the Iu UP protocol at a peer Iu User Plane protocol instance, an Iu-Status-Indication indicating the abnormal event is sent from there to the upper layers.

Figure 4 below shows this "external" error case where the abnormal event procedure is originally triggered by an Iu-UP-Status-Request. The abnormal event procedure acts on the received message by sending an abnormal event frame over the Iu interface. On the other side of the Iu interface, the reception of an abnormal event frame triggers an abnormal event procedure there, and an Iu-UP-Status-Indication is sent to the associated upper layers. The handling is symmetrical over the Iu UP protocol.

Figure 5 below shows an "internal" error case where the abnormal event procedure is originally triggered by an Iu UP function associated with an Iu User Plane protocol instance. The abnormal event procedure acts on this message by sending an abnormal event frame over the Iu interface. On the peer side of the interface, the reception of the abnormal event frame triggers a further abnormal event procedure, and an Iu-UP-Status-Indication is sent to the upper layers from the peer Iu User Plane protocol instance. Again, the handling is symmetrical over the Iu UP protocol.

It will be appreciated by the person of skill in the art that various modifications may be made to the above described embodiments without departing from the scope of the present invention. In particular, whilst the invention has been illustrated above with reference to an Iu interface between an RNC and a UMSC, this interface may exist between two RNCs, where the interface is carried transparently via the core network.

As an alternative to incorporating a distance counter into the abnormal event frame, a code may be incorporated which identifies the source of the error. For example, a code 0 may indicate that the error originating entity is an upper layer at a peer node (an application error), a code 1 may indicate that the error originating entity is an Iu UP protocol instance at a peer node (an Iu UP function error), and a code 2 may indicate that the error originating entity is an Iu UP protocol instance at the same node as the destination entity (again an Iu UP function error).

Claims

1. A method of reporting errors in a mobile telecommunications network comprising a core network and a UMTS Terrestrial Radio Access Network (UTRAN), the method comprising:

generating an error message at an error originating entity in one of the core network and the UTRAN;

sending the error message to an error destination entity in the other of the core network and the UTRAN over an Iu interface; and

at each intermediate entity through which the error message passes, incrementing a distance counter contained in or accompanying the error message,

wherein the error destination entity is able to identify the error originating entity on the basis of the value of the distance counter contained in or accompanying the received error message.

2. A method according to claim 1, wherein the error message is sent between a UMTS Mobile Switching Centre (UMSC) of the core network and a Radio Network Controller (RNC) of the UTRAN.

3. A method according to claim 1, wherein the error message is sent between two RNCs, via the core network.

4. A method according to any one of the preceding claims, wherein the error message is generated at either an Iu User Plane protocol instance or at an upper layer entity of a UMSC or RNC.

5. A method according to any one of the preceding claims, wherein the error message is sent over the Iu interface to either an Iu User Plane protocol instance or upper layer entity of the receiving UMSC/RNC.

6. A method according to any one of the preceding claims, wherein the error message is generated by an upper layer entity and is sent to a peer entity, over the Iu interface, via respective Iu User Plane protocol instances at the sending and receiving UMSC or RNC.

7. A method according to any one of the preceding claims, wherein the error message is generated by an Iu User Plane protocol instance and is sent to an upper layer entity of the same node, as well as over the Iu interface.

8. A method according to any one of the preceding claims, wherein the error message is incorporated into an abnormal event frame for sending over the Iu interface.

9. A method according to claim 8, wherein the frame contains an error type identifier and said distance counter.

10. A mobile telecommunications network comprising a core network and a UMTS Terrestrial Radio Access Network (UTRAN) each comprising a number of nodes communicating over an Iu interface with nodes of the other network, wherein each node comprises:

means for generating error messages at an error originating entity;

means for sending error messages to an error destination entity in another node, and means for receiving error messages from an error generating entity in another entity, over an Iu interface; and

at least one intermediate entity through which error messages pass and which are arranged to increment a distance counter contained in or accompanying each error message,

wherein an error destination entity is able to identify the error originating entity on the basis of the value of the distance counter contained in or accompanying the received error message.

11. A method of reporting errors in a mobile telecommunications network comprising a core network and a UMTS Terrestrial Radio Access Network (UTRAN), the method comprising:

generating an error message at an error originating entity in one of the core network and the UTRAN;

constructing an abnormal event frame incorporating said error message and a code which identifies the location of said error originating entity; and sending the error message to an error destination entity in the other of the core network and the UTRAN over an Iu interface,

wherein the error destination entity is able to identify the location of the error originating entity on the basis of said code contained in said abnormal event frame.

12. A method according to claim 11, wherein the method comprises constructing a second or modified abnormal event frame incorporating said error message and a code which identifies the location of said error originating entity, the first mentioned code identifying the originating entity as belonging to a different node than the destination entity, and the second mentioned code identifying the originating entity as belonging to the same node as the destination entity.

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UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): H4L (LFMX)

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Other: On-Line - EPODOC, JAPIO, WPI

Documents considered to be relevant:

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(54) CELLULAR NETWORK-BASED LOCATION SYSTEM

LOKALISIERUNGSSYSTEM AUF BASIS EINES ZELLULAREN NETZES

SYSTEME DE REPERAGE SE BASANT SUR UN RESEAU CELLULAIRE

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Description

[0001] The present invention relates to cellular communication systems and, more particularly, to a cellular configuration for determining the location of a mobile station.

[0002] The increased terminal mobility offered by cellular telephone networks as well as mobile radio data networks has brought about an increased demand for location-based services and applications. Fleet operators are interested in automated vehicle tracking applications to enhance their dispatch operations. Moreover, stolen vehicle recovery systems have enjoyed a significant amount of success during the past few years. However, most efforts to date have been designed around specialized equipment employed at the mobile operator site for acquiring location information. For example, U.S. Patent No. 5,043,736 to Darnell et al. discloses a cellular position locating system where the location of a remote unit is derived from data transmitted by a global positioning system to a specially equipped receiver at the remote unit.

[0003] WO-A1-94/01978 discloses a system for locating mobile vehicles and communicating therewith. There is provided a plurality of cellular systems each serving a plurality of base stations. Each of the base stations provides communication services to a plurality of cellular subscriber stations. An interface computer is connected to a home mobile switching centre of the cellular subscriber for accessing identification data in a roaming network relative to predetermined cellular subscriber stations. A location computer interconnected with the interface computer translates the interface computer's identification data into location data, indicating the geographical position of each cellular subscriber station, based upon the known geographical position of the particularly cellular system in which the subscriber station is currently registered.

[0004] It is the object of the present invention to provide a method for determining the location of a mobile station in a cellular system in a simplified manner.

[0005] This object is achieved by the subject matter of claim 1. Preferred embodiments of the invention are described by the dependent claims.

Figure 1 is a flowchart depicting a communications sequence in accordance with one embodiment of the present invention;

Figure 2 is a flowchart depicting a communications sequence in accordance with another embodiment of the present invention;

Figure 3 is a block diagram of a mobile system configuration employing the present invention; and

Figure 4 is a detailed block diagram representation of the mobile system configuration in Figure 3. In the following preferred embodiment of the invention are described with reference to the figures.

[0006] The implementation of certain cellular services requires that the mobile station location be made available to the service provider. For example, in a 911 emergency service, medical personnel need an accurate and precise reading on the source of a distress call in order for prompt medical attention to be made available within the entire coverage area of single or multi-carrier cellular networks. Although the location finding system disclosed by Darnell et al., supra, conveys highly accurate positional information from a modified mobile station specially configured to interface with a GPS system, a more desirable system from a subscriber perspective would keep intact the existing mobile station configuration.

[0007] The present invention concerns an enhancement to the existing cellular network topology permitting the acquisition of a mobile station location using cellular parameters from the network. The cellular parameters define the placement of each mobile station within its cellular network and its relationship to other mobile stations. For example, the parameters may include data identifying the communications trunk group serving the mobile station, a member number, and cell and/or sector ID. An accurate conversion of cellular data into a geographical profile may be performed using radio plans as a translational mechanism. The radio plans, which correspond to geographic maps of radio coverage, furnish information such as the latitude and longitude derived from the cell base station antenna location, elevation, radius, and angles for sectorized cells.

[0008] For purposes of discussion and clarity, the term "mobile station locator" (MSL or "Locator") is used hereinafter to encompass a facility, mechanism, or assembly in whatever form implemented, constructed, or operable, which interacts with and is the recipient of location-determinative cellular data from the cellular network. The MSL itself maintains an information resource responsive to input cellular data for generating a corresponding geographical location estimate. The resource is constructed by accumulating position data from radio coverage maps, for example, where cellular data is translatable into geographical information.

[0009] The basic configuration of a cellular network includes a plurality of base stations defining cell sites and providing wireless communication to mobile station units within the cell site coverage area. The cellular network is further configured with a plurality of mobile switching centers in communication with the base stations and other switching centers to perform processing and switching functions enabling connections between mobile stations and interfacing to external networks such as the PSTN.

[0010] In one embodiment of the present invention detailed in the flow diagram sequence of Figure 1, a code representing the identity of a mobile station is transmitted from the mobile switching center (MSC or "Center")to the mobile station locator. In particular, the identity code corresponds to a mobile Identification Number (MIN) and/or an Electronic Serial Number (ESN). The Locator then queries the Center with the MIN, requesting network data on the mobile station having the designated MIN. In response to this query, the Center retrieves the requested information such as trunk group and member number, and then forwards it to the Locator. A translation operation at the Locator converts the cellular network data into corresponding geographical location information.

[0011] In another embodiment of the present invention detailed in the flow diagram sequence of Figure 2, cellular network data is transmitted along with the MIN from the Center to the Locator; accordingly, in this embodiment, the Locator does not prompt the Center for cellular data. In a preferred implementation, the Center invokes the transmission of cellular data pertaining to a mobile station in response to a trigger command from the mobile station represented by certain dialed mobile digits known as a feature code.

[0012] Figure 3 is a system level block diagram illustratively representing a cellular configuration for implementing the present invention. For purposes of investigating the location-finding capability, an Assistance Center 31 was included to monitor the call from the mobile station and the position information from the Mobile Station Locator (MSL) 32. In particular, AC 31 is an entity receiving a voice channel over a cellular link connected to the Mobile Switching Center (MSC) 33, and receiving the geographical location data from Locator 32. The Assistance Center 31 includes a processing center with dispatching and/or storage capabilities which receives user calls and location data and provides services based upon that information. The Assistance Center 31 specifically contains equipment which provides the capability for a call-taker (i.e., operator or dispatcher) to talk with the cellular phone caller and display the caller's position on a graphical display.

[0013] The Mobile Switching Center 33 is a cellular telephone network switch that provides processing and switching functions to allow cellular phones to communicate with other phones (cellular and wireline). The Mobile Station Locator 32 is a facility performing the retrieval and storage of location information pertaining to mobile stations. In particular, Locator 32 receives, retrieves, stores and processes location information, and then furnishes it to AC 31. The Locator 32 is equipped with an MSL-MSC Interface (MMI) that performs the retrieval of location information from the Mobile Switching Center 33.

[0014] Base stations, also called cell sites, are connected to Center 33 and provide radio communication with the cellular phones. Base stations can be configured with omnidirectional or sectorized antennas. An omni cell provides radio coverage radiating out from the cell center in all directions; this type of a cell may be approximated by a circle on a map. A sectorized cell has antennas which provide coverage for a section of the circle; this type of a cell may be approximated by a pie-wedge shape on a map.

[0015] The cellular configuration shown in Figure 3 was exercised during a Location Assistance and Tracking Information Service (LATIS) field trial demonstration to explore the methods by which the location of a mobile station (e.g., cellular phone) originating a call may be made available to entities both internal and external to the cellular network. The Locator 32 principally serves the function of collecting location data from the cellular network, translating it, and providing it to AC 31. The location data comprised the geographic coordinates and size of the serving cellular network cell site (e.g., base station). The resolution of this location data was limited by the size of the cell site; however, the resolution of the data from multiple cell sites was enhanced by sector information such as the cell subset/section.

[0016] The LATIS trial activated the acquisition mode to determine a mobile station's position by engaging the operator into initiating a call into the cellular network. In particular, the mobile station operator dialed a recognizable feature code (FC) on a standard cellular phone. The Center 33 recognized the feature code and connected the call to AC 31 for establishing a voice connection between the answering personnel and the caller.

[0017] The acquisition of location information by Locator 32, and its subsequent delivery to AC 31, is accomplished during the LATIS trial by a first and second transport scheme hereinafter designated Methods I and II. In Method I, Center 33 transmits the caller's identity to AC 31 over a network connection. The caller's identity is defined by a Mobile Identification Number (MIN) which corresponds to the telephone number of the station originating a call. For the purposes of the trial, the MIN was ten (10) digits in length.

[0018] The AC 31 responds by forwarding to Locator 32 a message containing the caller's MIN in order to request cellular data relevant to the MIN. The Locator 32 then interacts with Center 33 to retrieve the cell-site trunk currently in use by that particular mobile station. The Locator 32 converts the trunk information received from Center 33 into a location "value" including a geographic coordinate (latitude and longitude), a resolution parameter (radius), and possibly two angle values (for sectorized cells). This information is then formatted and transmitted to AC 31 for graphical display. Depending upon the type of base station currently serving the cellular phone, the location value may be displayed by AC 31 in different ways, such as with a circle described by the geographic coordinate and the resolution, or a pie-wedge conveying this information and supplemented with the two angle values.

[0019] In Method II, Center 33 multiplexes the caller's identity (e.g., MIN) with cellular network data and transmits the combined signal to AC 31. For example, Center 33 may outpulse the MIN plus a 5-digit code representing the serving cell/sector. The AC 31 receives this code and forwards it to Locator 32, which converts it into a geographical location value that is transmitted to AC 31 for graphical display. The following table summarizes the features of the transport methods used during the trial.

Location Transport Method	Mobile Dialed Digits (Feature Code)	Signaling Data Outpulsed from MSC to AC
I	*57	MIN(10)
II	211	MIN (10) +cell&sector (5)

[0020] Although the LATIS field trial included specific routes for communicating cellular network data to Locator 32, these routes are indicated for illustrative purposes only and should not serve as a limitation of the present invention. Rather, the cellular network data may be transmitted to Locator 32 directly or indirectly via any type of communications link. Furthermore, the network data may be transmitted before or contemporaneously with the voice channel. For example, the voice channel may be forwarded to AC 31 or another entity over one link, while the network data may be independently routed over an alternative path to Locator 32. In addition, the MIN and/or network data (depending upon the application) may be multiplexed with the voice channel before transmission from Center 33.

[0021] Likewise, even though in Method I the Locator 32 was prompted with the MIN by Assistance Center 31, and in Method II the cell/sector location data was initially transmitted to AC 31 before being coupled to Locator 32 for conversion, this supervisory/coordinating role of AC 31 should not serve as a limitation of the present invention. Rather, it should be apparent to those skilled in the art that the MIN for Method I and the cellular network data for Method II could be transmitted directly to Locator 32 from Center 33, while the voice communication would be separately transmitted by Center 33 to AC 31 or any other end user.

[0022] Figure 4 is a further block diagram representation of the cellular configuration in Figure 3. The specific components, subsystems, and other entities mentioned in conjunction with Figure 4 should not be viewed as a limitation of the present invention, but as representative of one implementation of the cellular configuration. It should be apparent to those skilled in the art that the functions demonstrated in Figure 4 may be implemented by other equivalent means.

[0023] The mobile station employed standard cellular phones such as Motorola transportable cellular phones which did not require any non-standard modifications. The phones were initialized with MINs (telephone numbers) from the serving GTE Mobilnet cellular system so that the phone would be on its "home" system throughout the trial.

[0024] The Mobile Switching Center 33 was an AT&T Autoplex System 1000 comprising one Executive Cellular Processor (ECP) 41 and several Digital Cellular Switches (DCS) 42. Each DCS 42 is connected to several base stations (cell sites). The only hardware modification made to Center 33 was the connection of a dedicated T-1 span (trunk group) to carry the test calls to an Assistance Center Switch 43. The link between the DCS 42 and ACS 43 is designated interface A in Figure 4.

[0025] The ECP 41 was modified to provide the necessary digit translation, call routing, and trunk signaling. The following discussion enumerates the modifications made to certain forms of ECP 41.

(1) The Subscriber and Feature Information Form was modified to add Primary Dialing Class number 22. The MIN of each test phone was part of Dialing Class number 22; this class was created for the trial to restrict the dialing capabilities of the test phones and to prevent interference with the live traffic.

(2) Pattern matching was added to the Dialing Plan form (DPLAN). These modifications specified the feature codes that were used. If the dialed digits received form the mobile station matched *57 (Method I), or 211 (Method II), a Destination Index of 911 for the DXDRTE route and a Dialed Number Modification (DNMOD) of 13 were assigned. If the digits matched *58 + 12 or more digits (which would be latitude/longitude), a Destination Index of 911 and a DNMOD of 14 were assigned.

(3) Dialed Number Modification (DNMOD) of 13 performed cell and sector matching. If the call originated from one of the cells/sectors in the table, a corresponding set of digits was added to the dialed digits (*57 or 211), and the entire set was routed to the Digit-By-Digit Call Routing (DXDRTE).

(4) Dialed Number Modification (DNMOD) of 14 performed latitude and longitude translation. The *58 was deleted from the incoming digits, and the remaining lat/long digits were routed to the Digit-By-Digit Call Routing (DXDTRE).

(5) The Digit-By-Digit Call Routing (DXDTRE) assigned an outgoing trunk group and outpulsed the digits. The Feature Group D signaling method was used. The caller's MIN was outpulsed in the ANI (Automatic Number Identification) field, and the digits sent by the DNMOD forms were outpulsed in the Called Address field.

[0026] As noted above, Assistance Center 31 in Figure 3 is equipped with means for communicating with the mobile station via the cellular network over a communications link such as a voice channel, and for receiving and displaying the geographical position information of the mobile station caller. The Assistance Center 31 is represented in Figure

4 as an Assistance Center Switch (ACS) 43 and an Assistance Center Dispatch Station 46, discussed infra. The ACS 43 contains telephone switching equipment capable of receiving and discerning identity and location information pertaining to incoming calls, and routing those calls to operators as necessary.

[0027] The ACS 43 is configured to include a Summa Four SDS-500 switch 44 which was configured with two T1 cards, one used during the trial and the other used for testing. The ACS 43 may further include a dial tone generator, an MF (multifrequency) card for inband signaling-data capture, and an SLIC card to control attached telephone sets if so desired. A dedicated T1 span (interface A) from Center 33 was connected to one of the T1 cards; calls from Center 33 entered through ports on this card. The SDS switch 44 was controlled by an SDS host 45 which was running the SDS control software. The switch 44 communicated switch-related information and activity to the host 45 through reports; the host 45 issued commands to control the switch 44; and the switch 44 responded to commands with responses. The SDS host machine 45 was an HP-9000 series workstation.

[0028] The control software for the switch 44 was written in the C programming language and comprised five main modules (discussed infra) to execute the functions of receive messages, send messages, signal capture, analyze number, and prepare MSL input.

Receive Messages module

[0029] This module received messages from the SDS switch 44. This module was designed to support different types of applications; based upon the destination code and function ID in a message, the message was forwarded to an application module. For the trial, only one module, namely the signal capture module, was used.

Send Messages module

[0030] This module received messages from host modules and queued them for transmission to the switch. It returned several status responses to the calling module, including socket full/output pending and communication error.

Signal Capture module

[0031] This module reacted to changes in the T1 and telset resources; these changes were sent to the host via Inpulse Rule Complete reports, Incoming Port Change reports, Outgoing Port change reports, or responses to Outgoing Port Control commands. Based upon the report, a command was built and sent to the switch via the Send Messages module. The commands included the resource's virtual communication address, and were formulated with the SDS Application Program Interface (API).

[0032] The Inpulse Rule Complete report indicated that the signaling information from an inbound call (on the T1 span) was complete. The received signaling data were then sent to the Analyze Number module for analysis and further action.

Analyze Number module

[0033] This module analyzed the digits received by the signal capture module to determine which set of location data it contained (e.g., latitude & longitude, cell & sector, or none). The location data were then reformatted into a location information set and sent to the Prepare MSL Input module.

Prepare MSL Input module

[0034] This module prepared a location record for the MSL from the given location information set. If any error in the location set was detected, an appropriate error message was written to a log file. Otherwise, a data record was passed immediately to Locator 32 via the Send Messages module.

[0035] Additionally, this module sent an Outgoing Port Control command to the switch to perform an Outpulse Rule (ringing, etc.) for an ACDS telset (discussed infra). Since six telsets were used, if the first one was busy, the second one rang; if they both were busy, the call was queued (with ringback heard by the caller), and the first available telset received the call.

[0036] As noted above, the Assistance Center may also include an Assistance Center Dispatch Station (ACDS) 46 for housing telephone dispatching equipment 47 that enables an operator to talk with a caller and process the caller's location. This phone equipment would be interfaced to the SDS switch 44 through the SLIC card.

[0037] The ACDS comprised six standard telephones 47 and one HP-9000 series workstation 48. The telephones 47, connected to the ACS 43, allowed the operator to communicate with the callers/testers. Two software applications ran on the workstation: a Geographic Information System (GIS) for electronic mapping of callers' locations and a Graphical User Interface (GUI) which allowed the operator to quickly collect test scenario data.

[0038] The Geographic Information System is an X Window application which displays geographic data. In addition, GIS contains highly powerful algorithms for determining the shortest route/path between any two or more points. The following features were specifically added for use in the trial.

* A feature was added to display incoming location data with a car icon; this corresponded with "exact" locations where latitude and longitude data were present.
* A feature was added to display incoming location data with a circle; this corresponded with locations from omni-directional base stations.
* A feature was added to display incoming location data as a pie-wedge (section of a circle); this corresponded with locations from sectorized base stations.
* Capabilities were added to retrieve and delete the information related to a call. While any icon was illuminated, the operator could click on the icon and retrieve the specific information related to that call: MIN, latitude & longitude (if applicable), and cell/sector values (if applicable). The operator could also delete the entry, at which point the icon would be removed.

[0039] The GUI assists the operator in the gathering of necessary information. The GUI was built using X Windows/ Motif 1.1 widget family, and includes a menu bar with twelve fields which the operator can fill with test information. The fields are delineated below.

(a) Dialing MIN: The tester's MIN.
(b) Date: The date and times were obtained from the workstation's operating system.
(c) Dial Type: The dialing types (Method I or II) are listed.
(d) Cell: The name and number of the test cells were listed.
(e) Cell_id: The number of the cell used.
(f) Sector: The sector used by the tester in that cell.
(g) Caller: Caller's name.
(h) Call_taker: The operator's name.
(i) Weather: Four conditions were listed: sunny, partly cloudy, rainy, and foggy.
(j) Location: Thirty-two pre-assigned test locations were listed.
(k) Result: Pass or fail result was given to each test_index.
(l) Duration: Three call-duration times were listed: less than ten seconds, less than one minute, and greater than one minute.

[0040] A comment field was also provided to function as a server for location information. The Mobile Station Locator 32 was implemented with an HP-9000 series workstation.

[0041] The Locator 32 included an MSL Host & Server unit 49 containing software written in C and comprising the following six modules: main control, request, query-one, query-all, database-retrieval, GIS-interface. The MSL server 49 was designed to handle multiple simultaneous calls and operated as follows. The main control module waited for an incoming request from the ACS 43 (via interface B). For each incoming call, if the location data were present, the MSL server 49 translated it (if necessary) and formatted a data message which was sent to the ACDS 46. If the incoming call did not contain location data, the MSL server 49 checked if information from a Mobile Switching Center was included; if the Center was known, Locator 32 interacted with that particular Center using the query-one module. If the Center was not known, Locator 32 had the capability to interact with all connected Mobile Switching Centers using the query-all module. Both types of query modules were designed to use an MSL-MSC interface module 50, discussed below.

[0042] To ascertain the performance of the Mobile Station Locator 32, the main control module recorded the following events, with time-stamps, in log files:

* incoming mobile station call message received;
* query sent to MSC interface process by the MSC query process;
* query response received from the MSC interface process; and
* mobile station location record sent to ACDS.

MSL-MSC Interface

[0043] The purpose of the MSL-MSC Interface (MMI) module 50 is to perform MSC-specific processing to retrieve location information. The MMI 50 was written as an Expect script using TCL (Tool Command Language). The MMI 50 login routine established a connection with the Autoplex ECP 41 Recent Change port through the workstation's serial port. During the trial, this connection involved dialing a modem and logging into the ECP 41, all of which were handled automatically by the MMI 50. Once a connection was established, the MMI 50 main program continuously scanned an input file for query requests from the MSL server 49.

[0044] When a query request was found, the MMI 50 would issue an OP:DN command to the ECP 41; this command would contain the MIN received from Locator 32 in the query request message. Under normal operating circumstances, ECP 41 would return an MCR (Mobile Call Register) value. The MMI 50 would then issue an OP:MCR command with the MCR value. Under similar operating circumstances, ECP 41 would return, among other data, the cell site trunk information corresponding with the trunk currently serving the mobile station. The MMI 50 returned this information (trunk group and member number) to the MSL server 49 by writing it into an output file. If any errors were encountered, the MMI 50 would write an appropriate error message into the output file.

MSL Data Message Formats and Translations

[0045] The Locator 32 receives location data and performs conversions to provide a uniform output message format to applications (API). An illustrative output message format is as follows:

cell and sector	4 characters
longitude	8
latitude	8
elevation	5
radius	5
starting angle	5
real coverage angle	5
message/comments	125

A space was used to delimit each field.

[0046] The MSL host 49 executes certain conversion operations to properly translate the cellular network identification data for a specified mobile station into geographical position information. For example, transport Method I provides trunk group and member number data from the MSL-MSC Interface 50 to the MSL host 49. This data is translated in a first conversion operation into cell ID and sector ID information. In a second conversion operation, employed as a principal operation for transport Method II or as a secondary operation for transport Method I, the input data comprising cell/sector ID is converted into latitude and longitude, resolution (radius), angle 1, and angle 2.

[0047] The conversion operations are preferably performed using indexable tables previously generated and stored at Locator 32. The data for the first conversion operation was obtained, for example, from lists of trunk groups and member numbers used by each cell site (categorized by cell ID and/or sector ID). The data for the second conversion operation was gathered from radio plans (geographic maps of radio coverage) for the cells chosen for the trial, and organized into a tabular format. The latitude and longitude of each cell were taken directly from these radio plans using the base station antenna location as an index. The angles for sectorized cells were also extracted from the radio plans and other tables. The resolution of each cell/sector was determined from the radio plans as the distance from its center to the furthest point that provided at least -75dB radio signal coverage. The - 75dB figure was preferably used as a measure of the signal strength necessary to qualify as a threshold for handoff.

[0048] The following describes the interfaces among the units represented in Figure 4.

(1) MSC-ACS Interface (link "A")

This is a T1 span with Feature Group D (FG-D) signaling. The MSC 33 outpulsed ANI (the mobile's MIN) and, depending upon the location-transport method, a string of dialed digit which contained information pertaining to the location of the caller.

(2) ACS-MSL interface (link "B")

This is a file-transfer interface between the SDS host 45 and the MSL Server 49 processes. For all mobile-originated calls, a request message including the mobile's MIN and optional location information was written by the SDS Host 45 into a file. The MSL server 49 read the data from the file. The SDS Host 45 and MSL processes were executed on separate machines connected through an ethernet link.

(3) MSL-MSC interface (link "C")

This is a serial connection between the MSL interface unit 50 and the MSC's recent change port. Since Locator 32 is located remotely from Center 33, modems are used on a dial-up telephone line. The MSL's MMI 50 interacted with the MSC 33 to retrieve serving trunk group and member number data for a given MIN when transport Method I is operational.

(4) MSL-ACDS interface (link "D")

This is a file-transfer interface between the MSL Server 49 and the ACDS 46 application processes. The MSL writes its output messages containing the geographic location information into a file which is read by the ACDS application (GIS). Since the MSL and ACDS processes are executed on separate machines, an ethernet connection was used to transport the file read-write messages.

[0049] As an alternative to the location-finding schemes discussed above, the geographical location data may be obtained at the mobile station site using an enhanced mobile unit interfaced to an external position location system such as a GPS satellite. Location data for this service consisted of the latitude and longitude information uploaded by the enhanced mobile station. The resolution of this data was dependent upon the capabilities of the positioning equipment used at the mobile station.

[0050] For this service (designated transport Method III), an "enhanced" cellular phone employed an attached positioning device capable of determining the current location of the mobile unit. At the mobile operator's command, the enhanced phone read the current location information from the positioning device and automatically initiated a call. The dialed digits comprised a feature code plus the latitude and longitude location information. The Mobile Switching Center recognized this feature code and connected the call to the Assistance Center. In particular, the Switching Center outpulsed the MIN plus the latitude ('lat') and longitude ('lon') which were included in the digits dialed by the cellular phone; the 'lat' required eight digits, and the 'lon' required seven digits. The Switching Center transmitted this information to the Station Locator, which reformatted it and sent it to the Assistance Center for graphical display. Transport Method III is summarized in the following table.

Location Transport Method	Mobile Dialed Digits	Signaling Data Outpulsed to AC from MSC
III	*58+lon(8)+lat(7)	MIN(10)+lon(8)+lat(7)

[0051] The implementation of transport Method III required certain modifications to the mobile system configuration described above. The following discussion recites the enhancements made for the GPS-based implementation.

Enhanced Cellular Phones

[0052] Five GTE CCP-2000 Cellular Credit Card Phones (CCP) were modified for use in the aforementioned LATIS trial to implement Transport Method III. The modifications included the software and hardware revisions noted below.

[0053] Hardware modifications included the following.

* The RJ-11 data jack on the side of the CCP was modified to connect directly to the serial port of the CCP's microprocessor. This allowed the CCP to communicate with an attached positioning device via a serial link.

[0054] Several modifications were made to the CCP's operating software.

* The software polled the serial port once every second looking for location data from the connected positioning device. If data was found and valid position information was included, the data was flagged as valid and stored in a buffer. If no data was found, or if invalid position information was included, the data was flagged as invalid.
* The software displayed a location status on the CCP's display. If location data flag indicated valid data in the buffer, the display would be updated with latitude and longitude information alternating every five seconds. If the data was flagged as invalid, an "Invalid Loc Data" message was displayed every five seconds.
* The function of the "Data" key was changed to provide the following functionality. When the Data key was pressed by a user/tester, the CCP would automatically initiate a call. The dialed digits included a 3-digit programmable feature code (FC) followed by 15 digits of position information (8 longitude digits followed by 7 latitude digits). Once the call was successfully initiated, control of the CCP was returned to the tester.
* The "Lock" key functionality was modified such that it would act as a toggle for a Tracking Mode. If the Tracking Mode was currently off when the Lock key was pressed, the CCP software would enable the mode; if the mode was on when the key was pressed, the software turned off the mode. While in the Tracking Mode, the CCP software maintained complete control of the phone; the tester could only press the Lock key, which would lead to the mode being disabled and control returned to the tester. While in the Tracking Mode, the CCP would initiate calls automatically in a pre-programmed interval. The call initiation was identical to that corresponding to the Data key press,

but the duration of the call and the time between calls were determined by a set of programmable parameters.

* The CCP's service utility was modified to allow the feature code for the Data key to be programmed. Modifications were made also to allow programming of the feature code, call duration, and between-call interval for Tracking Mode.

[0055] The positioning devices were Lowrance OEM GPS receivers, although any such geographical positioning system may be employed. These receivers were capable of receiving signals from location acquisition systems such as GPS satellites, processing the signals, and computing a location estimate based on those signals. One GPS receiver was connected to each CCP-2000 phone through a serial data cable. The GPS receivers automatically forwarded location information messages once every second. These messages contained the receiver status, position status, and position information. The resolution of GPS receivers is highly dependent upon environmental factors and varies continuously. Under typical conditions, a GPS receiver that is receiving data from three or more satellites will have an accuracy of 50 to 100 meters.

[0056] While there has been shown and described herein what are presently considered the preferred embodiments of the invention, it will be apparent to those skilled in the art that various changes and modifications can be made therein without departing from the scope of the invention as defined by the appended claims.

Claims

1. A method of determining the location of a mobile station in a cellular system comprising a plurality of cell sites each including a plurality of mobile stations in communication with a base station, and comprising a plurality of interconnected mobile switching centres each in communication with the base stations of certain cell sites, wherein each mobile switching centre maintains network identification data for each mobile station being served in said certain cell sites, the method comprising the steps of:

   receiving network identification data from one of the mobile switching centres, wherein the network identification data defines the placement of the mobile station within the cellular system;

   converting the received network identification data into geographical location information using geographic maps of radio coverage;

   characterised in that
   the network identification data are transmitted contemporaneously with a voice channel from the mobile switching centre serving a cell site in which the mobile originates communication, and
   performing the following additional steps before transmitting said network identification data:

   transmitting an identity code assigned to the communicating mobile station in a cellular channel from the mobile switching centre;

   prompting the mobile switching centre with said identity code to request the network identification data for said communicating mobile station;

   at the mobile switching centre, responsively retrieving the requested network identification data using the identity code.

2. The method according to claim 1 **characterised in that** the method is performed in response to a trigger command from the mobile station.

3. The method according to one of claims 1 to 2 **characterised in that** the network identification data include data identifying the communications trunk group serving the mobile station, a member number, and cell and/or sector ID.

4. A location finding assembly in a cellular system adapted to perform all the steps of the method according to one of claims 1 to 3.

Patentansprüche

1. Verfahren zum Bestimmen des Ortes einer Mobilstation in einem zellularen System, das eine Vielzahl von Zellen-Standorten umfasst, die jeweils eine Vielzahl mit einer Basisstation in Verbindung stehender Mobilstationen enthält, und das eine Vielzahl von miteinander verbundenen Mobil-Vermittlungszentren umfasst, die jeweils mit den Basisstationen von bebestimmten Zellen-Standorten in Verbindung stehen, wobei jedes Mobil-Vermittlungszentrum Netzwerk-Identifikationsdaten für jede Mobilstation, die in den bestimmten Zellen-Standorten bedient wird, unterhält, wobei das Verfahren die folgenden Schritte umfasst
Empfangen von Netzwerk-Identifikationsdaten von einem der Mobil-Vermittlungszentren, wobei die Netzwerk-Identifikationsdaten die Platzierung der Mobilstation innerhalb des zellularen Systems definieren;
Umwandlen der empfangenen Netzwerk-Identifikationsdaten in geographische Lageinformation unter Verwendung geographischer Funkbedeckungskarten;
dadurch gekennzeichnet, dass
die Netzwerk-Identifikationsdaten gleichzeitig mit einem Sprachkanal von dem Mobil-Vermittlungszentrum gesendet wird, das einen Zellen-Standort bedient, in dem die Mobilstation eine Kommunikation hervorbringt, und Durchführen der folgenden zusätzlichen Schritte vor dem Senden der Netzwerk-Identifikationsdaten:

    Senden eines der kommunizierenden Mobilstation zugewiesenen Identitätscodes in einem Zellenkanal von dem Mobil-Vermittlungszentrum;

    Veranlassen des Mobil-Vermittlungszentrums mit dem Identitätscode, die Netzwerk-Identifikationsdaten für die kommunizierende Mobilstation zu verlangen, und

    als Reaktion, in dem Mobil-Vermittlungszentrum Rückgewinnen der verlangten Netzwerk-Identifikationsdaten unter Verwendung des Identitätscodes.

2. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** das Verfahren als Reaktion auf einen Auslösebefehl von der Mobilstation durchgeführt wird.

3. Verfahren nach einem der Ansprüche 1 bis 2, **dadurch gekennzeichnet, dass** die Netzwerk-Identifikationsdaten Daten enthalten, die die Kommunikations-Kanalgruppe, die die Mobilstation bedient, eine Elementnummer und Zelle und/oder Sektor-ID identifizieren.

4. Lagebestimmungeinrichtung in einem Zellensystem, die eingerichtet ist, alle Schritte des Verfahrens nach einem der Ansprüche 1 bis 3 durchzuführen.

Revendications

1. Procédé de détermination de la position d'une station mobile dans un système cellulaire comprenant une pluralité de sites cellulaires incluant une pluralité de stations mobiles en communication avec une station de base, et comprenant une pluralité de centres de commutation mobiles interconnectés chacun en communication avec les stations de base de certaine sites cellulaires, dans lequel chaque centre de commutation mobile maintient les données d'identification du réseau pour chaque station mobile servie dans les dits certains sites cellulaires, le procédé comprenant les étapes suivantes :

    réception des données d'identification du réseau depuis un des centres mobiles de commutation, dans lequel les données d'identification du réseau déterminent la position de la station mobile à l'intérieur du système cellulaire ;
    conversion des données reçues d'identification du réseau en une information de positionnement géographique en utilisant des cartes géographiques de couverture radio;

    caractérisé en ce que
    les données d'identification du réseau sont transmises simultanément avec le canal vocal depuis le centre de commutation mobile servant un site cellulaire dans lequel le mobile débute une communication, et
    que les étapes additionnelles suivantes sont effectuées avant de transmettre les dites données d'identification du réseau :

transmission d'un code d'identité assigné à la station mobile en communication dans un canal cellulaire à partir du centre de commutation mobile ;
appel du centre de commutation mobile avec le dit code d'identité pour requérir les données d'identification du réseau pour la dite station mobile en communication ;
reconstitution des données d'identification du réseau requises en réponse en utilisant le code d'identité au centre de commutation mobile.

2. Procédé selon la revendication 1, **caractérisé en ce que** le procédé est effectué en réponse à une commande de déclenchement de la station mobile.

3. Procédé selon l'une quelconque des revendications 1 et 2, **caractérisé en ce que** les données d'identification du réseau incluent des données identifiant le groupe de liaison des communications servant la station mobile, un numéro de membre et une identification de cellule et/ou secteur.

4. Ensemble de détermination d'une position dans un système cellulaire adapté pour effectuer toutes les étapes du procédé selon l'une des revendications 1 à 3.

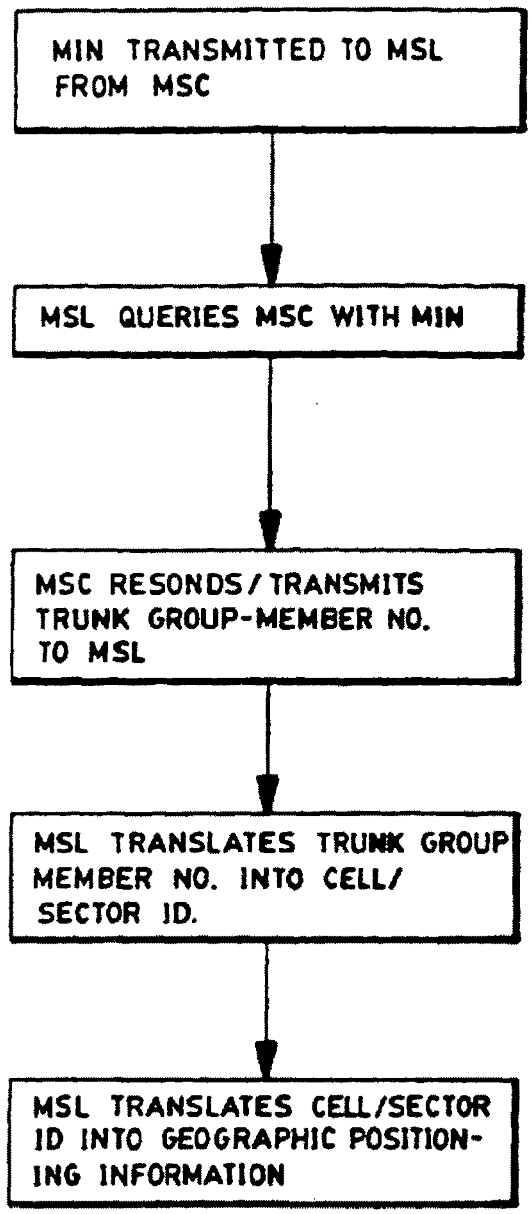
MIN TRANSMITTED TO MSL FROM MSC
MSL QUERIES MSC WITH MIN
MSC RESONDS/TRANSMITS TRUNK GROUP-MEMBER NO. TO MSL
MSL TRANSLATES TRUNK GROUP MEMBER NO. INTO CELL/ SECTOR ID.
MSL TRANSLATES CELL/SECTOR ID INTO GEOGRAPHIC POSITIONING INFORMATION

FIG. 1

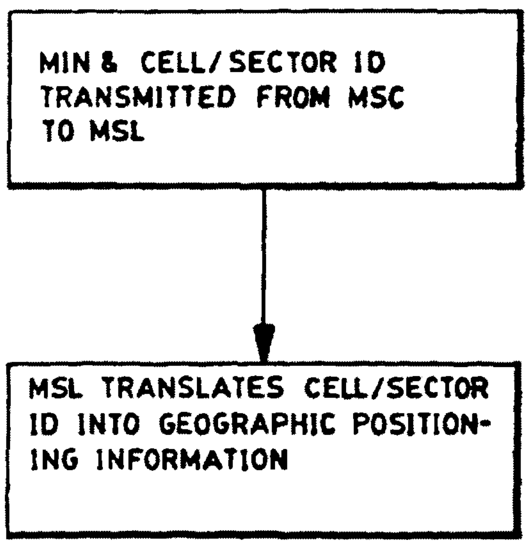
MIN & CELL/SECTOR ID TRANSMITTED FROM MSC TO MSL
MSL TRANSLATES CELL/SECTOR ID INTO GEOGRAPHIC POSITIONING INFORMATION

FIG. 2

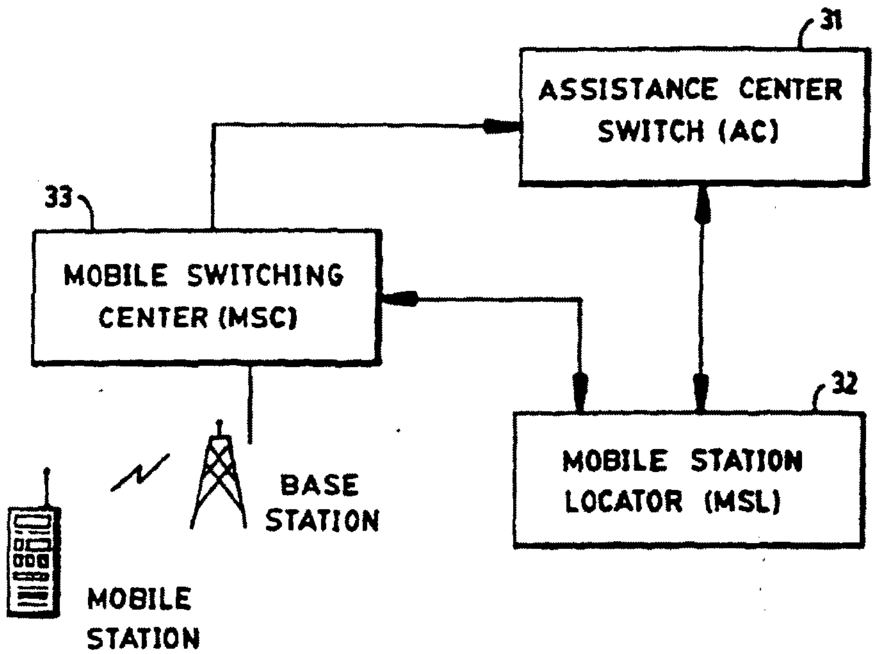
31
ASSISTANCE CENTER SWITCH (AC)
33
MOBILE SWITCHING CENTER (MSC)
32
MOBILE STATION LOCATOR (MSL)
BASE STATION
MOBILE STATION

FIG. 3

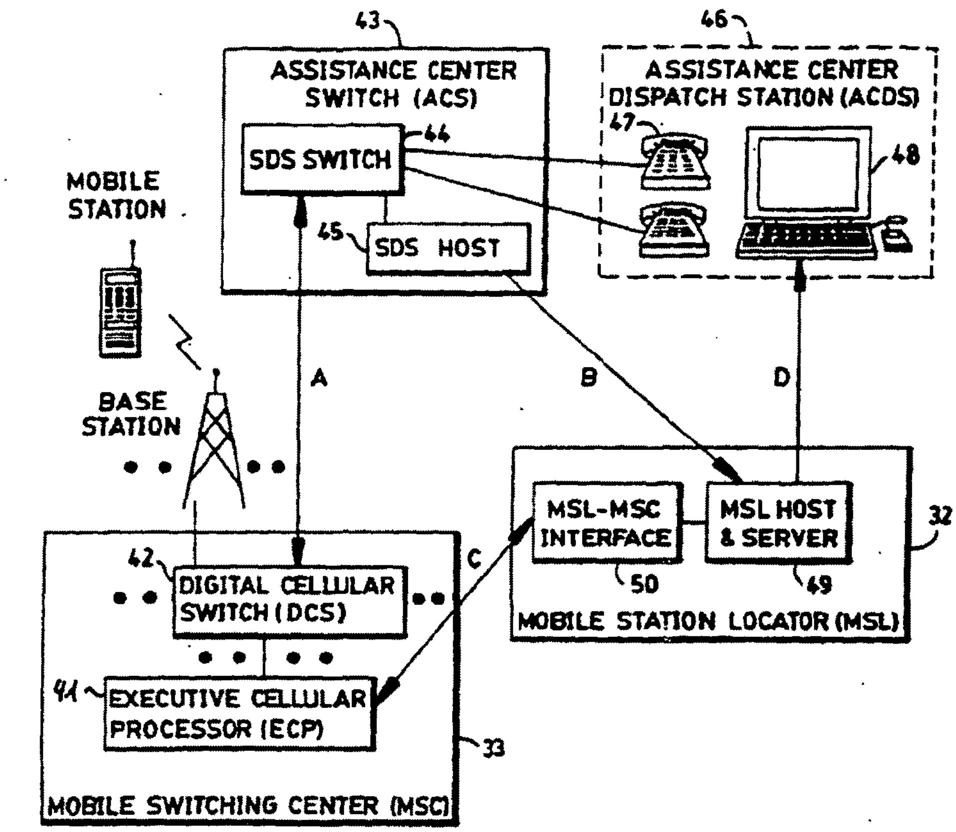
43
ASSISTANCE CENTER SWITCH (ACS)
46
ASSISTANCE CENTER DISPATCH STATION (ACDS)
47
SDS SWITCH
44
48
MOBILE STATION
45
SDS HOST
BASE STATION
A
B
D
MSL-MSC INTERFACE
MSL HOST & SERVER
32
42
DIGITAL CELLULAR SWITCH (DCS)
C
50
49
MOBILE STATION LOCATOR (MSL)
41
EXECUTIVE CELLULAR PROCESSOR (ECP)
33
MOBILE SWITCHING CENTER (MSC)

FIG. 4

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(54) Method for allocating downlink electromagnetic power in wireless networks

(57) A method for allocating downlink power in a wireless network determines downlink transmit powers to permit a target performance goal to be satisfied for defined radio frequency coverage areas. Base stations transmit electromagnetic transmissions. Received signal parameters of the electromagnetic transmissions are measured at measurement locations within defined radio frequency coverage areas. A data processing system determines propagation factors associated with the electromagnetic transmissions as a function of the measurement locations. The data processing system determines a downlink transmit power for at least one of the base stations based upon at least one target performance goal for the coverage areas and the propagation factors.

EP 1 028 543 A1

Description

Field Of The Invention

[0001] The invention relates to a method for allocating downlink electromagnetic power to enhance performance of a wireless network.

Background Of The Invention

[0002] Whenever a wireless network is initially installed or expanded, various wireless parameters must be tuned to proper values prior to full commercial operation. The tuning of wireless parameters is referred to as radio frequency (RF)network optimization. The RF optimization includes adjusting the downlink transmit power of base stations.

[0003] Wireless service providers often have relied upon a trial-and-error strategy to optimize radio frequency antenna coverage of cells or other geographic areas within a wireless network. The trial-and-error strategy requires repeated measurements at the same locations through iterative test drives until a feasible downlink transmit power for each base station is found. The test drive refers to taking radio frequency measurement samples from a vehicle which is equipped to measure radio frequency parameters versus location while driving through the coverage area of a wireless network. Based on recorded measurements of parameters in a cluster of cells during a test drive, recommendations on adjusting system parameters are established. However, the trial-and-error approach sometimes leads to quality deterioration or service interruption if incorrect recommendations are applied to an operational system. After the recommended changes to system parameters are implemented, another test drive typically is completed to validate system performance. If the latest test drive did not indicate adequate performance, the wireless network or expansion may be delayed from commercial operation, while yet another round of parameter adjustments is followed by a corresponding test drive.

[0004] Even if a wireless network timely goes into commercial operation, improper radio frequency optimization may reduce the capacity of a wireless network. Failure to accurately set the parameters of downlink transmit power may lead to unnecessary expenditures for capital intensive cellular infrastructure. For example, additional channel capacity or additional cell sites, which are not truly needed, may be added to compensate for an incorrectly optimized wireless system.

[0005] The trial-and-error approach to optimization wastes valuable time of engineering and technical resources by often entailing iterative or multiple field measurements to obtain an acceptable solution for radio frequency optimization. The repetitive nature of the trial-and-error tends to make such an approach difficult or impractical for handling large networks. Thus, a need exists for improving the accuracy of optimization rather than relying on the time-consuming and happenstance accumulation of empirical data.

[0006] During radio frequency optimization, the overall geographic coverage area may be divided into clusters of smaller geometric regions, each encompassing a few adjacent cells. The trial-and-error approach is then applied to the clusters, one after another. After finishing all clusters, the wireless network is reoptimized as a whole, particularly at the boundary between clusters, with the same trial-and-error method. Thus, the trial-and-error approach is time consuming and may not-even produce suitable or optimum coverage results.

Summary Of The Invention

[0007] In accordance with the invention, a method for allocating downlink transmit-power in a wireless network determines downlink transmit powers to permit a target performance goal to be satisfied for defined radio frequency coverage areas. Base stations transmit electromagnetic transmissions. Received signal parameters of the electromagnetic transmissions are measured at measurement locations within defined radio frequency coverage areas. A data processing system determines propagation factors associated with the electromagnetic transmissions as a function of the measurement locations. A data processing system determines a downlink transmit power for at least one of the base stations based upon at least one target performance goal for the coverage areas and the propagation factors.

[0008] The target performance goal may comprise a target carrier-to-interference ratio for the coverage areas with reference to the propagation factor associated with each of the measurement locations. The processing system may calibrate the downlink transmit power to satisfy the target carrier-to-interference ratio for the measurement locations with a defined reliability. For example, the downlink transmit power may be selected such that a corresponding actual carrier-to-interference ratio meets or minimally exceeds the target-to-carrier interference ratio for the measurement locations with a defined reliability. The defined reliability may be defined in terms of probability or other statistical measures.

[0009] The systematic attributes of the method and its associated data structure increase the efficiency of radio frequency optimization by eliminating the recursive or iterative nature of taking field measurements pursuant to the conventional trial-and-error approach. Moreover, the method of the invention is well-suited for reliable execution on a general purpose computer.

Brief Description Of The Drawings

[0010]

FIG. 1 is a flow chart illustrating a general method of allocating downlink transmit power in accordance with the invention.

FIG. 2 is a flow chart providing an illustrative example of the method of FIG. 1.

FIG. 3 shows a measuring procedure for measuring signal power in a wireless network in accordance with the invention.

FIG. 4 is an example of a data format for organizing signal power measurements acquired during the measuring procedure of FIG. 3.

FIG. 5 shows a received signal power at various measurement locations for the wireless network of FIG. 3 prior to adjusting downlink transmit power in accordance with the invention.

FIG. 6 shows a received signal power at various measurement locations for the wireless network of FIG. 3 after adjusting downlink transmit power in accordance with the invention.

FIG. 7 shows the received carrier-to-interference ratio at various measurement locations for the wireless network of FIG. 3 prior to adjusting downlink transmit power in accordance with the invention.

FIG. 8 shows the received carrier-to-interference ratio at various measurement locations for the wireless network of FIG. 3 after adjusting downlink transmit power in accordance with the invention.

FIG. 9 shows an illustrative system for allocating downlink power to base stations in a wireless network.

Detailed Description Of The Preferred Embodiments

[0011] In accordance with an example shown in FIG. 1, a method for allocating downlink transmit power includes measuring received signal powers; determining a propagation factor from the measured signal powers for each base station; calculating an initial downlink transmit power for each base station based on the corresponding propagation factor; and calibrating the initial downlink transmit power to obtain a resultant downlink transmit power to enhance performance of the wireless network. Performance may be enhanced by reducing co-channel interference in the wireless network or otherwise.

General Method for Power Allocation

[0012] Starting from step S10, a test receiver measures received signal parameters of corresponding base stations at measurement locations within defined radio frequency coverage areas. Although the signal parameters may include signal strength, background noise, or both, in an alternate embodiment the measured signal parameters may comprise signal-to-noise ratio, signal-to-interference ratio, frame-error rate, bit-error rate, or the like. Each defined radio frequency coverage area may represent a sector, a cell, or the like. In one example, step S10 includes measuring background noise associated with each of the measurement locations.

[0013] In step S12, a processing system accepts the measured received signal parameters from step S10 as input. The processing system determines a propagation factor of a respective electromagnetic signal for each of the base stations as a function of the measurement locations. The propagation factor characterizes the unique propagation path between a base station and each measurement location. The base station transmits a downlink electromagnetic transmission to the test receiver at the measurement location via one or more unique propagational paths. The propagation factor represents the aggregate impact of propagational variables for one or more propagational paths between a measurement location and a corresponding downlink base station. The propagation factor inherently considers propagational variables such as free space loss, diffraction loss, and obstruction loss, among others to provide a realistic indication of actual propagation conditions within the wireless network to an accuracy partially determined by the number of measurement locations per geographic area.

[0014] In step S14, the processing system generally determines (e.g., calculates) an initial downlink transmit power within a transmitter power interval for each of the base stations based upon a target carrier-to-interference ratio for the coverage areas. The initial downlink transmit power is determined with reference to the propagation factors associated with corresponding propagational paths between base stations and respective measurement locations. Although the target carrier-to-interference ratio may be uniform for the entire network, the target carrier-to-interference ratio may be different for different geographic coverage areas to tailor radio frequency coverage to meet traffic conditions or reliability concerns.

[0015] In one illustrative example, step S14 preferably includes calculating the initial downlink transmit power for each of the base stations with reference to each measurement location based upon the target carrier-to-interference ratio, the measured signal powers, the measured background noise, and the propagation factors.

[0016] In step S16, the processing system calibrates the initial downlink transmit power to obtain a resultant downlink transmit power satisfying the target carrier-to-interference ratio for the measurement locations with a defined reliability. The defined reliability may represent the probability of the resultant downlink transmit power meeting or exceeding a target threshold in a particular geographic coverage area, where the target threshold is a signal parameter (e.g., signal strength) corresponding to the target carrier-to-interference ratio. In an example, the resultant downlink transmit power is selected such that a corresponding actual carrier-to-interference ratio meets or minimally exceeds the target-to-carrier interference ratio for the measurement locations with a defined reliability.

[0017] The defined reliability may represent a minimum probability or percentage of time in which the actual carrier-to-interference ratio meets or exceeds the target carrier-to-interference ratio for the aggregate measurement locations associated with a corresponding geographic coverage area. The reliability may be expressed as a fraction in which the numerator includes the number of measurement locations in a geographic area that permit the target to carrier-to-interference ratio to be exceeded. The denominator of the fraction represents the total number of measurement locations in the same geographic area that are considered.

[0018] The resultant downlink power may be referred to as the minimal downlink power corresponding to an actual carrier-to-interference ratio meeting or exceeding the target carrier-to-interference ratio with a given probability. The actual carrier-to-interference ratio preferably meets or minimally exceeds the target-to-carrier interference ratio for the measurement locations with a defined reliability consistent with the known maximum power of each of the base stations. Each resultant downlink power may be viewed as a function of the calibration factor, the target carrier-to-interference ratio, the measured signal powers, the measured noise signal powers, the propagation factors, and the measurement locations.

[0019] At the fixed end, the base station is associated with a power adjuster for adjusting its downlink power. For example, the base station may include an integral power control device for producing a continuously variable transmit downlink power or discrete steps of transmit downlink power. In an alternate embodiment, a base station includes an adjustable attenuator coupled to a radio frequency transmit port of the base station. The maximum transmitter power is the highest transmit power that the base station is capable of producing based on hardware limitations, governmental regulations, or both. The downlink transmit power may be normalized for a scale ranging from 0 to 1, with one being the maximum transmitter power. The normalization of the downlink transmit power provides a convenient format for subsequent mathematical operations. The downlink power, once set, remains fixed for a reasonable time which exceeds the duration of a typical expected call.

[0020] Antennas are coupled to the base stations. The transmit-power allocation method of the invention produces the best results if the antennas are installed with proper orientations. If the antennas are installed with proper orientations, minimal or no radio frequency coverage improvement can be achieved by changing the antenna orientation or other antenna parameters. Here, a radio frequency coverage improvement means that the carrier-to-interference ratio could be enhanced without reducing traffic capacity of the wireless network. Nevertheless, even if the antennas are not properly oriented, antennas with corresponding fixed radiation patterns are sufficient to carry out the power allocation method. Although both the orientation and radiation patterns of the antennas contribute to the actual carrier-to-interference ratio of the wireless network, the antenna orientation for a directional antenna and the transmitter power are mutually independent parameters; hence, capable of independent power adjustment.

Mathematical Calculations for Power Allocation

[0021] FIG. 2 provides an illustrative example of the mathematical calculations that may underlie the general steps presented in FIG. 1. Step S18 of FIG. 2 describes step S10 of FIG. 1 in mathematical terms. Step S20 of FIG. 2 provides an illustrative mathematical equation which is applicable to step S12 of FIG. 1. Steps S22, S22 and S24 provide a group of mathematical equations which are applicable step S14. Step S28 and step S30 disclose mathematical equations which are applicable to step S16.

[0022] Beginning in step S18, a test receiver measures received signal powers $V_i(x)$ of corresponding base stations, i = 1, 2,...,n at measurement locations x within defined radio frequency coverage areas S_i for i = 1, 2,...,n. The measurement of the received signal power provides a basis for determination of the propagation factor in step S20. On the mobile side, m measurement locations are selected and considered representative of a desired radio frequency network coverage.

[0023] A measurement location is a geographical point where a mobile station is supposed to obtain communications service from the wireless network. A test receiver measures a received signal transmitted by the base station with a known downlink transmit power. The known downlink transmit power typically represents a pre-adjustment transmit power if any iteration of the allocating procedure is independently considered from all other iterations. In an illustrative example, the measured signal parameters include received signal strengths and background noise. The test receiver measures the received signal strength at the measurement locations which may be selected on the basis of traffic distribution or other business concerns. In addition, the test receiver may measure the noise N(x). The signal strength parameter measurements preferably are normalized to allow ready comparisons of all measurements and mathematical manipulation in subsequent procedures.

[0024] In step S20, a propagation factor $E_i(x)$ is determined for each of the base stations i= 1,2,...,n as a function of the measurement locations x in accordance with the following equation:

$$E_i(x)=\frac{V_i(x)\text{-}N(x)}{y_i} \qquad (1)$$

wherein y_i is a known downlink power of base station i, $V_i(x)$ is a received signal parameter (e.g., signal strength) as a function of measurement location x, and N(x) is a background noise power as a function of measurement location x.

[0025] In step S22, a processing system calculates an initial downlink transmit power w_i for each of the base stations i = 1,2...,n based upon a target carrier-to-interference ratio C_i for the coverage areas S_i for i = 1,2,...,n served by the base stations i and the propagation factors $E_i(x)$ for i = 1,2,...,n at each of the measurement locations x. The initial downlink transmit power w_i is calculated such that an actual carrier-to-interference ratio $C_i(x)$ for each cell meets or exceeds a target carrier-to-interference ratio selected as a goal by a user of the adjustment method. As used herein, the actual carrier-to-interference ratio shall refer to the post-adjustment carrier-to-interference ratio, unless otherwise specified. However, the actual carrier-to-interference ratio should just barely exceed or minimally exceed the target carrier-to-interference ratio, to minimize transmit power and thereby increase system capacity. Moreover, minimizing transmit power reduces concerns of electromagnetic biological hazards. To adjust the downlink transmit power, the actual carrier-to-interference ratio at those m locations are set above a target carrier-to-interference with reference to a certain probability. The probability and the corresponding target carrier-to-interference are selected as goals by a user of the power allocation method in accordance with the invention.

[0026] The actual carrier-to-interference ratio $C_i(x)$ may be expressed as a function of measurement location x, propagation factor $E_i(x)$, noise N(x), and transmitter power y_i in accordance with equation 18. (See equation 18 in the Mathematical Models section infra where many numerically referenced equations are presented in sequential order.) The actual carrier-to-interference ratio for a cell is determined for each measurement location within the cell, based on measurement of received signal parameters, such as signal strength, received noise, or both, in step S18. The measured signal strength and measured noise of step S18 may be used in conjunction with equation 18 to determine the actual carrier-to-interference ratio.

[0027] The target carrier-to-interference ratio C_i for a cell is selected as a goal by the user. If the actual-carrier to interference ratio is equal to or greater than the target carrier-to-interference with a given probability, the actual carrier to interference satisfies the target carrier-to- interference. Equation 20 (see Mathematical Models section infra) describes the target carrier-to-interference as a constant for all the measurement locations within a cell, a sector, or another defined geographic coverage area.

[0028] Step S22 involves calculating the initial selected downlink power within a downlink power interval by completing the following mathematical procedure. First, a vector

$$\mathbf{z}=\{z_i\}^n{}_{i=1}$$

and a matrix

$$\mathbf{A}=\{a_{ij}\}^n{}_{i,j=1}$$

are constructed in accordance with the following equations:

$$z_i = C_i \frac{\sum_{k=1}^{m} N(x_k) E_i(x_k)}{\sum_{k=1}^{m} E_i^2(x_k)} \quad (2)$$

$$a_{ij} = C_i \frac{\sum_{k=1}^{m} E_i(x_k) E_j(x_k)}{\sum_{k=1}^{m} E_i^2(x_k)} \quad (3)$$

wherein C_i represents a carrier-to-interference ratio for a defined coverage area i, $E_i(x)$ is a propagation factor for first set of defined coverage areas i, $E_j(x)$ is a propagation factor for a second set of defined coverage areas distinct from the first set, $N(x_k)$ represents background noise, m is the considered (e.g., total) number of measurement locations x, k represents a particular measurement location, and n is the total number of the defined coverage areas within the first set and the second set.

[0029] Second, an iterative procedure is applied to the vector **z** and matrix **A** to solve for the vector

$$\mathbf{w} = \{w_1, w_2, w_3, ...w_n\}$$

starting with

$$\mathbf{w}^{(0)} = \mathbf{z}$$

in accordance with the following equation:

$$\mathbf{w}^{(n)} = \mathbf{w}^{(0)} + \mathbf{A} \cdot \mathbf{w}^{(n-1)} \quad (4)$$

[0030] The foregoing equation (equation 4) is an iterative equation, which is applied until a desired precision is reached. A desired precision is reached if a difference between the result of the last previous iteration and the present result is less than a defined threshold. For example, the defined threshold may be empirically determined by field studies of wireless networks.

[0031] However, if the result of equation 4 does not converge, the solution for vector **w** may be estimated by a first iteration, a second iteration, or the latest iteration that is sufficiently reliable and consistent with earlier iterations. For example, the first iteration of equation 4 has

$$\mathbf{w} = \mathbf{z}.$$

[0032] Although the vector **w** falls within a downlink power interval, the initial downlink power is preferably mathematically treated to render a more exact solution or verify its exactness prior to adjusting the downlink transmit power of the base station. Once the initial downlink power is treated or verified to be sufficiently reliable, the initial downlink power may be referred to as the resultant downlink transmit power. In any event, the initial downlink transmit power should not be confused with the measured, received downlink transmit power of step S18, which merely represents a field measurement, as opposed to the determination of a suitable power setting for radio frequency coverage enhancement.

[0033] The rationale behind the equations for calculating the initial downlink power is best understood with reference to equation 23 (see Mathematical Models section infra), which forms the basis for equations 2, 3, and 4. Equation

23 represents a square error difference between the target carrier-to-interference and the measured carrier-to-interference. If the square error difference is minimized, the result defines a power interval in which a resultant downlink transmit power may be found for the base station. In practice, each base station may have a unique power interval and a corresponding unique resultant downlink transmit power.

[0034] Equation 23 is a basic expression of the minimum-square error approach for determining the resultant base station powers for each selected base station in the wireless network. The resultant base station downlink power is determined to achieve the target carrier-to-interference ratio or to minimally surpass the target carrier-to-interference ratio. Once the resultant downlink transmit power is applied to a wireless network, the resultant downlink transmit power may be referred to as a post-adjustment downlink transmit power. Equation 24 expresses the value of y that can minimize equation 23. Equation 26 is a vector representation of equation 24 used merely to simplify the expression of equation 24. Equation 26 may be rewritten as equation 31.

[0035] While the solution of equation 31 represents the resultant downlink transmit power for each base station, execution of equation 31 may be problematic because of typical computer hardware limitations. Typical hardware limitations include quantization error and limitations on the maximum number of significant digits for mathematical calculations. Accordingly, inverting the matrix of equation 31 tends to produce a crash of computer operations or lead to inaccurate results. Accordingly, instead of solving equation 31, the processing system first attempts to solve equation 26 by application of equation 4, as previously discussed to reduce the potential for inoperative problems with computers or inaccurate results. Thus, the foregoing approach as set forth in equations 2, 4, and 4, represents more than merely a theoretical solution to the problem of attaining a suitable resultant downlink transmit power for each selected base station in the wireless network. Rather, equations 2, 3, and 4 represent the refinement and tempering of raw mathematical equations into a practical algorithm well-suited for reliable operation in a general purpose computer or another data processing system. Moreover, in an example equation 4 is iterative and may be solved merely by using multiplication, which makes it resistant to the numerical instability as may occur by division or matrix inversion.

[0036] In step S24, a processing system determines if the above iterative calculation of the initial downlink transmit power w_i converge to indicate a solution for w_i

[0037] The relation between the convergence of the iteration of equation 4 and the physical attributes of a particular wireless network provides the additional information with regard to the quality of the network. Divergence of the algorithm indicates serious design weakness of the wireless network, such as an unintentionally redundant radio frequency coverage of different base stations.

[0038] Alternatively, rather than attaining a global solution of the equation 4 in step S22, an approximation can provide a local solution of an initial downlink transmit power within a transmit power interval for corresponding base stations. The global solution is preferred to the local solution because the results are more accurate. In step S26, the processing system calculates w_i in accordance with the following approximation:

$$w_i = \frac{C_i}{\min_{x \in S_i} C_i(x,1)} \tag{5}$$

wherein C_i represents a carrier-to-interference ratio for a defined coverage area i, x represents a measurement location, w_i represents an initial downlink power for base station i within a power interval, and S_i refers to defined measurement locations x within the coverage area i.

[0039] Alternately, the following set of equations may be used instead of equation 63:

$$y_i \approx C_i \cdot \frac{N^{M,i} + \sum_{j \neq i} E_j^{M,i}}{E_i^{m,i}} \qquad (6)$$

$$E_j^{M,k} = \max_{x \in S_k} E_j(x) \qquad (7)$$

$$E_i^{m,k} = \min_{x \in S_k} E_i(x) \qquad (8)$$

$$N^{M,i} = \max_{x \in S_i} N(x) \qquad (9)$$

wherein y_i is a known downlink power of base station i, C_i represents a carrier-to-interference ratio for a defined coverage area, $E_i(x)$ is a propagation factor for first set of defined coverage areas i, $E_j(x)$ is a propagation factor for a second set of defined coverage areas distinct from the first set, N(x) represents background noise, m is the considered (e.g., total) number of measurement locations x, k represents a particular measurement location, S_i represents defined measurement locations x (e.g., measurement locations that are relevant because of traffic considerations in the wireless network) within a coverage area i, and S_K represents defined measurement locations x within a coverage area k.

[0040] Both equations 5 and 74 represent a local approximation of the initial downlink transmit power. One of the difficulties in arriving at a solution is that any change of downlink transmit power in one geographic coverage area (e.g., cell) may theoretically have a secondary impact all other geographic coverage areas. Where the secondary impact on other geographic coverage areas is ignored to some extent, a localized solution for the initial downlink transmit power may be obtained, such as pursuant to equation 5. However, the accuracy of the solution of equation 5 is less than the accuracy of the solution of equation 4, so equation 4 may be preferred and equation 5 may be relegated to the role of a contingent alternative to equation 4. Equation 5 or 74 is particularly applicable where equation 4 diverges or does not converge.

[0041] In step S28, a processing system determines a calibration factor α based upon a known maximum power y_i^M of each of the base stations at each geographic area S_i FOR i = 1,2,...,n in accordance with the following equation:

$$\alpha = \min_{i=1}^{n} \left\{ \frac{y_i^M}{w_i}, \max_{i=1}^{n} \max_{x \in S_i} \frac{C_i \cdot N(x)}{w_i E_i(x) - C_i \sum_{j=1}^{n} w_j E_j(x)} \right\} \qquad (10)$$

wherein y_i^M is a known maximum downlink power of base station i, C_i represents a carrier-to-interference ratio for a defined coverage area, $E_i(x)$ is a propagation factor for first set of defined coverage areas i, $E_j(x)$ is a propagation factor for a second set of defined coverage areas distinct from the first set, N(x) represents background noise, x represents a measurement location, n represents a total number of the first set or the second set, w_i represents an initial downlink power for base station i within a power interval, and w_j represents an initial downlink power for base station j within a power interval.

[0042] Equation 10 is directed at solving a problem posed by the minimum-square error approach set forth in step S22 or of the approximation in step S26. In the minimum-square error approach the initial downlink power is represented as a downlink power interval containing the true resultant downlink power. The calibration factor is determined to bring out the true resultant downlink power from within the downlink power interval as further described in step S30.

[0043] In step S30, a processing system calibrates the initial downlink transmit power w_i for each base station i= 1,2,...,n with the determined calibration factor α to obtain a resultant downlink transmit power y_i superseding the initial downlink transmit power, in accordance with the following equation:

$$y_i = \alpha\, w_i \text{ for } i = 1,2,\ldots,n. \qquad (11)$$

The resultant downlink power represents a refinement of the initial downlink transmit power. Equation 10 takes an initial downlink transmit power within a transmit power interval and scales the initial transmit power to the resultant transmit power that equals or just exceeds the target carrier-to-interference ratio with reference to a probability. Because the initial downlink transmit power, w, is distributed within the transmit power interval corresponding to the target carrier-interference ratio, one value of w within the transmit power interval may correspond to an actual carrier to interference ratio that exceeds the target carrier to interference ratio, while another value of w within the transmit power interval may correspond to an interference ratio that is greater than the target carrier-to-interference ratio. The attenuation factor makes the result w fall within the portion of the power interval that corresponds to a resultant downlink transmit power that meets or minimally exceeds the target carrier-to-interference ratio. The determination of the minimum-square equation, in effect, redistributes the carrier-to-interference ratios along the measurement locations, while the calibration adjusts the minimum-square error result to fit the inequality given by the target carrier-to-interference ratio.

[0044] The solution expressed as resultant transmit powers may be accompanied with an appropriate cautionary language or a confidence factor indicating the reliability of the solution. For example, equation 4 has a sufficiently high reliability when a certain minimum number of iterations are completed and the successive differences between the solutions falls under a threshold value. Therefore, solutions from equation 4 have the highest confidence when the threshold value is met. If the successive iterations of equation 4 do not converge, the latest iteration before the nonconvergence is used and is associated with a lower level of confidence which is lower than a highest confidence value. If the successive iterations do not converge, Equation 5 may be invoked as an alternative solution with a confidence that is equal to or lower than that of the latest iteration of equation 4 prior to the nonconvergence or divergence.

[0045] While other mathematical methods can be used to solve equation 26 (see Mathematical Models section infra) and reach a set of resultant downlink transmit powers, the other mathematical methods would necessitate subjecting the matrix **A** to different conditions, which may not be appropriate for a realistic engineering model of radio frequency coverage of a wireless network. The method of the invention provides a systematic approach for adjusting transmit power through organized acquisition of field measurements. The method formalizes the testing procedure to reduce labor and effort by employing a mathematical framework representative of signal propagation in a wireless network. As to the quality of the result, the resultant downlink transmit power allocations are mathematically provable as generally optimal, following from the minimum of minimum-square error approach. Moreover, the new procedure applies to unloaded as well as loaded systems, which makes it a natural candidate for the so-called continuous optimization of network.

Mathematical Models for Power Adjustment

[0046] Now that the mathematical principles underlying the power allocation method have been generally discussed, several key mathematical modeling concepts are presented to provide a firm foundation for equations set forth herein. First, a basic definition of carrier-to-interference is presented. Second, a minimum-square error approach is described based upon the basic definitions of the carrier-to-interference and derivations thereof. Third, the mathematical framework surrounding the calibration process is described. Fourth, the local approximation is described as an alternative to the minimum-square error approach.

[0047] Usually, the carrier-to-interference ratio is defined as

$$(C/I)_i := \frac{V_i}{N + \sum_{j=1\, j\neq i}^{n} V_j} \qquad (12)$$

where $(C/I)_i$ refers to the carrier-to-interference ratio associated with base station i, N the background and V_i the received carrier signal power of cell i. It is, however, convenient from the measurement point of view, to use the definition

$$(C/I)_{i,1} := \frac{V_i}{N + \sum_{j=1}^{n} V_j} \qquad (13)$$

[0048] In fact, the procedure could use either definition. This is because there exists a unique mapping between

$(C/I)_{i,1}$ and $(C/I)_i$, i.e.

$$(C/I)_{i,1} = \frac{(C/I)_i}{1+(C/I)_i} \tag{14}$$

which is a one-to-one mapping

$$[0,\infty) \mapsto [0,1) \tag{15}$$

Equations 12 and 14 are equivalent and the definition $(C/I)_{i,1}$ will be used in the following equations. Two important terms underlie the power allocation method: (1) the propagation factor and (2) the minimum-square error. The bridge between the propagation factor and the minimum-square error is a basic relationship, which is sought.

[0049] $V_i(x)$ denotes the total received signal power of any geographic coverage region i and at any measurement location x. The geographic coverage region may comprise a sector, a cell, or the like. Now, let y_i be the downlink transmit power of geographic coverage region i. As a result of the linearity of the Maxwell's equations,

$$V_i(x)=y_iE_i(x)+N(x), \tag{16}$$

where $E_i(x)$ is a function that is independent of y_i, N(x) is the noise received at the measurement location x. The background noise N(x) includes all other signals than the wanted signal intended to serve the geographic coverage region. The background noise is received in the same frequency bandwidth, and includes more than just thermal noise. By this definition of N(x), $V_i(x)$ has been associated with all unwanted electromagnetic powers receivable at location x. Thus, the power allocation method of the present invention is advantageously applicable to a loaded wireless network, an unloaded wireless network, or both because of the manner in which the noise is defined.

[0050] Because both N(x) and $V_i(x)$ are physically measurable, $E_i(x)$ can be determined for given y_i. $E_i(x)$ refers to the propagation factor, because it accounts for the attenuation of the signal strength, or another measurable effect of a different signal parameter, caused by the propagation of electromagnetic waves. In a CDMA(e.g., CDMA IS-95) network, the quantity $y_iE_i(x)$ may correspond to the energy per chip E_c, which can be derived from the product of two values that can be measured by the pseudo-noise scanning receiver directly, for example,

$$\frac{E_c}{I_0} \cdot I_0 W = E_c \cdot W, \tag{17}$$

where W is the known bandwidth and I_0 refers to the total interference.

[0051] Let $C_i(x)$ be the carrier-to-interference ratio for geographic coverage area i and at measurement location x, then, according to the definition of expression 13,

$$C_i(x) = \frac{y_i \cdot E_i(x)}{N(x) + \sum_{k=1}^{n} y_k \cdot E_k(x)} \tag{18}$$

where $y_i \cdot E_i(x)$ is the signal power received at location x from geographic coverage area i and the wireless network includes a total of n co-channel cells. Through the signal power, function $C_i(x)$ is indirectly measurable at location x. In the denominator, N(x) is used to account for the background noise including the thermal noise; the background noise is dependent of location x. Under the definition given above,

$$N(x)=\sum_{j=1}^{n} V_j(x)-\sum_{j=1}^{n} y_jE_j(x) \tag{19}$$

Thus, while considering the pilot channel in an IS-95 system as an illustrative example, N(x) also includes the interference from the traffic signals in the example.

[0052] Prior to the deployment of the network, the coverage area of each cell is usually defined according to the network plan, so that correspondence between any test measurement locations x and a radio frequency geographic coverage area (i.e. cell) can be identified except for the hand-off region. The purpose of the RF power allocation is to achieve at actual carrier-to-interference ratio meeting or minimally exceeding the target carrier-to-interference ratio in all coverage areas (i.e. cells) with a given probability. The target carrier-to-interference ratio may depend on the cell in which the test mobile station is momentarily located. A realistic assumption is

$$C_i(x) \geq \begin{cases} C_i & \text{for} \quad x \in S_i \\ 0 & \text{elsewhere} \end{cases} \qquad (20)$$

for positive C_i's, where S_i refers to the area covered by cell i. In reality, the network operator is only concerned with measurement locations x that are relevant to the expected traffic. The test drive, as best illustrated in FIG. 3, preferably includes such measurement locations x. Consequently, S_i refers to the measurement locations x of geographic region i rather than any potential location in the whole geographic region (i.e. cell). Now that the target carrier-to-interference ratio of C_i is given, it follows from equation 18 that

$$y_i \frac{1}{C_i} E_i(x) \geq \sum_{k=1}^{n} y_k E_k(x) + N(x) \qquad (21)$$

for $x \varepsilon A_i$ with the only unknowns $y_1, y_2 \ldots, y_n$. The foregoing equation is the basic relation to begin the minimum-square error approach.

[0053] From equation 21 an equation and an inequality relation is obtained. One might first consider the equation and set the goal as finding y_i such that the equation holds true. However, equation 21 cannot hold true for all **x**, because usually the domain contains more points x than the number of base station (transmitters) n. In other words, the equation does not have a solution in C(S), where C(S) refers to the set of continuous functions over the domain of $E_i(x)$, i=1, 2, . ., n, and N(**x**)

$$S = \cup_{i=1}^{n} S_i, \qquad (22)$$

wherein S represents the route of the test drive over which one or more test receivers take measurements of the received signal at measurement locations x.

[0054] Instead of the above approach to solving equation 21, a solution in terms of the minimum-square error (MSE) between the left hand and the right hand of equation 21 can be found. Equation 21 may be solved with $L^2(S)$, the function space over S with Legesque L^2 norm, if the goal is changed to finding y_i, i=1, 2, . . ., n that makes the following equation minimal:

$$\int_S \left| \frac{1}{C_i} y_i E_i(x) - \sum_{j=1}^{n} y_j E_j(x) - N(x) \right|^2 dx \qquad (23)$$

The necessary mathematical conditions of the minimum-square error can be found by differentiating equation 23 with respect to y_i for i=1, 2, . . ., n, resulting in:

$$\sum_{j=1}^{n} y_i \langle E_i | E_j \rangle + \langle E_i | N \rangle = \frac{1}{C_i} y_i \langle E_i | E_i \rangle \qquad (24)$$

for $C_i \neq 1$, where

$$\langle E_i | E_j \rangle := \int_S E_i(x) E_j(x)\, dx \qquad (25)$$

If $\langle E_i | E_i \rangle \neq 0$, the equation 24 can be written in vector format as:

$$\mathbf{A} \cdot \mathbf{y} + \mathbf{z} = y \qquad (26)$$

where

$$\mathbf{y}^t = \{y_1, y_2, \ldots y_n\}$$
$$\mathbf{z}^t = \{z_1, z_2, \ldots, z_n\}$$
$$\mathbf{A} = \{a_{ij}\}$$

with

$$z_i = C_i \frac{\langle E_i|N \rangle}{\langle E_i|E_i \rangle} \qquad (27)$$

and

$$a_{ij} = C_i \frac{\langle E_i|E_j \rangle}{\langle E_i|E_i \rangle} \qquad (28)$$

As the power vector y is of primary concern as the solution of equation 26, the reasonable question to raise here is whether equation 24 has a solution, and if it does whether or not the solution is unique. The answer to this question may be based on the Fredholm alternative in Banach space, as set forth in L. Raade, B. Westergre, *BETA: Mathematics Handbook,* CRC Press, Boca 1992, pp.264-267.:

[0055] Let **K** be a compact (integral) operator in Banach space B. Then the equation

$$f - K\mathbf{f} = g \qquad (29)$$

has a unique solution f ε B for any g ε B if the equation

$$f\text{-}Kf = 0 \qquad (30)$$

admits only the trivial solution f = 0.

[0056] If equation 26 has a homogenous solution, then

$$\mathbf{A} =$$

$$\mathbf{I}.$$

So, as long as this is not the case, the solution of equation 26 is unique. The solution can be expressed as

$$\mathbf{y} = (\mathbf{I} - \mathbf{A})^{-1} \cdot \mathbf{z}$$

[0057] There are several methods of determining the inversion of **I** - **A**. However, from a practical point of view, inversion of matrix presents an absolutist yes-or-no solution. The inversion matrix may not provide an pragmatic result intermediate between the extremes. Because the result of solving the inversion matrix may not be adequate for engineers and technicians of wireless service providers, an iteration algorithm is well-suited for obtaining the resultant downlink transmit powers as a system-wide solution for each base station.

[0058] The requirement that ||**A**|| < 1 implies the convergence of the Neumann's series:
The limit of the partial sum

$$\lim_{k \to \infty} \sum_{i=0}^{k} \mathbf{A}^{i} \cdot \mathbf{z} \qquad (32)$$

exists, when the operator norm is less than unit, i.e. $\|\mathbf{A}\| < 1$. This limit of the partial sum represents a basic result of the functional analysis and can be found for instance in Theorem 3.48 in R. Kress, *Numerical Analysis*, Springer, Verlag, New York, 1998, pp.46-47. The following proposition follows, assuming $C_i \neq 1$ and $\langle E_i | E_i \rangle \neq 0$ for all i = 1, 2, . . . , n, so that $\|\mathbf{A}\| < 1$.

Then the series

$$\mathbf{y}^{(k)} = \mathbf{z} + \mathbf{A} \cdot \mathbf{y}^{(k-1)} \qquad (33)$$

converges for $k \to \infty$ and the limit

$$\lim_{k \to \infty} \mathbf{y}^{(k)} =: \mathbf{y} \qquad (34)$$

is the least square solution to equation 21. The above relationship is proved in the following manner. From equation 26, the iteration of equation 33 can be constructed, or the partial sum

$$\mathbf{y}^{(k)} = \sum_{i=0}^{k} \mathbf{A}^{i} \cdot \mathbf{z} \qquad (35)$$

the existence of the $\lim_{k \to \infty} \mathbf{y}^{(k)}$ follows the equation 32. Because equation 26 results from the least square minimization of difference between the left hand and the right hand of equation 21, the solution of equation 26 is the minimum-square error solution to equation 21.

[0059] Equation 26 leads to a result that minimizes the difference between the left hand and the right hand of equation 21 in L^2 norm. In other words, among all possible $\{y_i E_i(x)\}$ that can be found in $L^2(S)$, y generates the set that induces "in average" the smallest square difference between the left and the right hand of equation 21.

[0060] In reality, the carrier-to-interference ratio defined by equation 18 is always less than unitary. So is the target C/I value C_i. Thus, the condition $C_i \neq 1$ is fulfilled. The second condition $\langle E_i | E_i \rangle \neq 0$ is also satisfied, because E_i is the received signal power for unit transmit power. Still, there is the question when is the condition $\|\mathbf{A}\| < 1$ true. From the functional analysis, it is known that the spectral radius that determines the norm of the operator. The spectral radius is given by the maximum of the eigen values, hence

$$\|\mathbf{A}\| = \max\left(|\lambda| : \lambda \textit{ eigenvalues of } \mathbf{A}\right) \qquad (36)$$

To avoid the labor of finding the eigen values, it is in many situations sufficient to know the upper bound, e.g. given in R. Kress, *Numerical Analysis,* Springer Verlag, New York, 1998, pp. 46-47.

$$\|\mathbf{A}\| \leq \left\{ \sum_{i,j=1}^{n} a_{ij}^{2} \right\}^{1/2}. \qquad (37)$$

Roughly speaking, the smaller the a_{ij}s, the higher the chance, that the iteration converges. That means, the small values of a_{ij} indicates a higher practical chance that the minimum-square error problem can be solved. This behavior of the equation 26 has deeper implication to the network quality. This can be seen by introducing a normalization of the propagation factor in the following equation:

$$u_i(x)=\frac{E_i(x)}{\|E_i\|} \tag{38}$$

where $\|E\| = \sqrt{\langle E_i|E_i\rangle}$ is the L^2-norm of E_i. Thus, u_i is the normalized propagation factor, the matrix and the vector can be written in

$$a_{ij} = C_i < u_i \left| u_j > \frac{\|E_j\|}{\|E_i\|} \right. \tag{39}$$

$$z_i = C_i < u_i \left| n > \frac{\|N\|}{\|E_i\|} \right. \tag{40}$$

where $n = N(x)/\|N\|$. By doing so, each matrix element is decomposed into two independent parts. The term $\langle u_i|u_j\rangle$ depends only on the distribution of the normalized propagation factor, not on its absolute value. This is the product of u_i and u_j. Because $\langle u_i|u_j\rangle$ is independent of the downlink transmit power of the base station, $\langle u_i|u_j\rangle$ can be modified or improved by the orientation of the base station antennae rather than adjustment of the transmitter power. Hence, the quality of the network design can be measured by looking at the orthogonality property.

[0061] The normalized propagation factor u_i is a distribution function, describing how the radiated energy of base station i is distributed along the test route S, hence

$$\langle u_i|u_j\rangle \le 1 \tag{41}$$

where the equal sign holds when $i = j$. But, if the equal sign holds when $i \neq j$, then $u_i = u_j$. Physically, the foregoing case means the virtually complete redundancy of the radio frequency coverage of two base stations. On the other hand, if

$$\langle u_i|u_j\rangle = \delta_{ij} \tag{42}$$

where δ_{ij} is the Kronecker's symbol with $\delta_{i,j} = 0$ for $i \neq j$ and $\delta_{i,i} = 1$, then

$$a_{ij} = \delta_{i,j} C_i. \tag{43}$$

Since $\|A\| = \max^n{}_{i=1} C_i$, one can assert when C_i for all i = 1, 2, . . ., n, equation 26 can be solved by iteration of equation 33 if equation 42 is true. Condition equation 42 expresses radio frequency coverage orthogonality. An example of a network fulfilling coverage orthogonality is

$$E_i(x) = \begin{cases} E_i^0 & x \in S_i \\ 0 & x \in S_i \end{cases} \tag{44}$$

with $E^0{}_i > 0$. In the ideal coverage of any RF network, each cell is covered by the corresponding base station only until the cell boundary. That is, after a mobile station transgresses the cell boundary, the base station ideally would no longer provide a signal to the mobile station such that a discrete cell boundary existed.

[0062] However, in reality all signals transmitted by a base station will reach, albeit weaker, beyond the cell boundary, as a result of electromagnetic propagation of the downlink transmit signal. The downlink transmit signal power decays gradually and the coverage orthogonality only represents a mathematical idealization. Obviously, the reality lies between the extremes of complete redundancy (i.e. unwanted overlapping radio frequency coverage) and the coverage orthogonality, i.e. between $\langle u_i|u_j\rangle = 1$ and $\langle u_i|u_j\rangle = \delta_{ij}$. Consequently, the coverage orthogonality can be used as a measure for the radio frequency performance of the wireless network: the smaller $\langle u_i|u_j \rangle$for $j \neq i$, the better the wireless network. So, **A** of a good network has a diagonal or quasi diagonal structure. Besides the product $\langle u_i|u_j \rangle$, the term

$$\frac{\|E_j\|}{\|E_i\|} \quad (45)$$

in equation 40 also contains information about the wireless network. It indicates the balance of the network with respect to the coverage of its base stations. The ratio is unitary when the network is balanced, where no base station dominates the whole network and $\|E_i\|$ is constant for all geographic coverage regions i. Then, the matrix depends only on $\langle u_i|u_j \rangle$and $\langle u_i|u_j \rangle$is power independent for a resultant downlink transmit power. In reality, $\|E_i\|$ is different for different base station i due to the propagational environment and the measurement locations.

[0063] Next, the ratio $\langle u_i|u_j \rangle$is inspected more closely, to see its value in relation to the convergence of iteration of equation 33. The relationship between the ratio and the convergence can partly be retrieved from the upper bound of the operator norm of **A**. The upper bound of $\|\mathbf{A}\|$, as given by equation 37, can be written in terms of the normalized functions:

$$\sqrt{\sum_{i,j=1}^{n} C_i^2 < u_i \Big| u_j >^2 \frac{\|E_j\|^2}{\|E_i\|^2}} := UB \quad (46)$$

The smaller the upper bound, the smaller the operator norm and the better the convergence of the iteration algorithm. An objective is to find the conditions when UB becomes minimum. In reality, C_i is given and fixed, and $\langle u_i|u_j \rangle$is fixed and cannot be changed without redesigning the wireless network. Thus, the parameter to be tuned is the downlink transmit power. The foregoing minimum can be reached when radiated energies of base stations, summed over the measurement locations x, are the same for i = 1, 2, . . ., n. Precisely, for a given C_i and $\langle u_i|u_j \rangle$, i,j = 1, 2, . . ., n, the upper bound UB of the operator norm $\|A\|$ reaches minimum, when

$$\|E_j\| = \|E_i\| \quad (47)$$

for all i and j.

Equation 47 is proved as follows. Since $\langle u_i|u_j \rangle = \langle u_j|u_i \rangle$, there are n(n-1)/2 terms of

$$a_{ij}^2 + a_{ji}^2 = < u_i \Big| u_j >^2 \left\{ C_i^2 \left(\frac{\|E_j\|}{\|E_i\|}\right)^2 + C_j^2 \left(\frac{\|E_i\|}{\|E_j\|}\right)^2 \right\} \quad (48)$$

in UB, where $i \neq j$. Let $\|E_j\|^2 = \|E_i\|^2 + \varepsilon$, then

$$a_{ij}^2 + a_{ji}^2 = \langle u_i|u_j \rangle^2 \{C_i^2 + C_j^2 + \varepsilon(\frac{1}{\|E_i\|^2} - \frac{1}{\|E_j\|^2})|\}. \quad (49)$$

If $\|E_i\| > \|E_j\|$, then the term following ε is negative. But at the same time, $\varepsilon < 0$ due to the definition. Thus,

$$a_{ij}^2 + a_{ji}^2 = \langle u_i|u_j \rangle^2 \{C_i^2 + C_j^2 + |\varepsilon(\frac{1}{\|E_i\|^2} - \frac{1}{\|E_j\|^2})|\}. \quad (50)$$

So, it reaches minimum, when $\varepsilon = 0$.

[0064] The solution of equation 26 presents a mere minimum-square error solution of the equation in equation 21, and, as such, it does not make equation 21 equal for all x. Roughly speaking, having applied the minimum-square error solution y_i, i = 1, 2, . . ., n, to equation 21, it is still equally probable to find:

$$y_i \frac{1}{C_i} E_i(x) < \sum_{k=1}^{n} y_k E_k(x) + N(x) \tag{51}$$

and

$$y_i \frac{1}{C_i} E_i(x) > \sum_{k=1}^{n} y_k E_k(x) + N(x) \tag{52}$$

Therefore, the minimum-square error solution achieves a "fair" distribution of the deviation of the carrier-to-interference around the target values C_i for i = 1, 2, . ., n. The ultimate goal, however, is that equation 21 be fulfilled as much as possible. With respect to **y** of equation 26, only a fair re-distribution of carrier-to-interference ratio is obtained. The final goal can be reached by an additional step, in which the carrier-to-interference level shall be adjusted uniformly toward equation 21 for all i = 1, 2, . . ., n. This can be done, for instance, by changing the target carrier-to-interference value C_i, so that it lies above or beneath the actual threshold, which enables the fulfillment of equation 21. But this approach is limited by the fact that C_i is fixed and less that unit.

[0065] In order to find a feasible method to reach the target carrier-to-interference, let us look at the inequality of equation 21. Consistent with previous arguments, the following equation ensues:

$$\mathbf{y} \geq \mathbf{z} + \mathbf{A} \cdot \mathbf{y} \tag{53}$$

Thus, it turns out that the solution y of equation 26 is the lower bound of the solutions of equation 53. Let

$$C_i(x,\alpha) := \frac{\alpha y_i E_i(x)}{N(x) + \sum_{j=1}^{n} \alpha y_j E_j(x)} \tag{54}$$

It is found that:

$$C_i(x,\alpha) > \frac{y_i E_i(x)}{N(x) + \sum_{j=1}^{n} y_j E_j(x)} \tag{55}$$

for $\alpha > 1$ and

$$C_i(x,\alpha) < \frac{y_i E_i(x)}{N(x) + \sum_{j=1}^{n} y_j E_j(x)} \tag{56}$$

for $\alpha < 1$. Thus, the result can be correspondingly calibrated by replacing y by ay with $\alpha > 0$. Function $C_i(x,\alpha)$ is positive for positive α. It can be easily confirmed that $C_i(x,\alpha)$ has no maximum for $\alpha \in [0,\infty]$ and for all x. $C_i(x,\alpha)$ is a monotone increasing function of $\alpha \in [0,\infty]$ and its range is [0,1] with:

$$\lim_{\alpha \to \infty} C_i(x, \alpha) = \frac{y_i E_i(x)}{\sum_{j=1}^{n} y_j E_j(x)} \leq 1. \qquad (57)$$

One method to determine α is to solve the equation:

$$C_i(x,\alpha)=C_i \qquad (58)$$

for α, and obtain:

$$F_i(x) = \frac{C_i N(x)}{y_i E_i(x) - C_i \sum_{j=1}^{n} y_j E_j(x)} \qquad (59)$$

Then, let α be $\max^{n}_{i=1} \max_{x \varepsilon Si} F_i(x)$ with respect to i. If y_i is the minimum-square error solution of equation 21 with $y_i E_i(x) > 0$, i = 1, 2, . . ., n, and $N(x) > 0$ for all x, and if:

$$F_i = \max_{x \in S_i} \frac{C_i \cdot N(x)}{y_i E_i(x) - C_i \sum_{j=1}^{n} y_j E_j(x)} \qquad (60)$$

exists, then equation 21 holds true, when y_i is replaced by

$$y_i \cdot \max_{i=1}^{n} F_i \qquad (61)$$

with i = 1, 2, . . ., n.

The foregoing relationship may be proved by considering

$$\frac{N(x)}{\max_{i=1}^{n} F_i} \leq \frac{N(x)}{F_i} \leq \frac{N(x)}{F_i(x)} \qquad (62)$$

for all x and i = 1, 2, . . ., n, one obtains

$$C_i(\max_{i=1}^{n} F_i, x) = \frac{y_i E_i(x)}{N(x) / \max_{i=1}^{n} F_i + \sum_{j=1}^{n} y_j E_j(x)} \geq \frac{y_i E_i(x)}{N(x) / F_i(x) + \sum_{j=1}^{n} y_j E_j(x)} = C_i \qquad (63)$$

owing to $N(x) > 0$ and $y_i E_i(x) > 0$ for all x and i = 1, 2, . . ., n.

[0066] In reality, each transmitter power is limited by a given maximum value, say y^M_i. A realistic α must take account of this limitation. Therefore, let y^M_i be the maximal power available for base station i = 1, 2, . . ., n. Then, a realistic assessment of the resultant power is given by $\alpha \cdot y_i$ with:

$$\alpha := \min_{i=1}^{n}\{\frac{y_i^M}{y_i}, \max_{i=1}^{n} F_i\}, \qquad (64)$$

Equation 64 is provable by showing that $\alpha \cdot y_i$ is either mathematically optimal or that $\alpha \cdot y_i$ mathematically represents an optimal value among all feasible values. Let

$$\alpha_0 = \max_{i=1}^{n} F_i \qquad (65)$$

If $\alpha = \alpha_0$, then:

$$y_i\alpha \le y_i \cdot \frac{y_i^M}{y_i} \le y_i^M \qquad (66)$$

is mathematically optimal and feasible. On the other hand, if $\alpha \neq \alpha_0$, there is at least one i, such that

$$\frac{y_i^M}{y_i} < \min\{\alpha_0, \frac{y_j^M}{y_j}\ for\ j = 1,2,\ldots,n; j \neq i\} \qquad (67)$$

Upon consideration of equation 67, equation 58 is not satisfied for all x. That is, $\alpha \cdot y_i$ is not mathematically optimal. But

$$y_j\alpha \le y_j \cdot \frac{y_i^M}{y_i} < y_j \cdot \frac{y_j^M}{y_j} = y_j^M \qquad (68)$$

for all j = 1, 2, . . ., n, i.e., is still feasible. Because of equation 67, $\alpha \cdot y_i$ represents mathematically optimal choice among all feasible choices.

[0067] Another concern regarding the network power allocation method is based on equation 33 is the convergence. If the network is designed and installed so poorly that the partial sum of equation 33 does not converge, a viable alternative is needed for determining the downlink transmit powers of the base stations.

[0068] The minimum-square error solution comes from the minimization of left and right side of equation 21 in $L^2(S)$, where S is the union of the area of all cells. Now, instead of entire domain of S, the procedure is confined the scope to each cell S_i, while coping with the C/I of that cell. Restricting the procedure to the scope of each cell S_i is supported by the fact, that $y_iE_i(x)$ should dominate only in cell i. In other cells, say j, signal power of $y_iE_i(x)$ becomes interference and needs to be suppressed. Despite the fact that no $E_i(x)$ can be tuned on a local basis, an attempt may be made to find a quantity that can be used for the approximate estimation. For this purpose, the following inequality is examined,

$$\sum_{j\neq i} y_j E_j^{M,i} + N^{M,i} \le (\frac{1}{C_i} - 1) y_i E_i^{m,i} \qquad (69)$$

where

$$E_j^{M,k} = \max_{x \in S_k} E_j(x) \qquad (7)$$

$$E_i^{m,k} = \min_{x \in S_k} E_i(x) \qquad (8)$$

$$N^{M,i} = \max_{x \in S_i} N(x) \qquad (9)$$

wherein y_i is a known downlink power of base station i, C_i represents a carrier-to-interference ratio for a defined coverage area, $E_i(x)$ is a propagation factor for first set of defined coverage areas i, $E_j(x)$ is a propagation factor for a second set of defined coverage areas distinct from the first set, N(x) represents background noise, m is the considered (e.g., total) number of measurement locations x, and k represents a particular measurement location. If $E_j^{M,}$, $E_j^{m,}$, and $N^{M,i}$ exist so that equation 69 is true, then equation 21 holds, too. In fact, equation 69 is a tighter relation than equation 21. It suffices to consider the equation in equation 69, from which one obtains

$$y_i = \frac{C_i}{1 - C_i} \frac{N^{M,i} + \sum_{j \neq i} y_j E_j^{M,i}}{E_i^{m,i}} \qquad (70)$$

The foregoing expression contains unknowns y_j on the right. For clarity, the foregoing expression can be rewritten as the following equation:

$$y_i \cdot (1 - C_i) \frac{N^{M,i} + \sum_{j \neq i} E_j^{M,i}}{N^{M,i} + \sum_{j \neq i} y_j E_j^{M,i}} = C_i \cdot \frac{N^{M,i} + \sum_{j \neq i} E_j^{M,i}}{E_i^{m,i}} \qquad (71)$$

The right side of equation 71 does not depend on y_j. The left side, C_i, in units of watts, is very small compared to one, typically -5dB. From experience, the power power allocation affects the distribution of the interference power among i than the sum:

$$\sum_{j \neq i} E_j^{M,i} \approx \sum_{j \neq i} y_j E_j^{M,i} \qquad (72)$$

in cell S_i. Thus, the following estimation

$$(1-C_i)\frac{N^{M,i}+\sum_{j\neq i}E_j^{M,i}}{N^{M,i}+\sum_{j\neq i}y_jE_j^{M,i}}\approx 1 \qquad (73)$$

can be assumed. From the tighter relation equation 69 follows

$$y_i \approx C_i \cdot \frac{N^{M,i}+\sum_{j\neq i}E_j^{M,i}}{E_i^{m,i}}. \qquad (74)$$

This is the result of approximation of equation 21 under the premise that equation 69 exists and equation 73 is justifiable.

[0069] One advantage of equation 74 is that the calculation of y_i requires only local data, i.e. measured data at S_i. Therefore, equation 74 is simple and easy to use, particularly when the analytical algorithm fails. The physical interpretation of equation 74 is plausible, if the equation is considered in decibels (dB) as follows:

$$10\log(y_i)=10\log(C_i)-10\min_{x\in S_i}\log[C_i(x,1)]=C_i^{dB}-\min_{x\in S_i}C_i^{dB}(x,1) \qquad (75)$$

.

The resultant power value is just the difference between the target carrier-to-interference value and the actual carrier-to-interference value by unit power.

Procedure for Measuring Signal Parameters

[0070] FIG. 3 shows an illustrative example of measuring the received signal powers in step S10. FIG. 3 depicts an illustrative wireless network 114 including four base stations that are centrally located in four corresponding hexagonal cells 100. Each hexagonal cell 100 represents the radio frequency coverage of the corresponding base station centrally located within the hexagonal cell 100.

[0071] The base stations may be located with reference to an x axis and a y axis as shown. A first base station 102 has the x, y coordinates 4 km, 0 km, respectively. A second base station 104 has the x, y coordinates 0 km. 4 km, respectively. A third base station 106 has the x, y coordinates -4 km, 0 km, respectively. A fourth base station 108 has the x, y coordinates 0 km, - 4 km, respectively.

[0072] While a test route 110 through each radio frequency coverage area is shown as an elliptical path, a path with any shape, regardless of whether it is continuous or discontinuous may be used. The measurement locations x (112) may be located on the path of the test drive such that a statistically significant sample of test measurements are attained in each radio frequency coverage area. The measurement locations 112 may coincide with areas of anticipated heavy traffic or of critical importance to subscribers of the wireless communications network.

[0073] As shown in FIG. 3, the test route 110 is designed such that it goes through each cell 100. The test route 110 is a ellipse with a center that coincides with the origin 116 of the above coordinate system and the center of the square defined by the base stations. In the 4Km inter-site spacing of the above example, the long (x-direction) and short (y-direction) axes of the ellipse are approximately 10km and 3km, respectively. While in theory the progression through the measurement points may proceed by moving a test receiver along the elliptical test route 110 in an clock-wise or counter-clockwise nature, in practice an actual test drive may be limited to the local roads and highway system to appropriately limit the expense of the measurement process. The wireless network 114 may be subject to background noise and radio frequency slow fading with a characteristic deviation (e.g., 8 dB). There is no restriction as to whether the measurements are made simultaneously at all locations with multiple test receivers or sequentially with a single test receiver moving along a route that intercepts the measurement locations 112.

[0074] As shown in FIG. 4, in an example, step S12 includes organizing the determined propagation factors into a propagation factor matrix including respective propagation factors for each base station at the measurement locations 112. The propagation factor matrix may have columns representing uniform base station identifiers and rows representing uniform measurement locations 112. Each entry in the propagation factor matrix may be determined in accordance with equation 1.

Computer-Simulated Estimates of Potential Performance Improvement of a Wireless Network

[0075] FIG. 5 represents the measured downlink transmit signal power within the hypothetical (e.g., computer-simulated) wireless network of FIG. 3 prior to the adjustment (e.g., power allocation) method of the present invention. In contrast, FIG. 6 represents the measured downlink signal power within the hypothetical wireless network of FIG. 3 after conducting the adjustment (e.g., power allocation) method of the invention. FIG. 6 includes base stations adjusted to the resultant downlink transmit powers, whereas FIG. 5 does not. In both FIG. 5 and FIG. 6, the vertical axis shows transmitted downlink power in watts, whereas the horizontal axis represents various measurement locations 112, which include measurement locations 112 for illustrative purposes. The downlink transmit power of each base station is plotted as a distinct curve as received at the measurement locations 112. A first base station 102 is represented by a rotated rectangle symbol. A second base station 104 is represented by a ordinary rectangle symbol. A third base station 106 is represented by a triangular symbol. A fourth base station 108 is represented by an "x".

[0076] After power allocation as shown in FIG. 6, some of the downlink transmit signals are stronger than prior to power allocation such that the actual carrier-to-interference at all selected measurement locations 112 meets or just exceeds a target carrier-to interference level.

[0077] FIG. 7 and FIG. 8 are a pre-adjustment and post power-adjustment graph of carrier-to-noise ratio, respectively. FIG. 7 and FIG. 8 reflect the hypothetical characteristics of the inter-site spacing and the geometry of the test route 110 previously described in conjunction with FIG. 3, although the actual inter-site spacing and the geometry depends on the particular attributes of any wireless network to which the adjustment method is applied. Carrier-to-noise ratio or radio frequency signal-to-noise ratio is a better indication of system performance than merely downlink transmit power as expressed in FIG. 5 and FIG. 6 because maximum performance and subscriber capacity of the wireless network may depend upon minimizing noise. FIG. 7 and FIG. 8 use the same representational symbols for the first, second, third, and fourth base stations as FIG. 5 and FIG. 6. Although each of the base stations may include an omnidirectional antenna as illustrated by the polygonal cells of FIG. 3, an alternate embodiment may include at least one directional antenna coupled to any base station. Further, the vertical axis shows carrier-to-interference ratio in dB, whereas the horizontal axis shows measurement locations 112.

[0078] FIG. 7 and FIG. 8 include background noise and slow fading that blur the reception of a loaded wireless network. The received carrier-to-interference ratio is simultaneously recorded from all four base stations. The carrier-to-interference value varies from location-to-location, and from cell-to-cell, where each cell is identified by a dominant base station.

[0079] If for purposes of an illustrative example, the target carrier-to-interference for the wireless network is at the negative 5 dB level, the improvement between the pre-adjustment and the post power-adjustment graph is readily apparent. In the pre-adjustment graph of FIG. 7 only measurement location numbers 23-33 satisfied the target carrier-to-interference ratio for the second base station 104; only measurement location numbers 49-52 satisfied the target carrier-to-interference ratio for the third base station 106; only measurement location numbers 72-81 satisfied the target carrier-to-interference ratio for the fourth base station 108. Thus, the communications service provided to measurement location numbers 1-22, 34-48, 53-71, and 82-100 has an inadequate carrier-to-interference ratio.

[0080] In contrast, in the post power-adjustment graph of FIG. 8, substantially all of the measurement location numbers 1-100 are served with adequate carrier-to-interference ratios by the base stations. In particular, the first, second, third and fourth base stations each have some measurement locations 112 exceeding the target carrier-to-interference ratio of - 5 dB.

[0081] In terms of a statistical requirement, the minimum performance requirement for the network of this example is -5 dB with a probability of 0.9. The pre-adjustment graph of FIG. 7 does not attain the statistical requirement, but the post power-adjustment graph of FIG. 8 does. After adjusting the downlink transmit power of the base stations to the resultant downlink transmit power, the post power-adjustment graph, reveals that more than 95 percent of carrier-to-interference ratios for the cells are above the target threshold.

[0082] FIG. 7 and FIG. 8 could represent, for example, a test receiver's measurements of the carrier-to-interference ratio for the pilot channels of each cell on a test drive route through a CDMA network. The pilot channel in IS-95 is typically transmitted with the maximum available downlink power in conformance with the resultant downlink transmit power.

Power Allocation System

[0083] FIG. 9 discloses a system for allocating downlink transmit power that may be used to practice any power allocation method disclosed herein. The power allocation system includes a test receiver 502 coupled to a processing system 503 and a user interface 508 coupled to the processing system 503. The test receiver 502 measures electromagnetic transmissions from one or more base stations 501 as previously described. The user interface 508 allows a user to define one or more of the following: target performance goals, target carrier-to-interference ratios, and defined reliabilities. The processing system 503 accepts input from the user interface 508 and the test receiver 502 to determine a constellation (e.g., a system-wide set) of resultant downlink transmit powers for the base stations 501 in the wireless network over the measurement locations. The processing system 503 determines the constellation such that system-wide interference; particularly, co-channel interference is minimized or otherwise reduced.

[0084] The test receiver 502 measures received signal parameters (e.g., signal strengths), of electromagnetic transmissions from the base stations 501, at measurement locations within defined radio frequency coverage areas. The test receiver 502 may be capable of measuring background noise associated with each of the measurement locations. The measured background noise is within a frequency range of the electromagnetic transmissions.

[0085] The processing system 503 includes a determiner 504 for determining propagation factors and a calculator 506 for calculating initial downlink transmit powers for the base stations 501. The propagation factors are associated with the electromagnetic transmissions as a function of the measurement locations. The initial downlink transmit powers generally are within the bounds of the transmitter power intervals based upon the propagation factors and at least one target performance goal for the coverage areas.

[0086] In an alternate embodiment, the determiner 504 is arranged to determine a propagation factor matrix 505 including respective propagation factors for at least one propagational path between each measurement location and a corresponding base station 501. The propagation factor matrix 505 may have columns representing uniform base station 501 identifiers and rows representing uniform measurement locations.

[0087] The calculator 506 is arranged to calculate the initial downlink transmit power for each of the base stations 501 based upon the measured signal parameters (e.g., signal strength, measured background noise, or both) the propagation factors, and a target carrier-to-interference ratio as the target performance goal. In an alternate embodiment, the measured signal parameters may comprise signal-to-noise ratio, signal-to-interference ratio, frame-error rate, bit-error rate, or the like.

[0088] The processing system 503 may further include a calibrator 507 for calibrating the initial downlink transmit powers to obtain the constellation of the resultant downlink transmit powers. The resultant downlink transmit powers satisfy a target carrier-to-interference ratio as the target performance goal for the measurement locations with a defined reliability. The initial downlink transmit powers are used to derive resultant downlink transmit powers with corresponding actual carrier-to-interference ratios meeting or minimally exceeding a target carrier-to-interference ratio as the target performance goal for the measurement locations with a defined reliability. The calibrator 507 may calibrate the initial downlink transmit powers by considering a known maximum transmit power of each of the base stations 501. The processing system 503 is adapted to establish the defined reliability as a percentage of time in a coverage area during which the target-to-carrier interference ratio is met or exceeded.

Application of the Power Allocation Method

[0089] Any power, allocation method disclosed herein may be applied to the power allocation of wireless networks, such as code-division multiple access (CDMA), frequency-division multiple access (FDMA), and time-division multiple access (TDMA), among others. In an interference-limited wireless network, an appropriate transmit-power allocation of the downlink power is essential for achieving the expected service quality of the network. Particularly, the power levels of beacon channels are crucial for radio frequency coverage and efficient hand-offs. The power levels of beacon channels and traffic channels may be subjected to radio frequency power allocation in accordance with the invention to attain or approach the most efficient use of limited spectral resources.

[0090] A wireless network, such as a cellular radio network, provides traffic capacity through the reuse of frequency resources. As a result of frequency reuse, carrier signals are always subject to interference, which is measured by the carrier-to-interference ratio (C/I). The carrier-to-interference ratio is the ratio of the carrier signal power to the sum of all other signals received at the same frequency. The carrier-to-interference ratio represents a measure of signal-to-noise that serves as quality indicator equally well for (code-division multiple access) CDMA system and (time-division multiple access) TDMA system.

[0091] In order to achieve sufficient carrier-to-interference for the traffic channels, both CDMA and TDMA systems have introduced the power control mechanisms, which allows for the base station and the mobile stations to accommodate the transmit power to the path loss and fading. By doing so, the carrier-to-interference ratio of traffic channels is adapted to the particular location of the mobile stations. However, adjusting downlink transmit power alone does not necessarily achieve expected performance of the network, because the power control is usually not applicable to the common control channels. The common control channels include beacon channels, paging channels, access channels, overhead channels, or equivalent channels for controlling and managing subscriber traffic.

[0092] Beacon channels are often used to make hand-off decisions and to provide access for the mobile station accessing the network. Because a beacon channel needs to be simultaneously accessible by all mobile stations within a certain geographic coverage area, the beacon channel is typically prohibited from varying its downlink transmit power. The beacon channel is generally transmitted with the maximum downlink transmit power of all channels in a cell and remains constant. The broadcast control channel (BCCH) in Group Special Mobile (GSM) and PILOT in IS-95 are examples of beacon channels. The downlink transmit power of the beacon channel determines the "talk-out" radio frequency coverage of the cell served by the base station. As such, a predictable downlink transmit power of the beacon channel is crucial for the establishment of the cell boundary and for the hand-off efficiency.

[0093] In one common scheme, the downlink transmit power of the beacon channel in a CDMA system forms the reference of all other channels including traffic channels. In certain TDMA systems, the traffic channels are transmitted with the same fixed power as the beacon channel unless the power control is applied. Even under power control in a TDMA system, the maximum available downlink transmit power of the traffic channel is usually determined by the beacon downlink transmit power.

[0094] The present power allocation method recognizes that, in a wireless network, each base station requires an individual resultant downlink transmit power for its beacon channel, to accommodate to its unique radio frequency coverage environment. The transmit-power allocation of the proper downlink transmit power to the beacon channel of each base station is crucial to the optimal or proper performance of the network. Therefore, one significant application of the adjustment method of the invention involves finding the an optimal or adequate transmit-power allocation of the transmit power for each beacon channel. The traffic channels may then use the resultant downlink transmit power as a reference for their downlink transmit power to enhance radio frequency coverage of the entire wireless network, or a portion thereof.

[0095] In accordance with the invention, the transmit-power allocation method allocates just the requisite downlink power to various base stations, and preferably no more power than required, to attain reliable radio frequency coverage, maximize radio frequency capacity, or both. The transmit-power allocation method is well-suited for providing a network-wide solution as the resultant transmit downlink powers on a base-station by base-station basis. The resultant transmit downlink power may be mathematically verifiable as an optimal or appropriate downlink power, rather than relying upon an iterative trial-and-error technique to set transmit power levels for the base stations of a wireless network.

[0096] The transmit-power allocation method of the invention generally comprises an algorithm for execution on a general purpose computer. As input data, the algorithm primarily requires the signal power measured by a test receiver in as few as one test drive through the given network. Thus, the transmit-power allocation method not only enhances the radio frequency coverage reliability, but may also reduces the time and cost required for conducting network power allocation.

[0097] Further, unlike typical analytical approaches used in the network planning, the transmit-power allocation method of the invention does not require a priori or presumptive information for modeling the propagation environment, such as topographic data, antenna height above average terrain, location of the base stations, and antenna characteristics. Instead, the transmit-power allocation method of the invention only requires field measurements as input data to yield a system-wide solution for downlink transmit powers of the base stations. The field measurements implicitly provide data theoretically related to the foregoing presumptive information, but in a more accurate fashion based on a realistic tests of an actual wireless network. Accordingly, the transmit-power allocation method is insensitive to the inaccuracy associated with other analytical approaches using modeling techniques in network planning.

[0098] The algorithm infers just the requisite transmission power for one or more channels associated with each base station to achieve a target carrier-to-interference, or analogous reliability goal, over the geographic area of the wireless network, or a portion thereof. The target carrier-to-interference ratio may be expressed in decibels and as a probability for meeting or exceeding that decibel level. The requisite transmission power for each base station may be inferred based on a relationship between a target carrier-to-interference ratio and received downlink radio frequency signals. As result, the beacon channel of each base station may be adjusted to an appropriate or an optimal downlink power value that provides the expected carrier-to-interference ratio.

[0099] The resultant downlink transmit power may refer to the resultant downlink power of the beacon channels, such as the PILOT channels of an IS-95 CDMA system. In practice, controlling the resultant downlink transmit power of the beacon channels forms a reference for other radio frequency communications channels, such as traffic channels, as previously described. The resultant downlink power may also be applied to other common control channels, other than the beacon channels. Further, the resultant downlink transmit power may be directly applied to a downlink transmit power of a traffic channel in a TDMA system that is not equipped with a power control mechanism.

[0100] The criterion for the transmit-power allocation of the resultant downlink power preferably constitutes more than mere compliance with the target carrier-to-interference ratio. In particular, if the wireless network comprises a CDMA system, minimizing the downlink transmit power of each base station to a certain extent is desirable. Because the traffic capacity of a CDMA system is proportional to the number of users per unit power, the resultant downlink power should not unnecessarily exceed the target-to-carrier interference ratio. Further, a low downlink transmit power level may reduce concerns of electromagnetic biological hazards. Therefore, the resultant downlink power represents finding the minimum downlink power for each base station necessary to produce the just required carrier-to-interference ratio. The resultant downlink transmit power allocation on a system-wide basis is determined based on evaluation among other feasible transmit-power allocations of downlink power. Because the transmit-power allocation method is applicable to unloaded as well as loaded system, the transmit-power allocation method is an efficient tool for an initial post-installation power allocation as well as subsequent periodic network power allocations.

[0101] This specification describes various illustrative embodiments of the method of the present invention. The scope of the claims is intended to cover various modifications and equivalent arrangements of the illustrative embodiments disclosed in the specification. Therefore, the following claims should be accorded the reasonably broadest interpretation to cover the modifications, equivalent structures, and features, which are consistent with the spirit and scope of the invention disclosed herein.

Claims

1. A method for allocating downlink power in a wireless network comprising the steps of:

   measuring received signal parameters, of electromagnetic transmissions from base stations, at measurement locations within defined radio frequency coverage areas;

   determining propagation factors associated with the electromagnetic transmissions as a function of the measurement locations; and

   determining a downlink transmit power for at least one of the base stations based upon the propagation factors and a target performance goal for the coverage areas.

2. The method according to claim 1 further comprising the step of:

   calibrating the downlink transmit power to satisfy the target performance goal for the measurement locations with a defined reliability.

3. The method according to claim 1 further comprising the step of:

   calibrating the downlink transmit power to satisfy a target carrier-to-interference ratio as the target performance goal for the measurement locations with a defined reliability.

4. The method according to claim 1 further comprising the step of:

   calibrating the downlink transmit power to obtain a corresponding actual carrier-to-interference ratio meeting or minimally exceeding a target carrier-to-interference ratio as the target performance goal for the measurement locations with a defined reliability.

5. The method according to claim 2 wherein the calibrating step includes calibrating the initial downlink transmit power by considering a known maximum transmit power of each of the base stations.

6. The method according to claim 3 wherein the calibrating step comprises establishing the defined reliability as a percentage of time in a coverage area during which the target-to-carrier interference ratio is met or exceeded.

7. The method according to claim 1 wherein the measuring step further comprises measuring background noise associated with each of the measurement locations, the background noise being within a frequency range of the electromagnetic transmissions, and wherein the calculating step further comprises calculating the downlink transmit power for each of the base stations based upon the propagation factors, background noise and signal strengths as the measured signal parameters, and a target carrier-to-interference ratio as the target performance goal.

8. The method according to claim 1 wherein the determining of the propagation factors further comprises determining a propagation factor matrix including respective propagation factors for at least one propagational path between each measurement location and a corresponding base station.

9. The method according to claim 1 wherein the determining of the propagation factors further comprises determining a propagation factor matrix having columns representing uniform base station identifiers and rows representing uniform measurement locations.

10. The method according to claim 1 wherein the determining of the propagation factors is accomplished in accordance with the following equation:

$$E_i(x)=\frac{V_i(x)-N(x)}{y_i}$$

wherein y_i is a known downlink power of base station i, $V_i(x)$ is a received signal parameter as a function of measurement location x, and N(x) is a background noise power as a function of measurement location x.

11. The method according to claim 1 wherein the determining of the downlink transmit power includes the following steps:

constructing a vector

$$\mathbf{z}=\{z_i\}^n{}_{i-1}$$

and a matrix

$$\mathbf{A}=\{a_{ij}\}^n{}_{i,j-1}$$

in accordance with the following equations:

$$z_i=C_i\frac{\sum_{k=1}^{m}N(x_k)E_i(x_k)}{\sum_{k=1}^{m}E_i^2(x_k)}$$

$$a_{ij}=C_i\frac{\sum_{k=1}^{m}E_i(x_k)E_j(x_k)}{\sum_{k=1}^{m}E_i^2(x_k)}$$

wherein C_i represents a carrier-to-interference ratio for a defined coverage area i, $E_i(x)$ is a propagation factor for first set of defined coverage areas i, $E_j(x)$ is a propagation factor for a second set of defined coverage areas distinct from the first set, $N(x_K)$ represents background noise, m is the considered number of measurement locations x, k represents a particular measurement location, and n is the total number of the defined coverage areas within the first set and the second set.

applying an iteration

$$\mathbf{w}^{(n)}=\mathbf{w}^{(0)}+\mathbf{A}*\mathbf{w}^{(n-1)}$$

to the foregoing equations starting with

$$\mathbf{w}^{(0)}=\mathbf{z}$$

to solve for the vector

$$w=\{w_1, w_2, w_3 \ldots w_n\}.$$

12. The method according to claim 1 wherein determining of the downlink transmit power is accomplished by using a local approximation in accordance with the following inter-related equations:

$$y_i \approx C_i \cdot \frac{N^{M,i} + \sum_{j \neq i} E_j^{M,i}}{E_i^{m,i}}$$

$$E_j^{M,k} = \max_{x \in S_k} E_j(x)$$

$$E_i^{m,k} = \min_{x \in S_k} E_i(x)$$

$$N^{M,i} = \max_{x \in S_i} N(x)$$

wherein y_i is a known downlink power of base station i, C_i represents a carrier-to-interference ratio for a defined coverage area, $E_i(x)$ is a propagation factor for first set of defined coverage areas i, $E_j(x)$ is a propagation factor for a second set of defined coverage areas distinct from the first set, N(x) represents background noise, m is the considered number of measurement locations x, k represents a particular measurement location, and S_i refers to the defined measurement locations x within the coverage area i.

13. The method according to claim 1 further comprising the step of:

adjusting downlink transmit-power settings of corresponding base stations to conform with a system-wide constellation of the downlink transmit powers selected to meet or minimally exceed the target performance goal.

14. A method for allocating downlink power in a wireless network comprising the steps of:

measuring received signal strengths, of electromagnetic transmissions from base stations, at measurement locations within geographic coverage areas;

determining propagation factors of the electromagnetic transmissions for at least one propagational path between each of said measurement locations and a corresponding base station;

calculating an initial downlink transmit power within a transmitter power interval for each of the base stations based upon the propagation factors and target carrier-to-interference ratios for the measurement locations; and

calibrating the initial downlink transmit power to obtain a resultant downlink transmit power satisfying the target carrier-to-interference ratios for the measurement locations with at least a minimum probability.

15. The method according to claim 14 further comprising the step of:

selecting the target carrier-to-interference ratios as generally uniform throughout a majority of the geographic coverage areas in the wireless network.

16. The method according to claim 14 further comprising the step of:

selecting the target carrier-to-interference ratios as different for different ones of the geographic coverage areas, wherein the geographic coverage areas comprise one or more sectors of a cell with different estimated traffic loadings.

17. The method according to claim 14 further comprising the step of:

adjusting downlink transmit powers of the base stations to conform to resultant downlink transmit powers selected to satisfy the target carrier-to-interference ratios for the corresponding measurement locations.

18. The method according to claim 14 wherein the resultant downlink transmit power comprises a resultant downlink transmit power meeting or minimally exceeding the target carrier-to-interference ratios for the corresponding measurement locations.

19. The method according to claim 14 further comprising the step of:

adjusting a downlink transmit power of a beacon channel of a first one of the base stations to conform to the resultant downlink transmit power.

20. The method according to claim 19 further comprising the step of:

adjusting a downlink transmit power of traffic channels of at least the first one based on a power control algorithm using the beacon channel as a reference signal power for a maximum permitted downlink transmit power of the traffic channels.

21. The method according to claim 14 wherein the calibrating step calculates a calibration factor by executing the following equation:

$$\alpha = \min_{i=1}^{n} \left\{ \frac{y_i^M}{w_i}, \max_{i=1}^{n} \max_{x \in S_i} \frac{C_i \cdot N(x)}{w_i E_i(x) - C_i \sum_{j=1}^{n} w_j E_j(x)} \right\}$$

wherein • y_i is a known maximum downlink power of base station i, C_i represents a carrier-to-interference ratio for a defined coverage area, $E_i(x)$ is a propagation factor for first set of defined coverage areas i, $E_j(x)$ is a propagation factor for a second set of defined coverage areas distinct from the first set, N(x) represents background noise, x represents a measurement location, n represents a total number of the first set or the second set, w_i represents an initial downlink power for base station i within a power interval, and w_j represents a initial downlink power for base station j within a power interval.

22. The method according to claim 14 wherein the calibrating step establishes each resultant downlink power as a function of a calibration factor and a function of the target carrier-to-interference ratio as applied to the propagation factors.

23. The method according to claim 14 wherein the calibrating step establishes each resultant downlink power in accordance with the following equations:

$$w_i = \frac{C_i}{\min_{x \varepsilon S_i} C_i(x,1)}$$

$$y_i = \alpha w_i \text{ for } i = 1,2,\ldots n.$$

wherein C_i represents a carrier-to-interference ratio for a defined coverage area i, x represents a measurement location, w_i represents an initial downlink power for base station i within a power interval, S_i refers to defined measurement locations x within the coverage area i, α is an attenuation factor, and y_i is a resultant downlink transmit power for base station i.

24. A system for allocating downlink power in a wireless network including base stations, the system comprising:

a test receiver for measuring received signal strengths, of electromagnetic transmissions from the base stations, at measurement locations within defined radio frequency coverage areas; and

a processing system including a determiner for determining propagation factors and a calculator for calculating initial downlink transmit powers for the base stations, the propagation factors being associated with the electromagnetic transmissions as a function of the measurement locations, the initial downlink transmit powers being within corresponding transmitter power intervals based upon the propagation factors and at least one target performance goal for the coverage areas.

25. The system according to claim 24 wherein the processing system further comprises:

a calibrator for calibrating the initial downlink transmit powers to obtain resultant downlink transmit powers satisfying a target carrier-to-interference ratio as the target performance goal for the measurement locations with a defined reliability.

26. The system according to claim 24 wherein the processing system further comprises:

a calibrator for calibrating the initial downlink transmit powers to obtain resultant downlink transmit powers with corresponding actual carrier-to-interference ratios meeting or minimally exceeding a target carrier-to-interference ratio as the target performance goal for the measurement locations with a defined reliability.

27. The system according to claim 24 wherein the processing system includes a calibrator for calibrating the initial downlink transmit powers by considering a known maximum transmit power of each of the base stations.

28. The system according to claim 24 wherein the processing system is adapted to establish the defined reliability as a percentage of time in a coverage area during which the target-to-carrier interference ratio is met or exceeded.

29. The system according to claim 24 wherein the test receiver is adapted to measure background noise associated with each of the measurement locations, the background noise being within a frequency range of the electromagnetic transmissions, and wherein the calculator is arranged to calculate the initial downlink transmit power for each of the base stations based upon the measured signal strengths, the measured background noise, the propagation factors, and a target carrier-to-interference ratio as the target performance goal.

30. The system according to claim 24 wherein the determiner is arranged to determine a propagation factor matrix including respective propagation factors for at least one propagational path between each measurement location and a corresponding base station.

31. The system according to claim 24 wherein the determiner is arranged to determine a propagation factor matrix having columns representing uniform base station identifiers and rows representing uniform measurement locations.

FIG. 1

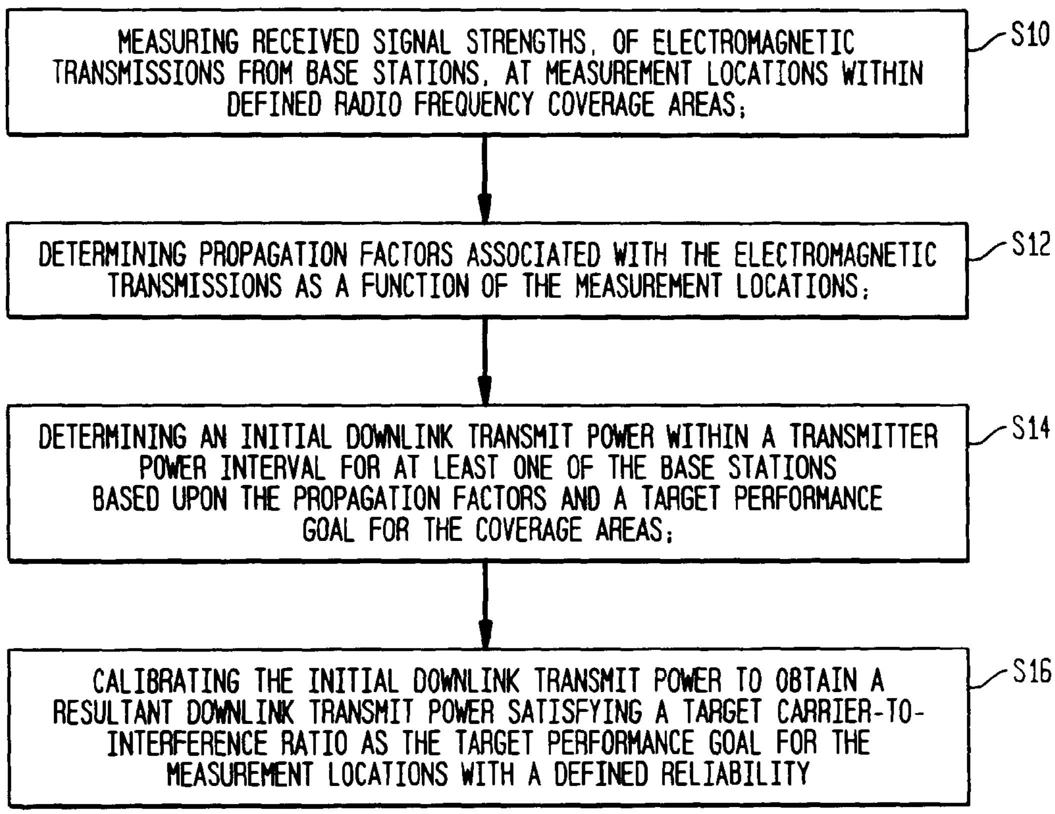

MEASURING RECEIVED SIGNAL STRENGTHS, OF ELECTROMAGNETIC TRANSMISSIONS FROM BASE STATIONS, AT MEASUREMENT LOCATIONS WITHIN DEFINED RADIO FREQUENCY COVERAGE AREAS;
S10
DETERMINING PROPAGATION FACTORS ASSOCIATED WITH THE ELECTROMAGNETIC TRANSMISSIONS AS A FUNCTION OF THE MEASUREMENT LOCATIONS;
S12
DETERMINING AN INITIAL DOWNLINK TRANSMIT POWER WITHIN A TRANSMITTER POWER INTERVAL FOR AT LEAST ONE OF THE BASE STATIONS BASED UPON THE PROPAGATION FACTORS AND A TARGET PERFORMANCE GOAL FOR THE COVERAGE AREAS;
S14
CALIBRATING THE INITIAL DOWNLINK TRANSMIT POWER TO OBTAIN A RESULTANT DOWNLINK TRANSMIT POWER SATISFYING A TARGET CARRIER-TO-INTERFERENCE RATIO AS THE TARGET PERFORMANCE GOAL FOR THE MEASUREMENT LOCATIONS WITH A DEFINED RELIABILITY
S16

FIG. 2

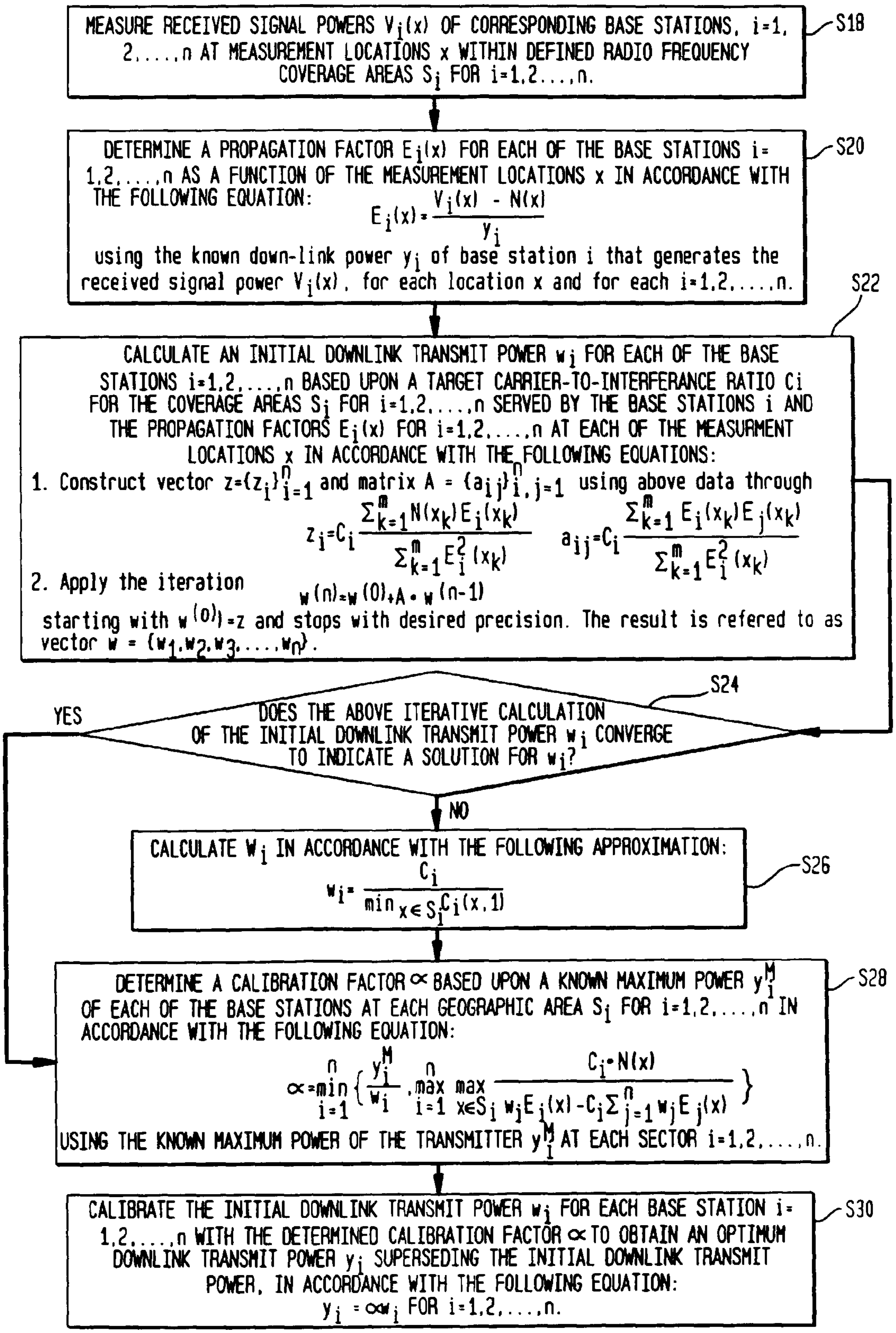

MEASURE RECEIVED SIGNAL POWERS $V_i(x)$ OF CORRESPONDING BASE STATIONS, i=1, 2,....,n AT MEASUREMENT LOCATIONS x WITHIN DEFINED RADIO FREQUENCY COVERAGE AREAS S_i FOR i=1,2...,n.
S18
DETERMINE A PROPAGATION FACTOR $E_i(x)$ FOR EACH OF THE BASE STATIONS i= 1,2,....,n AS A FUNCTION OF THE MEASUREMENT LOCATIONS x IN ACCORDANCE WITH THE FOLLOWING EQUATION: $E_i(x)=\frac{V_i(x) - N(x)}{y_i}$
using the known down-link power y_i of base station i that generates the received signal power $V_i(x)$, for each location x and for each i=1,2,....,n.
S20
S22
CALCULATE AN INITIAL DOWNLINK TRANSMIT POWER w_i FOR EACH OF THE BASE STATIONS i=1,2,....,n BASED UPON A TARGET CARRIER-TO-INTERFERANCE RATIO Ci FOR THE COVERAGE AREAS S_i FOR i=1,2,....,n SERVED BY THE BASE STATIONS i AND THE PROPAGATION FACTORS $E_i(x)$ FOR i=1,2,....,n AT EACH OF THE MEASURMENT LOCATIONS x IN ACCORDANCE WITH THE FOLLOWING EQUATIONS:
1. Construct vector $z=\{z_i\}_{i=1}^{n}$ and matrix $A = \{a_{ij}\}_{i,j=1}^{n}$ using above data through
$z_i=C_i\frac{\Sigma_{k=1}^{m} N(x_k)E_i(x_k)}{\Sigma_{k=1}^{m} E_i^2(x_k)}$ $a_{ij}=C_i\frac{\Sigma_{k=1}^{m} E_i(x_k)E_j(x_k)}{\Sigma_{k=1}^{m} E_i^2(x_k)}$
2. Apply the iteration $w^{(n)}=w^{(0)}+A\cdot w^{(n-1)}$
starting with $w^{(0)}=z$ and stops with desired precision. The result is refered to as vector $w = (w_1,w_2,w_3,...,w_n)$.
S24
YES
DOES THE ABOVE ITERATIVE CALCULATION OF THE INITIAL DOWNLINK TRANSMIT POWER w_i CONVERGE TO INDICATE A SOLUTION FOR w_i?
NO
CALCULATE W_i IN ACCORDANCE WITH THE FOLLOWING APPROXIMATION: $w_i=\frac{C_i}{\min_{x\in S_i} C_i(x,1)}$
S26
DETERMINE A CALIBRATION FACTOR $\propto$ BASED UPON A KNOWN MAXIMUM POWER y_i^M OF EACH OF THE BASE STATIONS AT EACH GEOGRAPHIC AREA S_i FOR i=1,2,....,n IN ACCORDANCE WITH THE FOLLOWING EQUATION:
$\propto=\min_{i=1}^{n}\left\{\frac{y_i^M}{w_i}, \max_{i=1}^{n} \max_{x\in S_i} \frac{C_i\cdot N(x)}{w_j E_j(x) - C_i \Sigma_{j=1}^{n} w_j E_j(x)}\right\}$
USING THE KNOWN MAXIMUM POWER OF THE TRANSMITTER y_i^M AT EACH SECTOR i=1,2,....,n.
S28
CALIBRATE THE INITIAL DOWNLINK TRANSMIT POWER w_i FOR EACH BASE STATION i= 1,2,....,n WITH THE DETERMINED CALIBRATION FACTOR $\propto$ TO OBTAIN AN OPTIMUM DOWNLINK TRANSMIT POWER y_i SUPERSEDING THE INITIAL DOWNLINK TRANSMIT POWER, IN ACCORDANCE WITH THE FOLLOWING EQUATION:
$y_i = \propto w_i$ FOR i=1,2,....,n.
S30

FIG. 3

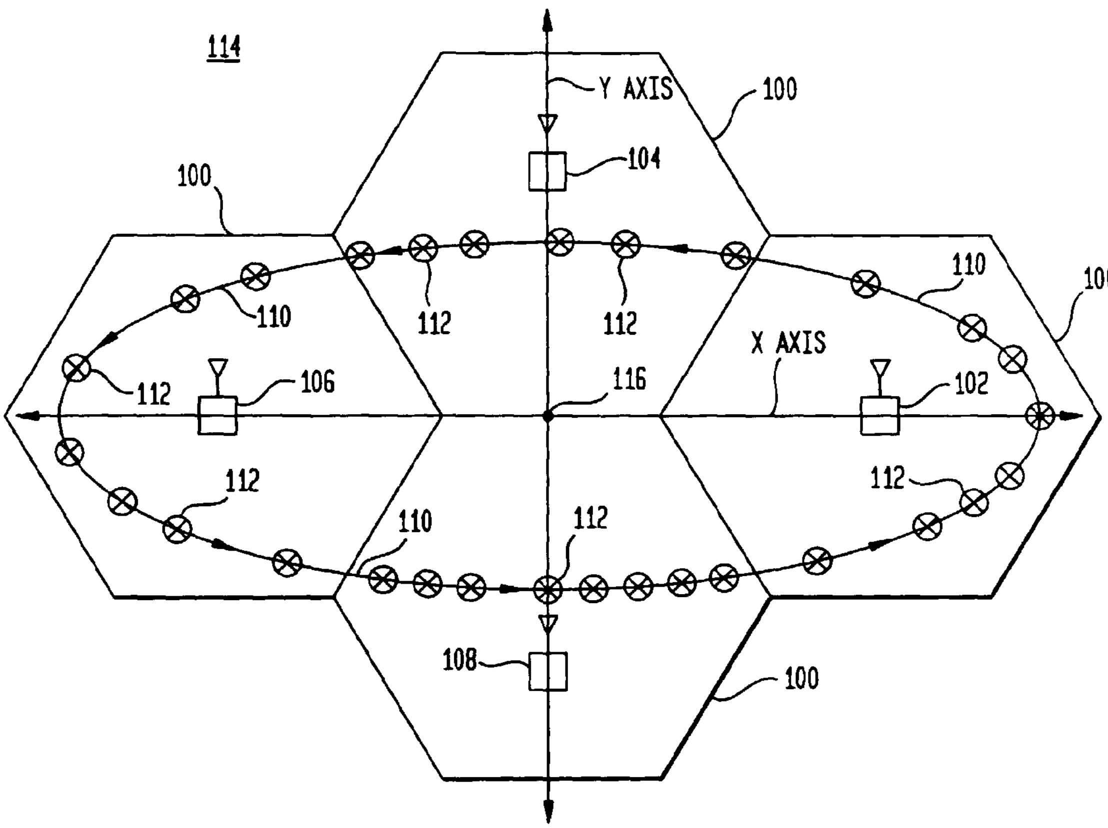
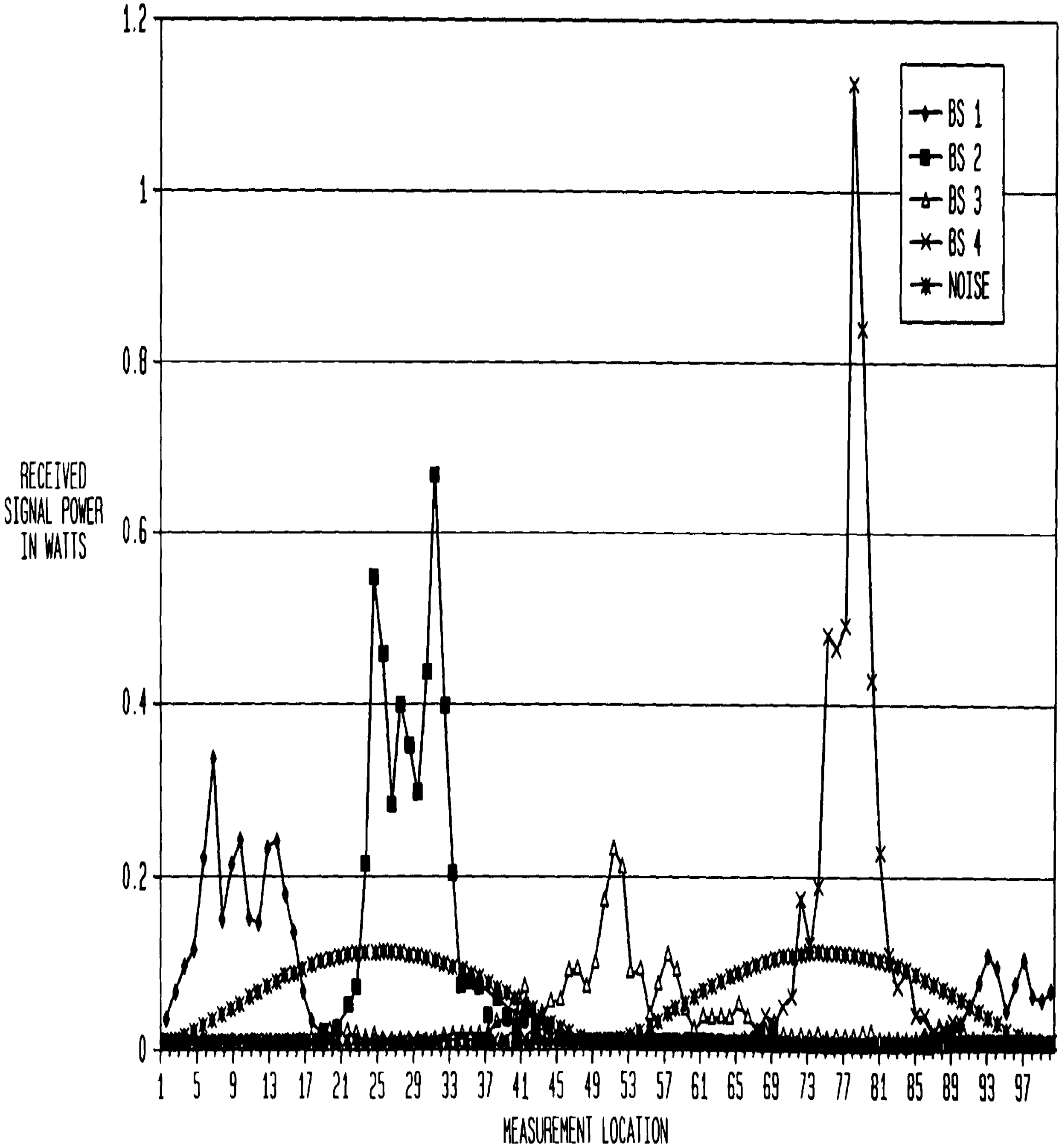


FIG. 4

118

$$\begin{Bmatrix} E_1(x_1) & E_2(x_1) & E_3(x_1) & \cdots & E_{n-1}(x_1) & E_n(x_1) \\ E_1(x_2) & E_2(x_2) & E_3(x_2) & \cdots & E_{n-1}(x_2) & E_n(x_2) \\ E_1(x_3) & E_2(x_3) & E_3(x_3) & \cdots & E_{n-1}(x_3) & E_n(x_3) \\ \vdots & \vdots & \vdots & & \vdots & \vdots \\ E_1(x_m) & E_2(x_m) & E_3(x_m) & \cdots & E_{n-1}(x_m) & E_n(x_m) \end{Bmatrix}$$

FIG. 5



RECEIVED SIGNAL POWER IN WATTS
MEASUREMENT LOCATION
BS 1
BS 2
BS 3
BS 4
NOISE
1.2
1
0.8
0.6
0.4
0.2
0
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93 97

FIG. 6

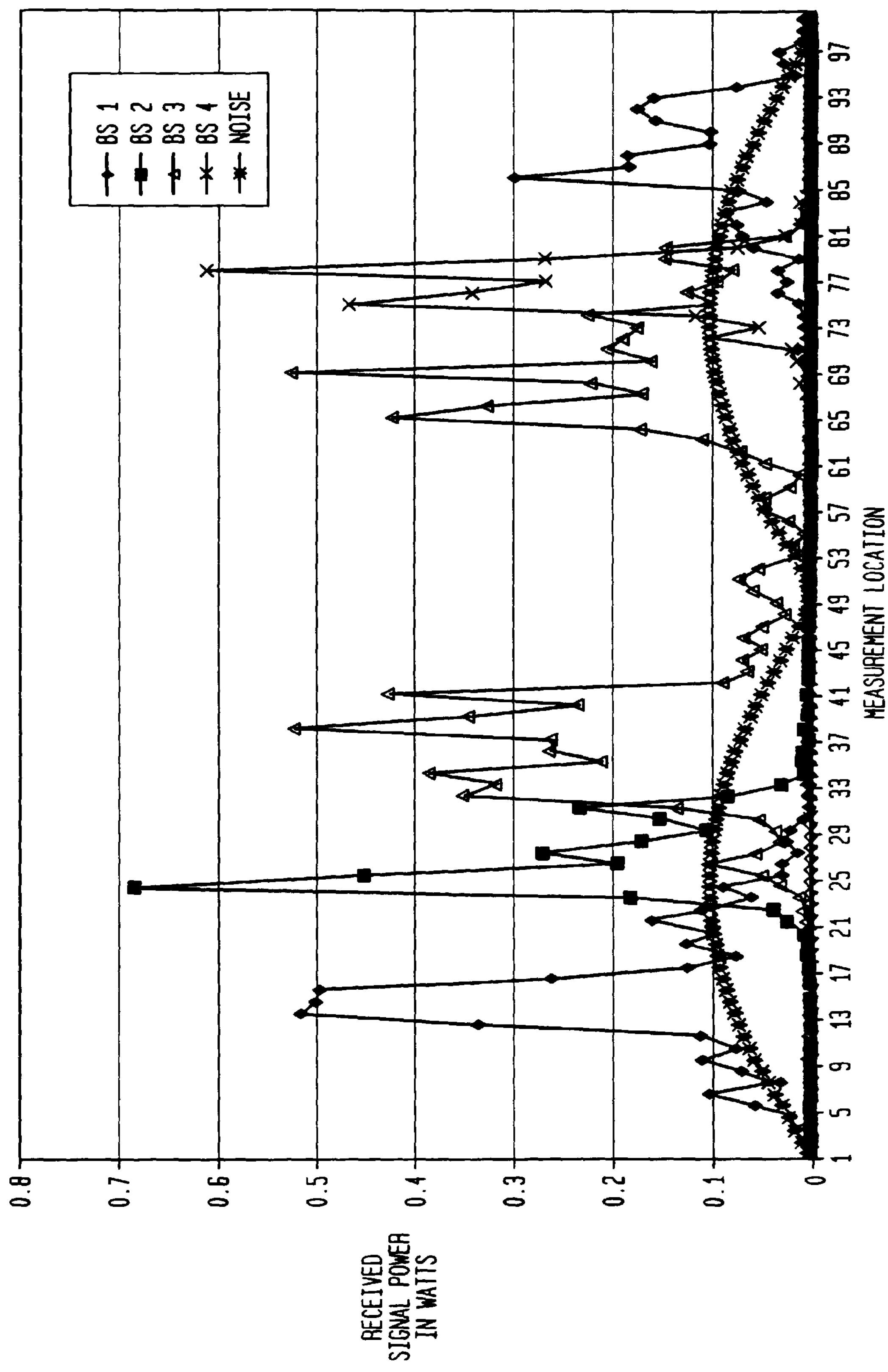

BS 1
BS 2
BS 3
BS 4
NOISE
RECEIVED SIGNAL POWER IN WATTS
MEASUREMENT LOCATION
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
1
5
9
13
17
21
25
29
33
37
41
45
49
53
57
61
65
69
73
77
81
85
89
93
97

FIG. 7

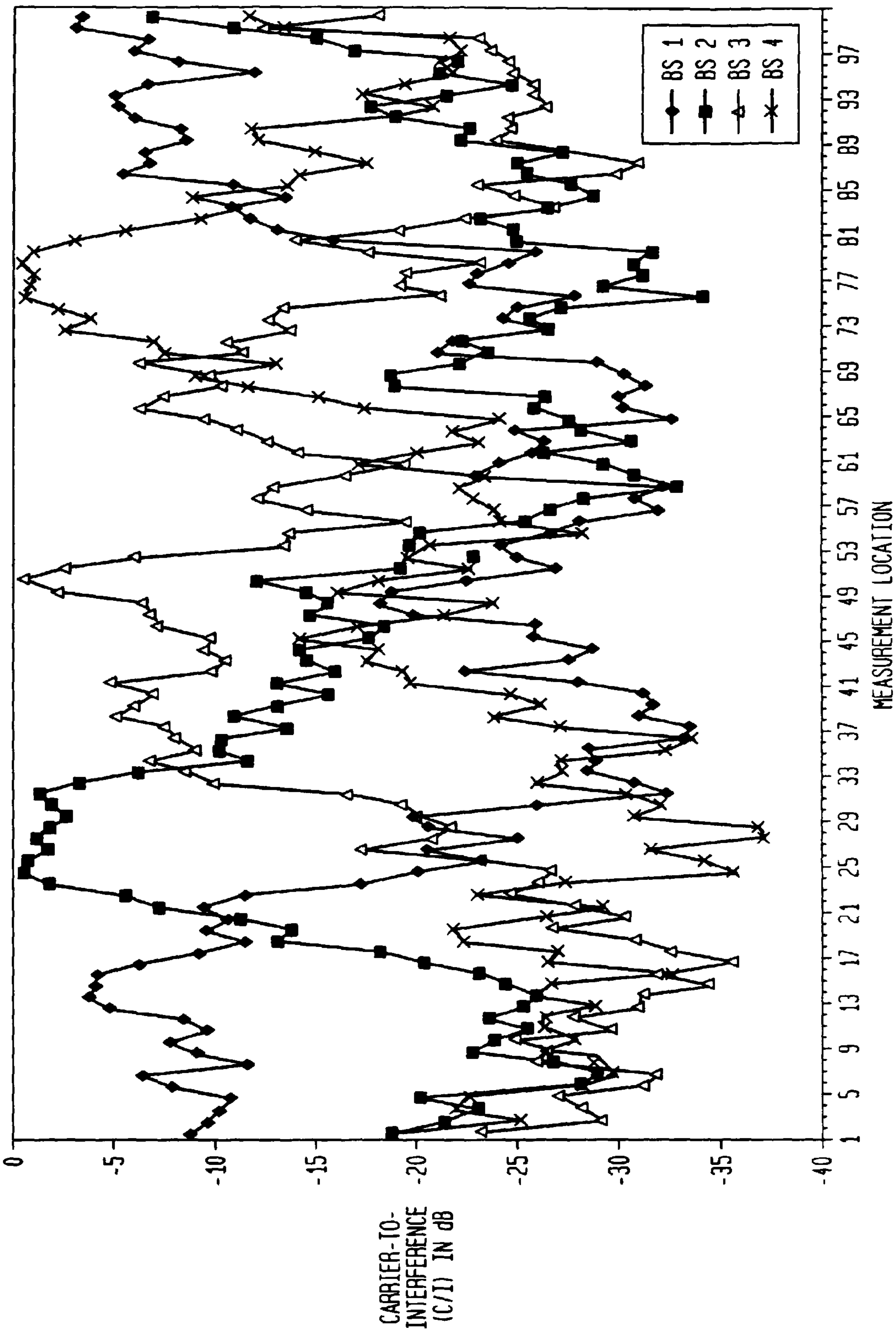

CARRIER-TO-INTERFERENCE (C/I) IN dB
0
-5
-10
-15
-20
-25
-30
-35
-40
MEASUREMENT LOCATION
1
5
9
13
17
21
25
29
33
37
41
45
49
53
57
61
65
69
73
77
81
85
89
93
97
BS 1
BS 2
BS 3
BS 4

FIG. 8

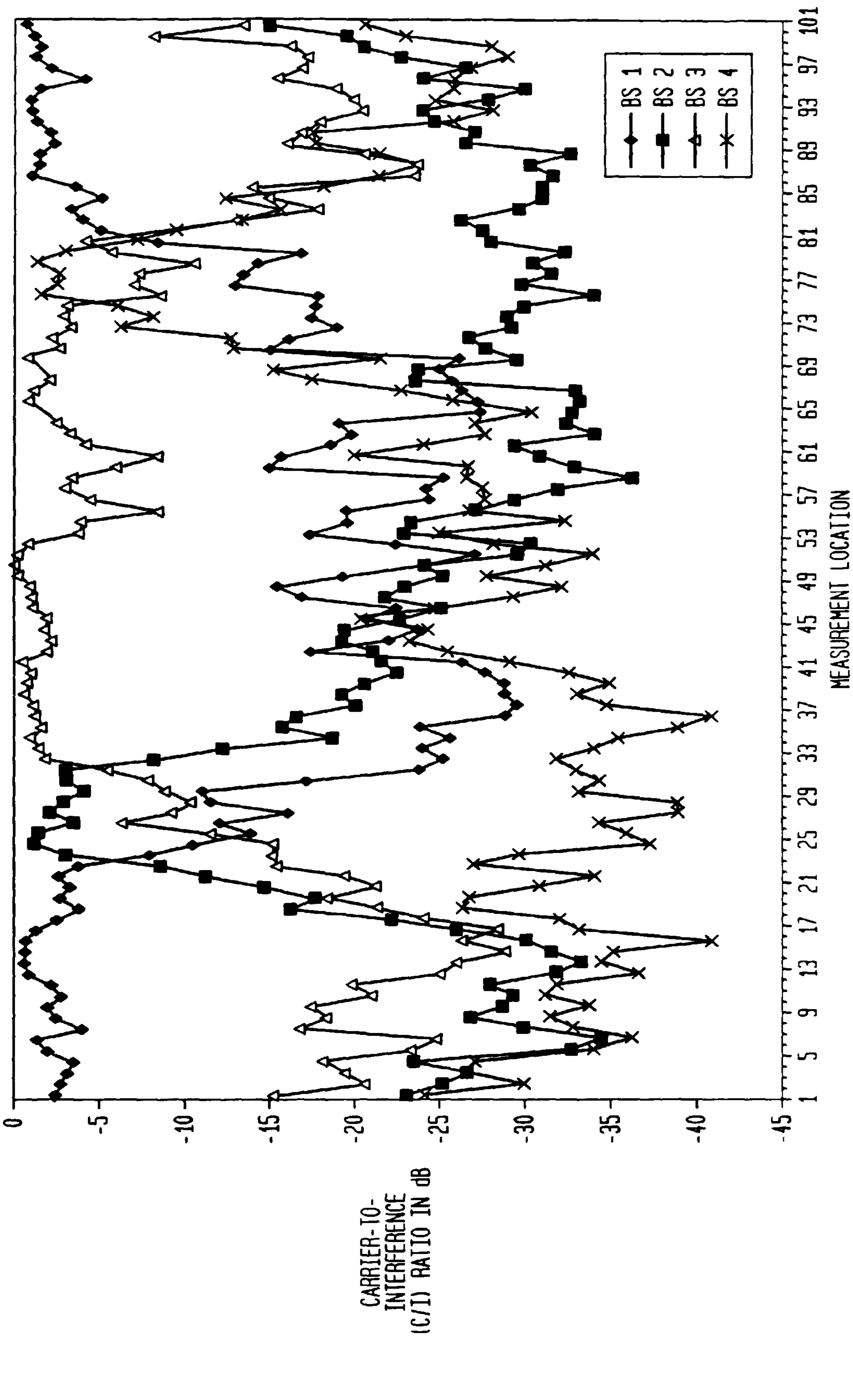
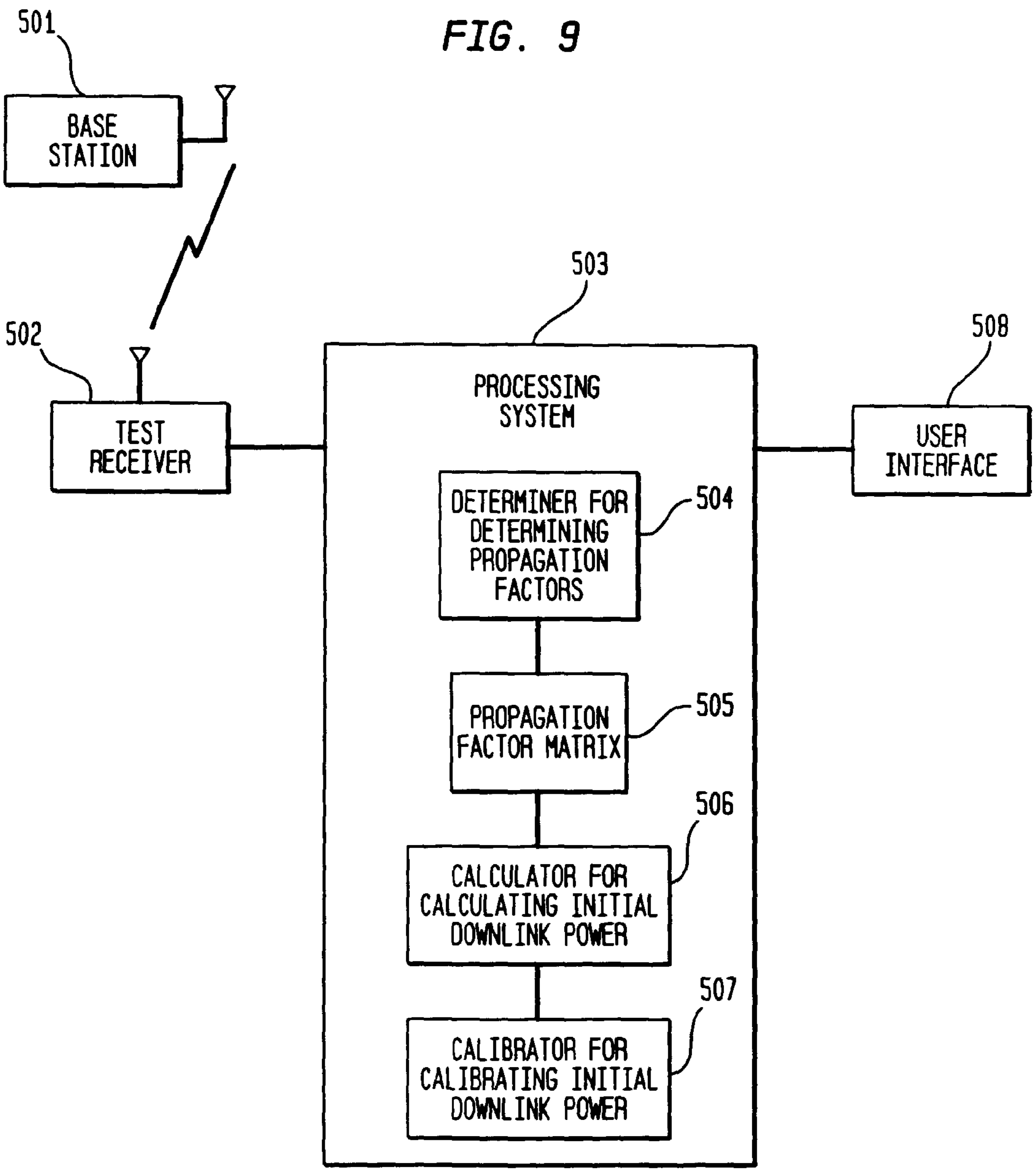

CARRIER-TO-INTERFERENCE (C/I) RATIO IN dB
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
MEASUREMENT LOCATION
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93 97 101
BS 1
BS 2
BS 3
BS 4

FIG. 9


501
BASE STATION
502
TEST RECEIVER
503
PROCESSING SYSTEM
DETERMINER FOR DETERMINING PROPAGATION FACTORS
504
PROPAGATION FACTOR MATRIX
505
CALCULATOR FOR CALCULATING INITIAL DOWNLINK POWER
506
CALIBRATOR FOR CALIBRATING INITIAL DOWNLINK POWER
507
USER INTERFACE
508

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 30 1034

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	EP 0 856 955 A (OKI ELECTRIC IND CO LTD ;YRP MOBILE TELECOMMUNICATIONS (JP)) 5 August 1998 (1998-08-05) * column 25, line 48 - column 30, line 57; figure 17 * ---	1-31	H04B7/005
A	EP 0 817 516 A (NIPPON ELECTRIC CO) 7 January 1998 (1998-01-07) * column 9, line 31 - column 11, line 50; figures 2,5 * ---	1,14,24	
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TECHNICAL FIELDS SEARCHED (Int.Cl.7)

H04B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	16 June 2000	Burghardt, G

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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E : earlier patent document, but published on, or after the filing date
D : document cited in the application
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& : member of the same patent family, corresponding document

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 00 30 1034

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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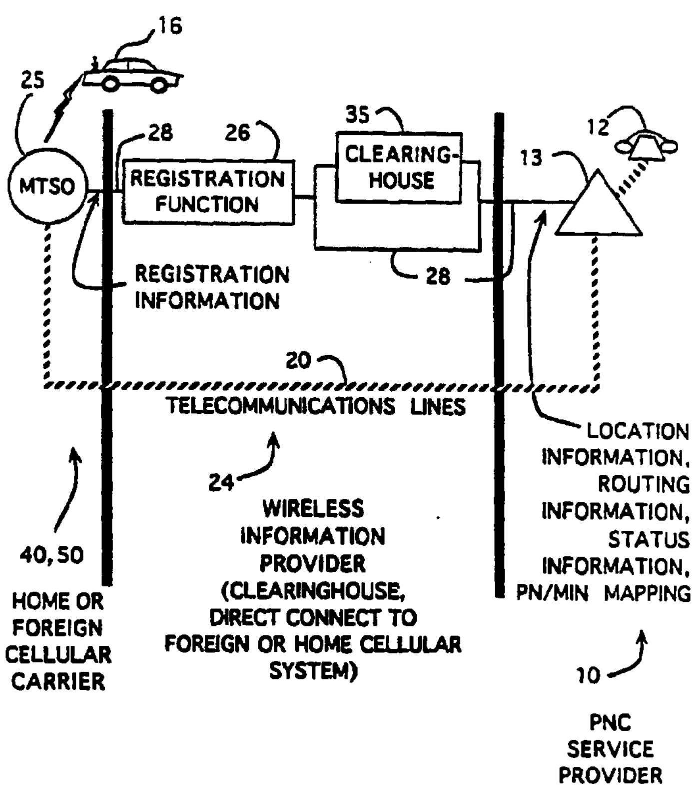
(54) Title: PERSONAL NUMBER COMMUNICATION SYSTEM WITH CELLULAR MOBILE RADIOTELEPHONE ROAMING CAPABILITY

(57) Abstract

A personal number communications system (10) operative to route personal number communications to subscribers at remote locations, for example to a subscriber's cellular mobile radiotelephones (16) operated in a roaming manner in a foreign cellular service area (40). Location information corresponding to the whereabouts of an active and registered mobile radiotelephone is transmitted, either directly or indirectly via a clearinghouse (35), to switching equipment that maintains a database of communications disposition information (13), comprising subscriber alternative destinations for personal number communications. The location information is continuously updated to reflect registrations and deregistrations, roaming, and other information indicative of subscriber location and status. In response to receipt of a call directed to a personal number, the switching equipment (15) is operative to route the call to the subscriber in the foreign cellular service area (40) if the communications disposition information indicates that the subscriber's cellular telephone (16) is activated and validated.



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PERSONAL NUMBER COMMUNICATION SYSTEM WITH CELLULAR MOBILE RADIOTELEPHONE ROAMING CAPABILITY

Technical Field

The present invention generally relates to communication systems, and more particularly relates to a system for automatically and interactively delivering communications to subscribers at preselected destinations, one or more of which can include cellular mobile radiotelephones, operated in a roaming manner.

Background of the Invention

Personal number communications (PNC) systems have been developed to facilitate the delivery of communications to individual subscribers. In such systems, a personal number (PN) is assigned to each subscriber. The system receives and stores communication routing information in the form of one or more destinations or hierarchical lists of destinations. Such destinations or lists of destinations are based on predetermined routing criteria such as time of day, day of the week, priority of calling party, status of communications device (e.g., busy or inactive), desire for privacy, or other predetermined condition. The hierarchy and composition of the destination lists may be changed by the subscriber, when convenient.

Any incoming communication directed to a subscriber's personal number is received by the system and, in some cases, the source of the communication is identified so that priority callers can be especially handled. In some systems, while the source of an incoming communication is being identified, the system selects a first destination from the list of destinations. If one of the destinations is a cellular mobile radiotelephone, some PNC systems will automatically select the cellular telephone from the list of destinations if the cellular telephone is active. In this case, the system must somehow detect that the cellular telephone is active, and assume the presence of the subscriber at the mobile telephone destination.

An example of such a personal number communication system is described in U.S. Patent Application Serial No. 07/936,384, filed August 26, 1992, entitled "Personal Number Communication Systems", which is assigned to the same assignee as the present invention, the disclosure of which is incorporated herein by reference and made a part hereof.

As will be understood from the referenced co-pending application, at the first of a plurality of destinations, the PNC system announces the identified source of a communication and requests communication disposition information from the subscriber as to the acceptance, formal rejection, or passive rejection, such as a "no answer", of the communication. If accepted, the system routes the communication to the first destination. If rejected, the system routes the communication to a next destination in the hierarchical list of destinations, until the communication is successfully routed or until a default destination is reached. If there is no response from the called party at the first destination, the lack of response is considered a passive rejection. The system them proceeds to request communication disposition information from the next destination in the destination list according to the hierarchy selected by the subscriber. The system continues to request communication disposition information from each sequential destination on the destination list until the communication is accepted or until the last destination on the destination list is reached, at which point the communication is routed to the last destination, which is often a voice mailbox or message service.

Certain difficulties with personal number communications systems occur when one or more of the possible destinations is a cellular mobile radiotelephone (CMR). A particular difficulty arises from the fact that cellular mobile radiotelephone service subscribers by definition are "mobile" -- it is expected that the physical location of the telephone may vary from cell to cell within a cellular system, and may even vary from cellular system to cellular system. Users of cellular mobile radiotelephones can travel between cities having different cellular systems operated by different operating companies. Detecting that a given cellular telephone is "active", and therefore able to send and receive communications, is a complex technical challenge.

Cellular mobile radiotelephone (CMR) systems are designed so that only "registered" and validated mobile telephones can make and receive calls. Registration of a cellular telephone occurs automatically via "autonomous registration" (AR) when the telephone is powered on within a cell of a system. To effect autonomous registration, radio signals carrying identifying information about the cellular telephone (such as the Mobile Identification Number or "MIN" and Electronic Serial Number or "ESN") are automatically transmitted from the telephone to an antenna at the cell site. Circuitry at the cell site and the mobile telephone switching office (MTSO) detects the identifying information in the radio signals and registers the cellular telephone as "present" and active. The telephone's MIN is validated by look-up in a computer database of authorized subscribers. Upon validation of the identifying information, the cellular system operator permits communications to occur by commanding a registered telephone to tune to a particular radio voice channel for making or receiving calls.

Normally, only cellular telephones that are identified by the system operator as subscribers or "home" units are allowed access to the system for making or receiving communications. Other, non-home mobile radiotelephones present within a system are known as "roamers", and cannot make or receive calls without additional steps. Cellular mobile radiotelephones are identified as "home" units or "roamers" by examining the identification information provided by the telephone when it registers. When a cellular telephone registers or originates a call, it transmits a series of data messages to the serving cell. These data messages contain the identification information, particularly the MIN and ESN, that uniquely identifies the telephone. The data messages are provided first to the cell, and then through a data link to the mobile telephone switching office (MTSO). The MTSO, also known as "the switch", then makes voice connections between mobile telephones and the main telephone network. At the MTSO, a validation determination is made whether the telephone is an authorized user (or subscriber) by looking up the MIN/ESN in the MTSO's computer database to see if there is an entry in the database corresponding to that particular telephone. If the MIN is valid and "home", calls are allowed to proceed. If the MIN indicates the presence of a "roamer", further validation steps are required.

A CMR subscriber's ability to receive incoming calls when roaming outside his or her home service area is restricted. Such restrictions create particular difficulties in delivering communications in a personal number communication service. Unanswered calls placed to a cellular subscriber's home number are typically answered with a voice message indicating that the subscriber cannot be found. While it is theoretically possible to use the information that the subscriber cannot be found to route a PNC call to an alternative destination, it would be preferable that the PNC call be delivered to the subscriber while roaming in the foreign service area.

One method for receiving incoming calls when roaming in a foreign service area requires would-be calling parties to know the whereabouts of the subscriber. If the caller knows the CMR system in which the roamer is present, then there are procedures for accessing the subscriber through the facilities known as the "local access number" of the foreign CMR system. However, callers must know the roamer's travel itinerary and the roamer local access number of the CMR system in which the roamer is present. Armed with this information, a would-be caller can dial the roamer local access number (typically ten digits) of the CMR system in which the roamer is present, and then reach the subscriber by dialing the subscriber's MIN.

Another method for receiving incoming calls when roaming in a foreign service area relies upon the use of cellular "clearinghouses". In this method, an intermediary or "clearinghouse" is notified by the subscriber when the subscriber enters the foreign service area and provides the service of connecting calls directed to the subscriber's MIN in the home service area to the telephone in the foreign service area. The clearinghouse performs the function of validation of the subscriber on behalf of the foreign service area MTSO, and provides call routing information to the home service MTSO.

One such clearinghouse-based system is described in U.S. Patent No. 4,901,340 to *Parker et al.*, entitled "System for the Extended Provision of Cellular Mobile Radiotelephone Service". This patent describes a system for enabling a roaming CMR subscriber to automatically receive, in a foreign service area (that is, the area outside his home service area), calls placed to his MIN at the home service area. This system underlies a service denominated the FOLLOW ME ROAMING® service provided by GTE Mobile Net, Inc., nominal assignee of the '340 patent, and/or GTE Telecommunications Services, Inc.

Other clearinghouse or roaming services are commercially available, for example, the ROAMING AMERICA service provided by Electronic Data Systems, Inc. ("EDS"), Personal Communications Corp., Dallas, Texas.

While clearinghouse systems facilitate the delivery of telephone calls to roamers in foreign service areas, they do not inherently provide any type of personal number communications (PNC) service. Moreover, not all cellular systems provide either FOLLOW ME ROAMING service or ROAMING AMERICA service -- some only allow access to roamers via a local access number.

The above-referenced clearinghouse-based roaming systems require that a roaming subscriber activate the call-delivery service by providing roaming notification information. Typically, this entails that the roaming subscriber enter a "star" code such as *18 via the telephone keypad upon entry into the foreign service area. The roaming notification information is a signal indicative that a roaming CMR subscriber desires to receive, in the foreign service area, calls placed to the home service area. The clearinghouse service then validates the roaming subscriber by communicating with the home MTSO. Upon validation of the roaming subscriber, the clearinghouse assigns a temporary line directory number (TLDN) to the roaming subscriber and transmits this TLDN to the home MTSO via a data communications link. Then, command information is provided to the roaming CMR subscriber's home service area MTSO so as to enable the home service area MTSO to call forward, via the TLDN, calls placed to the subscriber's MIN in his home service area.

At least partly because of the difficulties encountered with local access numbers and star-code roaming service activation, systems have been developed for detecting the presence of roamers and facilitating the delivery of calls to them. One such a system is described in pending U.S. Patent Application Serial No. 647,719, filed January 28, 1991, entitled "Interactive Roamer Contact System for Cellular Mobile Radiotelephone Network", which is assigned to the same assignee as the present invention. In this system, roamers are automatically detected via the identification information provided by the roaming telephone upon registration. When a roamer is detected, a call is automatically placed to the roaming telephone to initiate a communication session. During the call, the user is interactively provided with information concerning access to roaming services with synthesized voice messages. The subscriber can elect to activate roaming service, for example FOLLOW ME ROAMING, by pressing appropriate keys on the keypad during the interactive communication session.

While this interactive roamer contact system facilitates the detection and contact of roamers for the purpose of easing the use of roaming services, it does not fully address the problem of delivering calls to PNC subscribers when roaming. Given that identification information is automatically obtained from roaming telephones in the above-described interactive roamer contact system as a result of autonomous registration (AR), it would be desirable if the identification information could be automatically provided via a clearinghouse or direct data links to personal number communications (PNC) systems so as to facilitate the provision of personal number communication services to roamers.

The PNC system described in the referenced co-pending application is implemented utilizing known service control point (SCP) equipment, which includes a computer database that associates personal numbers (PNs) of subscribers with telephone numbers and other device numbers (such as the MIN of cellular telephones) of the various alternative destinations. In order to route a call to a mobile telephone, SCP equipment not only must know that a subscriber's mobile telephone is registered and active, but also must be able to route the call appropriately.

To support autonomous registration (AR) capability with a personal number communication service, therefore, the service control point (SCP) equipment must somehow obtain and store information that a subscriber is registered on their mobile telephone, whether home or roaming, and must also obtain and store routing information that allows the call to be forwarded appropriately. If the subscriber is currently served by the home MTSO, then the routing directory number is the MIN. If on the other hand the subscriber is roaming and visiting another MTSO, the routing directory number is generally a temporary line directory number (TLDN) obtained via a clearinghouse or directly from the visited MTSO. Presently, knowledge by SCP equipment of registrations and routing directory numbers is not possible because SCP equipment does not directly communicate with visited MTSOs or clearinghouses.

Accordingly, there is a need for a system to provide location information derived from registrations and other indications of roaming by personal number communications subscribers with cellular mobile radiotelephones so that the PNC systems can detect that the cellular telephone is active and correctly route calls to the subscriber in a visited or a home cellular system. There is also a need for systems and methods that speed the delivery of communications in personal number communications services where a subscriber utilizes a cellular mobile radiotelephone and roams from area to area.

Summary of the Invention

As will be seen, the present invention satisfies the foregoing criteria by providing a system and method for delivering communications to a subscriber of a personal number communication service that has a cellular mobile radiotelephone or other mobile communications device. Briefly described, the method comprises receiving location information corresponding to a present location of a subscriber. The location information can be obtained from a clearinghouse, or by other means such as directly from a visited cellular system. Next, the system receives communication routing information corresponding to a plurality of destinations associated with the subscriber. These destinations are generally arranged in hierarchical fashion by the subscriber, and are indicative of the subscriber's call routing preferences. When the system receives a communication directed to the subscriber, typically via the subscriber's personal number, the communication is routed to one of the destinations in accordance with the communication routing information and the location information.

More particularly described, when a personal number communications service provider receives calls for a person at their personal number, and one of the potential destinations for the communication is a cellular mobile radiotelephone, the present invention entails proper routing of communications to the person whether in their home cellular service area, or in a roaming cellular service area, and regardless of whether the individual reflects a "busy" or inactive status. The present invention is operative to obtain location information from the remote location and to properly route the call.

Generally, when a PNC subscriber is in their home area, the routing number is the cellular telephone number (MIN). When a subscriber is visiting outside of their home area, the routing generally is via the temporary line directory number (TLDN).

At least three possibilities are handled: (1) the cellular PNC subscriber is in the home area and registered to receive calls, (2) the subscriber is in a visiting cellular area and ready to receive calls, or (3) the cellular subscriber's telephone is busy or the telephone is switched off. In the present invention, such possibilities are indicated by status information in addition to the location information. Thus, according to another aspect of the invention, the communication is routed to one of the destinations in accordance with the communication routing information, location information, and status information.

Because of present day regulatory limitations, certain system operators may not be legally allowed to receive and respond to status information that the cellular phone is switched off or is busy. In the event that status information is not available, with the present invention calls are nonetheless routed appropriately via the home cellular carrier through appropriate switching arrangements, generally made through the subscriber's selected long distance carrier. In the event that status information is lawfully utilizable and available, the call can be routed to alternative destinations.

Advantageously, the present invention allows subscribers to continue use of a single personal number as a contact number for receipt of all communications including wire line, wireless (including cellular), facsimile transmissions, paging, voice mailboxes, etc. In certain embodiments, the provision of communications to the subscriber is transparent and seamless, without the need for entry of any special codes so that the subscriber is automatically detected as being either in a roaming mode or in a home mode, or if the location information and/or status information does not indicate that the cellular telephone is active and available, the communication is automatically routed to alternative destinations.

Furthermore, the present invention is still capable of routing personal number communications to most types of communication devices. Thus, the destinations may include office and home telephones, mobile telephones, voice mail services, other message services, facsimile transmission devices, and both digital and alphanumeric pagers. Features implemented in personal number communication systems as described in the referenced co-pending application are provided, with enhanced capability of automatic routing of calls to cellular subscribers.

Accordingly, it is an object of the present invention to provide an improved personal number communication system.

It is another object of the present invention to provide an improved personal number communication system that facilitates delivery of communications to subscribers with cellular mobile radiotelephones.

It is another object of the present invention to provide an improved personal number communication system that facilitates delivery of communications to subscribers with cellular mobile radiotelephones who roam.

It is another object of the present invention to provide an improved personal number communications systems with cellular roaming capability that supports remote autonomous registration.

It is another object of the present invention to provide a personal number communications system that is effective without requiring cellular carriers to support IS-41 or even SS7 connectivity, yet still provide PNC roaming capability.

It is another object of the present invention to provide an improved personal number communications system for subscribers with cellular mobile radiotelephones that are automatically operative, and do not require the subscriber to manually activate roaming by entry of star codes or other activation codes.

It is another object of the present invention to provide a personal number communications system that is operative to automatically route PNC communications to subscribers based on communication routing information and location information.

It is another object of the present invention to provide a personal number communications system that is operative to automatically route PNC communications to subscribers based on communication routing information, location information, and, if allowed, status information.

That the present invention and the preferred embodiment thereof overcomes the drawbacks set forth above and accomplishes the objects of the invention set forth herein will become apparent from the detailed description of the preferred embodiment to follow.

Brief Description of the Drawings

FIG. 1 is a block diagram illustrating general concepts, the flow of information, and the telecommunications connections in the present invention.

FIG. 2 is a block diagram illustrating the relationship between a home MTSO, a visited MTSO, and switching equipment in the preferred embodiment of the present invention.

FIG. 3 is a block diagram illustrating a personal number communications (PNC) system with cellular mobile radiotelephone roaming capability, constructed in accordance with the preferred embodiment of the present invention.

FIG. 4 illustrates an exemplary registration notification data packet that is transmitted between various communicating entities in the system of the preferred embodiment.

FIG. 5 illustrates a communication sequence between various elements of the system of the preferred embodiment in a situation wherein a PNC subscriber is roaming in an IS-41 capable foreign cellular service area.

FIG. 6 illustrates a communication sequence between various elements of the system of the preferred embodiment in a situation wherein a PNC subscriber is roaming in a non-IS-41 capable foreign cellular service area.

FIG. 7 illustrates a communication sequence between various elements of the system of the preferred embodiment in a situation wherein a PNC subscriber is roaming in a foreign cellular service area, without a clearinghouse intermediary.

FIG. 8 illustrates a communication sequence between elements of the system of the preferred embodiment in a situation wherein a PNC subscriber in a foreign cellular service area deactivates roaming.

FIG. 9 illustrates a communication sequence between elements of the system of the preferred embodiment in a situation wherein a PNC subscriber in a foreign cellular service area is implicitly de-activated by a clearinghouse.

FIG. 10 illustrates a communication sequence between elements of the system of the preferred embodiment in a situation wherein a PNC subscriber in a foreign cellular service area transmits predetermined codes activating various features of the PNC services to the service control point equipment.

FIG. 11 illustrates a communication sequence between elements of the system of the preferred embodiment involving use of a temporary line directory number (TLDN) to route personal number service calls to a PNC subscriber in a foreign cellular service area.

FIG. 12 illustrates a communication sequence between elements of the system of the preferred embodiment involving routing of calls to a PNC subscriber's voice mailbox in the event of detection of a busy or inactive status of the PNC subscriber in a foreign cellular service area.

FIG. 13 illustrates a communication sequence between elements of the system of the preferred embodiment in a situation wherein an inactive or busy response is obtained with respect to a PNC subscriber who was previously detected as roaming in a foreign cellular service area.

FIG. 14 illustrates a communication sequence between various elements of the system of the preferred embodiment in a situation wherein location information is provided from a line information database (LIDB) maintained by a validation service.

FIG. 15 is a diagram illustrating various information fields in the database maintained by the service control point (SCP) equipment in the system of the preferred embodiment.

Detailed Description of the Disclosed Embodiments

Referring now to the drawings, in which like numerals indicate like elements throughout the several figures, FIG. 1 is a block diagram illustrating certain basic concepts of a personal number communication (PNC) service or system **10** constructed in accordance with the present invention, involving subscribers that utilize at least one cellular mobile radiotelephone (CMR)(not shown). Stated generally, a PNC system **10** allows the provision of PNC services to subscribers. The system receives a communication from a calling party **12** directed to a subscriber/called party's personal number (PN), and routes the communication to a called party **16** at one of a possible plurality of alternative destinations. In accordance with the present invention, the called party **16** may designate a cellular mobile radiotelephone (CMR) as one of the alternative destinations.

It will be understood that two principal communication functions must be implemented in constructing the present invention or carrying out the methods of the present invention. First, there must be communication of data indicative of the PNC subscriber's location (e.g. location information) and routing path requirements (e.g. routing information) between various communicating and control entities that will enable the connection of voice grade trunks **20** to route calls to appropriate locations. Secondly, there must be establishment of appropriate voice grade trunks **20** between the various entities in accordance with such location information to route a communication to the PNC subscriber at the location. Various communicating entities carry out these communication functions.

In addition, and under certain circumstances, there is communication of data indicative of the PNC subscriber's status, e.g., whether the subscriber's equipment is busy, registered but idle, etc.

In general, switching equipment **13** is utilized in the system **10** to provide the function of receiving location information, receiving routing information, receiving status information, receiving PN calls, mapping a personal number to a destination number, establishing voice grade trunk connections, etc. However, those skilled in the art will understand that such switching equipment **13** may be constructed with a variety of different components, e.g. service node (SN) equipment, service control point (SCP) equipment, service switching point (SSP) equipment, private branch exchange (PBX) equipment, other central office (CO) equipment, etc. Often, such switching equipment **13** employs one or more computers connected for data communications; such computers receive, store, process, and transmit routing information via known protocols such as SS7, X.25, IS-41, etc., to facilitate the routing and maintenance functions of the telecommunications network. Thus, as used herein, the term "switching equipment" means any communications apparatus that is operative to connect an incoming communication to a destination, in accordance with predetermined criteria such as routing information.

For purposes of describing the present invention, a preferred embodiment of switching equipment **13** comprising SCP equipment and SSP equipment will be described in detail, it being understood that other types of telephone switching and computing equipment are considered equivalent and may be utilized to provide the functions of the invention.

Still referring to FIG. 1, the communicating entities include the switching equipment **13**, a wireless information provider **24** (which may include a clearinghouse **35**), and a foreign or home cellular carrier **40**, **50**, respectively. Preferably, the various communicating entities are connected for data communications via Signaling System 7 (SS7) data communication links **28**. These data communication links **28** enable cellular registration information, which is a species of location information, to be provided from a cellular carrier such as an MTSO **25** and the wireless information provider **24** to the switching equipment **13**.

In accordance with the invention, registration information indicative of the presence of a mobile telephone is obtained by a registration function **26** and provided to the system **10**. The registration information is utilized as location information, and under certain circumstance status information. The registration information is utilized by the PNC system to modify the communication disposition information maintained by the system, and selectably deliver communications to various destinations in accordance with the communication disposition information.

The registration function **26** can occur at a foreign (visited) cellular system, as the foreign system detects roamers, or by a clearinghouse, or in other manners. It is particularly contemplated that the registration function, which obtains the registration information, may comprise delivery of a "copy" of registration information obtained by communicating entities such as cellular telephone switching offices and clearinghouses as such communicating entities detect and handle roaming cellular mobile radiotelephones. Since such communicating entities obtain registration information as a normal part of their operations, the present invention may be implemented by utilizing "copies" of the registration information obtained via data communications links established with such entities.

While FIG. 1 shows that wireless information provider **24** comprising a clearinghouse **35**, it should be understood that the present invention contemplates use of any wireless information provider, including but not limited to clearinghouses, a visited foreign cellular system, or a home cellular system, any of which can obtain location information as a function of autonomous registrations, activation of roaming services, validation procedures, and the like. Thus, it is contemplated that the wireless information provider **24** will provide a registration function that at least partly entails detecting registration of cellular subscribers (whether roaming or home), and in certain cases, correlating or mapping personal numbers (PN) to mobile identification numbers (MIN). The wireless information provider then, upon determination that a registration corresponds to a communication intended for a personal number, provides location information via the data communications links **28** to the switching equipment **13**, sometimes via a clearinghouse **35**, which enables set up of appropriate routings of the call via voice grade telecommunications lines **20**.

It will also be understood that the registration information and location information may be directly provided from the registration function (regardless of where it occurs) to the switching equipment **13**. Thus, FIG. 1 shows a direct data communications path **28** from the registration function to the switching equipment, as well as via a clearinghouse **35**. The clearinghouse function is required only in embodiments of the invention where an intermediary is employed to provide location information and routing information to the service node, e.g. when ROAMING AMERICA or FOLLOW ME ROAMING services are utilized.

As used herein, the term "location information" means information indicative of the geographic location of a PNC subscriber, which information can be used to call-forward or route calls to a remote location. The term can include, in the appropriate context, but is not limited to, cellular "identification information" provided upon registration of a cellular telephone, such as, but not limited to, MIN, SID, REGH, REGR, REGID, REGINCR, SCM, ESN, etc. A "registration message" typically includes identification information, but can include other location information.

Upon receipt of a registration message containing registration information, identification information, or other location information at switching equipment **13**, the switching equipment will determine appropriate routing for subsequently received PNC calls.

It will therefore be understood that while location information in the preferred embodiment may be provided through the clearinghouse **35**, the present invention is not limited to obtaining location information from a clearinghouse, but may also obtain location information directly from cellular systems through appropriate contractual arrangements and establishment of data communication links (such as via SS7 links) so that the location information can be directly supplied from the visited location. Such arrangements are especially contemplated for use in systems operated by multi-state telecommunications service providers, such as BellSouth Corporation, that operate a number of different cellular systems in different geographical areas, so as to integrate the provision of personal number communication services within the jurisdiction of the multi-state operator.

Those skilled in the art will understand that switching equipment **13**, wireless information provider **24**, and any other communicating entities are preferably connected using SS7 data communications in the known manner. The SS7 communications protocol is provided in the document entitled "Bell Communications Research Specification of Signaling System 7," Document TR-NWT-000246, Issue 2 (June 1991), plus Revision 1 (December 1991), which is incorporated herein by reference and made a part hereof. However, it will be understood that other types of data communications media such as X.25 may also be utilized to communicate the data messages contemplated in the present invention.

Typically, the data messages or communications between the various entities relating to cellular telephone intersystem operations are provided in a format known to those skilled in the art as "IS-41". The requirements for communications utilizing IS-41 messages are based on the EIA/TIA document entitled "Cellular Radio-telecommunications Intersystem Operations: Functional Overview", IS-41.1, Sections 1-5, which is incorporated herein by reference and made a part hereof.

Referring now to FIG. 2, next will be described a generalized communications scenario involving an incoming PN call to the switching equipment **13**, and alternative routing pathways to the called party at his or her cellular telephone **16**. In the preferred embodiment, the switching equipment **13** comprises a service switching point (SSP) equipment **15** that is operative to route the incoming PN call to a destination (as yet unknown), and service control point (SCP) equipment **14** that is operative to receive location information and determine appropriate routing for the incoming call. Assume in FIG. 2 that the called party has a cellular mobile radiotelephone, is a subscriber for cellular service with a designated home MTSO **25***a*, and is roaming with his or her CMR at a visited MTSO **25***b*. The roaming CMR is designated at **16′**. Upon autonomous registration by the roaming CMR **16′**, the visited MTSO **25***b* provides a registration message to a clearinghouse **35** via data communications line **28***a*. In turn, the clearinghouse **35** provides the location information to the switching equipment **13** via data communications line **28***b*. In the preferred embodiment, the SCP **14** in the switching equipment **13** receives the location information.

An incoming PN call will arrive via telecommunications line **20***a* at the switching equipment **13**. In particular, the incoming PN call will be handled by SSP equipment **15**. The SSP equipment is operative to communicate with the SCP equipment to determine appropriate routing for the PN call. The routing will be determined by the location information (and possibly status information) maintained by the SCP. The PN call will then be routed to the visited MTSO **25***b* via telecommunications line **20***b*, assuming that the PNC subscriber has previously designated that he or she wishes to receive PN calls when roaming.

Still referring to FIG. 2, a similar routing function occurs if the PNC subscriber is not roaming, but desires to receive PN calls at his or her cellular telephone. In such a case, the switching equipment **13** will route the call to the home MTSO **25***a* via telecommunications line **20***c*, assuming that the PNC subscriber has previously designated that he or she wishes to receive PN calls when at the cellular telephone. The call is typically routed in accordance with the cellular telephone's MIN, which is determined when the switching equipment **13** maps or correlates the subscriber's personal number to the MIN. Under such circumstances, the location information will indicate that the subscriber is not roaming (or is not to be treated as roaming) because of messages from the clearinghouse **35** (e.g. a registration cancellation message) or other messages containing location information provided directly from the home MTSO **25***a*. It will therefore be appreciated that the clearinghouse can provide location information directly to the home MTSO **25***a* via data communications line **28***c*.

According to another aspect of the invention, the home MTSO **25***a* may further route the call to a visited MTSO **25***b* via a telecommunications link **20***d*. This situation would occur in an embodiment wherein PN calls are first routed to a home MTSO for the PN subscriber, and the home MTSO serves the function of the switching equipment **13**. Thus, it will be understood that the functional blocks shown in the various figures are for purposes of illustration only, and an important aspect of the present invention is routing of the PN calls to the PN subscriber in accordance with location information, status information, communication disposition information, etc.

Turning now to FIG. 3, the preferred embodiment of a system **10** constructed in accordance with the present invention, which implements a method and apparatus for a personal number communication (PNC) system, involving subscribers that utilize at least one cellular mobile radiotelephone (CMR) **16**, will be described. The system in FIG. 3 is a specific and preferred implementation of the concepts illustrated generally in FIGS. 1 and 2.

The preferred system **10** preferably operates in conjunction with the public switched telephone network (PSTN). The PSTN comprises the well-known components of at least one end or central office **18***a* associated with a calling party **12**, switching equipment **13** associated with a called party PNC subscriber **16** (which may include central office **18***b*), and a plurality of telecommunication lines **20**, shown as the thicker lines in FIG. 1, for conducting communications between the calling party and the PNC called party. In the exemplary embodiment of FIG. 1, the switching equipment **13** comprises service switching point (SSP) equipment **14** (which may include central office **18**b) and service control point (SCP) equipment **15** that implement the PNC service.

Since the present invention operates in conjunction with a PNC system, the called party may be at one of a number of different destinations or locations, such as at a cellular telephone **16** in the subscriber's home cellular system **50**, at a cellular telephone **16´** in a visited cellular system **40**, or at an alternative location such as **46**. It will be understood that the communication from the calling party **12** is made to the PNC subscriber's personal number (PN), which is routed to the called party's current location.

The telecommunications lines **20** are typically those associated with voice grade telecommunications wire line, connecting the calling party central office **18**a and the called party central office **18**b, which is operative to receive in the first instance the communication from the calling party **12**. An optional long distance carrier (LDC) **22**, such as provided by AT&T, U.S. Sprint, MCI, etc., may be interposed between the central offices **18**a, **18**b, in the known manner, when long distance communications are involved.

In the preferred embodiment, the SSP equipment **14** comprises known telephone switching equipment provided by telecommunications switching equipment vendors such as Ericsson, AT&T, Northern Telecom, etc. Likewise, the SCP equipment **15** preferably comprises a computer platform operative to run PNC application software including routine service, routing, and associated subscriber databases. Examples of SCP equipment vendors are Hewlett-Packard., IBM, Tandem Computers, AT&T, etc. Details of such computer platforms is available in the literature supplied by the manufacturers, and details of the PNC service logic is provided in the referenced and incorporated copending U.S. patent application Serial No. 07/936,384.

The public switched telephone network may comprise one or more MTSO's **25** in situations where at least one PNC destination involves a cellular mobile radiotelephone, as in the present case wherein the called party utilizes a cellular mobile radiotelephone **16** in the subscriber's automobile. Thus, as shown in FIG. 3, the preferred PNC system **10** comprises at least one MTSO **25***a* (directly or indirectly) that is considered the "home" location for the subscriber, that is a part of the subscriber's home cellular system **50**.

A type 2 trunking interface, consisting of twenty-four channels, provides voice trunks **20***a* between the home MTSO **25***a* and the SSP **14** via the central office **18***b*. As will be known to those skilled in the art, the SSP equipment **14** comprises or is directly connected to one or more central offices, such as the central office **18***b*. Through this interconnection, calls made by subscribers using their mobile telephones can be routed properly to wireline destinations, typically via the associated central office **18***b*. As known to those skilled in the art, the MTSO's **25** route calls to and from cellular users based on the Numbering Plan Area (NPA) and end office code (NXX), or 1,000 block number group, if required.

The MTSO's **25** utilized in the present invention typically include a Home Location Register (HLR)(not illustrated), which as described in IS-41.1 is a database operated by a cellular system operator to which a user identity is assigned for record purposes. The HLR database stores subscriber information such as the Electronic Serial Number (ESN) of a subscriber's telephone **16**, the Mobile Identification Number (MIN) of the telephone, any Directory Number (DN) associated with the telephone, profile information, current cell location, validation period, etc. The database may also store a Temporary Line Directory Number (TLDN) provided by a clearinghouse or by a visited MTSO to facilitate routing calls to the visited MTSO. The HLR may or may not be located within, and be indistinguishable from, MTSO equipment. The HLR database may serve more than one MTSO, and may be distributed over more than one physical entity.

The MTSO's **25** typically also include a Visitor Location Register (VLR)(not illustrated), which is a database other than the HLR used to store and retrieve information related to, for example, handling of calls to or from a visiting subscriber or roamer. The VLR may or may not be located within, and be indistinguishable from, MTSO equipment. A VLR may serve more than one MTSO.

The preferred cellular systems **40**, **50** further include a roamer detection module (RDM)(not shown) associated with the MTSO **25**. Such a roamer detection module is described in connection with the above-referenced co-pending patent application entitled "Interactive Roamer Contact System for Cellular Mobile Radio Telephone Network", the disclosure of which is incorporated herein by reference and made a part hereof. Such a roamer detection module may be utilized in the MTSOs **25** to detect registrations of roamers, to provide the registration function described in connection with FIG. 1, and to provide the location information to the clearinghouse **35** or to the switching equipment **13**.

In systems utilizing an RDM, when mobile telephones in a cell are powered on, mobile telephone registration information or identification information may be delivered by the RDM to the switching equipment **13** in the form of IS-41 signaling messages on the SS7 network. In FIG. 3, SS7 signaling connections or other data communications links are shown in dotted lines, identified with the reference numeral **28**. Accordingly, when the PNC cellular subscriber has activated the cellular telephone **16** within the home service area **50**, such as within a cell **30**, information indicative of the activation of the cellular telephone **16** is stored in a home location register (HLR) database associated with the MTSO **25***a*; and data indicative of the registration of the mobile telephone is transmitted via a data communications link **28***a* to the SCP equipment **15**. Such registration information also comprises location information inasmuch as it originates from the home cellular system, thereby indicating the current location of the PNC subscriber and a current status of "cellular phone turned on and active."

Generally, in the case where the PNC subscriber is located within his or her home cellular system **50**, the registration information is provided directly from an RDM located in the home cellular system. This registration information is then entered as location information into a PNC subscriber location database maintained in the switching equipment **13** as a part of the provision of the PNC service.

As will be known from the incorporated PNC system patent application, the PNC subscriber database also stores communication disposition information. Such communication disposition information, which comprises PNC destination information, is used to determine the locations to which PNC calls should be directed. Calls directed to the PNC subscriber's personal number are routed to the cellular telephone **16** if the PNC destination information so indicates.

It should be understood that in a PNC system, communications are "disposed" of in accordance with the communication disposition information. Communications are "disposed" of by, for example, delivering communications to selected destinations such as land line telephones, voice mail boxes, fax machines, pagers, or mobile telephones, as well providing announcements to callers. Thus, disposal of a communication is not limited to delivery of the communication, but can include other types of treatment such as providing announcements, etc.

Information stored in the PNC system indicative of a subscriber's preferred disposition of communications is a first species of communication disposition information. In addition to such first communication disposition information, it should also be understood that a second species of communication disposition information relates to information that can be provided by the subscriber in response to attempted delivery of a communication. For example, in the above-referenced PNC system patent application, an attempted call can be accepted, formally rejected (by entry of a *code or other similar command), or passively rejected (as with a no answer). Such information as to the acceptance, formal rejection or passive rejection of the communication may be detected at the foreign cellular system, and provided by foreign system to the PNC system, for example, in the form of an IS-41.5 RemoteFeatureControlRequest (RFCR) message.

As regards the data communications links **28**, those skilled in the art will understand that certain intersystem communications involving voice grade trunk connections are implemented utilizing multi-frequency signaling techniques, while others involve utilization of data communications links such as the links **28**. Preferably, the data communications links will utilize a data communications protocol specifically designed for telecommunications signaling functions such as IS-41. The EIA/TIA interim standard IS-41 establishes protocols for data communications between communicating entities such as between the proprietor of switching equipment associated with a calling party and the proprietor of switching equipment associated with a called party. As those skilled in the art will know, IS-41 was initially defined to support cellular inter-system hand-off and call delivery, such as between a home MTSO ***25a*** and a visited MTSO ***25b***. IS-41 utilizes the known X.25 protocol as a transport mechanism with contemplation for migration to a SS7 network. The data communications network lines **28** used in the present invention may comprise the existing SS7 network of the telephone system operating companies, but may also comprise various interconnected private SS7 networks and other forms of data communications networks.

The IS-41 signaling standard facilitates the hand-off of calls between dissimilar cellular systems, not unlike the way that calls are handed off between cells of a single system. Data that is communicated between the cellular systems is passed over the IS-41 network (using X.25 or SS7 protocols), and contains identifying information associated with the cellular telephone and other information which can comprise location information and trunk identification information for purposes of connecting voice grade trunks.

FIG. 4 illustrates an exemplary data packet or message **60** transmitted via the IS-41 protocol. In particular, the data packet illustrates a "registration notification" or REG.NOT message that corresponds to the registration function. Specific aspects of the REG.NOT message are found at Section 8.1.3.3 in IS-41.5, page 53. The information in a REG.NOT message comprises various fields of identification information in the form of a data record provided from an MTSO to another communications entity such as the switching equipment **13**. The message is includes information identifying the cellular telephone (e.g. MIN and ESN), identifying the cellular system in which registration occurred (MSCID), identifying a geographic area (LocationAreaId), and other related information. It will be understood that similar IS-41 packets are also utilized in connection with the present invention, as described further herein below.

Referring again to FIG. 3, a clearinghouse **35** may be utilized in the present invention to effect the registration function, by obtaining and transmitting location information to the switching equipment **13**. The clearinghouse is operative to obtain identification information and location information from a visited MTSO **25*b*** via the data link **28***c* in response to registration of the PNC subscriber's cellular telephone **16**′, validate the called party as a subscriber, and transmit location information via the data communications link **28***d* to the switching equipment **13**. The clearinghouse can comprise the GTE FOLLOW ME ROAMING® service, the EDS ROAMING AMERICA service, or other similar clearinghouse service.

It will be understood that the clearinghouse **35**, if utilized, provides various functions related to roaming services provided for roaming cellular telephones, many of which may be utilized in connection with the present invention but are not essential to the present invention. One such function that is described in U.S. Patent No. 4,901,340 is the assignment of a temporary directory number (TDN), also called a temporary line directory number (TLDN), for use in the remote service area. When calls are to be routed to a roamer, the FOLLOW ME® roaming processor provides the TLDN, via a data message provided on the data communications link **28***d* between the clearinghouse **35** and the switching equipment **13**. The switching equipment is thereafter operative to intercept and forward calls placed to the subscriber's MIN directed to the home MTSO **25***a* to the TLDN. Calls are subsequently forwarded via the public switched telephone network from the subscriber's home MTSO **25***a* to the foreign MTSO **25***b* via voice trunks **20**.

Interface Between Clearinghouse and PNC System

In order to implement the present invention, it is necessary that some type of call-forwarding facility such as FOLLOW ME ROAMING be available, but also, it is necessary that a translation function be effected. The translation function, which may be considered a mapping function, correlates calls made to the PNC subscriber's personal number to the subscriber's cellular telephone, so that calls are forwarded to an appropriate cellular number. With the present invention, the calls are forwarded to a roaming location, if the PNC subscriber's call destination hierarchy so indicates.

Next will be discussed the specifications for the signaling link requirements between the clearinghouse **35** or other information provider and the switching equipment **13** for the purpose of providing operators of systems constructed in accordance with the present invention with cellular registration information on specific PNC cellular users. The system operator will receive this information on behalf of the cellular carrier that provides the subscriber with a PNC service.

As discussed, the clearinghouse **35** is an information provider that conveys registration information to an operator of the PNC system. It is the function of the clearinghouse to send identification information and location information in the form of a notification (REG.NOT) when a cellular subscriber to the PNC service has requested that cellular calls be routed to his or her cellular telephone in a visited cellular system, such as **40**. A "visited system" is a cellular network **40** that allows the cellular user to roam into the network and receive cellular calls, for example, the visited MTSO **25*b*** in FIG. 3.

It will be understood that in systems utilizing the services of certain commercially available roaming systems as the clearinghouse **35**, "star-codes" ("* codes") are utilized to signal the clearinghouse that the subscriber wishes to invoke certain feature sets for the service provided. A "* code" is a code typically involving the dialing of an asterisk ("*") on the telephone keypad, followed by a one or more numbers, the totality of which comprises a * code. For example, in the FOLLOW ME ROAMING® service areas, a * code of *18 indicates that the cellular user understands that he or she has roamed into a visited cellular system and has requested to receive calls in the visited system utilizing the FOLLOW ME

ROAMING® service. Similarly, the subscriber can enter a cancellation * code, typically *19, that is used to indicate a request to stop receiving calls in the visited system. In similar fashion, the ROAMING AMERICA service utilizes *31 to activate roaming call reception, while *30 signifies deactivation of roaming.

Likewise, for use in the present invention, a PNC * code may be dialed by a PNC subscriber in his or her home cellular system when he or she wishes to receive PNC calls at the cellular telephone, which is also indicated by the entry of a "*" followed by a predetermined one or more digit number. When the following two conditions are satisfied, the PNC subscriber can receive PNC calls in the visited system: (1) the cellular PNC subscriber has activated some type of roaming service that enables calls to be forwarded to the visited MTSO **25*b***, and (2) the switching equipment **13** has received location information, typically via the clearinghouse, of this fact, so that PNC calls to the subscriber can be properly routed to the visited MTSO.

It will thus be understood that the clearinghouse **35** must receive cellular registration information from the cellular carrier via business arrangements between the cellular carrier that operates the visited MTSO **25*b*** and the clearinghouse. Typically, this information will be provided by IS-41 messages on SS7 or other data communications links such as **28*c***. Upon receipt of the registration information from the cellular carrier, the clearinghouse **35** passes this information to the system **10**, and primarily via a data communications link **28*d*** to the switching equipment **13** associated with the system **10**.

In the preferred embodiment, the clearinghouse **35** receives location information from the clearinghouse **35** and passes the information to the switching equipment **13** via a signaling transfer point (STP). Telephone system operators such as the assignee of the present invention typically interconnect with the clearinghouses via a pair of STP's utilizing a pair of a-links and a quad of b-links (not shown). Upon receipt of a registration message and other information from the clearinghouse **35** and STP, it will direct the message to an appropriate switching equipment **13**. Preferably, the clearinghouse **35** connects to the switching equipment via SS7 signaling links.

The protocol architecture for communications between the clearinghouse **35** and the switching equipment **13** utilizes SS7 ANSI standards with IS-41 mobile application part to provide registration functionality. The SS7 protocol architecture including the mobile application part is based on the EIA/TIA IS-41.1, referenced hereinabove.

It will also be understood that the clearinghouse **35** must have a business arrangement with the operator of the PNC system **10**, typically that will include at least one cellular carrier serving as the home cellular system **50**. The clearinghouse also has business arrangements with other cellular systems, such as the visited cellular system **40**. The PNC system operator, as will be understood, purchases and provides personal numbers (PNs) for use in connection with the present invention. Although the clearinghouse may record and track the fact that a particular roamer is a recipient of PNC service and is to be associated with a particular PN, it is not a requirement of the present invention that it do so. Rather, the clearinghouse serves the function of providing the location information to the PNC system operator, and thereby facilitates the registration function.

The registration function, and the corresponding provision of location and identification information from a visited cellular carrier via a clearinghouse **35**, requires support of various data communications operations specified in EIA/TIA IS-41.5, which is incorporated herein by reference and made a part hereof. In particular, the clearinghouse is preferably able to support the IS-41 operations of registration notification (RN or REG.NOT), registration cancellation (RC or REG.CAN), remote feature control request (RFCR), and the like. These parameters are specified in the referenced EIA/TIA IS-41.5. In addition, the clearinghouse preferably supports the error codes specified in IS-41.5.

Those skilled in the art will realize that IS-41 is an established protocol and is being used for that reason. It is, however, possible that another protocol may be used that serves the same intent as described in this embodiment.

It is further preferred that the clearinghouse **35** provide a series of additional information messages to support the provision of the location information, status information, registration information, etc. to the switching equipment **13**, thereby facilitating the connection of appropriate telecommunications lines **20** between the system operator's central office **18*b*** and the visited MTSO **25*b*** so as to connect a voice trunk for routing the call to the roaming PNC subscriber's telephone **16'**.

In this regard, the following TABLE I is a list of exemplary messages that are transmitted between a wireless information provider, such as **24** in FIG. 1, and Switching equipment **13**. The messages are general in the sense that such messages are communicated without regard to whether a clearinghouse is involved or not. In other words, certain messages must be communicated between the visited cellular system and the switching equipment in order to effect the preferred embodiment of the present invention. The messages can be communicated directly in certain cases, for example, when the operator of the system **10** has direct data communications with visited cellular systems, or indirectly via a clearinghouse **35**.

Thus, TABLE I is provided by way of example and not by way of limitation. These messages are utilized in the remaining figures, as explained further below. A signal indicated in the table below in "all capital letters" generally indicates a message initiated with one entity at a first time, while a corresponding entry in lower-case letters in the diagrams of FIGS. 2-10 indicate a reply or response to the message provided by the entity that receives the message.

TABLE I
MESSAGES BETWEEN WIRELESS INFORMATION PROVIDER AND SCP

Functional Description	**Abbr.**	**Description**
Registration Notification	REG.NOT	This message is sent to a home location register (HLR) of an MTSO to indicate that a visitor has been newly registered or re-registered and is active within a cell in the system This is described in 8.1.3.3 of IS-41.5. Once the visitor is validated, the MTSO also makes an entry in its visitor location register (VLR) and may indicate the presence of a roamer that is enabled to originate or receive calls.
Registration Cancellation	REG.CAN	This message is sent from the HLR to the VLR to indicate that it has been determined that a visitor is no longer in the VLR's service area or otherwise unable to send or receive calls.

Remote Feature Control	RFC	This message transmits a remote feature control request in the form of a feature * code provided by the cellular subscriber of the visited MTSO **25***b*, to invoke the provision of features, for example, features associated with the personal number communications service. It typically entails provision of the MIN, the ESN, and the control digits entered (typically * codes in the preferred embodiments).
Routing Request	RR or ROUT. REQ	This message is sent by switching equipment **13** to inquire as to the preferred method of routing a pending call to a visiting subscriber. It is substantially in accordance with the description in Section 8.1.3.6 of IS-41.5.

Location Request	LOC.REQ	This message is sent to a HLR from a switching system which has a call pending, thereby requesting information concerning the current whereabouts and routing information for routing the call to a visited MTSO **25*b***. It is described in Section 8.1.3.5 of IS-41.5. Optionally, the switching equipment **13** may use this message instead of the RR message. Essentially, this is a message that location information be obtained from the clearinghouse **35** and provided to the switching equipment **13**.
Transfer to Number Request	TTNR	If an inactive or busy response is obtained from a clearinghouse in response to a routing request query, a subsequent query can be made to determine subsequent call treatment. A response to a TTNR message is a directory number or TLDN to which a subscriber's call is to be forwarded if the subscriber is currently busy or inactive.

ServiceProfile Directive	SPD	This message is sent from a visited MTSO to a home MTSO whenever local circumstances result in a change in a roamer's service profile from one previously sent. For example, the message contemplates invoking of a Transfer To Number Request (TTNR) when the subscriber wishes to have calls transferred to a location typically in the same geographic location as the roaming PNC cellular subscriber but in an office, hotel room, etc.
Qualification Directive	QD	This message is sent from a home system to a visited system whenever local circumstances result in a change in a validation from that which was previously sent. It is described in Section 8.1.3.2 of IS-41.5.

It will be recalled that the preferred embodiment of the invention is constructed utilizing service switching point (SSP) equipment **14** and SCP equipment (SCP) **15** as the switching equipment **13** and to implement the PNC functions. It will therefore be understood that within the switching equipment **13**, various messages are transmitted between SSP equipment **14** and the SCP equipment **15**, so that information obtained via the data links **28** in connection with the location information and the like can be provided to the SSP for set up of call transfer to an appropriate location or destination. Certain of these messages are illustrated in the following table, which is provided by way of illustration and not limitation:

TABLE II
MESSAGES BETWEEN SSP AND SCP

Functional Description	Abbr.	Description
Query		A query is a message from the SSP 14 to the SCP 15 requesting subsequent treatment or routing instructions. Typically it is formulated as a result of a call to the PN hosted by the SSP.
Response		This message is a response provided by an SCP 15 to a query by an SSP 14. It generally includes some form of disposition to be applied to the call (i.e., to the PN call). The disposition may be an announcement, a request for digit collection from the caller, a routing DN, etc. The routing DN may be an MIN, TLDN or an alternate DN such as a pager number or a voice mail box identification.

It will also be understood that in cases where a clearinghouse is utilized as the wireless information provider, certain types of messages are communicated between the clearinghouse and the visited cellular system. In these cases, the nature of the messages between the clearinghouse and the visited system is similar to the information provided directly from the visited system to the switching equipment **13**. However, the messages may be somewhat different when a clearinghouse is involved since, with a direct data communication between a visited system and the switching equipment **13**, certain overhead information may or may not be required. Thus, there are certain messages that are common to either case of (1) direct data communications from a visited system to the switching equipment **13**, and (2) indirect data communications from a visited system via a clearinghouse to the switching equipment **13**. Examples of messages that are unique to the case of a clearinghouse include, but are not limited to, the following:

TABLE III
MESSAGES BETWEEN WIRELESS INFORMATION PROVIDER (CLEARINGHOUSE) AND VISITED SYSTEM

QUALIFI-CATION REQUEST	QUAL	This message relates to qualification or subscriber validation, which is required by the visited system before it will provide roaming service to a roaming cellular telephone. An appropriate message format is provided in IS-41.5, Section 8.1.3.1.

ROUTING REQUEST	RR or ROUT.REQ	This message relates to assigning a TLDN or other routing protocol in support of roaming and call delivery. Routing may be constrained by legal or regulatory guidelines.

While these functions are performed by the clearinghouse, similar functions are performed by the switching equipment **13** (by the SSP **14** and SCP **15**) in the absence of a clearinghouse.

Communication Scenarios Between System Components

Turning next to FIGS. 5-15, the preferred system **10** requires communication between the various entities involved including the switching equipment **13**, the clearinghouse **35**, a visited MTSO **25*b***, and in some cases, a home MTSO **25*a***. As described, the disclosed switching equipment **13** comprises SSP equipment **14** and SCP equipment **15**. Thus, although the following discussion will relate primarily to communications between the SSP equipment **14** and the SCP equipment **15**, it will be understood that such equipment comprises "switching equipment" and the term "switching equipment" is being used in the general sense.

It will be understood that a number of different communication scenarios arise given the various alternatives as to location of the PNC subscriber relative to a home MTSO versus a visited MTSO, roaming in an IS-41-capable versus a non IS-41-capable visited system, actuation of various PNC service features, utilization of long distance carriers, etc. The different scenarios of FIGS. 5-15 are handled in the preferred embodiment of the present invention. All of the various scenarios are based on two fundamental concepts: (1) provision of location information and (2) establishment of appropriate routing of an incoming PNC communication to the PNC subscriber.

Generally considered, the switching equipment **13** receives copies of information recording the location of a PNC subscriber. This location information can include routing information that indicates preferred routing of the call to the location of the PNC subscriber. With the location information, the switching equipment **13** is able to route that subscriber's PNC calls to the present location of the subscriber. As will be understood, this location could be a cellular location, either a home location or roaming in a visited cellular system location, or it could be a wire line location, an announcement, or any alternative destination.

Location information as to the whereabouts of the PNC cellular subscriber may be acquired in a number of different ways. The subscriber's location may be explicitly detected or implicitly detected. An explicit detection involves roaming requests provided by the roaming subscriber via his or her cellular telephone, requests provided by a clearinghouse service such as the FOLLOW ME ROAMING® service, or a direct REG.NOT message from a visited cellular system. An explicit detection may occur in response to validation or autonomous registration of a subscriber in a roaming environment.

As regards explicit location information, a clearinghouse or other communicating entity operative to provide the location information informs the switching equipment **13** about any explicitly detected subscriber events. For example, such explicitly detected subscriber events include information provided by the clearinghouse **35**, registration information provided by the home MTSO ***25a*** in response to detection of the presence of the subscriber in the home cellular system **50** (such as when the subscriber returns after roaming), or location information provided by other data communications elements such as an RDM function when a PNC subscriber registers or is detected.

Implicit location information, as the term is used herein, is typically derived from subscriber validation. Those skilled in the art will understand that subscriber validation for cellular telephones is available in the cellular industry and the wire line industry. Validation provides implicit location information about a subscriber because validation procedures do not necessarily imply that call delivery is required. Such validation information may be used in the present invention to determine routing information that can be used to route PNC calls. An example of such an implicitly detecting network element is a line information database (LIDB) (not illustrated) for the purpose of validating calling cards (or for that matter credit cards). Such a LIDB may be implemented by a telephone company, by clearinghouses, or within cellular systems that have established validation procedures with the home cellular systems of subscribers or any third party service provider.

As in the case of explicitly detecting systems, implicitly detecting systems also inform the switching equipment **13** about implicitly detected subscriber events. Foremost among such events of course is the validation of a subscriber within any cellular system. Those skilled in the art will understand and appreciate that the present invention therefore is not limited to situations involving a clearinghouse, but can encompass direct provision of location information from visited cellular systems by direct data communication links such as shown at **28*b*** in FIG. 3. In cases of direct data communication links from visited cellular systems such as **40** to switching equipment **13**, business arrangements have been made between the operator of the visited system, or the visited system is a cellular system controlled by the operator of the PNC service, perhaps in another geographic area served by the system operator. For example, BellSouth Corporation operates different cellular systems in different metropolitan areas, e.g. Atlanta's cellular system and Miami's cellular system. While all of such systems are ultimately managed by the same business entity, because of the geographic separation between the cities, location information must be provided to the switching equipment **13**, which can but need not handle PNC communications for subscribers in Atlanta and Miami simultaneously.

For purposes of describing the communication scenarios of the figures, the following general discussion is applicable. Messages passed between the various communicating entities described therein are illustrated temporally from top to bottom, with the first occurring event at the topmost position in the figure, with the arrow pointing in the direction of the communication or message. A thin line terminating in an arrowhead indicates a data message passed typically via SS7 or other data communications link **28**. A message in all caps such as "REG.NOT" indicates a message originating with a communicating entity, while a temporally later message between the same entities in lower case letters, such as "reg.not" indicates a response or reply to a previously-sent originating message. A bold line extending between various entities indicates a telecommunications trunk **20** such as a voice grade trunk, including but not limited to wireless and wire line connections, typically indicative of the switched voice path connected between SSP equipment **14** and/or another switch such as an MTSO **25**.

Referring now to FIG. 5, first will be discussed a scenario involving the roaming of a PNC subscriber with a cellular telephone **16′** within a visited cellular system **40**. Assume that the visited system **40** includes at least one IS-41-capable MTSO **25*b***. This scenario involves routing to the roaming PNC subscriber at an IS-41 compatible MTSO **25*b*** and typically involves use of only two messages: registration notification and registration cancellation when appropriate. A registration notification message REG.NOT is used to inform the SCP **15** that the PNC cellular subscriber has an active cellular telephone. This information then may be used to route PNC calls to the roaming subscriber at the visiting MTSO **25*b***, via the home MTSO **25*a***.

In this embodiment, the SCP **15** need only instruct the SSP **14** to route the call to the MIN at the home MTSO **25*a***. The home MTSO is already aware (through the IS-41 roaming and call delivery procedures) that their subscriber is visiting and prepared to receive calls. Thus, in this embodiment, the SSP **14** depends on the home MTSO capability to appropriately forward a call to the PNC subscriber.

A registration cancellation REG.CAN message, not illustrated in FIG. 5, will be used to inform the home MTSO **25*a*** that PNC calls are to be routed to the cellular subscriber at the home MTSO **25*a***.

In the situation of FIG. 5, only the MIN is required to properly route the call. Since the scenario presumes an IS-41-capable visited MTSO **25*b***, the home MTSO **25*a*** will receive REG.NOT from the clearinghouse **35** and thereby be enabled to effect routing to the visited MTSO.

Upon receipt of a PNC call, the SSP **14** provides a Query message to the SCP **15** based on the PN, and receives a Response containing the MIN as the routing DN. The MIN therefore directs the call to the home MTSO **25*a***. The home MTSO then issues a routing request (RR) to the visited MTSO **25*b***, and receives a TLDN from the visited MTSO.

The SSP **14** is thus operative to effect a voice path from the SSP via a first voice path **20*a*** to the home MTSO **25*a***, which is thereafter operative to establish a second voice path **20*b*** to the visited MTSO **25*b***. The PNC call is therefore delivered to the PNC subscriber at the roaming cellular telephone **16′** in the visited system **40**.

Again, it will be understood that the clearinghouse **35** is utilized to receive the registration notification message and provide it to the home MTSO. Whenever the clearinghouse **35** detects that a cellular PNC subscriber registers in the IS-41 visited MTSO **25*b***, the clearinghouse sends a corresponding REG.NOT message to the home MTSO **25*a***. This registration notification message therefore comprises location information that is used in the system **10** to detect that a cellular PNC subscriber is currently present at the visited MTSO **25*b***. Subsequently, the system **10** will route PNC calls directly to the cellular subscriber MIN. Thus, when a PNC call arrives at the SSP **14**, a Query message is provided to the SCP **15**, which responds with the MIN.

It will be understood that in circumstances wherein the PNC subscriber has elected alternative destinations, a different response will be provided by the SCP **15** to the SSP **14**, to effect the appropriate features or alternative destinations contemplated by the PNC service. For example, the PNC subscriber may have provided communication disposition information as described in the referenced co-pending patent application Serial No. 07/936,384, filed August 26, 1992, entitled "Personal Number Communication Systems", to the effect that, e.g., the call should be routed an alternative destination #1 during certain times of the day, or to an alternative destination #2 such as a voice mailbox or other default location if he or she does not wish to receive calls, etc. In the particular scenario of FIG. 5, and in response to provision in a Response by the SCP **15** with a MIN, the communication disposition information provided as a part of the PNC service indicates that the cellular telephone of the subscriber is the intended destination. Thus, a voice path is established from the SSP **14** to the home MTSO **25*a***, by commanding the home MTSO **25*a*** to provide appropriate trunk connection signaling information (via the appropriate signaling techniques such as the SS7 network) to the visited MTSO **25***b* and establish an appropriate voice connection on the line **20***b*.

Like a registration notification, a registration cancellation affects the disposition of a PNC call in the present invention. Like a registration notification, a registration cancellation can be explicit or implicit.

A registration cancellation is explicit when an IS-41 REG.CAN message is provided by a visited MTSO. This would occur when the clearinghouse detects that the PNC cellular subscriber has disabled roaming call delivery service such as FOLLOW ME ROAMING® or ROAMING AMERICA with appropriate * codes, or the clearinghouse detects that an automatic deregistration event has occurred.

Registration cancellation can also be implicit, as when automatic deregistration timers associated with roaming expire. For example, the GTE FOLLOW ME ROAMING® service presently clears its database at midnight of every day, thereby implicit deregistering all roamers. Similarly, registration cancellation can automatically occur after a predetermined time has elapsed since the last PNC cellular subscriber event at a visited MTSO. For example, clearinghouses such as the FOLLOW ME ROAMING® service automatically cancel registration status twelve hours since the last subscriber event.

In the case of a registration cancellation, either explicit or implicit, the following steps take place. The clearinghouse **35** determines explicitly or implicitly that a registration of a cellular subscriber has been canceled. The clearinghouse provides a registration cancellation REG.CAN message to the home MTSO **25***a*. The home MTSO then "knows" that, unless the subscriber has registered back in the home service area, a call (PNC or otherwise) cannot be routed to the cellular telephone. No ROUT.REQ will be issued, and no TLDN will be obtained. Any PNC call must be routed to an alternative destination.

Thus, subsequent to receipt of a registration cancellation message, the preferred system **10** is operative to route subsequent PNC calls to destinations other than the cellular destination, since a registration cancellation status indicates that the PNC subscriber's cellular telephone is not active or otherwise cannot receive the call. These alternative destinations may be derived from the communication disposition information stored in the SCP **15**, which may include a default time-of-day schedule, or a voicemail box that is explicitly designated for use in such de-registration events.

It will be observed in connection with FIG. 5 that the utilization of the clearinghouse **35**, while forming a part of the currently preferred and disclosed embodiment, is not necessary as a required element in all embodiments of the present invention. Alternative embodiments envision direct data communications between the visited cellular system **40** to the switching equipment **13**, with appropriate data communications messages of registration notification, registration cancellation, etc. The significant aspect to be understood in this regard is that the database associated with the switching equipment **13** is operative to store location information derived an MTSO (whether home or visited) indicating the presence and activation of a PNC subscriber's cellular telephone. Then, this location information is utilized in conjunction with communication routing information, also maintained in the database of the switching equipment **13**, typically in the form of the hierarchical list of destinations associated with the PNC subscriber.

It will therefore be understood that the foregoing illustrates a method of delivering a communication to a PNC subscriber having a mobile communications device such as a cellular mobile radiotelephone, comprising the steps of receiving location information corresponding to a present location of a subscriber, where the subscriber utilizes a cellular telephone. The switching equipment **13** performs steps of receiving and storing communication routing information corresponding to one of a plurality of selectable destinations associated with the subscriber. In response to receipt of a communication directed to the PNC subscriber, the switching equipment is operative to route the communication to a selected one of the destinations in accordance with the communication routing information hierarchy, and the location information.

It will also be understood that the database maintained at the switching equipment **13**, which corresponds the location information with the communication routing or disposition information, may be considered a personal number routing database (PNRDB) that facilitates the correspondence between the location information and the communication routing or destination information.

FIG. 6 illustrates a communication scenario in a situation wherein the PNC cellular subscriber activates roaming in a non-IS-41 visited MTSO **25*b***. In such a situation, it will be understood that registration notification messages are not automatically provided, via SS7 or otherwise, in response to detection of a roaming cellular subscriber. In order for the PNC subscriber to receive cellular calls in such as non-IS-41 MTSO, the subscriber must provide an appropriate activation code through the cellular telephone **16′**, and such an activation code must ultimately be transmitted to the switching equipment **13**, either directly or via a clearinghouse **35**, so that the switching equipment will know that the cellular phone is active and allowed to receive calls. Moreover, in visited systems that only allow access via a local access numbers, this number must also somehow be associated with the telephone's MIN and PN so as to effect proper call routing. In the preferred embodiment, this association is maintained at the SCP **15** in the switching equipment.

These considerations typically require provision of the activation * code, the MIN, and, in proper cases, the local access number (optional), by the non-IS-41 visited MTSO **25*b*** to the clearinghouse **35**. (Alternatively, the clearinghouse **35** can store local access numbers in its database, and provide same as a part of its clearinghouse service to the switching equipment.) Responsive to receipt of the activation * code, and validation by the clearinghouse **35** of the roamer via the required mechanism, the clearinghouse provides the registration notification message to the switching equipment **13**, and the remaining steps are substantially in accordance with that described in connection with FIG. 5. As in the case of FIG. 5, the voice path to the visited MTSO **25*b*** is established from the SSP **14** to the home MTSO **25*a*** via voice trunk **20*a***, and thence between the home MTSO and the non-IS-41 visited MTSO **25*b*** via voice trunk **20*b***.

FIG. 7 illustrates a scenario substantially the same as in FIG. 6, except without the intervention of a clearinghouse as intermediary. In other words, FIG. 7 assumes a direct data communications link (not necessarily SS7 or IS-41) between a visited MTSO **25*b*** and the home MTSO **25*a*** and the switching equipment **13**. The scenario assumes an appropriate business arrangement between the different cellular system operators so that registration information, validation, activation of roaming call receipt, etc. are handled satisfactorily between the system operators. The activation * code is provided directly from the non-IS-41 cellular system **40** to the home MTSO; alternatively, the activation code could be provided directly to the switching equipment **13**. It will therefore be appreciated that in such cases, the clearinghouse and either the home MTSO or the switching equipment perform much the same function. It will therefore be understood that the use of a clearinghouse is optional in the present invention, since the important consideration is the detection of the presence of a roaming PNC subscriber. and enablement of call routing to the PNC subscriber.

FIG. 8 illustrates a scenario wherein the PNC cellular subscriber provides a de-activation code at the visited MTSO **25*b*** indicative of a command by the subscriber to halt incoming calls to the cellular telephone **16′**. In this situation, a registration cancellation REG.CAN message is transmitted from the clearinghouse **35** to the switching equipment **13**, which updates its database to modify the location information. Essentially, the location information in the database maintained by the switching equipment will now show that the subscriber is not present in the visited MTSO **25*b***, and that subsequent PNC calls should be routed to alternative destinations in accordance with the communicating routing or disposition information associated with the PNC service profile stored at the SCP **15**.

Thus, in response to receipt of an incoming PNC call, a Query on the part of the SSP **14** to the SCP **15** will result in a Response from the SCP of information indicating an alternative destination. In one situation, the response might still be the MIN of the cellular telephone, in which case a voice path **20*a*** is established to the home MTSO **25*a***, which then routes the call to an alternative destination , such as a voice mail service **45** or an alternative telephone **46**, as shown in FIG. 3. Alternatively, the response can be an alternative routing directory number (DN) denominated ALT which results in the routing of the PNC call to an alternative destination indicated at **45** or **46**.

FIG. 9 illustrates a scenario of implicit de-activation by a clearinghouse, so as to cause subsequent incoming PNC calls to be redirected from a visited MTSO **40** to an alternative destination. As discussed earlier, various clearinghouse services such as FOLLOW ME ROAMING® and ROAMING AMERICA automatically remove registration information from their databases at predetermined times of day or after the passage of a predetermined amount of time. For example, the FOLLOW ME ROAMING® service automatically cancels registrations at midnight, while ROAMING AMERICA® does the same after twelve hours have elapsed since the last cellular event. In such a situation, an implicit de-activation has occurred, and the clearinghouse is operative to provide a registration cancellation message REG.CAN to the switching equipment **13**. Subsequently, a PNC call will be routed by the switching equipment to an alternative destination **45**, **46** as in the case of FIG. 8.

It will be understood from the foregoing discussions that situations not involving a clearinghouse operate substantially in the same manner as described above, with the exception that the communication messages relating to roaming, validation, registration, cancellation, etc. are directly passed directly between the communicating entities. Typically, this preferably involves direct SS7 data communications between a visited cellular system **40**, SCP equipment **15**, and the home MTSO **25***a*. Like the scenario of FIG. 7, an implicit de-activation as in FIG. 9 without use of a clearinghouse contemplates direct data communication links established between a visited MTSO **25***b* and the home MTSO **25***a*, with subsequent provision of appropriate messages from the home MTSO to the switching equipment **13**.

In this case, the home location register (HLR) associated with the home MTSO **25***a* maintains its database with requisite location information that can be provided to the switching equipment **13**. Whenever the home location register is provided with signals (such as a REG.NOT) indicating that cellular PNC subscriber has registered in a visited MTSO **25***b*, the HLR database is updated and a corresponding REG.NOT message is sent to the switching equipment **13**. The registration notification provides requisite information that allows routing of the PNC call to the visited MTSO **25***b* via the home MTSO **25***a*. The switching equipment **13** can route such calls to the visited MTSO by routing to the MIN, and the home MTSO forwards the call to the visited MTSO. Such operation requires that the home MTSO **25***a* provide a properly-formatted registration notification message to the switching equipment **13** when it receives a registration notification and location information from the visited MTSO **25***b*.

The remaining steps responsive to receipt of the PNC call at the SSP **14**, routing of the call to the home MTSO **25***a* via the PNC subscriber's MIN, and subsequent routing of the call from the home MTSO **25***a* via line **20** to the visited MTSO **25***b*, are substantially as described in connection with FIG. 7.

Still referring to FIG. 9, in like manner, registration cancellations are provided from the visited MTSO **25***b* to the clearinghouse **35**, and thence to the switching equipment **13** in response to detection that the PNC cellular subscriber wishes to disable any FOLLOW ME ROAMING® or ROAMING AMERICA type service while at the visited MTSO **25***b*, the home MTSO detects that the predetermined time or time block has occurred as a registration cancellation event, or that the home MTSO **25***a* has detected, via the autonomous registration operation, that the PNC cellular subscriber has returned to the home MTSO **25***a*. Since the switching equipment **13** must keep track of the location, it is expected that the home MTSO **25***a* will provide any location information, however detected, to the switching equipment **13** so as to facilitate subsequent routing. Note that in this embodiment, either the PNC user entered * codes (explicit deactivation) that were detected by a visited MTSO (or the home MTSO) and are sent to the clearinghouse, or the clearinghouse detects the passage of time (implicit deactivation). In either event, the clearinghouse in turn sends these to the switching equipment **13**.

Turning next to FIG. 10, when a remote feature control request (RFCR) is provided by a roaming PNC cellular subscriber, it is necessary that the codes indicative of a command to invoke a feature, for example * codes, be transmitted to the switching equipment **13** so that the feature can be implemented. The switching equipment **13** can receive remote feature control information indirectly via the clearinghouse **35**, or directly from the home cellular system if a data communications link is established, when the subscriber dials a roamer * code in a visited system, or the subscriber enters a roamer cancellation control code in the visited system. The clearinghouse is preferably operative to send a message containing the remote feature control request operation, typically in the form of an IS-41 RemoteFeatureControlRequest (RFCR) message, to the switching equipment **13** when the visiting subscriber dials the appropriate code and the visited MTSO ***25b*** transmits the code to the clearinghouse. Preferably, the RFCR message also provides the MIN and the assigned personal number (PN) if maintained at the clearinghouse. The format of a RemoteFeatureControlRequest is described in IS-41.5 at 8.1.3.7.

The timing for an exemplary RFCR scenario is shown in FIG. 10. When the subscriber dials a predetermined sequence of codes intended to invoke a feature, the information is passed from the visited MTSO ***25b*** to the clearinghouse **35**. The clearinghouse **35** then transmits an RFCR message to the switching equipment **13**. The database maintained by the SCP **15** is then updated to reflect that the subscriber possessing this particular MIN (associated with their particular PN) intends to invoke particular service features with respect to subsequently received communications.

When a PNC call arrives at the SSP **14**, a Query message is transmitted from the SSP **14** to the SCP **15**, and the SCP responds by handling the communication in the manner as modified by the remote feature. As a specific example, assume that the remote feature is to cause communications directed to the personal number to be routed to a next or alternate destination in the hierarchical list of destinations, such as a voice mailbox. Then, the Response provided from the SCP **15** to the SSP **14** will include a directory number (DN) indicative of the alternative destination such as **45**, **46**. The communication is then routed to this alternative destination represented by the DN.

Remote features are considered species of communication disposition information, since actuation of particular features affects the handling and/or routing of an incoming communication. Examples of remote features contemplated for use by roaming cellular PNC subscribers in the present invention include but are not limited to the following:

Code		Disposition
*10	-	Send call to home phone
*11	-	Send call to secretary
*14	-	Send call to voice mail
*15	-	Send call to cellular phone
*25NPA-NXXX	-	Send call to phone number NPA-NXXX

As another specific example of a remote feature, it is contemplated that the alternative destination can include a message service **45** that is operative to play a prerecorded announcement, such as, "We're sorry, but (name of subscriber) is not presently available. At the tone, please leave a voice message.", and then record a voice message.

It will be understood that in embodiments of the present invention which involve direct data communications between switching equipment **13**, a visited cellular system **40**, and a home cellular system **50**, the RFCR message is transmitted directly from the visited MTSO **25***b* to the home MTSO **25***a*. The home location register (HLR) database associated with the home cellular system **50** is updated to reflect the feature that is to be invoked. The HLR will transmit a corresponding RFCR to the switching equipment **13** so that the database can be updated to reflect activation of the feature. Again, this RFCR message is transmitted when it is detected that the PNC cellular subscriber wishes to enable special features, for example enablement of the FOLLOW ME ROAMING® or ROAMING AMERICA type of service, or when the feature code constitutes a specific request to forward cellular calls to a specific override directory number. Such features are generally indicated with dialed digits following the * code, for example *14, if not supported by the visited cellular system, can constitute a command to activate call forwarding to a remote location, and a string of digits can constitute the call-forwarding number.

In response to a RemoteFeatureControlRequest (RFCR) query, the switching equipment **13** provides an appropriate rfcr response back to the clearinghouse. If the received parameters are all valid, then the switching equipment **13** sends a response containing a return result to the clearinghouse. The parameters returned in the rfcr response may indicate a successful activation of the requested feature, as described in IS-41.5, Section 8.2.16.

As in previous cases, the information in the RFCR is used at the switching equipment **13** to appropriately route subsequent PNC calls to the cellular PNC subscriber or to the indicated alternative destinations.

FIG. 11 illustrates a communication scenario wherein a temporary line directory number (TLDN) is utilized to route a PNC call associated with the * code activation request to a visited MTSO **25***b*. This scenario should be contrasted with that illustrated in FIG. 5. The scenario of FIG. 5 is considered "MIN-based" routing, wherein the voice path is established via the MIN to the home MTSO **25***a*, and thence to the visited MTSO **25***b*. In FIG. 11, a TLDN is utilized to route the call directly from the SSP **14** to the visited MTSO **25***b*. As in the case of FIG. 5, when the roaming PNC cellular subscriber is detected at the visited MTSO **25***b*, either via activation of FOLLOW ME ROAMING® service or ROAMING AMERICA service, or autonomous registration, or otherwise in accordance with the present invention, a REG.NOT message is passed from the visited MTSO **25***b* to the clearinghouse **35**, and thence to the switching equipment **13**. Appropriate responses are provided, as indicated. The switching equipment **13** updates its database to reflect that the cellular subscriber is active on the cellular telephone.

In response to receipt of a PNC call, a PN-based Query is transmitted from the SSP **14** to the SCP **15**. The SCP responds with a PN or MIN-based ROUT.REQ message to the clearinghouse, which responds with a TLDN associated with the MIN. The SCP **15** receiving the TLDN provides a Response containing the TLDN back to the SSP **14**. The SSP is thereafter operative route the call via a voice path **20***a* directly to the visited MTSO that provided the TLDN in the first instance. It should be apparent that such a scenario is more direct and efficient than MIN-based routing, which requires voice paths from the SSP to the home MTSO, and thence to the visited MTSO.

FIG. 12 illustrates a communication scenario wherein the system is operative for routing a PNC call to an alternative destination (e.g. voice mail **45**) based on receipt of status information from a visited MTSO **25***b*, either directly or indirectly via the clearinghouse **35**, for example, busy or inactive status of the roaming PNC subscriber's telephone **16**′. It should be noted at this juncture that certain system operators may be legally precluded from routing calls to alternative destinations in response to status information such as busy or inactive, under the Modified Final Judgment, if such status information is obtained from outside the LATA. Accordingly, the method illustrated in FIG. 12 should be considered an alternative embodiment of the present invention.

The embodiment of FIG. 12 should be contrasted with the embodiment of FIG. 8, which involves routing to an alternative destination in response to status information in the form of a registration cancellation message (REG.CAN). Note that in the embodiment of FIG. 8, the routing to the alternative destination is in response to the cancellation of registration, and not in response to receipt of information that the roaming cellular subscriber telephone is busy or otherwise inactive. Accordingly, it will be understood that there may be cases where the subscriber has de-activated his or her cellular telephone, but no registration cancellation event has yet occurred that would cause the transmission of the REG.CAN message. It will be recalled from earlier discussion that REG.CAN triggers the routing to the alternate destination **45**. A situation of de-activation but no transmission of REG.CAN is likely to occur in the case of non-IS-41 systems, since there is no automatic and uniform mechanism in such systems for transmitting a REG.CAN to a roaming subscriber's home system.

In such a situation of de-activation in a non-IS-41 system, a PNC call would be routed via the home MTSO ***25a*** to the visited MTSO ***25b***, only to receive a busy or inactive message from the visited MTSO ***25b***. However, this would necessarily incur a long distance charge through a long distance carrier associated with the service package utilized by the PNC subscriber. Needless to say, such long distance expenses could be avoided on behalf of the subscriber if the routing to the alternative destination could be effected in response to status information indicating that the cellular telephone was busy or no longer active.

In the embodiment of FIG. 12, it is specifically contemplated that the system operator is lawfully entitled to respond to status information provided either directly from a visited MTSO or indirectly via a clearinghouse. As in prior scenarios, when the roaming PNC subscriber's telephone **16′** is registered at the visited MTSO **25*b***, a registration notification (REG.NOT) is sent to the clearinghouse **35**. A corresponding REG.NOT is passed from the clearinghouse to the switching equipment **13**, which updates its database to reflect that the cellular PNC subscriber is active and roaming.

In response to receipt of a PNC call to the SSP **14**, a Query is transmitted to the SCP **15**, as before. The SCP generates a route request message (ROUT.REQ) to the clearinghouse, which in turn passes a ROUT.REQ message based on the MIN to the visited MTSO **25*b***. Since FIG. 12 presumes that the subscriber is inactive or busy, but no registration cancellation (REG.CAN) has been indicated, the appropriate reply message to the route request is an indication of busy or inactive status. The reply message from the visited MTSO is a rout.req (busy/inactive), and typically includes a return result parameter containing an AccessDeniedReason = busy/inactive as described in IS-41.5, Section 8.1.3.6. As will be understood, an AccessDeniedReason can include inactive or busy, as specified in Section 8.2.18.

The busy/inactive status is then provided to the SCP **15** via a corresponding rout.req (busy/inactive) response message from the clearinghouse, which returns a Response to the SSP Query indicative of routing to a default destination. Thus, a voice path is established to the subscriber's alternative destination as determined by the database associated with the switching equipment **13** (the SCP **15** in the disclosed embodiment. In the example of FIG. 12, the default destination is a voice mailbox **45**.

It should also be noted that much of the scenario described in connection with FIG. 12 is applicable in the case where the home MTSO **25*a*** is substituted for the clearinghouse **35**, and a ROUT.REQ query and TLDN response communication mechanism occurs directly between the SCP **15** and the home MTSO. It will thus be understood that under circumstances wherein the system operator can act on a busy or inactive status, the clearinghouse (or home MTSO) will return a DN or TLDN if the call can be connected to the visited MTSO **25*b*** and thence to the roaming telephone **16′**, but the clearinghouse (or home MTSO) may also return an inactive or busy response. The TLDN or DN would be used to route the pending PNC call to the subscriber at the visited MTSO if the subscriber is active, while an inactive or busy response would be used to route the PNC call to one of the PNC subscriber's alternative destinations such as voice mail, secretary's telephone, or the like.

FIG. 13 illustrates an alternative communication scenario wherein a PNC cellular subscriber's call is to be forwarded or "transferred to" an alternative destination if the subscriber is currently busy or inactive. The scenario in this figure presupposes that some entity, such as the clearinghouse **35** is maintaining a service profile in a computer database of visiting cellular subscribers, together with associated "transfer to numbers" (TTNR) as forwarding numbers (it being understood that the home MTSO could also perform the function). If a subscriber enters a feature request indicating that calls should be transferred to a certain location (particularly a local land location in the foreign service area as an alternative destination), a TTNR comprising a DN of that alternative destination can be passed back to the switching equipment **13** for proper handling. Thus, a ServiceProfileDirective (SPD) message containing the TTNR is sent by the visited MTSO to the clearinghouse (or home MTSO). This message is described at 8.1.3.9 at IS-41.5, and can include a DN comprising a number of digits of a destination representing a TTNR.

It will of course be understood that the home MTSO **25a** itself, or the visited MTSO **25b**, can maintain the data indicative of the transfer to number.

Still referring to FIG. 13, in response to receipt of a PNC call, the SSP **14** passes a Query message to the SCP **15**, which passes a routing request ROUT.REQ to the clearinghouse **35** (or the home MTSO). This ROUT.REQ is in turn passed to the visited MTSO **25b** based on the MIN. In response to determination that the subscriber is busy or inactive, which is presumed, a busy/inactive status message is passed back from the visited MTSO **25b** to the clearinghouse **35**, and thence to the SCP **15**. Upon receipt of a busy/inactive status message, the SCP provides a TransferToNumberRequest (TTNR) message to the clearinghouse, which in turn provides the transfer to number previously received as the response, in the form of a transfer directory number (DN). The SCP **15** then provides its response to the SSP **14** in the form of a transfer directory number (DN). The SSP then routes the call to the transferred DN, which comprises an alternative destination such as the destination **48** (see FIG. 3).

Thus, it will be understood that once an inactive or busy response is obtained from the clearinghouse in response to a routing request message from the switching equipment **13**, the system queries the clearinghouse (or home MTSO) to determine subsequent call treatment. This entails transmission of a TTNR query to the clearinghouse, which in turn forwards this to the visited MTSO, if necessary. The cellular subscriber's profile, maintained either at the clearinghouse (or at the home MTSO) contains an alternative transfer to number. A response to the TTNR is a directory number (DN), which is where the subscriber's call is to be forwarded if that subscriber is currently busy or inactive.

It will also be understood that the scenario described in connection with FIG. 13 may involve routing via a subscriber's long distance carrier in order to reach the transfer-to location.

It will be further understood in connection with FIG. 13 that the invention can be implemented without the clearinghouse **35**. In such an embodiment, the routing request message ROUT.REQ is transmitted directly from the switching equipment **13** to the home MTSO (not shown), which stands in the place of the clearinghouse, and the response is a busy or inactive status indication. The TTNR is then passed directly from the switching equipment **13** to the home MTSO, and the response received is the transfer DN provided by the home MTSO. It will therefore be appreciated that in this scenario, which presumes no MFJ restrictions, once an inactive or busy response is obtained from a home MTSO in response to a routing request, the system can query the home MTSO directly by sending a TTNR query. The response to the TTNR is a DN to which the subscriber's call is to be forwarded if the subscriber is currently busy or inactive.

FIG. 14 illustrates a communication scenario that involves the validation of a cellular subscriber using a line information database (LIDB) **90**. For purposes of the present discussion, it will be understood that an LIDB **90** is a computer database primarily operative for validation and anti-fraud functions in connection with cellular telephone systems. For example, a commercially available LIDB is the Calling Card database manufactured by Tandem Computer Corp. The LIDB **90** matches a personal identification number (PIN) to a cellular telephone's MIN for validation purposes. Operation and maintenance of such a computer database is considered within the skill of the art. The operation is simply to match predetermined PIN's to MIN's on a real-time basis, with the system providing access or validation only in response to receipt of a validation message from the LIDB.

It will be further understood that an LIDB may be operated by a number of different business entities, including but not limited to the PNC system operator, clearinghouses, and anticipated validation databases established for future communication systems such as the anticipated Motorola IRIDIUM™ personal telecommunications system. Therefore, the present invention will be considered operative with such communication systems or any communications systems that require validation prior to access.

In this regard, FIG. 14 illustrates validation of a cellular subscriber using the LIDB database **90**. A cellular subscriber is validated using the MIN that is provided at autonomous registration, and a PIN or other password that is entered via the telephone keypad in response to, for example, a voice prompt message. It is assumed that the roaming subscriber with a telephone **16'** has entered his or her PIN, the MIN has been obtained by the visited MTSO ***25b***, and the PIN and MIN information has been passed in the form of a message to the home MTSO ***25a***. The information is passed directly to the home MTSO ***25a***, but it will be understood that the information could be passed via a clearinghouse (not illustrated) or directly to the LIDB **90**. For example, validation information may be passed in the form of a ServiceProfileDirective (SPD) message, as described in IS-41.5, ¶ 8.1.3.9.

The home MTSO ***25a*** passes the MIN and PIN to the LIDB **90**, which performs the validation function. If the MIN is properly validated, an appropriate response such as a QualificationDirective (QD), as described in IS-41.5, ¶ 8.1.3.2, is sent to the visited MTSO, indicating that the subscriber is authorized to access the system.

Once the LIDB has performed the validation, the LIDB transmits a QualificationDirective (QD) message to the home MTSO ***25a***, which in turn passes a QD to the visited MTSO ***25b***. According to one aspect of the invention, upon validation the LIDB **90** passes a registration notification message REG.NOT to the switching equipment **13**. This in effect informs the SCP **15** in the switching equipment that the cellular PNC subscriber is active and roaming. Subsequent PNC calls to that subscriber are routed via the MIN, as shown, which entails routing either to the home MTSO **25*a*** and thence to the visited MTSO **25*b***, or alternatively directly to the visited MTSO, via the TLDN (using ROUT.REQ), as legal circumstances permit for the system operator.

It should also be understood that in addition to registration detection in a visited system, preferred embodiments of the present invention provide notification of a registration of a PNC subscriber back at the home MTSO **25*a*** upon return to or entry into the home cellular system **50**. In preferred embodiments of the invention, it is anticipated that the subscriber will dial a PNC * code in the home cellular system to signal a return home. Alternatively, registration of the cellular PNC subscriber in the home MTSO can trigger the provision of the registration cancellation message REG.CAN to the switching equipment **13** when the registration is detected.

Turning now to FIG. 15, it will be understood that preferred embodiments of the present invention contemplate periodic correlation of information relating personal numbers (PN) to mobile identification numbers (MIN). Such correlated information is required by the wireless information providers such as home MTSO's and cellular systems that directly communicate with the switching equipment, by clearinghouses, by visited MTSO's with direct communications arrangements with the PNC service provider, and by any other communicating entities that are not associated with the provider of the personal number service. A correlation table, maintained in the form of a computer database, is required in order to determine which MIN's are associated with a PNC system and therefore should receive the registration function treatment. Those skilled in the art will understand that this database, the implementation is within the skill of the art, will require periodic updates in order to add or delete personal numbers, and relationships between the personal numbers and cellular telephone numbers. Preferably, updates will be provided on an as-needed basis, and can be provided through conventional mechanisms such as facsimile messages, electronic mail, or other methods.

In this regard, FIG. 15 illustrates an exemplary computer database record **100** that is utilized in switching equipment **13**, and in particular in the SCP **15** of the disclosed embodiment, to implement PNC service on behalf of roaming cellular subscribers. As known to those skilled in the art, a database record comprises a plurality of information fields that are associated with one another, and searchable by text string searching or via preconstructed indices. Fields utilized in the preferred record **100** include the personal number (PN), the Mobile Identification Number (MIN) of one or more cellular telephones as alternative destinations for the PNC subscriber, a principal destination directory number (DN1), one or more alternative destination directory numbers (DN2 -- DN*i*), activated feature codes, inactive feature codes, status fields (busy/inactive/non validated/validated), a routing DN to reach the voice mail system, an IEC code to be used when the PNC call needs to be forwarded across a LATA boundary, and other PNC related information as described in the incorporated PNC patent application referenced above.

Additionally, various of the fields in the computer database record **100** may include user control or status flags, ON/OFF, to signify that various features have been activated, or have been enabled for activation by the system operator. As a specific example, it is specifically contemplated that a subscriber may selectably activate delivery of calls to the mobile telephone when roaming, or may prevent delivery of calls when roaming. Therefore, the database record field for the mobile telephone includes an ROAMING DELIVERY ON/OFF field associated with cellular telephone. In the event that the flag indicates OFF status, calls will not be delivered to the mobile telephone when roaming, and the PNC hierarchy will cause an incoming communication to be directed to another destination, e.g. voice mail.

Likewise, the subscriber can indicate ON/OFF status for delivery of calls to the mobile telephone when in the home cellular service area, with the HOME DELIVERY ON/OFF flag.

Preferably, the subscriber will selectably actuate various feature ON/OFF flags by entry of * codes, which will be delivered to the system **10** with RFCR messages, whether home or roaming.

Other related information for storage in the database may occur to those skilled in the art.

In summary, there has been illustrated and described an improved method and system for providing personal number communication system enhancements that route PNC calls to roaming cellular subscribers, in various scenarios including intermediaries such as cellular clearinghouses, direct SS7 and IS-41 compatibility between home cellular service MTSO's and visited cellular system MTSO's, non-IS-41 capable communicating entities, and the like. Means have been described for obtaining location information corresponding to the present whereabouts of a roaming PNC cellular subscriber, and for utilizing the location information in conjunction with routing or destination information provided with the PNC service, and status information where permitted, for routing PNC calls to the subscriber at the roaming cellular site or to alternative destinations, as appropriate under the communication disposition information provided in connection with the PNC service.

Therefore, while particular preferred embodiments of the invention have been shown and described, it should be understood that the preferred embodiments have been disclosed by way of example, and that other modifications may occur to those skilled in the art without departing from the scope and the spirit of the appended claims.

CLAIMS

What is claimed is:

1. A method of delivering a communication to a subscriber, comprising the steps of:

receiving location information corresponding to a present location of a subscriber;

storing communication disposition information corresponding to a plurality of destinations associated with the subscriber;

receiving a communication directed to the subscriber; and

disposing of the communication to one of the destinations in accordance with the communication disposition information and the location information.

2. The method of Claim 1, wherein said communication disposition information comprises communication routing information.

3. The method of Claim 2, wherein said communication routing information comprises a directory number associated with one of the plurality of destinations.

4. The method of Claim 3, wherein the directory number comprises a temporary line directory number (TLDN).

5. The method of Claim 3, wherein the directory number comprises the Mobile Identification Number (MIN) associated with a cellular mobile radiotelephone.

6. The method of Claim 2, wherein the communication routing information comprises information indicative of a telephone line routing path to connect the communication to one of the destinations.

7. The method of Claim 1, wherein the step of receiving location information comprises the step of receiving explicitly detected location information.

8. The method of Claim 7, wherein the step of receiving explicitly detected location information comprises receipt of a registration notification message from a cellular telephone system.

9. The method of Claim 7, wherein the step of receiving explicitly detected location information comprises receipt of a registration cancellation message from a cellular telephone system.

10. The method of Claim 1, wherein the step of receiving location information comprises the step of receiving implicitly detected location information.

11. The method of Claim 10, wherein the step of receiving implicitly detected location information comprises receipt of information indicative that a cellular telephone has not been active in a cellular system within a predetermined time.

12. The method of Claim 1, wherein the step of receiving communication disposition information comprises receiving hierarchical routing information corresponding to a plurality of possible destinations for routing communications.

13. The method of Claim 12, further comprising the step of assigning the subscriber a personal number, and wherein the step of receiving communication disposition information comprises receiving hierarchical routing information corresponding to a plurality of possible destinations for routing communications directed to the personal number.

14. The method of Claim 1, wherein the location information is provided by a cellular telephone validation clearinghouse.

15. The method of Claim 1, wherein the location information is provided by a home mobile telephone switching office (MTSO) associated with the subscriber.

16. The method of Claim 1, wherein the location information is provided via a data communications link from a visited cellular radiotelephone system.

17. The method of Claim 1, wherein the location information is provided via a Signaling System 7 (SS7) data communications link.

18. The method of Claim 1, further comprising the step of modifying the communication disposition information based on the location information.

19. The method of Claim 18, wherein the step of modifying the communication disposition information based on the location information comprises selecting one of the plurality of destinations based on the location information.

20. The method of Claim 18, wherein the communication disposition information comprises a first directory number associated with a cellular telephone as a first one of the plurality of destinations and a second directory number associated with a second one of the plurality of destinations,

wherein the location information comprises information that the cellular telephone has been detected as roaming in a visited cellular telephone system, and

wherein the step of modifying the communication disposition information based on the location information comprises selecting the first directory number in response to the location information.

21. The method of Claim 20, wherein the step of modifying the communication disposition information based on the location information comprises selecting the second directory number in response to absence of receipt of the location information.

22. The method of Claim 18, wherein the step of modifying the communication disposition information comprises modifying a list of alternative destinations for the communication based on the location information.

23. The method of Claim 1, wherein the location information is provided from a remote cellular system in which the subscriber is roaming with a mobile telephone.

24. The method of Claim 1, wherein the location information comprises a copy of registration information obtained upon registration of the mobile telephone as a roamer in the remote cellular system.

25. The method of Claim 24, wherein the registration of the mobile telephone comprises autonomous registration.

26. A method of delivering a communication to a subscriber, comprising the steps of:

assigning a personal number to the subscriber;

storing communication disposition information corresponding to a plurality of destinations for communications, at least one of the destinations including a mobile telephone;

receiving location information indicative of the present location of the mobile telephone;

receiving a communication directed to the personal number;

selecting the destination of the mobile telephone from the communication disposition information in response to a first condition of the location information;

selecting an alternative destination from the communication disposition information in response to a second condition of the location information; and

disposing of the communication in accordance with the selected destination of the communication disposition information.

27. The method of Claim 26, wherein the first condition of the location information corresponds to information that the mobile telephone is active and able to receive calls.

28. The method of Claim 27, wherein the first condition of the location information is provided in the form of a registration notification message from a visited cellular system.

29. The method of Claim 27, wherein the second condition of the location information corresponds to information that the mobile telephone is not active.

30. The method of Claim 29, wherein the second condition of the location information is provided in the form of a registration cancellation message from a visited cellular system in which the mobile telephone was previously registered.

31. A method of delivering a communication to a subscriber, comprising the steps of:

assigning a personal number to the subscriber;

receiving location information corresponding to a present location of a subscriber;

receiving communication disposition information corresponding to a plurality of destinations associated with the subscriber;

receiving a communication directed to the subscriber's personal number; and

delivering the communication to one of the destinations in accordance with the communication disposition information and the location information.

32. The method of Claim 31, wherein the location information comprises routing information indicative of a telecommunications path for delivering the communication.

33. The method of Claim 32, wherein the communication disposition information indicates a mobile telephone one of the destinations for the communication, and wherein the routing information corresponds to a telecommunications path for delivering the communication to the mobile telephone.

34. The method of Claim 33, wherein the present location of the subscriber is roaming in a foreign cellular system, and wherein the routing information corresponds to a telecommunications path for delivering the communication to the mobile telephone while roaming in the foreign cellular system.

35. The method of Claim 31, wherein at least one of the destinations includes a mobile telephone as a first destination, and wherein the location information indicates whether the mobile telephone is active in a foreign cellular system.

36. The method of Claim 35, wherein the step of delivering the communication comprises:

selecting the first destination from the communication disposition information;

determining from the location information whether the mobile telephone is active in the foreign cellular system;

in response to determination that the mobile telephone is active in the foreign cellular system, delivering the communication to the mobile telephone in the foreign cellular system.

37. The method of Claim 36, further comprising the step of, in response to determination that the mobile telephone is not active in the foreign cellular system, delivering the communication to an alternative destination.

38. The method of Claim 36, wherein the communication disposition information includes information indicative whether communications are to be delivered to the mobile telephone when active in the foreign cellular system.

39. A method of delivering a communication to a mobile telephone of a personal number subscriber in a personal number communication system, comprising the steps of:

storing communication disposition information corresponding to a plurality of destinations associated with the subscriber;

receiving location information from a clearinghouse, the locating information including a directory number at which the mobile telephone can be reached;

receiving a communication for the subscriber at the subscriber's personal number; and

delivering the communication to the subscriber at the directory number associated with the personal number.

40. The method of Claim 39, wherein said clearinghouse is a roaming cellular mobile radiotelephone information and validation clearinghouse.

41. The method of Claim 39, wherein the clearinghouse is operative to obtain the location information from a mobile telephone switching office (MSTO) associated with a cellular system in which said mobile telephone is operated.

42. The method of Claim 41, wherein the clearinghouse obtains the location information from the MTSO via an SS7 data communications link.

43. The method of Claim 41, wherein the MTSO provides IS-41 data messages, and the clearinghouse obtains the location information via IS-41 messages.

44. The method of Claim 41, wherein the MTSO obtains registration information from subscriber's mobile telephone as it registers, and transmits at least a portion of the registration information to the clearinghouse as the location information.

45. The method of Claim 39, wherein the communication disposition information includes information indicative whether communications are to be delivered to the mobile telephone when roaming in a foreign cellular system.

46. A method of disposing of a communication to a personal number of a subscriber of a personal number communication system when roaming with a mobile telephone, comprising the steps of:

storing communication disposition information in the database in association with the subscriber's personal number;

receiving status information from a remote communication service corresponding to the status of the subscriber's mobile telephone;

modifying the stored communication disposition information with the status information;

receiving a communication directed to the subscriber's personal number;

querying the database as to disposal of the communication; and

disposing of the communication in accordance with the communication disposition information as modified by the status information.

47. The method of Claim 46, wherein the status information comprises location information corresponding to a location of the subscriber's mobile telephone.

48. The method of Claim 46, wherein the status information comprises registration information obtained upon registration of the mobile telephone at a cellular system.

49. The method of Claim 48, wherein the registration information is obtained upon registration of the mobile telephone when roaming at a foreign cellular system.

50. The method of Claim 46, wherein the status information comprises a busy signal obtained by a cellular system in which the mobile telephone is active.

51. The method of Claim 46, wherein the status information comprises a no answer signal obtained by a cellular system in which the mobile telephone is active.

52. The method of Claim 46, wherein the remote communication service comprises a cellular telephone clearinghouse.

53. The method of Claim 52, wherein the cellular telephone clearinghouse comprises a FOLLOW ME ROAMING® clearinghouse.

54. The method of Claim 46, wherein the remote communication service comprises a foreign cellular system.

55. The method of Claim 54, further comprising the step of communicating the status information from the foreign cellular system to the personal number communication system via an SS7 data link.

56. The method of Claim 46, wherein the status information comprises information indicative that the mobile telephone is active in a foreign cellular system and has enabled roaming services in the foreign cellular system.

57. The method of Claim 46, wherein the step of modifying the communication disposition information with the status information comprises updating a database record associated with the subscriber's personal number to indicate that the mobile telephone is active and roaming in a particular foreign cellular system.

58. The method of Claim 46, wherein the communication disposition information includes roaming delivery information indicative whether communications are to be delivered to the mobile telephone when roaming in a foreign cellular system, and further comprising the step of delivering the communication to the mobile telephone in accordance with the roaming delivery information.

59. The method of Claim 58, wherein the roaming delivery information is selectably actuatable by the subscriber, whereby communications are delivered to the mobile telephone when roaming or selectably blocked from delivery to the mobile telephone when roaming.

60. A method of delivering a communication to a subscriber, the subscriber being associated with a mobile communication device, comprising the steps of:

assigning a personal number to the subscriber;

receiving first communication disposition information including a plurality of possible dispositions of a communication;

receiving location information corresponding to a present location of the mobile communication device;

receiving a communication directed to the personal number;

selecting a first destination from the communication disposition information;

if the first destination corresponds to the mobile communication device, directing the communication to the mobile communication device utilizing the location information;

announcing at the first destination the receipt of the communication;

receiving second communication disposition information; and

disposing of the communication in accordance with the second communication disposition information.

61. The method of Claim 60, wherein the first communication disposition information comprises a plurality of destinations for delivery of communications.

62. The method of Claim 60, wherein the first communication disposition information comprises dispositions selected from the list including: land line telephones, call forwarding directory numbers, mobile telephones, facsimile machines, pagers, voice mail boxes, and announcements.

63. The method of Claim 60, wherein the second communication disposition information indicates acceptance, active rejection, or passive rejection of the communication.

64. The method of Claim 60, wherein the communication disposition information comprises a list of destinations hierarchically arranged in order of subscriber preference for communication routing, and wherein the step of receiving the first communication disposition information comprises receiving the list of destinations and hierarchy information for each of the destinations.

65. The method of Claim 64, wherein the destinations comprise devices having directory numbers, the devices comprising the following: land line telephones, mobile telephones, cellular telephones, voice mail services, facsimile devices, and paging devices; and

wherein the step of receiving the list of destinations comprises receiving at least two directory numbers, and storing the directory numbers in a database.

66. The method of Claim 65, wherein the step of selecting a first destination comprises selecting a first destination from a plurality of directory numbers in the database.

67. The method of Claim 60, wherein the step of receiving first communication disposition information further comprises receiving a default destination, and

wherein the method further comprises the step of routing the communication to the default destination in response to a predetermined condition of the second communication disposition information.

68. The method of Claim 67, wherein the predetermined condition of the second communication disposition information comprises a busy condition of the mobile communication device.

69. The method of Claim 67, wherein the predetermined condition of the second communication disposition information comprises a no answer condition of the mobile communication device.

70. The method of Claim 67, wherein said subscriber has a voice mail service, and wherein the step of routing the communication to said default destination comprises routing the communication to the voice mail service.

71. A method for delivering a communication to a subscriber, comprising the steps of:

receiving communication disposition information from the subscriber, the communication disposition information comprising a plurality of destinations, the destinations being hierarchically arranged in order of preference by the subscriber, at least one of the destinations corresponding to a mobile communication device;

receiving a communication directed to the subscriber;

selecting a first destination from the plurality of destinations in the order of the hierarchy;

receiving location information indicative that the mobile communication device is presently enabled to receive communications while operated in a roaming manner in a foreign service area;

determining whether the first destination corresponds to the mobile communication device;

in response to determination that the mobile communication device is enabled, routing the communication to the mobile communication device in the foreign service area.

72. The method of Claim 71, further comprising the step of:

in response to determination that the mobile communication device is not enabled, routing the communication to a second destination of the plurality of destinations.

73. The method of Claim 71, wherein the location information comprises registration information obtained by the foreign service area.

74. The method of Claim 71, wherein the location information includes routing information for routing the communication to the foreign service area.

75. The method of Claim 73, wherein the routing information comprises a temporary line directory number.

76. The method of Claim 71, wherein the location information is provided by a cellular telephone clearinghouse via data communications link.

77. The method of Claim 71, wherein the location information is provided directly from the foreign service area via a data communications link.

78. A method for delivering a communication to a personal number associated with a personal number communication service subscriber, comprising the steps of:

maintaining a personal number communication system database of information relating the personal number to communication disposition information associated with the subscriber;

storing communication disposition information in the communication disposition database corresponding to a plurality of selectable dispositions of communications directed to a personal number associated with the subscriber, at least one of the selectable dispositions corresponding to a mobile telephone associated with the subscriber;

detecting the registration of the subscriber's mobile telephone in a cellular system;

at the cellular system, providing a registration message indicative of the registration of the mobile telephone at the cellular system;

receiving the registration message at switching equipment;

at the switching equipment, receiving a communication directed to the subscriber's personal number;

in response to receipt of a communication directed to the subscriber's personal number, retrieving the communication disposition information associated with the subscriber's personal number from the personal number system database; and in response to the communication disposition information and the registration message, forwarding the communication to the subscriber's mobile telephone in the cellular system.

79. The method of Claim 78, wherein the communication disposition information is selectably variable by the subscriber.

80. The method of Claim 79, wherein the communication disposition information is selectably variable by the subscriber from a remote location utilizing command codes.

81. The method of Claim 78, wherein the step of detecting the registration of the subscriber's mobile telephone in a cellular system comprises detecting the registration of the subscriber's mobile telephone in a visited cellular system where the mobile telephone is roaming.

82. The method of Claim 81, wherein the registration message is delivered from the visited cellular system to the switching equipment via a data communications link.

83. The method of Claim 82, wherein the data communications link comprises an SS7 data link.

84. The method of Claim 78, wherein the communication disposition information includes information indicating whether a communication is to be forwarded to the mobile telephone while roaming in a foreign service area, and

wherein the step of forwarding the communication to the subscriber's mobile telephone comprises routing the communication to the mobile telephone in the foreign service area in response to an indication that the communication is to be forwarded to the mobile telephone while roaming in a foreign service area.

85. The method of Claim 84, wherein the step of forwarding the communication to the subscriber's mobile telephone comprises routing the communication to an alternative destination in response to an indication that the communication is not to be forwarded to the mobile telephone while roaming in a foreign service area.

86. The method of Claim 78, further comprising the step of providing communication routing information from the cellular system to the switching equipment.

87. The method of Claim 86, wherein the step of providing communication routing information comprises providing a temporary line directory number (TLDN) to the switching equipment.

88. A method of delivering a communication to a subscriber roaming in a remote communications system, comprising the steps of:

at the remote communications system, detecting the presence of a mobile telephone associated with the subscriber;

providing a copy of registration information indicative of the presence of the subscriber's mobile telephone;

receiving the copy of the registration information provided by the remote communications system;

receiving a communication directed to the subscriber; and

routing the communication to the subscriber's mobile telephone in the remote communications system.

89. The method of Claim 88, wherein the remote communications system is a cellular mobile radiotelephone system.

90. The method of Claim 88, wherein the method is carried out in connection with a personal number communication (PNC) system where incoming communications are directed to a personal number associated with the subscriber.

91. The method of Claim 90, wherein the PNC system stores communication disposition information indicative of a plurality of possible dispositions of communications directed to the subscriber, at least one of the possible dispositions corresponding to delivery of the communication to the subscriber's mobile telephone when roaming in a remote communications system.

92. The method of Claim 91, wherein the communications disposition information includes a selectably actuatable user flag to allow the subscriber to selectably indicate whether communications are to be delivered to the remote communications system.

93. A personal number communication system, comprising:

a location information system for obtaining subscriber location information corresponding to a remote location of a subscriber mobile communications device;

switching equipment operative to receive a subscriber communication directed to a subscriber at a subscriber personal number, and responsive to a routing message to route said subscriber communication to said subscriber;

a subscriber database containing information concerning subscriber location, subscriber personal numbers, and subscriber mobile communications devices;

a first communications channel for communicating said subscriber location information from the clearinghouse to the subscriber database;

a second communications channel for communicating a routing inquiry from said switching equipment to said subscriber database in response to receipt of a subscriber communication channel;

a third communications channel for sending said routing message indicative of communications routing information and said subscriber location information from said subscriber database to said switching equipment, whereby said switching equipment is operative for routing said subscriber communication to said subscriber at said remote location.

94. The system of Claim 93, where said location information system comprises a cellular clearinghouse.

95. The system of Claim 93, wherein said location information system comprises a mobile telephone switching office (MTSO) associated with a foreign cellular service area.

96. The system of Claim 93, wherein said location information system comprises a home mobile telephone switching office (MTSO) associated with said subscriber mobile communication device, and wherein said home MTSO is operative for obtaining said location information from a cellular clearinghouse.

97. The system of Claim 93, wherein said location information system comprises a home mobile telephone switching office (MTSO) associated with said subscriber mobile communication device, and wherein said home MTSO is operative for obtaining said location information directly from a foreign MTSO where said subscriber mobile communication device is roaming.

98. The system of Claim 93, wherein the first communications channel is an SS7 data communications link.

99. The system of Claim 93, wherein said subscriber database is maintained at service control point (SCP) equipment associated with a telephone switching office, and wherein the second communications channel and said third communications channel comprises a data communications channel between service switching point (SSP) equipment and said SCP equipment.

100. The system of Claim 93, wherein said third communications channel

service switching point equipment responsive to communications routing information for routing calls made to a subscriber personal number to a remote location indicated by said location information.

101. A system of delivering a personal number communication to a subscriber with a mobile telephone while roaming in a foreign cellular system remote from a home cellular system associated with the mobile telephone, comprising:

a personal number communication (PNC) system operative for disposing of communications to the subscriber in accordance with predetermined communication disposition information provided by the subscriber,

said predetermined communication disposition information including the subscriber's mobile telephone when roaming in said foreign cellular system;

a roamer detection module associated with said foreign cellular system, said roamer detection module being operative to detect the presence of the subscriber's mobile telephone while roaming in said foreign cellular system and to obtain registration information corresponding to the subscriber's mobile telephone;

a data communication pathway for communicating a registration message including said registration information from said foreign cellular system to said PNC system;

an incoming telecommunications pathway associated with said PNC system for receiving an incoming personal number communication directed to the subscriber;

an outgoing telecommunications pathway associated with said PNC system for connecting said incoming personal number communication to a destination in accordance with said communication disposition information: and

said PNC system being operative for directing said incoming personal number communcation via said outgoing telecommmunications pathway to said subscriber's mobile telephone roaming in said foreign cellular system.

102. The system of Claim 101, wherein said data communications pathway comprises a Signaling System 7 (SS7) data communications link.

103. The system of Claim 101, wherein said registration message comprises a plurality of independently communicated IS-41 messages.

104. The system of Claim 101, wherein said registration message is delivered from said foreign cellular system to said PNC system via a clearinghouse.

105. The system of Claim 101, wherein said registration message is delivered from said foreign cellular system directly to a home mobile telephone switching office (MTSO) associated with the subscriber's mobile telephone.

106. The system of Claim 101, wherein said registration message includes routing information for connecting said outgoing telecommunications pathway to said foreign cellular system.

107. The system of Claim 104, wherein said routing information is provided in a subsequent communication via said data communication pathway, in response to a query provided by said PNC system.

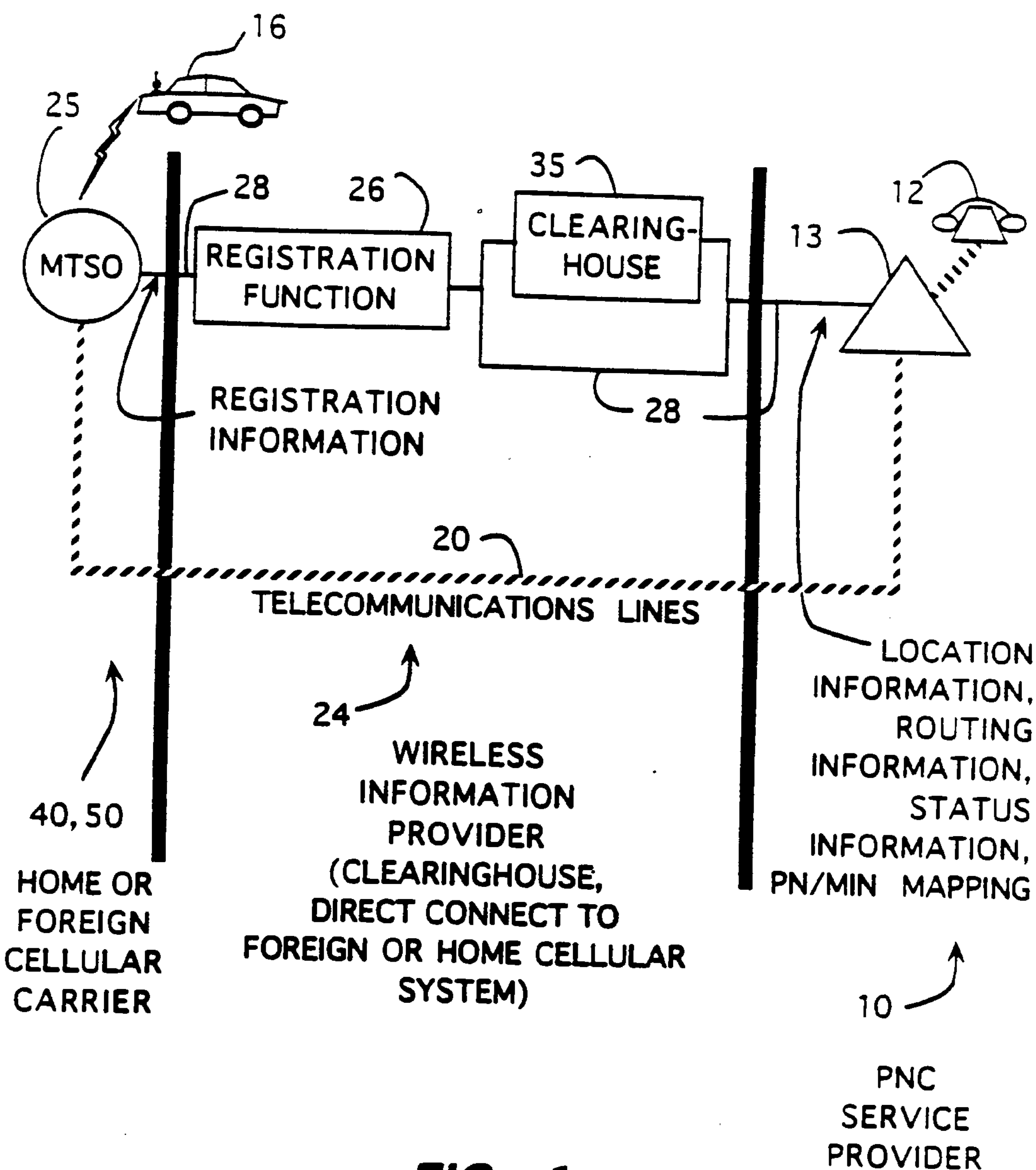

16
25
MTSO
28
26
REGISTRATION FUNCTION
35
CLEARING-HOUSE
12
13
REGISTRATION INFORMATION
28
20
TELECOMMUNICATIONS LINES
LOCATION INFORMATION, ROUTING INFORMATION, STATUS INFORMATION, PN/MIN MAPPING
24
WIRELESS INFORMATION PROVIDER (CLEARINGHOUSE, DIRECT CONNECT TO FOREIGN OR HOME CELLULAR SYSTEM)
40, 50
HOME OR FOREIGN CELLULAR CARRIER
10
PNC SERVICE PROVIDER

FIG. 1

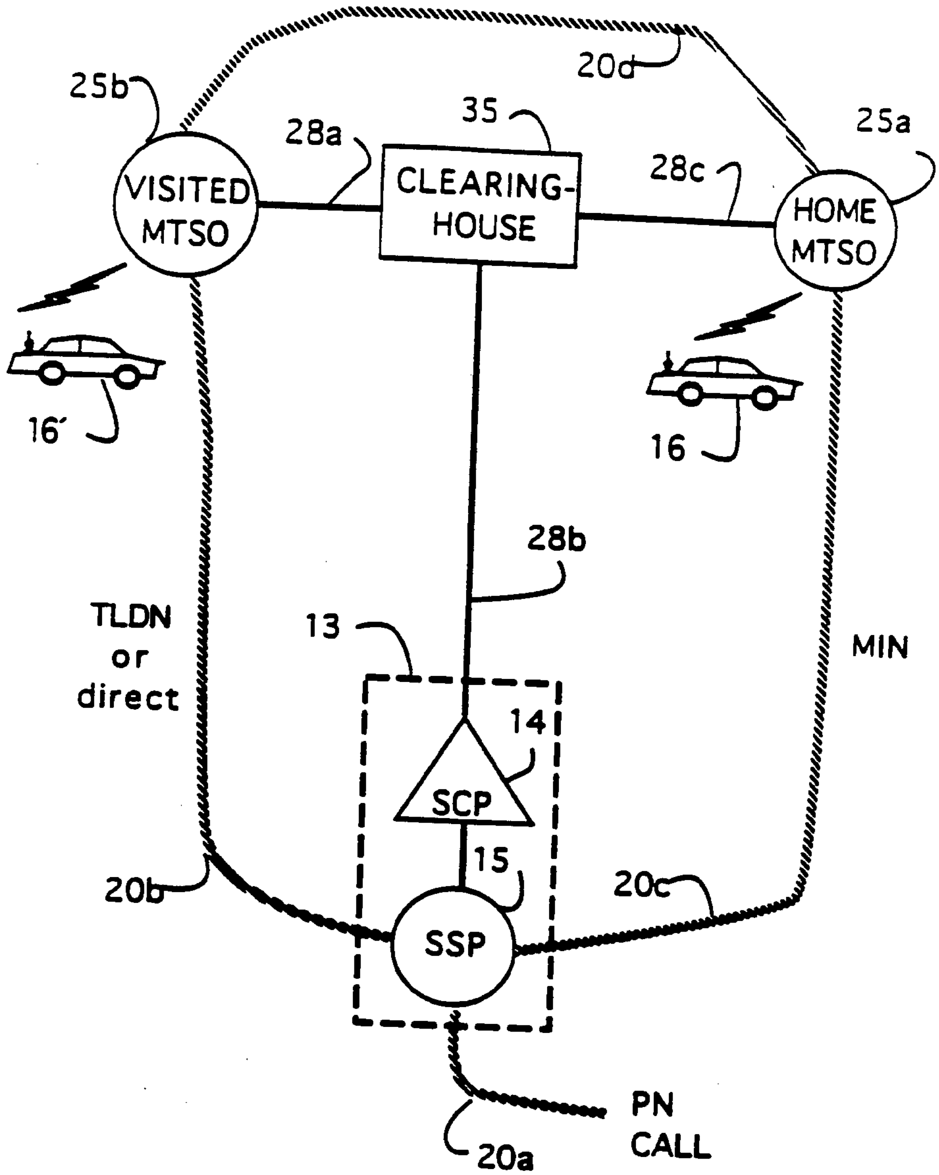

25b
20d
35
25a
28a
CLEARING-HOUSE
28c
VISITED MTSO
HOME MTSO
16'
16
28b
TLDN or direct
13
MIN
14
SCP
15
20b
20c
SSP
PN CALL
20a

FIG. 2

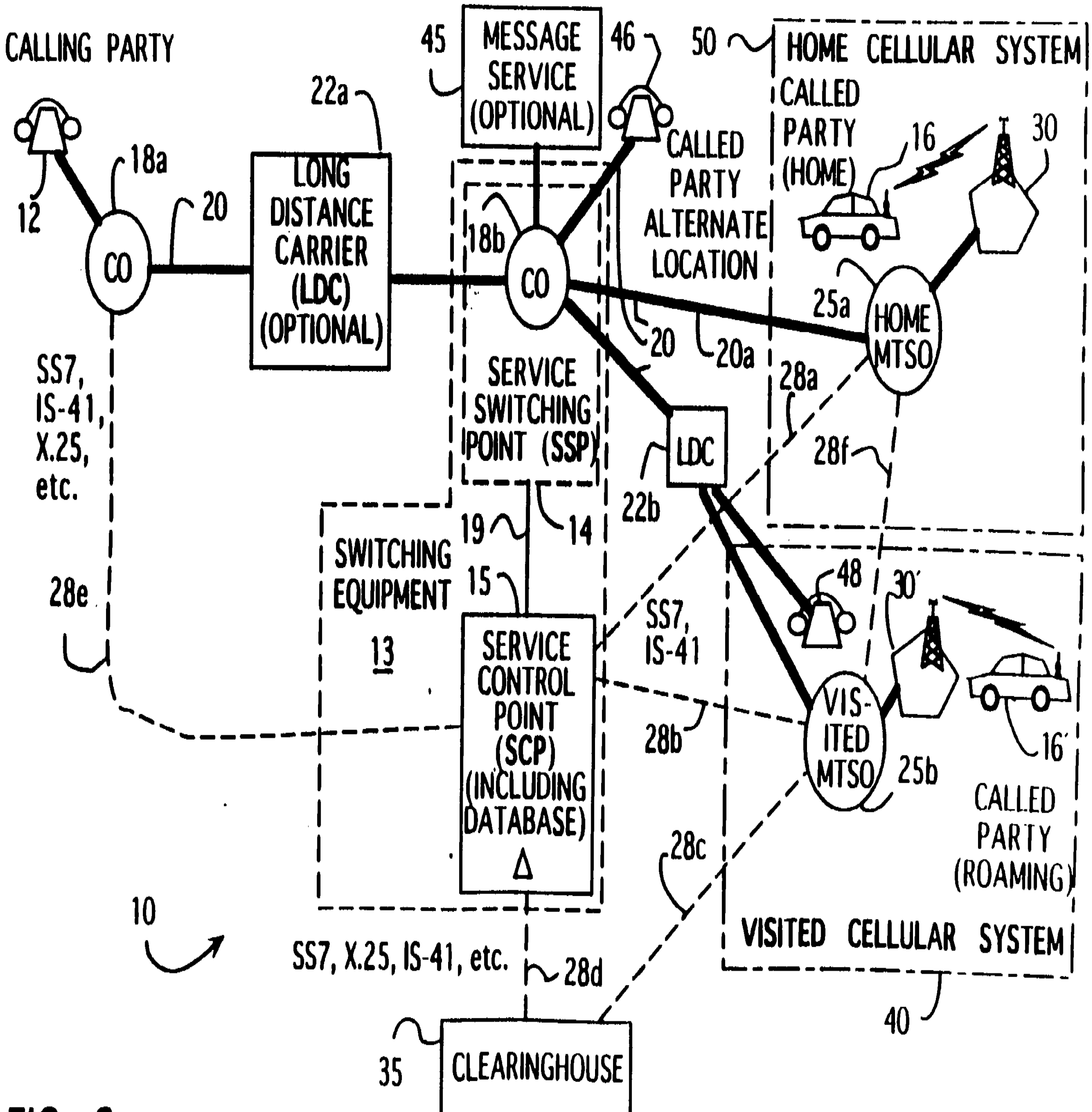

CALLING PARTY
12
18a
CO
20
22a
LONG DISTANCE CARRIER (LDC) (OPTIONAL)
45
MESSAGE SERVICE (OPTIONAL)
46
50
HOME CELLULAR SYSTEM
CALLED PARTY (HOME)
16
30
CALLED PARTY ALTERNATE LOCATION
18b
CO
20
20a
25a
HOME MTSO
28a
28f
SERVICE SWITCHING POINT (SSP)
14
19
15
LDC
22b
SWITCHING EQUIPMENT
13
SS7, IS-41, X.25, etc.
28e
SERVICE CONTROL POINT (SCP) (INCLUDING DATABASE)
SS7, IS-41
48
30′
VIS-ITED MTSO
25b
28b
16′
CALLED PARTY (ROAMING)
28c
VISITED CELLULAR SYSTEM
40
10
SS7, X.25, IS-41, etc.
28d
35
CLEARINGHOUSE

FIG. 3

OPERATION: RegistrationNotification (REG.NOT)
INVOKE PARAMETERS
MobileIdentificationNumber (MIN) MobileSerialNumber (MSN or ESN) QualificationInformationCode SystemMyTypeCode (VLR) MSCID (Serving) PC SSN LocationAreaID
RETURN RESULT PARAMETERS
SystemMyTypeCode (HLR) AuthorizationDenied AuthorizationPeriod OriginationIndicator Digits (destination) TerminationRestrictionCode CallingFeaturesIndicator Digits (carrier)
RETURN ERROR CODE
Error Code
RETURN ERROR PARAMETERS
FaultyParameter

(Ref. IS-41.5, 8.1.3.3)

FIG. 4

FIG. 5

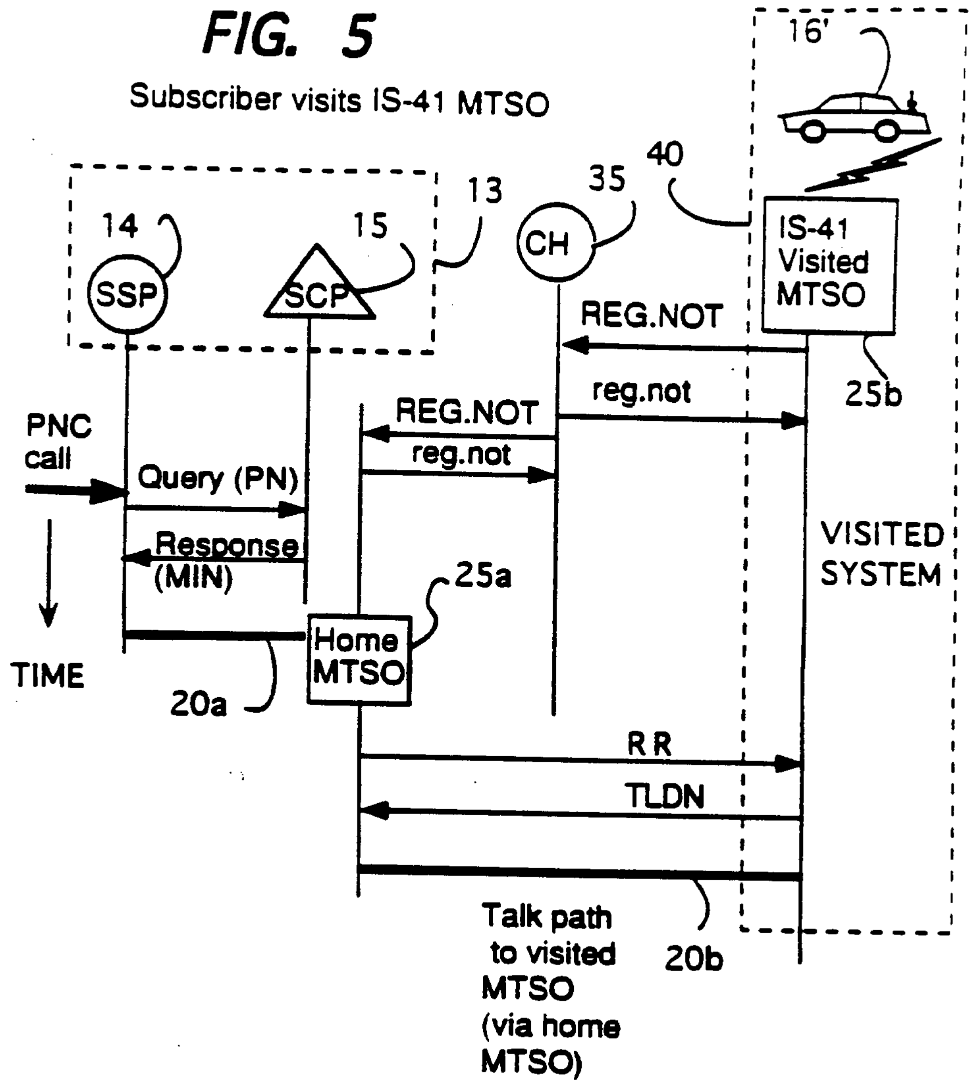

Subscriber visits IS-41 MTSO
16'
40
35
13
14
15
SSP
SCP
CH
IS-41
Visited
MTSO
REG.NOT
reg.not
25b
REG.NOT
reg.not
PNC
call
Query (PN)
Response
(MIN)
VISITED
SYSTEM
25a
Home
MTSO
TIME
20a
R R
TLDN
Talk path
to visited
MTSO
(via home
MTSO)
20b

FIG. 6

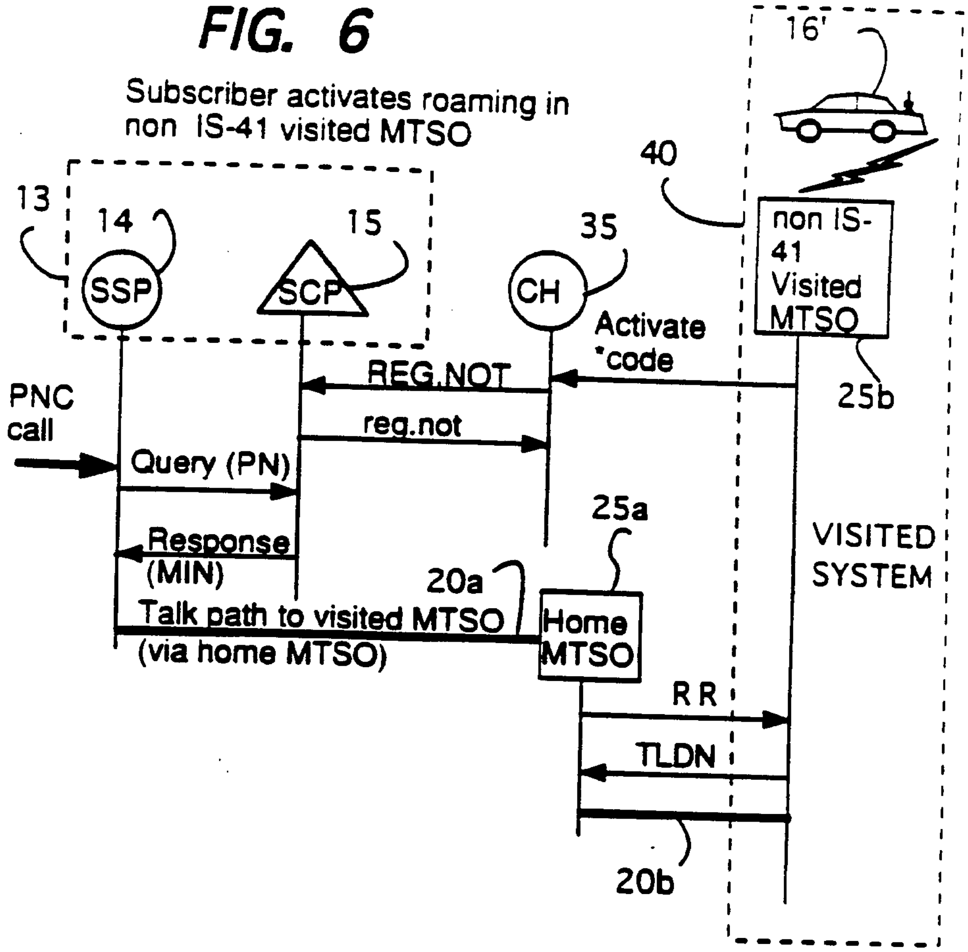

Subscriber activates roaming in non IS-41 visited MTSO
16'
40
13
14
15
35
SSP
SCP
CH
non IS-41 Visited MTSO
Activate *code
REG.NOT
25b
PNC call
reg.not
Query (PN)
25a
Response (MIN)
VISITED SYSTEM
20a
Talk path to visited MTSO (via home MTSO)
Home MTSO
RR
TLDN
20b

FIG. 7

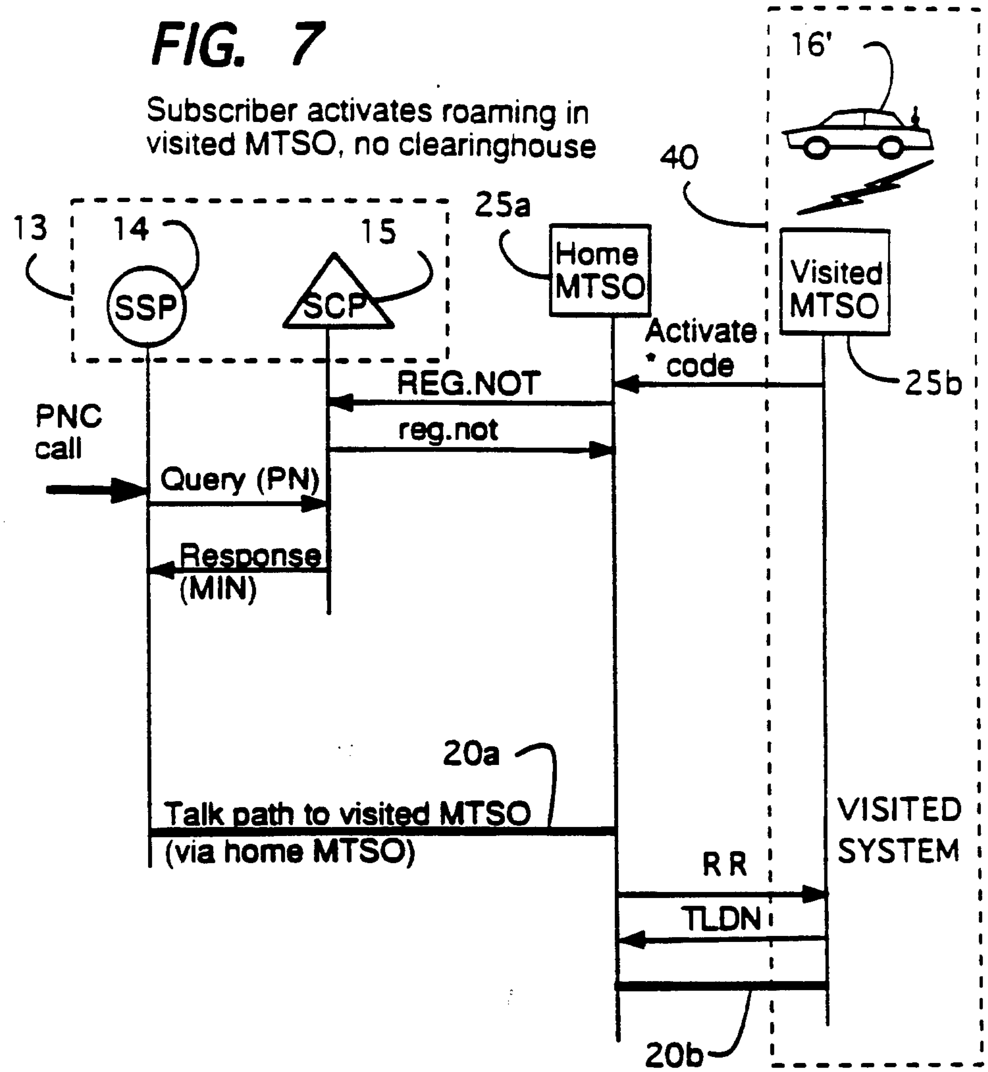

Subscriber activates roaming in visited MTSO, no clearinghouse
16'
40
13
14
15
25a
SSP
SCP
Home MTSO
Visited MTSO
Activate * code
25b
REG.NOT
reg.not
PNC call
Query (PN)
Response (MIN)
20a
Talk path to visited MTSO (via home MTSO)
VISITED SYSTEM
RR
TLDN
20b

FIG. 8

SUBSCRIBER DEACTIVATES ROAMING

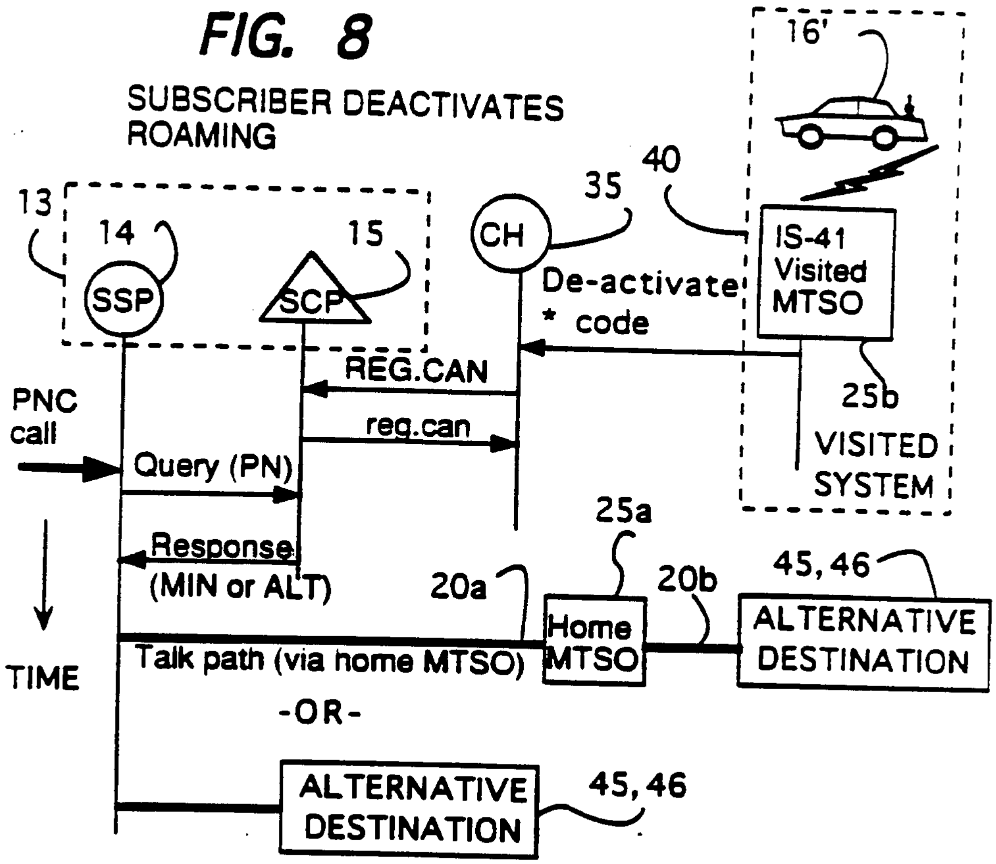


FIG. 9

IMPLICIT DE-ACTIVATION BY CLEARINGHOUSE

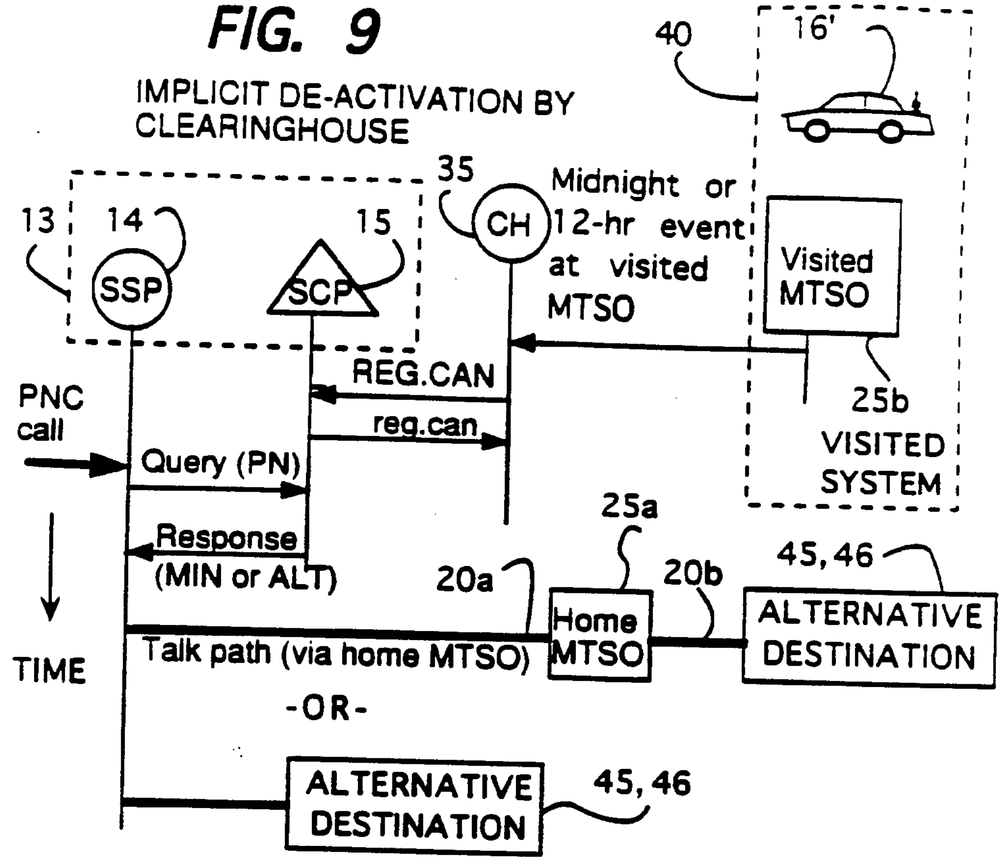


FIG. 10

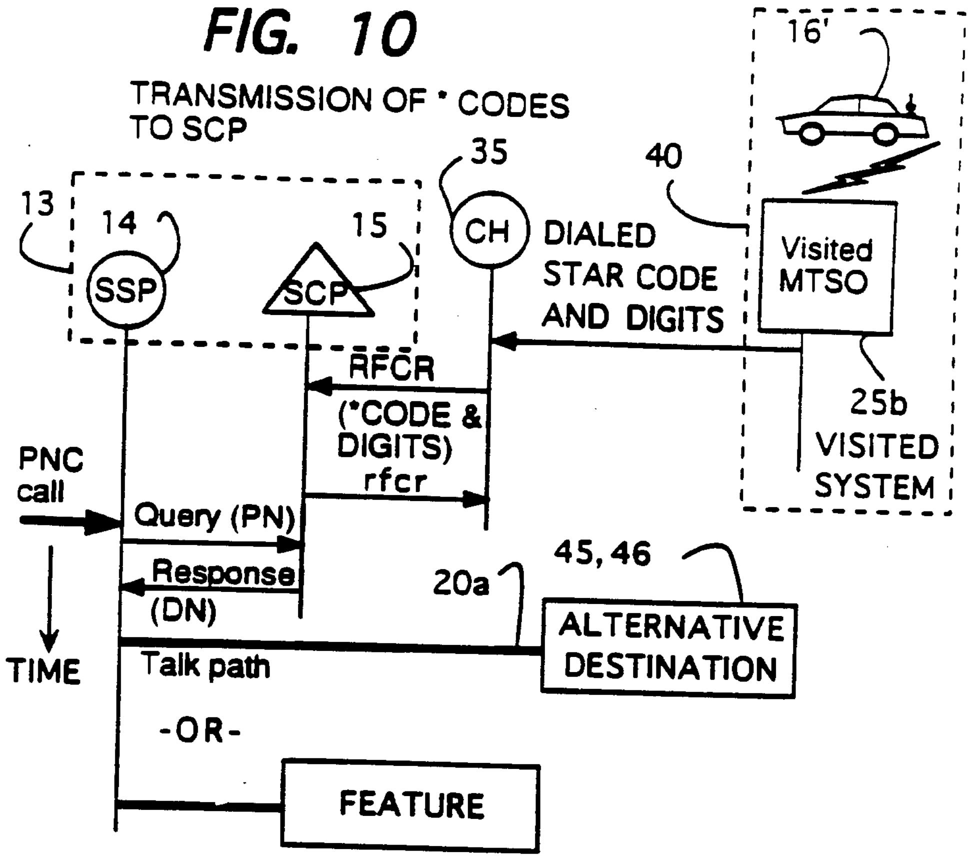

TRANSMISSION OF * CODES TO SCP
13
14
15
35
40
16'
SSP
SCP
CH
DIALED STAR CODE AND DIGITS
Visited MTSO
25b
VISITED SYSTEM
RFCR
(*CODE & DIGITS)
rfcr
PNC call
Query (PN)
Response (DN)
TIME
20a
45, 46
ALTERNATIVE DESTINATION
Talk path
-OR-
FEATURE

FIG. 11

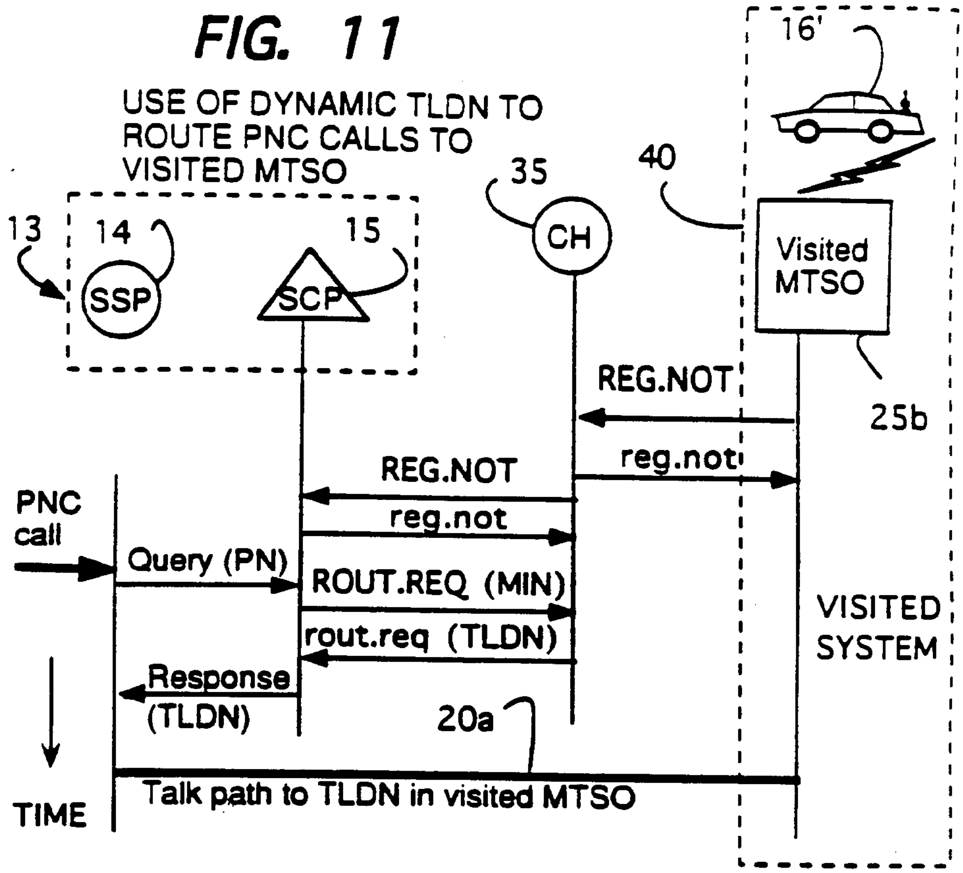

USE OF DYNAMIC TLDN TO ROUTE PNC CALLS TO VISITED MTSO
16'
40
35
13
14
15
SSP
SCP
CH
Visited MTSO
REG.NOT
25b
REG.NOT
reg.not
reg.not
PNC call
Query (PN)
ROUT.REQ (MIN)
rout.req (TLDN)
Response (TLDN)
20a
VISITED SYSTEM
TIME
Talk path to TLDN in visited MTSO

FIG. 12

USE OF ROUTE REQUEST INFO TO ROUTE PNC CALLS TO SUBSCRIBER VOICEMAIL

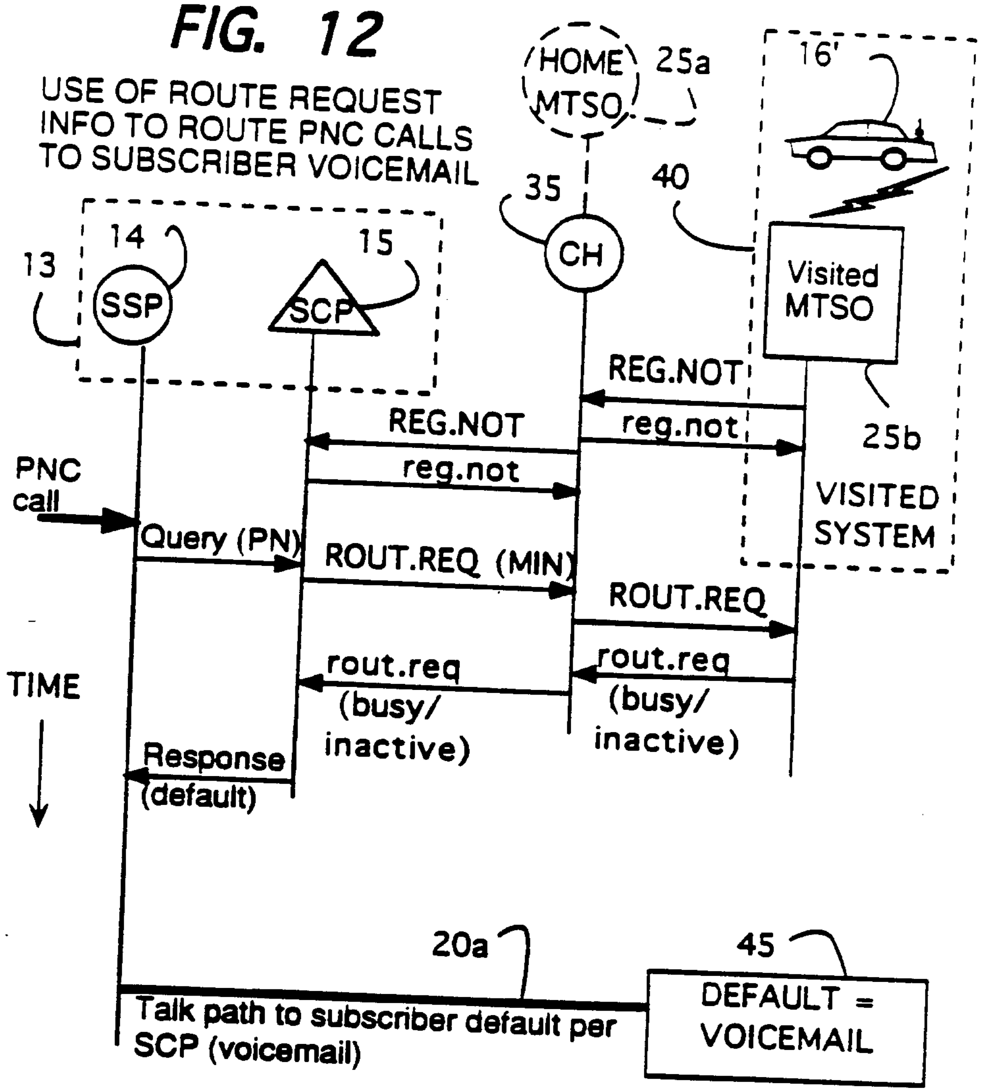


FIG. 13
USE OF TTNR TO FORWARD PNC CALLS TO TRANSFER DN

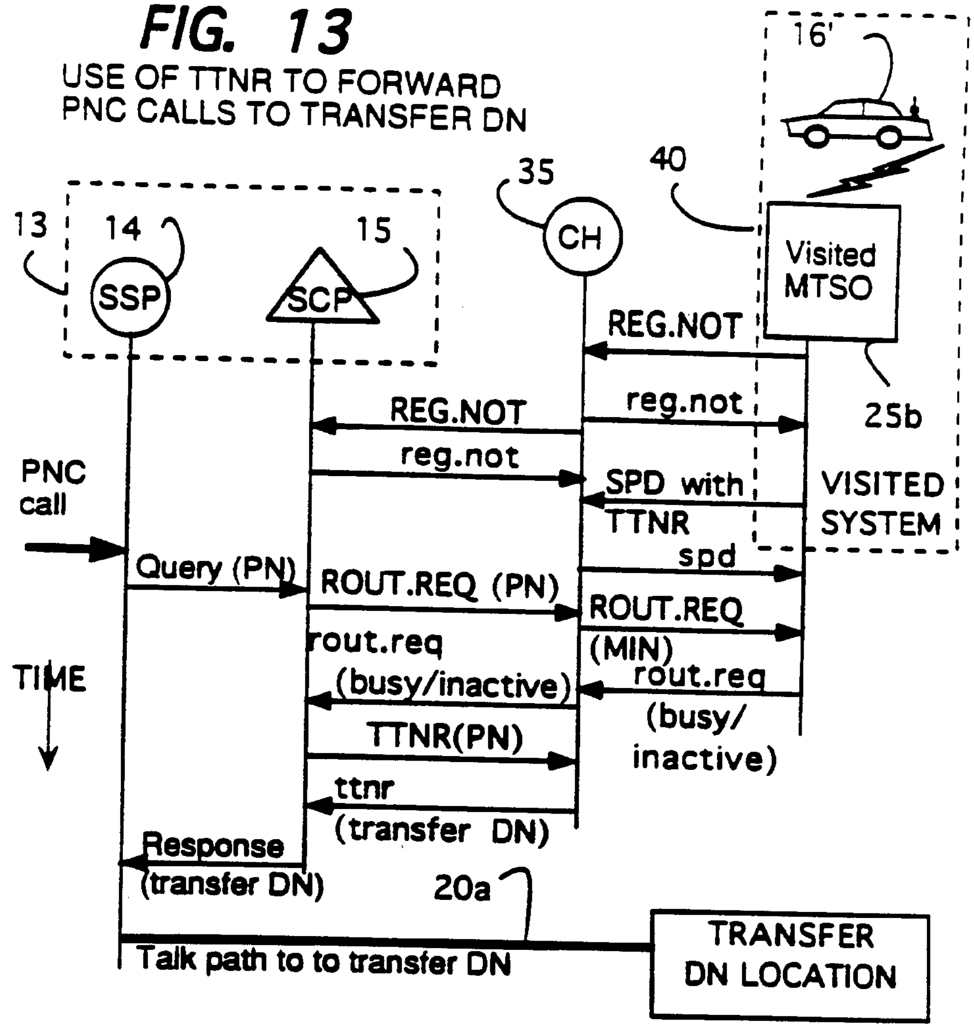
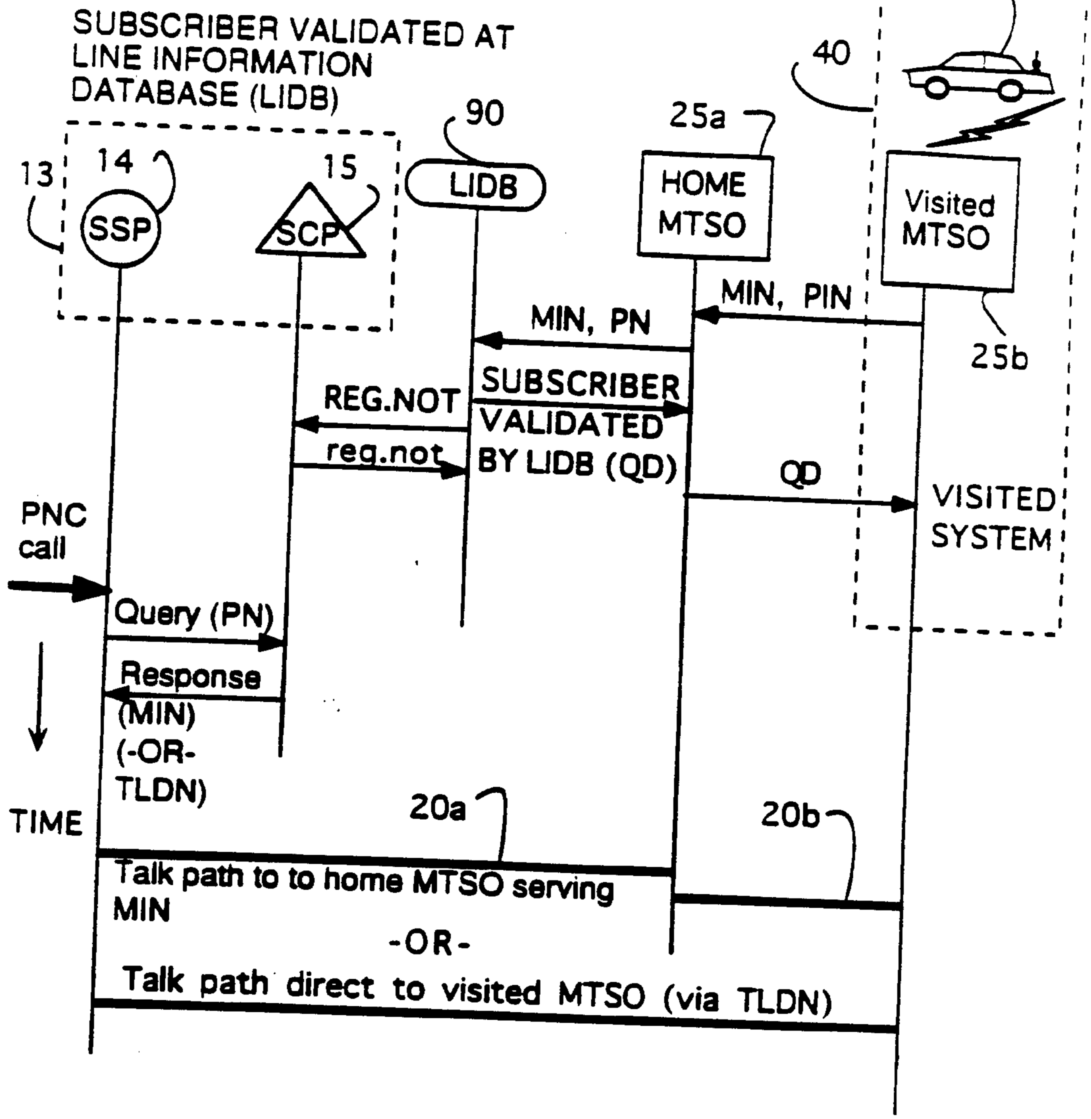


FIG. 14


SUBSCRIBER VALIDATED AT LINE INFORMATION DATABASE (LIDB)
16'
40
90
25a
13
14
15
SSP
SCP
LIDB
HOME MTSO
Visited MTSO
MIN, PIN
MIN, PN
25b
SUBSCRIBER VALIDATED BY LIDB (QD)
REG.NOT
reg.not
QD
VISITED SYSTEM
PNC call
Query (PN)
Response (MIN) (-OR- TLDN)
TIME
20a
20b
Talk path to to home MTSO serving MIN
-OR-
Talk path direct to visited MTSO (via TLDN)

100

PN - PERSONAL NUMBER		
DN1 - PRINCIPAL DESTINATION (e.g. CELLULAR MIN)		
DN2 - ALTERNATIVE DESTIONATION #1		
DN3 - ALTERNATIVE DESTINATION #2		
DN*i* - ALTERNATIVE DESTINATION # *i*		
• • •		
MIN		
FEATURE CODES - POSSIBLE		
FEATURE CODES - PRESENTLY ENABLED		
STATUS OF CELLULAR PHONE (REGISTERED, HOME or ROAM)		
USER CONTROL FLAG	HOME DELIVERY	ON/OFF
USER CONTROL FLAG	ROAM DELIVERY	ON/OFF

DATABASE RECORD MAINTAINED BY PNC SYSTEM

FIG. 15

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/11910

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04M 11/00; H04Q 07/22
US CL :379/60
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 379/60, 58, 59, 63, 97, 230; 455/33.1, 33.2

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ---- Y	US, A, 4,901,340 (PARKER ET AL) 13 February 1990, abstract, col. 3, line 30 - col. 4, line 45.	88-89 --------- 20-22, 34, 90-92, 101-107
Y, P	US, A, 5,341,410 (ARON ET AL) 23 August 1994, figure 2, col. 2, lines 1-65, abstract.	14-17, 23, 39-87, 93-100, 104
Y, P	US, A, 5,315,636 (PATEL) 24 May 1994, figure 1, col. 2, line 20 - col. 4, line 15.	1-38
Y, P	US, A, 5,329,578 (BRENNAN ET AL) 12 July 1994, Col. 4, lines 19-35, figure 1, col. 10, lines 7-22, tables 1-5, col. 9, lines 18-21, col. 8, lines 47-60.	1-87, 90-107

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be part of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 JANUARY 1995	09 MAR 1995

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	WILLIAM TROST
Facsimile No. (703) 305-3230	Telephone No. (703) 308-5318

Form PCT/ISA/210 (second sheet)(July 1992)★

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/11910

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Electronic Industries Association, 18 June 1985, "Straw Man for Automatic Roaming", pages 9-11.	8-9, 24-25, 28, 30
Y	EIA/TIA Interim Standard, December 1991, "Cellular Radio-Telecommunications Intersystem Operations: Automatic Roaming", pages 25-26, page 43.	10-11
A	British Telecommunications Engineering, Vol. 9, August 1990, A. Batten, "Personal Communications Services and the Intelligent Network", see whole document.	1-107
A	Electrical Communication, Vol. 63, No. 4, 1989, M. Ballard et al, "Cellular Mobile Radio as an Intelligent Network Application", see whole document	1-107

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(19) World Intellectual Property Organization
International Bureau

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09/466,169 19 December 1999 (19.12.1999) US

(71) Applicant (*for all designated States except US*): **GRID DATA, INC.** [US/US]; Suite 100, 7408 W. Detroit Street, Chandler, AZ 85226 (US).

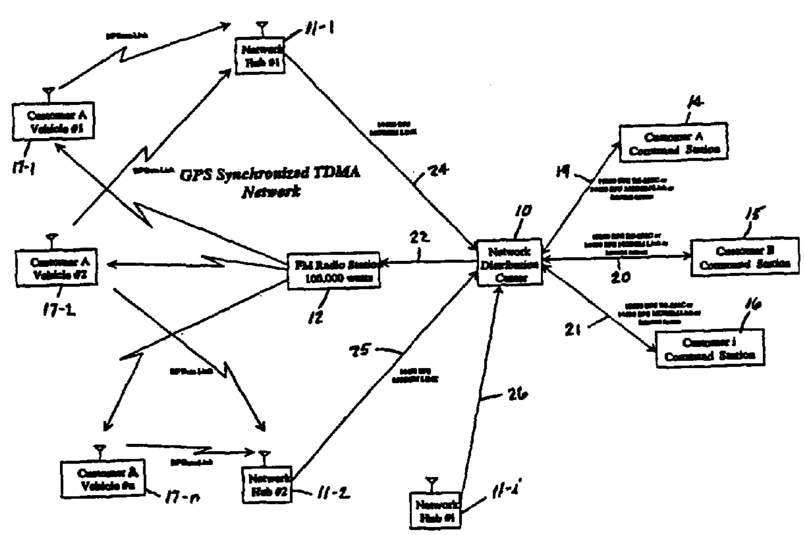
(72) Inventors; and
(75) Inventors/Applicants (*for US only*): **COFFEE, John, R.** [—/US]; 1438 E. Encinas Avenue, Gilbert, AZ 85234 (US). **RUDOW, Richard, W.** [—/US]; 424 N. Norfolk, Mesa, AZ 85205 (US). **ALLEN, Robert, F.** [—/US]; Apartment 1008, 801 N. Federal Street, Chandler, AZ 85226 (US). **DYE, David, A.** [—/US]; 3012 E. Woodland Drive, Phoenix, AZ 85048 (US). **MARVIN, Kevin, M.** [—/US]; 1265 S. Quail Lane, Gilbert, AZ 85223 (US). **BILLINGS, Mark** [—/US]; 7619 48th Avenue, Glendale, AZ 85301 (US). **KIRCHNER, Mark, L.** [—/US]; 5101 N. 10th Place, Phoenix, AZ 85014 (US). **LEWIS, Robert, W.** [—/US]; 15005 S. 9th Street, Phoenix, AZ 85048 (US). **SLEEPER, Robert, D.** [—/US]; RRI, Box 540, Laveen, AZ 85339 (US). **TEKNIEPE, Willialm, A.** [—/US]; 7805 E. Neville, Mesa, AZ 85208 (US).

(74) Agent: **GREENE, Donald, R.**; P.O. Box 12995, Scottsdale, AZ 85267-2995 (US).

(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR,

[Continued on next page]

(54) Title: VEHICLE TRACKING, COMMUNICATION AND FLEET MANAGEMENT SYSTEM



(57) Abstract: A vehicle fleet management information system for identification of location and direction of movement of each vehicle in the fleet in real-time and automatic communication directly with management offices to report its location and heading, and status of predetermined events in which the vehicle may be engaged. Each fleet vehicle is assigned a unique time slot to transmit its reporting information over a communications network without substantially interfering with transmissions from other vehicles in their own respective time slots. Precise time synchronization is provided by a timing control PLL which provides timing corrections as necessary from GPS based time reference. The network includes a dual band full-duplex interface with TDMA on one-half of the interface and broadcast on the other half. Additionally, time processing units of microprocessors in components throughout the network perform precise clock synchronization. A protocol is established for entry by vehicle transmitters into the network in the assigned time slots for periodic transmission of messages, and space diversity id performed on messages received from the vehicle transmitters to avoid data corruption. Different periodic transmission intervals are provided for different vehicles in the network by dynamically allocating the slots for various update rates. And auxiliary reporting slots are provided to allow prompt reporting of important data by the respective vehicle transmitters independent of slower periodic transmission intervals. Basedband filtering of data reduces the occupied bandwidth of the transmission channel, and includes removal of synchronization data to minimize overhead of non-information bearing data. Certain repeated events in which the vehicle is operated according to basic usage and specific usage for its industry are sensed, detected or measured and automatically reported to management offices.

WO 01/46710 A2

HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)***:** ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:

— *Without international search report and to be republished upon receipt of that report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

VEHICLE TRACKING, COMMUNICATION AND FLEET MANAGEMENT SYSTEM

Background of the Invention

The invention disclosed herein broadly relates to asset management systems, and more particularly to a system for tracking the real-time location and status of vehicles of a fleet, and for communicating between the vehicles and a dispatcher or expediter in the fleet offices.

Operators of fleet vehicle businesses need to know where each vehicle in the fleet is located and what it is doing in order to make decisions on how to use the vehicles most efficiently. In recent years, vehicle locating systems have been developed using Global Positioning System (GPS) satellite information, and, for greater accuracy, differential GPS (DGPS) systems. These systems are highly accurate where line of sight (LOS) conditions exist, that is, where the vehicle (or more accurately, the vehicle's GPS receiver) has a clear LOS to the appropriate number of GPS satellites. But such conditions are typically unavailable or are at least less frequently available for a vehicle operating on city streets, particularly in areas where multi-story buildings are present, owing to the shielding that such buildings effect. In those circumstances an alternative navigation system such as dead reckoning (DR) navigation may be used to provide vehicle position and velocity data in urban canyons (i.e., streets bordered by tall buildings) where GPS measurements are only intermittently available. Or a map matching technique or navigation grid may be used as another or additional alternative.

Currently, wireless voice communication between dispatchers and drivers is the primary means of addressing the need of the fleet owner or operator to know what each vehicle is doing, i.e., its operations taking place at any given time, and where the vehicle is located when a particular operation is occurring. In industries where vehicles perform a repetitive sequence of events with each load, such as for ready mix concrete operations, "status boxes" have recently come into use. The status boxes require the driver to press a button at each stage of operation such as "load," leave plant," "arrive job," "begin pour," and so forth.

The primary problem with either wireless voice communication or status box systems is that data are manually provided to the dispatcher from the driver of the vehicle. This leads to untimely (late) and, perhaps worse, inaccurate data more than ninety percent of the time, according to analyses performed by the fleet owners/operators. The availability of timely, accurate data is essential if the fleet operator is to operate its business efficiently and economically.

Time Division Multiple Access (TDMA) wireless networks, which are in use for many applications including digital cellular telephones and wireless local area networks, may be used for the communication between dispatchers and drivers. A TDMA network allows multiple users of a single channel or frequency by assigning specific time slots to each user to use exclusively for transmission. For optimal performance of TDMA networks, precise time synchronization between members of the network is required. Efficient use of bandwidth in the network requires that the gap times between transmissions of each user, which is wasted time, be minimized. An important component to the gap time is uncertainty of time in all the participants in the network. Synchronization of wireless networks is often very coarse, requiring large gaps between transmissions, if specialized hardware is not used. Moreover, synchronization of network elements to a precise reference like GPS based timing information involves having a GPS receiver located on each network element, both mobile and fixed, increasing installation costs and complexity for both fixed network infrastructure and mobile network devices, especially if navigation data provided by GPS is not required.

Precise time synchronization between all of the wireless devices in the network can be performed in a number of ways. Typically, a precise, stable time reference, such as one based on the Global Positioning System (GPS) or other time distribution services, is located within each wireless device or within just the fixed infrastructure of the network, with synchronization information being transmitted to the mobile units. In these cases, device or infrastructure costs are increased because timing equipment has to be distributed among several locations or devices and installed where space and access for maintenance are limited.

Transmitting as much information as possible in a given amount of bandwidth is an important design goal in any communications network. This is especially true in wireless networks in which available bandwidth is very limited and customer requirements for data throughput are immense. Operation on most wireless bands is subject to occupied bandwidth constraints, requiring the data signal to be contained in a vary narrow region of the electromagnetic spectrum. In TDMA networks, a challenge is to minimize the gap times between transmissions and the overhead associated with each data packet in order to send as much information bearing data over the network as continuously as possible. The present invention addresses these two requirements with digital filtering to control occupied bandwidth and data recovery by the receiving system that requires no synchronization patterns to be transmitted.

Summary of the Invention

The primary goal of the fleet management system of the present invention (sometimes hereinafter called the PROTRAK system or the Galileo system (each of PROTRAK and Galileo, either alone or with various suffixes attached, is a trademark of Fleet Management Services, Inc. of Chandler, Arizona, to which the present patent application is assigned), the fleet management system, or simply the system) is to provide fleet management information to customers (i.e., the owners, operators, subscribers, or users of the fleet who seek to avail themselves of the advantages of a vehicle tracking, communication and fleet management system) to enable them to manage their assets more profitably. The system provides its customers with several means to accomplish this. First, the PROTRAK system gives the fleet operator the capability to locate vehicles of the fleet in real-time. Second, the system allows the operator to communicate with those vehicles over a very efficient and reliable wireless network -- a time division multiple access (TDMA) wireless network. Third, the system enables the operator to receive timely, accurate data regarding what each vehicle of the fleet is doing, i.e., what operation(s) it is performing at any given time. Fourth, the system provides the operator with an ability to correlate the position and messaging information generated by the system with the operator's other management information systems to provide an integrated information source for improved fleet business management.

With respect to the latter, a fleet operator's existing management systems typically consist of accounting, human resources, inventory, and other systems which may not be well integrated. In addition, the operator may not have a reliable way to measure vehicle and driver performance which is critical to the operator's operations. The PROTRAK system provides the required vehicle and driver information together with a database management system that is capable of collecting such information and integrating it with data retrieved from the operator's other information systems in a database management application. This application can be used by the operator to generate reports that are tailored to its business and are based on all of the available data.

The PROTRAK system is particularly designed to operate in a market niche between cellular, specialized mobile radio (SMR), and paging services. The system may be used to track virtually any number of vehicles in a fleet across all metropolitan areas covered by the network.

Timely, accurate data can be made available to the fleet operator automatically by combining wireless data network technology, a wireless data computer (also referred to herein as a tracking computer, or simply a tracker), sensors, and dispatch and/or database reporting software and computers at the fleet operator's facilities to receive, display, and process the data provided by the vehicles. The vehicle computer has interfaces to various sensors that indicate operations being performed by the vehicle. Data provided by the sensors are processed by software algorithms in the computer to determine when events of interest occur. The event, relevant parameters, and the time of the event are then immediately transmitted through the wireless network to the fleet operator.

The network used to enable event driven status reporting is designed to provide frequent small packets of data from vehicles to fleet owners very efficiently. The network architecture is a unique, full duplex design for metropolitan area operations. Data are transmitted to vehicles over a subcarrier on an FM radio station. Vehicles transmit their data using a TDMA protocol on a single UHF channel. Vehicle data are received by Network Hubs, which are receivers placed on commercial towers around the metropolitan area of interest. The received data are sent back to a Network Distribution Center (NDC, occasionally referred to herein as Network Control Center) via telephone lines and are relayed to the fleet owners via the Internet, telephone connection, or other preferably wireless means. Data sent to the vehicles by the owners is first sent to the NDC which sends it to transmitting equipment at the radio station via telephone lines.

The TDMA protocol in the network is controlled by servers in the NDC. The

precise timing required by the TDMA network for efficient operation is controlled by a synchronization pattern contained in the subcarrier data broadcast that is received by the vehicles and the network hubs within the PROTRAK system. This enables all vehicles and hubs to have a common time reference that is accurate to about three microseconds. This, in turn, enables a multiplicity of (e.g., 50) vehicle reports in the TDMA network each second. The servers assign reporting intervals and time slots to vehicles so that they can send data and status changes automatically. Typical periodic updates of navigation data or other non-critical information are provided at two to three minute intervals; it is impractical for the vehicle computer (tracker)
to wait for a periodic interval of that length to send time critical event data.

A total of 50 20-msec long time slots are available for periodic transmissions. Multiple vehicles share slots, the number depending upon the update rate of the slot. For example, 60 vehicles can share a one minute update interval slot. Slots not assigned to periodic updates are open for any vehicle to use to request access to the network. If more than one vehicle tries to use the same interval in a particular slot, both may still be heard if each is heard by a separate hub receive site. Otherwise there is a collision (interference) of data, and the vehicles involved must retry their requests.

According to an aspect of the invention, a method and apparatus are disclosed for automatically determining and reporting events from a vehicle to an owner or dispatcher of the vehicle at a remote location. Events to be reported are changes in status of vehicle operation, location, or measurements of vehicle systems or cargo. A computer (tracking computer, generally referred to herein as the tracker) installed on the vehicle is connected to various sensors which measure parameters of interest to the dispatcher or owner and reports critical changes in parameters over the wireless TDMA network. Computers at a fixed location display these status changes for use by the dispatcher or record the data for later analysis. Software in the tracker in the vehicle together with data supplied by what may be a small number or a wide variety of sensors allows multiple, complicated, and abstract status events that are relevant to specific vehicle or industry applications to be determined and reported by the tracker. Automatically generated reports from the trackers provide more accurate and timely data to the fleet management offices of the customer than is available from the drivers of the vehicles.

The tracking computer has navigation hardware and software for determining the location, speed, and direction of travel of the vehicle in which it is installed. The application software used by operators to receive data from their vehicles also enables them to send "site dispatch" commands to the trackers which indicates a rectangular region to be used to indicate where events such as "load," or "unload," for example, should take place. Location information is then combined with the sensor data in the algorithms to determine event sequencing, provide exception reporting to indicate that the vehicle performed a specific action at the wrong location, performed unauthorized stops on the way to or from a job, or other events specific to a particular business or industry.

In an exemplary embodiment of this aspect or feature of the invention, three basic components are combined to enable vehicle data to be useful to the fleet operator, namely: (1) sensors on the vehicle to measure parameters to be combined in a computer to automatically determine when events of interest occur, (2) a wireless network that allows prompt, economical transmission of small packets of data containing event status to the fleet operator, and (3) software applications to store and further process event information for improved asset management by the fleet operator.

The tracker has several inputs and outputs to allow it to sense and control numerous vehicle functions simultaneously, with configurable interfaces that include serial interfaces, analog inputs, discrete inputs, discrete outputs, and an interface for pulse measurement or clock outputs. The tracker also has dedicated interfaces for measuring battery voltage, ignition, speed, and reverse. These enable measurement of a wide variety of vehicle functions, either directly or through auxiliary sensor modules that provide data to the computer serial interfaces. The outputs allow control of vehicle functions remotely, through the wireless network.

Tracker software permits processing and integration of various sensor inputs to enable higher level or abstract status events to be determined and reported. For example, in a "loading" status for a ready mix truck, a loading is determined from a number of inputs by combining truck location at the plant, truck stationary, and truck drum rotating in the charge direction at a speed greater than a predetermined minimum speed for a minimum time interval. Examples of other status events include "ambulance emergency lights on" or "four wheel drive engaged," which, as with other simpler status events, are simply detected and reported.

The tracker reports events over the wireless network whose architecture and protocols are tailored for prompt reporting of events while concurrently supporting slower, periodic update intervals for less critical data. As noted above, the network uses a TDMA protocol to enable a large number of vehicles to send short data packets frequently on a single wireless channel. Data is sent to the vehicles over a subcarrier on an FM broadcast channel. An important aspect of the invention is the provision of precise time synchronization required for the TDMA protocol over the FM link to the vehicles and receive sites. In the exemplary embodiment, as many as fifty vehicles per second can report data at a variety of update intervals ranging between five seconds and one hour.

Typical periodic updates of navigation data and other non-critical information are provided at two to three minute intervals. However, it is not practical for the tracker to wait for periodic intervals of that length to send time critical event data. Accordingly, for such events, the network maintains a number of time slots for additional access to the network on request of any vehicle needing to transmit event data. The requesting vehicle is then granted sufficient auxiliary reporting times at twelve second intervals to send its data. The total latency between an event being detected and the transmission of data is kept under thirty seconds.

Owners and dispatchers of fleet vehicles are provided with computer software applications that enable connection of their desktop PC's to the TDMA network using the Internet or other means. Data furnished from the vehicles are routed to these applications by the network servers, and are also stored in a local database. One of these software applications allows viewing the vehicle locations as icons on a map displayed on a monitor, showing event changes for each vehicle on the map in real time as they occur, and also enables the dispatcher to send messages or dispatch locations to the vehicles. Automated events may be provided as well to other dispatch or vehicle management applications, as required. Advantageously, these applications integrate vehicle event data with other systems utilized in the fleet operator's business, such as order entry and call management. Reports on vehicle events may be generated from these applications over the Internet from data stored in the network database.

According to another of its aspects, the present invention minimizes infrastructure cost for time references in the TDMA wireless network and locates the time reference in a central network control facility that is easily maintained and monitored. The time reference uses GPS referenced time, and TDMA network time is held in synchronization to the GPS reference by a wireless phase lock loop (PLL), removing the requirement to locate the time reference within the wireless transceiver devices or infrastructure elements. This aspect of the invention enables precise time synchronization of all wireless network elements by using special timing hardware and by distributing a single, remote GPS based time reference throughout the network using a wireless PLL. Digital data is remotely synchronized in the TDMA network, a full duplex system designed to efficiently transmit short bursts of data from mobile vehicles to their owner on a frequent basis. Vehicles transmit data using a TDMA protocol in the UHF frequency band in precisely controlled time slots at a rate of 50 vehicles per second. Vehicles send location, status, and message data to the fleet owners or dispatchers who are connected to the wireless network through the Internet or other means. Data transmitted to the vehicles is broadcast over a subcarrier of an FM radio station, including network timing and control information as well and messages and information from fleet operators.

Timing of the TDMA portion of the network is controlled from a central network control facility that houses the servers which control vehicle access to the network and manage fleet owner connections to the network. Synchronization of the vehicle devices and fixed hub receiver systems that receive vehicle data is maintained through synchronization information contained in the FM subcarrier broadcast. The FM subcarrier timing data is, in turn, referenced to a GPS based time source at the network control center.

A Subcarrier Control Computer (SCC), responsible for providing the data to the subcarrier modulator, is located at the FM radio station transmitter or studio facilities. It clocks the transmit data at precise intervals based on timing commands from a Network Timing Control Computer (NTCC), located at the network control center. The NTCC and SCC are connected through a modem for data and timing control commands sent to the SCC. The NTCC computes timing commands based on the synchronization information from a GPS receiver time reference and that from an FM subcarrier receiver which receives data from the SCC. The difference in time from the GPS time reference and the received synchronization data over the FM subcarrier is processed by the NTCC using a PLL algorithm to generate a timing correction which is sent to the SCC.

This wireless PLL timing control loop enables a single, remotely located time reference to synchronize the TDMA network. In addition, the feedback inherent in the control loop allows the system to compensate for variations in FM radio station group delay so that the broadcast synchronization data is applicable at the FM antenna. This is important for large networks based on this technology that require multiple FM stations to cover overlapping geographical areas, because it enables the FM stations to be synchronized.

The invention also relates to bandwidth optimizations for the transmission of data over wireless TDMA data networks. The invention minimizes occupied bandwidth in a wireless channel by digitally filtering the data to be transmitted before modulation. The filter is implemented in a low-cost microcontroller, which replaces each edge in a digital square wave data stream with transitions that have the shapes of rising or falling sine waves. This has the advantages of reducing higher harmonics in the data signal, especially at the highest data rate, where the square wave is effectively replaced by a sine wave. Another aspect of the invention maximizes the efficiency of the TDMA network by refraining from sending any special bit synchronization information in addition to the data. In most systems, a large number of bits is devoted to synchronization, framing, or data clock recovery. In one aspect of the present invention, the bit clock and data synchronization are performed by the receiver by using forward error correction algorithms, special bit interleaving, and high performance digital signal processing hardware and software. Still another aspect of the invention uses space diversity combining between multiple receive sites to improve the reliability of receiving data. More reliable data reception saves bandwidth by reducing the number of retries required to move data through the network.

Brief Description of the Drawings

The above and other aims, objects, features, aspects, and attendant advantages of the invention will become apparent from the following detailed description of the presently contemplated best mode of practicing the invention, with reference to presently preferred exemplary embodiments and methods thereof, in conjunction with the accompanying drawings, in which:

FIG. 1 is a simplified block diagram of the overall PROTRAK system, including the TDMA network, of the invention;

FIG. 2 is a block diagram of the system architecture for customer application interfaces;

FIG. 3 is a detailed schematic diagram of the components of the wireless network and customer interfaces;

FIG. 4 illustrates details of the NDC in the network of **FIG. 3**;

FIG. 5 is a time-line of data flow in the network;

FIG. 6 is a block diagram of the base message feedback loop for bit-sync timing;

FIG. 7 is a diagram of the base message broadcast format;

FIG. 8 is a diagram of an exemplary tracker module message transmit frame;

FIG. 9 is a diagram illustrating the repeating interval relationship to slots, frames and frame cycles for tracker message packets;

FIG. 10 illustrates the relationship between trackers, slots, and repeating intervals;

FIG. 11 is a diagram of a nominal navigation grid used in the system of the invention;

FIG. 12 is a diagram of a timing control phase locked loop (PLL) according to an aspect of the invention for the TDMA network of **FIG. 1**;

FIG. 13 is a timing diagram of the synchronization pulse sequence transmitted by the SCC on the FM subcarrier at the start of each second's data, for the control loop of **FIG. 12**;

FIGS. 14A-D are flow charts of timing control loop processing performed in operational modes of the NTCC software synchronization of the TDMA network to GPS time;

FIG. 15 is a block diagram (mathematical) of the timing control loop;

FIG. 16 is a block diagram of the transmit TDMA data processing performed by the tracking computer (tracker) installed in a fleet vehicle;

FIG. 17 is a table illustrating the TDMA transmit data interleaving pattern;

FIGS. 18A-C are diagrams comparing an original TDMA data sequence to the delay coded version of that sequence, and also illustrating premodulation filtering of the delay coded sequence;

FIG. 19 is a flow chart of the filtering algorithm performed by a specially selected microcontroller which implements premodulation filtering for the result shown in **FIG. 18C**;

FIG. 20 is a diagram representing a comparison of the approximate relative power spectrums of the unencoded, delay coded, and filtered data of **FIGS. 18A-C**;

FIG. 21 is a block diagram that illustrates the receive TDMA data processing performed by the Network Hub receiver;

FIG. 22 is a flow chart of the space diversity algorithm used by the NDC server to combine vehicle data received by the network hubs;

FIG. 23 illustrates an exemplary placement of the tracker, a Mobile Data Terminal (MDT) and antennas on a typical fleet vehicle, the vehicle being further equipped for accommodating various sensors for event reporting;

FIG. 24 is a simplified block diagram of a tracker installed in a vehicle of **FIG. 23**;

FIG. 25 is a block diagram of the internal power distribution to the tracker;

FIG. 26 is a block diagram of the tracker power distribution summary;

FIG. 27 is a diagram of the power mode state transition logic of the tracker;

FIG. 28 is a synchronization timing and data clocking diagram for the tracker and Network Hubs;

FIG. 29 is a timing diagram of tracker data transmissions;

FIG. 30 is a simplified block diagram of a Network Hub;

FIG. 31 is a simplified block diagram of a Subcarrier Control Computer (SCC);

FIG. 32 is a diagram of the NTCC/SCC data flow;

FIG. 33 is a diagram illustrating various sensors, inputs, outputs and interfaces to the tracker of **FIG. 24**;

FIG. 34 is an exemplary rectangular zone on a stored map used to determine and display the tracker's location (in particular, that of the vehicle in which the tracker is mounted);

FIG. 35 is a simplified block diagram of a drum rotation sensor used for a ready-mix concrete truck;

FIG. 36 is a timing diagram of the pulses resulting from the interaction of sensor and magnets on drum rotation, for the sensor embodiment of **FIG. 35**;

FIG. 37 is a state transition diagram that defines logic used by the tracker to combine sensor and navigation data to automatically derive status of a ready-mix concrete truck; and

FIG. 38 is a flow chart of a preferred diversity algorithm used by the tracker for recovering corrupted data.

Detailed Description of Exemplary Embodiments and Methods

I. *The Overall PROTRAK System*

It is desirable, first, to provide an overview of the overall PROTRAK vehicle tracking, communication and fleet management system, a simplified block diagram of which is shown in **FIG. 1**. In addition to definitions of acronyms and other abbreviated terms presented herein, a glossary of abbreviated terms used throughout this specification is set forth in Appendix A. The "brain" of the system is the Network Distribution Center (NDC) **10** which is responsible for interfacing with subscriber (variously also referred to herein as customer, owner, operator, fleet subscriber, or user) fleets via a modem on a public switched telephone network (PSTN) line or Internet or other wide area network, and interfacing with fleet vehicles through a multiplicity of Network Hubs (sometimes referred to herein as Net Hubs, or simply, Hubs) such as **11-1**, **11-2**, ... **11-i**, and one or more FM Radio Stations such as **12**.

Information to be passed to vehicles in one or more fleets of interest is generated by a fleet dispatch office terminal or customer command station (CCS) such as **14** for Customer A, **15** for Customer B, ... and **16** for Customer i, for delivery to the vehicles such as **17-1**, **17-2**, ... **17-n** for Customer A (and so forth for customers B, ... i). The information is initially sent from the respective CCS via modem over the PSTN (e.g., lines **19**, **20**, **21**) or via the Internet or other means to NDC **10**. The NDC prioritizes the information and sends it via a modem over the PSTN (e.g., line **22**) or over such other means to FM Radio Station **12**, from which the information is broadcast, e.g., on a 67 KHz or 92 KHz FM subcarrier. The information is broadcast with precise timing defined by GPS satellite navigation information.

All vehicles in the network receive the approximately 4,664 bits per second (bps) binary frequency shift keyed (BFSK) FM subcarrier broadcast from the FM Radio Station (and others, if applicable) and decode the information contained therein. Each vehicle is assigned a slot in time to broadcast its location and responses to CCS requests. The assigned slots are unique to preclude simultaneous broadcasting by two or more vehicles, and the broadcast timing is precisely controlled through GPS and FM subcarrier synchronization.

When a vehicle's time to broadcast arrives, it sends a 144 bit message at a rate of 7,812.5 bits per second. This information is received by at least one of the Network Hubs **11-1, ..., 11-i**, which demodulates the message and provides data therefrom via a modem to NDC **10** over the PSTN (e.g., via lines **24**, **25**, **26**). NDC **10** parses all received data and provides the vehicle location and status information for each specific fleet subscriber to its respective CCS over the PSTN.

Real-time tracking of vehicle location and status may be performed by the PROTRAK system as often as once every five seconds, for example, but more generally is updated at a rate of once every three minutes. Vehicle locations are tracked with an accuracy to about 5 meters through the use of DGPS information provided by the FM subcarrier broadcast. Where GPS is intermittently unavailable because of signal masking when vehicles are located on city streets bordered by tall buildings or because of other obstructions, the system employs dead reckoning (DR), map-matching and/or other navigation techniques to detect the vehicle location.

The wireless system provides a versatile medium for sending brief messages consisting of short packets of information to or from a vehicle mounted instrument or other wireless communications device. Although the system is aimed at business asset management, wireless service supports a wide range of packet communication needs for fixed as well as mobile assets. Use of GPS in the receiving device is not required, by virtue of GPS synchronization of the FM subcarrier broadcasts.

The system capacity is sufficient to accommodate at least 5,000 individual vehicles being tracked in the network at any one time with the bandwidth provided by a single FM radio station subcarrier at 67 KHz or 92 KHz for outbound communications and a single

UHF or narrowband personal communication services (PCS) 12.5 KHz bandwidth frequency for inbound vehicle messages. System expansion may be provided, for example, in 5,000 vehicle blocks by the addition of another FM radio station subcarrier and another UHF or narrowband PCS frequency. Where feasible, frequency reuse principles on UHF or narrowband PCS frequencies are applied before another inbound frequency is added, to maximize channel capacity.

Communications in the PROTRAK system provide greater reliability than cellular or specialized mobile radio (SMR), and possibly than paging systems, with anticipated reliable reception of messages by vehicles and dispatchers 97% first time. If information is not received the first time, the system is able to make that determination and will re-attempt transmission until successful, or until it is found that delivery cannot be made. At least some fleet operators (e.g., ambulance services) require reliable operation despite adverse conditions, such as power outages. The overall system has internal backups to avoid single point failures.

Fleet subscriber vehicles are allowed to "roam" from one network of the system to another, such as where a vehicle is in transit from one metropolitan area to another. The system enables the vehicle to gracefully exit the first city network and similarly enter the second city network when in range of the second city.

System components are designed to support a wide range of fleet subscribers. Vehicle trackers (i.e., on-board tracker modules) are capable of hosting a number of peripheral functions, such as analog, digital, serial interface, and higher speed data collection required by some subscribers. Network Hubs are capable of supporting various antenna and receiver configurations to enhance coverage and various power configurations to support remote site operation. Unavailability of telephone lines does not present a problem, since wireless means are used for indirect or direct interface to the NDC.

II. *The Fleet Data Management Application*

PROTRAK system architecture and database management applications that interact with each subscriber's (customer's) existing information systems include the NDC and CCSs which are used to provide real-time vehicle location and message capability for dispatchers. The customer side of the PROTRAK system consists of three applications, including (1) a database management and CCS server (DMCS) that ties the network and customer information together, (2) the CCSs with their real-time location and messaging services, and (3) report generation that allows customers to access and manipulate the data managed by the DMCS.

A block diagram of the system architecture with respect to customer application interfaces is shown in **FIG. 2**. NDC **10** runs two server applications, namely, an NDC Server **32** that provides real-time information to connected customers, and a tracking data log server **33** that collects tracking information from the system in real-time and stores it in a large capacity database, with additional capability to respond to queries for historical tracking data. The customer establishes a single conventional TCP/IP connection (**34, 35**) to each of these servers through a single dial-up line directly to the NDC or through the Internet (via an Internet service provider, or ISP).

The connections to the NDC are controlled by DMCS **27** which may be located at the customer's facility **28** remote from the NDC **10**. All of the real-time data available for all of the customer's vehicles are provided to this DMCS application. DMCS **27** stores these data and passes them on to the CCS applications **30** in filtered format so that CCS operators can observe (e.g., as icons on a monitor display or screen at their respective stations) and communicate with only those vehicles for which they are responsible.

Another function of DMCS **27** is to provide interfaces to a customer's other management applications such as accounting **31**, human resources **32**, inventory control **33**, and computer aided dispatching **34** systems. Data are accessed and reports are generated by a database reporting application **36**. The interface between DMCS **27** and CCS **30** and database reporting **36** applications is conventional TCP/IP. These applications may run on the same or separate computers using, for example, Windows (trademark of Microsoft Corporation) 95, Windows 98 or Windows NT (or any advance of such software, or any software of other providers which enables the same or similar functions to be performed). The operator's other applications interface to DMCS **27** through standard or custom interface protocols.

The DMCS application is responsible for tying together the NDC server applications, CCS and database reporting applications, and the operator's existing applications (e.g., the customer's management information and back office systems) into an integrated system. The DMCS acts as the enterprise connection to NDC **10**. It establishes TCP/IP socket connections to the NDC real-time and data log servers **32** and **33** as required, and maintains access to data for all of the fleet operator's vehicles to be tracked by the PROTRAK system. Vehicle location and message data is provided by NDC **10**, and DMCS **27** sends real-time messages and commands to the vehicles and may request archived tracking information from the NDC for time periods when the DMCS was not logged-in to the NDC.

The CCS (or each of multiple CCSs) **30** is primarily a real-time vehicle location display and messaging tool to support dispatching functions. DMCS **27** routes commands and messages from CCS **30** to NDC **10**, and provides tracking data from the NDC to the CCS for only those vehicles that the CCS operator is controlling (i.e., dispatching, monitoring, scheduling, etc.). The DMCS supports multiple CCS applications operating simultaneously, controlling and viewing different groups of vehicles in an overall fleet.

DMCS **27** also supports database queries from multiple CCS **30** and database reporting **36** applications. Each CCS **30** requires real-time information from the database regarding vehicle drivers, dispatching, scheduling, and cargo. The database reporting application requires historical tracking data and information from other systems as necessary to produce reports pertaining to the customer's business.

III. *The Network Distribution Center*

The NDC **10** architecture will be briefly described with reference to the exemplary NDC software and hardware system in the simplified block diagram of **FIG. 3**, which emphasizes communication protocols used by the NDC software applications. As noted above, the NDC **10** controls information flow between vehicles (e.g., **17**) and their fleet subscriber command station (e.g., CCSs **14** and **15** at customer site **13**) logged into the system. The RF network is managed by the NDC by controlling network timing, and determining the nature of the data transmitted to the vehicles. All data received by Network Hubs (e.g., **11-1**, **11-2**) are collected by NDC **10** for processing, distribution to customers, and data archiving, and the NDC allows customers to log in via the Internet, TCP/IP network, or other suitable connection **40**. An interface to a PROTRAK Data Center (PDC, not shown) supports roaming between cities and overall tracker-fleet subscriber identification.

An NDC Server **42** in NDC **10** communicates with the CCSs **14**, **15**, etc., as well as with NDC command stations (not shown) within the NDC, and Network Hubs **11-1**, ... **11-i**, through respective sockets and related net connections including a router and a modem, and also with a Network Timing and Control Computer (NTCC) **47** through a serial interface **49**. The NDC Server has only one interface -- a messaging protocol which will be described presently. NDC administrators use NDC Command Stations (which are similar to CCSs, but within the NDC) for display, control, analysis and maintenance of the NDC Server. NDC Server **42** is assigned a registered domain name and an IP address on the Internet to allow fleet subscribers and/or NDC command stations to connect to the Server through the Internet rather than using a system modem bank. By way of illustrative example and not limitation, three different connectivity options are shown in the NDC hardware block diagram of **FIG. 4**.

As noted above, DMCS **27** interfaces with the customer's critical business applications **31**, etc. including accounting, inventory control, human resources, etc., as well as with CCSs **14**, **15**, etc., and NDC **10**. NDC Server **42** controls all data sent to and received from vehicles and command stations, and also controls the configuration of the TDMA vehicle transmission UHF radio network by assigning vehicles to specific time slots for transmission and controlling which vehicles are allowed to operate. Data from vehicles **17** received from the Network Hubs **11-1**, etc. are combined and decoded, and then provided to fleet subscriber CCSs for use in maintaining control of the radio network. Data from CCSs are sent to vehicles as required, and are also used to schedule the appropriate level of update service, with the data being transmitted to the vehicles over a serial interface to each NTCC computer at the NDC.

The network control function is the most critical task of NDC server **42**, performed in real-time based on prompts from NTCC **47**. System requirements for substantial TCP/IP support, Internet, and maintenance and support workstations require use of a platform such as Windows NT, which allows the system to make use of third party hardware and software. Running this task periodically, once per second, is accomplished, first, by providing the network control function with sufficient priority to complete its required tasks within the one second period allowed; and, second, by polling the NTCC serial interface at a high rate to detect the reception of timing data indicating that the server should start the network control task.

NTCC **47** controls the real-time portion of the PROTRAK system, including the SCC **48** transmit timing through a feedback loop (to be discussed presently in connection with **FIG. 6**) using an FM receiver in a roof module. One NTCC roof module **55 (FIG. 4)** exists for each FM radio station **12** supported by NDC **10**. The NTCC **47** is also responsible for introducing frame ID data and differential correction data into the transmitted data stream. Data packets generated by server **42** are sent to NTCC **47** for inclusion in the output data stream. By having NTCC **47** communicate with SCC **48** via a dedicated modem **51** and telephone line or other line that is not part of the modem rack used for the Network Hubs and the CCSs, the time-critical interface for timing and corrections is separated from any unpredictable activities of the modem rack or ethernet interface.

NTCC **47** monitors the FM station **12** broadcast for timing and content. If the broadcast was received skewed with respect to the GPS integer second, then timing correction commands are sent to SCC **48**. The NTCC also compares the received broadcast data to the data block that was transmitted, to ensure the data was correct. FM received signal strength is also monitored to detect changes in FM broadcast power. Broadcast and SCC status are provided to the server **42** so that it can determine what action to take in the event of a failure.

A number of Windows NT workstations constitute the NDC command stations (e.g., **43**, **45**, **FIG. 4**), which are connected to NDC server **42** via 100 Mbps ethernet or other suitable path such as a local area network (LAN). These stations provide the capability to perform several functions, including displays of different areas of the navigation grid, network and modem monitoring, data log analysis, user account maintenance, and software development.

The NDC server **42** may communicate with the Network Hubs and CCSs via a TCP/IP, or by way of other connectivity options such as those shown in **FIG. 4**. A US Robotics Total Control modem rack, for example, may be used to provide TCP/IP connectivity to the server. Each rack is implemented to support 48 modems via 2 conventional T1 lines, and several racks can be stacked to support a larger number of modems. The server may, for example, have two independent ethernet networks, and the modem rack is on a separate network from the NDC command stations so that NDC command station network activity will not introduce any latency in the modem data. User connections do not have any real-time requirements, but data transferred between the server **42** and the Network Hubs (e.g., **41-1**, ..., **41-I**) must occur regularly at one second intervals.

A time-line of the network data flow is shown in **FIG. 5**. Data transmitted by the vehicles on frame 1 is available to the NDC server **42** **(FIG.3)** at the beginning of frame 3. On the detection of the start of frame status from the NTCC **47**, that data and user data received over frame 2 are processed. Data packets to be transmitted to vehicles are also sent to the NTCC. In the last part of frame 3, the NTCC formulates a data block which is sent to SCC **48** during frame 4. The SCC finally broadcasts the data block on frame 5.

The network control function comprises radio network management, vehicle and user input data processing, and base output data processing. Based on the time-line shown in **FIG. 5**, these tasks combined must begin promptly with the detection of the start of a frame (based on serial data received from the NTCC) and complete within roughly one-half second.

NDC **10** controls the assignment of network transmit slots to the vehicles and manages the exit and entry of vehicles into and out of the network. It also coordinates the broadcast of network control, vehicle control, message, and system identification packets to the vehicles. Network management in the system must run at one second intervals and complete within about one-half second. The system maintains data structures for all active vehicles and fleet subscriber command stations, and has a capability to cross-reference vehicles to fleets and to assigned broadcast slots. Data required includes:

- vehicle position for transmission to fleet subscribers, and for data logging; position data may also be used for UHF frequency reuse or FM channel assignment;
- the transmit slot(s) occupied by the vehicle;
- the vehicle's tracker ID, local control ID, owner, and group;
- message and control acknowledges, retries, and time-outs;
- roaming information; and
- service type, including nominal update rates, real-time service or track history requirements.

The NDC server requires efficient and logical algorithms to assign vehicles to the transmit slots. The various vehicle update rates, as well as reserving space for network entry and polled response vehicle transmissions must be taken into account. Periodic transmit slot defragmentation may also be required. In practice as the system runs, vehicles enter and exit the network continuously, and slots must be reassigned for use by subsequent vehicles.

Data transmitted by the vehicles such as **17** (**FIG. 3**) is received at NDC **10** from the Network Hubs (e.g., **11-1**, **11-2**) via a modem bank in which the modems connected to the Hubs have the highest priority with respect to data transfer between Hubs and NDC server **42**. NDC **10** processes the network data in one second intervals, and therefore, the vehicle data from each Hub must be available for processing by the NDC server during the one second interval after that frame's data was received by the Hubs.

The server **42** performs space diversity processing, error control decoding and error correction, and decryption on the received vehicle data packets. Data received in time slots assigned to vehicles may be available from multiple Hubs. Since only one vehicle **17** has been transmitting, the received data at each Hub should be the same. Multi-path signal loss and other factors can cause errors in the received data, but those errors are likely to be different for each Hub. NDC **10** can then blend the data from all Hubs to produce a most likely solution.

After diversity processing is completed, error detection/correction processing is performed. The vehicle data packets are coded to allow numerous bit errors to be corrected through interleaving of the data bits and forward error correction coding. The data packets are then decrypted.

The received data packets are parsed and the information is used to update the NDC network control data structures. State and status data are logged for off-line analysis. Vehicle state data and fleet subscriber data are provided to the logged in fleet subscribers as it is received. The logged state data may be used to provide fleet subscribers with vehicle tracking history rather than real-time tracking data.

In the case of data received from customers (fleet subscribers, owners, or lessees, for example) **13**, the data is processed as follows. Commands and data requests from logged-in fleet subscribers will be combined with vehicle information to generate vehicle control, network control, and messaging packets to be transmitted to the respective vehicles **17**. Events such as customers logging in or out may control whether or not vehicles are allowed to enter the network or are forced to exit. For customers desiring real-time tracking data only, the respective vehicles are not allowed in the network unless they are logged-in. Other customers may require track history information and, in those cases, vehicles are tracked any time they are on. Fleet subscribers with low update rate needs, e.g., a few times per day, may request vehicle positions manually through their command stations. Their vehicles are polled by the NDC **10** based on a fleet CCS request, but cannot enter the periodic part of the network. Some subscribers, such as those that provide emergency response services, are able to request changes in vehicle position update rates from their command stations.

When roaming is implemented, fleets are allowed to track vehicles on any grid regardless of their NDC connection. Since fleet subscribers may not know where their vehicles are located at any given time, the system of the invention aggregates data for all vehicles through a wide area network connecting each NDC to enable the CCS to display all vehicles, regardless of the market (metropolitan or other area) in which they are located.

Transmit data is generally processed as follows. On each one second frame, the NDC **10** generates base message data packets to be broadcast to the vehicles **17**. The NDC periodically sends Grid, FM, and UHF identification packets. Text message and user data packets are sent as requested by the CCSs such as **14**, **15**. Network configuration and vehicle control packets are generated from the network management function. All packets are sent from the NDC server **42** over a high speed serial interface **49** to the NTCC **47**. The NTCC blends NDC packets with real-time packets and differential corrections and sends a complete base message block to SCC **48**. SCC **48** then transmits the base message at the start of the next second. At least a two second delay exists between the time NDC server **42** sends a packet to NTCC **47** and the time it is transmitted by the **48**.

Since the NDC server **42** essentially places data packets into an output queue on the NTCC computer, NTCC **47** must indicate to the server the space available in the buffer. Depending on vehicle and user actions, some frames may generate many network/vehicle control or message packets and others may not generate any. NTCC-supplied DGPS correction packets also use bandwidth periodically. This produces a variable delay between the time the packets are generated by server **42** and the time they are actually received by the vehicles **17**. The NTCC **47** must provide server **42** information regarding size of the queue, so that the server does not, on average, overflow the output bandwidth of the FM broadcast from station or tower **12**.

A data packet priority system may be implemented so that some packets are sent sooner than lower priority packets that were queued first. For example, text message packets may have a lower priority than vehicle control packets. As packets are delayed in the queue, their priority is increased so that they are certain to be transmitted with a maximum of a few frames of delay.

Data to be logged by the NDC server includes information for billing, vehicle track history for some subscribers, and detailed radio packet log data for test, analysis, and maintenance purposes.

A PROTRAK Data Center ties the individual city NDCs **10** together into an integrated system to support national roaming, and serves as a central point for a database of vehicle-mounted tracker IDs and customer IDs with a cross-reference. Subscriber profiles indicate what services and update rates each vehicle tracker requires. Data for roaming vehicles is transferred from the NDC **10** at which it is received to the NDC at which the subscriber is located through the PDC.

The NDC database from which the server dispenses information to CCSs, NDC command stations, etc. upon request is a high capacity database program such as Microsoft structured query language (SQL) server or Oracle 8 enterprise. Since these applications and their associated users are only allowed to access a subset of the data stored in the database, the NDC server is responsible to authenticate users and prevent the unauthorized access of data. For example, a CCS used by Customer A is not normally allowed to access tracking data logged for Customer B unless authorized by Customer B.

IV. *The PROTRAK Network*

The PROTRAK system time division multiple access (TDMA) RF network control, messaging and user data are transmitted to tracking computers (trackers) installed in the respective fleet vehicles to be tracked, over an FM broadcast subcarrier. Tracker transmissions include tracker position, network status, and user data. Vehicle data are transmitted to Network Hub sites using the conventional UHF business band. Network frame timing and tracker transmit slot timing are ultimately controlled by GPS-derived precise timing. The NDC manages the network and tracker slot allocation. Data sent by the NDC are transmitted via modem to the FM broadcast station, and data received from the trackers are provided via modem from the hub sites.

For the base broadcast, the TDMA network timing is based on precise time from GPS. The network is partitioned into one second long frames, 3600 frames are present in a frame cycle, and 168 frame cycles exist in one week. Since the frame cycle period is an even divisor of 604800 (the number of seconds in a week), the frame number can be directly determined from GPS time. To support network users (fleet subscribers) without GPS receivers, the frame number is transmitted in each base message.

A bit-sync in the base broadcast controls the timing of the entire network, indicative of the start of each network frame to the trackers and Network Hubs, all of which have FM receivers. The Hubs and trackers with position information account for their distances to the FM transmit antenna to derive the frame start time.

The manner of handling closed loop timing will be described with reference to **FIG. 6**, which illustrates the base message feedback loop for bit-sync timing. The base message contains a bit synchronization pattern which is used to control tracker broadcast timing. The synchronization is controlled to indicate each GPS integer second by a closed loop feedback system. NTCC **47** at the NDC uses an FM receiver **58** and GPS receiver **54** to measure the delay between the integer second and the arrival of the bit-sync in the FM subcarrier transmission received at the FM receiver. After accounting for the predetermined distance between the FM broadcast antenna **53** and the NDC, the difference between the GPS indicated integer second and that indicated by the bit-sync is sent to SCC **38** at the FM station via modem(s) **47**. SCC **38** then slews the broadcast start time to correct for the measured error.

The SCC receives transmit data and timing control information from the NTCC computer **47**, and clocks the data out to the subcarrier modulator **68**. For example, an external USRobotics 28.8Kbps modem is connected to SCC **48** via a Motorola 68332 peripheral serial communications interface (SCI). SCC **48** answers calls from NTCC **47**, data to be transmitted on the next frame is provided by the NTCC, and the SCC buffers that data for transmission. NTCC **47** also provides SCC **48** with timing control commands, which the SCC uses to adjust the start time and period of its transmit frame clock to maintain coherency with the GPS integer second. The SCC sends mode and status information to the NTCC.

SCC **48** must accurately control the timing of the start of the output data stream so that the bit-sync pattern leaves the transmit antenna at a precise time with respect to the GPS integer second. It is desirable that the start of the data transmission be repeatable to less than one microsecond (μsec) and be controllable to about 0.4 μsec. The SCC uses programmable timers within the time processing unit (TPU) of the Motorola 68332 microprocessor to trigger the transmission of data to the subcarrier modulator. NTCC **47** uses data from FM receiver **58** and GPS receiver **54** to evaluate the offset and period of the base transmission. Synchronization is achieved by changing the timer period based on commands from the NTCC. When the system is first turned on, a period of about 20-30 seconds is required to achieve synchronization. Thereafter, minor corrections to the SCC clocking are provided periodically. The data clock is accurate to less than about 2 parts per million (ppm) relative to the receive data clocks on the remote trackers. A detailed description of the timing control algorithms employed by NTCC and the trackers installed on the vehicles is presented in Section V below.

In practice, SCC **38** is mounted together with subcarrier modulator **68**, modem, and DC power supply for the SCC in a rack. Subcarrier modulator **68** may be an SCA-300B subcarrier modulation generator available from Circuit Research Labs, Inc. of Tempe, Arizona, which receives binary data from SCC **48** at a ±12V data input port **61**. The binary data is filtered and modulated on a digitally generated subcarrier. Subcarrier modulator **68** also has two discrete switch closure inputs **59**, **60** which are used by SCC **48** to turn the subcarrier on and off.

The NTCC roof module **55** includes GPS receiver **54**, PROTRAK CPU **56**, and FM receiver **58**. CPU **56** compares the time at which the FM bit synchronization is received by receiver **58** to the integer second pulse-per-second (PPS) from the signal received by GPS receiver **54**. Time difference is measured by recording at a timing control register of the TPU in the Motorola 68332 microprocessor on receipt of the PPS and on receipt of the bit-sync. The TPU timer resolution is on the order of 0.2 μsec. The measured time difference provided to NTCC **47** is used to compute timer corrections for SCC **48** to apply to its transmit timer.

The NTCC acts as the real-time interface between the NDC server and the network. For timing control, NTCC **47** maintains the network frame count based on GPS time and computes and provides updates to the SCC transmit timer to keep the base transmission aligned with GPS time. Three timing controls are available, as follows: (1) In frame lag/advance control, for PPS-bit-sync offsets greater than 0.5 seconds the NTCC can delay or advance the frame number contained in the output data so that the transmitted frame number matches the actual frame as defined by GPS, which allows the time to be adjusted in one second steps. (2) In SCC transmit timer lag/advance control, for offsets 0.5 seconds or less the transmit timer can be loaded with a longer or shorter value to introduce a one-time shift in the output time with respect to the GPS integer second. (3) In SCC transmit timer period adjustment control, the interval between bit-sync epochs and the PPS integer second can be measured, and scale factor (frequency) errors in the transmit timer can be corrected by adjusting the nominal timer value up or down.

A period of 20-30 seconds of coarse alignment may be necessary or desirable using controls (1) and (2), above. Once the SCC is synchronized, controls (2) and (3) are used to make fine corrections to the synchronization to account for small timer errors attributable to temperature and residual synchronization errors.

"Base messages" are data sent from the NDC to the trackers over the broadcast network on the FM subcarrier. The base message data contains network control information, repeating interval slot allocation definitions, DGPS correction data, messaging/paging data, and user specific data. The format of the base data broadcast to trackers will be described presently herein.

For information flow, message data which controls network activity (network and tracker control packets) is created by the NDC server **42 (FIG. 4)** in response to data received from trackers and from CCSs (e.g., **44**) (or NDCs, e.g., **43**). Paging and user data packets are created from commands by the users. These packets are sent to NTCC **47** for assembly into a base message. The NTCC adds a network frame number and DGPS correction data, as required, and then applies encryption, error control coding, and bit interleaving. The resulting message is sent to SCC **48**, which inserts the bit-sync pattern and transmits the message data at the beginning of the next frame. The processing steps are summarized as follows:

1. NDC **10** computes base message data packets and sends them to NTCC **47**.
2. On each one second interval, NTCC **47**:
    a) Assembles available data packets from NDC **10**, frame number, and DGPS corrections, if necessary, into a single message block. Unused bytes are filled with a pad.
    b) Performs encryption on the message block.
    c) Performs error control coding on the message block. A Golay (23,12) code is used in the presently preferred embodiment, but a different code may be used.
    d) Performs bit inter-leaving. Data is transmitted by sending long segments of all bit 1's followed by bit 2's etc., which provides significant burst error correction capability.
    e) Sends the message block to SCC **48** for transmission.
3. SCC **48** inserts a bit synchronization pattern in front of the message block, Miller encodes the data, and transmits it to the sucarrier modulator **68 (FIG. 6)** at the start of the frame after the message block is received from NTCC **47**.

The format of the message block is as follows. The maximum bit rate for the SCA-300B subcarrier modulation generator used as **68** is 4800 bps. It is desirable to use the maximum available bit rate consistent with modulation index requirements (for receiver sensitivity) and data block size. A Golay (23,12) code is used with bit interleaving; data is sent in 40x23 = 920 bit blocks. Five blocks are transmitted for a total of 4600 bits. SCC **48** Miller encodes the data and adds the bit sync. The Miller code doubles the number of bits so the SCC will transmit data at a bit rate of approximately 9328.36 bps. 4600 bits require 986.24 milliseconds. Since an 8 bit preamble and 24 bit long bit sync require 6.8608 msec, SCC **48** has a 6.8992 millisecond gap time to restart the transmit clock with updated synchronizations to send the next message.

FIG. 7 is a diagram of the base (NDC) message broadcast format. At the start **70** of each integer second the bit-sync pattern **71** is transmitted, followed by the base message data **72**, and finally by a very brief interval **73** of dead time up to the start of the next integer second. Bit interleaving is applied to the base message to reduce susceptibility to burst errors. Interleaving is applied on a block by block basis. The Golay code corrects 3 errors in 23, so 40 bit deep interleaving allows a burst of 120 bits or 25.728 milliseconds to be corrected. This is long enough to correct desensitization that occurs in the shared transmit/receive antenna when a tracker transmits in its 20 millisecond TDMA slot.

For bit synchronization, the trackers and Net Hubs use the bit-sync in the FM broadcast to synchronize their clocks for transmission and reception of tracker data. Trackers with valid position data can use the known range to the FM broadcast site to offset their transmissions to account for the delay in reception of the bit-sync.

For tracker identification, all trackers are assigned a 30 bit tracker ID at the factory, unique throughout the PROTRAK system. While this could be the only ID used to identify a tracker, a shorter ID is assigned to trackers when they receive their main repeating interval slot assignment, which allows the NDC Server to identify trackers in its RF network grid with fewer data bits. The shorter IDs consist of a Network ID and an Interface ID. Since two network sizes are used, the most significant bit of the 16 bit ID is used to indicate the network size. **Table 1** below shows the Network/Interface ID format for the two lot sizes used.

Table 1. Network/Interface ID Format

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	Network ID							Interface ID							
1	Network ID											Interface ID			

To minimize disruption of the text, other tables are, for the most part, set forth in Appendix B.

Trackers may be assigned an ID within one of the 128 Networks with 256 Interface IDs or one of the 2048 Networks with 16 Interface IDs. Network IDs are used by the NDC Server to reduce the number of bits required to identify a subset of a customer's tracker modules. For example, if a fleet operator sends a message to ten of its trackers (vehicles) that are all contained in the same 16 tracker network, the NDC server may individually address these trackers using 52 bits, with 12 bits indicating the Network ID an only 4 bits being required to identify each tracker Interface ID.

Since the DMCS manages customer groups, the NDC server may coordinate with the DMCS to learn about customer groups. Or, the NDC server may use logged data to determine what trackers have been grouped together. As a result, the NDC server places trackers of the same group and/or customer ID into the same network. While trackers from different customers and/or groups may be placed in the same network, tracker groups that are placed together in the same network may be identified with a relatively small number of bits.

The Network/Interface ID assignment scheme is used in data packet formats. The base broadcast data contains a variable number of short data packets concatenated together, which are of fixed or variable length depending on type. The packets include DGPS correction data, network description information, user commands and messaging, and tracker control commands.

A. *Data Packets and Formats*

Data packet decoding is performed after error detection/correction and decryption. Each base message (i.e., from NDC **10**) begins with a frame ID. Data packets follow until the available space in the data block is filled or no packets remain to be sent. The unused space in the message is filled with all zeros that encode to an alternating one-zero pattern in Miller code. Each packet starts with a packet ID byte followed by the data in the packet and a checksum/parity word. Synchronization of the packet decoder on the data is maintained by verifying the first byte after the frame ID is a packet ID, and then looking ahead the number of bytes in the first packet to verify that checksum is correct and the subsequent byte is also a valid packet ID. This continues until all of the data packets are decoded. A Base Packet Summary is set forth in **Table 2** (Appendix B).

Text message packets are generated in response to messages/paging commands from user command stations (i.e., from the CCSs). By way of example for the present exemplary embodiment, the maximum message length is assumed to be 80 characters. In addition, an optional 28 character response set may be appended as discussed below with reference to pre-defined message response sets.

Text messages may be addressed to the trackers (i.e., to tracking computers installed in the vehicles **17**) in the following ways:

- Tracker ID
- Network/Interface ID
- Customer ID
- Interface ID
- Interface ID range within a Network

In the present exemplary embodiment, the tracker ID number is 30 bits, the

Network/Interface ID is 16 bits, and the customer ID is 24 bits. A variable number of address bits are reserved depending on address mode and number of trackers being addressed.

Acknowledgment of text messages is performed by the tracker requesting an auxiliary repeating interval time slot. The auxiliary slot repeats at 12 second intervals and includes enough slots to send the acknowledgment, e.g., one plus additional slots to allow for retries. **Table 3**: "Text Message Packet - Single Tracker or Entire Fleet"; **Table 4**: "Pre-Defined Message Response Sets"; **Table 5**: "Test Message Packet - Tracker Group"; **Table 6**: "Tracker Group Message Interface ID List Packet"; and **Table 7**: "Tracker ID List Block", are set forth in Appendix B.

A "Pre-Defined Message Definition" packet (**Table 8**, Appendix B) provides trackers (sometimes referred to herein as tracker modules) with a text message that should be associated with a specified pre-defined message ID. Although individual trackers request this definition, the message is broadcast to all trackers associated with a particular customer (fleet operator, subscriber or user, as those terms are used interchangeably herein). Trackers receiving this message store the pre-defined message definition if the specified customer ID matches their known customer ID. This stored association is then used to display the appropriate message upon receipt of a "Pre-Defined Message Packet." The latter packet allows a shorter message format for "canned" user messages that are frequently transmitted by an individual customer. Since the trackers know the text of these messages a priori, only a message ID and a 16-bit cyclic redundancy check (CRC) need be sent by the NDC. The ID identifies the message and the CRC allows the tracker to determine whether the text matches the CRC of the known pre-defined message.

Pre-defined message CRCs are computed using the entire pre-defined message. Hence, a tracker may determine if the ID has been reassigned to a new message. If that is true, or if a specified pre-defined message is unknown, the tracker may request the entire pre-defined message using a "Pre-Defined Message Request Packet." Upon receipt of such a request packet, the NDC server provides the requesting tracker with the pre-defined message in a "Pre-Defined Message Definition Packet." Tracker addressing is similar to that for text messages. The "Pre-Defined ID Message Packet" structure for a single tracker or entire fleet is shown in **Table 9**, and for a tracker group, in **Table 10**, of

Appendix B.

DGPS correction data packets (**Table 11**) are generated by the NTCC and inserted into the base message block at roughly 10 second intervals. The range/range-rate corrections are computed by the GPS receiver (e.g., **54**, **FIG. 6**) in the NTCC roof module **55**. These may be in RTCM or other desired format. The scaling on the corrections is the same as that in RTCM-104. The NTCC transmits correction data in a format with complete "Type 1" and "Type 2" style corrections. Other RTCM message types may alternatively be supported if desired. RTCM message types 1 and 2 have the same format, with only the frame IDs being different. The packet is of variable length depending upon the number of corrections therein. The number of bytes is $5+5N_{sv}$.

A User Data message packet supports generic, user specific data that is sent to the trackers from CCSs. The format of the message is similar to the text message packet, having 80 data bytes available for any customer purpose. Customer specific software must be programmed into the tracker, MDT, and CCS for the customer to make use of this message. User Data packet addressing and acknowledgments are identical to those of text packets. The "User Data Message Packet" structure for a single tracker or entire fleet is shown in **Table 12**, and for a tracker group is shown in **Table 13**.

A "Grid Identification packet" (**Table 14**) provides the trackers with the center of local and adjacent PROTRAK navigation grids (e.g., see **FIG. 11**, to be discussed presently herein). In an exemplary embodiment, the navigation grid is a square area about 262 Km on a side, roughly centered on each PROTRAK market area. Each navigation grid (market) has a unique 15 bit ID number. The "Grid ID packet" is transmitted at roughly 20 second intervals, and alternates between the local grid and adjacent grids. Adjacent grid information is provided to allow roaming trackers to quickly locate the PROTRAK system in new markets as they move through markets. Preferably, the trackers store grid information in non-volatile memory.

The center of the navigation grid is provided in 24 bit scaled integers with an LSB (least significant bit) of about 2.4m in latitude, which should be adequate for most tracker navigation applications. The nominal navigation grid is assumed to be square and made up of 1024 adjoining 64 square Km squares. If necessary, additional data may be added to this message to define rectangular or oddly shaped navigation grids.

An "FM Identification packet" (**Table 15**) provides the trackers with the FM base broadcast frequencies and transmitter locations for the local and adjacent PROTRAK navigation grids. The transmitter location is used for broadcast delay time computations. The frequency of the subcarrier is also provided. Preferably, the trackers also store transmitter information in non-volatile memory. The transmitter location is provided in 24 bit scaled integers with an LSB of about 2.4m in latitude, which is quite adequate for broadcast delay computations. Each navigation grid may have multiple FM transmitters. The packet supports up to 4 transmitters by a transmitter ID number. If required, additional data in this message or another message may be used to define grid areas served by each transmitter for capacity or coverage reasons.

A "UHF Identification packet" (**Table 16**) provides the trackers with the UHF frequency on which they are to transmit their state data. Frequencies are provided for the local and adjacent PROTRAK navigation grids. Here again, the trackers should store the UHF frequency information in non-volatile memory. Each navigation grid may have multiple tracker transmit frequencies, and the "UHF Identification packet" supports up to 4 frequencies by a frequency ID number. If necessary, additional data in this message or another message may be used to define grid areas in which to use each UHF frequency for capacity or coverage reasons.

NDC **10** transmits a packet containing the current GPS time at 10-20 second intervals to aid the initialization of the vehicle-mounted GPS receivers associated with the trackers. The "GPS time packet" (**Table 17**) is computed and inserted into the base message block by the NTCC. The time zone offset and UTC leap seconds are added to the current GPS time to determine local time.

A "set main repeating interval slot definition packet" (**Table 18**) assigns a continuous repeating interval and a Network/Interface ID to a tracker. Trackers receiving this packet send a tracking update to NDC server **42** when (Frame ID) mod (Interval Length) is equal to the repeating interval index indicated in the packet. If a tracker already has an assigned main repeating interval, it will be replaced by the interval in this packet. Trackers can determine if this packet is addressed to them by checking whether the tracker ID field is equal to the recipient's tracker ID. If it is, the tracker will use the assigned repeating interval and Network/interface ID. Otherwise, the tracker will ensure that none of its repeating intervals match the described interval. If the described interval matches the tracker's current main interval, the tracker will cease using this interval (and Network/Interface ID) and attempt a network entry. Or, if the described interval matches one the tracker's current auxiliary intervals, the tracker will remove this interval from its list.

The Network/Interface ID assigned with the main repeating interval is valid while the main repeating interval is valid. As a result, trackers will respond to messages with their Tracker ID or their temporary Network/Interface ID while they are in the RF network. Once a tracker exits from the RF network (or had its main repeating interval purged), the associated Network/Interface ID is no longer valid for that tracker. Trackers receiving a main repeating interval assignment may use the assigned interval until they request to exit the network, acknowledge a purge repeating interval packet, or exceed the self- purge update count.

An "add auxiliary repeating interval slot definition packet" assigns a repeating interval to a tracker for a single interval (**Table 19**). Trackers that receive this packet send a tracking update to NDC server **42** when (Frame ID) mod (Interval Length) is equal to the repeating interval index indicated in this packet. As a result of receiving this packet, trackers will send a single update. Trackers may determine if this packet is addressed to them by using the tracker ID or the Network/Interface ID field. If the tracker ID field identifies the recipient, the tracker will use the assigned repeating interval to report its tracking information to the NDC server. Otherwise, the tracker will ensure that it does not report its tracking information using the described interval. It should be noted that although a tracker may have multiple auxiliary repeating intervals, each tracker only has one main repeating interval. **Table 20** (Appendix B) shows the "Add Auxiliary Repeating Interval Slot Definition packet" structure for a single interval by network/interface ID.

The "add auxiliary repeating interval slot definition" packet for a limited number of intervals assigns a repeating interval to a tracker for a specified number of intervals. Trackers that receive this packet send a tracking update to the NDC server when (Frame ID) mod (Interval Length) is equal to the repeating interval index indicated in this message, and these updates are sent by the trackers an interval count number of times. Here again, trackers may determine if this packet is addressed to them by using the tracker

ID or the Network/Interface ID field, and report their respective tracking information to the NDC server, or not, in the same manner as specified above. **Tables 21** and **22** show the structure of the "Add Auxiliary Repeating Interval Slot Definition" packet structure for a limited number of intervals by tracker ID and by network/interface ID, respectively.

An "Available Network Entry Slots" Packet **(Table 23)** contains a slot count that indicates the number of slots within a one-second frame, and a bit mask that indicates the slots that are currently available for network entry. Bit 0 of byte 2 indicates if slot 0 is available, bit 1 of byte 2 indicates if slot 1 is available, bit 0 of byte 3 indicates if slot 8 is available, etc. Before a tracker is allowed to send a "Net Entry Request" packet, it must receive an "Available Network Entry Slots" packet and successfully receive every base packet message prior to sending its "Net Entry Request." The packet is only valid until the next one is received, so the tracker will not send a network entry request in a slot that is no longer available. The NDC server **42** broadcasts this packet as the available network entry slots change, and also sends it at least once every 10 seconds.

A "Repeating Interval Slot Configuration Information" Packet (**Table 24**), sent every 30 seconds by the NDC Server, indicates the frame cycle length, the self-purge interval count, and the tracker ID request mode. Each of these values is needed for a tracker to determine the transmit timing and/or format of its periodic tracking update packets. The frame cycle length indicates the number of one-second frames that are contained in a frame cycle. Since this number will always be a divisor of the number of seconds in a GPS week, a frame ID may be determined using GPS time. The Frame ID is calculated using the GPS Second as follows:

$$\text{Frame ID} = (\text{GPS Second}) \bmod (\text{frame cycle length})$$

The self-purge update count indicates the number of periodic updates that a tracker may provide in an assigned repeating interval slot without requesting to re-enter the network. Trackers with an assigned repeating interval slot must request to have their repeating interval slot re-assigned to them by indicating "Re-assign Main Repeating Interval Slot Request" or "Re-assign Auxiliary Repeating Interval Slot Request" for their network status code. Trackers that fail to have their repeating interval slot re-assigned before reaching the self-purge update count will purge their assigned repeating interval slot.

The "Tracker ID Request Mode" indicates if trackers are required to supply their tracker ID number within tracker data packets. This request mode may indicate that trackers are not required to supply their tracker ID number, trackers are required to supply their tracker ID for their next update only, or trackers are required to supply their tracker ID for all updates.

Tracker modules collect built-in test (BIT) information, which is then supplied to the NDC Server at the rate (in seconds) specified in the "Repeating Interval Slot Config Info" packet. If the rate is zero, the tracker is not required to supply the BIT packet. If the rate is greater than zero, the tracker will provide its BIT packet at the rate indicated. To supply a BIT packet update, trackers request an auxiliary slot when (tracker ID) mod (BIT packet rate) equals the current frame ID. As a result, tracker requests for auxiliary slots are distributed evenly. If a request for auxiliary slot would interfere with a tracker's scheduled update, the tracker will defer the request to a later time.

The NDC server uses a "Network Entry Response" packet **(Table 25)** to respond to a tracker's network entry request when the tracker's service type does not otherwise permit network entry. The assigned tracker state code contained in this packet enables a tracker to determine its type and requirements to be assigned a repeating interval slot. Manual tracking trackers are to wait for a "Repeating Interval Slot Definition (Single Interval)" packet, and login-only tracking and unknown trackers must wait for a "Network Entry Request Permission" message. The NDC server **42** may send a "Network Entry Request Permission" message as a result of a CCS (e.g., **14, FIG. 3)** connecting to the DMCS **27** or because an individual tracker's service type has changed.

The NDC erver sends a "Network Entry Request Permission" packet **(Table 26)** to a subscriber's entire fleet of LOT trackers, to a subscriber group of trackers, or to an individual tracker, for one or more trackers to request network entry. If a subscriber is not connected to view its group of LOT trackers, the trackers are not allowed to enter the RF network but are notified instead to wait for network entry request permission. When a subscriber connects to the DMCS using CCS software, the DMCS checks whether a subscriber with this ID is already connected, and, if not, sends a message to the NDC Server identifying all trackers in the CCS user's group. The NDC Server responds to this message by sending a "Network Entry Request Permission" packet to allow the trackers in the CCS user's group to request network entry. Depending on the subscriber group size or subscriber fleet size, this packet may be sent by the server to the entire fleet or to only a group of trackers, with a view to reduce the required RF bandwidth as much as possible. The "Network Entry Request Permission" packet may also be sent if a tracker's service type is modified, such as if a manual tracking tracker is changed to a continuous tracking tracker.

A "Purge Assigned Repeating Intervals" message **(Table 27)** is sent by the NDC server by Tracker ID, Customer ID, or Tracker ID List Packet, to indicate that a tracker or a group of trackers should purge some or all of its assigned repeating intervals. This would be done, for example, when the only subscriber in a group of LOT trackers disconnects from the DMCS, because information from those trackers is no longer reported when its viewing is ceased by the disconnected subscriber. The DMCS provides a list of trackers to be removed from the RF network to the NDC Server. The "Purge Assigned Repeating Intervals" message may also be sent to individual trackers, such as where a continuous tracking tracker has its service changed to manual tracking, in which case the tracker in question is informed of its new service and to wait for a repeating interval slot. Similarly, if an individual tracker's service type and update rate are both changed (e.g., from continuous with an update rate of 30 seconds to LOT with an update rate of 60 seconds) it will be sent this message if its subscriber is not connected to the NDC server. And where a tracker has been assigned an auxiliary interval for an emergency condition, to report data at a high update rate, for example, for a short period in addition to its main repeating interval, the message is sent by the NDC server to that tracker when the emergency ends, to purge its auxiliary repeating interval.

Trackers acknowledge receipt of the "Purge Assigned Repeating Intervals" message by setting the appropriate status bit in their next periodic update, or, if necessary, by requesting a one-time slot to provide an acknowledgment. A tracker whose main repeating interval slot is purged may use that slot a final time to provide the acknowledgment in a state and status tracker packet. When the NDC server receives a purge acknowledgment, it may reassign the repeating interval slot at that time, or wait until a self-purge update count has been reached to re-assign it.

When a Text or Pre-defined text message is sent to a tracker, a pre-defined or custom response set may be identified, indicating the text labels associated with the mobile data terminal softkeys when the message is displayed. When a softkey is pressed to respond to a message, the softkey number is returned to the NDC server in a "Message Response State and Status" or a "Message Response Reduced State and Status." A "Message Response Acknowledge" base message **(Table 28)** acknowledges the NDC server's successful receipt of a response packet. A message response is only discarded by the tracker module if it successfully received an acknowledgment within 2 minutes; otherwise, the response is re-sent.

A "Site Dispatch" Message **(Table 29)** aids in automating the fleet operator's ability to determine when a specific tracker has arrived/departed from a job site, by providing the tracker module a pair of latitude/longitude values that define the tracker's next job site, and a text description of the site location (destination address). Upon receipt, the tracker module acknowledges the message using a "Message Response State and Status" or "Message Response and User Data" packet.

Trackers send "Site Status" packets when they enter or leave one of their known sites. A "Site Purge" Message packet **(Table 30)** from the NDC requests a tracker to remove one of its known sites. After receiving this packet, the tracker will no longer provide a "Site Status" message for the site associated with the "Site ID" specified in the "Site Purge" Message.

A "User Data Acknowledge" packet **(Table 31)** serves to acknowledge the NDC's receipt of a reliable user data message from a vehicle's tracker. The tracker retains a copy of all reliable user data packets until it receives this acknowledgment message from the NDC server. If the acknowledgment is not received within 2 minutes, the tracker will resend the reliable user data packet.

An "NDC server Boot Sequence ID" may be used by the tracker to determine if the NDC server of a navigation grid (see the reference to and discussion of the "Grid Identification" packet above) has re-booted. When a tracker module discovers that this ID has changed, it purges all RF state information (including RI Slot assignments) received with a previous boot sequence ID. New RF state information received is then associated with the new "NDC server Boot Sequence ID." The "NDC Server Boot Sequence ID" allows trackers in low-power mode or trackers that have been out of FM subcarrier range to determine if their RI Slot and other information is still valid. Trackers that have been so for an extended period of time must ensure that the NDC Server boot count has not changed before they provide a tracking update. A "Grid Identification Packet2" **(Table 32)** provides the "NDC Server Boot Sequence ID."

A "Site Status Acknowledge" packet **(Table 33)** is used to acknowledge the NDC's receipt of a reliable "Site Status" message from a tracker. The tracker retains a copy of each reliable site status message packet until it receives this acknowledgment message from the NDC Server. If the acknowledgment is not received within 2 minutes, the tracker re-sends the reliable "Site Status" packet.

B. *Tracker Messages*

Tracker messages are transmitted from the trackers to the NDC over the TDMA UHF radio network. Tracker data consist of navigation state information, responses to network related commands from the NDC, paging/messaging responses, and user specific data. Each tracker has its own unique assigned repeating interval slot(s) to transmit its data. The data are received by the network hubs and transmitted to the NDC when each frame is complete. According to an aspect of the invention, since a tracker data packet may be received by more than one hub, the NDC is provided with a capability to perform diversity processing to aid in recovering corrupted data.

Although, according to the invention, trackers generally have an assigned continuous repeating interval time slot in the TDMA network, provision is made for trackers with low update rate requirements to operate in a polled mode, in which NDC **10** must request such low update-need tracker installed on a vehicle **17** to transmit during a single repeating interval time slot. A short time before the tracker's assigned transmit time, the tracker must assemble a packet of data for transmission. Based on the broadcast FM bit-sync received at FM receiver **58** of NTCC roof module **55** and estimated distance to the broadcast antenna **53 (FIG. 6)**, the applicable tracker must begin its transmission at its assigned transmit time within its assigned repeating interval slot with an accuracy of about one microsecond.

Over each frame, each Network Hub **11-1**, etc., attempts to receive data from trackers in every time slot. At the end of the frame, Hub-received packets are packed into a single message and sent via modem to the NDC **10**. The NDC server **42** performs error correction and diversity processing on the tracker packets from all of the hubs. Tracker state data is logged and/or transmitted to the applicable CCS and/or NDC Command Stations via the TCP/IP or other connectivity application. Summarizing, the processing steps are:

1. On the frame prior to its assigned repeating interval transmit slot, the tracker:
   a) Forms a data packet to be transmitted;
   b) Performs encryption on the message;
   c) Performs error control coding on the message (preferably using a (12,8) code, although a different code may be employed if desired);
   d) Performs bit interleaving (a complicated interleave pattern is required to reduce bit errors when the data is shifted by 1 bit from truth, to permit the hub baseband processing. The interleave scheme provides a depth of 11 bits, which improves burst error correction capability).
2. A high resolution timer synchronized to the GPS integer second using the FM bit-sync and tracker position is set to trigger the tracker transmission at the appropriate time with an accuracy of about one microsecond.
3. Each hub attempts to clock in data at the appropriate time for each slot.
4. At the end of a frame, the hubs send all tracker data received over the frame to the NDC.

Tracker message timing, and format of the tracker data block must be considered. The tracker broadcast TDMA network consists of 168 frame cycles in one week, with each frame cycle having 3600 one second long frames. Each frame is divided into several tracker transmit time slots. The number of slots depends on the tracker message length, the transmit bit rate, and the required gap between slots for transmitter power up/down and message propagation delay. The transmit rate is 7812.5 bps (15625 bps Miller encoded). A tracker message length is 144 bits, 8 Miller bits of preamble (10101010). The transmit data requires 18.944 milliseconds. A total slot time of 20 milliseconds is therefore allocated to allow for speed of light delays and transmitter power on/off time; accordingly, 50 tracker transmit slots are available on each frame. An example of one tracker transmit frame is shown in **FIG. 8**, in which vehicle (tracker) message packets **76** are sequentially transmitted in their (the trackers') respective assigned slots from the start **77** of an integer second, and followed by an interval of dead time **78** (if necessary) which is sufficient to occupy the balance of the frame up to the start **79** of the next integer second.

Because of hardware limitations and CPU load times required to setup transmit timers and clocks, a tracker cannot transmit in two adjacent time slots. The gap between tracker transmission slots must be large enough to account for propagation delay of the radio signal through the air and time required for the transmitter to come on and off power. The worst case propagation delay is 1.2 msec. This is the time it takes light to travel twice the length of the navigation grid diagonal. A gap time this long will prevent the transmission from a tracker that is 181 Km from the FM transmitter and is using only the FM bit-sync for transmit timing from overlapping with the transmission from a tracker that is near the FM transmitter and using GPS to aid transmit timing. Given tracker transmit power and antenna heights, a reasonable distance at which a hub can hear a tracker transmission will be about 30 Km. Therefore, the gap time must support about 211 Km or 0.7 msec. The radio on/off power time is required to be less than 0.1 msec. Hence, the total gap time between tracker transmissions must be at least 0.8 msec.

The normal tracker data packet requires 90 data bits (including 24 user data bits). The other tracker data packets require 90 or 96 data bits. These message packet size requirements directly drive error control coding requirements for the packets. The present exemplary tracker packet error coding design uses a (12,8) code for all tracker packets, which provides a total packet length of 144 bits with 96 data bits for all time slots.

The trackers use the one second interval bit-sync in the FM broadcast for their transmit timing. The transmission time is accurate to within one microsecond. In the present approach, the tracker estimates the integer second time from the received FM broadcast bit-sync event time. The timer value of a TPU (i.e., time processing unit of the 68332 microprocessor used in the trackers, CCSs, and Networks Hubs) for each integer second will then be known. From that, the TPU timer value for the start of the tracker's transmit time can be computed. The TPU is programmed to assert the transmit key to start the output data clock precisely at the start of the transmit slot time, and to de-assert the key to stop the data clock when the message is complete.

For data clocking at the Network Hub (e.g., **11-1**, which is to be described in greater detail in the subsequent description of **FIG. 31**, but for present purposes brief reference is now made to the latter), a digital signal processor (DSP microprocessor) **80** is used at the Hub to demodulate the message data received from the vehicle trackers by the Hub's UHF receiver **81** and provide it to the Hub CPU **82**. CPU **82** determines the TPU time (of the Motorola 68332 microprocessor **83**) for the integer second based on the FM broadcast bit sync received at FM receiver **85**. The two receivers **81, 85** and the DSP **80** are on an RF card **86** of the Hub. CPU **82** signals DSP **80** to begin sampling UHF data at the start of each transmit slot time. The DSP then collects data, recovers the bit clock, and samples the bits. It performs Miller decoding, de-interleaving, and (12,8) error detection for up to 13 different bit delays to support the unknown speed of light delay from the tracker to the hub. The bit delay with the lowest number of code words with errors is selected, and that data is clocked to CPU **82** for transmission by the Net Hub to NDC server **42 (FIG. 3)** at NDC **10** via a modem **87** or other connectivity option. DSP **80** must complete all of its processing in the 20 millisecond window available for each tracker transmission.

As described earlier herein, each one second frame is divided into fixed length tracker packet transmit slots. Since the number of slots within a frame is also fixed, the trackers in the system of the invention must share these transmit slots. Most trackers transmit their state, position, and/or user data information on a periodic basis. Accordingly, a periodic slot allocation scheme is selected for use by which to share individual slots within a frame across an interval of time.

In this periodic slot allocation scheme, individual slots are associated with repeating intervals. This allows trackers with a common periodic update rate to share a specific slot across an interval (equivalent to the common periodic update rate) of time that contains multiple frames and is a divisor of 3600. **FIG. 9** illustrates a repeating interval for several individual transmit slots for tracker message packets, showing the repeating interval relationship to slots, frames, and frame cycles. Frame cycle **90** consists of a multiplicity of frames (e.g., **90-1**, ..., **90-i**, ..., **90-n**) as mentioned above. Each frame contains a multiplicity of slots **91** which are allocated to tracker message transmissions according to the scheme. The interval index for the repeating interval **92** associated with slot 0 is different from the interval index for the repeating interval **93** for slot 1, and so forth for slots 2, ..., n-2, n-1, n. The interval index shown may be calculated using the following equation:

Repeating interval index = (frame ID) mod (interval length)

Trackers are assigned one main repeating interval and/or multiple auxiliary repeating intervals to transmit their tracking data. Tracking data is transmitted by the trackers during their main repeating interval until they are informed to cease transmitting by the NDC server, or until the tracker's state changes (e.g., switches to low-power mode). Main intervals are only assigned to trackers with continuous or LOT tracking service. Trackers transmit their tracking data during auxiliary intervals for a specified number of times unless their state changes or the NDC server informs them otherwise. One or more auxiliary repeating intervals may be assigned to trackers of all service types.

As indicated in **FIG. 9**, each repeating interval is defined by a slot, a repeating interval index, and an interval length. In addition, auxiliary repeating intervals have an interval count. Since a tracker may calculate the frame ID using the GPS second, the repeating interval index may also be calculated using the repeating interval length and the frame ID. Trackers will transmit their tracking information in their assigned slot during the frame when the (frame ID) mod (interval length) is equal to their assigned interval index. Auxiliary repeating interval updates are provided by trackers an interval count number of times. Trackers that are assigned an auxiliary repeating interval with an interval count of -1 will provide tracking updates indefinitely during their assigned repeating interval.

As noted above, very long update intervals -- e.g., longer than 3600 seconds -- may be handled by polling. Trackers having such long update needs do not have an assigned continuous repeating interval, but transmit only on command from the NDC server. Tracker update repeating interval rates are summarized in **Table 34** (Appendix B).

Since slots within a frame are dynamically associated with a repeating interval, so that trackers with a common tracking update rate may share a slot across an interval of time, the NDC server uses a set of repeating interval slot assignment algorithms to dynamically associate slots with repeating intervals, as follows.

Initialization:

Make all slots network entry slots.

Add a tracker to a desired repeating interval for a desired interval count:

1) Add tracker to best available repeating interval:

- Search for a slot associated with the desired repeating interval with the least amount of space available,
- If an available repeating interval is found, add the tracker to the repeating interval for the desired interval count and set interval

status equal to assigned,

- If tracker was not added to a repeating interval, go to step 2,
- Else, grant request.

2) Associate desired repeating interval with an available network entry slot.

- Search for an available network entry slot,
- If an available network entry slot is found, associate the slot with the desired repeating interval,
- Else, if repeating interval ≠ to frame cycle length, change desired repeating interval to next available repeating interval. Go to step 1.

3) Add tracker to the interval associated with a slot in step 2.

- Add tracker to the interval for the desired interval count,
- Grant request.

Find the tracker ID for a received packet (and decrement interval count if necessary):

1) Use the packet's slot number to determine if the slot is associated with a repeating interval.

2) If the slot is associated with a repeating interval, determine the tracker ID using the interval index, reset the missed update count, decrement the interval count if necessary, set the interval status to active, and free slot if necessary.

- Compute the interval index: (packet frame ID) mod (interval length)
- Use the interval index to determine the tracker ID.
- Set the missed update count to 0.
- If interval count is ≠ to -1, decrement the interval count.
- If interval count = 0, remove tracker from repeating interval. If no other trackers are associated with this slot's repeating interval, convert this slot to be a network entry slot.

3) Else, the slot is a network entry slot. The tracker ID should be in tracker packet.

Process empty slot:

1) Use the missed packet update slot number to determine the slot type.

2) If the slot is associated with a repeating interval, increase the tracker's missed update count.

3) If interval status = assigned or interval status = active, poll tracker.

4) If interval status = assigned, re-broadcast repeating interval slot assignment.

Remove tracker from repeating interval:

1) Search for slot associated with the tracker's repeating interval.

2) Remove tracker from repeating interval.

- Set interval status = empty.
- Send base packet to tracker to purge assigned repeating interval.

3) If no other trackers are associated with this slot's repeating interval, convert slot to be a network entry slot.

The NDC server **42** maintains information in memory regarding the relationship between trackers, slots, and repeating intervals, as a form of repeating interval slot assignment storage. **FIG. 10** is a diagram that illustrates the repeating interval slot entity relationship, with the diagram notations that:

box = entity	oval = attribute
double box = weak entity	underline = key
diamond = relationship	dashed underline = partial key
double diamond = weak relationship	dashed oval = derived attribute

(x, y) = (minimum, maximum)

Also, uncaptured constraints are as follows:

1 <= interval length <= frame cycle length
Interval length is a divisor of the frame cycle length
Interval index = (Frame ID) mod (interval length)
If the interval count = -1, trackers provide updates indefinitely.
Interval status = {empty, assigned, active, inactive}
Interval type = {main, auxiliary, none}

Thus, for example, the "Requests Network Entry in" relationship (diamond **100**) in **FIG. 10** indicates that trackers may request network entry in slots (double box **101**) that are not associated with a repeating interval (double box **102**). Hence, trackers must be notified of valid network entry slots before they attempt to request network entry. And the "provides updates in" relationship (diamond **103**) indicates that trackers provide tracking updates in repeating intervals (double box **102**). In addition, attributes such as interval type (oval **104**), interval count (oval **105**), interval status (oval **106**) and missed update count (oval **107**) are associated with this relation. Interval count indicates the number of repeating intervals a tracker should transmit its tracking information. Missed update count indicates the number of successive times a tracker has missed providing its tracking update during its assigned repeating interval. Interval status is an enumerated type that indicates if an interval is empty, assigned, active, or inactive. Interval type is an enumerated type that indicates if a repeating interval with a non-empty status is a main or auxiliary interval or no interval is assigned.

The tracker message block format of the data transmitted by the trackers consists of an error coded and bit-interleaved data block. Since the UHF transmitter/receiver requires that the data contain frequent state changes so that the phase-locked-loop (PLL) does not chase the data, the transmit data is Miller line encoded to ensure such state changes content.

The basic data size requirements for information transmitted by the trackers, and the minimum space requirements for tracker state, network status, and network command responses are defined as follows. Tracker state consists of position, speed, and direction. As previously stated, the PROTRAK system navigation grid for the presently preferred embodiment is about 262 Km on a side. The grid is broken down into 1024 8.192 Km by 8.192 Km grid zones. The position supplied by the tracker consists of a grid zone and an offset into the zone from the southwest corner. The nominal navigation grid is square, but other forms such as odd-shaped grids may be used if desired or more suitable in a particular system/network configuration. The odd shaping may be accomplished by arranging zones in unique patterns.

FIG. 11 is a diagram of a nominal navigation grid, for a latitude of 45 degrees at the center. It should be noted that in practice (but not shown in the idealized Figure) the curvature of the earth causes the grid to be wider in latitude at the north than in the south. The lines of constant longitude bounding the grid are about 3 Km closer together at the north end than at the south end of the grid.

For a given grid, the grid center latitude and longitude (ϕ_0, λ_0) is provided to the trackers by the NDC in the grid identification packet. The tracker computes its latitude and longitude, (ϕ, λ), and then computes the offset from the grid center: $\Delta\phi = \phi - \phi_0$ and $\Delta\lambda = \lambda - \lambda_0$. The north and east delta positions from the grid center are:

$$\Delta N = \rho_0 \Delta\phi$$
$$\Delta E = \nu_0 \Delta\lambda \cos(\phi)$$

where ρ_0 and ν_0 are the earth radii of curvature:

$$\nu_0 = a/\mathrm{sqrt}(1 - e^2 \sin^2(\phi_0))$$
$$\rho_0 = \nu_0 (1 - e^2)/(1 - e^2 \sin^2(\phi_0))$$

where a is the earth semi-major axis and e is the earth eccentricity.

For example, the lower left corner of the 8.192 Km square containing the position is:

$$\Delta N_{8K} = \mathrm{floor}(\Delta N/8192)$$
$$\Delta E_{8K} = \mathrm{floor}(\Delta E/8192)$$

The offset into the square is:

$$\Delta N_{Off} = \Delta N - 8192(\Delta N_{8K})$$
$$\Delta E_{Off} = \Delta E - 8192(\Delta E_{8K})$$

For the nominal square navigation grid, the 8 Km zone number is computed as

$$Z = (16 + \Delta E_{8K}) + 32(15 - \Delta N_{8K})$$

The NDC computes the original latitude and longitude by adding the north and east offsets to the north and east coordinates of the SW corner of the zone indicated by the tracker using the following equations:

$$\Delta N_{8K} = 15 - (Z/32)$$
$$\Delta E_{8K} = (Z \bmod(32)) - 16$$
$$\Delta N = 8192(\Delta N_{8K}) + \Delta N_{Off}$$
$$\Delta E = 8192(\Delta E_{8K}) + \Delta E_{Off}$$

Then it computes latitude as:

$$\phi = \phi_0 + \Delta N/\rho_0$$

Then longitude may be computed as:

$$\lambda = \lambda_0 + \Delta E/(\nu_0 \cos(\phi))$$

The full latitude and longitude are provided to the applicable CCS by way of message data from the tracker to the Network Hub(s), which is forwarded on to the NDC and then to the customer site.

The amount of data required to describe the tracker state is 48 bits. The zone ID number requires 10 bits. The north and east offsets within the zone each require 11 bits for a resolution of 4 meters. Speed requires 7 bits for a resolution of 0.5m/sec (about 1.1 mph) and a maximum value of about 143 mph. Heading requires 7 bits for a resolution of 0.015625 semicircles (about 2.8 deg). Two state data validity bits are defined. Two additional spares can be provided to make the state data fit simply into a 48 bit "Tracker State Data Block" (of which Byte/Bit Definitions are summarized in **Table 35**).

A "Reduced State Data Block" (Byte/Bit Definitions summarized in **Table 36**) is required so that trackers may provide their full tracker ID number, respond to user messages and/or NDC Commands, and provide user data. This data block contains only a low-resolution position (8 meters), and requires 34 bits.

A "Network Status Code" (Definitions in **Table 37**) is used by trackers to enter and exit the RF network. Additional codes may be provided to automate tracking service changes. In the present exemplary embodiment, nine network status codes, out of an available total of 32, are defined.

Most data packets provide room for customer defined data to be provided to CCSs. The NDC simply passes the data through to the customer, the content of the data being specific to the needs of the respective customers. The user data consists of a minimum of 1 byte, and may be as long as a full tracker transmit packet. All of this is defined by the user, and the user data is referred to here as the "User Data Block."

Text messages, pre-defined messages, user data, and site dispatch messages are acknowledged by trackers to indicate their receipt. In addition, text messages, pre-defined messages, and site dispatch messages may require two responses, one being a return receipt that indicates when the message was read, and the other indicating the recipient's softkey response. Acknowledgments/responses are sent to the NDC Server in a "Message Acknowledgment/Response" Block **(Table 38)**.

A packet ID number is used to identify each packet. The packet ID requires 4 bits for a total of 16 different packet types. The first 4 bits of each packet are reserved for the ID Block.

Tracker data packet formats include the following. The tracker transmit data block consists of a single data packet, each of which is 96 bits long for a (12,8) error coded block. Initially, all trackers must send a "Net Entry Request" Packet to enter the RF network. The latter packet allows trackers to request their main repeating interval slot or a single auxiliary repeating interval.

Once in the RF network, trackers can send a variety of different packet types depending upon the tracker state. The normal packet used by periodic trackers is a state and status packet. A short state and status packet is also used by trackers when the NDC Server requests trackers to provide their tracker ID number. Trackers needing to send a large amount of user data may use the "User Data" packet and/or "Short User Data" packet during its repeating interval. When trackers need to send their tracker ID number, position information, and user data, a "Reduced State User Data and Status" data packet may be used. Trackers needing to acknowledge user data or acknowledge/respond to text/pre-defined messages may use "Message Response" and "User Data" packets.

Tracker packet types are identified by packet ID, with space being provided for 16 different packet types (summarized in **Table 39**). Unused or spare data bits and bytes in the packets are set to zero. Packets consist of bit-packed data blocks, each of which has been defined earlier herein.

A "Net Entry Request" packet (Bit Definitions shown in **Table 40)** is used by tracker modules to enter the RF network. Trackers may request their main repeating interval slot or a one-time auxiliary repeating interval slot. Before a tracker is allowed to send such a request, it must receive an "Available Network Entry Slots" base packet and continue to successfully receive the FM base broadcast until it sends a "Net Entry Request" packet. Of the network entry slots available, trackers will generate a random number to select the next frame to send the request and generate a second random number to select an available slot. For each random number generated, the trackers may use their tracker ID. If a tracker does not receive a repeating interval (RI) slot assignment within 60 seconds after sending a network entry request, it resends the request.

Since it is possible that multiple trackers may talk within the same slot, the "Net Entry Request" packet indicates the RI slot type and tracker ID multiple times to allow the NDC server to determine if the packet is valid. Trackers must purge their main RI slot prior to sending a "Net Entry Request" packet. For example, a tracker that has been in "low-power" mode will purge its low power slot before sending the net entry request. This rule allows the NDC server to release re-assigned RI slots associated with a tracker requesting net entry.

A "State and Status" packet is the normal packet transmitted by periodic trackers. This packet contains full resolution tracker position, velocity, network status information, and five user data bytes. The "State and Status" packet bit definitions are shown in **Table 41**.

A "Reliable User Data" packet (Bit Definitions in **Table 42**) provides several bytes of user data. Instead of providing position information during its assigned repeating interval, a tracker may utilize this user data packet to send ten user data bytes at one time. If necessary, a one-time repeating interval slot may be requested to send/resend this packet.

Upon receipt of a "Reliable User Data" packet, the NDC server broadcasts a "Message Response Acknowledge" message with the same User Data Sequence ID. Trackers must retain a copy of each "Reliable User Data" packet until the NDC server successfully acknowledges it. If an acknowledgment is not received within 2 minutes, the tracker will resend the user data packet.

A "Short State and Status" packet (bit definitions illustrated in **Table 43**) is broadcast by trackers during their normal transmission slot when the NDC Server requests that trackers send their status. It contains full resolution tracker position, velocity, one user data byte, and network status information.

A "Reliable Short User Data" packet (**Table 44** showing its bit definitions) is transmitted to provide several bytes of user data. Instead of providing position information during its assigned repeating interval, a tracker may employ this user data packet to send six bytes of user data at one time. Upon receipt of a "Reliable User Data" packet, the NDC server broadcasts a "Message Response Acknowledge" message with the same User Data Sequence ID. Trackers must retain a copy of each "Reliable User Data" packet until the NDC server successfully acknowledges it. If an acknowledgment is not received within 2 minutes, the tracker resends the packet.

A "Reduced State User Data and Status" packet (bit definitions shown in **Table 45**) is used by trackers to provide a reduced state and status with user data. The packet contains network status, the full tracker ID number, reduced state data, and user data.

A "Message Response and User Data" packet (bit definitions shown in **Table 46**) is broadcast during a tracker's normal transmission slot. This packet provides both an acknowledgment/response and user data. If necessary, tracker modules may elect to request a single slot to provide this response to the NDC server more quickly than waiting for their normal transmission slot to send the packet. Single slots may be assigned to a tracker using a "Net Entry Request" packet.

A "Short Message Response and User Data" packet (**Table 47**) is broadcast during a tracker's normal transmission slot when the NDC server requests that trackers send their tracker ID. This packet contains the full 30 bit tracker ID, an acknowledgment/response, and user data. As in the case of the regular "Message Response and User Data" packet discussed above, if necessary trackers may elect to request a single slot to provide this response to the NDC server more quickly than using their normal transmission slot. Single slots may be assigned to a tracker using a "Net Entry Request" packet.

A "Site Dispatch" message from the customer dispatch office (through a CCS) indicates to the tracker the area of a job site. Consequently, the tracker is able to determine when the tracker has arrived at or departed from a job site. A "Site Status" packet (**Table 48**) is used by a tracker to indicate job site arrival/departure. This packet indicates the tracker ID, message sequence ID (originally associated with the site dispatch message), arrival/departure status, time of arrival/departure, the source of arrival/departure status, and user data.

Geocoding with mapping data may not always be accurate. Hence, it is not always possible to determine if a tracker has reached the job site using the expected latitude/longitude for an address. The tracker sends a "Site Status" packet based on latitude/longitude if arrival/departure occurs (using the latitude/longitude values in the "Site Dispatch" message) to allow the user to manually indicate arrival/departure. The site source bit in this packet indicates how arrival/departure was determined. Initially, the "Site Status" packet may be sent twice for arrival and twice for departure using the two status sources. If necessary, here also the trackers may elect to request a single slot to provide this response to the NDC server more quickly than would occur using their normal transmission slot. Single slots may be assigned to a tracker using a "Net Entry Request" packet.

A "Built-In Test" (BIT) tracker packet is sent to provide the NDC with information about trackers to aid in system testing and to determine whether trackers are functioning properly. At a rate specified in the "RI Slot Config" base packet, trackers provide one of the valid "BIT" packets in an auxiliary slot requested by each tracker. Each "BIT" packet type should be sent in rotation. If necessary, the "BIT" packet type rotation may be modified to supply urgent built-in test information. The bit definitions for the "BIT" Packet are shown in **Table 49**, and the various types of "BIT" packet data blocks are shown in in **Tables 50** (Network and RF System, Type = 0), **51** (Vehicle and Environment, Type = 1), **52** (Navigation, Type = 2), **53** (Version, Type = 3), and **54** (Ready Mix, Type = 4). All values supplied in a "BIT" packet data block indicate the values recorded since the last "BIT" packet of the same packet type was supplied to the NDC server.

When a tracker receives a pre-defined message, discussed earlier herein, it displays the known message associated with the specified pre-defined message ID/16 bit CRC. However, if the tracker does not know the message associated with that ID, or determines that the CRC of the known message does not match the CRC in the received packet, it may request the message definition by transmitting a "Pre-Defined Message Definition Request" packet. For more efficient use of bandwidth, this packet may be sent by the tracker in a network entry slot.

When the NDC server receives this request packet, it broadcasts a "Pre-Defined Message Definition" packet **(Table 55)** that provides the tracker with a pre-defined message ID/message pair. Since pre-defined messages are defined on a customer-by-customer basis, all trackers associated with the same customer benefit from this message definition packet. Hence, trackers need not always request the message definition packet from the NDC server even when they receive a pre-defined message ID for the first time.

V. *Time Division Multiple Access (TDMA) Network Timing*

As has been discussed hereinabove, a feature of the TDMA network is that it allows multiple users of a single channel or frequency by assigning specific time slots to each user to use exclusively for transmission of data. Efficient use of bandwidth in such a network requires that the gap times between transmissions of each user, which is wasted time, be minimized. The gap time must be sufficient to account for uncertainties in user clocks, propagation delays, and transmitter turn-on and turn-off times. Minimization of clock uncertainty is a primary objective of this aspect of the invention.

Transmitter on/off times are a function of the electronics hardware. In the overall system, the vehicle computer network interface hardware is optimized to turn on and off in less than 128 microseconds. Minimization of propagation delays is limited by speed of light delays between vehicles and hub receive sites. Approximately 800 microseconds are allotted in the network for worst case near/far vehicle locations of 240 kilometers. With these parameters fixed, then, attention is turned to minimizing the clock uncertainty.

The simplified block diagram of **FIG. 1**, described earlier herein but to which reference is again made for purposes of the present discussion, illustrates the entire TDMA wireless network utilized in the exemplary embodiment of the invention. NDC **10** maintains precise synchronization of the vehicles **17-1, 17-2**, ..., **17-n** on-board trackers and the Network Hubs **11-1, 11-2**, ..., **11-i** to enable operation of the TDMA network. Synchronization of the timing of the trackers with each other and with the Network Hubs which receive the data transmitted by the trackers is achieved through the reception of a synchronization pattern in the data transmitted over the modulated subcarrier broadcast from FM radio station **12**. Receivers in the NDC, the trackers and the Hubs receive the

FM subcarrier data, and these units align their internal clocks to synchronization pulses contained in the data.

The error budget for clock synchronization between each vehicle (or more specifically, the tracker thereof), e.g., **17-1**, and the Net Hub sites, e.g., **11-1**, is 10 microseconds. It is essential that trackers have the correct time within this window, or run the risk of transmitting at the same time as another tracker, reducing the likelihood that either transmission will be correctly received. Similarly, if Hub receivers (e.g., **81, FIG. 31**) lack the correct time within the 10 microsecond window, they may not activate at the correct time to receive tracker transmissions.

The internal clock reference for each network component, SCC, tracker, Hub receiver, and NDC receiver, in the exemplary embodiment is a temperature compensated crystal oscillator (TCXO) with 1.5 ppm frequency stability. This means that the clock will generate less than 1.5 microseconds of error in one second; however, the 10 microsecond error budget would be violated in seven seconds of free running operation. Clocks in all of the vehicle and receive sites will drift at different rates and different directions. A stable clock reference is required to keep all of the clocks synchronized to each other. A GPS receiver located at the NDC as opposed to the transmitter site, is the stable time reference for the TDMA network.

FIG. 12 is a simplified diagram of the timing control loop **110** -- a remote timing control phase locked loop (PLL) -- for the TDMA network. Timing control loop **110** includes a GPS receiver **111** time reference, an FM subcarrier receiver **112**, and the NTCC **47**, all located at NDC **10** (here and occasionally elsewhere herein referred to as the Network Control Center). PLL **110** also includes SCC **48** at the FM radio station **12** to control the timing of the transmitted data, and subcarrier modulator **68** to provide the data to the mixing equipment in a transmitter **113** at the radio station, for broadcast on FM subcarrier signal **114** via transmitter tower **53**.

Crystal oscillators (including TCXOs) are relatively accurate time sources, but drift over time without periodic correction. The GPS receiver **111** acts as a stable, precise time reference for the TDMA network timing synchronization, that provides a Pulse Per Second (PPS) on a discrete output interface. The PPS is at a GPS time indicated by a message in the serial output interface of receiver **111**, typically on integer second boundaries, and is typically accurate to about 300 nanoseconds when subject to Selective Availability introduced into the GPS satellite signals **115**.

FM subcarrier receiver **112** at NDC **10**, which is identical to the FM subcarrier receivers used by the trackers and the Network Hubs, receives the synchronization pulses from SCC **48** in the FM subcarrier signal **114**. The same hardware ensures that variation in delay through the receivers is minimized. The subcarrier receiver **112** determines the time of reception of the synchronization pulses relative to the reception of the PPS from GPS receiver **111**. The difference *dt* between the average time of the synchronization pulses and the time of the PPS is provided through a serial interface **116** to NTCC **47**. The NTCC software processes the time difference, and computes in different ways depending upon its mode of operation a time correction command to be sent to SCC **48**. In its normal, continuous mode, time corrections are computed using a low bandwidth control loop.

Every second, SCC **48** sends a new block of data which is slightly shorter than one second in length, leaving a very short gap in the data from one second to the next. A sequence of three synchronization pulses is present at the start of the data. SCC **48** applies the received time correction commands to the time at which it starts sending the next block of data. The gap between data blocks allows the start time of the data to be adjusted to be earlier or later than the interval used by SCC **48** at the time the command was issued.

FIG. 13 illustrates the three time synchronization pulses **120**, **121**, **122** of precisely timed length of 964.8 microseconds with a precise interval of 750.4 microseconds, transmitted by the SCC **48** **(FIG. 12)** at the start **125** of each second's data. The transmit data **126** immediately follow this synchronization sequence and last for 986240 microseconds. The resulting gap **127** -- roughly 8600 microseconds long; but varying in length as time corrections sent from the NTCC **47** to the SCC **48** **(FIG. 12)** are applied -- occupies the remainder of the one second interval to the start **128** of the next one second interval.

The NTCC software performs synchronization of the network to GPS time, illustrated by the process flow charts of **FIGS. 14A-D**. The NTCC runs through four operational modes of time alignment, viz.: Initialization **(FIG. 14A)**, Coarse Offset **(14B)**, Coarse Rate (**14C**), and Fine Rate (**14D**). In the Initialization mode (**FIG. 14A**), NTCC **47** (**FIG. 12**) ensures that the clock interval reported by SCC **48** is within 10 ppm of the nominal one second count. Under normal circumstances, the SCC clock interval should be within 2.2 ppm, which is the root sum square (RSS) of the 1.5 ppm accuracy of the SCC and subcarrier receiver clocks. If it is outside the 10 ppm window, NTCC **47** commands SCC **48** to adjust its clock interval to the nominal value. The SCC waits for each command to take effect, and when it is within tolerance, sets the time alignment mode to Coarse Offset.

In the Coarse Offset mode (**FIG. 14B**), NTCC **47** takes three samples of the time difference *dt* between the PPS from GPS receiver **111** and the synchronization pattern received at FM receiver **112** from the FM subcarrier. An average offset from GPS time is computed ($\Sigma dt/3$) from the three values. If the magnitude of the offset is greater than or equal to 100 μsecs, a command is sent to SCC **48** to shift the start time of the synchronization pulse sequence by the offset amount. NTCC **47** then waits three seconds, repeats the process until the 100 microsecond tolerance is achieved, and then sets the time alignment mode to Coarse Rate.

The Coarse Rate mode (**FIG. 14C**) is used to bring the SCC time offset and clock interval into near alignment in preparation for closed loop operation of the Fine Rate mode. The time difference *dt* reported by the subcarrier receiver **116** is sampled each second for 20 seconds, and a least squares linear fit to the 20 samples is performed. The result of the fit is a line with slope m and offset b:

$$dt = mt + b$$

where *dt* is a function of time, t. A rate command is sent to SCC **48** to correct m to zero. Then an offset command is sent to the SCC which compensates for the time required for the fit to be computed and the time required for the command to take effect -- a total of 23 seconds: $m(20+3) + b$. Once the average offset from the last three samples is under 20 microseconds, the time alignment mode is changed to Fine Rate.

In the Fine Rate mode (**FIG. 14D**), the NTCC runs a low bandwidth PLL to continuously control the network timing and monitors the control loop for error conditions. The values of *dt*, offset and rate of the SCC clock are continually monitored by NTCC **47**. If the value of *dt* is in error by more than 40 microseconds for three consecutive samples, and the average offset is in error by more than 16 microseconds, then the time alignment mode is set back to Coarse Offset, and the synchronization flag is cleared. A least squares fit is continuously run on the clock error signal. If the average value is in error by more than 8 microseconds or the rate is in error by more than 1 ppm for 5 samples in a row, then the mode is set back to Coarse Rate, and the synchronization flag is cleared. If both of those conditions are met when the loop is not synchronized, then the synchronization flag is set.

A block diagram of the timing control PLL **110** in **FIG. 15** mathematically illustrates the functions of the subcarrier receiver **112**, NTCC **47**, and SCC **48** in performing timing control. The closed loop bandwidth of the PLL is about 0.014Hz, (roughly a 70 second period). NTCC **47** continuously samples the *dt* output of subcarrier receiver **112** and runs the PLL controller **130** to generate rate commands to send to SCC **48**. The rate commands serve to correct for small clock errors **131**, **132** in the TCXOs of SCC **48** and subcarrier receiver **112**.

Each computer receiving or transmitting on the TDMA network in the present exemplary embodiment uses a Motorola 68332 microcontroller -- a 32 bit processor with a 68020 core with on-chip server peripherals. One of the peripherals is a Time Processing Unit (TPU, e.g., shown in conjunction with processor **83** in the Hub block diagram of **FIG. 30**), which has 16 channels of specialized hardware for measuring pulse widths and generating clocks. With a 20 MHz clock, it can make measurements with a resolution of 0.2 microseconds. The TPU is used to detect the FM subcarrier synchronization pulses and generate the precise clocks for transmitted data, both on the subcarrier and by the vehicle tracking computers in the TDMA network.

In so doing, the TPU detects and times the synchronization pulse pattern transmitted over the FM subcarrier. Processing in this regard performed by the NDC subcarrier receiver, the tracker, and the Network Hub receivers is virtually identical. The CPU runs two timers, viz., a 2048 Hz clock for task scheduling and the internal TPU 5 MHz clock (system clock divided by four). For timing purposes, the 2048 Hz clock is used to account for ambiguity in the TPU time due to rollover of its 16 bit counter every 13 milliseconds. TPU channel function assignments are shown in **Table 56** (Appendix B).

Referring to that table, in operation of the TPU for synchronization and clock generation, the synchronization pulse sequence is detected by running a Period/Pulse Width Accumulation (PPWA) function on TPU channel 4. The TPU interrupts the processor on each falling edge detected in the input data and provides the processor with the time of the falling edge and the preceding pulse width. When the processor detects three pulses of the appropriate width and spacing, within a tolerance window, it determines the start time of the synchronization in TPU counts based on the average falling edge time of the received pulses. The tracker has two receivers for FM data. Depending on the quality of signal available at either antenna, it may attempt to detect the synchronization sequence on the second channel using the method described immediately above with TPU channel 11.

The start of the synchronization pattern is used as a reference by all receivers to generate the data clock necessary to clock the FM data into shift registers and into the processor memory for decoding. An identical synchronization algorithm is used by all of the network elements to ensure that variability in time estimates is minimized. An estimate of the synchronization start time is maintained by the CPU using a low bandwidth PLL similar to that used by the NTCC to control the synchronization relative to GPS time. The CPUs in the tracker, Network Hub, and NDC subcarrier receiver all run a second order PLL with a 0.05 Hz bandwidth to create an estimate of the synchronization start time, so that noise in the receive data does not cause substantial jitter in the synchronization time. It also allows the processor to maintain a time estimate that only degrades slowly in accuracy (TCXO error) when synchronization pulses are missed, thus maintaining the capability to receive and transmit data under poor RF reception conditions. The time estimate is used to start the data clocks using four TPU channels.

TPU channel 5 runs an Output Compare (OC) function which is designed for generating single output transitions or continuous clocks. Using the synchronization time estimate, the CPU programs the channel to output a pulse at a precise delay from that time. TPU channel 6 runs the Input Transition Capture/Count (ITC) function which is set up to detect changes on an input line and interrupt the processor and/or initiate processing on other TPU channels. In this case it detects the pulse from channel 5 and starts OC functions on channels 7 and 8 which generate a bit clock and a byte clock. The bit clock toggles for each receive bit and causes each bit to be shifted into a shift register. The byte clock runs at one eighth the rate of the bit clock and latches the byte into processor. Once all of the data bits are clocked in, the processor turns off the clocks in the gap time before the next second's data.

As previously described herein, the NDC subcarrier receiver **112 (FIG. 12)** compares the received synchronization time to the PPS time from GPS receiver **111** to provide the *dt* measurement to the NTCC **47** software. The precise measurement of *dt* is made by connecting the PPS output signal from GPS receiver **111** to TPU channel 11 on the subcarrier receiver CPU. Channel 11 runs an ITC function which detects the pulse and interrupts the processor. The processor records the PPS time. Under normal conditions, the three synchronization pulses are then detected on channel 4, and the synchronization time is computed. These times have a precision of 0.2 microseconds and an accuracy of the TCXO, 1.5 ppm, the *dt* being simply the difference between the times.

Trackers use the synchronization time estimate as a reference for starting the transmit data sequence. Approximately one second before the time slot assigned to a tracker occurs, the CPU sets up processing tasks to format data to be transmitted, loads output buffers, and initializes TPU channels. TPU channel 0 runs an OC function that is initialized about 6 milliseconds before the transmit sequence is to begin. This channel asserts the transmit key line of the RF card and also initiates the chain of other TPU events required to transmit data in the TDMA network. The OC function generates a single transition at the start of the appropriate 20 millisecond time slot, turning on the transmitter. This signal is also fed into channel 1 of the TPU which runs the ITC function. The detection of the transition on channel 0 starts a transmit data clock on channel 2, delayed by 96 microseconds to allow the transmitter power to stabilize. The clock transmits data from a shift register on the TPU, a queued serial peripheral interface (QSPI, e.g., see processor **83, FIG. 30**). The clock is also fed into TPU channel 3, which runs an ITC function to count the number of bits transmitted. The transmit bit count is used by the processor to refill the QSPI output register based on an interrupt from the ITC when the desired output count is reached. The CPU also turns off the OC transmit key on channel 0 by scheduling an opposite transition 19200 microseconds after the key signal was asserted.

The Net Hub receive site CPU uses the TPU to generate the framing information to denote the start of each 20 millisecond TDMA time slot. Based on the estimated synchronization start time, the CPU sets up an OC function on a TPU channel to toggle at precise 20 millisecond intervals. This signal controls processing start times for a digital signal processor (DSP) to clock and data recovery on any data received in each slot. In this case, the TPU cannot be used to generate the data clock because the speed of light delays from vehicle-mounted trackers to the Hub receiver are variable and unpredictable. The DSP processor (e.g., **80**, **FIG. 30**) performs batch processing on the prior slot's recorded data, while data for the current slot is stored into a bank of memory. On the next slot interval toggle, the DSP switches banks, and the new data is stored in the bank just processed.

The SCC is the generator of the synchronization pattern in the FM broadcast data that is used by the other elements in the system as a precise time reference for operating in the TDMA network. The SCC uses the same sequence of TPU functions on channels to send its data to the FM subcarrier modulator as the tracker uses to transmit data in the TDMA network. The differences are that the SCC transmits for nearly one second, and the start time of the transmission is controlled by command from the NTCC over a modem link. The SCC runs on a 10 MHz TCXO instead of a 20 MHz clock, so its time resolution is 0.4 microseconds instead of 0.2 microseconds.

Near the beginning of each integer second, the SCC receives a clock correction command from the NTCC and the data to be transmitted on the next second. While it is receiving these data, the SCC is transmitting the current second's data. The SCC formats a bit stream that includes the synchronization pulse sequence at the start, followed by the data. At the end of the current data transmission cycle, the CPU sets up TPU functions and loads the output buffer (also the QSPI) with the data to be transmitted. An OC function is initialized to toggle at the current one second interval count of the TPU, as modified by the NTCC command.

The NTCC command can be either a one-time offset during initial time alignment of the SCC, or a rate adjustment command during normal Fine Rate time alignment mode. For example, the nominal TPU count for a one second interval on the SCC is 2500000. If the NTCC determines that the SCC clock is fast by 0.4 ppm, it will send a rate adjustment command to the SCC to lengthen its count by one to 2500001, so the fast SCC clock must count one additional 0.4 microseconds to reach a true interval of one second. The SCC uses this interval until corrected again by the NTCC.

As with the tracking computer, an ITC function on another channel is used to detect the OC transition and initiate an OC continuous bit clock on a third channel. A fourth channel counts bits transmitted and refills the QSPI buffers as required. Once all of the bits are transmitted, the CPU turns off the output clock and starts a repeat of the process.

VI. *Bandwidth Efficient Wireless Transceiver System*

As observed in the above section on the TDMA network, the efficient use of bandwidth is essential for wireless TDMA digital data networks. The techniques employed according to another aspect of the invention, to be described in this section of the specification, maximize efficiency by filtering the baseband data to reduce the occupied bandwidth of the channel and eliminating the transmission of synchronization information to minimize the overhead of non-information bearing data. The baseband filter is implemented by a digital microcontroller and replaces the original square wave data stream with deterministic transitions that reduce harmonic content and maintain bit widths, regardless of data input frequency. Removal of synchronization data is enabled by the addition of processor intensive clock and data recovery algorithms at the receive site. The network also uses forward error correction coding and space diversity processing, according to other aspects of the invention, to increase the reliability of received data which reduces bandwidth used for retransmission of corrupted data.

The TDMA network of the exemplary embodiment is split into 50 vehicle transmit time slots per second. By means described in the preceding section of this specification, the trackers and Net Hub receiver computers are all synchronized within a few microseconds of timing accuracy so that gap times between the 50 time slots are at a minimum. The trackers maintain an accurate time count to determine the point in time at which a data packet is to be transmitted. Processing performed by the trackers to transmit the data packet includes Forward Error Correction (FEC) coding, bit interleaving, delay line encoding, premodulation filtering, and Binary Frequency Shift Keying (BFSK). On reception of the packet, the Hub computer performs FSK demodulation to an Intermediate

Frequency (IF), digital sampling of the IF signal, bit clock recovery, bit synchronization using an iterative process, and data decoding. Each second, up to 50 vehicle data packets are transmitted to the NDC Network server which combines data from other Net Hub receivers in a diversity processing algorithm and performs FEC decoding on the resultant data packet.

FIG. 16 is a block diagram of the transmit TDMA data packet processing performed by the tracker (tracking computer) **135** in each vehicle. A data packet **137** consists of 12 total information bearing data bytes, or 96 bits. The data to be transmitted is bitwise packed very tightly in most cases so that there are few wasted bits between data item fields. The contents of the data packets sent by the tracker vary depending on the type of data the tracker needs to report; the packets typically contain navigation data in periodic reporting slots and special data such as event (e.g., what the vehicle is doing or encountering) reports, network control information, or outbound message codes in auxiliary reporting slots.

The tracker first performs forward error correction (FEC) coding **138** of the data. A (12,8) code is employed which uses codes words that are 12 bits long to encode each data byte. This is a modified BCH error correcting code that enables the server to correct one bit in each 12 bit code word. The (12,8) code is also used by the Net Hub receiver processor in its bit synchronization algorithm to locate the likely start of the data packet by selecting the clock offset which minimizes the number of code word errors. The result of the FEC coding step **138** is a total of 144 data bits to be transmitted.

Next the 144 data bits are interleaved, at **139**, without which each code word would be transmitted in order. Wireless data in mobile environments can be corrupted by burst errors which cause several consecutive bits to be received in error. Since the FEC algorithm can only correct one bit in each code word, a burst of bit errors would make a word uncorrectable. Bit interleaving assures that the first bit of each word is sent first, followed by all of the second bits, and so on, to provide some immunity to burst errors. This enables the FEC algorithm to correct a burst that destroys all of the first bits, for example, since it affects only one bit in all of the code words instead of all of the bits in a single code word. In each packet, all of the code words must be successfully decoded to make sense of the packet.

A unique interleaving scheme is used for the data transmitted by the vehicle tracker to enable the bit synchronization algorithm used by the hub receiver to work. Instead of the simple ordering of all first bits, all second bits, through all twelfth bits, the ordering used is shown in **FIG. 17**. This provides an interleaving depth of 11 instead of the 12 possible with simple interleaving, but provides a randomization of the data bits to ensure that single bit shifts in received data cause errors in all code words. In **FIG. 17**, the interleaved bit ordering is shown in tabular form: the rows are interleaved 12 bit words, and the columns are the bits within the words. Bits are transmitted from left to right and top to bottom. The bits of the original FEC code words are identified by the W/B format at each interleaved bit position. These are the bits, B, of code word, W.

Returning to **FIG. 16**, after interleaving, the CPU encodes the data using a delay, or Miller, line encoding algorithm **140**. Delay coding is similar to Manchester coding in that it guarantees transitions in the encoded digital data. It differs in that it does not increase the maximum baud rate of the unencoded data. A disadvantage of the delay code is that it is slightly more complicated to encode than Manchester. The delay code replaces each '1' in the original data stream with a transition at the mid bit point; the transition begins at the previous bit's output level. A '0' in the original data is represented by no state change, except if the previous unencoded bit was a '0'. In that case, the second '0' is encoded as a state change between bit boundaries. The algorithm ensures that there are three distinct bit widths: 1, 1.5, and 2 times the width of the original bits. **FIGS. 18A-C**, which will be discussed further presently, provide a comparison of an original data sequence to the delay coded version of that sequence, and an illustration of the filtering of the delay coded sequence.

Returning again to **FIG. 16**, square wave digital data as with the original data sequence and the delay coded version thereof must be filtered so as to round off the edges so that harmonics which cause the occupied bandwidth of the transmitted data to be wide are minimized. A premodulation filter **141** for the delay coded version is implemented in the present exemplary embodiment using a PIC™ 16F84-10I/SO microcontroller (PIC is a trademark of Microchip Technology Inc. of Chandler, Arizona, manufacturer of the device), followed by a digital to analog converter (DAC) **142** constructed using a precise resistor network. The filtered, analog representation of the original digital data stream is modulated using frequency shift keying, at **143**, and transmitted by the tracker from an antenna **145** thereof after amplification at **144**.

The filtering algorithm used in premodulation filter **141** to ensure that there are three distinct bit widths: 1, 1.5, and 2 times the width of the original bits, is shown in flow chart form in **FIG. 19**. The PIC™ microcontroller continuously samples the input digital data looking for a transition. When a transition occurs, at **147**, the microcontroller executes in-line code to rapidly output byte values that represent the transition as a sine wave shape to the DAC **142**. When the output of the transition curve is complete, the microcontroller software goes back to searching for the next input data transition.

The PIC™ microcontroller digitally replaces each data transition with a rising or falling half sine wave, as required. The maximum baud rate of the delay coded data is 7812.5 bps. This is equivalent to a maximum data frequency of 3906.25Hz. In this application, the microcontroller runs with a 10 MHz clock, and has an instruction cycle of 4 clock cycles. The method for the fastest output of data to the DAC requires two instructions per point, or 0.8 microseconds. The period of the highest frequency data is 256 microseconds. Ideally, each transition would be replaced with a 160 point half sine curve (128 microseconds divided by 0.8 microseconds per point) so that the highest frequency data present would appear to the modulator as a pure sine wave.

It is not possible to use all of the 128 microseconds to produce the filtered transition output because time must be left for the overhead of transition detection and other functions. Therefore, a 150 point transition curve is used. **FIGS. 18B** and **18C**, respectively, illustrate the delay coded data and the filtered output created by the digital premodulation filter. Each edge in the data in the delay coded version of **FIG. 18B** is delayed by approximately 64 microseconds. Since this filtering delay is constant, it is accounted for in the transmit data clocking provided by the CPU. **FIG. 20** provides a diagrammatic comparison of the approximate power spectrums of the unencoded **137**, delay coded **140**, and filtered data of **FIGS. 18A-C**. Delay coding concentrates more energy at an average of about 3/4 of the maximum frequency. The spectra for two filter versions are shown in the diagram of **FIG. 20**, one being an ideal 160 point transition filter **148** illustrated for reference purposes, and the other being a 150 point practical implementation **141**. The latter has slightly higher power between one and three times the fundamental frequency. The filter substantially cuts the channel bandwidth required for transmitting the TDMA FSK data, for reasons noted above.

A digital filter of this type provides the considerable advantage that its output has a constant delay, regardless of input frequency, which is equivalent to linear phase delay with increasing frequency. This is a property of digital finite impulse response filters. Traditional digital or analog infinite impulse response filtering techniques have nonlinear phase, which can distort bit widths as the input frequency varies. Depending on the filter cutoff frequency, this can cause intersymbol interference. The constant delay allows precise bit widths to be transmitted without distortion. When data with deterministic and repeatable bit widths is received, the bits and bit values can be reliably clocked and decoded.

In the UHF transmitter modulator section used in the present exemplary tracker data processing of **FIG. 16**, the microcontroller **141** takes the transmit data (TXD) input and provides as output a byte value. That output feeds a Bourns 2QP16TF6235 resistor ladder network that acts as DAC **142**. Microcontroller **141** also performs the task of keying the tracker transmitter based on precisely timed signals from the CPU card **149**.

After filtering, the data are modulated on a UHF carrier in the 450-470 MHz shared use business band on a 12.5 KHz offset channel. The bandwidth control provided by the premodulation filter is a key element in allowing a data rate of 7812.5 bps on such a narrow channel, while using a very simple FSK modulation technique. The modulation uses about 2KHz of deviation. The tracker transmitter has a two Watt output.

Network hub receivers are located around the metropolitan area to receive the TDMA transmissions from the vehicle trackers. **FIG. 21** is a block diagram of the processing performed by each Network Hub **11** on the received RF signals. The UHF TDMA receiver front end hardware (RF card **151**) is always turned on. Signals received at antenna **152** are demodulated at **153** to a 455 KHz intermediate frequency (IF) signal which is digitized at **154**. The IF frequency is further processed by an application-specific integrated circuit (ASIC) **155** that performs digital filtering and demodulation to a baseband signal. At precise 20 millisecond intervals corresponding to the boundaries between vehicle transmissions, each 20 millisecond segment of the baseband signal is sampled **(156)** at a high rate and stored in memory.

A digital signal processor (DSP) (e.g., **80**, **FIG. 29**) in the CPU section **158** of the Net Hub is used to extract the data from the sampled baseband signal. The processing is performed in a batch mode on the entire data packet after it has been received. In the meantime, data being received is stored in an alternate memory bank for processing on the next 20 millisecond cycle. Batch processing provides for the use of more powerful algorithms because then data set can be analyzed in its entirety. Real-time processing requires the algorithm to recover data on the fly without the benefit of subsequent input data. The DSP performs clock recovery and then locates the data within the 20 millisecond window. The recovered data are de-interleaved, and the data for all 50 time slots are ultimately sent to the NDC Network server for further processing.

Recovering the data is a processor intensive algorithm. To reduce the number of bits transmitted by the vehicles, and therefore increase the number of vehicles that are able to report each second, no special bit patterns are sent with the data packet for the receiver to detect. Requiring bit synchronization patterns to detect the data also reduces reliability in a mobile RF environment because if the bit pattern is corrupted, the message packet cannot be recovered, even if it is received without error. Each vehicle transmission occurs at a very precise moment, but its reception is delayed by the speed of light over the distance between the vehicle and the hub receiver by up to 800 microseconds. The Hub must locate the start of the message within the 20 millisecond window without aid from special bit synchronization patterns. For this, it uses an iterative search that sequentially clocks in the data at greater and greater delays from the nominal message start time until a valid data packet is located.

First, the DSP algorithm recovers the bit clock (**160**, **FIG. 21**) for the received data, by differentiating the received data. The differentiated data will have large magnitude values at the bit edges. With delay coding, bit edges will be frequent, since transitions are guaranteed in the data. The time delay from the beginning of the data set to each apparent bit edge is measured, modulo 64 microseconds. The modulo delay is averaged to determine a mean data clock edge time that is applicable for the entire data set. A mid bit time is computed as a 32 microsecond offset from the average delay.

With this offset, the data in the buffer is sampled at 15625 bits per second (64 microsecond intervals). This clock rate is used to recover the delay code, since it has transitions at the mid bit point for ones in the original, unencoded data. A total of 288 delay coded bits are clocked in.

Delay decoding **(161)** is performed on the sampled 288 bits to produce 144 original data bits. Only certain allowable bit patterns are present in the delay code. If a bit error causes an invalid pattern, the pattern is decoded to one of the possible bits represented by the pattern. If subsequent error detection processing on the decoded data indicates an error, then, if only one ambiguous data pattern was encountered in that particular code word during the delay decoding process, the other bit value is used and the error detection is repeated. If successful, the second bit value is retained. If more than one bit is ambiguous or the second bit also fails to result in valid data, the original value is retained, and processing is allowed to move forward. The bit error may be correctable at a later stage in the data processing chain.

The bits are then de-interleaved **(162)**, and the FEC code words are checked for errors **(163)** but not corrected. The interleaving sequence plays an important role in this process. Standard interleaving of all first bits followed by all second bits, etc. will only cause the first or last code word to be in error if the bit clock is in error by up to 12 bits. This makes the use of error detection for aligning the bit clock to locate the correct data useless. The interleaving scheme used in this case jumbles the data sufficiently and single bit shifts cause all code words to be in error.

The number of correct code words is counted and stored. The bit clock is then shifted (delayed) by 64 microseconds, and the delay decoding **161**, de-interleaving **162**, and error detection **163** process is repeated **(164)**. In the present exemplary embodiment this is done 12 times to cover the entire 800 microsecond range of possible delays. The decoded data **165** at the clock offset that has the most correct code words, as determined by this processing by the Network Hub **11** of the vehicle **17** tracker data in the received RF signals, is packaged for transmission to the NDC server **42 (FIG. 3)**.

Each second, server **42** receives data for all 50 time slots from all Network Hub receivers. The network is designed so that multiple Hubs will receive each single tracker data transmission. This redundant data is combined by the server using a space diversity voting algorithm that increases the reliability of received data. A flow chart of the space diversity algorithm of NDC server **42** is shown in **FIG. 22**, this algorithm being performed for each of the 50 time slots in each one second period.

Each tracker packet has 12 code words. The server uses the FEC code to detect errors in the code words provided by each Hub. If at least 6 code words of the 12 are error free (**170**), the packet is retained for further processing (**171**). The assumption is that if most code words have errors, the probability of successfully recovering valid data from the entire packet is low. Once all likely valid packets are collected for the time slot (**172**), one of two processing paths is taken.

If the time slot is defined for periodic reporting (**173**), then the diversity voting algorithm is applied as indicated in processing path **174**. The packets collected in the first phase are summed bit by bit using received signal strength reported by the Hub as a weighting factor (**175**). Signal strength is used as an indication of the likelihood that the message was received successfully. Set bits in the message packet are added to the sum using the positive signal strength; cleared bits are added to the sum using negative signal strength (**176**). As a simple example, consider the three bit sequences below with their corresponding signal strengths. After summing, bits with positive valued sums are decoded as set bits, and bits with negative valued sums are decoded as cleared bits. If a packet contains a bit with a sum of zero (a tie), the packet is discarded.

bit	01234567	
Packet A:	11001010	Signal Strength: 100
Packet B:	11011110	Signal Strength: 30
Packet C:	11001110	Signal Strength: 80

Voting Results:

bit 0:	+100+30+80 = +210 > 0 => 1
bit 1:	+100+30+80 = +210 > 0 => 1
bit 2:	-100 -30 -80 = -210 < 0 => 0
bit 3:	-100+30 -80 = -150 < 0 => 0
bit 4:	+100+30+80 = +210 > 0 => 1
bit 5:	-100+30+80 = +010 > 0 => 1
bit 6:	+100+30+80 = +210 > 0 => 1
bit 7:	-100 -30 -80 = -210 < 0 => 0
Voted Packet:	11001110

After voting, forward error correction is applied to the result to correct remaining errors in the code words (**177**). The (12,8) code allows one error in each code word to be corrected. Each packet contains an 8 bit or 16 bit CRC (cyclic redundancy check) code to verify that the packet is unlikely to have errors (**178**); however, it is still possible for the packet to contain bit errors. The final check on the data consists of verifying the reasonableness of the data contained in the packet, and, if so, the packet is stored (**179**).

If a time slot is not defined for periodic reporting, it is available for any tracker to transmit a "Network Entry Request" packet to obtain a primary or auxiliary reporting interval slot. Vehicles **17** (**FIG. 3**) near each other that transmit simultaneously will almost certainly corrupt each other's transmissions. If they are widely separated, their tracker data packets can be received reliably by Hubs **11-1**, **11-2**, ..., **11-i**, near each of the vehicles. Server **42** processes packets in these slots individually. In lieu of using the diversity voting algorithm, processing proceeds along path **180** (**FIG. 22**). Network entry packets contain redundant data in addition to the CRC, which enables the server to determine if the packet is valid with a high degree of confidence. Here, no voting is performed but forward error correction (**181**) and CRC checks (**182**) are performed, followed by a determination of data packet validity from the redundant data in the respective "Network Entry Request" packet (**183**). If the data packet is determined to be valid by this processing scheme, it is stored in memory (**184**).

VII. *Tracker and Tracker Software*

The primary functions of the tracker installed in each respective vehicle are navigation and radio communication. Its secondary tasks are supporting the user interface of the Mobile Data Terminal (MDT), discrete and analog data collection, and power control of itself and peripherals. **FIG. 23** is a representative illustration of an exemplary placement of the tracker **135**, MDT **190**, and antennas (including FM receive antenna **191**, UHF/FM antenna **192**, and GPS antenna **193**) on a typical fleet vehicle **195** (illustrated as a cement mixer, for example). As illustrated, the vehicle **195** is further equipped for accommodating various sensors for event reporting, which will be described in another section of this specification, below.

A flexible, but efficient real time executive is employed to support the primary functions of the tracker. Before describing the real time executive, however, reference is made to a simplified block diagram of the tracker (tracking computer) **135** shown in **FIG. 24**. It consists of two primary circuit cards or sections: a CPU section **200** and a wireless network interface, or RF, section **201**. The CPU section **200** contains the power supplies for the tracker, the main microprocessor (central processing unit, or CPU) **203** to perform all data processing, a GPS chip set (including an RF front end component, GP 2010, and a correlator component, GP2021, of an exemplary Plessey chip set) integrated with the processor for reception and decoding of GPS satellite signals, and sensor electronics and interfaces. The CPU section **200** performs the navigation (partly through GPS navigation section **204** but also through dead reckoning and/or map matching or other navigation sensors via inputs to CPU **203**), as well as data processing and sensor processing through the CPU **203**.

Dead reckoning navigation in a land vehicle environment maintains a robust navigation solution when GPS data may be unavailable as a result of satellite masking in tunnels or by tall buildings during travel of the vehicle or at a job site. A gyroscope (not shown) is mounted inside the tracker box to sense angular rate in the vertical axis. The tracking computer, which uses angular rate to estimate heading of the vehicle, is also tied into a vehicle speed sensor output from the transmission and into the reverse lights of the vehicle to indicate if the speed sensed is in the forward or reverse direction. The speed sensor is an integral part of other sensor measurement functions that rely on distance traveled outputs or verification that the vehicle is stationary or moving at a low speed.

As will be discussed further in connection with a subsequent Figure, three power supplies (generally designated by block **205**) are provided on the CPU card **200**, one a 12 VDC supply that provides power to the RF card, a second a 12 VDC supply that provides power to the MDT and other external peripherals of the unit, including sensors, and the third a 5 VDC supply for the CPU **203** processing functions.

The RF section or card **201** contains the radio frequency circuits (including receivers **207** and **208** which receive inputs from vehicle-mounted antennas **191** and **192**, respectively) necessary for reception and demodulation of radio frequency data received over the FM subcarrier from radio station **12**. RF section **201** also contains circuits (in transmitter **210**) necessary for modulation and amplification to transmit data in the UHF band using the TDMA network protocol. However, the RF card does not perform any data processing of its own. Rather, the main CPU **203** is responsible for all baseband data processing for message decoding and encoding, forward error correction, and data clocking in the tracker **135**.

In terms of tracker software, referring back to the real time executive employed to support the primary functions of the tracker, it will be useful to again note that the CPUs used in each of the trackers and Net Hubs are substantially identical. The Net Hub CPU **82** illustrated in the simplified block diagram of **FIG. 29**, for example, shows a Motorola 68332 microprocessor with associated on-chip peripherals such as a TPU, QSPI, and SCI, and related shift register as preferably constituting the CPU. The tracker CPU **203** corresponds therewith. It has two periodic interrupt sources for task scheduling and dispatching, namely, an accumulator interrupt (ACCUMINT) from the GP2021 and a periodic interrupt timer (PIT) derived from the CPU clock. The ACCUMINT is used to run a simple, high priority, real-time dispatcher, while the PIT is used to run a slower, priority-driven scheduler for long-duration navigation and communication tasks.

The interrupt priority is:

1. TPU	level 6
2. SCI	level 4
3. ACCUMINT	level 3
4. PIT	level 2

The ACCUMINT interrupt runs a periodic, high-priority dispatcher for short (< 1 msec) duration tasks. TPU interrupts occur from TPU events related to network communication and timing. The PIT runs a secondary, low rate, and must be the lowest priority interrupt because it can only be enabled when the ACCUMINT interrupt service routine (ISR) completes. The SCI generates UART interrupts from serial communication with the compass or other peripherals. The QSPI is used for vehicle transmit data, must be serviced twice during a vehicle transmission, and does not generate interrupts. The TPU and SCI interrupt handlers should be as fast as possible.

The ACCUMINT is supplied by the GP2021 and is derived from the 10 MHz TCXO which also drives the 20 MHz processor clock (also from the GP2021). The ACCUMINT rate is nominally programmed for an approximate rate of 2048.131 Hz (the period is 488.25 μsec). This is in error from a true 2048 Hz rate by 64 ppm. The ACCUMINT can be disabled and re-enabled by writing to a GP2021 register. The GP2021 timer tick (TIC) flag, which is programmed for a rate of 8 Hz, controls when GPS measurement data is available and is used to schedule dead reckoning navigation processing.

The structure of the ACCUMINT handler/real-time dispatcher is outlined as:

```
disable GP2021 interrupts by writing to the correlator
read all new accumulator data
if (TIC)
{
  store and time-tag wheel/speed sensor data
  set flag to collect GPS channel measurement data
  set flag to run dead reckoning navigation functions
}
(GP2021 interrupts are still disabled on the correlator)
update tracking loop(s) for specified channel(s)
service either GP2021 UART (universal asynchronous receiver/transmitter) A or B
update network event timing
schedule high priority communication and data collection events as required
enable GP2021 interrupts by writing to the correlator
dispatch high priority periodic tasks
dispatch communication and data collection tasks
enable PIT interrupts if previously enabled
return
```

With the tracking loop implementation of the present exemplary embodiment, the tasks of reading the accumulator data and updating the tracking loops requires on average about 160 μsecs for 8 channels. This includes data collection and demodulation for all channels and tracking loop closure for one channel. Each channel generates accumulation data at l msec intervals (approximately every other ACCUMINT). It is important that the tracking loop update processing for each channel be completed before new accumulation data is available for that channel.

The scheduler starts tasks related to network timekeeping and communication, reading and storing GPS measurement data, periodic tasks that include A/D and discrete I/O processing, synthesizer programming, and any other high-priority, short duration (less than 500 μsec) tasks.

A TIC flag is generated by the GP2021, and indicates when GPS measurement data have been latched. The default TIC rate is approximately 10 Hz. For the tracker, the rate is programmed to approximately 8 Hz (a period of 0.125000050 secs), and is used to latch odometer/wheel sensor data in addition to GPS measurement data. The 8 Hz rate allows simple power of two math for time intervals and reduces the measurement processing by 20%. GPS processing functions are required to keep the TIC rate periodic with GPS time, but it · ٦ot necessary (on the tracker) to align the TIC with the GPS integer second. As part of the navigation processing, the TIC periou . ˍdjusted for single TICs as required to maintain an average TIC rate of 0.125 seconds with respect to GPS time. The ACCUMINT dispatcher updates the TIC interval as required by the navigation processing.

The GP2021 chip has two UARTs, which do not generate interrupts so they must be polled. Each UART has an 8 byte FIFO (first in - first out). If the data rate on the UARTs is restricted to 38.4 kbps, then the FIFO can be filled about every 2 msecs. The CPU can service each UART every other ACCUMINT and not lose data. One of the UARTs is used to communicate with the MDT; and the other may be used for a suitable peripheral.

Time-critical RF communications tasks are run as required, which include setting up the TPU channels to:

- start and stop data clocks
- start and stop the QSPI
- turn on and off the transmitter
- program the TPU to detect the next bit-sync.

Scheduling these tasks requires a few milliseconds of resolution in some cases.

The tracker uses the QSPI for message transmission. The transmit data are line encoded in Miller format, which requires 288 code bits to be transmitted at 15625 bps for an equivalent of 144 data bits at 7812.5 bps. The QSPI output buffer can hold 256 bits, so the QSPI can be preloaded with 256 bits and then refilled with the remainder of the message a few milliseconds later. An additional data word (for at total of 304 bits) has to be clocked out to the RF card. A preamble of 8 bits precedes the data, and 8 bits follow the data after the transmitter is turned off to ensure the last data bit transmitted is low.

The tracker uses the TPU to clock data into external shift registers for receive data. Two FM data streams are received from spatially diverse antennas. The data is line encoded in Miller format which requires 9200 code bits to be transmitted at about 9328.36 bps, for an equivalent of 4600 data bits at about 4664.18 bps. A preamble and synchronization pattern of 64 bits precedes the data. The two data streams are clocked synchronously but processed independently. The bytes are read from the shift register on the falling edge of the latch clock, leaving 428.8 μsecs to read the data.

With respect to data collection tasks, TIC events signal that GPS measurement data are available from the GP2021 correlator. When these occur, the processor must read the data before the next TIC (about 125 msecs). The processor also reads wheel/odometer data. In the ISR, data is only stored -- data processing takes place under control of the PIT scheduler.

The tracker software also has a number of periodic, short duration tasks that can be run by the ACCUMINT dispatcher. These include A/D functions for reading data from the gyro and other data sources; as well as bit toggling for implementing simple serial interfaces for programming RF card synthesizers and the PIC used for power control of the Tracker Module.

The TPU is used for RF communication timing, RF data input and output clocking, and vehicle wheel or speed sensor inputs. As previously described herein, the TPU channels (16) and functions are summarized in **Table 56** (Appendix B).

In handling of wheel and speed sensor inputs from the dead reckoning navigation of the PROTRAK system, the TPU counts pulses from these sensors to measure vehicle speed. In the TPU, channels 13 and 14 are reserved for quadrature inputs from the wheel sensors, channels 12 and 15 are reserved for vehicle direction and cruise control speed sensor inputs, channel 15 runs an ITC function, and channel 12 runs a discrete input function. In most systems, a cruise control speed sensor is used.

The SCI UART on the Motorola 68332 processor is used for a magnetic compass interface or other relatively low data rate device (4800-9600 bps). When running, the SCI generates transmit or receive interrupts at approximately 1 msec intervals (at 4800bps). These interrupts must be serviced within 1 msec.

The PIT of the processor runs at 32 Hz, and in that mode the PIT ISR runs a prioritizing executive which performs the following tasks, in the following order of priority:

1. Communication and RF timing/scheduling tasks
2. FM data error decoding
3. Dead reckoning (DR) navigation (8 Hz solution propagation)
4. FM data parsing
5. GPS measurement processing (pseudorange/range-rate measurements, satellite acquisition)
6. Combined GPS/dead reckoning filtering (Kalman Filter update of DR solution)
7. GPS satellite visibility/channel allocation

For the executive, tasks are scheduled periodically or on demand in order of priority. High priority tasks are allowed to interrupt lower priority tasks.

The power supply architecture for tracker **135** includes four independent power supplies which run from input battery power (6-28 V). Referring to **FIGS. 25** and **26**, which are block diagrams of the internal power distribution to the tracker and power distribution summary, respectively, one of these supplies is a linear 5V supply **215** that provides power to the Microchip PIC™ microcontroller (μC) **216** used for master power control of the tracker. It also keeps an SRAM (not shown) powered so that machine state is maintained while the processor is off.

Microcontroller **216** runs on very low current and is on at all times, controlling a 5V CPU supply **217** and 12V radio supply **218**. 5V supply **217** is a switched power supply that provides power to CPU **203**, digital electronics and GPS receiver **204** of CPU section **200**. 12V radio supply **218** supplies power to the RF card **201**, and also powers the GPS antenna low noise amplifier (LNA) **219** through a 5V linear regulator **220**. Since the TCXO which ultimately drives the CPU clock resides on RF card **201**, CPU **203** requires both this supply **(218)** and 5V CPU supply **217** to be on. The last of the four independent power supplies is a 12V auxiliary supply **222** that provides regulated 12V power to all external peripherals (e.g., MDT **190**, compass **230**, and others **232, FIG. 26)** designated by **223** (in **FIG. 25)** and power to an on-board gyro **224** through a 5V linear regulator **225**. CPU **203** controls this 12V auxiliary supply **222**. The tracker also receives 12 volt discrete input **226** to the CPU **203** and microcontroller **216** which indicates that the ignition switch **233** is in the RUN/ACC position.

Microcontroller **216** controls power to tracker **135**, and, together with the CPU's SRAM, remains turned on at all times. These two draw less than 5 mA of current. When the ignition discrete indicates that the switch is in the RUN or ACC position, microcontroller **216** turns on CPU **203** and power supplies **217** and **218**. When the ignition is off, CPU **203** can command microcontroller **216** to turn off the power for time intervals between 5 and 630 minutes, or until then ignition is turned on, which ever occurs first.

Tracker **135** supports power saving modes so that vehicle battery power consumption is minimized when the vehicle ignition is turned off, and which also have radio network control and data retention implications. The tracker power saving modes are:

- Full On: Tracker **135** and external peripherals are turned-on and operating normally.
- Peripherals Off: Tracker **135** is on and operating normally, but auxiliary 12V peripheral power supply **222** is off. Peripherals are turned off immediately or, if desired, within a predetermined time T1, e.g., 1-2 minutes after ignition turn off, which inhibits DR navigation because both internal gyro **224** and the external compass **230** will be off.
- Sleep: With the ignition off, CPU **203** is turned off for a prespecified time duration T2 (e.g., about 40 minutes). When the CPU is turned back on (Peripheral Off mode), it can listen for any new message or other data, respond and then turn off again. Sleep mode allows login-only and continuous track systems to receive data from the command station while the ignition is off. Poll-only vehicles will remain in Sleep mode and not wake up until the ignition is turned on. The system also remains in Sleep mode if the battery voltage drops below a predetermined lower limit.
- Off: In this mode, power is not applied to the tracker.

Depending upon specific customer requirements, the tracker power saving mode control may vary, e.g.:

- Emergency vehicle operators may want the system to always be in Full On mode to enable ability of the CCS to communicate at all times (via the TDMA network) with the vehicle.
- Some users may prefer a staged power saving approach in which vehicles that are periodically turned on and off, such as delivery trucks, remain in the network while turned off.

FIG. 27 is a diagram illustrating the logic for the power mode control state transitions of the tracker **135**. Time durations T1 and T2 are set as desired. The Sleep Time is the off time commanded by the CPU for the Sleep Mode **240**. The mode transitions and network related operation in each mode are as follows.

The Off state **241** is reached when external battery power is removed from the tracker. When battery power is applied to the tracker, the power control processor (microcontroller **216**) resets and turns on the CPU **203** and radio supplies **218**, turning on the tracker, but leaving peripherals **223** turned off (mode **242**).

In the Full On mode (**243**), the RF and CPU sections **201** and **200** are turned on. The system will navigate and operate in the RF network normally. Continuous Track (CT) trackers are assigned periodic transmit slots. Login-Only Track (LOT) trackers are assigned periodic transmit slots if the respective customer is logged in. Without a customer (i.e., fleet subscriber or owner) being logged in, these units will occasionally attempt to enter the network or remain quiet until notified by the NDC that their owner has logged in. Poll-only trackers will attempt a network entry and then remain quiet until requested to transmit.

When the ignition is turned off, peripherals (e.g., MDT **190**, magnetic compass **230**, if attached, etc., and the internal gyro **224** (optional)) powered by the tracker are turned off immediately, or after time duration T1 expires (mode **242**). The compass and gyro navigation sensors are turned off based on the assumption that if the ignition is off, the vehicle will not be moving. The tracker will return to the Full On mode **243** if the ignition is turned back on.

From the Peripheral Off mode **242**, the LOT and CT trackers may enter the Sleep mode **240** after a time duration of T2 since the ignition was turned off. To reach Sleep, the tracker requests a low-power periodic network slot from the NDC which has a long transmit interval. When the slot is granted, the tracker stores necessary data to an area in SRAM, saves any data to flash memory as required, and commands microcontroller **216** to turn off CPU **203** for a sleep period of a few minutes less than the low-power transmit interval. Poll-Only trackers will request low-power shutdown from the NDC. When the shutdown request is acknowledged or times out, the tracker stores data to SRAM and flash memory, if required, and commands microcontroller **216** to turn off CPU **203** until the ignition is turned back on.

When microcontroller **216** wakes the tracker (actually, the CPU **203**) from Sleep mode **240**, the CPU checks battery voltage and the previous system state stored in SRAM. If the tracker is in a low power slot, it will listen to the FM subcarrier data for a 3-4 minute window around the slot time to determine if the NDC sends any information meant for it. At this time, the NDC has the opportunity to send the tracker message or other data. Once all network transactions are complete, the tracker will again command the microcontroller to turn the CPU off.

If the ignition remains off for a predetermined time duration or the battery voltage drops below the minimum threshold V_{MIN}, the tracker will request a low-power shutdown from the NDC on its next transmit opportunity. When the shutdown request is acknowledged or times out, the microcontroller **216** is commanded to not awaken the

CPU **203** until the ignition is turned back on.

SRAM state recovery is achieved as follows. Since the entire contents of the global variables and stack are maintained during Sleep mode **240**, CPU **203** may restart a specific point in the code with all data intact. This can be done if the registers, program counter, and stack pointer are pushed onto the stack, and the stack pointer is stored at a known location. A CRC must be performed on pertinent parts of the SRAM to ensure data integrity on restart, after which the CPU is allowed to send a power down command to the microcontroller. On reset, the CPU checks the CRC on the SRAM to determine if it was restarting. If so, the software sets appropriate flags, and then retrieves the stack pointer and registers from the stack. It is then able to jump to the point at which it left off before powering down. If the CRC on the SRAM fails, the CPU executes a normal startup.

When the tracker is turned on, it must search for the SCC broadcast on the received FM subcarrier. Under normal conditions, the tracker will have channel information stored in flash memory for the primary FM channel to be used, and will initially search channels and subcarriers that it has stored in memory. If no SCC synchronization patterns are found, it must systematically search all FM channels and subcarriers. To that end, bit-sync hunt is performed by searching for a predetermined unique synchronization pattern. If the bit-sync event is missed (i.e., not all three pulses occur within the expected time window) no new correction is applied, and the clock is allowed to free run. The time estimate is still updated based on changing distance to the transmitter if navigation data are valid. If the bit-sync is missed continuously for more than 20 seconds, the error in the integer second time estimate may drift out of allowable limits. When this occurs, the CPU must resume bit-sync hunt on the current and other available FM channels.

Timing and clocking for tracker (and Net Hub) FM data reception, are handled as indicated by the timing and clocking diagram of **FIG. 28**. The clocking of received FM data **246** is scheduled by CPU **203** to begin at a specific TPU timer value which is not directly related to the FM data synchronization pattern **247**, but is related to the estimated integer second time plus the estimated speed of light delay **248**. Timing in the Figure is indicated in units of TPU 5 MHz TICs. The rising edge of the shift clock **250** causes bits to be shifted into an external shift register. The rising edge of the latch clock **252** latches the received byte in the output of the shift register. CPU **203** receives an interrupt on the falling edge of the latch clock to read in the data, with 428.8 μsecs to read the byte.

The difference **253** between the time of received synchronization pattern and the time it was expected by the CPU is shown in **FIG. 28** in exaggerated scale. Difference **253** is normally less than 20 μsecs, caused by vehicle motion, clock errors between the SCC and the tracker/Hub, and jitter and other errors caused by the FM receiver. CPU **203** uses the average difference for the three pulses to correct its current estimate for the integer second time for the next second.

Tracker UHF data transmission, timing and clocking are handled as shown in the tracker data transmission timing and clocking diagram of **FIG. 29**. On the frame just before or during the frame the tracker is to transmit, the real-time executive must schedule the data transmission tasks. The tasks are scheduled to run with appropriate lead time (up to 6.5 msecs) to start TPU tasks to generate output state changes at the desired TPU timer values. The transmitter key and serial data clock should be precisely started and stopped. The first 16 bytes of the output data are loaded into the QSPI shift register before transmission begins, and the last part of the data is loaded before the QSPI empties. Times indicated in **FIG. 29** are also in units of TPU 5 MHz timer ticks. TPU channel 3 may be required to count output bits so that the data clock and QSPI can be stopped gracefully.

Of course, data transmitted by the tracker includes information to identify the precise location or position of the vehicle in which the tracker is installed. As previously noted herein, the tracker utilizes high performance dead reckoning (DR) navigation to provide vehicle position and velocity data in urban canyons where GPS measurements are only intermittently available. The DR sensors include speed measurement which, in the present exemplary embodiment, is preferably based on the vehicle's cruise control speed sensor, if available, and an azimuth gyro and possibly a magnetic compass which are utilized for heading determination. A reverse direction sensor may be tied to the tail lights. These sensors are calibrated through the use of a Kalman filter based on DGPS corrected raw measurement inputs. The accuracy goal for the DR navigator is 0.2% of distance traveled (95% probable) after 4 minutes of DGPS measurement availability over a "typical" vehicle trajectory.

DR algorithm requirements take the following into account. Update rate of the DR navigation system is about 8 Hz in the presently preferred embodiment. Azimuth gyro data are sampled at a high rate (about 100 Hz) and integrated to propagate an estimate of heading. Speed sensor or wheel pulse count data are sampled with high priority to ensure regular time tagging intervals at 8 Hz and are transformed through heading and integrated to propagate an estimate of position.

GPS measurement requirements include pseudorange measurements available from the GPS section of the software at 8 Hz. These measurements are sampled and pre-processed as required. The GPS measurements are used by a Kalman filter run at two second intervals. Either the latest available measurement or an average of measurement data available up to the update time is used. The Kalman filter requirements recognize that the Kalman filter used to blend DGPS and dead reckoning data must support and estimate sensor error states with enough fidelity to achieve the desired dead reckoning navigation accuracy. In addition, the Kalman filter supports coarse alignment (heading error uncertainty larger than a small angle) and operates when some aiding sensors (such as a compass) are not connected.

A raw measurement filter must have three dimensional position and velocity error states and a good clock error model. Filter error states include:

- 3 Position Error (NED)
- 3 Velocity Error (NED)
- 1 Heading or Wander Angle Error State
- 2 or 3 Clock Error States
- 2 Gyro Error States (bias and scale factor)
- 2 Odometer Error States (scale factor and scale factor non-linearity)
- 1 Compass alignment error state

Magnetic compasses typically have error characteristics that vary sinusoidally with heading, so it is important to utilize an efficient method to handle the variable compass alignment error. Compass errors may be handled outside the structure of the Kalman filter. The processor has a temperature sensor which can be used for temperature compensation of the gyro.

When the navigation system is turned on, it can be initialized from position and heading stored at power down. However, these data are not entirely reliable, so initial co-variances must be large. If the system has a magnetic compass, initial measurements from it may be corrupted by nearby magnetic fields. The filter must be able to support a "coarse-align" mode, which typically involves using error states that are the sine and cosine of the heading/wander angle error because error propagation is linear with these terms. Once the sine and cosine errors are small, the system can switch to a single heading error state.

The Kalman filter propagates the error model for the dead reckoning process based on gyro and speed sensor data. It also propagates aiding sensor error models including GPS clock errors and compass alignment errors. Measurements available to the filter include:

1) GPS pseudorange
2) Compass magnetic heading
3) Gyro bias at zero velocity

Zero velocity (zero angular rate) measurements are only available when the vehicle is stopped.

The Kalman filter error propagation and update cycle may require more than one second to complete. When filter processing starts, measurement data and error model information must be latched in software so that 8 Hz dead reckoning navigation solution propagation can continue in real-time while the filter operates on the previous cycle's data.

Time tagging of dead reckoning and GPS measurement data is critical to successful navigation. Dead reckoning speed sensor pulse counts and gyro data are sampled so that they are valid at GPS TIC events. The GPS raw measurements are also valid at the TIC events, so that time alignment may be performed in a simple manner.

Part of the Kalman filter estimate is a bias and velocity error of the receiver clock (the master 10 MHz TCXO). Because of this error and the inability to set the TIC interval precisely, the TIC interval drifts slightly from a true 8 Hz rate with respect to GPS time. It is desirable to account for this error and periodically adjust the TIC interval to correct for the drift.

The tracker has several analog inputs which must be shared through a multiplexed A/D. The highest priority analog input is the gyro, which must be sampled at between 50 Hz and 100 Hz when the vehicle may be moving (i.e., at any time the ignition is on). The battery voltage is monitored, mostly when ignition is off to ensure the unit is not draining the battery. Several external analog sensors may be connected to the tracker to provide customer specific information on vehicle parameters. Requirements for monitoring of these sensors is customer specific.

The RF card has a Received Signal Strength Indicator (RSSI) that is sampled periodically to determine the strength of the FM subcarrier broadcast. The temperature sensor on the CPU board is yet another analog signal, used for gyro calibration.

Parameter storage handling is an important aspect. The tracker CPU card uses flash memory for long term parameter storage when the unit is off or disconnected from vehicle power. The SRAM is backed up by vehicle power so that short term, sleep mode storage of the machine state will remain intact. Data is stored to flash memory on a daily or weekly basis so that loss of power will only cause the most recent data to be lost.

The CPU card has, for example, 512 K bytes of bank-erasable flash memory. The program and constant data preferably occupy the lower half of the memory, with the upper 256K reserved for parameter storage. A disadvantage of flash memory is that if any bank is being written or erased, the entire device is unavailable, until the operation completes. Since the code is in flash memory, care must be taken when writing to the device. The code which writes to flash must run in RAM with interrupts disabled. Erasing must use the suspend erase feature of the device. This is implemented with interrupt handling while the erase is being performed. In most cases, writing and erasing flash memory will occur when the CPU intends for the microcontroller to turn it off. Therefore, it is not a problem to disable all of the interrupts because no navigation or radio communications will be taking place.

The flash memory device is word (16-bit) addressable. Data written to flash must be done word-wise on even byte boundaries. Bytes can be read on odd byte boundaries, however.

As a storage method, a Linear File Store (LFS) system is preferably used to store parameter data. This method generates a linked list of variable length records which extends to fill a block of memory. When the block becomes full, the records not marked for reclamation are copied to a new block, and the old block is erased. The file system must recover from power loss during writing and reclamation. The LFS approach supports robust handling of power loss conditions. Records stored in flash memory should have a CRC or checksum to ensure the data are valid.

Parameter data are stored in at least one bank of flash memory, and updated periodically as new information becomes available. The flash memory stores the following types of data:

1. GPS satellite almanac data for satellite acquisition: New almanac data is stored on a weekly basis. It is read when the CPU is turned on and written when new data from the satellites is at least one week newer than the stored data. A full set of almanacs requires 2K of memory.
2. PROTRAK system market information: Data on the location and frequencies of the FM subcarrier transmitters used in each market is stored as the data are transmitted from the NDC. Storing this information allows the tracker to search known PROTRAK frequencies for the NDC broadcast data, thereby speeding system initialization. The navigation grid centers and UHF transmission frequencies for each market are also stored. Adequate space should be reserved for these data to allow 5-10 sets of data to be stored.
3. Tracker Serial Number: The unit's serial number is stored in flash memory, and is never erased or modified, except at the factory. Serial number and customer/device specific configuration data are stored separately from the parameter data in the flash memory.

Other parameters are defined as required.

The tracker supports log data, e.g., logging of position and other sensor information to flash memory for later download. This is useful for determining the location of a vehicle when it moves outside the service area; and, on return to the service area, the data can downloaded through the MDT interface or the radio.

VIII. *Mobile Data Terminal*

The MDT **190** serves as a control and display unit (CDU) for the tracker **135** **(FIGS. 23, 26)**, primarily for the convenience of the vehicle operator. The MDT is a small conventional programmable computer similar to but generally smaller than a notebook PC (with customer-specific software) and display terminal with liquid crystal display (LCD), keypad, associated memory, and internal (integrated) circuitry, to enable display of text and other data, and to enable the vehicle operator to respond to text paging messages and to enter other data to be transmitted to the dispatcher. MDT **190** and tracker **135** communicate over a balanced, differential, asynchronous serial interface, which, in the exemplary embodiment, uses a Texas Instruments (TI) SN65C1167NS dual differential driver/receiver interface circuit. Tracker **135** supports "standard" baud rates up to 38400 bps, and MDT **190** should support a baud rate of at least 4800 bps. Programming of the

MDT is controlled through the serial interface as well. The protocol and message formats, as well as the power and programming interfaces, are described in further detail below.

The preferred serial interface protocol for communication between the tracker and the MDT, and which is also used in other PROTRAK system serial interfaces, is based on the Rockwell NavCore V GPS engine interface described in the Rockwell International "NavCore Designer's Guide," Rev. H, 14 December 1993 (hereinafter referred to as the NavCore interface protocol). The MDT interface uses different baud rates and message timing.

In keeping with NavCore and other message numbering conventions, each interface is identified by a different thousands place in the message ID number. The MDT-tracker interface uses 7000 as the interface identifier. Messages transmitted by tracker **135** use ID numbers beginning with 7100 and messages received by it use ID numbers beginning with 7200. In the exemplary embodiment, the message IDs are:

For tracker to MDT:
- 7101 Navigation Data
- 7102 Received Message Data
- 7103 Received User Data
- 7104 Available Message Data
- 7106 User Data Message List

For MDT to tracker:
- 7201 Data Request
- 7202 Text Message Response
- 7203 User Data Output
- 7204 Request Available Message Data
- 7205 Request Message
- 7206 Request User Data Message List

When requested by MDT **190** (by action of the vehicle operator), tracker **135** sends navigation data (message 7201, **Table 57**, Appendix B) including current position, velocity, and time at approximately 1 Hz to the MDT. When the tracker receives a "Request Message" (7205, **Table 66**) from the MDT, it sends the data for the requested text message to the MDT using a "Received Message Data" packet (7102, **Table 58**). The latter either contains the full text of the received message or an ID number indicating a "canned" text to display. A response set is sent along with the text message, containing a unique set of text items that can be selected by the vehicle operator in response to the received message.

Each message has an identifier, or issue of data (IOD), a rollover counter, to differentiate messages within the system and to associate messages with their responses. When the operator selects a response to a message (e.g., an inquiry from the dispatcher), that message's IOD is sent back to the tracker with the response in message 7202. The response is selected using arrow keys on the face (keypad) of the MDT. The MDT stores the text, which can be up to a maximum of 80 characters, of a single message while it is displayed for the operator. The text of each response may be limited (e.g., to about 10 characters) attributable to screen size.

In the "Received Message Data" (**Table 58**), the Message Type indicates whether the message contains a canned or full text message. If the message is canned, the next byte contains the ID number of the message; otherwise, it contains the length in bytes of the received message text. The next 2 bytes contain the IOD number of the received text message and the user response if a message has already been sent. The next 3 words indicate the date and time the message was received. The next word contains the number of valid responses in the response list. Next is the list of 4 text responses to be displayed above softkeys of the MDT. Unused response strings are zero filled. If the message is full text, the characters of the message follow in order. For an odd number of bytes, the last message byte is set to 0. The data checksum follows the response set in the case of a canned message or the text data in the case of a full text message.

The tracker receives customer-defined data from the NDC in a packet consisting of a data identifier (1 byte) and 20 bytes of data. Depending upon customer requirements and the type of data received, the tracker either acts on the data itself, or relays it to the MDT by sending a "Received User Data" message (7103, **Table 59**) for vehicle operator attention. At the MDT, customer-specific software processes the received data.

The tracker is capable of receiving and storing numerous text messages from the NDC. When the tracker receives a new message (as well as at periodic intervals), it sends an "Available Message Data" message (7104, **Table 60**) to the MDT, indicative of the number of unread messages and the number of saved messages, as well as a unique ID for each message for use to retrieve a specific message from the tracker. Upon receipt of this message 7104, the MDT periodically beeps a speaker or other alert device (e.g., a lamp, LED, or the LCD display itself) within the MDT if the number of unread messages is not zero, to informs the vehicle operator of unread messages needing a response. Individual unread messages are retrievable from the tracker by the driver sending a Request Message (7205, **Table 66**) from the MDT.

Tracker **135** is programmed with a set of canned "User Data" messages, a list of which (message 7106, **Table 61**) may be requested for display on the MDT by the driver's sending "Request User Data Message List" message (7206, **Table 67**). Upon subsequent receipt of a "Request Message" for a specific "User Data" message, the tracker will provide the text of that requested message to the MDT. Each message is a fixed 30 characters in length with unused locations set to 0x00.

A number of status and debugging messages are available from the tracker for periodic output, and the MDT can request that these messages -- or specific ones of them by designation of message ID -- be turned on or off by sending a "Data Request" message (7201, **Table 62**). By default, all of the available ones of these periodic messages are off. Once such a message is turned on, however, the tracker will continue to output it periodically, until the message is turned off or full power is removed from the tracker.

When the vehicle operator selects a response to a received text message, the MDT sends that response to the tracker using a Text Message Response message (7202, **Table 63**) which contains the IOD of the message being answered and the numeric response value.

The tracker is used to send customer-defined data to the NDC and on the dispatcher or subscriber via the Hub(s), using an output packet consisting of a data identifier (1 byte) and either 1 or 9 bytes of data, with customer-specific MDT interfaces that allow data entry. The data may consist of emergency requests, or a simple status of the vehicle as "job complete," or more complex information. In any case, after data entry it is sent from the MDT to the tracker by means of a "User Data Output" message (7203, **Table 64**), for transmission by the tracker to the NDC. The message is fixed length with actual space for 10 data bytes, and only 1 or 9 is meaningful based on the LSB of word 6. The remaining data bytes have their values set to zero.

When the vehicle operator desires to view any saved messages, he or she inputs MDT **190** to send a "Request Available Message Data" message (7204, **Table 65**) to the tracker to retrieve the list of available text messages, and the tracker responds with a list of the "Available Message Data" (7104, **Table 60**). Thereafter, a "Request Message" (7205, **Table 66**) is sent by the vehicle operator from the MDT to retrieve from the tracker a specific one of the available text messages from those contained in the list. As noted above, a "Request User Data Message List" (7206, **Table 67**) is sent by the vehicle operator from the MDT to retrieve a list of the canned "User Data" messages stored by the tracker.

Returning to power considerations, tracker **135** supplies 12 VDC power to MDT **190** as previously indicated in **FIG. 26**, with maximum current drawn by the MDT, including power-on and back light turn-on, preferably limited to 0.5 A. The MDT has a single interface connector, which is a printed circuit board mounted 9 pin D type in the present exemplary embodiment. The connector signals from the tracker to the MDT are:

1. Boot Load Control (not connected)
2. + RX Data
3. - RX Data
4. + TX Data
5. - TX Data
6. Ground
7. +12V
8. +12V
9. Ground

MDT read-only memory (ROM) is programmable through the serial interface. The MDT is put into programming mode by asserting (pulling low) a Boot Load Control signal, and is then programmed by sending blocks of data through the serial port.

IX. *Network Hubs*

Referring now to the simplified block diagram of an exemplary Network Hub in **FIG. 30**, the Hub **11** receives vehicle data transmissions, recovers the binary data, and sends the data to the NDC via a telephone line. The Network Hub includes an FM radio receiver **85** (which is identical to the FM radio receiver in each vehicle tracker) to receive broadcast messages for timing purposes, a UHF radio receiver **81** to receive vehicle transmissions, and a modem **87** for communication with the NDC.

The Network Hubs are installed at strategic points -- typically, leased space on existing radio towers in and around the metropolitan area being served -- to receive vehicle data transmissions. The Hubs require only 110V AC power and business quality telephone line to operate. In a typical market, between 10 and 30 Hubs are needed to serve the various fleet operations calling for vehicle tracking. This relatively small number of units and need for high RF performance makes cost a less significant factor for the Hubs than for the trackers in the vehicles. FM and UHF receiver sensitivity and system reliability are very important.

Each Network Hub is divided into four major functional areas, namely: 1) CPU **82**, 2) Power Supply **84**, 3) Modem **87**, and 4) RF Card **86**. The CPU **82** corresponds closely to the tracker CPU, using a Motorola 68332 microcontroller running at 20 MHz. The 68332 is ideally suited for this application because of the SCI, QSPI, and TPU peripherals. Hub CPU **82** utilizes processor, SRAM, and flash memory as in the tracker, but does not require the GPS section of the tracker. Other similarities/differences to/from the tracker CPU in the Hub CPU are the addition in the latter of a TCXO, level conversion for the modem interface, and replacement of the UHF transmitter interface with a UHF receiver interface, but retention of the same FM receiver interface. The CPU flash memory is in-circuit programmable through a header or connector using the processor's BDM mode interface.

The Hub uses the FM data stream, which is at a rate of about 4664 bps from the FM receiver **85**, for system time synchronization just as the trackers do. The FM data is intended to be used by trackers, but still must be decoded at the Hub to the extent required to derive the timing data. The TPU in the 68332, to which the FM data stream is sent, and software running on the CPU use bit-synchronization information in the FM data stream to enable the TPU to generate the bit and byte data clocks used to control a shift register **88** on the CPU card, which also receives the FM data stream, and clocks the data into the processor **83**. As with the tracker CPU, the Hub CPU is responsible for programming the FM frequency and subcarrier offset of the RF card over a serial interface.

For the UHF receiver interface, the UHF receiver **81** uses a DSP microprocessor **80** to extract the bit and byte clocks from the received UHF data stream. The processor on the UHF card is provided with timing information from the CPU, by which it can determine the windows in time to search for the received vehicle data.

The 68332 microcontroller **83** uses the peripheral SCI UART to communicate with external USRobotics modem **87** which has an RS-232 interface. Conversion is performed between 5V and RS-232 level signals. The SCI supports a bit rate of 19200 bps, generating up to about 2800 receive and transmit interrupts per second, with the modem connecting at 14400 bps. If support of faster bit rates is desirable, it may be attained using an external UART with a FIFO or including the GP2010 and GP2021 components of the GPS chip set to provide buffered, poled UARTs.

The power supply **84** converts 110V AC to 12V DC for the CPU and RF sections of the Hub which separately regulate power to 5V DC so as to isolate the two sections. AC to DC conversion is performed by an off-the-shelf linear power supply and transformer.

Modem power is supplied via a plug-in transformer, and the CPU provides the serial interface signals to support hardware flow control with the modem. The CPU software controls the modem to dial the NDC, login, and verify that the connection is operational. If the connection is broken, the Hub will hang-up and re-dial to re-establish it, repeatedly re-dialing until a connection is made if the NDC modem does not answer initially. The NDC phone number and the Hub user ID and password are stored in CPU flash memory. A connection speed of 14400 bps is used to maximize connection reliability. An EMI (electromagnetic interference) hardened modem may be needed in some situations since the system operates near RF transmitters.

The RF section **86** of the Hub receives the NDC broadcast on the FM subcarrier at FM receiver **85**, and receives the TDMA vehicle transmissions on a UHF channel at UHF receiver **81**. The data are provided to the CPU as serial streams. The CPU generates the data clocks for the NDC broadcast data as well as programs the receive frequencies of the RF card, and the RF card generates the clocks for the vehicle data.

The FM subcarrier data is on a 67 KHz or 92 KHz offset from normal FM channels, and the FM receive frequency and offset are fully programmable by the CPU. The subcarrier data is modulated by the SCA-300B **68 (FIG. 6)** which uses a simple BFSK modulation scheme.

The vehicle trackers transmit data packets at assigned times on a frequency in the UHF business band, the UHF receive frequency also being programmable by the CPU in 12.5 KHz offsets between 450 MHz and 470 MHz. For efficient use of available bandwidth, the vehicle data rate is 7812.5 bps.

The CPU software enables it to perform its primary tasks, including time synchronization to the TDMA network, communication with the NDC via modem, RF card programming and control, reception and decoding of FM subcarrier data, and reception of vehicle UHF data and relay of the data to the NDC. Various software functions are written to be common with the same functions in other parts of the system. For example, many functions related to modem communication with the NDC are identical to those used in the SCC, although the serial data messages are different and the Hub must dial and login while the SCC is not required to do so. RF synthesizer programming, FM data reception, and FM data stream time synchronization code are identical to that of the tracker.

X. *Subcarrier Control Computer (SCC)*

The Subcarrier Control Computer **48** (**FIG. 6**) hardware of an exemplary embodiment is shown in the simplified block diagram of **FIG. 31**. The SCC controls the transmission of the NDC base broadcast message. The message is clocked out to SCA-300B subcarrier modulator **68** with precise message start times and a precise data rate. The SCC is preferably rack mounted along with the subcarrier modulator at the FM radio station **12**. NTCC **47** at NDC **10** dials the SCC modem **57** to connect SCC **48** to the NDC. NTCC **47** provides the broadcast message data to be sent by the SCC to modulator **68**, and the NTCC also controls the time at which each transmission begins.

CPU **260** of the SCC (as in the examples of the CPUs used for the Net Hub and the tracker, preferably a 16 MHz Motorola 68332 processor) uses a peripheral SCI UART (see, e.g., CPU **83** of the Net Hub of **FIG. 30**) as the interface for communication with external (preferably USRobotics) modem **57** via an input/output (I/O) card **262**. A conversion is made between 5V and RS-232 level signals. The modem is set to communicate with CPU **260** at 19200 bps, and is allowed to connect to NTCC **47** at rates between 14400 bps and 19200 bps. At this communication rate, the SCI can generate up to about 2800 receive and transmit interrupts per second.

CPU **260** uses the peripheral QSPI of the 68332 device (see again, e.g., CPU **83** of the Net Hub of **FIG. 30**) for the subcarrier modulator interface, to send the serial transmit data to subcarrier modulator **68**. Here also, a conversion is made between 5V and RS-232 level signals. The QSPI is clocked by the TPU of the 68332 processor for precisely controlled clock phasing. The output data rate is approximately 4664.18 bps (2.5 MHz/536). However, the transmit data is Miller encoded so that 2 Miller code bits are transmitted for every data bit (9328.36 code bps), for a divisor of 268. The OC (output compare) TPU function uses a half cycle count of 134. An existing RF serial clock from the TPU to the QSPI is used for the output data clock.

Transmit data timing and clocking requires three TPU channels, since starting the data clock at the correct time requires using two additional TPU channels. The first TPU channel is wired to the second channel. On the first channel, the CPU initiates a single transition OC at a desired time and programs a third channel for OC with continuous pulse mode with a precise timing control register (TCR) start time equal to the actual desired start time. The second channel is set up to run ITC (input transition count/capture) with a link to the third channel. When the processor initiates the transition on the first channel, the TPU, through the ITC link, starts the data clock on the third channel at the precise start time.

In keeping with the precise timing required by the PROTRAK system, SCC **48** is run directly from a 1.5 ppm TCXO crystal oscillator. To maintain common bit rates between the SCC, the Network Hubs and the trackers, which run at 20 MHz, the TPU of CPU **260** is run at 10 MHz. The real time executive is run at a 1 KHz rate which allows the required programming resolution of the TPU functions. The executive needs the value of the TPU TCR counter at each executive timer tick so that executive time can be synchronized with the TPU timer for programming of data transmission functions. To that end, it is convenient to use the ITC TPU function to generate interrupts for the executive. Interrupts are generated by detecting transitions from a second TPU channel running a pulse-width modulation (PWM) function at the desired executive rate.

CPU **260** initiates a 50% duty cycle square wave on the first channel of the TPU. The PWM frequency should be a convenient divisor of 2.5 MHz; a half period width of 2500 (1 KHz executive rate) is deemed adequate. The output of this channel is fed into the input of the second channel which runs ITC. The ITC samples TCR1 and interrupts the processor on every transition of the PWM signal. The executive can then read the

TPU register to determine the TCR1 value at that interrupt TIC.

The primary function of SCC **48** is to transmit the base broadcast message provided by NTCC **47** at a precise 1 Hz rate, synchronized to the GPS integer second. NTCC **47** listens to the SCC initiated broadcast and controls the timing by comparing the start of each received broadcast message to GPS time, computing a timing correction based on the difference between the time of reception and GPS time and sending a correction back to the SCC. SCC **48** then adjusts the transmission time of the subsequent messages based on this correction. This timing process has been described in further detail hereinabove.

The NTCC **47** modem interface is implemented such that the SCC **48** will answer the call placed by the NTCC to its modem. The SCC receives broadcast message data and timing control commands over the serial interface, with the broadcast message from NTCC **47** typically being sent in five packets. The SCC then assembles the packets in order and sends the message data to subcarrier modulator **68** on the next integer second. An LCD panel display **263** on SCC **48** is used to display status and debugging information.

A number of software functions are written to be common with functions in other parts of the system. For example, many functions related to modem communication by the SCC with the NTCC are identical to those used in the Network Hub. However, the serial data messages are different and, unlike the SCC, the Hub must dial and login. Parts of the time synchronization code and executive are common with the Network Hubs and trackers.

During normal operations, SCC **48** receives 5 blocks of 155 bytes of data from NTCC **47**, to be transmitted each second on the FM subcarrier broadcast by radio station **12**. The SCC Miller encodes the data, inserts a preamble and synchronization pattern at the beginning, and places the resulting 9264 bits into an output buffer. Before the next transmit time, the output data clock is stopped and set to start again at the next desired start time as commanded by the NTCC. The QSPI output buffer is primed, and CPU **260** toggles a TPU output channel to start the transmit synchronization process.

For NTCC-SCC synchronization, NTCC **47** coordinates the timing of sending the broadcast data to SCC **48** by basing it on the time of reception of an SCC Status message (see **Table 72** of Appendix B, referenced in the NTCC Section discussion below). The

SCC sends this message each time it initiates a data transmission. At that time, NTCC **47** sends new broadcast data message (1102, see **Table 71** of Appendix B, also referenced in the NTCC Section discussion below). This timing scheme ensures minimum latency of the broadcast data, and eliminates timing ambiguities between the NTCC and the SCC attributable to the lack of an absolute time reference at the SCC.

The complete 5 blocks (575 bytes) transmitted by NTCC **47** requires approximately 500 msecs to be sent to SCC **48**, at 14400 bps. The SCC allows a total of about 900 msecs for the reception of new data before the processing must be completed for transmission of the data on the next second. This extra time allows for retry of one or two message blocks that may have been corrupted. A higher connect bit rate will allow additional retries, but with the possibility that it may be less reliable. Invalid broadcast data from an NTCC message with a valid header should be transmitted even if an error-free retry from the NTCC is not available, because the Golay coded data may be correctable by the vehicle trackers themselves.

For message data processing, SCC **48** forms the complete transmit data buffer by putting the preamble and bit-sync pattern in the buffer and then appending the data. The transmit data is sent by the NTCC to the SCC with non-return to zero (NRZ) line coding. The SCC is required to Miller encode the data, which converts the 4600 NRZ data bits to 9200 Miller bits. The encoding process takes about 12 - 15 msecs. Miller code uses memory of the previously encoded bits so it can only be performed on a data block if the previous block has been received. The preamble is an alternating one-zero Miller bit pattern inserted before the bit-sync pattern: 11 00 11 00 11 00 11 00, with the left most bit transmitted first. The bit-sync pattern is 48 Miller bits long and is 9 high bits followed by 7 low bits, repeated 3 times.

The QSPI of the 68332 processor of CPU **260** is used as the output shift register. The internal QSPI buffer holds 16 bytes if it is configured for 8 bit transfers. With 8 bit transfers it will empty every 13.72 msecs, so a task must be scheduled in the real time executive to service the QSPI queue. The QSPI sends data with most significant bit first, which is taken into account when forming the preamble and bit-sync patterns and when loading the QSPI.

The NTCC/SCC data flow is illustrated in the timing diagram of **FIG. 32**. SCC **48** simultaneously sends broadcast data **265** for the current frame and received data **266** from the NTCC for the next frame. After about 900 msecs into the current frame (at **267**), the SCC must cut off reception of data from NTCC **47** and begin processing the available blocks. If data blocks are completely missing, the SCC assumes the NRZ data to be all zeros and performs Miller encoding accordingly. SCC **48** must also compute a new transmit time based on received commands from the NTCC. The TPU is programmed with the new transmit time during the gap time **269** between the broadcast data transmissions.

All of the transmit timing and synchronization occurs in the approximately 6.9 msec gap time **269** between transmissions. During this time, SCC **48** performs the following steps to begin transmitting the data for the next time:

1. Stop the QSPI.
2. Turn off the OC data clock on TPU channel 3.
3. Switch the output data buffer to the newly received data.
4. Program TPU channel 3 for continuous pulse mode to start at the next transmit time.
5. Load the QSPI with the new data and enable the QSPI.
6. Send the SCC status message to the NTCC.
7. Toggle TPU channel 1 OC state to start the synchronization process.

Transmit data timing and clocking requires 3 TPU channels: Channel 1 is programmed to be a single transition OC function, which is set up to toggle during the gap time by the CPU. The output of channel 1 is wired into the input of channel 2.

The channel parameters are:

PSC = 11	do not force any state
PAC = 010	toggle on match
TBS = 0100	output channel, match TCR 1
OFFSET = 0	
(REF_ADDR 1) =	TCR1 time for transition
(REF_ADDR2) =	don't care
(REF_ADDR3) =	don't care

Channel 2 is programmed with the ITC function to continually generate links to channel 3. The ITC is set up to trigger on any transition.

The channel parameters are:

PSC = 11	
PAC = 011	detect either edge
TBS = 0000	input channel, capture TCR1
MAX_COUNT = 1	

START_LINK_CHANNEL = 3
LINK_CHANNEL_COUNT = 1
BANK_ADDRESS = unused TPU parameter RAM location

Channel 3 is programmed with a continuous pulse OC function. This is the output data clock and is wired to the clock input of the QSPI. During the gap time, it is reprogrammed with an updated REF_TIME which is the transmit start time.

The channel parameters are:

PSC = 10 force low on initialization
PAC = 010 force low on match
TBS = 0100 output channel, match TCR1
RATIO = IFF
(REF_ADDRI) = don't care
(REF_ADDR2) = 134
(REF_ADDR3) = transmit TCR1 time

The reference address pointers point to locations in TPU parameter RAM (random access memory). Therefore, the parameter space of unused channels must be used to store the data for this channel. Interrupts from these channels may be disabled.

SCC **48** has three modes of operation: initialization, idle, and run. When the SCC is turned on, it enters the initialization mode. In this mode, the software initializes system variables, turns on the LCD **263** and backlight, initializes the modem **57**, and sets up the TPU to start the real time executive. After initialization is complete, the SCC enters the idle mode.

In the Idle mode, SCC **48** waits for a call to be received from NTCC **47**. While waiting, the SCC does not send data to subcarrier modulator **68**, and the output remains high or low. Modem **57** is monitored for a connection event. When the modem connects, the SCC enters the Run mode and receives commands from the NTCC.

In Run mode, NTCC **47** commands SCC **48** into one of two data transmission modes, viz.: synchronization or broadcast. The NTCC uses synchronization mode first, to align the broadcast synchronization pattern with GPS time. In this mode, the SCC chooses an arbitrary start time and transmits a preamble and bit-sync pattern without any data at one second intervals. The NTCC commands the SCC to move the transmit start time until synchronization with GPS time is achieved. At this point, the NTCC commands the SCC to assume broadcast mode. In this mode, the NTCC provides the five blocks of data each second to be transmitted. During run mode operation, the SCC sends its status message to the NTCC before each transmission starts as described above.

If valid message data stops are being received from the NTCC for a predetermined period of time, the SCC hangs up the modem, reinitializes the modem, and returns to idle mode to await another call from the NTCC.

XI. *Network Timing and Control Computer (NTCC)*

As has been described hereinabove (and with brief reference again to **FIG. 6**), NTCC **47** interfaces with a number of other applications, including NDC Server **42**, NTCC roof module **55**, and via a modem, SCC **48**. The NTCC serves as a real-time control interface to the radio network for the NDC, and also receives timing data and DGPS corrections from a NavSymm XR5M GPS receiver **54** in the roof module. Interfaces between the computers are serial. PPS and reset discretes are supported between NTCC **47** and roof module **55**.

NDC server **42**, roof module **55**, and SCC **48** all use the same protocol and message formats to communicate with NTCC **47**, based on the aforesaid NavCore interface protocol. The NavCore interface protocol is modified for purposes of the present exemplary embodiment of the PROTRAK system, in that the lower byte of the status flag word in the header is used for a free running message counter. The message counter uniquely identifies the message and is used in an ACK/NACK reply if an acknowledge to the message is required. This enables multiple messages of the same type to be pending (awaiting acknowledges) simultaneously. The message counter in the ACK/NACK identifies the specific message being acknowledged.

In keeping with NavCore and certain other message numbering conventions, each interface is identified by a different thousands place in the message ID number. Messages transmitted by NTCC **47** use ID numbers beginning with x100 and messages received by the NTCC use ID numbers beginning with x200, where x is the thousands place interface identifier. The message IDs for each serial interface are shown in **Table 68** below.

Table 68: Serial Interface Message ID Numbers

Interface	Message ID Range
SCC	1100/1200
NDC Server	2100/2200

The NTCC serial interfaces are performed using a Contec COM-8SF-2 multi-port serial IO board, which is capable of communicating at up to 115200 bps. PPS and reset discretes are supported by a Contec P10-48W board.

The NTCC communicates with the SCC, NDC server, and roof module with serial data messages. With reference again to **FIG. 6**, NTCC **47** establishes a connection to SCC **48** by placing a call to the SCC through modem **57**. When the modem is connected, the NTCC begins sending timing control messages, and the SCC begins sending status messages. After time synchronization is achieved, the NTCC begins sending full transmit data sets consisting of DGPS data and NDC generated messages consisting of 5 frames of 115 bits in length. The SCC is responsible for generating the bit sync and the start of the FM broadcast. The messages used for communication between the NTCC and the SCC are summarized in **Table 69** (Appendix B), and in further detail below and in other tables of Appendix B, as indicated below.

NTCC **47** controls the timing of the FM subcarrier broadcast using a "Timing Control" message (1101, **Table 70**). SCC **48** uses the data in this message to adjust its transmit timer so that the broadcast data bit sync will be synchronized with GPS time. The timing control message is transmitted by the NTCC near the beginning of a one-second interval. The SCC integer second timer is programmed using the timer control contained in the timing control message before the current timer expires.

In brief, and with reference to **Table 70** (Appendix B), the timing control mode is the least significant byte of word 6 in the timing control message, and has three values: 0 = off, 1 = coarse, and 2 = fine. The control type is the most significant byte of word 6, indicating how the timer control in words 7 and 8 of the message is to be applied. The control type has three values: 0 = do not use, 1 = add to nominal, and 2 = one shot. If the control type is 0, it is ignored; if it is 1, the value of the timer control is added to the nominal timer value and the timer is reprogrammed; and if it is 2, the timer is programmed with the value of the timer control one time and then reverts to the nominal value.

A "Transmit Data Frame" message (1102, **Table 71**), contains a portion of the full SCC broadcast message which is broadcast each second. The broadcast message is broken into smaller frames, so that if part of the message is missed it can be repeated more quickly than repeating the entire broadcast message.

The nominal broadcast message typically consists of five 115 byte frames (23 bit interleaving of (23,12) Golay code), which makes the entire broadcast message 4600 data bits long. Data frame messages containing data to be transmitted on the next broadcast frame are transmitted to the SCC from the NTCC on the current frame. The SCC transmits the available broadcast data at the beginning of each second. If frames of data are missing, the missing frames are replaced by zeros in the transmit data stream.

Near the beginning of each second, the NTCC determines the data to be transmitted on the next second, and these data are broken up into frames. Several messages with ID 1102, one for each frame, are queued at one time.

The broadcast frame ID in word 6 of the "Transmit Data Frame" message indicates the broadcast frame for which the transmit data is intended. The SCC uses this value to preclude mixing of the data intended for different broadcast frames. The frame number and total number of frames are contained in the least significant and most significant bytes of word 7 to indicate the manner of assembly of the frames of data if the messages are received out of order. The number of bytes in the frame, *l* (in word 8), indicates the number of data bytes to follow. If *l* is odd, the most significant byte of the last data word is padded with 0x00. The data bytes are ordered so that they are transmitted to the SCC in the same order as they are to be re-transmitted by the SCC.

SCC **48** transmits status information to NTCC **47** at one-second intervals, in "SCC Status" messages (1201, **Table 72**). A current nominal timer in the message contains the present nominal value of the transmit timer countdown. SCC status in word 8 is bit-coded.

NTCC **47** communicates with NDC server **42** via an 115200 bps serial interface, or TCP/IP directly, or over dial-up. The server supports two simultaneous NTCC systems for FM station/NTCC redundancy, sending the same tracker data to both NTCC systems, but trackers and Network Hubs operate from only one at a time. This is the primary system, and if that system fails, NDC server **42** commands the Net Hubs to switch to the secondary FM station, and the trackers will soon thereafter also switch to the secondary station.

During normal operation, server **42** sends packets containing data to be transmitted to the vehicles (i.e., to the trackers installed thereon) to NTCC **47**. The NTCC formats the data into transmit data frames and sends them to the SCC. The NTCC provides server **42** with a status message to be transmitted at the beginning of each integer second to allow the server to schedule processing tasks. The status message indicates status of the NTCC and SCC to the server, and informs the server regarding available space in the output queue for data to be sent to the vehicles.

Messages used in communication between NTCC **47** (as well as an additional NTCC, if present) and NDC server **42** are summarized in **Table 73**. Dial-up NTCCs must login twice, with a 3Com/U.S.Robotics Modem Bank and Radius server for the first login using standard "login:" and "password:" prompts to authenticate user ID and password. If a dial-up NTCC is successfully logged into the network, it is connected to a TCP port on the NDC server reserved for Network Hub connections. Once connected, the NDC server sends a "Login Info Request" message (2104, **Table 74**) to the connecting Network Hub to authenticate it to the NDC server. The same user ID/password pair used to login to the modem bank is sent as a response in a "Login Info Response" message (2304, **Table 75**). However, NTCCs with TCP/IP connectivity to the NDC server need not login to the modem bank, but rather may simply connect to a TCP port on the NDC server and respond to the "Login Info Request" message."

After the NTCC is authenticated, the NDC server requests an NTCC Profile by sending an "NTCC Profile Request" message (4105, **Table 76**). Although the NTCC may modify its profile, the NDC server maintains an accurate profile by using the information contained in an "NTCC Profile Response" message (4305, **Table 77**) which is sent by the NTCC in reply to the request message.

The NTCC controls the real-time portion of the radio network for the NDC server. A "Status Message 2" (2103, **Table 78**) is sent by the NTCC to the server at the start of each second, to be used by the server as a rough time mark for scheduling periodic tasks. The accuracy of the time mark depends on the rate at which the NTCC and the server service their serial transmit and receive data queues, respectively. If two NTCCs are connected to the server, the server uses the time mark information from the primary NTCC.

When the NTCC requests connection to the NDC server, the server transmits data describing the FM radio station to which the NTCC will attempt to connect in an "FM Data" message (2201, **Table 79)** which indicates the frequency of the FM station and the subcarrier frequency on which the PROTRAK system is operating. The position of the FM transmitter in latitude, longitude and altitude is provided in the message to enable the NTCC to compute the propagation delay of the broadcast. The telephone number in the message is a null-terminated, ASCII string that the NTCC must dial to connect to the SCC.

For each base station transmit packet generated by the NDC server, e.g. "FM Identification," "Slot Allocation," etc., the server sends a "Vehicle Packet" message (2202, **Table 80)** containing the transmit packet to the NTCC, which is ultimately to be transmitted to the vehicles by the SCC via the FM subcarrier. The NTCC places this packet in the output queue, and in the base station broadcast message as space permits. "Vehicle Packet" messages are not acknowledged by the NTCC, simply because of the volume of messages to be coordinated by the server.

When the NTCC connects to the NDC server, the latter sends a "Local Time Zone Offset" message (2203, **Table 81)** to the NTCC indicative of the offset, which the NTCC broadcasts to trackers (via the SCC and the FM subcarrier radio transmission) with the "GPS Time" base packet. The NDC Server sends this offset message 2203 to the NTCC not only in response to receiving a valid NTCC profile response message, but at the start of each hour. In this way, the NTCC maintains the latest time zone information in all local time zones that change on the hour.

NTCC **47** communicates via a 38400 bps serial interface with roof module **55**, whose CPU **56** receives the FM broadcast via receiver **58** from SCC **48** at radio station **12**. As previously described herein, the time of arrival of the FM data is compared to the GPS integer second, and the difference between the integer second start and the time the message data are received is provided to NTCC **47** to develop a correction for timing control feedback to SCC **48**. The NTCC compares the received data to the data provided to the SCC, to verify that the correct data was transmitted. NTCC **47** furnishes RF information to roof module **55** to enable the latter to tune FM receiver **58** to the proper channel and subcarrier.

Messages used for communication between NTCC **47** and roof module **55** are summarized in **Table 82**. The NTCC sends a "Frequency Control" message (3101, **Table 83**) to the roof module during initialization, commanding the latter to tune to the proper FM radio frequency

The NTCC furnishes time and status information to the roof module by sending a "Time/Status" message (3102, **Table 84**) at one-second intervals. Although the roof module in the exemplary embodiment uses GPS time for synchronization to the PPS from the GPS receiver, as an alternative a roof module CPU **56** may be used that does not require periodic time information, but simply initialization information for GPS receiver **54**. The "Time/Status" message, sent shortly after the PPS, contains the time at the PPS. Other mode and status information are also provided to the roof module CPU.

In a "Status" message (3201, **Table 85**), the roof module provides its status to the NTCC, including the current frequency being used. A timing status word in the message indicates the GPS time synchronization status with bit 0 = received time valid and bit 1 = time synchronized. FM status word is coded with bit 0 = synthesizers locked, bit 1 = bit-sync hunt mode, bit 2 = sync detected.

The roof module reports received FM data in a message (3202, **Table 86**) to the NTCC, which the NTCC compares to the data transmitted for frame time synchronization and monitoring of the transmitter and roof module receiver. During normal operation, the FM data is received starting near the beginning of the integer second and ends shortly before the end thereof, so the FM data for a one-second interval is reported to the NTCC at the beginning of the next interval.

The roof module indicates the time difference (delay) between the integer second and the received FM bit-sync to the NTCC in a "Timing" message (3203, **Table 87**), for timing loop control. The integer second is defined by the GPS PPS, and the "Timing" message must be sent immediately after the delay is computed to allow the NTCC to compute a clock correction and send it to the SCC before the start of the next integer second. In the normal run mode, the sync is detected about 15 msec after the integer second. The GPS week and time are provided in the "Timing" message for the start of the integer second for which the delay is computed. The delay specified is the time from start of integer second to detection of the sync. The TPU running at 5 MHz has a resolution of 0.2 μsec.

The GPS receiver **54** of roof module **55** is a NavSymm XR5M GPS receiver for DGPS correction generation. The NTCC has two serial interfaces to the XR5M receiver -- a CDU port and the DGPS output port -- the CDU port being used to control receiver operation and the DGPS port supplying RTCM-104 format DGPS corrections. Alternatively, roof module **55** may be implemented so that the interface with its CPU **56** supports the GPS functions.

Discrete Interfaces include PPS (pulse-per-second) and Reset, the NTCC requiring a PPS for synchronizing its executive to GPS time. The roof module also uses a PPS for timing of the subcarrier broadcast, and in the current embodiment, the Navstar XR5M GPS receiver provides the PPS and the NTCC uses a reset signal to control initialization of that receiver.

XII. *Database Management and CCS Server (DMCS)*

The DMCS (e.g., **27**, **FIG. 3**) at a customer site **13** is conveniently described in conjunction with control of the interface between NDC server **42** and components that communicate with the server including the CCSs (e.g., **14**, **15**), the NDC command stations (e.g., **43, 45, FIG.4**), the Network Hubs (e.g., **11-1, 11-2, FIG. 3**), and NTCC **47**, and messages used for those communications.

The standard message format used to communicate between the NDC Server and all other systems is based on the message format defined in the aforesaid NavCore interface protocol, with a fixed five-word header section and an optional data section as shown in **Table 88**. The standard message header format is shown in **Table 89**.

The Message Start Word is always 0x81FF, indicating the start of a valid message. The Standard Message Type ID (IDNN) indicates the interface (I) where a message is used, the message direction (D), purpose, and number (NN). The valid Message Type ID range for the software components that interface with the NDC server is shown in **Table 90**, and, for those software components that interface with the DMCS, in **Table 91**. The Data Word Count field indicates the number of 16-bit words contained in the data portion of a message (this field being 0 if the message has no data section), excluding the Data Checksum field.

In the Flags/Message ID field, the least significant byte (bits 7 - 0) identifies the message if an acknowledgment or negative acknowledgment is necessary, and bits 12, 11, and 10 are flags indicating Required Acknowledgment, Acknowledgment, and Negative Acknowledgment, respectively. If a message is sent with the Required Acknowledgment bit (12) set, the receiver must respond using the same Message ID with the Acknowledgment bit (11) or the Negative Acknowledgment bit (10) set. If a required acknowledgment is not received within a preset amount of time, or a Negative Acknowledgment is received, the sender must send the message again.

The Header Checksum is computed by adding all words contained in the header and performing a 2's complement on the sum, expressed mathematically as (from the NavCore interface protocol):

$$\text{SUM} = \text{Mod } 2^{16} \sum_{I=1}^{4} \text{word (I)}$$

Header Checksum = -SUM if SUM ≠ -32768
Header Checksum = SUM if SUM = -32768

Where:

1. Unary negation is computed as the 2's complement of some 16-bit data word.
2. Mod 2^{16} indicates the least 16 bits of an arithmetic process (only lower 16 bits kept).
3. The summation is the algebraic binary sum of the words indicated by subscript (I).
4. The -32768 Sum Value must be treated as a special case since it cannot be negated.

Most standard messages used to communicate with the NDC server have a data section as shown in **Table 92**. The Data Word Count in the message header identifies the number of data words in the data section, these being16-bit data words that form a message in the format indicated by the Standard Message Type ID. Messages without a data section have no data checksum. Messages with a data section do have a data checksum, which is computed in the same way as the header checksum. The only difference between the two calculations is that the header checksum is calculated using the first four words of the header while the data checksum is calculated using all of the data words prior to the Data Checksum field.

Each byte of the Standard Message is transferred with bits ordered from least significant to most significant, i.e., the least significant bit being transmitted/received first. Each word is sent with the least significant byte first.

The message formats used for the NDC server/DMCS interface are as follows. With respect to command/response messages and message request/response sequences that may be initiated by NDC server **42**, once a DMCS **27** has connected to the NDC server, it must be ready to receive and respond, if necessary, to messages sent by the server. The Message Type ID of 71XX identifies messages that are initiated by the NDC server while necessary responses to these messages are indicated by Message Type ID 73XX (as shown in **Table 90**).

Dial-up DMCS applications are required to login twice. A U.S. Robotics Modem Bank and Radius server perform the first login, using standard PPP login prompts to request authentication of the user ID and password. If a dial-up DMCS is successfully logged into the network, it may connect a TCP port on the NDC server, at which point the server sends a "Login Info Request" message (7101, **Table 93**) to the connecting DMCS for authentication to the server. The same user ID/password pair used to login to the modem bank is sent as a response in a "Login Info Response" message (7301, **Table 94**). A "Login Info Response Result" message (7107, **Table 95**) is returned by the NDC server to indicate the result of the login attempt. The double login is necessary to control access to both the NDC server network and the NDC server itself, and is hidden from dial-up DMCS users. DMCS applications with TCP/IP connectivity to the NDC server do not require login to the modem bank, but simply connect to a TCP port on the NDC Server and respond to the "Login Info Request" message.

When messages (Text, Predefined, or Site Dispatch) are sent to trackers, a timeout value may be specified. If a message is not acknowledged before its specified timeout value, the NDC server sends a "Message Timeout" message (7107, **Table 96**) to indicate that the message was not acknowledged and that no further attempt will be made to send the message unless a re-send request is made. Messages sent to multiple trackers may be acknowledged by a subset of the original recipient list. The tracker IDs listed in the "Message Timeout" are for those trackers that failed to acknowledge the message prior to the timeout.

NDC command stations have the option to send an "NDC Command" message (7102, **Table 97**) to CCSs connected to the DMCS, to notify CCS users of important events (e.g., system shutdown warning during testing). A DMCS that receives an "NDC Command" message responds using an "NDC Command Response" message (7302, **Table 98**) and forwards it to all CCSs.

While the DMCS is connected to the NDC server it receives real-time tracking data from the server in a "Real-time Tracking Data" message (7103, **Table 99**) for trackers associated with the respective customer. Such messages, which may contain messages of several different types, e.g., tracker location, tracker speed, tracker heading, user data received from a tracker, message acknowledgments/responses, and site status information, are sent to the DMCS as they are received by the server. Tracking data messages for trackers with continuous tracking service or login only tracking (LOT) service are received at a rate specified by the tracker's associated active update rate. And for trackers with manual tracking service, tracking data messages are received as a result of a request made by the DMCS with a Send Tracking Request Message. The Real-time Tracking Data Message Format is shown in **Table 100**.

As previously described herein, the trackers have a capability to sense when the associated vehicle's ignition has been turned on or off. If a tracker is in the RF network and a vehicle's ignition is turned off for a predetermined interval of time, the tracker requests a low- power slot from the NDC server. After receiving its low-power slot, the tracker shuts down until just prior to its next update. Trackers continue to provide updates in this slot while the ignition remains off or the vehicle's battery voltage is below a minimum value. A "Tracker Power Mode" message (7107, **Table 101**) is sent to the applicable DMCS each time a tracker for which it is accountable switches to or from low power mode.

When the DMCS or NDC command station updates a tracker profile, the updated profile information is forwarded to all connected DMCS applications associated with the profile in the form of a "Tracker Profile Update" message (7104, **Table 102**), with the Tracker Profile Format shown in **Table 103**.

NDC server **42** does not manage the installation history for trackers, but can query the DMCS (e.g., **27**) to determine when trackers have been installed and removed from vehicles. A "Retrieve Tracker Installation History" message (7105, **Table 104**) allows the NDC server to specify an installation date range. A "Retrieve Tracker Installation History Response" message (7305, **Table 105**) is used by the DMCS to supply information to the NDC server for all trackers that were installed into vehicles during the specified time period. Since the response message may be quite large, an individual response message is returned for each tracker installed. An exemplary Tracker Installation Record is shown in **Table 106**.

DMCS **27**, which is responsible for management of vehicle profile information (e.g., vehicle identification number (VIN), state, license, make, model, year), provides this information to NDC server **42** in the form of a "Retrieve Vehicle Profile List" message (7106, **Table 107**), upon request. The NDC server typically makes this request if it knows a VIN (which it has learned from the "Retrieve Tracker Installation History Response" message) and needs additional information about the vehicle. If the VIN is not known, the Retrieve Vehicle Profile by Installed Tracker may be used. A Retrieve Vehicle Profile List Response message and Vehicle Profile Format are shown in **Tables 108** and **109**, respectively.

Once a DMCS has successfully logged into the NDC server, it may send command messages to the server with a Message Type ID of 72XX. Any responses from the server to these command messages are identified by Message Type ID 74XX. Command/response messages and message request/response sequences initiated by a logged on DMCS are discussed below.

When messages (Text, Predefined, or Site Dispatch) are sent to trackers, a message sequence ID is associated with the message. Messages pending acknowledgment may be cancelled by sending a "Cancel" message (7215, **Table 110**) with the associated message sequence ID, which is followed by a "Cancel Message Response" message (7415, **Table 111**).

A user ID and password combination is necessary for dial-up access or TCP access to the NDC server. Users that login to the NDC server network and application use the same user ID and password for both. Once a user has logged into the NDC server, a "Modify Account Password" message (7201, **Table 112**) may be used to modify the password, and is responded to by a Modify Account Password Response message (7401,

Table 113).

When a tracker profile is entered into the NDC server database, a tracking service is entered as part of the profile. Each tracker has a tracking service, with valid tracking services being continuous tracking, LOT, and manual tracking. Trackers with continuous tracking service send their tracking information on a periodic basis even if a DMCS is not connected to the NDC server to receive this information. Trackers with LOT service transmit their information periodically if a DMCS is connected to the NDC server to receive this tracking information. Manual tracking service trackers only transmit their tracking information upon request. For continuous and LOT, an update rate (in seconds) is also entered as part of the profile to indicate the periodic rate at which the tracker should send its tracking information, the rate being used to initially set a tracker's active update rate when a tracker is first eligible to enter the radio network. A "Modify Tracking Service" message (7202, **Table 114)** may be sent to modify the tracking service and the associated update rate, and is followed by a "Modify Tracking Service Response" message (7402, **Table 115**).

DMCS applications may send a "Ping Request" message (7203, **Table 116)** to verify their connection to the NDC server. If a "Ping Response" message (7403, **Table 117)** is received, the connection is active and the NDC server is operational.

Referring back to the "Message Timeout" message sent by the NDC server, described above, a "Resend" message (7216, **Table 118)** is sent to the server to indicate that a message should be re-sent to trackers from the original list of recipients that failed to acknowledge the message before the timeout period, followed by a "Resend Message Response" message (7416, **Table 119**).

As with the DMCS's responsibility for management and maintenance of vehicle profile information, and the use of a Retrieve Vehicle Profile List, described above, the NDC server maintains an information profile for each tracker, which contains information to identify the tracker. The information includes the tracker's update rate, service type, and service flags. A "Retrieve Tracker Profile List" message (7204, **Table 120)** is sent to retrieve a list of tracker profiles associated with a customer account. The list to be returned may be limited by specifying the tracker IDs. The applicable response message (7404) is shown in **Table 121**. Text messages may be sent to vehicles with a tracker and an MDT. A "Send" message (7205, **Table 122**) commands the NDC server to send a text message to all trackers associated with the requesting user or to a list of individual trackers identified by tracker ID. Pre-defined Exemplary Message Response Sets are shown in **Table 123**. If the NDC server successfully queues a message to be sent, a "Send Message Response" message (7405, **Table 124**) is used to indicate a Message Sequence ID associated with the message being sent. If the message is successfully acknowledged and/or responded to by a tracker, the DMCS receives a "Message Response And User Data" or "Short Message Response and User Data" packet within a "Real-time Tracking Data" Message (discussed above) that contains the same Message Sequence ID.

Pre-defined text messages also may be sent to vehicles with a tracker and MDT. A "Send Pre-defined Message ID" message (7206, **Table 125**) commands the NDC server to send a pre-defined message ID to all trackers associated with the requesting user or to a list of individual trackers identified by tracker ID. If the NDC server successfully queues a message to be sent, a "Send Pre-defined Message ID Response" message (7406, **Table 126**) is used to indicate a Message Sequence ID associated with the message ID being sent. If the message is successfully acknowledged and/or responded to by a tracker, the DMCS will receive a "Message Response And User Data" or "Short Message Response and User Data" packet within a "Real-time Tracking Data" message that contains the same Message Sequence ID.

A "Send Site Dispatch" message (7207, **Table 127**) is used to facilitate dispatching and automating the recording of site arrival/departure. It is sent by the DMCS to a tracker to indicate a job site area and a message (e.g., site street address) to be displayed to the vehicle operator. A pre-defined or custom response set may be defined to permit a manual response. Upon arrival/departure at/from the site defined by the message, the tracker sends a "Site Status" packet within a "Real-time Tracking Data" Message to indicate site arrival/departure, either by virtue of the tracker's determination based on its latitude/longitude relative to the job site area, or of the vehicle operator using the MDT to indicate the tracker site arrival/departure, and a consequent "Send Site Dispatch Response" message (7407, **Table 128**).

A "Send User Data" message (7208, **Table 129**) commands the NDC server to send a User Data message to all trackers associated with the requesting user (customer) or to a list of individual trackers identified by tracker ID. If the NDC server successfully queues a message to be sent, a "Send User Data Response" message (7408, **Table 130**) indicates a Message Sequence ID associated with the message being sent. If the message is successfully acknowledged by a tracker, the DMCS receives a "Message Response And User Data" or "Short Message Response and User Data" packet within a "Real-Time Tracking Data" message that contains the same Message Sequence ID.

Trackers that have manual tracking service only transmit their tracking information upon request. A "Send Tracking Request" message (7209, **Table 131**) allows the DMCS to request tracking information from a specific tracker. If a tracker successfully receives a tracking information request, it transmits its tracking information during the next available time slot reserved for such a transmission, and the requesting DMCS receives a "Real-time Data" message with the requested tracking information. A "Send Tracking Request Response" message (7409) is shown in **Table 132**.

When the DMCS creates/updates/modifies a tracker installation record, the record is forwarded to the NDC server as an update sent in the form of a "Tracker Installation Record Update" message (7210, **Table 133**). Also, when the DMCS updates a vehicle profile, the updated profile information is forwarded to the NDC server in the form of a "Vehicle Profile Update" message (7212, **Table 134**).

XIII. *Event Driven Status Reporting*

This aspect of the invention provides a method and apparatus for automatically determining and reporting events from a vehicle to an owner or dispatcher of the vehicle at a location which is remote from the vehicle. Events to be reported include changes in status of vehicle operation, location, or measurements of vehicle systems or cargo. The tracking computer (tracker) in the vehicle is connected to various sensors which measure parameters of interest to the dispatcher or owner, and reports critical changes in parameters over the TDMA network. CCS/DMCS computers at the customer's location display status changes for use by the dispatcher, or record data for later analysis. Software in the tracker and a variety of sensors allows multiple, complicated, and abstract status events that are relevant to specific vehicle or industry applications to be determined and reported by the tracker. Automatically generated reports from vehicles enables considerably more accurate and timely data to be provided to the customer's site than is available from the human operators of the vehicles.

FIG. 33 is a diagram of various types of sensors and/or measurement sources that are readily connected/supplied to the tracking computer (tracker) **135**, either singly or in combination with each other, including certain "basic" sensors, analog inputs, discrete inputs, TPU inputs, and serial interfaces to the tracker that can be configured for almost any measurement and control purpose. An expanded list of sensor inputs is set forth below. These fall into the two broad categories of (1) basic vehicle functions and (2) operational functions of the vehicle specific to the industry in which it is used. Operational functions require the addition of sensors to a standard vehicle. The reader is also referred back to **FIG. 23** which illustrates certain particularly significant sensors of operational functions for ready-mix trucks, such as truck **195** -- a drum rotation sensor **281** and a washout water flow detection sensor **281** --, as well as a generalized set of inputs **280** to tracker **135** from sensors/measurement sources of the types referenced in this section of the specification.

Basic vehicle functions or parameters that are measured directly by the tracker may vary from vehicle to vehicle, but typically include the following:

- Vehicle Ignition and Run Time
- Headlights
- Reverse
- Wheel Speed (from the transmission)
- Passenger/Driver Door Open
- Four Wheel Drive Engagement
- Ambulance Lights/Sirens
- Fuel Level
- Coolant temperature
- Oil Pressure
- Battery Voltage
- Engine Warnings

Other vehicle functions may require the addition of sensors for measurement, or may be measured directly on equipment added to the vehicle to perform a function specific to the business in which the vehicle is used. Some typical parameters or functions that fall into this category are:

- Theft or Tamper Alarms
- Cargo Door Open

- Cargo Temperature
- Vehicle Weight
- Power Takeoff Engagement: Power TakeOffs (PTOs) can run a wide range of equipment, including:
  - Pumps
  - Winches
  - Cranes
  - Augers
- Engine Data Bus Parameters and Tolerance Checking
- Dump Box Up or Hatch Open
- Ready Mix Drum Rotation Speed and Direction
- Ready Mix Wash Water Usage
- Ready Mix Fill Water Volume

Vehicle functions are combined with location and speed information from the navigation system. Correlation of measurements to vehicle motion enables events to be triggered based on vehicle location, or to qualify measured data as proper operation of a vehicle -- or as an exception to normal operations, such as opening a cargo door outside of normal customer or company loading/unloading zones.

In this respect, the system allows the owner or dispatcher of the vehicle to define rectangular zones on a stored map of the metropolitan area of interest; for example, a zone **300** as shown in **FIG. 34**. The corners defining the zones (e.g., **301, 302, 303, 304** for zone **300**) are sent to the vehicles so that the tracker can determine, based on its navigation solution, whether it is inside or outside any particular zone. These zones are typically set up to identify home or plant sites where vehicles are usually based or pick up cargo, or job sites where vehicles are usually dispatched to deliver cargo or perform a service.

Zones can also define map regions for other purposes such as restricted speed, restricted weight, or borders that the vehicle is not allowed to cross. Using navigation alone, the tracker can report:

- Distance Traveled Between Zones
- Engine On and Off
- Driving Over a Specified Speed
- Driving at Inappropriate Times
- Unauthorized Stops
- Times of Arrival and Departure to and from Specified Locations

Combining location information with other measured parameters on the vehicle can generate other status events, such as using the vehicle location to confirm the correct vehicle status, notifying the dispatcher if a cargo door opens at an inappropriate time or place, or correlating an engine problem to a particular location to understand the underlying circumstances.

When a vehicle tracker needs to transmit event data, it requests special time slots using one of these time slots. It is then granted sufficient auxiliary reporting times at twelve second intervals to send its data. The total latency between an event being detected and the transmission of data is preferably kept under thirty seconds.

All data passed through the network and other status information is stored on large database servers for later retrieval for reports on vehicle activity or analysis. The tracker reports events using different types of data packets depending on the event. Events indicated simply by direct measurement of an input are reported in a common event packet format that indicates the input measured (discrete or analog) and the new value. These are events such as cargo door open, four wheel drive engaged, or PTO driven pump on. These data are stored in the database and passed on to the customer applications. Since a fleet owner (operator or subscriber) may have many types of vehicles in the fleet, and each may have different event data of interest on the same inputs to the tracker, the data must be clearly identified from vehicle to vehicle.

Identifying the event reports by the tracker is accomplished by a tracker configuration application running in the NDC. When a tracker is installed in a vehicle and sensors are connected to its inputs, the configuration application activates the tracker by sending it a command for the attached inputs which identifies thresholds and hysteresis on triggering an event on the input. The configuration application also stores the association of each of the tracker's inputs to the specific event type, such as cargo door open. In more complicated situations where a vehicle has a detailed set of logic to operate to determine when and what type of events occur, for example a ready mix truck or an ambulance, the configuration application sends a command to the vehicle's tracker to activate an entire section of software to process inputs. In these cases, industry specific data packets are sent by the tracker to identify detailed event status and data corresponding to the event.

A number of specific applications for event driven reporting of vehicle status are described below. Examples of applications to specific industries, by way of illustration and not limitation, are the following: ready mix concrete, bulk powder transport, bulk aggregate transport, and ambulance operation. Many more examples of applications that require automated event reporting might be listed. The combinations and applications of parameters that can be measured and reported are virtually limitless.

A. *Ready Mix Concrete*

While efficient use of fixed assets is important in any business, it is particularly important in the ready mix concrete industry. This is primarily a delivery business, since the product being delivered is essentially a commodity and the raw material costs do not vary significantly between suppliers. The business, therefore, is one in which the efficient use of very expensive transportation assets makes the difference between profit and loss.

The transit mixer truck has a well defined sequence of events through which it runs in the process of delivering concrete, generally comprising the steps of:

1) Load
2) Leave Plant
3) Arrive Job
4) Begin Pour
5) End Pour
6) Wash
7) Leave Job
8) Arrive Plant

It is known that the ready mix concrete industry has been in search of a method to indicate these events to the dispatcher in a cost effective, timely, and accurate manner. Reliable indication of these events to the dispatcher results in the most efficient use of the truck fleet. By knowing the stage of operation each truck is in, the dispatcher can choose the best available trucks for the next loads. This is particularly true when planned schedules are changed by customer needs or delays in delivery. Ready mix companies have typically used driver voice enunciation for these events or driver operated status boxes.

Voice and status box use have a fundamental limitation in that they require the driver to take action to notify the dispatcher of his current state of operation. Even well intentioned drivers too often forget to notify the dispatcher. Industry estimates are that less than 10% of data provided through these means is accurate. Status boxes are control heads interfaced to the voice radios, the status box having multiple buttons, typically a button operable to indicate each of the above-noted delivery phases. An advantage of the status box is that data from it can be provided to common dispatch applications used in the industry to enable the dispatch software to track the truck through the phases without manual intervention by the dispatcher. However, this advantage is rarely realized because of unreliability of the data from the driver, and the consequent inability of the dispatcher to make proper decisions for the most efficient use of assets.

With the appropriate sensors on the transit mixer truck and software in the wireless data computer, the ready mix concrete delivery phases can be automatically and reliably determined. Reliable, automated sequencing is achieved according to this aspect of the present invention by implementation of three basic sensors on the truck, as well as reliable navigation, and involved state logic. In a preferred embodiment, the sensors comprise a drum rotation sensor **280 (FIG. 23)** that measures both speed and direction of the mixer drum, a water flow sensor **281** that measures water being used to wash off the truck, and a door switch (e.g., associated with the switch that senses an open door to turn on the interior lights in the truck cab) that indicates when the driver's door is open. Information regarding location and speed of the vehicle is required to determine when the truck is at a plant or a job site (or en route to the site). The state logic ties all of this information together to allow the tracker to report each phase of the delivery process back to the subscriber's site.

Drum rotation sensor **280** measures the speed and direction of the drum **287** of truck **195**. In a preferred embodiment, sensor **280** is unlike typical drum revolution counters installed on mixer trucks that use limit switches or Hall effect magnetic or proximity switches to count drum revolutions, but instead accurately provides both speed and direction -- parameters which are needed to help determine when the truck is being loaded, when pouring of the wet concrete contents of the drum is commenced and when it is completed. Loading is typically performed by running the drum in the "charge" direction at high speed, whereas normal mixing is performed while the truck is on the road and at a much slower charge speed. Pouring is typically performed at a very slow discharge speed, and drum speed is often increased as the drum empties. Referring to the block diagram of the drum rotation sensor **280** of **FIG. 35**, two Allegro 3240 Hall effect sensors **288, 289** are employed, separated by approximately two inches on a bracket **290** that mounts to the top of the transmission **291** that drives the ready mix drum **287**. Sensor **280** is activated by six magnets that are placed around the axis of drum rotation on the interface plate between the transmission and the drum. Magnet assemblies **292** used to actuate the Hall effect sensors **288, 289** are attached to the drum-transmission interface flange **293**.

The transmission to drum interface is the ideal location for rotation sensor **280** when added to the mixer after it is built. Direct measurement of transmission RPM is preferred but is only practical if the transmission can be modified at the factory to supply a rotational speed/ direction output. The transmission interface has well controlled dimensions and is relatively free of contaminants and from driver interference. It is also common among front and rear discharge mixers. Other potential locations for sensor placement, such as the idler wheels at the drum mouth or between the midpoint of the drum and the truck chassis, have drawbacks that include dimensional variations from manufacturer to manufacturer and from vehicle model to model. These locations are also more exposed to grease, dirt, damage, and variations in gap distances due to flexure of the truck frame and bouncing of the drum out of its idler wheels.

The top of the standard transmission interface has mounting holes available for oil coolers and water tanks and may be used for sensor mounting. Despite the large size of a transit mixer truck **195 (FIG. 23)**, the clearances around the transmission interface are very tight. Also, roughly one inch of clearance exists between the bolts holding the drum to the interface plate and the pedestal to which the transmission is mounted. Options for magnet mounting are restricted if factory installed rotation counters must be accommodated. These sensors are of several varieties including reed switches using a similar magnet bolt design, limit switches actuated by a flange attached one of the drum bolts, or proximity sensors actuated by a flange just outside the interface plate radius.

To mount magnets in the drum bolt radius of the interface plate for all manufacturers' mixer trucks, a magnet holder bracket is used. For contemporary mixer truck models, the following configurations are supported: (1) no bracket, (2) single bracket used to offset a rotation counter actuation magnet, or (3) six brackets used to hold in-radius magnets when bolt holes are unavailable. Mixers using ZF transmissions from most manufacturers do not require the bracket. In these cases, six threaded holes in the interface plate are available for magnet bolts to be inserted. Mixers manufactured by McNeilus with ZF transmissions have a reed switch rotation counter actuated by a factory installed magnet bolt in the interface plate, which is replaced by a magnet rivet offset from the normal bolt radius by the bracket. The reed switch is moved from its factory bracket to a hole in the newly installed speed and direction sensor bracket. EIP transmissions populate all but two holes in the interface plate with bolts to hold the drum to the transmission. For this transmission, the bracket is rotated 90 degrees and flipped over so that the magnet rivet is held between the bolts that mate the drum to the plate. Either six bracket-rivet assemblies are used, or a combination of two magnet bolts and four brackets-rivet assemblies.

Sensor **280** in this exemplary embodiment has a four wire interface **294** to the tracker **135**: power, ground, and a signal line from each Hall effect sensor. The signals are inputs to the TPU of the Motorola 68332 microcontroller (CPU) for the tracker. The TPU has dedicated hardware for measuring pulses with very precise timing. When a magnet on the drum passes by a sensor, the sensor outputs a low going pulse. Referring now to **FIG. 36** which is a timing diagram of the pulses resulting from the interaction of the sensors and the magnet on drum rotation, with the two sensors **288**, **289** denoted A and B, respectively, a simple determination is made of drum **287** speed and direction. Speed is determined by two successive pulses **295, 296** from sensor A. The time between pulses ($T_{A/A}$) in seconds divided by 6 magnets (pulses) per revolution multiplied by 60 seconds in a minute yields the RPM of the drum. The maximum speed of a ready mix drum is about 16 RPM. Direction is determined by the relative timing of pulses detected by both sensors. If the time between a pulse **295** on sensor A and a pulse **297** on sensor B ($T_{A/B}$) is less than the time to the next pulse **296** on sensor A ($T_{A/A}$), then the drum is rotating in the A to B direction, which is the charge direction. Conversely, if the time between a pulse on sensor A and a pulse on sensor B is greater than the time to the next pulse on sensor A, then the drum is rotating in the B to A direction, which is the discharge direction.

The gap **298 (FIG. 35)** between the faces of the magnets and the sensor is an important consideration. During loading and over the road, the truck experiences very heavy shock and vibration loads. These loads can cause the drum to bounce on its idler wheels and the truck frame to flex. As trucks and transmissions age, the problem becomes worse. Preferably, a gap **298** of at least about three quarters of an inch is provided to avoid damage to sensors or magnets.

Transit mixer trucks typically have a water tank that stores water under pressure. The water is used to add water to the concrete mixture and also to wash off the truck when a pour has been completed. In order to determine when wash is occurring, the water flowing through the hose is measured using a flow switch. The flow switch triggers at a preset flow volume threshold. A number of technologies for the flow switch can be used to detect flow, viz.: water tank air pressure, eddy current, differential pressure through an orifice, and spring deflection sliders or flappers. A flow switch is a preferred sensor **281 (FIG. 23)** for this application because the volume of flow is not important, just the time being spent washing the truck. A key design consideration for a flow switch or sensor is that it must work with water that is contaminated with dirt and debris such as rocks and large fragments of rust.

For rear discharge mixers, the driver must exit the truck to set up the chutes before pouring. A door switch is used to determine when the driver's door is opened. Driver door opening is used to confirm arrival at the job site, but is not critical for proper operation of the system.

A state transition diagram which defines the logic used by the tracker to combine sensor and navigation data to automatically derive mixer status is shown in **FIG. 37**. The logic is necessarily complex to account for all of the anomalies from the normal concrete delivery flow that may be encountered. Thresholds and timeouts are set to prevent false triggers of logic states at the expense of a small delay in indicating the event. The primary states listed above are shown in bold in the Figure.

The delivery process starts with the truck ignition being turned on **(310)** at the plant **(311)**. Once the navigation system is initialized, the tracker installed in the truck determines that it is at the plant. Mixers are loaded by parking under the batch plant and running the drum in the charge direction very fast. This is detected by the tracker if the truck has a speed of less than two miles per hour, the truck is at the plant, and the drum speed and direction is about the fast charge threshold, all for 60 seconds. When this is detected **(312)**, the tracker transmits the loading status **(313)**.

After loading, the truck typically proceeds to the wash rack where water is added to the mix, dust is washed from the truck, and the water tank on the truck is topped off. A state that is detectable but not usually required by a ready mix company is identifying if a truck is at the wash rack **(314)**. This can be determined by a slight change in position of the truck and parking after loading without leaving the plant. Next the truck will leave the plant. This is determined by having a location outside the predetermined rectangular zone (e.g., see **FIG. 34**) that defines the plant and a speed above 15 miles per hour. When this is detected **(315)**, the tracker transmits the leave plant status **(316)**. Hysteresis is placed on the zone boundary crossing so that a truck driving along the edge of the zone does not cause multiple arrive-leave plant sequences.

Optimal use of the system requires the dispatcher to send a dispatch message to the truck that indicates to the tracker the rectangular zone defining the boundaries of the job site, but it is not required for the tracker to provide automated status. Job site location information enables the tracker to determine job arrival separately from the beginning of the pour, enables the tracker to determine exception information about pours taking place away from job sites, and allows route optimization software to have reliable information about trip times.

Job arrival is determined by the truck entering the defined job zone and then having a speed below five miles per hour for at least one minute, or the driver's door opening, whichever occurs first **(317)**. If a job zone is not defined, then job arrival is determined by the drum operating in the discharge direction for more than 10 seconds **(318)**. Alternatively, a fraction of a revolution of the drum in the discharge direction can be used . When these conditions are detected, the tracker transmits the arrive job status **(319)**.

The start of pour condition is determined when the drum is run in the discharge direction for 20 seconds, or alternatively, one or two revolutions. Once this is detected **(320)**, start pour is transmitted by the tracker **(321)**. This places the tracker software in the pouring state **(322)**, and it is then looking for an end of pour condition.

End of pour may be detected in a number of ways. Some pours are conducted in slow discharge. When the drum is near empty, the drum is sped up to extract the last remaining concrete. If the drum is run in fast discharge for 10 seconds after running in slow discharge **(323)**, this will trigger end of pour **(324)**. If wash water is used for two minutes **(325)**, end of pour is also triggered **(326)** because use of that much water almost certainly indicates the truck is being washed. End pour **(327)** can also be triggered is the speed of the truck is over 30 miles per hour **(328)**. Trucks can rarely move that fast on a job site, particularly if they are still pouring because the chutes are typically left attached to the truck until pour is complete. An alternative method can be enabled if information about the amount of concrete loaded on the truck is provided to the vehicle tracker from the dispatcher (from a CCS at the subscriber site via the DMCS, NDC server, NTCC, SCC, subcarrier modulator and FM broadcast). In this case, end of pour can be better estimated by the number of revolutions required to empty the drum for a given volume originally loaded. A second alternative is to use an on-board weight measurement system such as the AW4600 or AW5600 from Air-Weigh. The tare weight of the truck can be compared to the weight during pour, and an end of pour can be detected when the weight approaches the tare weight.

The beginning of wash is determined by use of water to wash the truck for a predetermined amount of time. If end pour **(324)** was detected by a fast discharge event **(323)**, then water must be used for one minute **(329)** to indicate wash status **(330)**. If end pour **(326)** was determined from the use of water for two minutes **(325)**, then wash status **(331)** is transmitted along with the end pour status **(326)**.

A leave job event is transmitted when the vehicle leaves the defined job site. A back up is provided, as shown in **FIG. 37**, to enable sending of the leave job status in case a job zone was not defined. Leave job **(332, 333)** is determined in any case if the vehicle speed is greater than 30 miles per hour **(334)**. It should be noted that the system state can return to pouring **(322)** in some cases after wash **(331)** or leave job **(333)** are detected, if the drum is run in discharge again before the truck returns to a plant site **(335)**. This enables the system to support operational anomalies like pouring concrete from one truck in two different locations at one overall job site.

If job sites are defined for the tracker, they can be used to monitor behavior of the vehicle or driver that is contrary to the fleet operator's (subscriber's) policy. For example, if a pour is detected outside the defined job site rectangle, the vehicle computer can generate an exception and transmit it. This will alert the dispatcher that the driver may be pouring concrete at an unauthorized location and reduce loss of material and improve efficiencies. Finally, arrive plant **(311)** is detected when the truck enters a rectangle that defines a plant location and the speed is less than 15 miles per hour **(337)**.

In addition to the normal ready mix delivery sequence, the business owner is interested in determining the amount of water added to the mixing drum at the job site. Again, drivers are an unreliable source of this information because they rarely record the actual amount added. It is critical that the correct amount be added and known because an incorrect mixture may not cure properly.

Determining the amount of water added can be accomplished by placing a water flow meter in line with the pipe that fills the drum. An example of one of these units is EMCO/Fluidyne part no. 1200-1-1. These types of meters typically provide a pulse or analog output. Either type is easily integrated into the standard inputs of the tracking computer. Water added is counted between the time the truck arrives at the job site and finishes pouring. The amount added is transmitted out as an event along with the end of pour event.

B. *Bulk Powder Transport*

Bulk transport trucks haul powdered material such as lime, cement, and fly ash. The bulk hoppers are loaded from the top by gravity. They are unloaded by forcing air through a network of pipes under the hoppers which, along with gravity, pulls the material out of the hoppers and pumps it up into storage silos. Bulk hauling companies need to know when the truck arrives at a customer's site, when it begins unloading, when it ends unloading, and when it leaves the site. The basic requirements are very similar to those described above for the ready mix concrete industry.

Unloading is performed by pumping air through the pipes under the bulk hoppers. Air pressure is usually generated by the truck itself. It is either done by a PTO driven pump or with an exhaust gas driven turbo pump. In most companies, the exhaust driven pump is more popular because it weighs much less than the PTO pump. With either pump the truck engine is run at high RPM to generate the required air pressure.

Determining when the PTO pump is on is quite straightforward. One of the discrete inputs is connected to the input for the light on the pump that indicates it has been turned on. The input wiring is designed to ensure that the input is triggered even if the light is burned out. Any time the PTO is turned or off, a corresponding status message is transmitted by the tracker to indicate the status change event.

On trucks with exhaust driven turbo pumps, directly measuring if the pump has been engaged is very difficult. Since the pump is driven by the engine exhaust, the housing is very hot. Integrated circuit electronics cannot be used reliably in this kind of environment, so electronic flow switches and pressure switches would be difficult to use. The engagement lever on the pump is mechanically sloppy and difficult to instrument. In addition, any sensors outside the truck near the pump are subject to tampering.

With these difficulties in mind, a tachometer sensor is used to determine if the truck is pumping material. The sensor circuit is designed to detect a low-level analog signal, convert it to a digital signal level and divide the frequency to a lower value. The lower frequency signal is connected to the tracker through the TPU interface for a discrete input. Software in the tracker CPU counts the received pulses and converts them to an RPM.

Engine speed is used in conjunction with the truck being stationary to determine the unload status. If the truck is stationary and the engine speed is above the appropriate RPM threshold for enough time for the driver to set up the truck and connect the delivery hoses, then the unload status is transmitted. If the dispatcher has provided the tracker with site information, that is used to ensure the unloading is taking place at the site. If it is outside the site, the tracker transmits an exception to warn the dispatcher.

C. *Aggregate Bulk Transport*

Aggregate bulk transport trucks are dump trucks that haul gravel, rock, and sand generally for use by ready mix companies, construction, or landscaping. This industry has similar requirements for truck status reporting as the bulk powdered material haulers. The vehicle owners need to know when and how often a dump truck empties its load. Vehicles in this industry are often rented by ready mix or other companies that do not own aggregate hauling trucks of their own. The vehicle owner needs reports on run time hours, odometer mileage, and number of loads hauled for billing purposes; and the renter needs to know the same things to ensure that it is getting the desired efficiency from the truck.

In order to determine if the truck dump bed is up, a reliable sensor must be used that is immune to vibration, shock, and the extreme environment of loading. A proximity sensor that can sense the presence of metal at distances of over one half inch is preferred, and such a sensor is available in a range of sensor models from Turck sensor company. The sensor is connected to one of the discrete inputs on the tracker. When the tracker determines that the dump bed has left the proximity of the sensor for a guard time interval to eliminate noise, it transmits the dump status.

Dump truck owners are also interested in preventing loss of cargo. As with ready mix, if applicable geographical zone or boundary definitions are provided in mapping data or otherwise to the tracker, then it can determine if the dump was raised outside of the areas where product should be delivered.

D. *Ambulance*

Ambulance operators must demonstrate to the government that they meet the required response times for emergency and non-emergency calls. They do this by providing reports on each trip, with respect to the pick up location, the hospital delivered to, the times of the calls, and other factors. The reports are often collected manually based on recorded call logs. Ambulance companies also must comply with special local rules, regulations and ordinances that apply to operating emergency vehicles such as to refrain from using emergency lights and sirens on freeways or in non-emergency situations.

These functions can be automated to a significant degree by sensing when the lights and sirens are turned on and off and by using dispatch zones. When call scene locations and hospital or clinic locations are encompassed by zones and provided to the vehicle tracker, and sensors are installed on the emergency lights, the tracker can determine the response times and delivery locations automatically.

When the tracker detects that the emergency lights are turned on, it transmits the event and the time at which the lights are turned on. It then also begins counting time and distance until the vehicle arrives at the call scene. Call scene arrival can be determined automatically if a zone is provided to the tracker or can be determined manually by the driver pressing a status button on the display terminal. Once on-scene arrival is determined, the tracker transmits the arrival time and the distance traveled. The sequence of leaving the scene and arriving at the hospital is similarly ascertained through zone detection and sensors.

For report generation, all data reported by the tracker is stored for later processing at the ambulance owner's site. The report then contains each call location, distance traveled and response time along with the emergency condition for each leg of the trip.

XIV. *Tracker FM Diversity Processing*

Reliable reception of data in a mobile radio environment is difficult to accomplish. Signal quality is rapidly time varying as a vehicle moves through the clutter of obstructions, reflections, and interfering radio sources. The FM subcarrier data signal received by the vehicle tracker can rapidly fade in an out due to signal obscuration and multipath reflections. In order to recover data in the most reliable fashion possible, the network design uses a combination of FEC coding, bit interleaving, CRCs on message packets, and space diversity in the vehicle antenna system. Although the first three of these have been discussed earlier herein, they will be re-visited briefly for convenience of the reader.

The forward error correction is a Golay (23,12) code. This algorithm encodes each 12 bits of message information into 23 code bits. When received, the decoding algorithm is able to correct errors in up to 3 of the 23 code bits. The FM transmitter sends 300 message bytes (2400 bits) of data encoded this way into 4600 code bits each second.

To improve the immunity of the link to bursts of errors caused by multipath or blockage effects, the transmitted bits are interleaved. The 200 code words transmitted on the FM subcarrier each second are split into five 40 word blocks. Within each 40 word block, the bit order of the transmitted data is rearranged so that the 40 first bits of each word are sent first followed by the 40 second bits and so on. This interleaving enables the Golay algorithm to correct up to 120 consecutive bit errors.

Some error conditions are severe enough that they cannot be reliably corrected by the FEC code. To guard against this, each message packet in the FM data contains a standard 16 bit CRC used for error detection. If the CRC is not correct for a packet, then the packet is thrown out. The CRC can detect any odd bit errors, all double bit errors, and many other error combinations. For short message packet lengths typically transmitted in the system, the 16 bit CRC algorithm is sufficient when coupled with the forward error correction and interleaving.

Space diversity in the receiving system of the vehicle is used to reduce errors caused by longer duration multipath fading or obscurations that cannot be corrected with interleaving alone. Two independent receivers (**207, 208, FIG. 24**) and antennas (**191, 192**, see, also, **FIG. 23**) are used to receive the FM subcarrier signal for the tracker **135**. The receive antennas are separated on the roof of the vehicle as much as is reasonably possible. At 100 MHz FM frequencies, the distance between the antennas on the vehicle should be about 4ft for optimum diversity processing. This distance is usually achievable for most vehicles. Signals from the two antennas are independently demodulated to baseband data using two receiver chains. The tracker CPU **203** then uses a diversity processing algorithm to recover the data.

Tracker CPU **203** decodes the received data using a sequence of algorithms: (1) bit de-interleaving, (2) Golay FEC decoding, (3) message packet parsing and diversity processing. The de-interleaving and Golay decoding are relatively straightforward algorithms. The parsing and diversity algorithm are described below.

A flow chart of the diversity algorithm is shown in **FIG. 38**. Each second, the tracker begins processing data received over the FM subcarrier. The two received data streams are denoted by stream A and stream B. Diversity decoding starts at the beginning of the message block, with either stream A or B. Message synchronization is set at the beginning because the first byte to be processed in each second's data is the start of a message packet. A flag is also set to allow switching to the alternate stream (**350**) if a message cannot be properly decoded.

If the next byte to be processed is a valid message ID (**351**), then the current stream is parsed for the message packet (**352**). If the CRC passes for the packet (**353**), message synchronization is held (**354**) and the pointer is incremented by the message length (**355**). Then the next byte is checked for a valid message ID (**351**). This is the normal flow of processing until the end of buffer mark is detected (**358**) or there is no more room in the buffer for messages (**359**).

If a valid message ID is not detected and the other stream has not been checked, then the corresponding byte in the other stream (**360**) is checked for a valid message ID (**351**). If it is valid, then the message is parsed as described above. Alternatively, in either of the above cases, if the CRC is not valid (**362**), then the message packet is corrupted. If there was message synchronization (**363**), then an error count is incremented (**364**); otherwise, this indicates that the message ID was not the start of an actual message. If the other stream had not been parsed for the message, it is tested.

If at any point both streams fail to produce a valid message ID or properly parsed message packet, the algorithm reverts to checking both streams on a byte by byte basis to locate the next valid message packet.

It will be appreciated from the foregoing detailed description that certain objectives, features and aspects of the present invention are particularly noteworthy. For one, a vehicle fleet management information system for fleet asset management is provided which enables identification of location and direction of movement of each vehicle in the fleet in real-time and automatic communication directly with management offices to report vehicle location and direction, and as well, status of predetermined events in which the vehicle may become engaged, in which apparatus at a network control or distribution center assigns each vehicle in the fleet a unique time slot to transmit its reporting information over a communications network without substantially interfering with transmissions from other vehicles in their own respective time slots. For another, precise time synchronization is provided for all elements of the network, which is at least in part a TDMA wireless network, by means of a timing control PLL for distributing a single, remote global positioning satellite GPS based time reference throughout the network. The network includes a dual band full-duplex interface with TDMA on one-half of the interface and broadcast on the other half. Also, microprocessors in components throughout the network each have a time processing unit for performing precise clock synchronization within 10 microseconds for the TDMA portion of said network.

Still another resides in the provision of apparatus for establishing a protocol for entry by vehicle transmitters into the network in assigned time slots for periodic transmission of messages, and apparatus for providing space diversity of the messages received from the vehicle transmitters to avoid data corruption. Also, different periodic transmission intervals are provided for different vehicles in the network by dynamically allocating the slots for various update rates. Additionally, auxiliary reporting slots are provided to allow prompt reporting of important data by the respective vehicle transmitters independent of slower periodic transmission intervals. And apparatus in the system supports both guaranteed and non-guaranteed delivery of message data. Further, assigned slots are unique to respective vehicles, so as to minimize bandwidth usage by allowing identity of the transmitting vehicle to be inferred from the time slot in which the transmission is received. Each vehicle transmitter has a filter for baseband data to reduce the occupied bandwidth of the channel on which data is transmitted, including removal of synchronization data to minimize overhead of non-information bearing data. The baseband filter is implemented by a digital microcontroller that replaces an original square wave data stream of the baseband data with deterministic transitions that reduce harmonic content and maintain bit widths, regardless of data input frequency. Each receiver in the network has the capability to recover the transmitted data without transmitted synchronization information by locating the start of each data message within a predetermined scant time window without aid from bit synchronization patterns. To that end, an iterative search is performed that sequentially clocks in the data at greater and greater delays from the nominal message start time until a valid data packet is located.

Yet another provides for sensing, detecting or measuring certain repeated events in which the vehicle will be engaged according to the very basic nature of its use, and according to the industry in which it is being used, and for automatic reporting of the detected events to the fleet management office. These are especially important aspects for vehicles which must follow a routine prescribed for efficiency's sake by the fleet management office, such as ready mix concrete trucks, powdered and aggregate materials transport haulers, ambulances, etc.

Although certain presently preferred and exemplary embodiments and methods have been described herein to illustrate the best mode presently contemplated of practicing the invention, it will be apparent to those skilled in the relevant art that variations and modifications may be made without departing from the true spirit and scope of the invention. Accordingly, it is intended that the invention shall be deemed limited only to the extent required by the appended claims and the rules and principles of pertinent law.

APPENDIX A: GLOSSARY OF ABBREVIATED TERMS

ACCUMINT (accumulator interrupt)

BSFK (binary frequency shift keying)

CCS (Customer Command Station)

CDU (control and display Unit)

CPU (central processing unit)

CRC (cyclic redundancy check)

DGPS (differential global positioning system)

DMCS (Database Management and CCS Server)

DR (dead reckoning navigation)

DSP (digital signal processor)

FEC (forward error correction)

FM (frequency modulation)

FSK (frequency shift keying)

GP 2010 (RF front end component of Plessey GPS chip set)

GP2021 (correlator component of Plessey GPS chip set)

GPS (global positioning system)

IF (intermediate frequency)

IOD (issue of data)

ISP (Internet service provider)

ISR (interrupt service routine)

ITC (input transition capture/count)

LFS (linear file store)

LNA (low noise amplifier)

LOT (login only tracking)

MDT (Mobile Data/Display Terminal)

NDC (Network Distribution Center)

NTCC (Network Timing Control Computer)

OC (output compare)

PCS (personal communications services)

PDC (PROTRAK™ Data Center)

PIT (periodic interrupt timer)
PPM (parts per million)
PPP (point-to-point protocol)
PPWA (periodic pulse width accumulation)
PSTN (public switched telephone network)
PWM (pulse-width modulation)
QSPI (queued serial peripheral interface, a Motorola 68332 processor peripheral)
RF (radio frequency)
RI (repeating interval)
RSS (root sum square)
RXD (receive data)
SCA (subsidiary communications authorization)
SCC (Subcarrier Control Computer)
SCI (serial communications interface)
SMR (specialized mobile radio)
SQL (structured query language)
SRAM (static random access memory)
TCR (timing control register)
TCXO (temperature compensated crystal oscillator)
TIC (time mark (timer ticks) from GPS chip set)
TDMA (time division multiple access)
TPU (time processing unit)
TXD (transmit data)
UART (universal asynchronous receiver/transmitter)
UHF (ultra high frequency)

APPENDIX B

TABLES

Table 2: Base Packet Summary

Description	ID Number	Length (Bytes)	Comments
Text Message Packet – Single Tracker or Entire	0x01	Variable	Indicates message and response set for a tracker/fleet message.
Text Message Packet – Tracker Group	0x02	Variable	Indicates message and response set for group message.
Tracker Group Message Interface ID List Packet	0x03	Variable	Indicates group of recipient ID's for text and user data messages.
Pre-defined Message Definition	0x1D	Variable	Provides a pre-defined message definition to tracker modules on a per customer basis.
Pre-defined ID Message Packet – Single Tracker or Entire Fleet	0x04	Variable	User Specific
Pre-defined ID Message Packet – Tracker Group	0x05		Indicates user data for group message.
DGPS Packet	0x06	Variable	Computed by NTCC
User Data Message Packet – Single Tracker	0x07	Variable	User specific
User Data Message Packet – Tracker Group	0x08	Variable	User specific
Grid ID Packet	0x09	11	
FM Identification Packet	0x0a	13	
UHF Identification Packet	0x0b	5	
GPS Time Packet	0x0c	7	Computed by NTCC
Set Main Repeating Interval Slot Definition Packet	0x0d	12	Assigns main repeating interval and Network/Interface ID.
Add Auxiliary Repeating Interval Slot Definition – Single Interval by Tracker ID Packet	0x0e	10	Assigns auxiliary repeating intervals
Add Auxiliary Repeating Interval Slot Definition – Single Interval by Network/Interface ID Packet	0x0f	8	
Add Auxiliary Repeating Interval Slot Definition – Limited Number of Intervals by Tracker ID Packet	0x10	11	Assigns auxiliary repeating intervals
Add Auxiliary Repeating Interval Slot Definition – Limited Number of Intervals by Network/Interface ID Packet	0x11	9	
Available Network Entry Slots Packet	0x12	8	Sent once per minute.

Table 2 (continued)

Repeating Interval Slot Config Info Packet	0x13	3	Sent once per minute. Used to determine transmit timing/format of periodic update tracker packets.
	0x14		
Network Entry Response Packet	0x15	6	
Network Entry Request Permission Packet	0x16	5	
Purge Assigned Repeating Intervals – By Tracker ID, Customer ID, or Tracker ID List Packet	0x17	6	
Message Response Acknowledge	0x18	Variable	Acknowledges Text and Predefined Message Responses
Site Dispatch Message	0x19	Variable	Provides tracker with job site location and message for user.
User Data Acknowledge	0x1a	Variable	Acknowledges reliable user data packets.
Grid Identification 2	0x1b	13	Defines RF Navigation grid and indicates NDC Server Boot Sequence ID
Site Purge Message	0x1c	Variable	Erases a known site from a tracker.
Site Status Acknowledge	0x1e		

Table 3: Text Message Packet – Single Tracker or Entire Fleet

# of bytes	Description
1	Packet ID: 0x01
1	Bits 0-2: Response Set[1] (predefined set of response choices) Bit 3-4: Address Mode 0= Tracker ID, 1 = Network/Interface ID, 2 = Customer ID Bit 5-7: Spare
3	Message Sequence ID (unique for each customer)
Variable	Tracker ID (4 bytes), Network/Interface ID (2 bytes), Customer ID (3 bytes)
3	Send Time[2] (GPS Second)[2]
1	Message Length (L_1)
L_1	Message

[1] The table below indicates the predefined response sets.
[2] Indicates the time the message was originally sent. NOTE: Since only the GPS second is provided, tracker modules may assume that the message is less than one GPS week old.

Table 4: Pre-defined Message Response Sets

Response Set ID	MDT Softkey 1	MDT Softkey 2	MDT Softkey 3	MDT Softkey 4
0[1]	{BLANK}	{BLANK}	{BLANK}	{BLANK}
1	Yes	No	Call	{BLANK}
2	OK	{BLANK}	{BLANK}	{BLANK}
3	OK	Cancel	Call	{BLANK}
4	Accept	Decline	Call	{BLANK}
5	{BLANK}	{BLANK}	{BLANK}	{BLANK}
6	{BLANK}	{BLANK}	{BLANK}	{BLANK}
7	{BLANK}	{BLANK}	{BLANK}	{BLANK}

[1] Response Set ID indicates that no pre-defined response is required. However, a custom response set may still be defined within the message. Custom response sets may be defined by appending response set values to the message. Response set values are delimited by a "|" (vertical bar) character.

Table 5: Text Message Packet – Tracker Group

# of bytes	Description
1	Packet ID: 0x02
1	Bits 0 –2: Response Set (predefined set of response choices) Bits: 3 – 7: spare
3	Customer ID
3	Message Sequence ID (unique for each customer)
3	Send Time (GPS Second)[2]
1	Message Length (L_1)
L_1	Message

[1] See Pre-defined Message Response Sets for more information about response sets.
NOTE: Text messages sent to a group of trackers will be sent two packets. One packet contains the text message, Customer ID, and Message Sequence ID while the other packet contains the tracker ID's, Customer ID, and Message Sequence ID.
[2] Indicates the time the message was originally sent. NOTE: Since only the GPS second is provided, tracker modules may assume that the message is less than one GPS week old.

Table 6: Tracker Group Message Interface ID List Packet

# of bytes	Description
1	Packet ID: 0x03
2	Message Length[1]
1	Tracker ID List Block Count ($TILBC_1$)
Variable	Tracker ID List Block #1
...	
Variable	Tracker ID List Block #$TILBC_1$
3	Message Sequence ID (unique for each customer)
3	Customer ID

[1] Indicates the total length of this message excluding the packet ID and the Message Length value.

Table 7: Tracker ID List Block

# of bytes	Description			
1	Tracker ID Block Type/Size Bits 0 – 3 : ID Type (0 – Network ID List[1], 1 – Interface ID List Within a Network[1], 2 – Interface ID Range Pairs Within a Network[1], 3 – Network/Interface ID, 4 – Tracker ID) Bit 4 : Network Size ID[1] (0 = 256 Trackers, 1 = 16 Trackers) 5 – 7 : Spare			
1	Network ID Count (NC)/ID Count (IC)			
Variable	ID Type	Network Size	# of bytes	Description
	0	0	1	Network ID #1
			...	
			1	Network ID #NC
		1	3	Bits 0 – 11: Network ID #1 Bits 12 – 23: Network ID #2
			...	
			3	Bits 0 – 11: Network ID # NC - 1 Bits 12 – 23: Network ID # NC
	1	0	1	Network ID #1
			1	Interface ID Count (IIC_1)
			1	Interface ID #1
			...	
			1	Interface ID #IIC_1
			...	
			1	Network ID #NC
			1	Interface ID Count (IIC_{NC})
			1	Interface ID #1
			...	
			1	Interface ID # IIC_{NC}
		1	2	Network ID #1
			1	Interface ID Count (IIC_1)
			1	Bits 0 – 3: Interface ID #1 Bits 4 – 7: Interface ID #2
			...	
			1	Bits 0 – 3: Interface ID # IIC - 1 Bits 4 – 7: Interface ID # IIC
			...	
			2	Network ID #NC
			1	Interface ID Count (IIC_{NC})

Table 7 (continued)

			1	Bits 0 – 3: Interface ID #1 Bits 4 – 7: Interface ID #2
			...	
			1	Bits 0 – 3: Interface ID # IIC_{NC} - 1 Bits 4 – 7: Interface ID # IIC_{NC}
	2	0	1	Network ID #1
			1	Interface ID Pair Count ($IIPC_1$)
			1	Interface ID Pair #1 Start
			1	Interface ID Pair #1 End
			...	
			1	Interface ID Pair # $IIPC_1$ Start
			1	Interface ID Pair # $IIPC_1$ End
			...	
			1	Network ID #NC
			1	Interface ID Pair Count ($IIPC_{NC}$)
			1	Interface ID Pair #1 Start
			1	Interface ID Pair #1 End
			...	
			1	Interface ID Pair # $IIPC_{NC}$ Start
			1	Interface ID Pair # $IIPC_{NC}$ End
		1	2	Network ID #1
			1	Interface ID Pair Count ($IIPC_1$)
			1	Bits 0 – 3: Interface ID Pair #1 Start Bits 4 – 7: Interface ID Pair #1 End
			...	
			1	Bits 0 – 3: Interface ID # $IIPC_1$ Start Bits 4 – 7: Interface ID # $IIPC_1$ End
			...	
			2	Network ID #NC
			1	Interface ID Pair Count ($IIPC_{NC}$)
			1	Bits 0 – 3: Interface ID #1 Start Bits 4 – 7: Interface ID #1 End
			...	
			1	Bits 0 – 3: Interface ID # $IIPC_{NC}$ Start Bits 4 – 7: Interface ID # $IIPC_{NC}$ End
	3	N/A	2	Bits 0 – 15: Network Interface ID #1
			...	
			2	Bits 0 – 15: Network Interface ID # IC_1
	4	N/A	4	Tracker ID #1
			...	
			4	Tracker ID # IC_1

Table 8 : Pre-defined ID Message Definition Packet

# of bytes	Description
1	Packet ID: 0x1D
3	Customer ID
1	Pre-defined Message ID
1	Message Length (L_1)
L_1	Message

Table 9: Pre-defined ID Message Packet – Single Tracker or Entire Fleet

# of bytes	Description
1	Packet ID: 0x04
1	Bits 0-2: Response Set[1] (predefined set of response choices) Bits 3-4: Address Mode 0= Tracker ID, 1= Network/Interface ID, 2 = Customer ID Bit 5-7: Spare
3	Message Sequence ID (unique for each customer)
Variable[2]	Tracker ID (4 bytes), Network/Interface ID (2 bytes), Customer ID (3 bytes)
3	Send Time (GPS Second)[3]
1	Pre-defined Message ID
2	Pre-defined Message 16 Bit CRC
1	Custom Response Set Length (L_1)
L_1	Custom Response Set[3]

[1] See Pre-defined Message Response Sets for more information about response sets.
[2] Indicates the time the message was originally sent. NOTE: Since only the GPS second is provided, tracker modules may assume that the message is less than one GPS week old.
[3] If the Pre-defined response set is 0, this pre-defined message packet may contain a custom set of pre-defined response sets.. Custom response set values are delimited by a "|" (vertical bar) character.

Table 10: Pre-defined ID Message Packet – Tracker Group

# of bytes	Description
1	Packet ID: 0x05
2	Message Length[1]
1	Bits 0-2: Response Set[2] (predefined set of response choices) Bit 3-7: Spare
1	Tracker ID List Block Count ($TILBC_1$)
Variable	Tracker ID List Block #1
...	
Variable	Tracker ID List Block #$TILBC_1$
3	Send Time (GPS Second)[3]
1	Pre-defined Message ID
2	Pre-defined Message 16 Bit CRC
1	Custom Response Set Length (L_1)
L_1	Custom Response Set[4]

[1] Indicates the total length of this message excluding the packet ID and the Message Length value.
[2] See Pre-defined Message Response Sets for more information about response sets.
[3] Indicates the time the message was originally sent. NOTE: Since only the GPS second is provided, tracker modules may assume that the message is less than one GPS week old.
[4] If the Pre-defined response set is 0, this pre-defined message packet may contain a custom set of pre-defined response sets. Custom response set values are delimited by a "|" (vertical bar)

Table 11: DGPS Packet

Byte Number	Description
0	Packet ID: 0x06
1	Bits 0-5: RTCM Frame ID (0-63) Bits 6-7: Spare
2	Bits 0-4: Number of SVs in the message (0⇒32 SVs=N_{SV}) Bits 5-7: Spare
3-4	Bits 0-12: RTCM–104 Modified Z-Count Bits 13-15: Station Health
(i=0-N_{SV}–1)	Correction Data for each SV follows (5 bytes each)
5+5i	Bits 0-4: SV PRN ID of this correction (0⇒PRN 32) Bits 5-6: User Differential Range Error Bit 7: Scale Factor
6+5i	IODE
7+5i-8+5i	Pseudorange Correction
9+5i	Pseudorange-rate Correction

Table 12: User Data Message Packet – Single Tracker or Entire Fleet

# of bytes	Description
1	Packet ID: 0x07
1	Bits 0-2: Spare[2] Bits 3-4: Address Mode 0= Tracker ID, 1=Network/Interface ID, 2 = Customer ID Bit 5-7: Spare[2]
3	Message Sequence ID
Variable	Tracker ID (4 bytes), Network/Interface ID (2 bytes), Customer ID (3 bytes)
3	Send Time (GPS Second)[1]
1	Message Length (L_1)
L_1	Message

[1] Indicates the time the message was originally sent. NOTE: Since only the GPS second is provided, tracker modules may assume that the message is less than one GPS week old.
[2] Spare values were split to allow Address Mode to be in same position for all messages.

Table 13: User Data Message Packet – Tracker Group

# of bytes	Description
1	Packet ID: 0x08
3	Customer ID
3	Message Sequence ID
3	Send Time (GPS Second)[1]
1	User Data Length (L_1)
L_1	User Data

NOTE: User data sent to a group of trackers will be sent two packets. One packet contains the user data, Customer ID, and Message Sequence ID while the other packet contains the tracker ID's, Customer ID, and Message Sequence ID. See Tracker Group Message Interface ID List Packet to identify the trackers receiving this user data packet.
[1] Indicates the time the message was originally sent. NOTE: Since only the GPS second is provided, tracker modules may assume that the message is less than one GPS week old.

Table 14: Grid ID Packet

Byte Number	Description
0	Packet ID: 0x09
1-2	Bits 0-14: Grid ID number Bit 15: local grid=1; adjacent grid=0
3-5	Grid Origin Latitude: LSB=2^-23 semicircles
6-8	Grid Origin Longitude: LSB=2^-23 semicircles
9-10	Grid Origin Altitude (HAE): LSB=1 meter

Table 15: FM Identification Packet

Byte Number	Description
0	Packet ID: 0x0a
1-2	Bits 0-14: Grid ID number Bit 15: local grid=1; adjacent grid=0
3	Bits 0-1: Transmitter ID Bits 2-3: Number of transmitters (0⇒4 transmitters) Bits 4-7: Spare
4-6	FM Transmitter Latitude: LSB=2^-23 semicircles
7-9	FM Transmitter Longitude: LSB=2^-23 semicircles
10-11	FM Transmitter Altitude (HAE): LSB=1 meter
12	Bits 0-6: Frequency 0⇒87.5MHz, 1⇒87.7MHz, 102⇒107.9MHz Bit 7: Subcarrier: 0⇒67KHz, 1⇒92KHz

Table 16: UHF Identification Packet

Byte Number	Description
0	Packet ID: 0x0b
1-2	Bits 0-14: Grid ID number Bit 15: local grid=1; adjacent grid=0
3	Bits 0-1: UHF Frequency ID Bits 2-3: Number of frequencies (0⇒4 frequencies) Bits 4-7: Spare
4-5	Bits 0-11: Frequency 0⇒450MHz, 1⇒450.0125MHz, 1600⇒470MHz Bits 12-15: Spare

Table 17: GPS Time Packet

Byte Number	Description
0	Packet ID: 0x0c
1-2	Bits 10-15: Leap Seconds Bits 0-9: GPS Week 0-1023
3-5	Bits 0-19: GPS Second 0-604799 Bits 20-23: Rollover Count
6	Bits 0-6: Time Zone Offset from GPS/UTC, LSB=15 minutes Bit 7: Spare

Table 18: Set Main Repeating Interval Slot Definition Packet

Byte Number	Description
0	Packet ID: 0x0d
1-4	Bits 0-29:Tracker ID Bit 30: entry type flag (0=normal, 1=low power)[1] Bit 31: spare
5-6	Network/Interface ID
7	Slot
8-9	Repeating Interval Index
10-11	Interval Length

[1] Tracker modules may enter the network by requesting network entry or by requesting a low power slot with their state and status tracking update. If a tracker requested net entry using a net entry request packet, this flag is 0. If a tracker requested a low power RI slot, this flag is 1.

Table 19: Add Auxiliary Repeating Interval Slot Definition – Single Interval by Tracker ID Packet

Byte Number	Description
0	Packet ID: 0x0e
1-4	Tracker ID
5	Slot
6-7	Repeating Interval Index
8-9	Interval Length

Table 20: Add Auxiliary Repeating Interval Slot Definition – Single Interval by Network/Interface ID Packet

Byte Number	Description
0	Packet ID: 0x0f
1-2	Network/Interface ID
3	Slot
4-5	Repeating Interval Index
6-7	Interval Length

Table 21: Add Auxiliary Repeating Interval Slot Definition – Limited Number of Intervals by Tracker ID Packet

Byte Number	Description
0	Packet ID: 0x10
1-4	Tracker ID
5	Slot
6-7	Repeating Interval Index
8-9	Interval Length
10	Interval Count

Table 22: Add Auxiliary Repeating Interval Slot Definition – Limited Number [illegible] by Network/Interface ID Packet

Byte Number	Description
0	Packet ID: 0x11
1 - 2	Network/Interface ID
3	Slot
4 – 5	Repeating Interval Index
6 – 7	Interval Length
8	Interval Count

Table 23: Available Network Entry Slots Packet

# of bytes	Description
1	Packet ID: 0x12
1	Slot Count
(SlotCount+7)/8	Bit map of available slots Flag (0 = not available, 1 = available) Slot 0 Flag = bit 0, byte 2, Slot 1 Flag = bit 1, byte 2, . . . Slot 8 Flag = bit 0, byte 3, Slot 9 Flag = bit 2, byte 3, . . .

Table 24: Repeating Interval Slot Config Info Packet

Byte Number	Description
0	Packet ID: 0x13
1-2	Frame cycle length
3	Self-purge update count
4	Tracker ID Request Mode 0 = Tracker ID Not Required, 1 = Tracker ID required for next update only, 2 = Tracker ID required for all updates
5 - 6	BIT Packet Rate (in seconds).

Table 25: Network Entry Response Packet

Byte Number	Description
0	Packet ID: 0x15
1-4	Tracker ID
5	Bits 0 –1 : Assigned Tracker State Code: 0 = wait for auxiliary repeating interval slot, 1 = wait for net entry permission, 2 = wait for registration[1]

[1] Indicates that the tracker has not been registered with the NDC Server. Unregistered trackers may continue to request network entry each hour.

Table 26: Network Entry Request Permission Packet

# of bytes	Description
1	Packet ID: 0x16
4 or 1[1]	Bits 0-1: Address Mode 0 = by tracker ID, 1 = by customer ID, 3 = by Tracker ID List Bits 2 - 31: Address (by Tracker ID) Bits 2-25: Customer ID (by customer ID)
2 or Variable[1]	2 bytes: Network/Interface ID (by Network/Interface ID)
	Variable: Tracker ID List Block (by Tracker ID List)

[1] If address type indicates "by tracker ID" or "by customer ID", the ID follows immediately afterwards. If "by Network/Interface ID" or "by Tracker ID List" is indicated, the ID starts in the next byte.

Table 27: Purge Assigned Repeating Intervals – By Tracker ID, Customer ID, or Tracker ID List Packet

# of bytes	Description
1	Packet ID: 0x17
4 or 1[1]	Bits 0-1: Address Mode 0 = by tracker ID, 1 = by customer ID, 2 = by Network/Interface ID, 3 = by Tracker ID List Bits 2 - 31: Address (by Tracker ID)[3] Bits 2-25: Customer ID (by customer ID)
2 or Variable[1]	2 bytes: Network/Interface ID (by Network/Interface ID) or
	Variable: Tracker ID List Block (by Tracker ID List) or
1	Bits 0 – 3: 0 = Purge all repeating intervals, 1 = Purge all auxiliary repeating intervals, 2 = Purge main repeating interval[2] 3 = Purge specified repeating interval[4] Bit 4: 0 = Wait for Net Entry Request Permission, 1 = Request Network Entry
1 (optional)[4]	Specified Repeating Interval: Slot[4]
2 (optional)[4]	Specified Repeating Interval: Index[4]
2 (optional)[4]	Specified Repeating Interval: Length[4]

[1] If address type indicates "by tracker ID" or "by customer ID", the ID follows immediately afterwards. If "by Network/Interface ID" or "by Tracker ID List" is indicated, the ID starts in the next byte.

[2] Trackers should purge their Network/Interface ID when their main repeating interval is purged.

[3] 0x0000 = Broadcast tracker ID. If a purge assigned repeating interval is sent to 0x0000, all tracker modules should purge the indicated repeating interval(s).

[4] Optional portion of the message that only exists if "Purge specified repeating interval" is indicated.

Table 28: Message Response Acknowledge

# of bytes	Description
1	Packet ID: 0x18
1	Bits 0-2: Response Key ID 1 = Softkey #1, 2 = Softkey #2, 3 = Softkey #3,4 = Softkey #4 Bits 3-4: Address Mode 0=Tracker ID, 1= Network/Interface ID Bit 5-7: Spare
3	Message Sequence ID[1] (unique for each customer)
Variable	Tracker ID (4 bytes), Network/Interface ID (2 bytes)

[1] The Message Sequence ID is the same ID associated with the original text/site dispatch message that required the response.

Table 29: Site Dispatch Message

# of bytes	Description
1	Packet ID: 0x19
1	Bits 0-2: Response Set[1] (predefined set of response choices) Bit 3-4: Address Mode 0= Tracker ID, 1 = Network/Interface ID, 2 = Customer ID Bits 5-6: Site Type[3] (0=job site, 1=home base, 2= customer defined, 3 = customer defined) Bit 7: spare
3	Message Sequence ID (unique for each customer)
Variable	Tracker ID (4 bytes), Network/Interface ID (2 bytes), Customer ID (3 bytes)
3	Send Time (GPS Second)
3	Site ID (unique per type per customer)[4]
3	Northeast Latitude -90° to +90° (LSB = 180° * 2^{-23})
3	Northeast Longitude -180° to +180° (LSB = 180° * 2^{-23})
3	Southwest Latitude -90° to +90° (LSB = 180° * 2^{-23})
3	Southwest Longitude -180° to +180° (LSB = 180° * 2^{-23})
1	Message Length (L_1) (Max = 128 bytes, including response)[5]
L_1	Message[2]

[1] See the Pre-defined Message Response Sets table for more information.

Table 30: Site Purge Message

# of bytes	Description
1	Packet ID: 0x1c
1	Bits 0-2: Response Set[1] (predefined set of response choices) Bit 3-4: Address Mode 0= Tracker ID, 1 = Network/Interface ID, 2 = Customer ID Bits 5-6: Site Type[3] (0=job site, 1=home base, 2= customer defined, 3 = customer defined) Bit 7: spare
3	Message Sequence ID (unique for each customer)
Variable	Tracker ID (4 bytes), Network/Interface ID (2 bytes), Customer ID (3 bytes)
3	Send Time (GPS Second)
3	Site ID (unique per type per customer)[2]

[1] See the Pre-defined Message Response Sets table for more information.

[2] Site ID values are unique per customer per site type, except for the mass purge Site ID of 0x1FFFFF. The Site ID 0x1FFFFF tells the tracker to purge all messages of the type indicated in the Site Type field.

[3] The tracker module may use the site type to determine the length of time a site should be retained and the algorithm that should be used to determine arrival/departure status. Job sites should be retained by the tracker until the tracker enters and leaves the site. Home base sites should be retained until deleted. And, types 2 & 3 should be retained based on customer defined rules.

# of bytes	Description
1	Packet ID: 0x1a
1	Bits 0: Address Mode 0=Tracker ID, 1= Network/Interface ID Bit 1-7: spare
1	User Data Sequence ID[1]
Variable	Tracker ID (4 bytes), Network/Interface ID (2 bytes)

[1] Sequence ID assigned by tracker when reliable user data packet was transmitted. See Reliable User Data and Reliable Short User Data for more information.

Table 32: Grid ID Packet2

# of bytes	Description
1	Packet ID: 0x1b
2	Bits 0-14: Grid ID number Bit 15: local grid=1; adjacent grid=0
3	Grid Origin Latitude: LSB=2^-23 semicircles
3	Grid Origin Longitude: LSB=2^-23 semicircles
2	Grid Origin Altitude (HAE): LSB=1 meter
2	NDC Server Boot Sequence ID

Table 33: Site Status Acknowledge

# of bytes	Description
1	Packet ID: 0x1d
1	Bits 0: Address Mode 0=Tracker ID, 1= Network/Interface ID Bits 1-2: Site Type[3] (0=job site, 1=home base, 2= customer defined, 3 = customer defined) Bit 3-7: spare
Variable	Tracker ID (4 bytes), Network/Interface ID (2 bytes)
3	Site ID
1	Site Sequence ID[1]

[1] Sequence ID assigned by tracker when reliable site status packet was transmitted. See Site Status for more information.

Table 34: Planned Tracker Update Repeating Interval Rates

Transmit Interval (sec)	Transmit Interval (min)	Comments
3600	60	Low power repeating interval
1800	30	
1200	20	
900	15	12 hrs/day, 1000 updates/month
600	10	8 hrs/day, 1000 updates/month
300	5	
225	3.75	12 hrs/day, 4000 updates/month
144	2.4	8 hrs/day, 4000 updates/month
60	1	
30	0.5	
10	0.166667	
5	0.083333	Emergency Vehicles

Table 35: Tracker State Data Block Byte/Bit Definitions

Byte/Bit, Bit Length	Description
0/0, 10	Grid Zone ID
1/2, 24	Bits 0-10: ΔN_{off} Bits 11-21: ΔE_{off} Bit 22: State Data Validity 1=valid Bits 23: GPS Validity 1=DGPS current
4/2, 7	Bits 0-6: Speed
5/1, 7	Bits 0-6: Heading

Table 36: Reduced State Data Block Byte/Bit Definitions

Byte/Bit, Bit Length	Description
0/0, 10	Grid Zone ID
1/0, 24	Bits 0-10: ΔN_{off} Bits 11-21: ΔE_{off} Bit 22: State Data Validity 1=valid Bits 23: GPS Validity 1=DGPS current

Table 37: Network Status Code Definitions

Code	Description
0	No status
1	Network exit request
2	Low Power Repeating Interval Slot Request
3	Low Power exit request
4	All Repeating Interval Slots Purged
5	Main Repeating Interval Slot Purged
6	Auxiliary Repeating Interval Slot Purged
7	Re-assign Main Repeating Interval Slot Request
8	Re-assign Auxiliary Repeating Interval Slot Request
9-31	

Table 38: Message Acknowledgement/Response Block

Byte/Bit, Bit Length	Description
0/0, 1	Acknowledgement/Response Flag (0 = Ack Only, 1 = Response)
0/1, 3	Response Key ID (0=Return Receipt[2], 1= Softkey #1, 2 = Softkey #2, 3 = Softkey #3, 4 = Softkey #4)
0/4, 1	spare
0/5, 21	Message/Site Sequence ID
3/2, 20	GPS Second Receipt/Response Time[1]

[1] Indicates the GPS Second when the message was received for acknowledgment or the GPS Second when the Softkey was pressed for a response.
[2] Indicates that message was read by driver.

Table 39: Tracker Packet Summary

Description	ID Number	Comments	Spare Bits
Net Entry Request	0	Used to request main RI Slot or a one-time auxiliary RI Slot.	14
State and Status	1	Normal Periodic Transmission	1
Reliable User Data	2	User Specific	4
Short State and Status	3	Contains Tracker ID	3
Reliable Short User Data	4	User Specific with Tracker ID	6
Reduced State User Data and Status	5	State, Tracker ID, and User Data	3
Message Response and User Data	6	Message response with user data.	6
Short Message Response and User Data	7	Message response with full tracker ID and user data.	0
Site Status	8	Used to indicate job site arrival/departure	2
Built-in test (BIT)	9	Packet to provide info about the tracker, it's environment and the RF network.	Varies by type.
Pre-defined Message Definition Request	0x0a	Used by tracker to request a pre-defined message definition. NOTE: This packet may be sent in a network entry slot.	0

Table 40: Net Entry Request Packet Bit Definitions

Byte/Bit,bit length	Bit Number	Description
0/0, 4	0-3	Packet ID Block (0x00)
0/4, 1	4-4	0 = Main RI Slot, 1 = Single Auxiliary RI Slot
0/5, 1	5-5	0 = Main RI Slot, 1 = Single Auxiliary RI Slot
0/6, 30	6-35	Bits 0-29: Tracker ID Number
4/4, 30	36-65	Bits 0-29: Tracker ID Number
8/2, 5	66-70	Aux Interval Count
8/7, 5	71-75	Aux Interval Count
9/4, 4	76-79	Spare
10/0, 16	80-95	CRC 16

Table 41: State and Status Packet Bit Definitions

Byte/Bit, bit length	Bit Number	Description
0/0, 4	0-3	Packet ID Block (0x01)
0/4, 5	4-8	Network Status Code
1/1, 48	9-56	Tracker State Data Block
7/1, 24	57-80	User Data Block
10/1,7	81-87	Spare
11/0, 8	88-95	CRC 8

Table 42: Reliable User Data Packet Bit Definitions

Byte/Bit,bit length	Bit Number	Description
0/0, 4	0-3	Packet ID Block (0x02)
0/4, 8	4-11	User Data Sequence ID
1/4, 72	12-83	User Data Block
10/4, 4	84-87	Spare
11/0,8	88-95	CRC 8

Table 43: Short State and Status Packet Bit Definitions

Byte/Bit,bit length	Bit Number	Description
0/0, 4	0-3	Packet ID Block (0x03)
0/4, 30	4-33	Bits 0-29: Tracker ID Number
4/2, 5	34-38	Network Status Code
4/7, 48	39-86	Tracker State Data Block
10/5, 1	87-87	Spare
11/0, 8	88-95	CRC 8

Table 44: Reliable Short User Data Packet Bit Definitions

Byte/Bit,bit length	Bit Number	Description
0/0, 4	0-3	Packet ID Block (0x04)
0/4, 30	4-33	Bits 0-29: Tracker ID Number
4/2, 8	34-41	User Data Sequence ID
5/2, 40	42-81	User Data
10/2, 6	82-87	Spare
11/0, 8	88-95	CRC 8

Table 45: Reduced State User Data and Status Packet Bit Definitions

Byte/Bit,bit length	Bit Number	Description
0/0, 4	0-3	Packet ID Block (0x05)
0/4, 30	4-33	Bits 0-29: Tracker ID Number
4/2, 5	34-38	Network Status Code
4/7, 34	39-72	Reduced State Data Block
8/7, 8	73-80	User Data
10/7, 7	81-87	Spare
11/0, 8	88-95	CRC 8

Table 46: Message Response and User Data Packet Bit Definitions

Byte/Bit,bit length	Bit Number	Description
0/0, 4	0-3	Packet ID Block (0x06)
0/4, 46	4-49	Message Acknowledgement/Response Block
6/2, 32	50-81	User Data Block
10/2, 6	82-87	Spare
11/0, 8	88-95	CRC 8

Table 47: Short Message Response and User Data Packet Bit Definitions

Byte/Bit,bit length	Bit Number	Description
0/0, 4	0-3	Packet ID Block (0x07)
0/4, 30	4-33	Bits 0-29: Tracker ID Number
4/2, 46	34-79	Message Acknowledgement/Response Block
10/0, 8	80-87	User Data Block
11/0, 8	88-95	CRC 8

Table 48: Site Status Packet Bit Definitions

Byte/Bit,bit length	Bit Number	Description
0/0, 4	0-3	Packet ID Block (0x08)
0/4, 30	4-33	Bits 0-29: Tracker ID Number
4/2, 2	34-35	Site Type (0=job site, 1=home base, 2= customer defined, 3 = customer defined)
4/2, 21	36-56	Site ID
7/0, 1	56-56	Status (0 = Arrival, 1 = Departure)
7/1, 1	57-57	Automatic Source Flag[2]
7/2, 1	58-58	User Source Flag[3]
7/2, 20	59-79	GPS Second Arrival/Departure Time[1]
9/6, 8	80-87	Site Status Sequence ID
11/0, 8	88-95	CRC 8

[1] Indicates the GPS Second value upon arrival/departure.
[2] Set for "event-driven" initiated event.
[3] Set for user initiated event.

Table 49: Built-in Test (BIT) Packet Bit Definitions

Byte/Bit,bit length	Bit Number	Description
0/0, 4	0-3	Packet ID Block (0x09)
0/4, 4	4-7	BIT Packet Type
1/0, 80		BIT Packet Data Block[1]
11/0, 8	88-95	CRC 8

[1] See following tables for the BIT Packet Data Blocks.

Table 50: Built-in Test (BIT) Packet Data Block (Network and RF System, Type = 0)

# of bytes	Description
2	Missed Bit Sync Count
2	CRC Error Count A
2	CRC Error Count B
1	Number of Times Sync Was Lost
1	Max Sync Loss Duration
1	Number of Network Entry Attempts
1	Number of Reliable Packet Retries

[illegible]

# of bytes	Description
1	Highest Battery Voltage
1	Lowest Battery Voltage
1	Number of Times Ignition Was Turned Off
1	Shortest Off Duration (min)
1	Longest Off Duration (min)
1	Highest Temperature (°C)
1	Lowest Temperature (°C)
3	Spare (0x000000)

Table 52: Built-in Test (BIT) Packet Data Block (Navigation, Type = 2)

Byte/Bit, bit length	Bit Number	Description
0/0, 8	0-7	Number of Times Nav was Invalid
1/0, 8	8-15	Maximum Duration Nav was Invalid (min)
2/0, 8	16-23	Number of Times without DGPS
3/0, 8	24-31	Maximum Duration without DGPS (min)
4/0, 4	32-35	Number of SVs tracked
4/4, 5	36-40	SNR for Channel 0
5/1, 5	41-45	SNR for Channel 1
5/6, 5	46-50	SNR for Channel 2
6/3, 5	51-55	SNR for Channel 3
7/0, 5	56-60	SNR for Channel 4
7/5, 5	61-65	SNR for Channel 5
8/2, 5	66-70	SNR for Channel 6
8/7, 5	71-75	SNR for Channel 7
9/4, 4	76-79	Spare

Table 53: Built-in Test (BIT) Packet Data Block (Version, Type = 3)

# of bytes	Description
1	Tracker Software Major Release
1	Tracker Software Minor Release
1	Tracker Software Build
1	Tracker Hardware Major Release
1	Tracker Hardware Minor Release
1	MDT Software Major Release
1	MDT Software Minor Release
1	MDT Software Build
1	MDT Hardware Major Release
1	MDT Hardware Minor Release

Table 54: Built-in Test (BIT) Packet Data Block (Ready Mix, Type = 4)

# of bytes	Description
2	Number of times wash out hose was on for 15 minutes continuously
2	Number of times water was turned on
2	Number of times door was opened
2	Number of times drum was charged
2	Number of times drum was discharged

Table 55: Pre-Defined Message Definition

Byte/Bit,bit length	Bit Number	Description
0/0, 4	0-3	Packet ID Block (0x0A)
0/4, 30	4-33	Bits 0-29: Tracker ID Number
4/2, 30	34-63	Bits 0-29: Tracker ID Number
8/0, 8	64-71	Pre-defined Message ID
9/0, 8	72-79	Pre-defined Message ID
10/0, 16	80-95	CRC 16

Table 56: TPU Channels and Functions

Channel	Signal	Input From	Output To	Linked To	Priority	TPU Function	Mode	Purpose
TP0	TX Key		TP1		L	OC	Host Initiated Pulse	Turn on transmitter
TP1	TX Timing	TP0		TP2	L	ITC	Single Shot/Link(1)	Start TX serial clock at correct time
TP2	RF Serial Clk		SCLK, TP3		H	OC	Continuous Pulse	TX serial bit clock to QSPI
TP3	RF Serial Clk	TP2		TP2	H	ITC	Single Shot/Link(1)	Count transmitted bits
TP4	RX Data A	Rcv FM Data A			M	PPWA	Pulse Accum/No Link	Detect bit-sync pulses, alt. TP11
TP5	RX Timing 1		TP6		L	OC	Host Initiated Pulse	Initiate FM data reception
TP6	RX Timing 2	TP5		TP7, TP8	L	ITC	Single Shot/Link(2)	Start RX serial clocks at correct time
TP7	Shift Clk		Shift Reg		H	OC	Continuous Pulse	RX bit clock
TP8	Latch Clk		Shift Reg		M	OC	Continuous Pulse	RX byte clock, interrupt to rcv byte
TP9								Used for RAM
TP10								Spare: may need for RAM
TP11	RX Data B	Rcv FM Data B			M	PPWA		Detect bit-sync pulses, alt. TP04
TP12	Direction	External			L	ITC		Detect direction change
TP13	Wheel Sens A	External			L	QDEC		Count wheel sensor pulses
TP14	Wheel Sens B	External			L	QDEC		Count wheel sensor pulses
TP15	Cruise Sens	External			L	ITC	Single Shot/No Link	Count speed sensor pulses
TP11	PPS	GP2021/Extern.						Roof Module Receiver

Table 57: Navigation Data

Word Number	Description	Type	Units/ LSB	Range
1-5	Header			
6	Status			
7-8	Latitude	Long	2^{-31} semicircles	±0.5
9-10	Longitude	Long	2^{-31} semicircles	±1.0
11	Altitude	Short	0.125m	
12	North Velocity	Short	2^{-8} m/sec	
13	East Velocity	Short	2^{-8} m/sec	
14	Down Velocity	Short	2^{-8} m/sec	
15	Year	Ushort		
16(lsb)	Month	Uchar		1-12
16(msb)	Day	Uchar		1-31
17(lsb)	Hour	Uchar		0-23
17(msb)	Minute	Uchar		0-59
18	Second	Ushort	2^{-7} sec	0-7679
19	Data Checksum			

Table 58: Received Message Data (7102)

Word Number	Description	Type	Units/ LSB	Range
1-5	Header			
6(lsb)	Message Type 1=canned, 2=full text	uchar		
6(msb)	Canned ID/Text Length(L)	uchar		
7(lsb)	IOD	uchar		0-255
7(msb)	User Response	uchar		0-4
8	Year	ushort		
9(lsb)	Month	uchar		1-12
9(msb)	Day	uchar		1-31
10(lsb)	Hour	uchar		0-23
10(msb)	Minute	uchar		0-59
11(lsb)	Number of valid responses	uchar		0-4
11(msb)	Spare	uchar		
12-16	Response 1 Text	char		
17-21	Response 2 Text	char		
22-26	Response 3 Text	char		
27-31	Response 4 Text	char		
next L/2	Text if type=2, padded with 0 in last byte if L is odd	char		

Table 59: Received User Data (7103)

Word Number	Description	Type	Units/ LSB	Range
1-5	Header			
6	Data Type Identifier	ushort		0-255
7-16	20 Data bytes	uchar		

Table 60: Available Message Data (7104)

Word Number	Description	Type	Units/ LSB	Range
1-5	Header			
6	Number of unread messages (X)	ushort		0-255
7	Id of most recent unread message	ushort		0-255
...	...	...	...	...
7+X-1	Id of oldest unread message	ushort		0-255
7+X	Number of saved messages (Y)	ushort		0-255
7+X+1	Id of most recent saved message	ushort		0-255
...	...	...	...	...
7+X+Y-1	Id of oldest saved message	ushort		0-255
7+X+Y	Data Checksum			

Table 61: User Data Message List (7106)

Word Number	Description	Type	Units/ LSB	Range
1-5	Header			
6	Number of messages in the list (N)	ushort		0-255
7-21	Message 1	char		0-255
...	...	...	...	...
(7+N*15)-(21+N*15)	Message N	char		0-255
7+N*15	Data Checksum			

Table 62: Data Request (7201)

Word Number	Description	Type	Units/ LSB	Range
1-5	Header			
6	Message ID	ushort		
7	On/Off	ushort		
8	Data Checksum			

Table 63: Text Message Response (7202)

Word Number	Description	Type	Units/ LSB	Range
1-5	Header			
6(lsb)	IOD	uchar		0-255
6(msb)	Response	ushort		0-7
7	Data Checksum			

Table 64: User Data Output (7203)

Word Number	Description	Type	Units/ LSB	Range
1-5	Header			
6(lsb)	Number of Bytes	uchar		1 or 9
6(msb)	Data Type Identifier	uchar		0-255
7-11	10 Data bytes (1 or 9 will be used)	uchar		
12	Data Checksum			

Table 65: Request Available Message Data (7204)

Word Number	Description	Type	Units/ LSB	Range
1-5	Header			

Table 66: Request Message (7205)

Word Number	Description	Type	Units/ LSB	Range
1-5	Header			
6	Message Identifier	ushort		0-255
7	Data Checksum			

Table 67: Request User Data Message List (7206)

Word Number	Description	Type	Units/ LSB	Range
1-5	Header			

Table 69: NTCC/SCC Message Summary

Message ID	Source	Description	Rate
1101	NTCC	Timing Control	1Hz
1102	NTCC	Transmit Data Frame (1 of *N*)	*N* frames at 1Hz
1201	SCC	SCC Status	1Hz

Table 70: Timing Control (1101)

Word Number	Description	Type	Units	Range
1-5	Header			
6(lsb)	Timing Control Mode	uchar		0-2
6(msb)	Control Type	uchar		0-2
7-8	Timer Control	long	0.1 microsec	±0.5 sec
9	Data Checksum			

Table 71: Transmit Data Frame (1102)

Word Number	Description	Type	Units	Range
1-5	Header			
6	Broadcast Frame ID	short		0-188
7(lsb)	Frame Number (*n*)	uchar		0-?
7(msb)	Total Number of Frames (*N*)	uchar		0-?
8	Number of Bytes per Frame (*l*)	short		
9-8+(*l*+1)/2	Frame Data Bytes	uchar		
9+(*l*+1)/2	Data Checksum			

Table 72: SCC Status (1201)

Word Number	Description	Type	Units	Range
1-5	Header			
6-7	Current Nominal Timer	long	0.1 microsec	0-1.0+ sec
8	SCC Status	coded		
9	Data Checksum			

Table 73: NTCC/Server Message Summary

Message ID	Source	Description	Rate
2104	Server	Login Info Request	At Initialization
2304	NTCC	Login Info Response	At Initialization
2105	Server	NTCC Profile Request	At Initialization
2305	NTCC	NTCC Profile Response	At Initialization
2103	NTCC	Status 2	1Hz
2201	Server	FM Data	At Connection
2202	Server	Vehicle Packet	High Rate
2203	Server	Local Time Zone Offset	At Initialization and once per hour

Table 74: Login Info Request Message (2104)

# of bytes	Description	Value or Range
10	Header	

Table 75: Login Info Response Message (2304)

# of bytes	Description	Value or Range
10	Header	
2	User ID Length	0x0000 – 0x0020
L_1	User ID	
2	Password Length	0x0000 – 0x0020
L_2	Password	
Padding[1]		
1	Data Checksum	

[1] 0x00 will be used for padding if necessary to make entire body word aligned.

Table 76: NTCC Profile Request Message (4105)

# of bytes	Description	Value or Range
10	Header	

Table 77: NTCC Profile Response Message (4305)

# of bytes	Description	Value or Range
10	Header	
4	NTCC Serial Number	
4	Roof Module Serial Number	
2	Data Checksum	

[1] 0x00 will be used for padding if necessary to make entire body word aligned.

Table 78: Status Message 2 (2103)

# of bytes	Description	Value or Range
10	Header	
2	Timing Status	0= No Sync 1= In Sync
2	Week Roll-over Count	
2	Leap Seconds	
2	GPS Week	
4	GPS Second	
2	Current Network Frame Number	
1	System Status Mode	1=Init, 2=Sync, 3=Run
1	Bits 0-3: Timing Mode Bits 4-7: Timing Sub Mode	Bits 0-3: 0=Init, 1=Coarse Offset, 2=Coarse Rate, 3=Fine Rate Bits 4-7: 0=Sample, 1=Wait, 2=Command, 3=Check
1	Bits 0-3: GPS Status Bits 4-7: System Time Status	Bits 0-3: 0=Waiting For GPS,1=GPS Initialized Bits 4-7: 0=Invalid, 1=Valid
2	SCC Clock Rate	LSB=0.1 PPM
1	Bits 0-3: SCC Port Status Bits 4-7: SCC Port Connection Status	Bits 0-3: 0=Inactive, 1=Active Bits 4-7: 0=Not Connected, 1=Connected
4	Sync Loss Events	
4	Total Sync Loss Time	
1	NDC Port	0=Inactive, 1=Active
1	Bit 0: Roof Module Status Bits 1-2: Roof Module Channel Status Bit 3: FM Sync Bit 4: FM Sync Message Bits 5-7: spare	Bit 0: 0 = Inactive, 1 = Active Bits 1-2: 0 = No Frequency Date, 1 = Not Locked, 2 = Locked Bit 3: 0 = Unreliable, 1 = Reliable Bit 4: 0 = Unreliable, 1 = Reliable Bits 5-7: 0
1	FM Bit Sync Reliability	LSB=1%
1	Sync Data Status	0=Unreliable, 1=Reliable, 2=Timed out
1	Sync Data Reliability	LSB=1%
1	Bits 0-3: GPS CDU Port Bits 4-7: PPS	Bits 0-3: 0=Inactive, 1=Active Bits 4-7: 0=Invalid, 1=Valid
1	GPS SVID Count (C_1)	0-12
1	GPS SVID #0	
...		
1	GPS SVID #(C_1-1)	
1	GPS CN0 Count (C_2)	0-12
1	GPS CN0 #0	
...		
1	GPS CN0 #(C_2-1)	
1	Bits 0-3: RTCM Port Bits 4-7: Data	Bits 0-3: 0=Inactive, 1=Active Bits 4-7: 0=Unavailable, 1=Available
1	RTCM T1 SVID Count (C_3)	0-12
2 (if C_3 >	RTCM T1 Frame Number	0-3599

Table 78 (continued)

0)		Note: T1 Frame Number not supplied if $C_3 = 0$.
1	RTCM T1 SVID #0	
...		
1	RTCM T1 SVID #(C_3-1)	
1	RTCM T2 SVID Count (C_4)	0-12
2 (if $C_4 >$ 0)	RTCM T2 Frame Number	0-3599 Note: T2 Frame Number not supplied if $C_4 = 0$.
1	RTCM T2 SVID #0	
...		
1	RTCM T2 SVID #(C_4-1)	
2	FM Error Frame	
2	FM Error Count	
2	FM Bit Count	
4	FM Total Error Count	
4	FM Total Bit Count	
4	Bert PPM	LSB = .001 PPM
2	Total Bytes Sent on Last Frame	short
2	Free Bytes After Last Frame	short
2	Packets Received	short
2	Packet Bytes Received	short
2	Packets Sent	short
2	Packet Bytes Sent	short
2	Packets in Queue	short
2	Packet Bytes in Queue	short
Padding[1]		
1	Data Checksum	

Table 79: FM Data (2201)

Word Number	Description	Type	Units	Range
1-5	Header			
6	Frequency	short	0.1 MHz	875-1079
7	Subcarrier	short	kHz	67 or 92
8-9	Latitude	long	2^{-31} semicircles	–1 to 1
10-11	Longitude	long	2^{-31} semicircles	–0.5 to 0.5
12	Altitude	short	meters	
13-27	Telephone Number String	char		
28	Data Checksum			

Table 80: Vehicle Packet (2202)

Word Number	Description	Type	Units	Range
1-5	Header			
6	Vehicle Data Length (l)	short	bytes	
7-6+(l+1)/2	Packet Contents			
7+(l+1)/2	Data Checksum			

Table 81: Local Time Zone Offset (2203)

Word Number	Description	Type	Units	Range
1-5	Header			
6	Time Zone Offset	short	LSB = 15 min	-48 to 48
7	Data Checksum			

Table 82: NTCC/Roof Module Message Summary

Message ID	Source	Description	Rate
3101	NTCC	Frequency Control	At Initialization
3102	NTCC	Time/Status	1Hz
3201	Roof Module	Status	1Hz
3202	Roof Module	Received FM Data	1Hz
3203	Roof Module	Timing	1Hz

Table 83: Frequency Control (3101)

Word Number	Description	Type	Units	Range
1-5	Header			
6	Frequency	short	0.1 MHz	875-1079
7	Subcarrier	short	KHz	67 or 92
8	Data Checksum			

Table 84: Time/Status (3102)

Word Number	Description	Type	Units	Range
1-5	Header			
6	Timing Status	coded		
7	GPS Week	short		0-1023
8-9	GPS Second	long		0-604799
10	Current Network Frame Number	short		0-188
11	Mode	coded		
12	System Status	coded		
13	Data Checksum			

Table 85: Status (3201)

Word Number	Description	Type	Units	Range
1-5	Header			
6	Frequency	short	0.1 MHz	875-1079
7	Subcarrier	short	kHz	67 or 92
8	Timing Status	coded		
9	System Status	coded		
10	FM Status	coded		
11	Data Checksum			

Table 86: Received FM Data (3202)

Word Number	Description	Type	Units	Range
1-5	Header			
6	Frame Number	short		0-188
7	Number of Bytes (l)	short		
8-7+(l+1)/2	Data Bytes	uchar		
8+(l+1)/2	Data Checksum			

Table 87: Timing (3203)

Word Number	Description	Type	Units	Range
1-5	Header			
6	GPS Week	short		0-1023
7-8	GPS Second	long		0-604799
9-10	Delay to Sync	long	0.1 microsec	0-1 sec
11	Data Checksum			

Table 88: Standard Message Format

Message Section	# of words	Description	Value or Range
Header	1	Message Start Word	0x81FF
	1	Standard Message Type ID	
	1	Data Word Count (N)	
	1	Flags	0xXX00
	1	Header Checksum	
Data (Optional)	1	Data Word #1	
	...		
	1	Data Word #N	
	1	Data Checksum	

Table 89: Standard Message Header Format

Message Section	# of words	Description	Value or Range
Header	1	Message Start Word	0x81FF
	1	Standard Message Type ID	
	1	Data Word Count (N)	
	1	Flags/Message ID	0xXX00
	1	Header Checksum	

Table 90: Message Type ID Range – NDC Server

Software Component with an Interface to NDC Server	Direction/purpose	Reserved Message ID Range
NTCC	From NDC Server	2100 – 2199
	To NDC Server	2200 – 2299
	Response to NDC Server initiated message	2300 – 2399
	Response to NTCC initiated message	2400 – 2499
Network Hub	From NDC Server	4100 – 4199
	To NDC Server	4200 – 4299
	Response to NDC Server initiated message	4300 – 4399
	Response Network Hub initiated message	4400 – 4499
NDC Command Station	From NDC Server	5100 – 5199
	To NDC Server	5200 – 5299
	Response to NDC Server initiated message	5300 – 5399
	Response to NDC Command Station initiated message	5400 – 5499
DMCS	From NDC Server	7100 – 7199
	To NDC Server	7200 – 7299
	Response to NDC Server initiated message	7300 – 7399
	Response to DMCS initiated message	7400 – 7499

Table 91: Message Type ID Range - DMCS

Software Component with an Interface to DMCS	Direction/purpose	Reserved Message ID Range
CCS	From DMCS	6100 – 6199
	To CCS	6200 – 6299
	Response to DMCS initiated message	6300 – 6399
	Response to CCS initiated message	6400 – 6499

Table 92: Standard Message Data Section

Message Section	# of words	Description	Value or Range
Optional data section	1	Data Word #1	
	...		
	1	Data Word #N	
	1	Data Checksum	

Table 93: Login Info Request Message (7101)

# of bytes	Description	Value or Range
10	Header	

Table 94: Login Info Response Message (7301)

# of bytes	Description	Value or Range
10	Header	
2	User ID Length (L_1)	0x0000 – 0x0010
L_1	User ID	
2	Password Length (L_2)	0x0000 – 0x0010
L_2	Password	
Padding[1]		
2	Data Checksum	

[1] 0x00 will be used for padding if necessary to make entire body word aligned.

Table 95: Login Info Response Result Message (7501)

# of bytes	Description	Value or Range
10	Header	
2	Result	0x0000 = SUCCESS, 0x0001 = Invalid User Name/Password, 0x0002 = Add Connection Failure, 0x0003 = Database Access Error
2	Data Checksum	

Table 96: Message Timeout Message (7107)

# of bytes	Description	Value or Range
10	Header	
3	Message Sequence ID	
2	Number of Trackers N_1[1]	0x0000 – 0x0800[5]
4	Tracker ID #1	0x00000000 – 0x03FFFFFF
...		
4	Tracker ID #N_1	0x00000000 – 0x03FFFFFF
1	Padding	0x00
2	Data Checksum	

[1] The number of tracker modules that failed to acknowledge the message before the timeout. If the message was sent to all trackers associated with the customer, this number will indicate the trackers that have not yet responding to the message.

Table 97: NDC Command Message (7102)

# of bytes	Description	Value or Range
10	Header	
2	NDC Command Station User Name Length (L_1)	0x0000 – 0x0020
L_1	NDC Command Station User Name	
2	Message Length (L_2)	0x0000 – 0x0100
L_2	Message	
2	NDCS Command Sequence ID[1]	0x0000 – 0xFFFF
Padding[2]		
2	Data Checksum	

[1] Response should use this ID value.
[2] 0x00 will be used for padding if necessary to make entire body word aligned.

Table 98: NDC Command Response Message (7302)

# of bytes	Description	Value or Range
10	Header	
2	NDCS Command Sequence ID[1]	0x0000 – 0xFFFF
2	Status	0x0000 = Success/Forwarded to Customer Command Stations(s), 0x0001 = No Customer Command Stations connected.
2	Data Checksum	

[1] Response should use the same ID sent with the request message.

Table 99: Real-time Tracking Data Message (7103)

# of bytes	Description	Value or Range
10	Header	
2	Year[2]	
1	Month[2]	1 – 12
1	Day[2]	1 – 31
1	Hour[2]	0 – 23
1	Minute[2]	0 – 59
1	Second[2]	0 – 59
2	Tracking Sequence Value[3]	0x0000 – 0xFFFF
2	Type ID[1]	0x0000 – 0x0004
1	Tracker Low Power Mode Flag[5]	0 = not low power, 1 = low power
4	Tracker ID	0x00000000 – 0x3FFFFFFF
Variable	Tracking Data Message[1]	
Padding[4]		
2	Data Checksum	

[1] See Real-time Tracking Data Message Format table.
[2] Date/Time values indicate when the NDC Server received the message and are specified using Greenwich Mean Time (GMT).
[3] The NDC Server maintains a tracking sequence counter for each vehicle. This counter is used to assign tracking sequence values to messages sent from a vehicle to the NDC Server. Message sequence values may be used by CCS applications to determine if any messages are missing from a set of vehicle tracking messages.
NOTE: Tracking sequence values for each tracker rollover every 65536 updates.
[4] 0x00 will be used for padding if necessary to make entire body word aligned.
[5] This flag indicates if the tracker is currently in low power mode. When trackers enter low power mode, they request a low power update slot in the RF network. The low power update rate is less frequent (1 hour) than most tracker update rates. As a result, trackers may power down between updates to conserve their vehicle's battery. Trackers in low power mode will not be able to provide immediate acknowledgement to messages. Messages sent to trackers in this mode will be queued by the NDC Server until the message is acknowledged or the message reaches its timeout.

Table 100: Real-time Tracking Data Message Format

Type ID	Name	# of bytes	Description	Value or Range
0x0001	State	4	Latitude[1]	-90° to +90° (LSB = 180° * 2^{-31})
		4	Longitude[1]	-180° to +180° (LSB = 180° * 2^{-31})
		1	Speed	0x00 – 0x7F (LSB = 0.5 m/s ≈ 1.1 mph)
		1	Heading	-180° to +180° (LSB = 360° * 2^{-7} = 2.8125°)
		3	User Data Block	
		1	Spare	7 spare bits are available
0x0002	Reliable User Data	9	User Data Block	
		1	Spare	
0x0003	Short State	4	Latitude[1]	-90° to +90° (LSB = 180° * 2^{-31})
		4	Longitude[1]	-180° to +180° (LSB = 180° * 2^{-31})
		1	Speed	0x00 – 0x7F (LSB = 0.5 m/s ≈ 1.1 mph)
		1	Heading	-180° to +180° (LSB = 360° * 2^{-7} = 2.8125°)
		1	Spare	1 spare bit is available
0x0004	Reliable Short User Data	5	User Data	
		1	Spare	
0x0005	Reduced State and User Data	4	Latitude[2]	-90° to +90° (LSB = 180° * 2^{-31})
		4	Longitude[2]	-180° to +180° (LSB = 180° * 2^{-31})
		1	User Data	
		1	Spare	7 spare bits are available
0x0006	Message Response and User Data	1	Ack/Response Flag	0 = Acknowledge only, 1 = Response
		1	Response Key ID	0 = Acknowledge only/Return Receipt[6] 1 = Softkey #1, 2 = Softkey #2, 3 = Softkey #3, 4 = Softkey #4
		3	Message Sequence/ Site ID[5]	
		2	GMT Year[3]	
		1	GMT Month[3]	1 – 12
		1	GMT Day[3]	1 – 31
		1	GMT Hour[3]	0 – 23
		1	GMT Minute[3]	0 – 59
		1	GMT Second[3]	0 – 59
		4	User Data	
		1	Spare	6 spare bits are available
0x0007	Short Message Response and User Data	1	Ack/Response Flag	0 = Acknowledge only, 1 = Response

Table 100 (continued)

		1	Response Key ID	0 = Acknowledge only/Return Receipt[6] 1 = Softkey #1, 2 = Softkey #2, 3 = Softkey #3, 4 = Softkey #4
		3	Message Sequence/ Site ID[5]	
		2	GMT Year[3]	
		1	GMT Month[3]	1 – 12
		1	GMT Day[3]	1 – 31
		1	GMT Hour[3]	0 – 23
		1	GMT Minute[3]	0 – 59
		1	GMT Second[3]	0 – 59
		1	User Data	
0x0008	Site Status	3	Site ID[4]	
		1	Status	0 = Arrival, 1 = Departure
		1	Status Source	1 = GPS, 2 = User, 3 = GPS and User
		2	GMT Year[3]	
		1	GMT Month[3]	1 – 12
		1	GMT Day[3]	1 – 31
		1	GMT Hour[3]	0 – 23
		1	GMT Minute[3]	0 – 59
		1	GMT Second[3]	0 – 59
		1	User Data	
		1	Spare	

[1] ± 4 meters of resolution
[2] ± 8 meters of resolution
[3] Time of receipt for acknowledgements and time when Softkey was pressed for a response.
[4] This Site ID is the same ID associated with the Site Dispatch message. See Send Site Dispatch for more information.
[5] Message sequence ID associated with a text or pre-defined message. Or, site ID associated with a site dispatch message. See "Send Message Response Message", "Send Pre-defined Message ID Response Message ", or "Send Site Dispatch" for more information.
[6] If ack/response flag is 0, 0 indicates ack only. If ack/response flag is 1, 0 indicates that user read the message.

Table 101: Tracker Power Mode Message (7107)

# of bytes	Description	Value or Range
10	Header	
1	Tracker Low Power Mode Flag[1]	0 = not low power, 1 = low power
4	Tracker ID	0x00000000 – 0x3FFFFFFF
1	Padding (=0x00)	
2	Data Checksum	

[1] This flag indicates if the tracker is currently in low power mode. When trackers enter low power mode, they request a low power update slot in the RF network. The low power update rate is less frequent (1 hour) than most tracker update rates. As a result, trackers may power down between updates to conserve their vehicle's battery. Trackers in low power mode will not be able to provide immediate acknowledgement to messages. Messages sent to trackers in this mode will be queued by the NDC Server until the message is acknowledged or the message reaches its timeout.

Table 102: Tracker Profile Update Message (7104)

# of bytes	Description	Value or Range
10	Header	
8	Tracker Format[1]	
Padding[4]		
2	Data Checksum	

Table 103: Tracker Profile Format

# of bytes	Description	Value or Range
4	Tracker ID	0x00000000 – 0x3FFFFFFF
1	Tracking Service	0=LOT, 1= Continuous, 2=Manual
2	Default Update Rate (in seconds)	0x0000 (0), 0x0005 (5), 0x000a (10), 0x001e (30), 0x003c (60), 0x0090 (144), 0x00e1 (225), 0x012c (300), 0x0258 (600), 0x0384 (900), 0x04b0 (1200), 0x0708 (1800), 0x0e10 (3600) (0x0000 for manual tracking trackers)
1	Bit 0: Track History Service Flag Bit 1: Message Service Flag Bit 2: Modify Update Rate Service Flag Bit 3: Modify Tracking Service Flag Bits 4-7: spare	Bit 0: 0= Not Available, 1=Available Bit 1: 0 = Not Available, 1= Available Bit 2: 0 = Not Available, 1 = Available Bit 3: 0 = Not Available, 1 = Available

Table 104: Retrieve Tracker Installation History Message (7105)

# of bytes	Description	Value or Range
10	Header	
2	Install StartYear[2] (0x0000 = All)	
1	Install Start Month[2]	1 – 12
1	Install Start Day[2]	1 – 31
1	Install Start Hour[2]	0 – 23
1	Install Start Minute[2]	0 – 59
1	Install Start Second[2]	0 – 59
2	Install End Year[2] (0x0000 = All)	
1	Install End Month[2]	1 – 12
1	Install End Day[2]	1 – 31
1	Install End Hour[2]	0 – 23
1	Install End Minute[2]	0 – 59
1	Install End Second[2]	0 – 59
2	NDCS Command Sequence ID[1]	0x0000 – 0xFFFF
2	Data Checksum	

[1] Response should use this ID value.
[2] Date range used to indicate desired tracker install date/time. If start and/or end year is set to 0x0000, the corresponding start and/or end date is NOT used to limit the result.

Table 105: Retrieve Tracker Installation History Response Message (7305)

# of bytes	Description	Value or Range
10	Header	
2	NDCS Command Sequence ID[1]	0x0000 – 0xFFFF
2	Status	0x0000 = Success, 0x0001 = Database Access Error
2	Total Response Count[2]	
2	Response Number[2]	
4	Tracker ID	0x00000000 – 0x3FFFFFFF
2	Tracker Installation Record Count (C_1)	
Variable	Tracker Installation Record #1	
...		
Variable	Tracker Installation Record #C_1	
2	Data Checksum	

[1] Response should use the same ID sent with the request message.

[2] For each tracker in the request date range, a separate response message is sent to the NDC Server. The Total Response Count indicates the total number of response messages while the Response Number indicates the zero-based response number.

Table 106: Tracker Installation Record

# of bytes	Description	Value or Range
2	VIN Length (L_1)	0x0000 – 0x0020
L_1	VIN	
2	Install Year	
1	Install Month	1 – 12
1	Install Day	1 – 31
1	Install Hour	0 – 23
1	Install Minute	0 – 59
1	Install Second	0 – 59
2	Uninstall Year[1]	
1	Uninstall Month[1]	1 – 12
1	Uninstall Day[1]	1 – 31
1	Uninstall Hour[1]	0 – 23
1	Uninstall Minute[1]	0 – 59
1	Uninstall Second[1]	0 – 59

[1] If uninstall date has not been set and/or tracker is still installed in vehicle, all uninstall date values should be set to NULL.

Table 107: Retrieve Vehicle Profile List Message (7106)

# of bytes	Description	Value or Range
10	Header	
2	VIN Count[1] (C1)	
2	VIN Length #1 (L_1)	
L_1	VIN #1	
...		
2	VIN Length #C1 (L_{C1})	
L_{C1}	VIN #C1	
2	NDCS Command Sequence ID[2]	0x0000 – 0xFFFF
2	Data Checksum	

[1] If VIN Count is 0x0000, all customer profiles are returned.
[2] Response should use this ID value.

Table 108: Retrieve Vehicle Profile List Response Message (7306)

# of bytes	Description	Value or Range
10	Header	
2	NDCS Command Sequence ID[1]	0x0000 – 0xFFFF
2	Status	0x0000 = Success, 0x0001 = Database Access Error
2	Total Number of Profiles in Response	
2	Vehicle Profile Number[2] (N)	
Variable	Vehicle Profile Format[3] #1	
...		
Variable	Vehicle Profile Format[3] #N	
2	Data Checksum	

[1] Response should use the same ID sent with the request message.
[2] Profile number N out of the total number of profiles in the profile list being returned.
[3] See Vehicle Profile Format below.

Table 109: **Vehicle Profile Format**

2	VIN Length (L_1)	
L_1	VIN	
2	Alias Length (L_2)	
L_2	Alias	
2	State Length (L_3)	
L_3	State	
2	License Length (L_4)	
L_4	License	
2	Make Length (L_5)	
L_5	Make	
2	Model Length (L_6)	
L_6	Model	
2	Year	
2	Data Checksum	

Table 110: **Cancel Message (7215)**

# of bytes	Description	Value or Range
10	Header	
3	Message Sequence ID	
1	Padding	0x00
2	Data Checksum	

Table 111: **Cancel Message Response Message (7415)**

# of bytes	Description	Value or Range
10	Header	
1	Client Request ID[3]	0x00 – 0xFF
2	Status	0x0000 = Success[1], 0x0001 = Invalid Message Sequence ID, 0x0002 = Message Ack Already Received
2	Data checksum	

[1] Success indicates that no further attempt will be made to send the message. However, it's still conceivable that the message was sent.

Table 112: **Modify Account Password Message (7201)**

# of bytes	Description	Value or Range
10	Header	
2	Current Password Length (L_1)	0x0000 – 0x0020
L_1	Current Password	
2	New Password Length (L_2)	0x0000 – 0x0020
L_2	New Password	
1	Client Request ID[2]	0x00 – 0xFF
Padding[1]		
2	Data Checksum	

[1] 0x00 will be used for padding if necessary to make entire body word aligned.
[2] The Client Request ID is assigned by the DMCS and is returned by the NDC Server in the response message.

Table 113: Modify Account Password Response Message (7401)

# of bytes	Description	Value or Range
10	Header	
1	Client Request ID[1]	0x00 – 0xFF
2	Status	0x0000 = Success, 0x0001 = Success – NDC Server Password Only, 0x0002 = Incorrect Current Password, 0x0003 = Invalid New Password, 0x0004 = Database access error
1	Padding	0x00
2	Data checksum	

[1] The ID associated with the request sent by the DMCS.

Table 114: Modify Tracking Service Message (7202)

# of bytes	Description	Value or Range
10	Header	
4	Tracker ID	0x00000000 - 0x3FFFFFFF
2	Tracking Service	0x0000=LOT, 0x0001= Continuous, 0x0002=Manual
2	Update Rate in Seconds	0x0005 (5), 0x000a (10), 0x001e (30), 0x003c (60), 0x0090 (144), 0x00e1 (225), 0x012c (300), 0x0258 (600), 0x0384 (900), 0x04b0 (1200), 0x0708 (1800), 0x0e10 (3600)
1	Client Request ID[2]	0x00 – 0xFF
1	Padding	0x00
2	Data Checksum	

[1] The Client Request ID is assigned by the DMCS and is returned by the NDC Server in the response message.

Table 115: Modify Tracking Service Response Message (7402)

# of bytes	Description	Value or Range
10	Header	
1	Client Request ID[2]	0x00 – 0xFF
2	Status	0x0000 = Success, 0x0001 = Service Not Available[1], 0x0002 = Invalid Update Rate, 0x0003 = Invalid Tracking Service, 0x0004 = Invalid Tracker ID, 0x0005 = Requested Rate Not Currently Available
1	Padding	0x00
2	Data Checksum	

[1] The ability to modify the tracking service is an optional service that is maintained on a per tracker basis. Trackers without this service will receive this error message.
[2] The ID associated with the request sent by the DMCS.

Table 116: Ping Request Message (7203)

# of bytes	Description	Value or Range
10	Header	

Table 117: Ping Response Message (7403)

# of bytes	Description	Value or Range
10	Header	

Table 118: Resend Message (7216)

# of bytes	Description	Value or Range
10	Header	
3	Message Sequence ID	
1	Timeout[1] (in minutes)	0x00 = No Timeout, 0x01- 0xF0 = timeout value in minutes
2	Data Checksum	

[1] Indicates the maximum retry timeout value. A Message Timeout message will be sent to the CCS/DMCS if the message is not acknowledged by the timeout value. If 0x00 is specified for the timeout, the message is sent until the PROTRAK system max timeout is reached.

Table 119: Resend Message Response Message (7416)

# of bytes	Description	Value or Range
10	Header	
1	Client Request ID[3]	0x00 – 0xFF
2	Status	0x0000 = Success[1], 0x0001 = Invalid Message Sequence ID, 0x0002 = Message Ack Already Received
2	Data checksum	

[1] Success indicates that no further attempt will be made to send the message. However, it's still conceivable that the message was sent.

Table 120: Retrieve Tracker Profile List Message (7204)

# of bytes	Description	Value or Range
10	Header	
2	Number of Tracker ID's (N_1)[1]	
4	Tracker ID #1	0x00000000 – 0x3FFFFFFF
...		
4	Tracker ID #N_1	0x00000000 – 0x3FFFFFFF
1	Client Request ID[3]	0x00 – 0xFF
Padding[2]		
2	Data Checksum	

[1] Specifying 0x0000 for the number of Tracker ID's will return all of the tracker profiles associated with the customer's login account profile.
[2] 0x00 will be used for padding if necessary to make entire body word aligned.
[3] The Client Request ID is assigned by the DMCS and is returned by the NDC Server in the response message.

Table 121: Retrieve Tracker Profile List Response Message (7404)

# of bytes	Description	Value or Range
10	Header	
1	Client Request ID[5]	0x00 – 0xFF
2	Status	0x0000 = Success, 0x0001 = Database Access Error, 0x0002 = Invalid Tracker ID[2]
2	Total Number of Profiles in Response List	
2	Tracker Profile Number (N)[1]	
Variable	Tracker Profile #N[3]	
Padding[4]		
2	Data Checksum	

[1] Profile number N out of the total number of profiles in the profile list being returned.
[2] Invalid only applies to ID's that are not in the valid range and/or format. ID's missing from the database (or associated with other customer ID's) will result in the profile not being returned without an error code.
[3] See Tracker Profile Format table.
[4] 0x00 will be used for padding if necessary to make entire body word aligned.
[5] The ID associated with the request sent by the DMCS.

Table 122: Send Message (7205)

# of bytes	Description	Value or Range
10	Header	
2	Number of Trackers N_1[1]	0x0000 – 0x0800[5]
4	Tracker ID #1	0x00000000 – 0x03FFFFFF
...		
4	Tracker ID #N_1	0x00000000 – 0x03FFFFFF
2	Message Length (L_1)	0x0000 – 0x0050
L_1	Message	
1	Response Set ID[2]	0x0000 – 0x0007
1	Timeout[6] (in minutes)	0x00 = No Timeout, 0x01- 0xF0 = timeout value in minutes
1	Client Request ID[4]	0x00 – 0xFF
Padding[3]		
2	Data Checksum	

[1] If the number of trackers is 0x0000, the Customer ID associated with the customer's login account profile is used.
[2] A pre-defined response set (see Pre-defined Message Response Sets) may be selected. Trackers will respond using a response ID that indicates the response selected from the pre-defined set. This response ID is returned to the DMCS in a "Message Response and State" or a "Message Response and Reduced State" packet within a "Real-time Tracking Data Message" that contains the same Message Sequence ID.
[3] 0x00 will be used for padding if necessary to make entire body word aligned.
[4] The Client Request ID is assigned by the DMCS and is returned by the NDC Server in the response message.
[5] Due to FM sub-carrier bandwidth limitations, messages sent to a large number of trackers may take several seconds (or minutes) to be delivered. Groups are expected to be small (around 20 – 60 trackers). However, the NDC Server uses an ID allocation scheme that allows it to communicate with a large number of trackers in its RF network if tracker group associations are known ahead of time. The DMCS is responsible to provide these tracker group associations.
[6] Indicates the maximum retry timeout value. A Message Timeout message will be sent to the CCS/DMCS if the message is not acknowledged by the timeout value. If 0x00 is specified for the timeout, the message is sent until the PROTRAK system max timeout is reached.

Table 123: Pre-defined Message Response Sets

Response Set ID	MDT Softkey 1	MDT Softkey 2	MDT Softkey 3	MDT Softkey 4
0[1]	{BLANK}	{BLANK}	{BLANK}	{BLANK}
1	Yes	No	Call	{BLANK}
2	OK	{BLANK}	{BLANK}	{BLANK}
3	OK	Cancel	Call	{BLANK}
4	Accept	Decline	Call	{BLANK}
5	{BLANK}	{BLANK}	{BLANK}	{BLANK}
6	{BLANK}	{BLANK}	{BLANK}	{BLANK}
7	{BLANK}	{BLANK}	{BLANK}	{BLANK}

[1] Response Set ID indicates that no pre-defined response is required. However, a custom response set may still be defined within the message. Custom response sets may be defined by appending response set values to the message Response set values are delimited by a "|" (vertical bar) character.

Table 124: Send Message Response Message (7405)

# of bytes	Description	Value or Range
10	Header	
1	Client Request ID[3]	0x00 – 0xFF
2	Status	0x0000 = Success[1], 0x0001 = Service Not Available[4], 0x0002 = Invalid message format, 0x0003 = Message too long, 0x0004 = Invalid Tracker ID, 0x0005 = Invalid Response Set, 0x0006 = Database Access Error, 0x0007 = Service Temporarily Not Available, 0x0008 = Null Message Error, 0x0009 = Low Power Mode, 0x0010 = Out of Network
3	Message Sequence ID[2]	0x000000 – 0xFFFFFF
2	Data checksum	

[1] Success indicates that the message has been successfully queued so that it may be sent to the specified tracker(s).

[2] ID associated with the message being sent. When the tracker successfully acknowledges and/or responds to this message, the DMCS will receive a "Message Response and State" or a "Message Response and Reduced State" packet within a "Real-time Tracking Data Message" that contains the same Message Sequence ID.

[3] The ID associated with the request sent by the DMCS.

[4] If message was sent to a list of trackers, all trackers in the list must have message service available or this error code will be returned.

Table 125: Send Pre-defined Message ID Message (7206)

# of bytes	Description	Value or Range
10	Header	
2	Number of Trackers N_1[1]	0x0000 – 0x0800[4]
4	Tracker ID #1	0x00000000 – 0x03FFFFFF
...		
4	Tracker ID #N_1	0x00000000 – 0x03FFFFFF
1	Pre-defined Message ID	0x00 – 0xFF
1	Response Set ID[2]	0x0000 – 0x07
1	Timeout[5] (in minutes)	0x00 = No Timeout, 0x01- 0xF0 = timeout value in minutes
1	Client Request ID[3]	0x00 – 0xFF
2	Data Checksum	

[1] If the number of trackers is 0x0000, the Customer ID associated with the customer's login account profile is used.
[2] A pre-defined response set (see Pre-defined Message Response Sets) may be selected. Trackers will respond using a response ID that indicates the response selected from the pre-defined set. This response ID is returned to the DMCS in a "Message Response and State" or a "Message Response and Reduced State" packet within a "Real-time Tracking Data Message" that contains the same Message Sequence ID.
[3] The Client Request ID is assigned by the DMCS and is returned by the NDC Server in the response message.
[4] Due to FM sub-carrier bandwidth limitations, messages sent to a large number of trackers may take several seconds (or minutes) to be delivered. Groups are expected to be small (around 20 – 60 trackers). However, the NDC Server uses an ID allocation scheme that allows it to communicate with a large number of trackers in its RF network if tracker group associations are known ahead of time. The DMCS is responsible to provide these tracker group associations.
[5] Indicates the maximum retry timeout value. A Message Timeout message will be sent to the CCS/DMCS if the message is not acknowledged by the timeout value. If 0x00 is specified for the timeout, the message is sent until the PROTRAK system max timeout is reached.

Table 126: Send Pre-defined Message ID Response Message (7406)

# of bytes	Description	Value or Range
10	Header	
1	Client Request ID[3]	0x00 – 0xFF
2	Status	0x0000 = Success[1], 0x0001 = Service Not Available[4], 0x0002 = Invalid message format, 0x0003 = Message too long, 0x0004 = Invalid Tracker ID, 0x0005 = Invalid Response Set, 0x0006 = Database Access Error, 0x0007 = Service Temporarily Not Available, 0x0009 = Low Power Mode, 0x0010 = Out of Network
3	Message Sequence ID[2]	0x000000 – 0xFFFFFF
2	Data checksum	

[1] Success indicates that the message ID has been successfully queued so that it may be sent to the specified tracker(s).
[2] ID associated with the message being sent. When the tracker successfully acknowledges and/or responds to this message, the DMCS will receive a "Message Response and State" or a "Message Response and Reduced State" packet within a "Real-time Tracking Data Message" that contains the same Message Sequence ID.
[3] The ID associated with the request sent by the DMCS.
[4] If pre-defined was sent to a list of trackers, all trackers in the list must have message service available or this error code will be returned.

# of bytes	Description	Value or Range
10	Header	
2	Number of Trackers N_1[1]	0x0000 – 0x0800
4	Tracker ID #1	0x00000000 – 0x03FFFFFF
...		
4	Tracker ID #N_1	0x00000000 – 0x03FFFFFF
1	Site Expiration[7]	0x00 (all trips), 0x01 – 0xff
1	Response Set ID[2]	0x0000 – 0x07
4	Northeast Latitude	
4	Northeast Longitude	
4	Southwest Latitude	
4	Southwest Longitude	
1	Message Length (L_1)	0x00 – 0x64
L_1	Message[7]	
1	Timeout[5] (in minutes)	0x00 = No Timeout, 0x01- 0xF0 = timeout value in minutes
1	Client Request ID[3]	0x00 – 0xFF
Padding[4]		
2	Data Checksum	

[1] If the number of trackers is 0x0000, the Customer ID associated with the customer's login account profile is used.
[2] A pre-defined response set (see Pre-defined Message Response Sets) may be selected. Trackers will respond using a response ID that indicates the response selected from the pre-defined set. This response ID is returned to the DMCS in a "Message Response and State" or a "Message Response and Reduced State" packet within a "Real-time Tracking Data Message" that contains the same Message Sequence ID.
[3] The Client Request ID is assigned by the DMCS and is returned by the NDC Server in the response message.
[4] 0x00 will be used for padding if necessary to make entire body word aligned.
[5] Indicates the maximum retry timeout value. A Message Timeout message will be sent to the CCS/DMCS if the message is not acknowledged by the timeout value. If 0x00 is specified for the timeout, the message is sent until the PROTRAK system max timeout is reached.
[6] Site duration indicates how long a specified site should be used. Single trip indicates that the tracker should retain the site information until the tracker enters and leaves the specified site. Every trip indicates that the tracker should indicate every time the tracker enters or leaves the specified site.
[7] Indicates the number of hours that the site is valid.

Table 128: Send Site Dispatch Response Message (7407)

# of bytes	Description	Value or Range
10	Header	
1	Client Request ID[3]	0x00 – 0xFF
2	Status	0x0000 = Success[1], 0x0001 = Service Not Available, 0x0002 = Invalid message format, 0x0003 = Message too long, 0x0004 = Invalid Tracker ID, 0x0005 = Invalid Response Set, 0x0006 = Database Access Error, 0x0007 = Service Temporarily Not Available, 0x0009 = Low Power Mode, 0x0010 = Out of Network
1	Site ID[2,4]	0x000000 – 0xFFFFFF
2	Data checksum	

[1] Success indicates that the message ID has been successfully queued so that it may be sent to the specified tracker(s).
[2] ID associated with the message being sent. When the tracker successfully acknowledges and/or responds to this message, the DMCS will receive a "Message Response and State" or a "Message Response and Reduced State" packet within a "Real-time Tracking Data Message" that contains the same Site ID.
[3] The ID associated with the request sent by the DMCS.

Table 129: Send User Data Message (7208)

# of bytes	Description	Value or Range
10	Header	
2	Number of Trackers N_1[1]	0x0000 – 0x0800[4]
4	Tracker ID #1	0x00000000 – 0x03FFFFFF
...		
4	Tracker ID #N_1	0x00000000 – 0x03FFFFFF
1	User Data Type	0x00 – 0xFF
2	User Data Length (L_1)	0x0000 – 0x0050
L_1	User Data	
1	Timeout[5] (in minutes)	0x00 = No Timeout, 0x01- 0xF0 = timeout value in minutes
1	Client Request ID[3]	0x00 – 0xFF
Padding[2]		
2	Data Checksum	

[1] If the number of trackers is 0x0000, the Customer ID associated with the customer's login account profile is used.
[2] 0x00 will be used for padding if necessary to make entire body word aligned.
[3] The Client Request ID is assigned by the DMCS and is returned by the NDC Server in the response message.
[4] Due to FM sub-carrier bandwidth limitations, messages sent to a large number of trackers may take several seconds (or minutes) to be delivered. Groups are expected to be small (around 20 – 60 trackers). However, the NDC Server uses an ID allocation scheme that allows it to communicate with a large number of trackers in its RF network if tracker group associations are known ahead of time. The DMCS is responsible to provide these tracker group associations.
[5] Indicates the maximum retry timeout value. A Message Timeout message will be sent to the CCS/DMCS if the message is not acknowledged by the timeout value. If 0x00 is specified for the timeout, the message is sent until the PROTRAK system max timeout is reached.

Table 130: Send User Data Response Message (7408)

# of bytes	Description	Value or Range
10	Header	
1	Client Request ID[3]	0x00 – 0xFF
2	Status	0x0000 = Success[1], 0x0001 = Service Not Available[4], 0x0002 = Invalid message format, 0x0003 = Message too long, 0x0004 = Invalid Tracker ID, 0x0006 = Database Access Error, 0x0007 = Service Temporarily Not Available, 0x0009 = Low Power Mode, 0x0010 = Out of Network
1	Message Sequence ID[2]	0x000000 – 0xFFFFFF
2	Data checksum	

[1] Success indicates that the message has been successfully queued so that it may be sent to the specified tracker(s).
[2] ID associated with the message being sent. When the tracker successfully acknowledges and/or responds to this message, the DMCS will receive a "Message Response and State" or a "Message Response and Reduced State" packet within a "Real-time Tracking Data Message" that contains the same Message Sequence ID.
[3] The ID associated with the request sent by the DMCS.
[4] If user data was sent to a list of trackers, all trackers in the list must have message service available or this error code will be returned.

Table 131: Send Tracking Request Message (7209)

# of bytes	Description	Value or Range
10	Header	
4	Tracker ID	0x00000000 – 0x03FFFFFF
1	Client Request ID[1]	0x00 – 0xFF
1	Padding	0x00
2	Data Checksum	

[1] The Client Request ID is assigned by the DMCS and is returned by the NDC Server in the response message.

Table 132: Send Tracking Request Response Message (7409)

# of bytes	Description	Value or Range
10	Header	
1	Client Request ID[2]	0x00 – 0xFF
2	Status	0x0000 = Success[1], 0x0001 = Service Not Available, 0x0002 = Invalid Tracker ID, 0x0003 = Database Access Error, 0x0004 = Service Temporarily Not Available
1	Padding	0x00
2	Data checksum	

[1] Success indicates that the message has been successfully queued so that it may be sent to the specified tracker.
[2] The ID associated with the request sent by the DMCS.

Table 133: Tracker Installation Update Message (7210)

# of bytes	Description	Value or Range
10	Header	
4	Tracker ID	
8	Tracker Installation Record[1]	
Padding[4]		
2	Data Checksum	

[1] See Tracker Installation Record.

Table 134: Vehicle Profile Update Message (7212)

# of bytes	Description	Value or Range
10	Header	
8	Vehicle Profile Format[1]	
Padding[4]		
2	Data Checksum	

[1] See Vehicle Profile Format.

What is claimed is:

1. A vehicle fleet management information system for fleet asset management by enabling identification of location and direction of movement, if any, of each vehicle in said fleet in real-time and to automatically communicate directly therewith for reporting of vehicle location, direction and status of predetermined events in which the vehicle may become engaged, said system comprising:

apparatus for broadcasting information to vehicles in the fleet over a communications network in which each vehicle is a participant, with precise time synchronization of the broadcast information according to timing employed in a navigation system for said fleet relative to a stable reference point,

apparatus in each vehicle for detecting predetermined events of interest and reporting information concerning vehicle location and said detected events to a fleet management office over said communications network, and

said broadcast apparatus including apparatus for assigning each vehicle in the fleet a unique time slot to transmit its reporting information without substantially interfering with transmissions from other vehicles in their own respective time slots.

2. The fleet management information system of claim **1**, wherein said broadcast apparatus includes means for broadcasting via FM radio subcarrier.

3. The fleet management information system of claim **1**, wherein said stable navigation reference for position determination is a satellite Global Positioning System (GPS).

4. The fleet management information system of claim **1**, wherein at least some of said owners have low update rate requirements, and including means for polling vehicles associated with low update rate owner requests for information, without need for entry of the polled vehicle reporting transmissions into specific predetermined time slots of the network.

5. The fleet management information system of claim **4**, wherein said low update rate requests for owners providing emergency response services include means for varying their respective vehicle position update rates in times of emergency.

6. The fleet management information system of claim **1**, including a network distribution center including means for providing space diversity processing of said received vehicle data packets for recovery of possibly corrupted data.

7. The fleet management information system of claim **1**, including means for dynamically allocating slots to accommodate update rates of information according to different periodic reporting intervals by different vehicles in the network.

8. The fleet management information system of claim **1**, including means for dynamically allocating slots to allow higher priority data packets to be transmitted to or from vehicles before lower priority packets that were queued first.

9. The fleet management information system of claim **8**, including means for increasing the priority of delayed lower priority packets according to a predetermined maximum time of delay.

10. The fleet management information system of claim **1**, including means for providing auxiliary reporting slots for vehicles to accommodate need for prompt reporting of important information independent of slower periodic reporting intervals.

11. The fleet management information system of claim **1**, including means for inferring the identity of a reporting vehicle to accommodate need for prompt reporting of important information independent of slower periodic reporting intervals.

12. The fleet management information system of claim **1**, wherein said communications network is a time division multiple access (TDMA) wireless network.

13. The fleet management information system of claim **12**, wherein said broadcast apparatus includes means for broadcasting via FM radio subcarrier, said stable navigation reference for position determination is a satellite Global Positioning System (GPS), and said FM radio subcarrier is used to broadcast synchronization data to all TDMA network participants independent of separate delivery of time information from said GPS navigation reference.

14. A management information system for a multiplicity of movable, information communicating assets whether stationary or undergoing movement, to identify the location of each asset in real-time and to communicate therewith, said system comprising:

apparatus for transmitting information to each of said assets via a communications network in which each of said assets is a participant,

apparatus for receiving information transmitted by each of said assets via said communications network,

apparatus for detecting the location of each asset relative to an arbitrary stable reference point in a navigation system,

apparatus for precise time synchronization of information transmitted to each of said assets with timing information derived from said navigation system, and

apparatus for assigning each of said assets a unique time slot in which to transmit information to said receiving apparatus over said communications network without substantially interfering with information transmissions by others of said assets in their respective time slots.

15. A time division multiple access (TDMA) wireless network for real time reporting of fleet vehicle locations and other information in data packets in respective assigned time slots to a central data processing location on a UHF band, with a minimum of gaps between reporting transmissions, said network comprising

means for precise time synchronization of all elements of said TDMA wireless network, including wireless phase lock loop (PLL) timing control loop means for distributing a single, remote global positioning satellite GPS based time reference throughout said network.

16. The TDMA wireless network of claim **15**, including FM subcarrier broadcast means having timing data referenced to a GPS based time source for broadcast to the fleet vehicles.

17. The TDMA wireless network of claim **16**, including means for providing navigation data for the fleet vehicles by other than GPS.

18. The TDMA wireless network of claim **16**, including means on each of said fleet vehicles for receiving data requests and messages from said central station and other information to synchronize said network elements without a GPS receiver.

19. The TDMA wireless network of claim **16**, wherein said PLL timing control loop means operates as an algorithm for synchronization of the different elements of the network to a synchronization pattern, using said algorithm to eliminate variability in synchronization.

20. The TDMA wireless network of claim **19**, including means for processing difference in time from said GPS time reference and received synchronization data on said FM subcarrier using said PLL algorithm to generate a timing correction.

21. A fleet management system for tracking the locations and paths of vehicles at rest and in transit for management of dispatch and operation of said vehicles, comprising:

a radio frequency network,

a plurality of geographically disparate network hubs for communication with fleet management offices and said vehicles over said network,

a tracking computer on each of said vehicles for developing and transmitting navigation and status messages to at least one of said network hubs for communication to a fleet management office responsible for the respective transmitting vehicle,

apparatus for establishing a protocol for entry by said tracking computers into the network in assigned time slots for periodic transmission of messages by the respective tracking computers, and

apparatus for providing space diversity of the messages received by said network hubs from said tracking computers to avoid corruption of messages received from a single tracking computer at more than one of said network hubs.

22. The fleet management system of claim **21**, wherein said network is a time division multiple access (TDMA) network.

23. The fleet management system of claim **21**, wherein said protocol establishing apparatus provides management of different periodic transmission intervals by different vehicles in the network by dynamically allocating said slots for various update rates.

24. The fleet management system of claim **21**, wherein said protocol establishing apparatus provides auxiliary reporting slots to allow prompt reporting of important data by the respective tracking computers independent of slower said periodic transmission intervals.

25. The fleet management system of claim **21**, including apparatus for supporting both guaranteed and non-guaranteed delivery of message data.

26. The fleet management system of claim **21**, wherein said network includes a dual band full-duplex interface with TDMA on one-half of said interface and broadcast on the other half of said interface.

27. The fleet management system of claim **21**, wherein said assigned slots are unique to respective ones of said tracking computers, whereby to minimize bandwidth usage in said network by enabling identity of the vehicle whose tracking computer is transmitting according to the time slot in which the transmission is received.

28. A fleet management system for tracking the locations and paths of vehicles at rest and in transit for management of dispatch and operation of said vehicles, comprising:

a wireless network,

apparatus for modulating broadcasts transmitted on said network with message data including a synchronization pattern,

a plurality of geographically disparate network hubs for communication with fleet management offices and said vehicles over said network,

a tracking computer on each of said vehicles for developing and transmitting navigation and status messages to at least one of said network hubs for communication to a fleet management office responsible for the respective transmitting vehicle, and

apparatus for synchronizing the timing of said tracking computers with each other and with said network hubs by aligning respective internal clocks thereof to said synchronization pattern pulses in received broadcasts of data on said network,

said synchronizing apparatus including a timing control for correcting drifts in the timing to maintain synchronization between said tracking computers and said network hubs.

29. The fleet management system of claim **28**, wherein said timing control comprises a remote phase locked loop (PLL) that includes said apparatus for modulating broadcasts and a network control center that receives broadcasts of data on said network and computes and transmits a time correction to said apparatus for modulating broadcasts, to maintain said synchronization.

30. The fleet management system of claim **29**, wherein said network control center includes a receiver for receiving Global Positioning System (GPS) satellite signals including a GPS time reference and means for obtaining the difference between the average time of said received synchronization pattern and the time of said received GPS time reference from which to compute said time correction.

31. The fleet management system of claim **30**, wherein said network includes a time division multiple access (TDMA) network, and said timing control PLL includes means for maintaining said synchronization in said TDMA network to about three microsecond accuracy.

32. The fleet management system of claim **28**, wherein said timing control comprises an RF link phase lock loop to maintain clock synchronization to a reference.

33. The fleet management system of claim **30**, wherein said network includes a dual band full-duplex interface with TDMA on one-half of said interface and broadcast on the other half of said interface.

34. The fleet management system of claim **33**, including a remote reference controlled through a wireless link for synchronizing the TDMA portion of said network to GPS time.

35. The fleet management system of claim **33**, wherein each of said tracking computers and said network hubs includes a central processing unit comprising a microprocessor with a time processing unit for performing precise clock synchronization within 10 microseconds for the TDMA portion of said network.

36. The fleet management system of claim **28**, including means for maintaining synchronization between said tracking computers and said network hubs and to a synchronization pattern, using the same algorithm to eliminate variability in synchronization.

37. An article management system for tracking the locations of articles at rest and in transit for maintaining a desired flow of said articles, said system providing bandwidth efficient wireless transceiver operation and comprising:

a plurality of data transmitters and a plurality of data receivers for communication via a wireless network with respect to location of said articles,

means in each of said transmitters for filtering baseband data to reduce the occupied bandwidth of the channel on which data is transmitted, including removal of synchronization data to minimize overhead of non-information bearing data,

said baseband filter being implemented by a digital microcontroller that replaces an original square wave data stream of said baseband data with deterministic transitions that reduce harmonic content and maintain bit widths, regardless of data input frequency.

38. The article management system of claim **37**, including

means in each of said receivers for applying processor intensive clock and data recovery algorithms to facilitate said removal of synchronization data by said filter means at said transmitters.

39. The article management system of claim **38**, wherein said transmitters and receivers further employ forward error correction coding and space diversity processing to increase the reliability of received data, whereby to further optimize bandwidth reduction by eliminating bandwidth needed for retransmission of corrupted data.

40. The article management system of claim **37**, wherein said digital microcontroller comprises a digital filter that uses sine wave segments for transitions.

41. The article management system of claim **37**, wherein each of said receivers includes means to facilitate recovery of transmitted data without transmitted synchronization information by locating the start of each transmitted data message within a predetermined scant time window without aid from bit synchronization patterns.

42. The article management system of claim **41**, wherein said data recovery means performs said start message start location within said predetermined scant time window by an iterative search that sequentially clocks in the data at greater and greater delays from the nominal message start time until a valid data packet is located.

43. The article management system of claim **37**, wherein each of said transmitters further includes means for performing a bit interleaving pattern on the data to be transmitted to provide a randomization of the data bits to ensure that single bit shifts in received data cause errors in all code words.

44. The article management system of claim **43**, wherein each of said receivers further includes means for de-interleaving received data according to said bit interleaving pattern introduced by said interleaving means at each of said transmitters.

45. The article management system of claim **37**, wherein said wireless network includes a time division multiple access (TDMA) network, and each of said receivers includes means for batch processing of received messages from said transmitters to recover clock and data on a packet by packet basis in said TDMA network.

46. The article management system of claim **45**, wherein said means for batch processing of received messages includes means for delay decoding sampled bits of the received data, with only predetermined allowable bit patterns present in the delay code, whereby if a bit error causes an invalid pattern, the pattern is decoded to one of the possible bits represented by the pattern, and if subsequent error detection processing on the decoded data indicates an error, then, if only one ambiguous data pattern was encountered in that particular code word during the delay decoding process, the other bit value is used and the error detection is repeated, and, if successful, the second bit value is retained.

47. The article management system of claim **46**, wherein said delay decoding means retains the original value of said one of the possible bits if more than one bit is ambiguous or the second bit also fails to result in valid data, and allows processing to move forward on the premise that the bit error may be correctable at a later stage in the data processing chain.

48. The article management system of claim **47**, wherein each of said receivers further includes means for de-interleaving received data according to a bit interleaving pattern introduced at each of said transmitters in which the transmitted data is jumbled sufficiently that single bit shifts cause all code words to be in error.

49. The article management system of claim **37**, including further processing of received data by diversity processing using a combination of error detection and voting.

50. A fleet management system for tracking the locations of vehicles in the fleet and determining the status of events related to the usage or function of the vehicles, comprising:

navigation apparatus on each vehicle for detecting the location of the vehicle relative to a predetermined reference point,

a tracking computer on each of said vehicles for receiving inputs indicative of the location of the vehicle and transmitting navigation and status messages to a fleet management office responsible for the respective transmitting vehicle,

at least one non-human sensor on each vehicle for detecting one of said events and supplying an input indicative of the detected event to said tracking computer, and

said tracking computer including apparatus for automatic reporting of the detected events to said fleet management office.

51. The fleet management system of claim **50**, wherein said fleet vehicles and said fleet management office are connected for communication by a wireless network.

52. The fleet management system of claim **51**, wherein each vehicle has a plurality of sensors for detecting or measuring various ones of said events and supplying inputs indicative thereof to said tracking computer for prompt reporting of event data as it happens over said wireless network.

53. The fleet management system of claim **52**, wherein at least some of said plurality of sensors are selected from a group consisting of detectors of vehicle ignition, vehicle run time, headlights on, transmission in forward and reverse directions, wheel speed, passenger or driver door open, four wheel drive engagement, vehicle emergency lights or sirens operating, fuel level, coolant temperature, oil pressure, battery voltage, engine warning indications, theft or tamper alarms, cargo door open, cargo temperature, vehicle weight, power takeoff engagement for equipment including pumps, winches, cranes, or augers, engine data bus parameters and tolerance checking, dump box up or hatch open, ready mix drum rotation speed and direction, ready mix wash water usage, ready mix fill water volume, distance traveled between predetermined zones, engine on and off, excessive vehicle speed, driving at improper times, unauthorized stops of vehicle, and arrival/departure times at specified locations.

54. The fleet management system of claim **51**, including apparatus at said fleet management office for correlating a detected event to a vehicle location or vehicle speed.

55. The fleet management system of claim **54**, wherein said vehicle location correlation apparatus includes means for comparing the vehicle location detected by said navigation apparatus to predetermined geographically mapped zones.

56. The fleet management system of claim **51**, including apparatus at said fleet management office for defining map regions constituting zones in areas expected to be traversed by said fleet vehicles, and wherein said apparatus for automatic reporting includes using said navigation apparatus of the associated fleet vehicle to report one or more of distance traveled by the vehicle between zones, vehicle engine on and off, vehicle being driven at excessive speed, vehicle being driven at improper times, vehicle making unauthorized stops, and times of arrival and departure at preselected locations.

57. The fleet management system of claim **51**, wherein said fleet vehicles are ambulances and said automatic reporting reports trips, call times, pick up locations, and hospitals to which deliveries are made to said fleet management office.

58. The fleet management system of claim **50**, wherein said apparatus for automatic reporting of the detected events reports exceptions to routine operations of the vehicle to said fleet management office.

59. The fleet management system of claim **52**, wherein said fleet vehicles are ready mix concrete or other slurry material mixer trucks, and said plurality of sensors detect or measure at least some of the events of truck fully loaded at plant site, truck departure from plant site, truck arrival at job site, truck commencing pour, truck pour ended, truck undergoing wash, truck departure from job site, truck arrival at plant site, and deviations from a routine sequence of said events; and at least some of said events are detected based on truck speed or time interval over which an event takes place.

60. The fleet management system of claim **59**, wherein at least some of said mixer trucks of said fleet vehicles are equipped with hall effect sensors that measure both speed and direction of rotation of the mixer drum of the truck.

61. The fleet management system of claim **50**, wherein said fleet vehicles are bulk powdered material transport trucks in which air is pumped through pipes under the bulk hopper of the truck for unloading the powdered material therefrom, and each of said transport trucks includes a tachometer sensor for on/off detection of pumping to indicate unloading and cessation of unloading of powdered material from the respective said transport truck to report same to said fleet management office.

62. The fleet management system of claim **50**, wherein said fleet vehicles are bulk aggregate material transport trucks each having a dumper for unloading the aggregate material therefrom, and each of said transport trucks includes a sensor for detection of dumper operation to indicate unloading and cessation of unloading of aggregate material from the respective said transport truck to report same to said fleet management office.

63. A fleet management system for a fleet of vehicles, comprising transceivers on said vehicles and in geographically disparate hubs for communication between a fleet management office and said vehicles, a network for said communication, and a central processing unit in each of said transceivers comprising a microprocessor with a time processing unit for performing precise clock synchronization of said transceivers throughout said network.

64. The fleet management system of claim **63**, wherein said network is a wireless network.

65. The fleet management system of claim **64**, wherein said wireless network is a time division multiple access (TDMA) network.

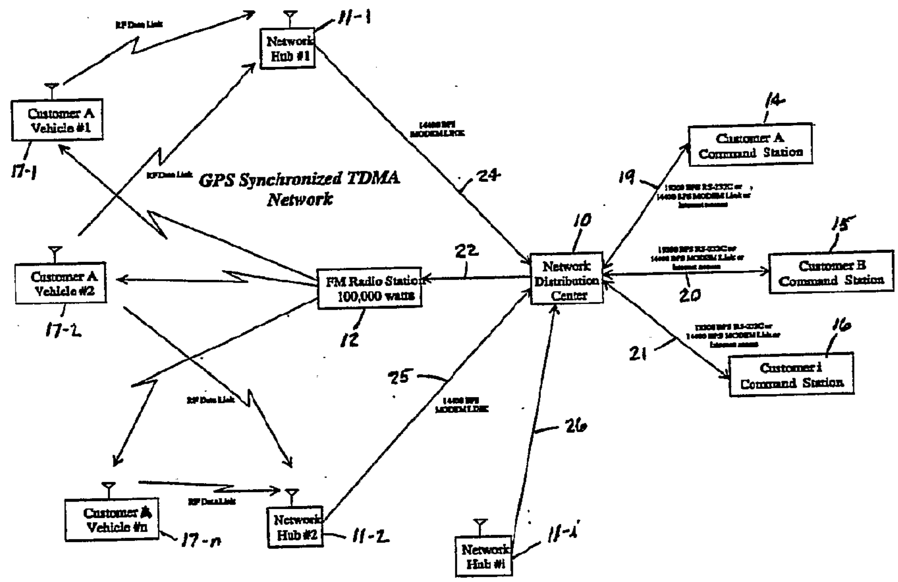

Network Hub #1
11-1
Customer A Vehicle #1
17-1
GPS Synchronized TDMA Network
24
14
Customer A Command Station
19
10
15
Customer A Vehicle #2
17-2
22
FM Radio Station 100,000 watts
12
Network Distribution Center
20
Customer B Command Station
21
16
Customer i Command Station
25
26
Customer A Vehicle #n
17-n
Network Hub #2
11-2
Network Hub #i
11-i

FIG. 1

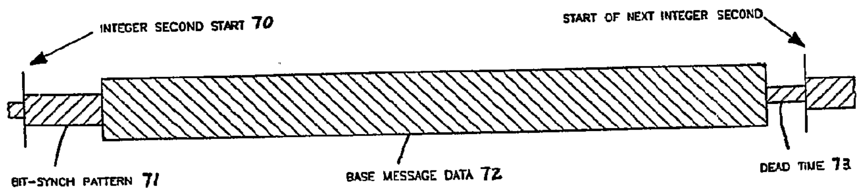
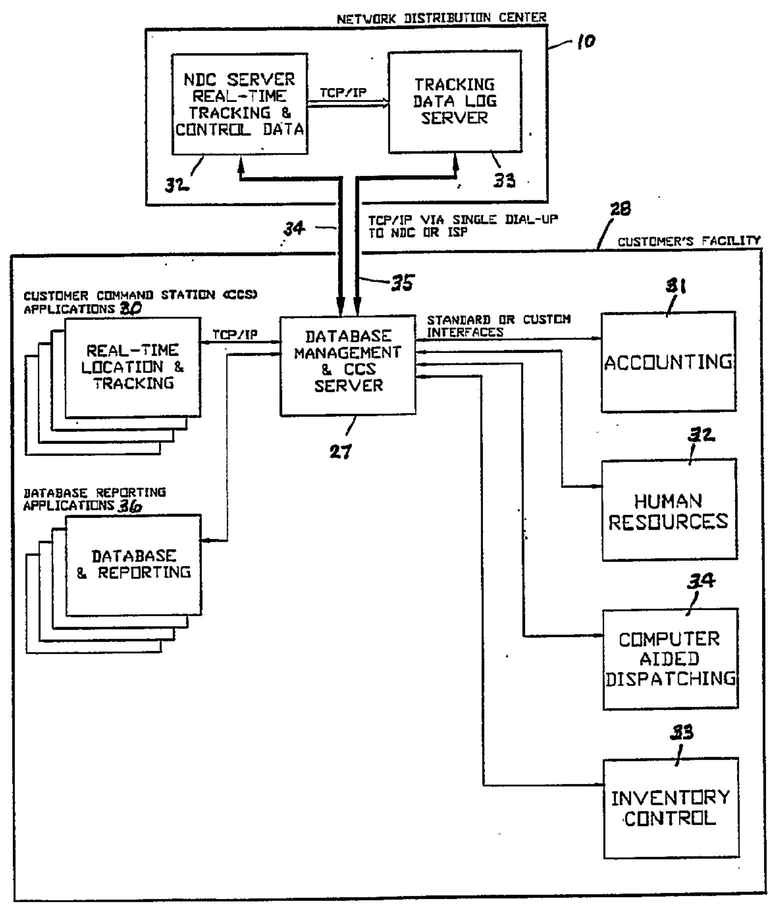

INTEGER SECOND START 70
START OF NEXT INTEGER SECOND
BIT-SYNCH PATTERN 71
BASE MESSAGE DATA 72
DEAD TIME 73

FIG. 7



NETWORK DISTRIBUTION CENTER
10
NDC SERVER REAL-TIME TRACKING & CONTROL DATA
TCP/IP
TRACKING DATA LOG SERVER
32
33
34
TCP/IP VIA SINGLE DIAL-UP TO NDC OR ISP
28
CUSTOMER'S FACILITY
35
CUSTOMER COMMAND STATION (CCS) APPLICATIONS 30
REAL-TIME LOCATION & TRACKING
TCP/IP
DATABASE MANAGEMENT & CCS SERVER
STANDARD OR CUSTOM INTERFACES
31
ACCOUNTING
27
32
HUMAN RESOURCES
DATABASE REPORTING APPLICATIONS 36
DATABASE & REPORTING
34
COMPUTER AIDED DISPATCHING
33
INVENTORY CONTROL

FIG. 2

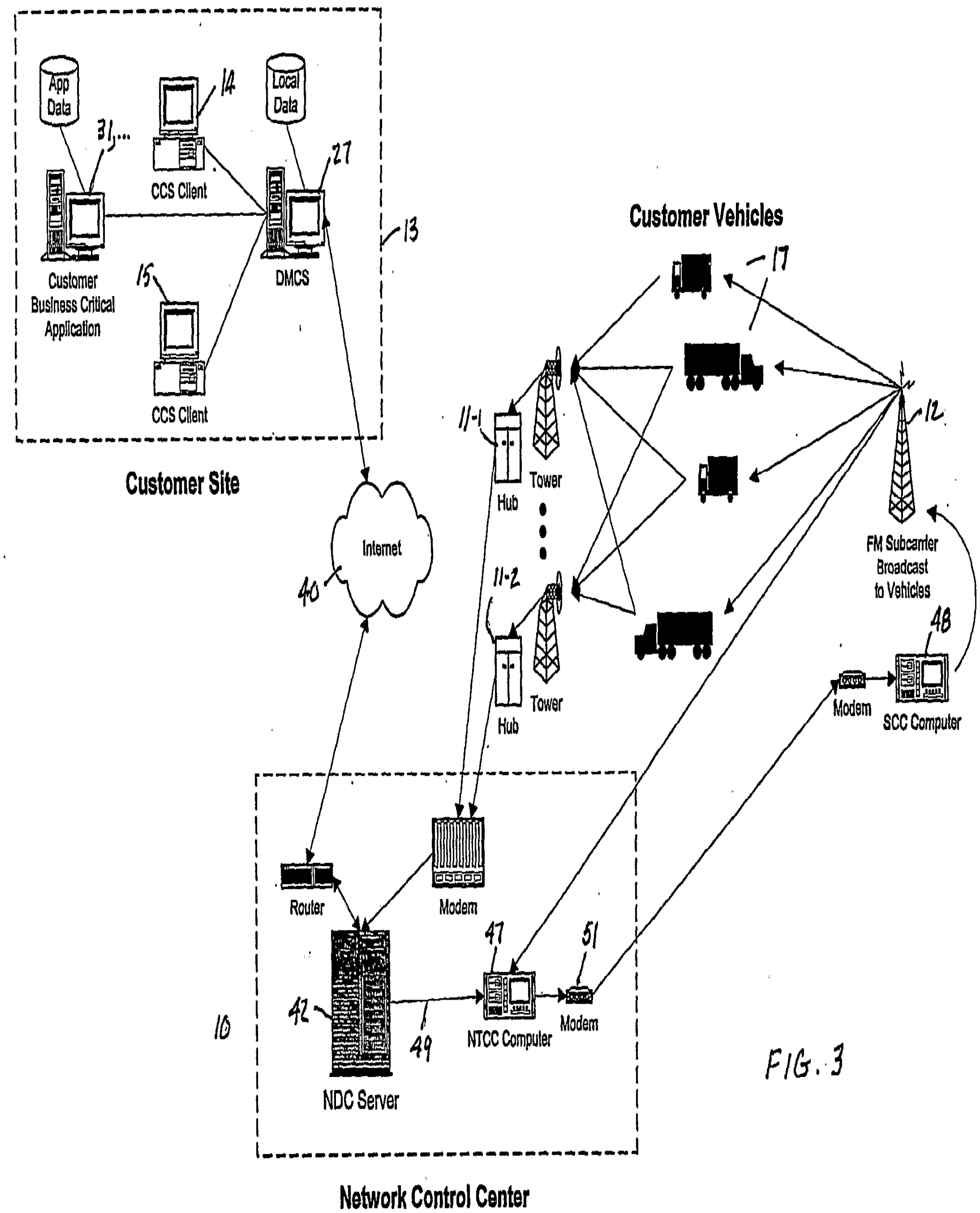

App Data
Local Data
14
31,...
27
CCS Client
13
Customer Business Critical Application
15
DMCS
CCS Client
Customer Site
Customer Vehicles
17
11-1
Hub
Tower
12
Internet
40
11-2
FM Subcarrier Broadcast to Vehicles
48
Hub
Tower
Modem
SCC Computer
Router
Modem
47
51
10
42
49
NTCC Computer
Modem
NDC Server
Network Control Center

FIG. 3

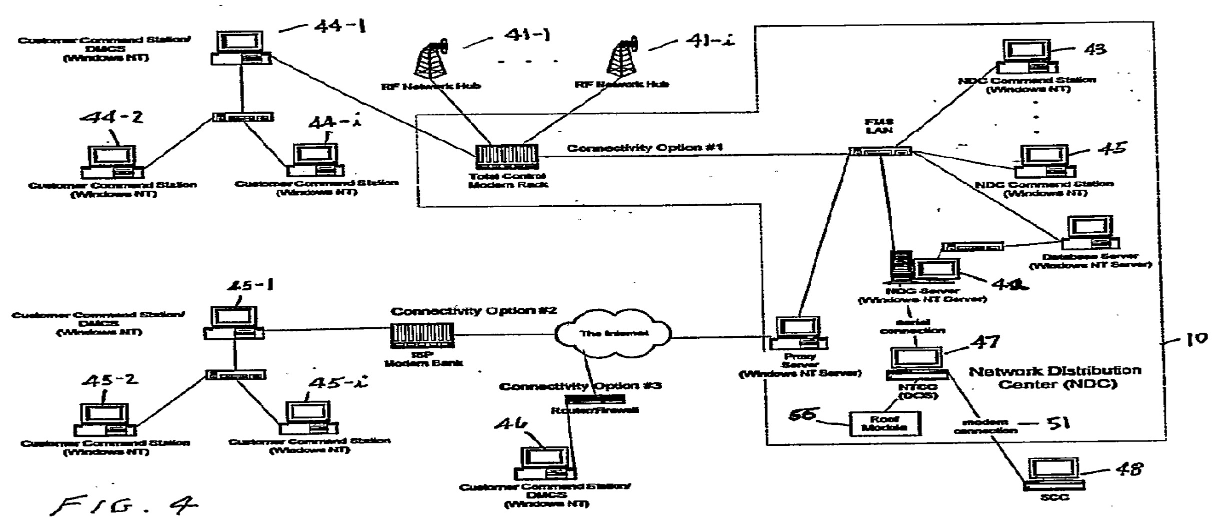

44-1
Customer Command Station/
DMCS
(Windows NT)
44-2
Customer Command Station
(Windows NT)
44-i
Customer Command Station
(Windows NT)
41-1
41-i
RF Network Hub
RF Network Hub
Total Control
Modem Rack
Connectivity Option #1
FX48
LAN
43
NDC Command Station
(Windows NT)
45
NDC Command Station
(Windows NT)
Database Server
(Windows NT Server)
NDC Server
(Windows NT Server)
44
serial
connection
47
NTCC
(DCS)
Network Distribution
Center (NDC)
10
45-1
Customer Command Station/
DMCS
(Windows NT)
45-2
Customer Command Station
(Windows NT)
45-i
Customer Command Station
(Windows NT)
Connectivity Option #2
ISP
Modem Bank
The Internet
Connectivity Option #3
Router/Firewall
46
Customer Command Station/
DMCS
(Windows NT)
Proxy
Server
(Windows NT Server)
56
Roof
Module
modem
connection
51
48
SCC

FIG. 4

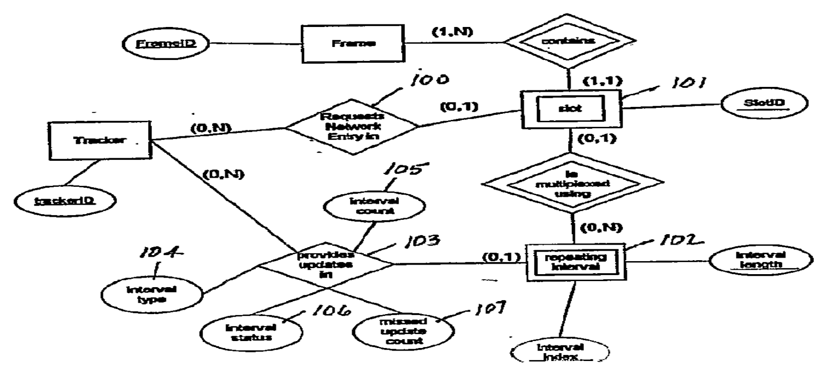

FrameID
Frame
(1,N)
contains
(1,1)
101
SlotID
slot
100
Requests
Network
Entry In
(0,1)
Tracker
(0,N)
(0,1)
trackerID
(0,N)
105
interval
count
is
multiplexed
using
(0,N)
104
103
102
provides
updates
in
(0,1)
repeating
interval
interval
length
interval
type
106
107
interval
status
missed
update
count
interval
index

FIG. 10

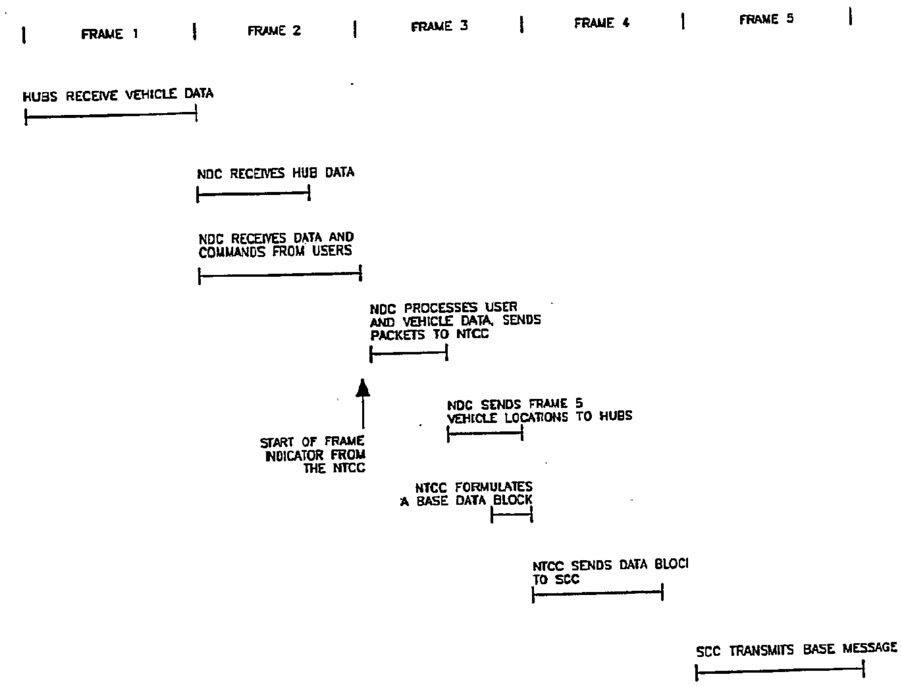

FRAME 1
FRAME 2
FRAME 3
FRAME 4
FRAME 5
HUBS RECEIVE VEHICLE DATA
NDC RECEIVES HUB DATA
NDC RECEIVES DATA AND COMMANDS FROM USERS
NDC PROCESSES USER AND VEHICLE DATA, SENDS PACKETS TO NTCC
START OF FRAME INDICATOR FROM THE NTCC
NDC SENDS FRAME 5 VEHICLE LOCATIONS TO HUBS
NTCC FORMULATES A BASE DATA BLOCK
NTCC SENDS DATA BLOCI TO SCC
SCC TRANSMITS BASE MESSAGE

FIG. 5

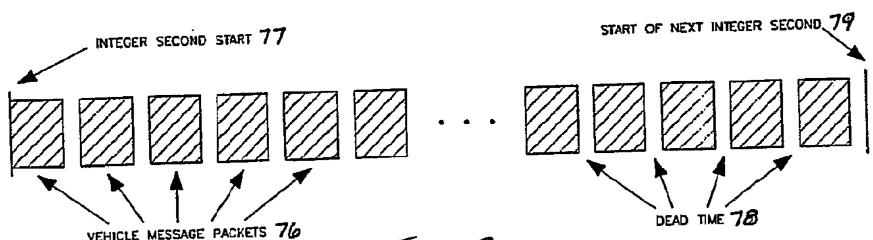

INTEGER SECOND START 77
START OF NEXT INTEGER SECOND 79
VEHICLE MESSAGE PACKETS 76
DEAD TIME 78

FIG. 8

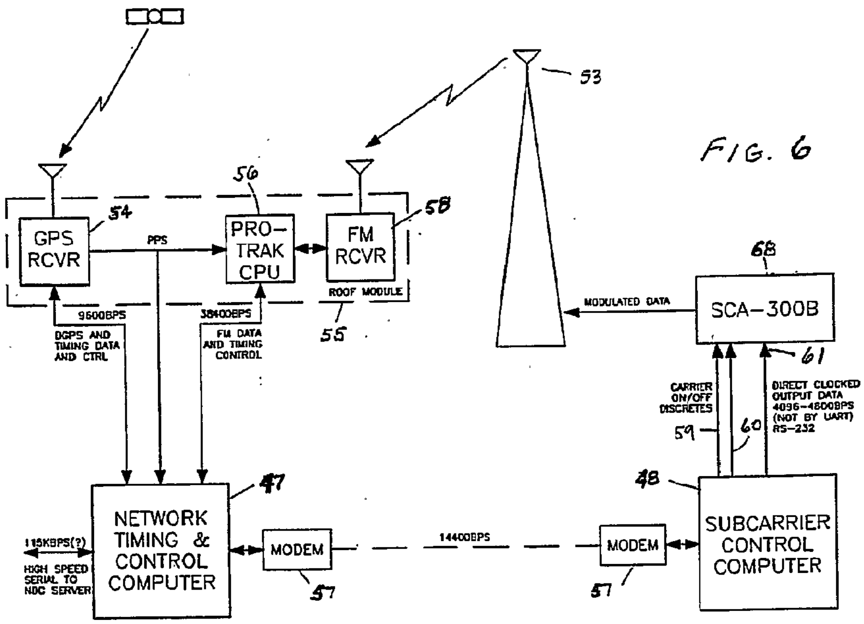


FIG. 6
GPS RCVR
PPS
PRO-TRAK CPU
FM RCVR
ROOF MODULE
MODULATED DATA
SCA-300B
9600BPS
38400BPS
DGPS AND TIMING DATA AND CTRL
FM DATA AND TIMING CONTROL
CARRIER ON/OFF DISCRETES
DIRECT CLOCKED OUTPUT DATA 4096-4800BPS (NOT BY UART) RS-232
NETWORK TIMING & CONTROL COMPUTER
MODEM
14400BPS
SUBCARRIER CONTROL COMPUTER
HIGH SPEED SERIAL TO NDC SERVER
53
54
55
56
58
68
61
59
60
47
48
57

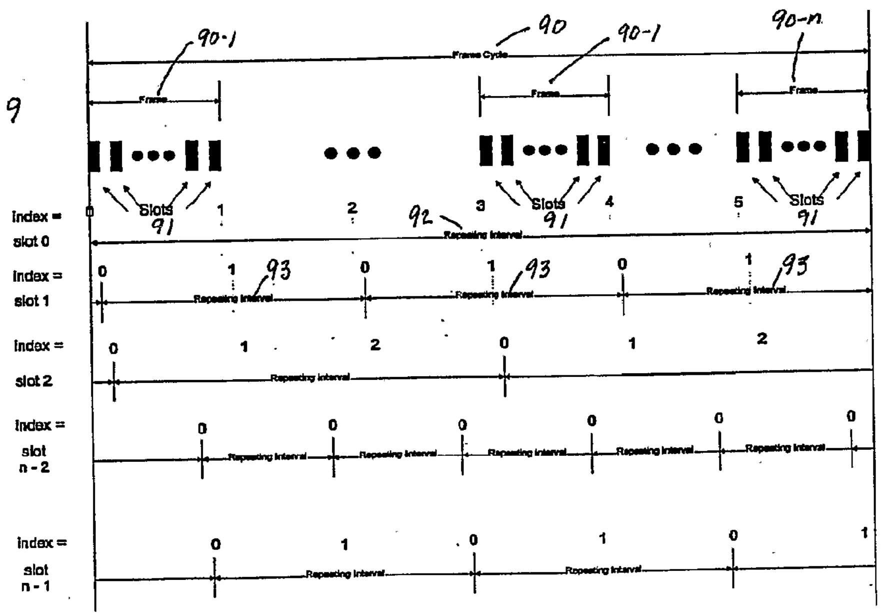


FIG. 9
Frame Cycle
Frame
Slots
Index = slot 0
Index = slot 1
Index = slot 2
Index = slot n-2
Index = slot n-1
Repeating Interval
90
90-1
90-n
91
92
93

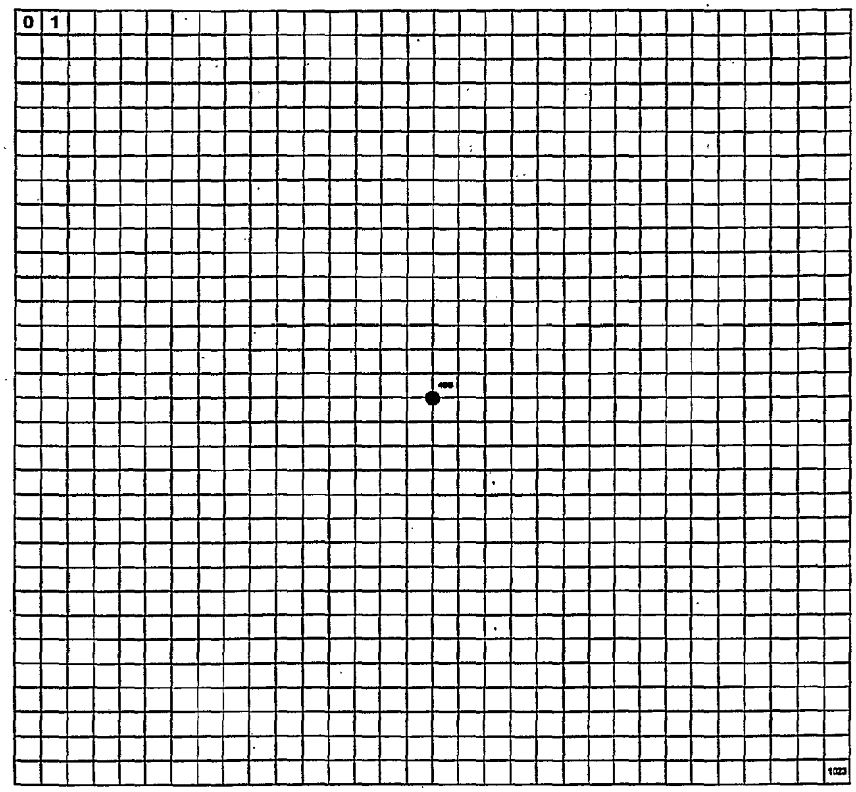


FIG. 11

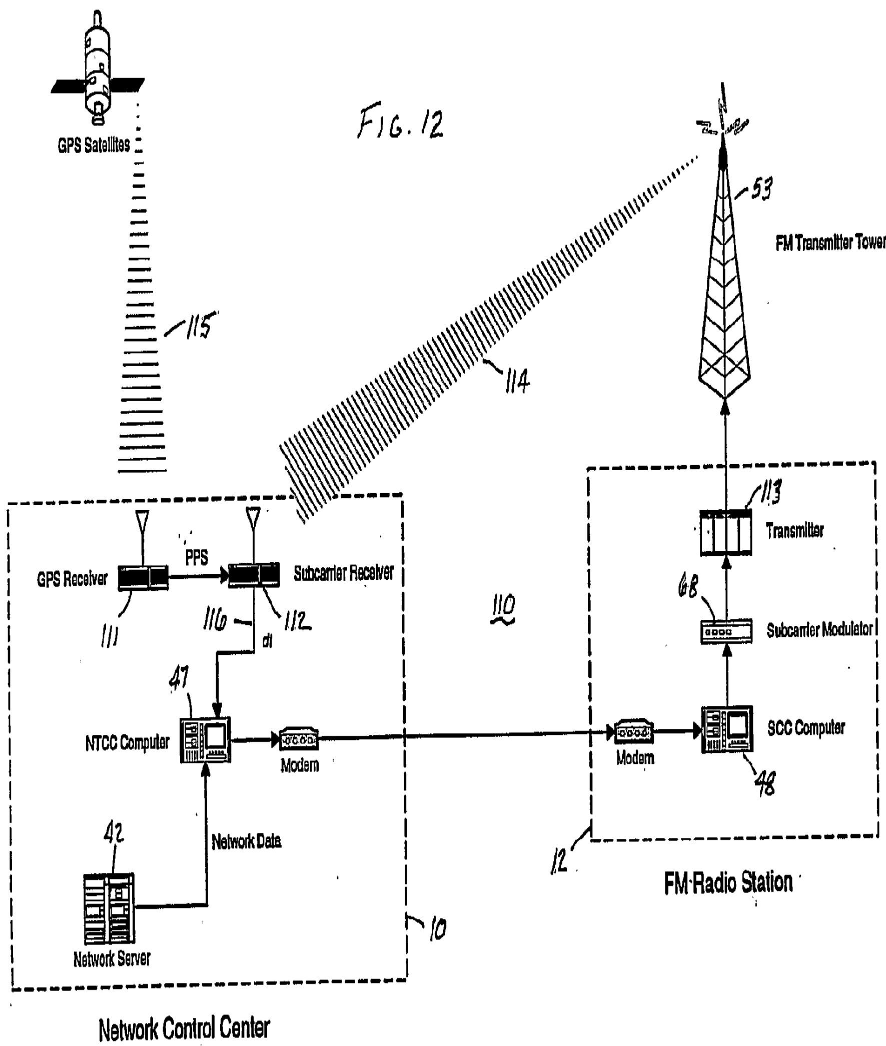

GPS Satellites
115
114
53
FM Transmitter Tower
PPS
GPS Receiver
Subcarrier Receiver
111
116
112
di
110
113
Transmitter
68
Subcarrier Modulator
47
NTCC Computer
Modem
Modem
SCC Computer
48
42
Network Data
12
FM Radio Station
Network Server
10
Network Control Center

FIG. 12

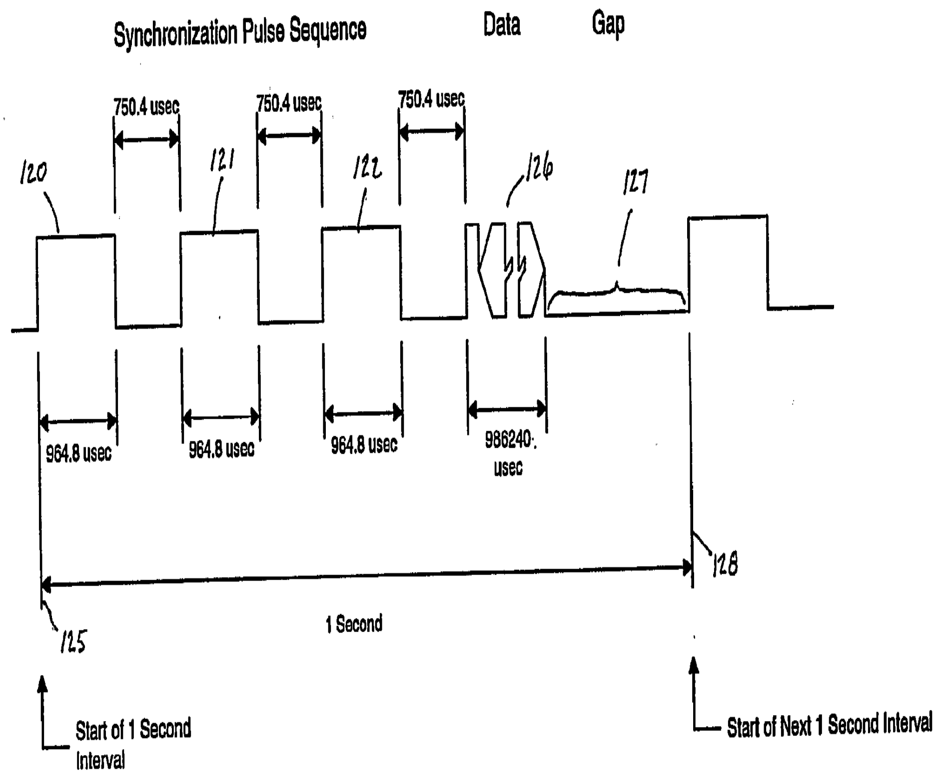

Synchronization Pulse Sequence
Data
Gap
750.4 usec
750.4 usec
750.4 usec
120
121
122
126
127
964.8 usec
964.8 usec
964.8 usec
986240
usec
128
1 Second
125
Start of 1 Second Interval
Start of Next 1 Second Interval

FIG. 13

Initialization Mode

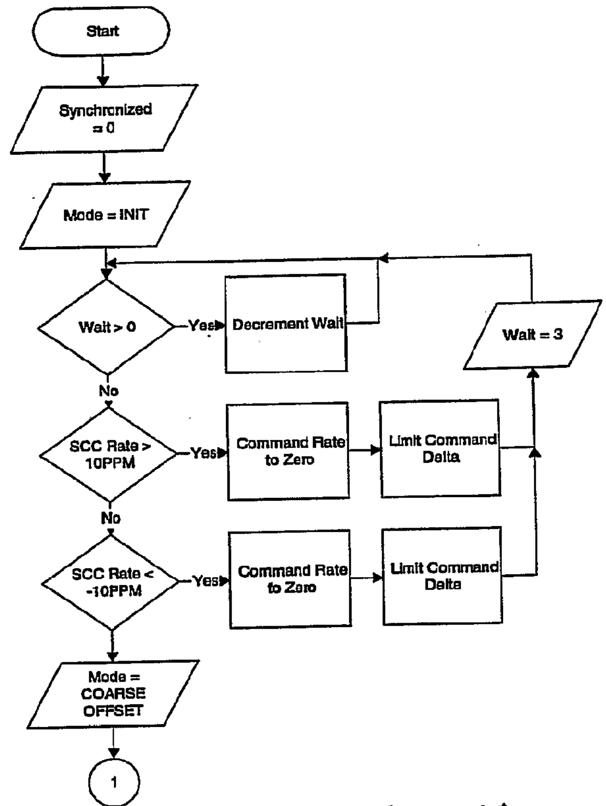


FIG. 14A

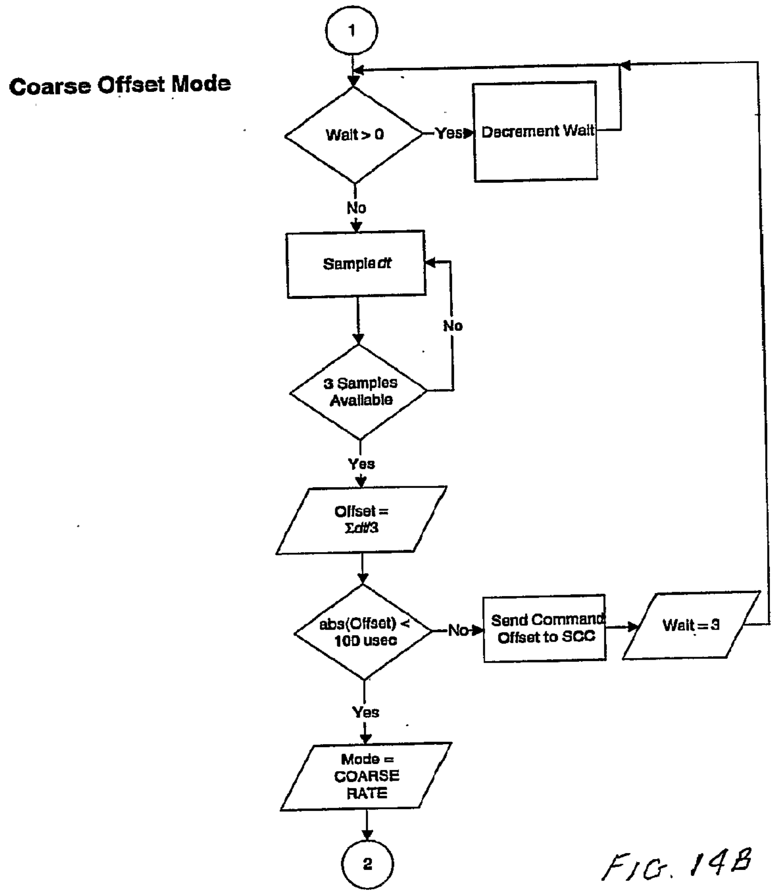

Coarse Offset Mode
1
Wait > 0
Yes
Decrement Wait
No
Sample dt
No
3 Samples Available
Yes
Offset = Σdt/3
abs(Offset) < 100 usec
No
Send Command Offset to SCC
Wait = 3
Yes
Mode = COARSE RATE
2

FIG. 14B

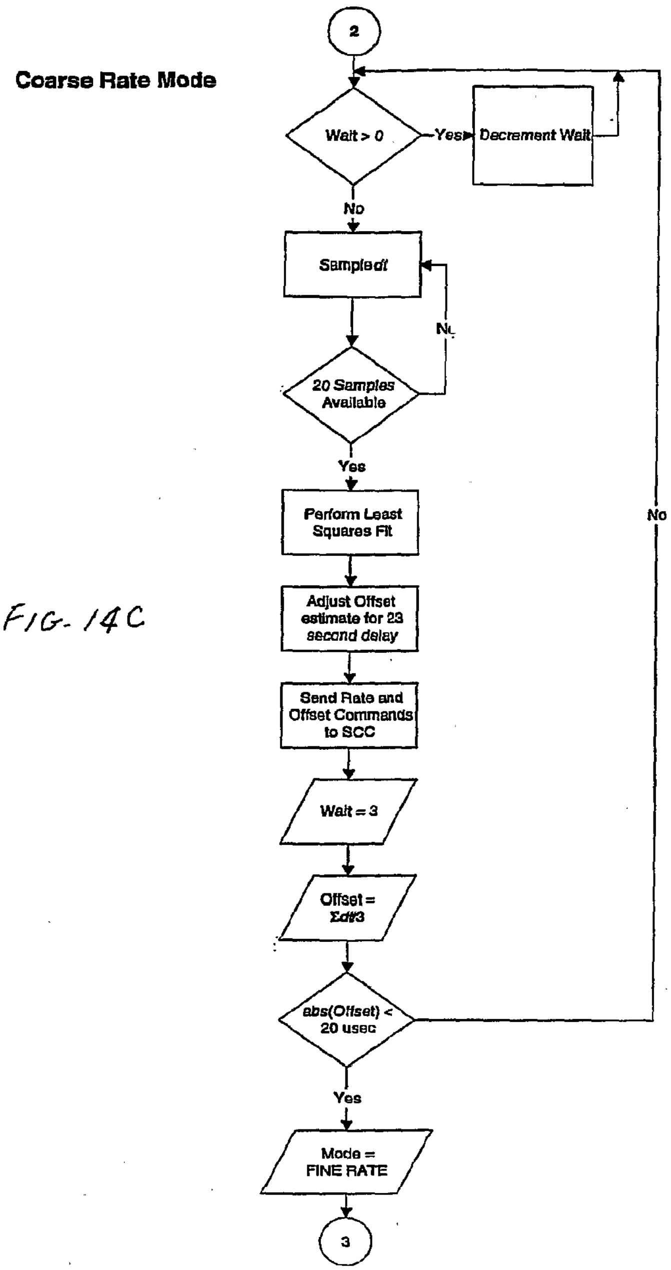

2
Coarse Rate Mode
Wait > 0
Yes
Decrement Wait
No
Sample dt
No
20 Samples Available
Yes
Perform Least Squares Fit
Adjust Offset estimate for 23 second delay
Send Rate and Offset Commands to SCC
Wait = 3
Offset = Σdt/3
abs(Offset) < 20 usec
No
Yes
Mode = FINE RATE
3

FIG. 14C

Fine Rate Mode

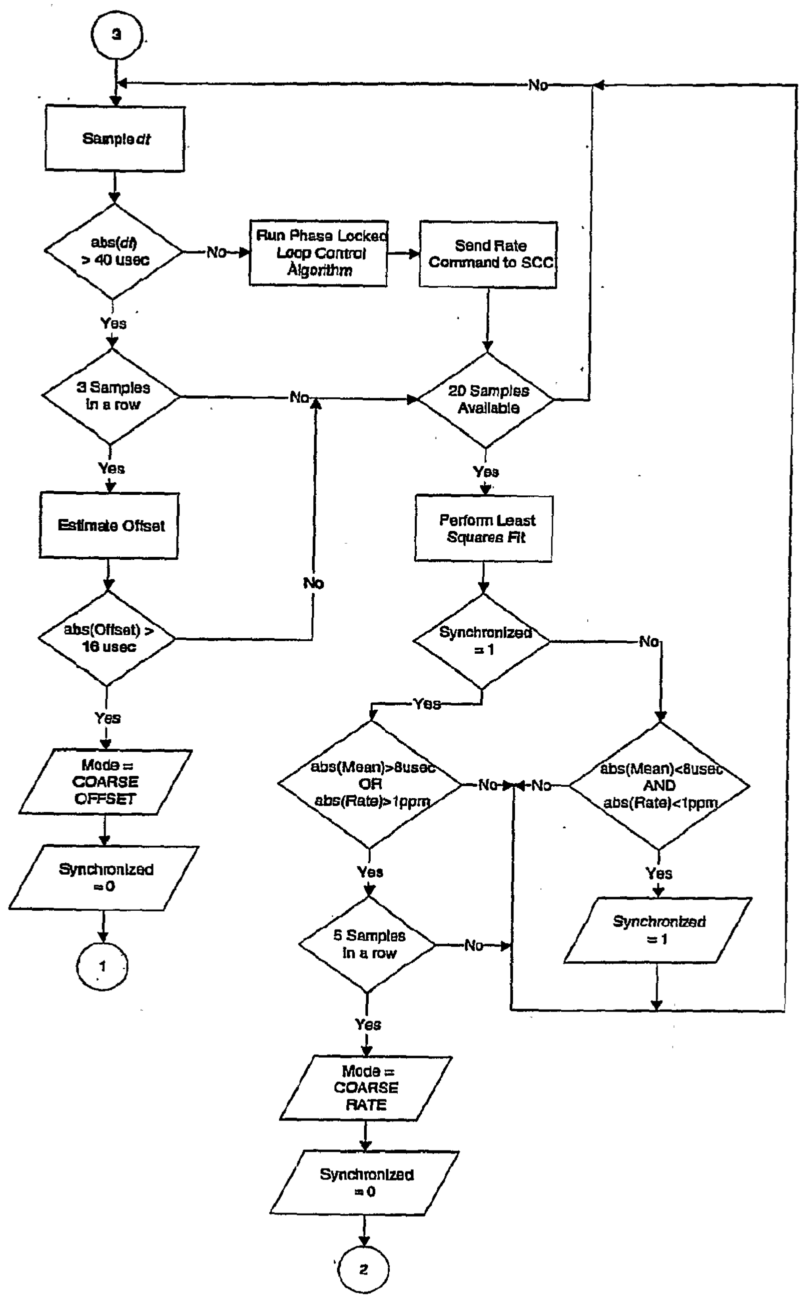


FIG. 14D

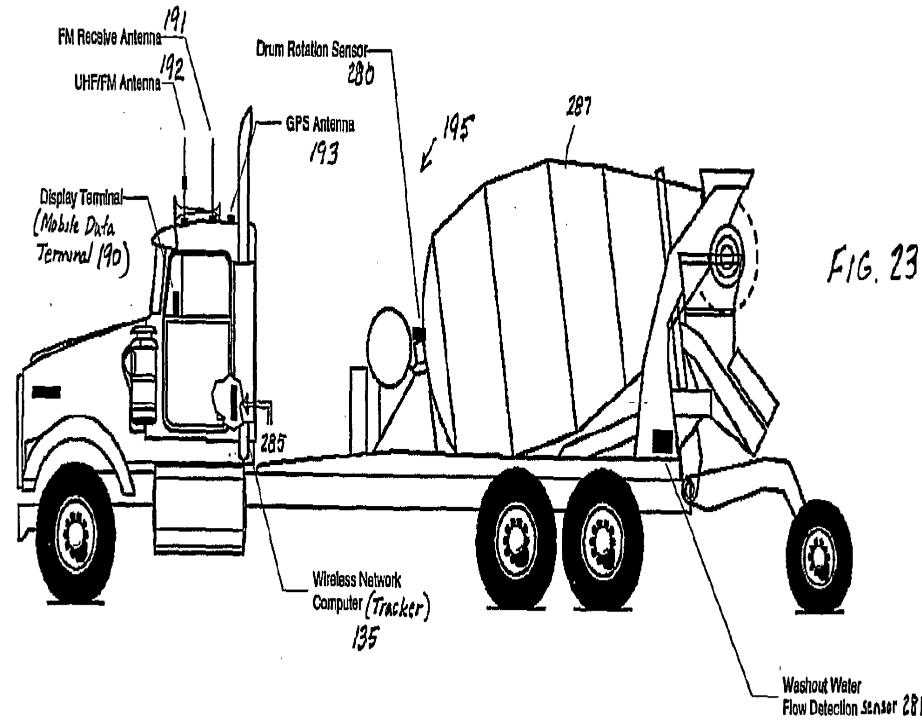

FM Receive Antenna 191
UHF/FM Antenna 192
GPS Antenna 193
Display Terminal (Mobile Data Terminal 190)
Drum Rotation Sensor 280
195
287
285
Wireless Network Computer (Tracker) 135
Washout Water Flow Detection sensor 281

FIG. 23

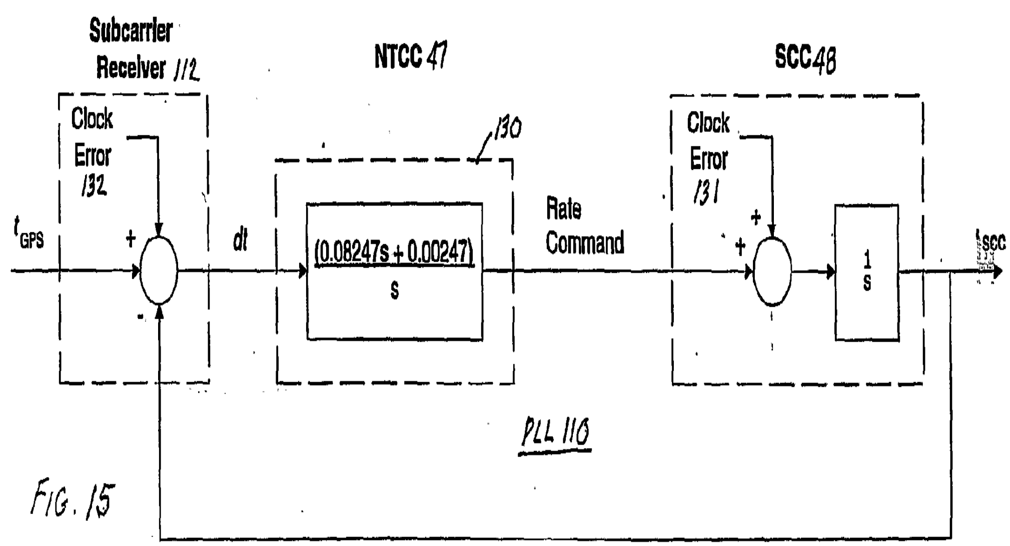

Subcarrier Receiver 112
Clock Error 132
t_{GPS}
+
-
dt
NTCC 47
130
(0.08247s + 0.00247)
s
Rate Command
SCC 48
Clock Error 131
+
+
1
s
t_{SCC}
PLL 110

FIG. 15

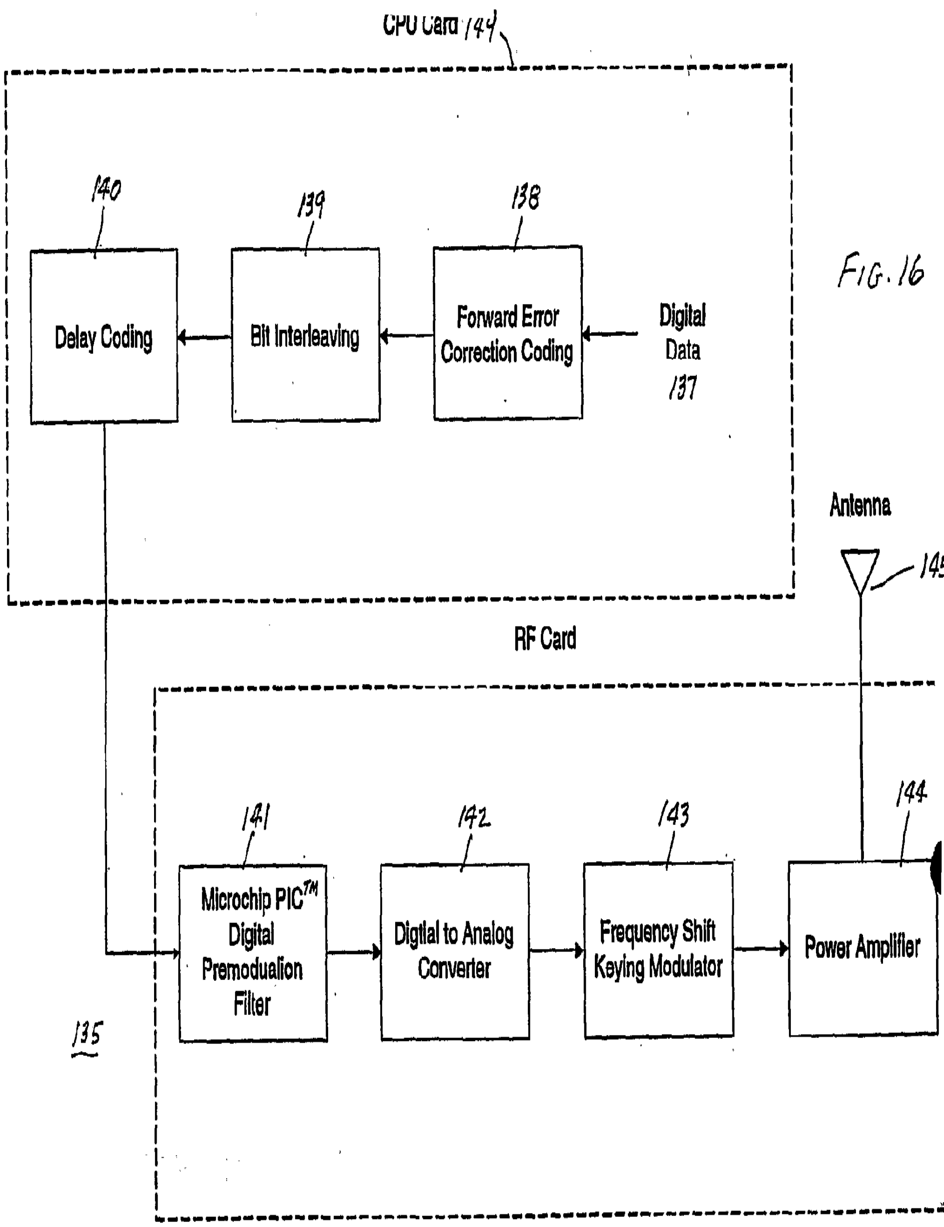

CPU Card 149
140
Delay Coding
139
Bit Interleaving
138
Forward Error Correction Coding
Digital Data 137
Antenna
145
RF Card
141
Microchip PIC™ Digital Premodualion Filter
142
Digital to Analog Converter
143
Frequency Shift Keying Modulator
144
Power Amplifier
135

FIG. 16

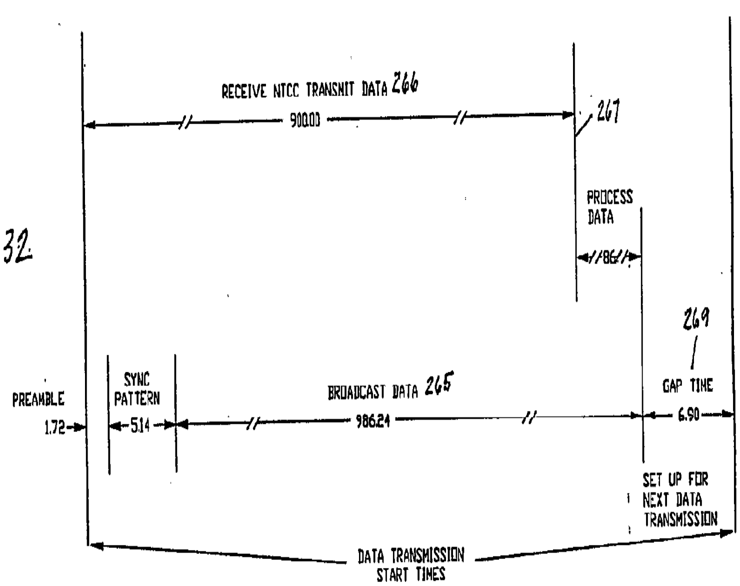
TDMA Transmit Bit Interleaving

Words	Bits 11	10	9	8	7	6	5	4	3	2	1	0
0	1/0 000	2/0 001	3/0 002	4/0 003	5/0 004	6/0 005	7/0 006	8/0 007	9/0 008	10/0 009	11/0 010	0/1 011
1	2/1 012	3/1 013	4/1 014	5/1 015	6/1 016	7/1 017	8/1 018	9/1 019	10/1 020	11/1 021	0/2 022	1/2 023
2	3/2 024	4/2 025	5/2 026	6/2 027	7/2 028	8/2 029	9/2 030	10/2 031	11/2 032	0/3 033	1/3 034	2/3 035
3	4/3 036	5/3 037	6/3 038	7/3 039	8/3 040	9/3 041	10/3 042	11/3 043	0/4 044	1/4 045	2/4 046	3/4 047
4	5/4 048	6/4 049	7/4 050	8/4 051	9/4 052	10/4 053	11/4 054	0/5 055	1/5 056	2/5 057	3/5 058	4/5 059
5	6/5 060	7/5 061	8/5 062	9/5 063	10/5 064	11/5 065	0/6 066	1/6 067	2/6 068	3/6 069	4/6 070	5/6 071
6	7/6 072	8/6 073	9/6 074	10/6 075	11/6 076	0/7 077	1/7 078	2/7 079	3/7 080	4/7 081	5/7 082	6/7 083
7	8/7 084	9/7 085	10/7 086	11/7 087	0/8 088	1/8 089	2/8 090	3/8 091	4/8 092	5/8 093	6/8 094	7/8 095
8	9/8 096	10/8 097	11/8 098	0/9 099	1/9 100	2/9 101	3/9 102	4/9 103	5/9 104	6/9 105	7/9 106	8/9 107
9	10/9 108	11/9 109	0/10 110	1/10 111	2/10 112	3/10 113	4/10 114	5/10 115	6/10 116	7/10 117	8/10 118	9/10 119
10	11/10 120	0/11 121	1/11 122	2/11 123	3/11 124	4/11 125	5/11 126	6/11 127	7/11 128	8/11 129	9/11 130	10/11 131
11	0/0 132	1/1 133	2/2 134	3/3 135	4/4 136	5/5 137	6/6 138	7/7 139	8/8 140	9/9 141	10/10 142	11/11 143

W/B indicates bit, B, of the original code word, W.
Words are transmitted MSB first; the small number indicates transmit bit order

FIG. 17

FIG. 32



NOTE: TIMES IN MILLISECONDS

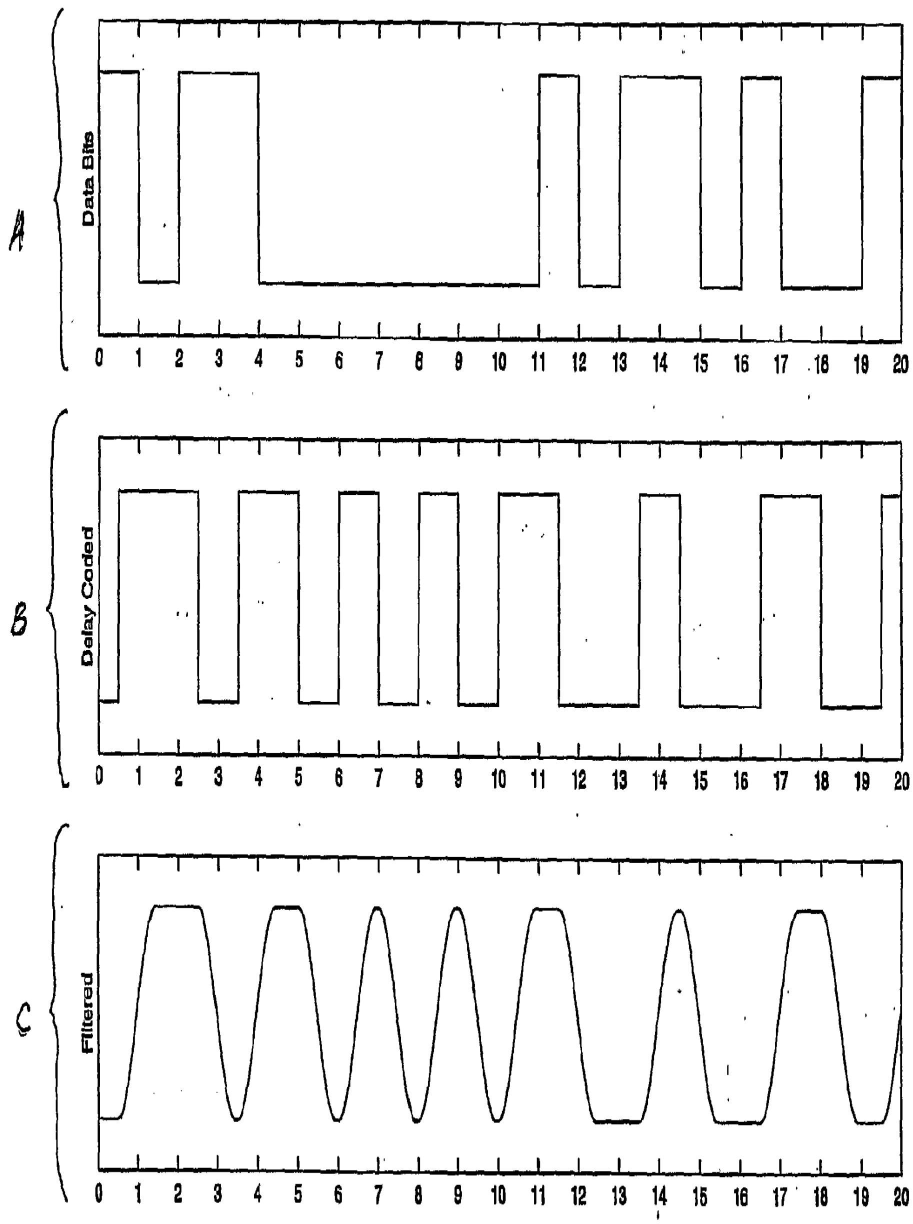

A
Data Bits
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
B
Delay Coded
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
C
Filtered
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

FIG. 18

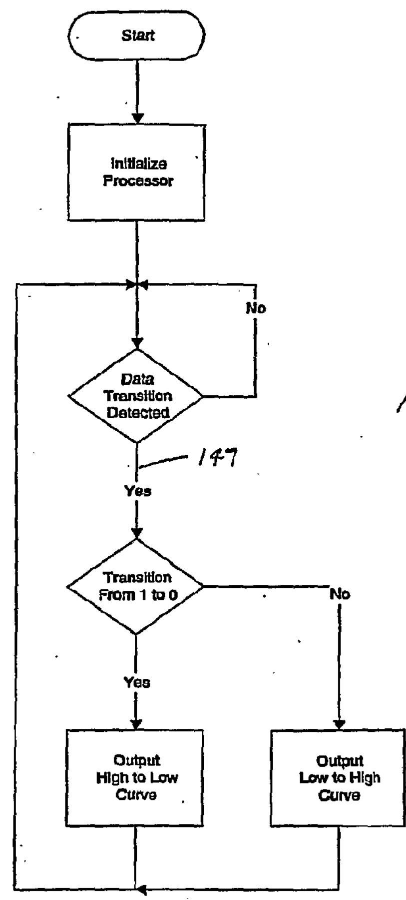

Start
Initialize Processor
Data Transition Detected
No
147
Yes
Transition From 1 to 0
Yes
No
Output High to Low Curve
Output Low to High Curve

FIG. 19

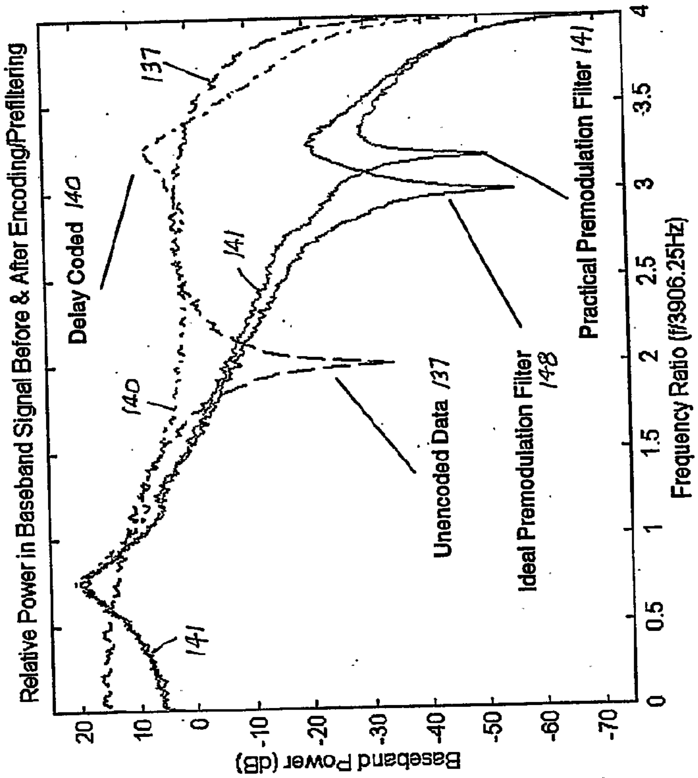

Relative Power in Baseband Signal Before & After Encoding/Prefiltering
Delay Coded 140
137
140
141
141
Unencoded Data 137
Ideal Premodulation Filter 148
Practical Premodulation Filter 141
Baseband Power (dB)
20
10
0
-10
-20
-30
-40
-50
-60
-70
0
0.5
1
1.5
2
2.5
3
3.5
4
Frequency Ratio (f/3906.25Hz)

FIG. 20

FIG. 21

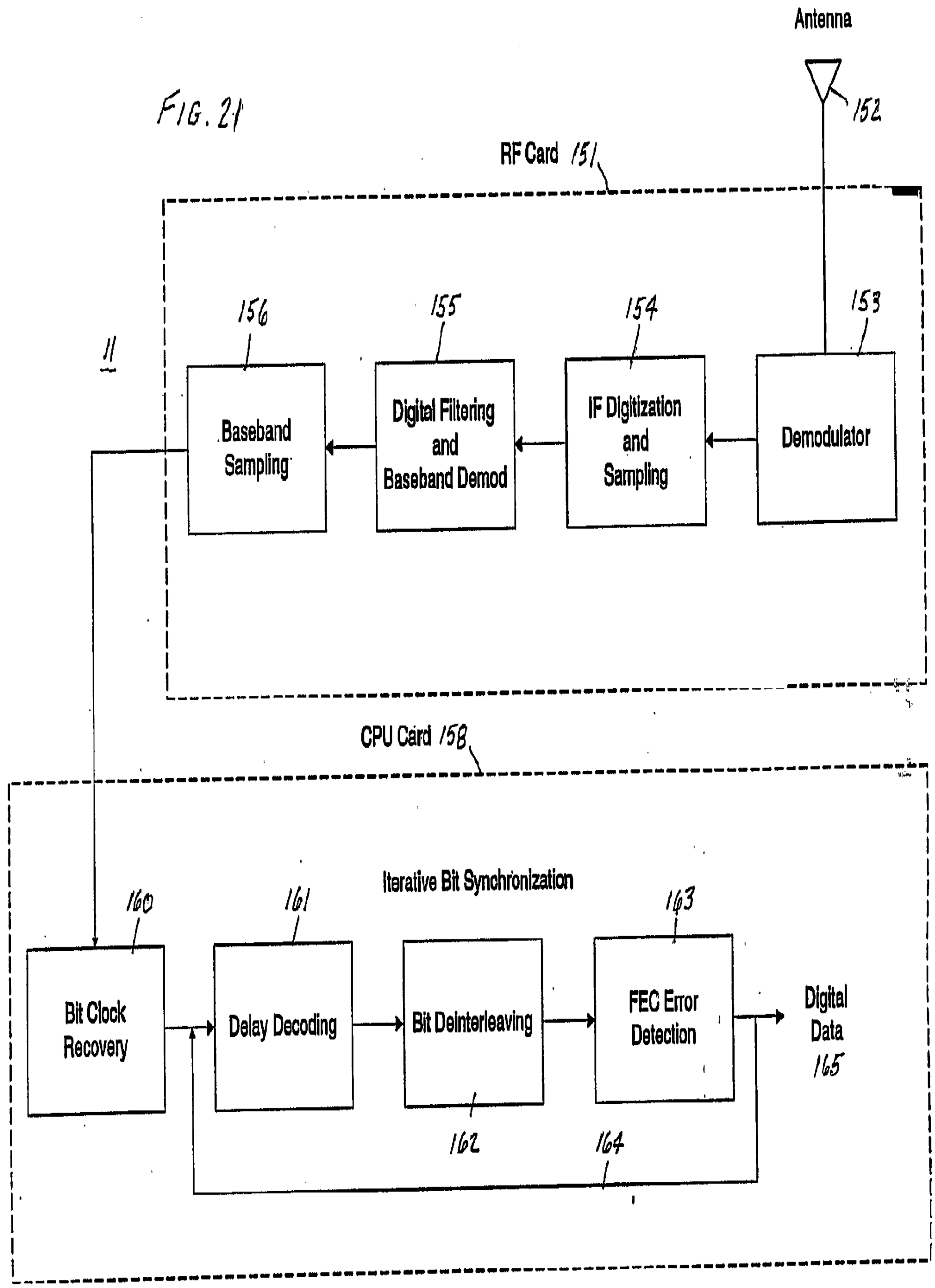
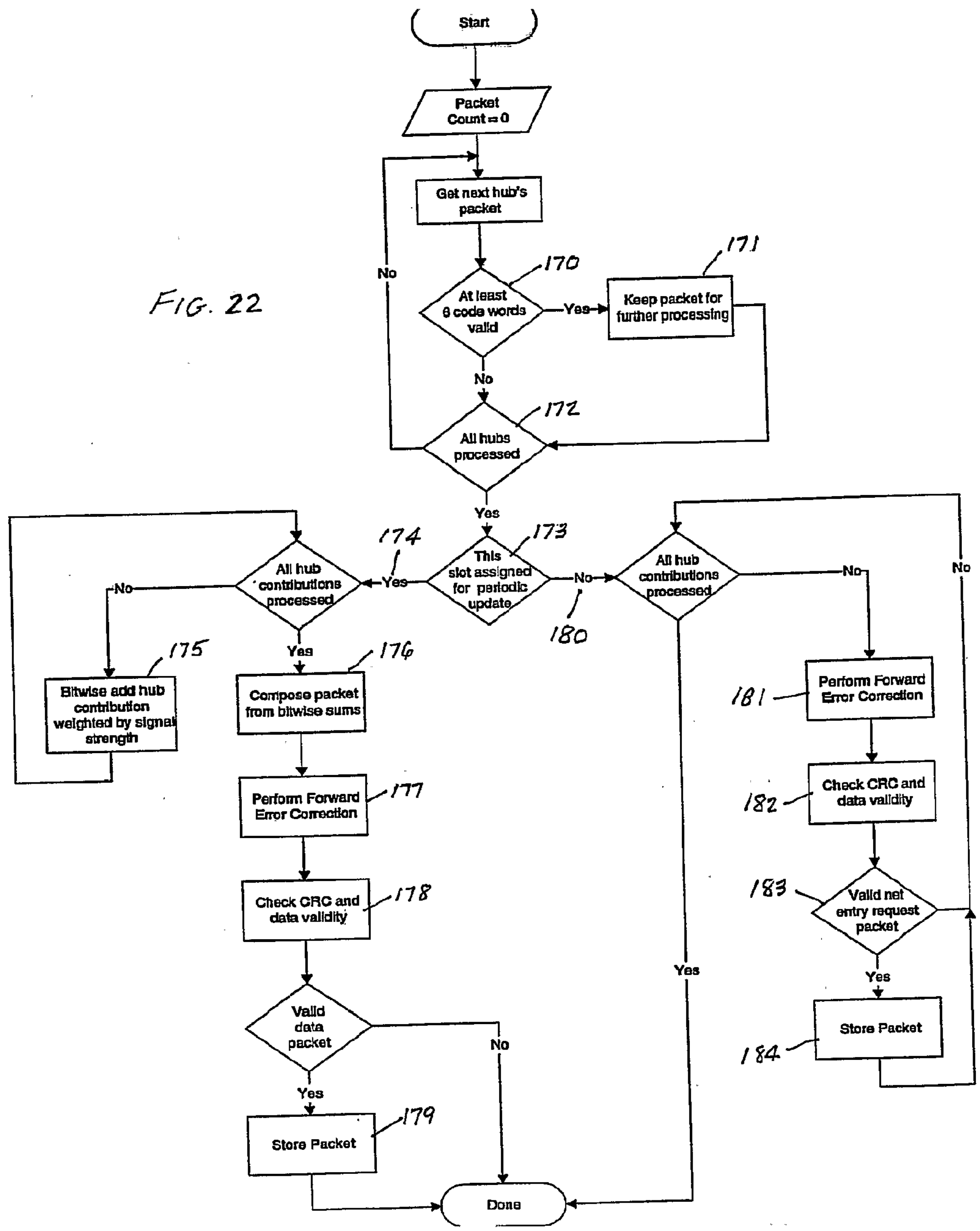

Antenna
152
RF Card 151
153
154
155
156
11
Demodulator
IF Digitization and Sampling
Digital Filtering and Baseband Demod
Baseband Sampling
CPU Card 158
Iterative Bit Synchronization
160
161
163
Bit Clock Recovery
Delay Decoding
Bit Deinterleaving
FEC Error Detection
Digital Data 165
162
164

FIG. 22


Start
Packet Count = 0
Get next hub's packet
At least 6 code words valid
170
Yes
No
Keep packet for further processing
171
All hubs processed
172
No
Yes
This slot assigned for periodic update
173
Yes
No
174
180
All hub contributions processed
No
Yes
Bitwise add hub contribution weighted by signal strength
175
Compose packet from bitwise sums
176
Perform Forward Error Correction
177
Check CRC and data validity
178
Valid data packet
Yes
No
Store Packet
179
Done
All hub contributions processed
No
Yes
Perform Forward Error Correction
181
Check CRC and data validity
182
Valid net entry request packet
183
Yes
No
Store Packet
184

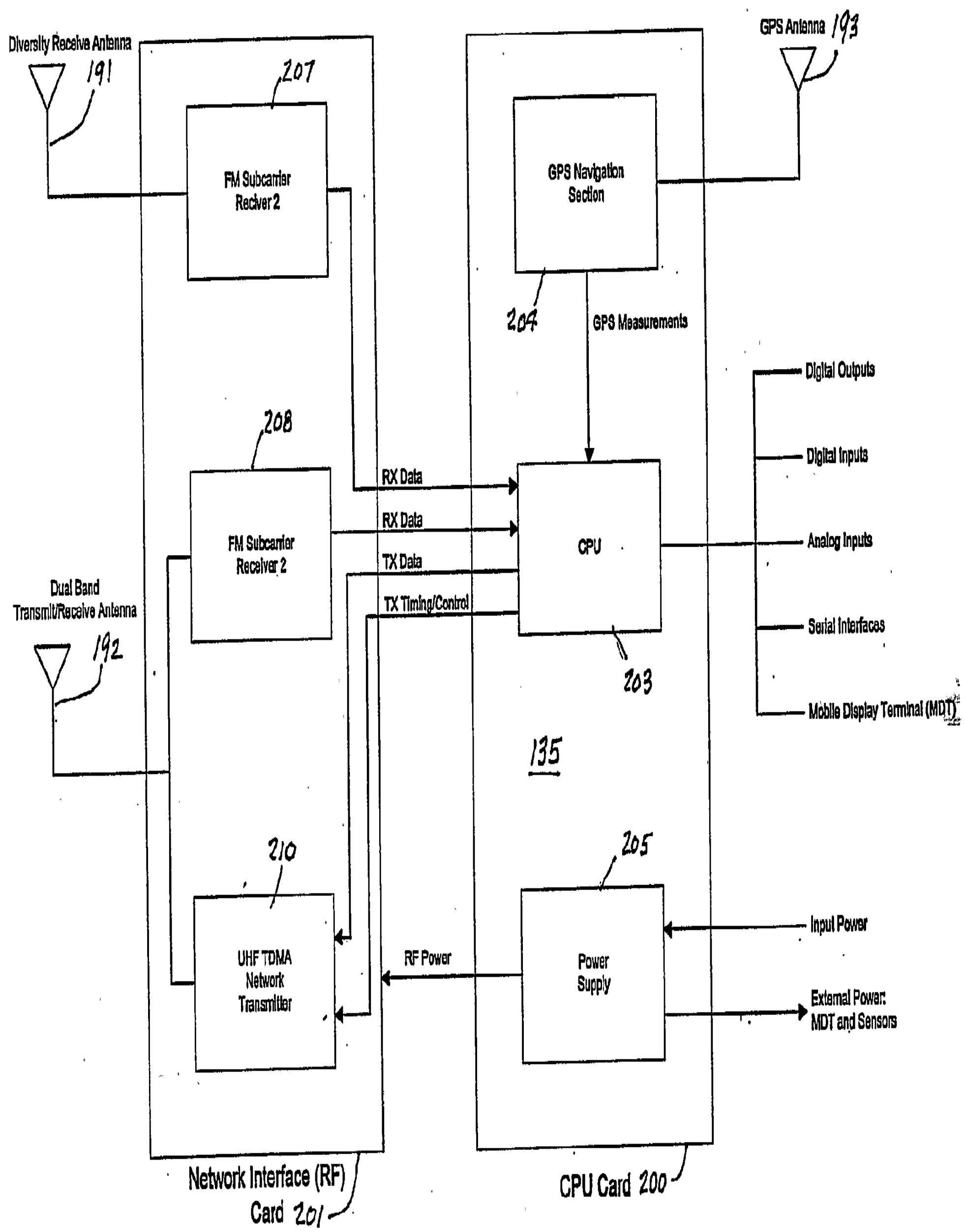

Diversity Receive Antenna 191
GPS Antenna 193
207
FM Subcarrier Reciver 2
GPS Navigation Section
204
GPS Measurements
Digital Outputs
208
Digital Inputs
RX Data
RX Data
TX Data
TX Timing/Control
CPU
Analog Inputs
FM Subcarrier Receiver 2
Dual Band Transmit/Receive Antenna 192
Serial Interfaces
203
Mobile Display Terminal (MDT)
135
210
205
UHF TDMA Network Transmitter
RF Power
Power Supply
Input Power
External Power: MDT and Sensors
Network Interface (RF) Card 201
CPU Card 200

FIG. 24

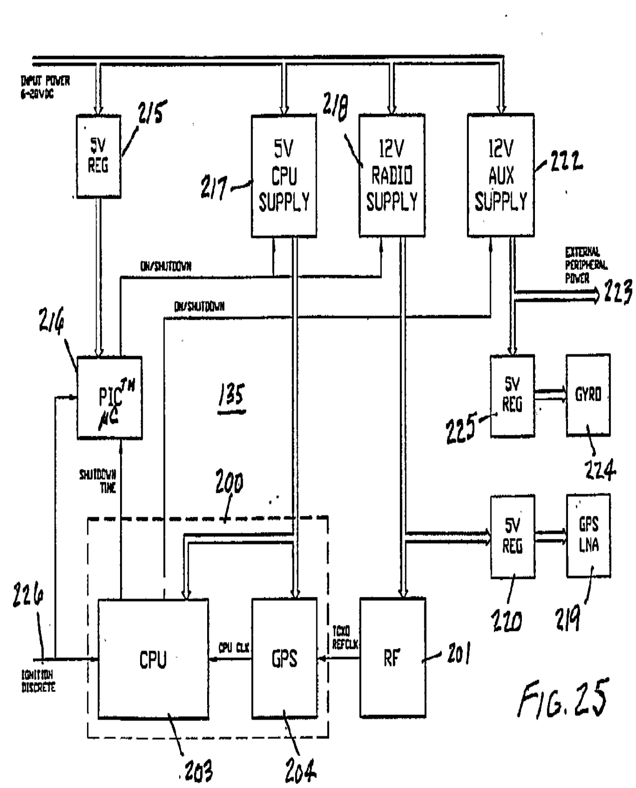

INPUT POWER
6-28VDC
5V
REG
215
5V
CPU
SUPPLY
217
218
12V
RADIO
SUPPLY
12V
AUX
SUPPLY
222
ON/SHUTDOWN
ON/SHUTDOWN
EXTERNAL
PERIPHERAL
POWER
223
216
PIC
135
5V
REG
GYRO
225
224
SHUTDOWN
TIME
200
5V
REG
GPS
LNA
226
220
219
CPU
CPU CLK
GPS
TCXO
REFCLK
RF
201
IGNITION
DISCRETE
203
204

FIG. 25

FIG. 26

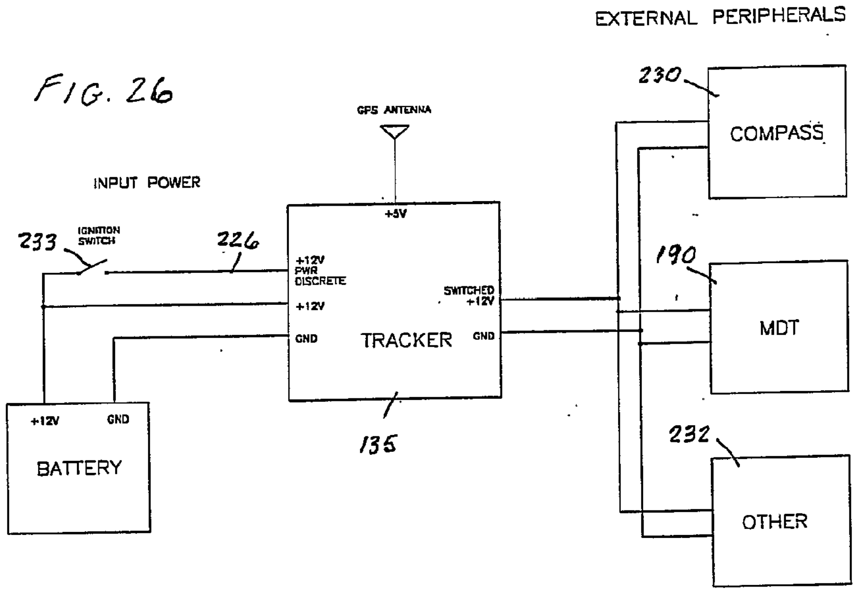
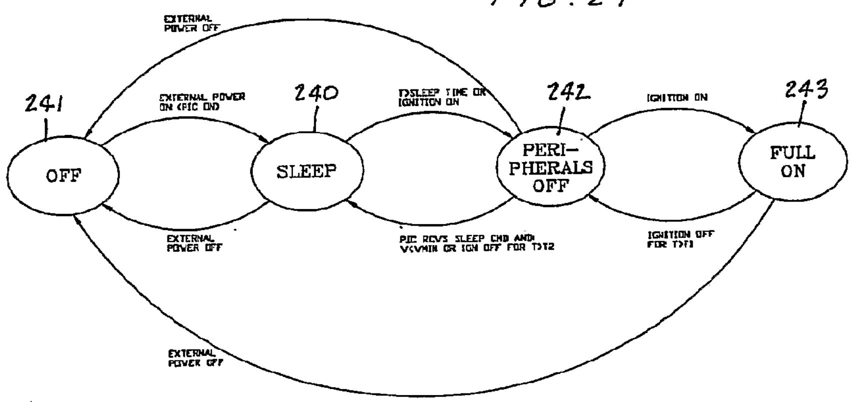

EXTERNAL PERIPHERALS
230
COMPASS
190
MDT
232
OTHER
GPS ANTENNA
+5V
INPUT POWER
233
IGNITION SWITCH
226
+12V PWR DISCRETE
+12V
GND
TRACKER
SWITCHED +12V
GND
135
+12V
GND
BATTERY

FIG. 27


EXTERNAL POWER OFF
241
OFF
EXTERNAL POWER ON (PIC ON)
240
SLEEP
T>SLEEP TIME OR IGNITION ON
242
PERI-PHERALS OFF
IGNITION ON
243
FULL ON
EXTERNAL POWER OFF
PIC RCVS SLEEP CMD AND V<VMIN OR IGN OFF FOR T>T2
IGNITION OFF FOR T>T1
EXTERNAL POWER OFF

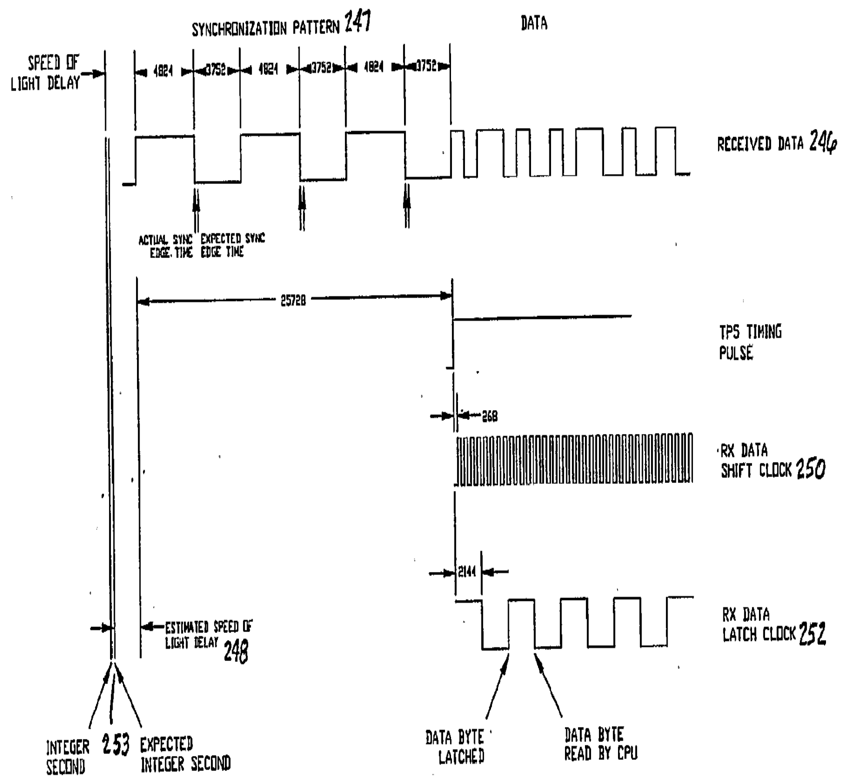

SYNCHRONIZATION PATTERN 247
DATA
SPEED OF LIGHT DELAY
4824
3752
4824
3752
4824
3752
RECEIVED DATA 246
ACTUAL SYNC EDGE TIME
EXPECTED SYNC EDGE TIME
25728
TPS TIMING PULSE
268
RX DATA SHIFT CLOCK 250
2144
RX DATA LATCH CLOCK 252
ESTIMATED SPEED OF LIGHT DELAY 248
INTEGER SECOND
253
EXPECTED INTEGER SECOND
DATA BYTE LATCHED
DATA BYTE READ BY CPU

FIG. 28

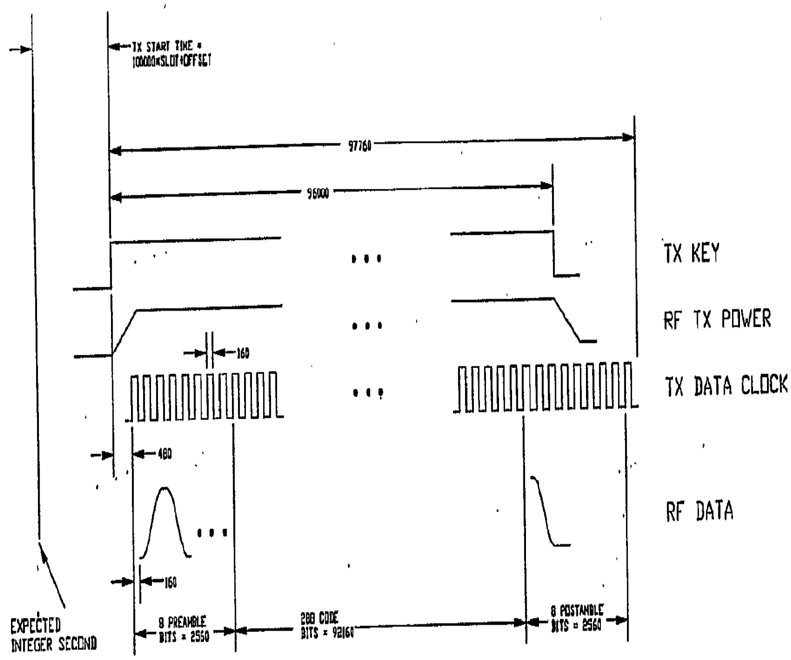

TX START TIME =
100000×SLOT+OFFSET
97760
96000
TX KEY
RF TX POWER
160
TX DATA CLOCK
480
RF DATA
160
EXPECTED
INTEGER SECOND
8 PREAMBLE
BITS = 2560
288 CODE
BITS = 92160
8 POSTAMBLE
BITS = 2560

FIG. 29

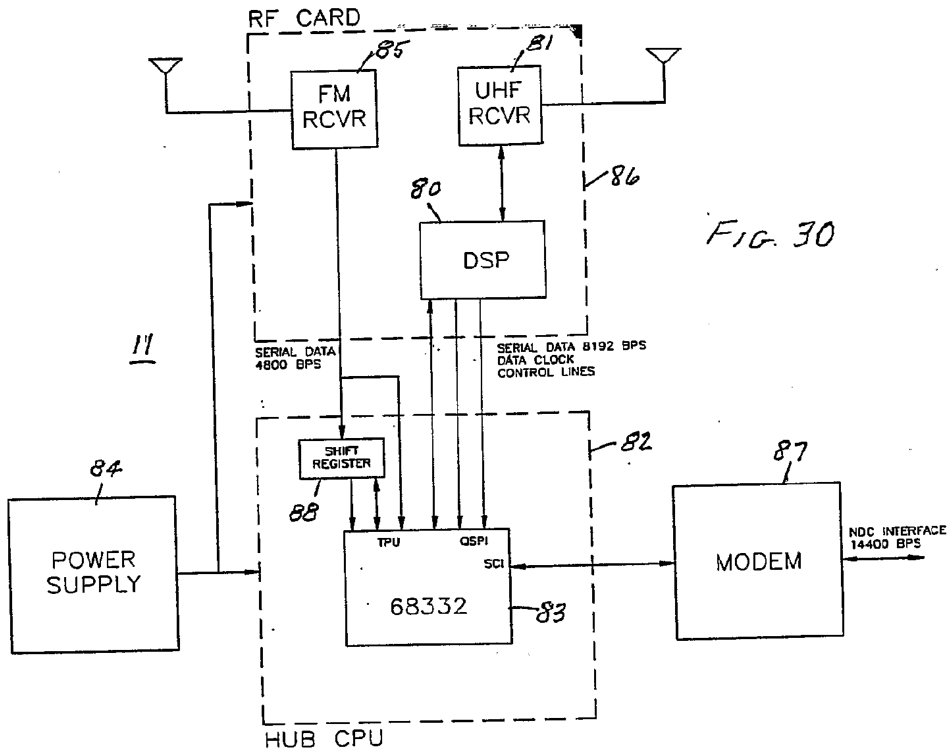

RF CARD
85
FM RCVR
81
UHF RCVR
86
80
DSP
11
SERIAL DATA 4800 BPS
SERIAL DATA 8192 BPS
DATA CLOCK
CONTROL LINES
82
87
84
SHIFT REGISTER
88
TPU
QSPI
SCI
POWER SUPPLY
68332
83
MODEM
NDC INTERFACE 14400 BPS
HUB CPU

FIG. 30

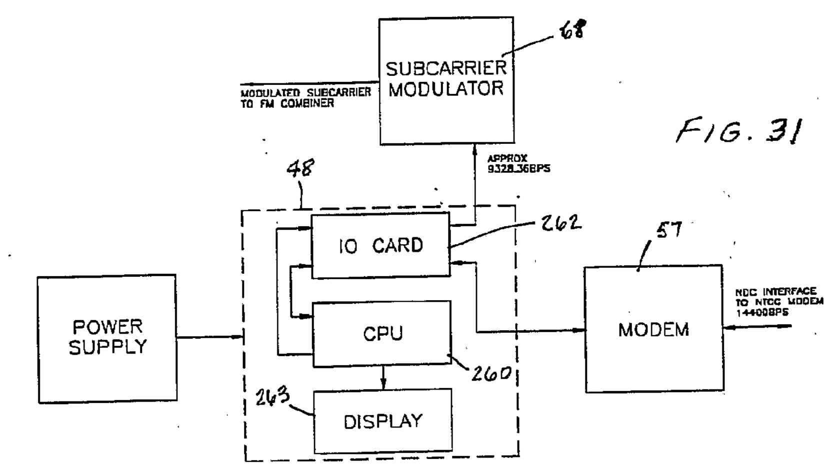

SUBCARRIER MODULATOR
68
MODULATED SUBCARRIER TO FM COMBINER
APPROX 9328.36BPS
48
IO CARD
262
57
POWER SUPPLY
CPU
MODEM
NDC INTERFACE TO NTCC MODEM 14400BPS
260
263
DISPLAY

FIG. 31

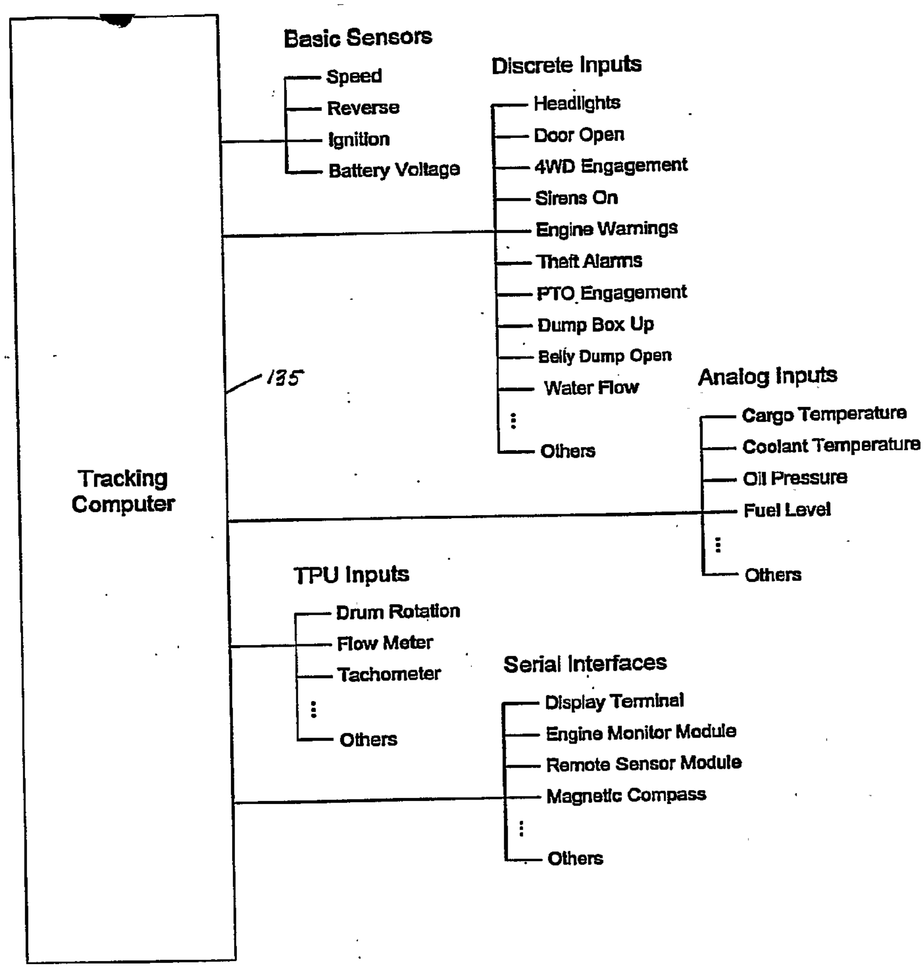

Tracking Computer
135
Basic Sensors
Speed
Reverse
Ignition
Battery Voltage
Discrete Inputs
Headlights
Door Open
4WD Engagement
Sirens On
Engine Warnings
Theft Alarms
PTO Engagement
Dump Box Up
Belly Dump Open
Water Flow
Others
Analog Inputs
Cargo Temperature
Coolant Temperature
Oil Pressure
Fuel Level
Others
TPU Inputs
Drum Rotation
Flow Meter
Tachometer
Others
Serial Interfaces
Display Terminal
Engine Monitor Module
Remote Sensor Module
Magnetic Compass
Others

FIG. 33

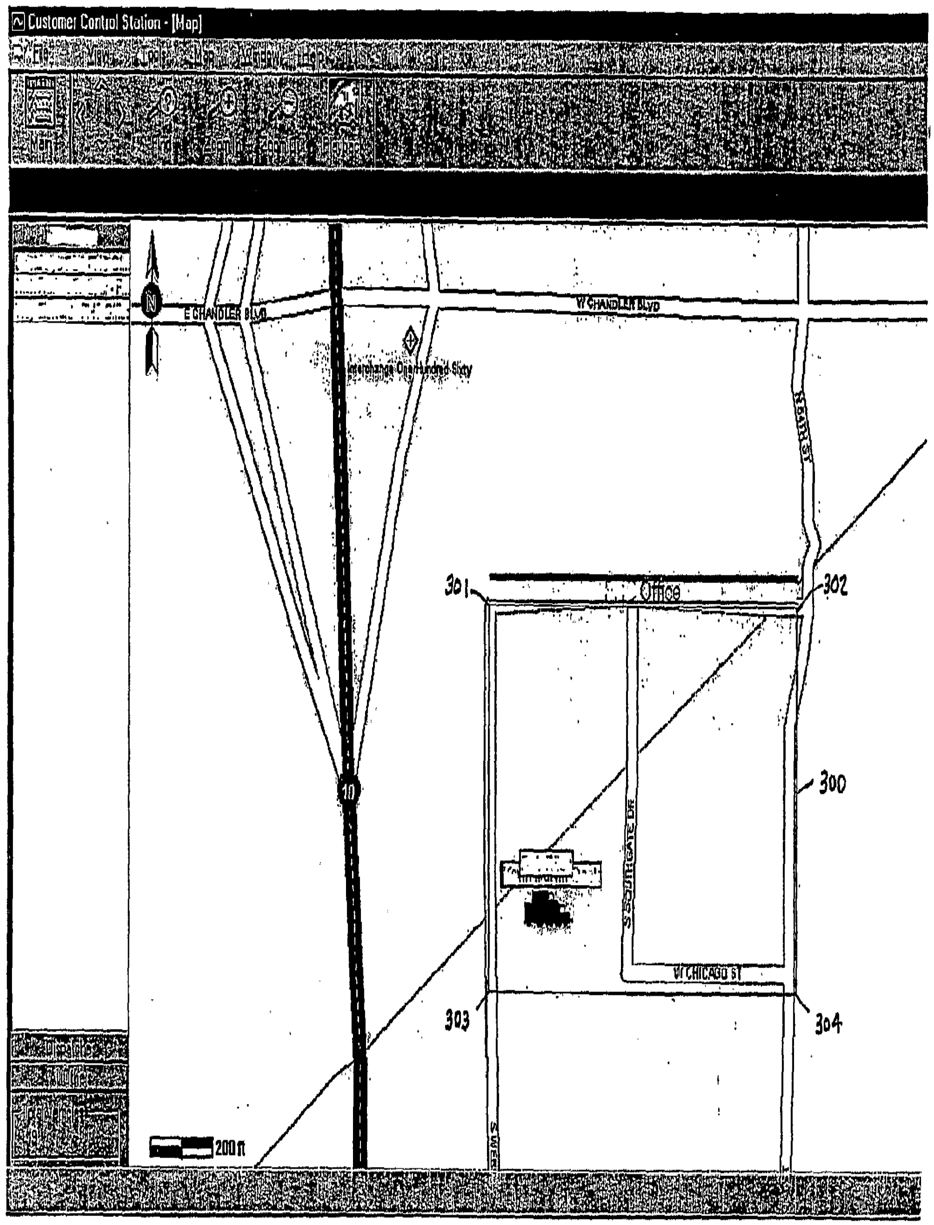

Customer Control Station - [Map]
E CHANDLER BLVD
W CHANDLER BLVD
Office
S SOUTHGATE DR
W CHICAGO ST
200 ft
301
302
300
303
304

FIG. 34

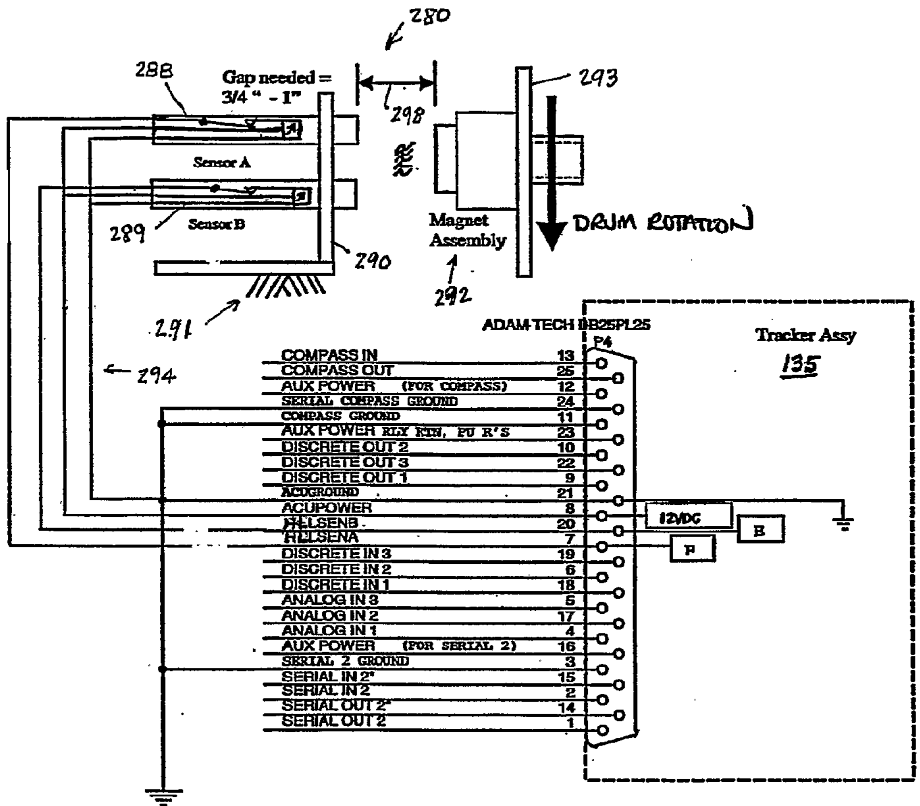

280
288
Gap needed = 3/4" - 1"
298
293
Sensor A
Sensor B
289
290
Magnet Assembly
292
DRUM ROTATION
291
294
ADAM-TECH DB25PL25
P4
Tracker Assy
135
COMPASS IN 13
COMPASS OUT 25
AUX POWER (FOR COMPASS) 12
SERIAL COMPASS GROUND 24
COMPASS GROUND 11
AUX POWER RLY RTN, PU R'S 23
DISCRETE OUT 2 10
DISCRETE OUT 3 22
DISCRETE OUT 1 9
ACUGROUND 21
ACUPOWER 8
HLLSENB 20
HLLSENA 7
DISCRETE IN 3 19
DISCRETE IN 2 6
DISCRETE IN 1 18
ANALOG IN 3 5
ANALOG IN 2 17
ANALOG IN 1 4
AUX POWER (FOR SERIAL 2) 16
SERIAL 2 GROUND 3
SERIAL IN 2* 15
SERIAL IN 2 2
SERIAL OUT 2* 14
SERIAL OUT 2 1
12VDC
B
F

FIG. 35

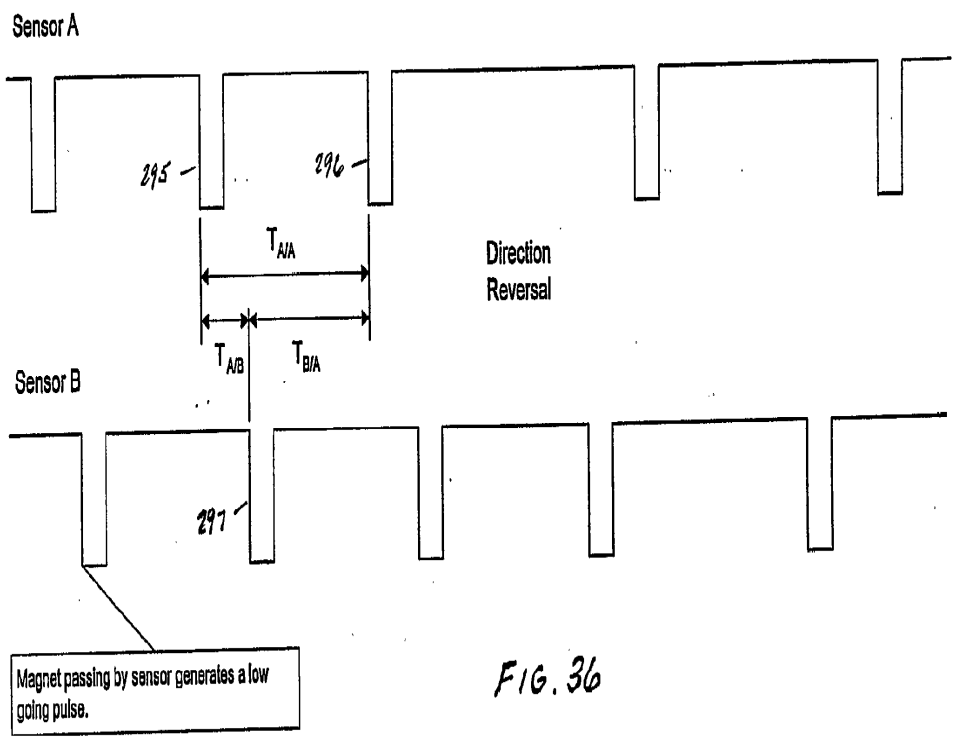

Sensor A
295
296
$T_{A/A}$
Direction Reversal
$T_{A/B}$
$T_{B/A}$
Sensor B
297
Magnet passing by sensor generates a low going pulse.

FIG. 36

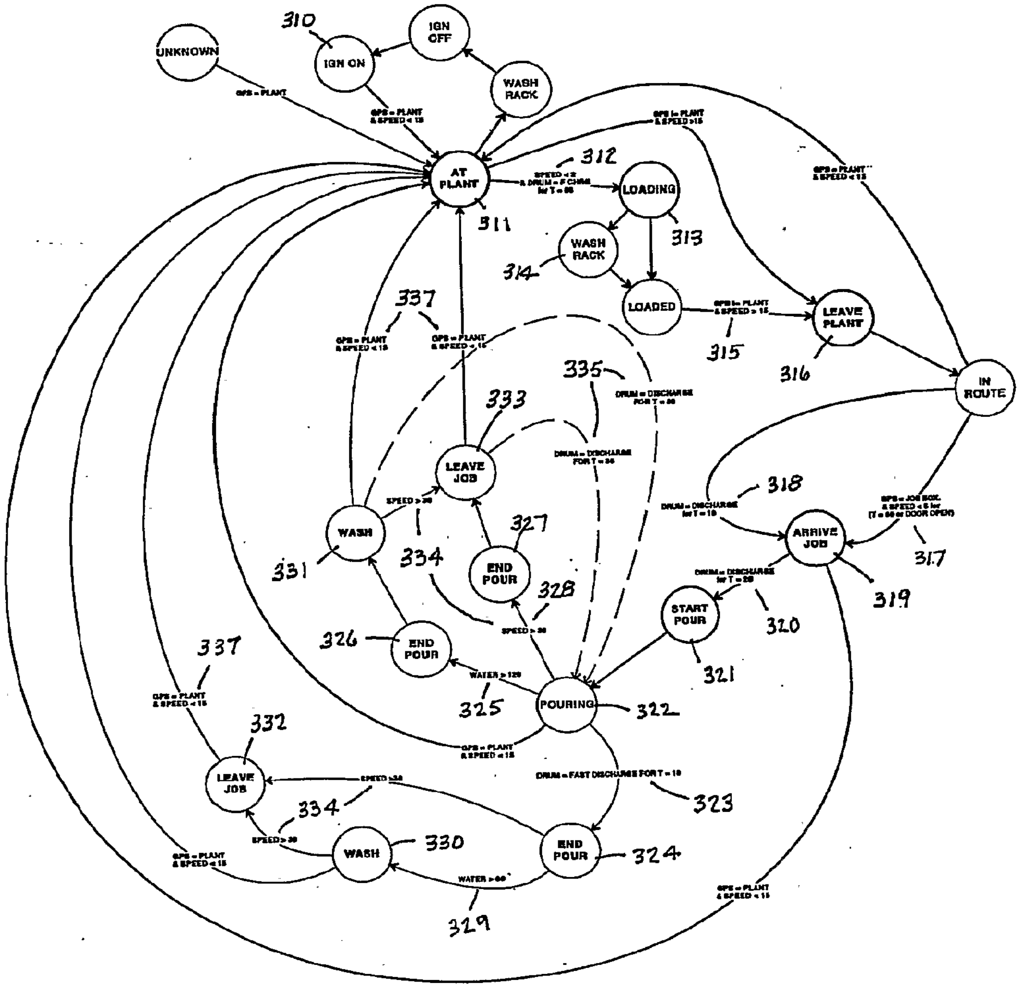

UNKNOWN
IGN ON
IGN OFF
WASH RACK
AT PLANT
LOADING
WASH RACK
LOADED
LEAVE PLANT
IN ROUTE
ARRIVE JOB
START POUR
POURING
END POUR
WASH
LEAVE JOB
END POUR
WASH
LEAVE JOB
END POUR
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
337

FIG. 37

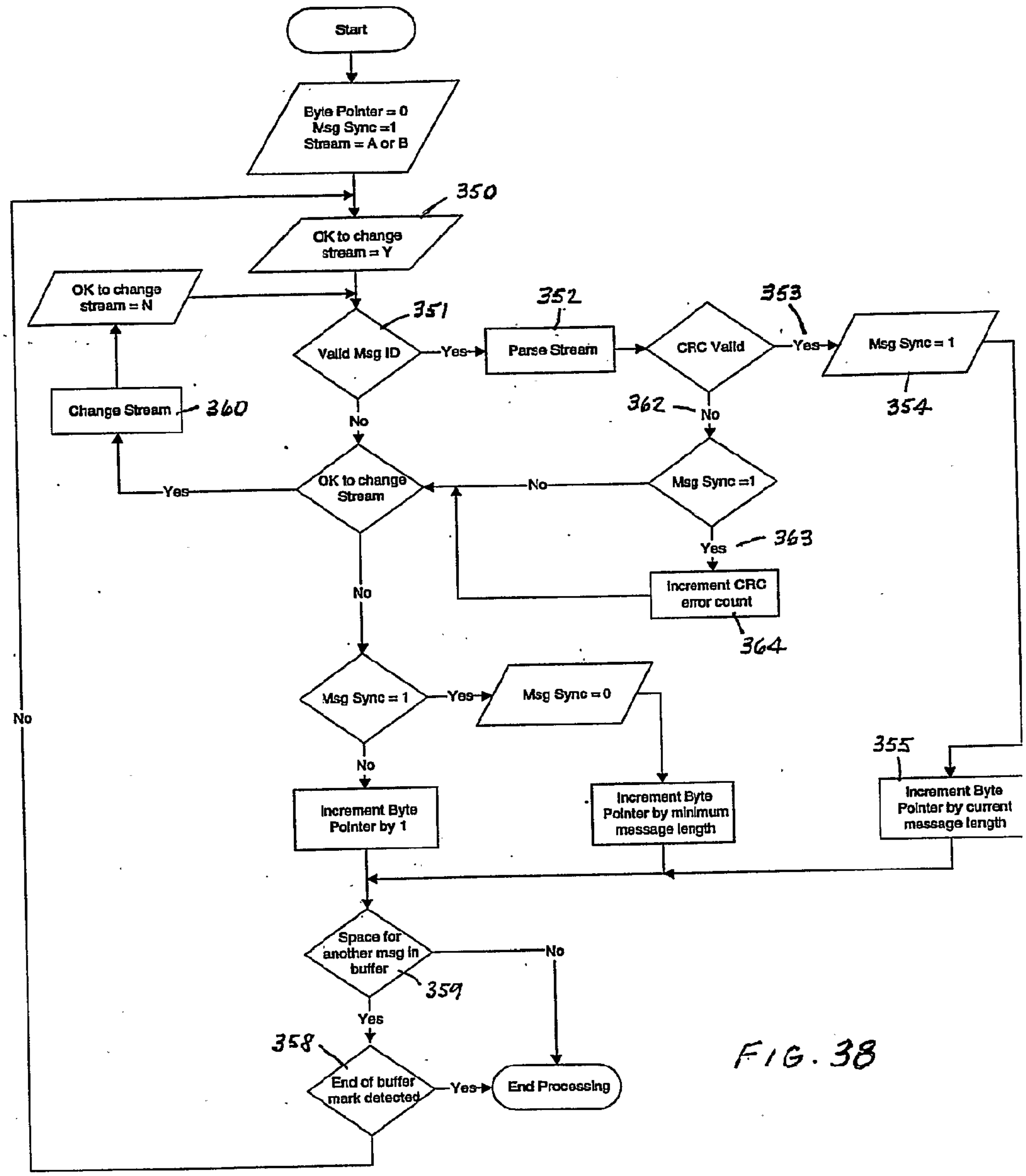

Start
Byte Pointer = 0
Msg Sync =1
Stream = A or B
350
OK to change stream = Y
OK to change stream = N
351
Valid Msg ID
Yes
352
Parse Stream
CRC Valid
353
Yes
Msg Sync = 1
354
Change Stream
360
No
362
No
Msg Sync =1
OK to change Stream
Yes
No
Yes
363
Increment CRC error count
364
No
No
Msg Sync = 1
Yes
Msg Sync = 0
355
No
Increment Byte Pointer by 1
Increment Byte Pointer by minimum message length
Increment Byte Pointer by current message length
Space for another msg in buffer
No
359
Yes
358
End of buffer mark detected
Yes
End Processing

FIG. 38

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09/229,130 12 January 1999 (12.01.99) US

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(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

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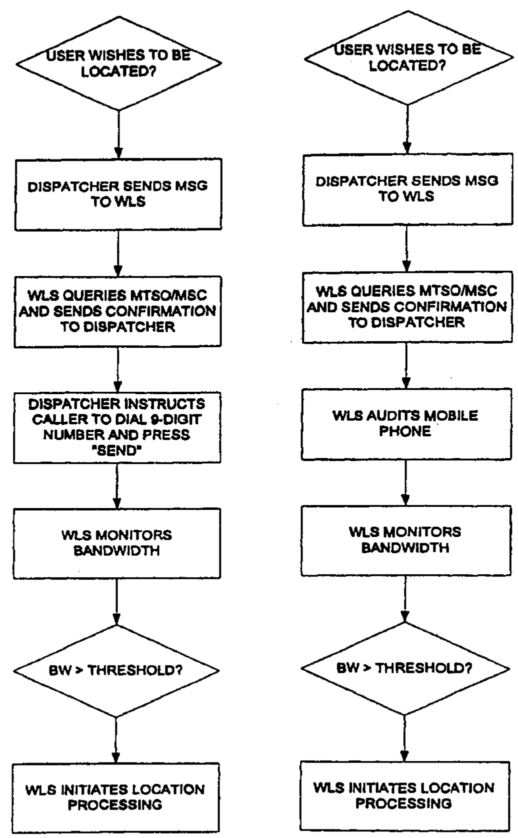
(54) Title: LOCATION METHOD FOR A WIRELESS LOCATION SYSTEM

(57) Abstract

A method for use in locating a mobile transmitter in an emergency situation comprises the steps of (a) upon determining that the emergency situation exists, monitoring a bandwidth of a reverse voice channel (RVC) signal transmitted by the mobile transmitter; (b) determining (fig. 10A) whether the bandwidth exceeds a predetermined threshold; (c) if the bandwidth exceeds the predetermined threshold, measuring the location of the mobile transmitter; and (d) if the bandwidth does not exceed the predetermined threshold, performing a predetermined action to increase the bandwidth and subsequently measuring the location of the mobile transmitter.



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CM	Cameroon			**PL**	Poland		
CN	China	**KR**	Republic of Korea	**PT**	Portugal		
CU	Cuba	**KZ**	Kazakstan	**RO**	Romania		
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LOCATION METHOD FOR A WIRELESS LOCATION SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

This is a continuation of U.S. Patent Application Serial No. __ (attorney docket ACOM-0091), filed on January 8, 1999, entitled "Calibration for Wireless Location System."

FIELD OF THE INVENTION

The present invention relates generally to methods and apparatus for locating wireless transmitters, such as those used in analog or digital cellular systems, personnel communications systems (PCS), enhanced specialized mobile radios (ESMRs), and other types of wireless communications systems. This field is now generally known as wireless location, and has application for Wireless E9-1-1, fleet management, RF optimization, and other valuable applications.

BACKGROUND OF THE INVENTION

Early work relating to the present invention has been described in U.S. Patent Number 5,327,144, July 5, 1994, "Cellular Telephone Location System," which discloses a system for locating cellular telephones using novel time difference of arrival (TDOA) techniques. Further enhancements of the system disclosed in the '144 patent are disclosed in U.S. Patent Number 5,608,410, March 4, 1997, "System for Locating a Source of Bursty Transmissions." Both patents are owned by the assignee of the current invention, and both are incorporated herein by reference. The present inventors have continued to develop significant enhancements to the original inventive concepts and have developed techniques to further improve the accuracy of Wireless Location Systems while significantly reducing the cost of these systems.

Over the past few years, the cellular industry has increased the number of air interface protocols available for use by wireless telephones, increased the number of frequency bands in which wireless or mobile telephones may operate, and expanded the number of terms that refer or relate to mobile telephones to include "personal communications services", "wireless", and others. The air interface protocols now include AMPS, N-

AMPS, TDMA, CDMA, GSM,TACS, ESMR, and others. The changes in terminology and increases in the number of air interfaces do not change the basic principles and inventions discovered and enhanced by the inventors. However, in keeping with the current terminology of the industry, the inventors now call the system described herein a *Wireless Location System*.

The inventors have conducted extensive experiments with the Wireless Location System technology disclosed herein to demonstrate both the viability and value of the technology. For example, several experiments were conducted during several months of 1995 and 1996 in the cities of Philadelphia and Baltimore to verify the system's ability to mitigate multipath in large urban environments. Then, in 1996 the inventors constructed a system in Houston that was used to test the technology's effectiveness in that area and its ability to interface directly with E9-1-1 systems. Then, in 1997, the system was tested in a 350 square mile area in New Jersey and was used to locate real 9-1-1 calls from real people in trouble. Since that time, the system test has been expanded to include 125 cell sites covering an area of over 2,000 square miles. During all of these tests, techniques discussed and disclosed herein were tested for effectiveness and further developed, and the system has been demonstrated to overcome the limitations of other approaches that have been proposed for locating wireless telephones. Indeed, as of December, 1998, no other wireless location system has been installed anywhere else in the world that is capable of locating live 9-1-1 callers. The innovation of the Wireless Location System disclosed herein has been acknowledged in the wireless industry by the extensive amount of media coverage given to the system's capabilities, as well as by awards. For example, the prestigious Wireless Appy Award was granted to the system by the Cellular Telephone Industry Association in October, 1997, and the Christopher Columbus Fellowship Foundation and Discover Magazine found the Wireless Location System to be one of the top 4 innovations of 1998 out of 4,000 nominations submitted.

The value and importance of the Wireless Location System has been acknowledged by the wireless communications industry. In June 1996, the Federal Communications Commission issued requirements for the wireless communications industry to deploy location systems for use in locating wireless 9-1-1 callers, with a deadline of October

2001. The location of wireless E9-1-1 callers will save response time, save lives, and save enormous costs because of reduced use of emergency responses resources. In addition, numerous surveys and studies have concluded that various wireless applications, such as location sensitive billing, fleet management, and others, will have great commercial values in the coming years.

Background on Wireless Communications Systems

There are many different types of air interface protocols used for wireless communications systems. These protocols are used in different frequency bands, both in the U.S. and internationally. The frequency band does not impact the Wireless Location System's effectiveness at locating wireless telephones.

All air interface protocols use two types of "channels". The first type includes control channels that are used for conveying information about the wireless telephone or transmitter, for initiating or terminating calls, or for transferring bursty data. For example, some types of short messaging services transfer data over the control channel. In different air interfaces, control channels are known by different terminology, but the use of the control channels in each air interface is similar. Control channels generally have identifying information about the wireless telephone or transmitter contained in the transmission.

The second type includes voice channels that are typically used for conveying voice communications over the air interface. These channels are only used after a call has been set up using the control channels. Voice channels will typically use dedicated resources within the wireless communications system whereas control channels will use shared resources. This distinction will generally make the use of control channels for wireless location purposes more cost effective than the use of voice channels, although there are some applications for which regular location on the voice channel is desired. Voice channels generally do not have identifying information about the wireless telephone or transmitter in the transmission. Some of the differences in the air interface protocols are discussed below:

AMPS – This is the original air interface protocol used for cellular communications in the U.S. In the AMPS system, separate dedicated channels are assigned for use by control channels (RCC). According to the TIA/EIA Standard IS-553A, every control channel block must begin at cellular channel 333 or 334, but the block may be of variable length. In the U.S., by convention, the AMPS control channel block is 21 channels wide, but the use of a 26-channel block is also known. A reverse voice channel (RVC) may occupy any channel that is not assigned to a control channel. The control channel modulation is FSK (frequency shift keying), while the voice channels are modulated using FM (frequency modulation).

N-AMPS – This air interface is an expansion of the AMPS air interface protocol, and is defined in EIA/TIA standard IS-88. The control channels are substantially the same as for AMPS, however, the voice channels are different. The voice channels occupy less than 10 KHz of bandwidth, versus the 30 KHz used for AMPS, and the modulation is FM.

TDMA – This interface is also known D-AMPS, and is defined in EIA/TIA standard IS-136. This air interface is characterized by the use of both frequency and time separation. Control channels are known as Digital Control Channels (DCCH) and are transmitted in bursts in timeslots assigned for use by DCCH. Unlike AMPS, DCCH may be assigned anywhere in the frequency band, although there are generally some frequency assignments that are more attractive than others based upon the use of probability blocks. Voice channels are known as Digital Traffic Channels (DTC). DCCH and DTC may occupy the same frequency assignments, but not the same timeslot assignment in a given frequency assignment. DCCH and DTC use the same modulation scheme, known as $\pi/4$ DQPSK (differential quadrature phase shift keying). In the cellular band, a carrier may use both the AMPS and TDMA protocols, as long as the frequency assignments for each protocol are kept separated.

CDMA – This air interface is defined by EIA/TIA standard IS-95A. This air interface is characterized by the use of both frequency and code separation. However, because adjacent cell sites may use the same frequency sets, CDMA is also characterized by very careful power control. This careful power control leads to a situation known to those skilled in the art as the near-far problem, which makes wireless location difficult for most approaches to function properly. Control channels are known as Access Channels, and voice channels are known as Traffic Channels. Access and Traffic Channels may share the same frequency band, but are separated by code. Access and Traffic Channels use the same modulation scheme, known as OQPSK.

GSM - This air interface is defined by the international standard Global System for Mobile Communications. Like TDMA, GSM is characterized by the use of both frequency and time separation. The channel bandwidth is 200 KHz, which is wider than the 30 KHz used for TDMA. Control channels are known as Standalone Dedicated Control Channels (SDCCH), and are transmitted in bursts in timeslots assigned for use by SDCCH. SDCCH may be assigned anywhere in the frequency band. Voice channels are known as Traffic Channels (TCH). SDCCH and TCH may occupy the same frequency assignments, but not the same timeslot assignment in a given frequency assignment. SDCCH and TCH use the same modulation scheme, known as GMSK.

Within this specification the reference to any one of the air interfaces shall automatically refer to all of the air interfaces, unless specified otherwise. Additionally, a reference to control channels or voice channels shall refer to all types of control or voice channels, whatever the preferred terminology for a particular air interface. Finally, there are many more types of air interfaces used throughout the world, and there is no intent to exclude any air interface from the inventive concepts described within this specification. Indeed, those skilled in the art will recognize other interfaces used elsewhere are derivatives of or similar in class to those described above.

The preferred embodiments of the inventions disclosed herein have many advantages over other techniques for locating wireless telephones. For example, some of these other techniques involve adding GPS functionality to telephones, which requires that significant changes be made to the telephones. The preferred embodiments disclosed herein do not require any changes to wireless telephones, and so they can be used in connection with the current installed base of over 65 million wireless telephones in the U.S. and 250 million wireless telephones worldwide.

SUMMARY OF THE INVENTION

In view of the difficulties presented by the limited bandwidth of the FM voice and supervisory audio tone (SAT) reverse voice channel signals, a primary object of the present invention is to provide an improved method by which reverse voice channel (RVC) signals may be utilized to locate a mobile transmitter, particularly in an emergency situation. Another object of the invention is to provide a location method that allows the location system to avoid making location estimates using RVC signals in situations in which it is likely that the measurement will not meet prescribed accuracy and reliability requirements. This saves system resources and improves the location system's overall efficiency.

The improved method is based upon two techniques. The first technique includes monitoring the instantaneous bandwidth of the transmission in the voice channel to determine when the bandwidth is at a level that enables the wireless location system to make a high quality estimate of location. The second technique includes forcing the mobile unit to temporarily increase its bandwidth through a manual or automatic action.

According to the present invention, a method for use in locating a mobile transmitter in an emergency situation comprises the steps of (a) upon determining that the emergency situation exists, monitoring the bandwidth of a reverse voice channel (RVC) signal transmitted by the mobile transmitter; (b) determining whether the bandwidth exceeds a predetermined threshold; (c) if the bandwidth exceeds the predetermined threshold, measuring the location of the mobile transmitter; and (d) if the bandwidth does not exceed the predetermined threshold, performing a predetermined action to increase the bandwidth and subsequently measuring the location of the mobile transmitter. In a presently preferred embodiment of the invention, one predetermined action comprises requesting the user to take an action to cause the mobile transmitter to transmit an RVC signal comprising a prescribed number of digits. For example, the predetermined action may comprise asking the user to dial a 9-digit number. In one exemplary implementation, the predetermined action comprises asking an emergency dispatcher to instruct the user to dial the 9-digit number.

Moreover, in a presently preferred embodiment, the predetermined threshold is within the range of approximately +/-8 to +/-12 KHz, and preferably is approximately +/-10 KHz. In another preferred embodiment of the invention, the wireless location system instructs the wireless switch (MSO) to send an audit command to the mobile telephone. The mobile transmitter will respond to the audit command with an audit response message.

Other details of the invention are described below.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1 and 1A schematically depict a Wireless Location System in accordance with the present invention.

Figure 2 schematically depicts a Signal Collection System (SCS) 10 in accordance with the present invention.

Figure 2A schematically depicts a receiver module 10-2 employed by the Signal Collection System.

Figures 2B and 2C schematically depict alternative ways of coupling the receiver module(s) 10-2 to the antennas 10-1.

Figure 2C-1 is a flowchart of a process employed by the Wireless Location System when using narrowband receiver modules.

Figure 2D schematically depicts a DSP module 10-3 employed in the Signal Collection System in accordance with the present invention.

Figure 2E is a flowchart of the operation of the DSP module(s) 10-3, and Figure 2E-1 is a flowchart of the process employed by the DSP modules for detecting active channels.

Figure 2F schematically depicts a Control and Communications Module 10-5 in accordance with the present invention.

Figures 2G-2J depict aspects of the presently preferred SCS calibration methods. Figure 2G is a schematic illustration of baselines and error values used to explain an external calibration method in accordance with the present invention. Figure 2H is a flowchart of an internal calibration method. Figure 2I is an exemplary transfer function of an AMPS control channel and Figure 2J depicts an exemplary comb signal.

Figures 2K and 2L are flowcharts of two methods for monitoring performance of a Wireless Location System in accordance with the present invention.

Figure 3 schematically depicts a TDOA Location Processor 12 in accordance with the present invention.

Figure 3A depicts the structure of an exemplary network map maintained by the TLP controllers in accordance with the present invention.

Figures 4 and 4A schematically depict different aspects of an Applications Processor 14 in accordance with the present invention.

Figure 5 is a flowchart of a central station-based location processing method in accordance with the present invention.

Figure 6 is a flowchart of a station-based location processing method in accordance with the present invention.

Figure 7 is a flowchart of a method for determining, for each transmission for which a location is desired, whether to employ central or station-based processing.

Figure 8 is a flowchart of a dynamic process used to select cooperating antennas and SCS's 10 used in location processing.

Figure 9 is diagram that is referred to below in explaining a method for selecting a candidate list of SCS's and antennas using a predetermined set of criteria.

Figures 10A and 10B are flowcharts of alternative methods for increasing the bandwidth of a transmitted signal to improve location accuracy.

Figures 11A-11C are signal flow diagrams and Figure 11D is a flowchart, and they are used to explain an inventive method for combining multiple statistically independent location estimates to provide an estimate with improved accuracy.

Figures 12A and 12B are a block diagram and a graph, respectively, for explaining a bandwidth synthesis method.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The Wireless Location System (Wireless Location System) operates as a passive overlay to a wireless communications system, such as a cellular, PCS, or ESMR system, although the concepts are not limited to just those types of communications systems. Wireless communications systems are generally not suitable for locating wireless devices because the designs of the wireless transmitters and cell sites do not include the necessary functionality to achieve accurate location. Accurate location in this application is defined as accuracy of 100 to 400 feet RMS (root mean square). This is distinguished from the location accuracy that can be achieved by existing cell sites, which is generally limited to the radius of the cell site. In general, cell sites are not designed or programmed to cooperate between and among themselves to determine wireless transmitter location. Additionally, wireless transmitters such as cellular and PCS telephones are designed to be low cost and therefore generally do not have locating capability built-in. The Wireless Location System is designed to be a low cost addition to a wireless communications system that involves minimal changes to cell sites and no changes at all to standard wireless transmitters. The Wireless Location System is passive because the it does not contain transmitters, and therefore cannot cause interference of any kind to the wireless communications system. The Wireless Location System uses only its own specialized receivers at cell sites or other receiving locations.

Overview of Wireless Location System (Wireless Location System)

As shown in Figure 1, the Wireless Location System has four major kinds of subsystems: the Signal Collection Systems (SCS's) 10, the TDOA Location Processors (TLP's) 12, the Application Processors (AP's) 14, and the Network Operations Console (NOC) 16. Each SCS is responsible for receiving the RF signals transmitted by the wireless transmitters on both control channels and voice channels. In general, each SCS is preferably installed at a wireless carrier's cell site, and therefore operates in parallel to a base station. Each TLP 12 is responsible for managing a network of SCS's 10 and for providing a centralized pool of digital signal processing (DSP) resources that can be used in the location calculations. The SCS's 10 and the TLP's 12 operate together to determine the location of the wireless transmitters, as will be discussed more fully below. Digital signal processing is the preferable manner in which to process radio signals because DSP's are relatively low cost, provide consistent performance, and are easily re-programmable to handle many different tasks. Both the SCS's 10 and TLP's 12 contain a significant amount of DSP resources, and the software in these systems can operate dynamically to determine where to perform a particular processing function based upon tradeoffs in processing time, communications time, queuing time, and cost. Each TLP 12 exists centrally primarily to reduce the overall cost of implementing the Wireless Location System, although the techniques discussed herein are not limited to the preferred architecture shown. That is, DSP resources can be relocated within the Wireless Location System without changing the basic concepts and functionality disclosed.

The AP's 14 are responsible for managing all of the resources in the Wireless Location System, including all of the SCS's 10 and TLP's 12. Each AP 14 also contains a specialized database that contains "triggers" for the Wireless Location System. In order to conserve resources, the Wireless Location System can be programmed to locate only certain pre-determined types of transmissions. When a transmission of a pre-determined type occurs, then the Wireless Location System is triggered to begin location processing. Otherwise, the Wireless Location System may be programmed to ignore the transmission.

Each AP 14 also contains applications interfaces that permit a variety of applications to securely access the Wireless Location System. These applications may, for example, access location records in real time or non-real time, create or delete certain type of triggers, or cause the Wireless Location System to take other actions. Each AP 14 is also capable of certain post-processing functions that allow the AP 14 to combine a number of location records to generate extended reports or analyses useful for applications such as traffic monitoring or RF optimization.

The NOC 16 is a network management system that provides operators of the Wireless Location System easy access to the programming parameters of the Wireless Location System. For example, in some cities, the Wireless Location System may contain many hundreds or even thousands of SCS's 10. The NOC is the most effective way to manage a large Wireless Location System, using graphical user interface capabilities. The NOC will also receive real time alerts if certain functions within the Wireless Location System are not operating properly. These real time alerts can be used by the operator to take corrective action quickly and prevent a degradation of location service. Experience with trials of the Wireless Location System show that the ability of the system to maintain good location accuracy over time is directly related to the operator's ability to keep the system operating within its predetermined parameters.

Readers of U.S. Patents 5,327,144 and 5,608,410 and this specification will note similarities between the respective systems. Indeed, the system disclosed herein is significantly based upon and also significantly enhanced from the system described in those previous patents. For example, the SCS 10 has been expanded and enhanced from the Antenna Site System described in 5,608,410. The SCS 10 now has the capability to support many more antennas at a single cell site, and further can support the use of extended antennas as described below. This enables the SCS 10 to operate with the sectored cell sites now commonly used. The SCS 10 can also transfer data from multiple antennas at a cell site to the TLP 12 instead of always combining data from multiple antennas before transfer. Additionally, the SCS 10 can support multiple air interface protocols thereby allowing the SCS 10 to function even as a wireless carrier continually changes the configuration of its system.

The TLP 12 is similar to the Central Site System disclosed in 5,608,410, but has also been expanded and enhanced. For example, the TLP 12 has been made scaleable so that the amount of DSP resources required by each TLP 12 can be appropriately scaled to match the number of locations per second required by customers of the Wireless Location System. In order to support scaling for different Wireless Location System capacities, a networking scheme has been added to the TLP 12 so that multiple TLP's 12 can cooperate to share RF data across wireless communication system network boundaries. Additionally, the TLP 12 has been given control means to determine the SCS's 10, and more importantly the antennas at each of the SCS's 10, from which the TLP 12 is to receive data in order to process a specific location. Previously, the Antenna Site Systems automatically forwarded data to the Central Site System, whether requested or not by the Central Site System. Furthermore, the SCS 10 and TLP 12 combined have been designed with additional means for removing multipath from the received transmissions.

The Database Subsystem of the Central Site System has been expanded and developed into the AP 14. The AP 14 can support a greater variety of applications than previously disclosed in 5,608,410, including the ability to post-process large volumes of location records from multiple wireless transmitters. This post-processed data can yield, for example, very effective maps for use by wireless carriers to improve and optimize the RF design of the communications systems. This can be achieved, for example, by plotting the locations of all of the callers in an area and the received signal strengths at a number of cell sites. The carrier can then determine whether each cell site is, in fact, serving the exact coverage area desired by the carrier. The AP 14 can also now store location records anonymously, that is, with the MIN and/or other identity information removed from the location record, so that the location record can be used for RF optimization or traffic monitoring without causing concerns about an individual user's privacy.

As shown in Figure 1A, a presently preferred implementation of the Wireless Location System includes a plurality of SCS regions each of which comprises multiple SCS's 10. For example, "SCS Region 1" includes SCS's 10A and 10B (and preferably others, not shown) that are located at respective cell sites and share antennas with the base stations at those cell sites. Drop and insert units 11A and 11B are used to interface fractional T1/E1 lines to full T1/E1 lines, which in turn are coupled to a digital access and control system (DACS) 13A. The DACS 13A and another DACS 13B are used in the manner described more fully below for communications between the SCS's 10A, 10B, etc., and multiple TLP's 12A, 12B, etc. As shown, the TLP's are typically collocated and interconnected via an Ethernet network (backbone) and a second, redundant Ethernet network. Also coupled to the Ethernet networks are multiple AP's 14A and 14B, multiple NOC's 16A and 16B, and a terminal server 15. Routers 19A and 19B are used to couple one Wireless Location System to one or more other Wireless Location System(s).

Signal Collection System 10

Generally, cell sites will have one of the following antenna configurations: (i) an omnidirectional site with 1 or 2 receive antennas or (ii) a sectored site with 1, 2, or 3 sectors, and with 1 or 2 receive antennas used in each sector. As the number of cell sites has increased in the U.S. and internationally, sectored cell sites have become the predominant configuration. However, there are also a growing number of micro-cells and pico-cells, which can be omnidirectional. Therefore, the SCS 10 has been designed to be configurable for any of these typical cell sites and has been provided with mechanisms to employ any number of antennas at a cell site.

The basic architectural elements of the SCS 10 remain the same as for the Antenna Site System described in 5,608,410, but several enhancements have been made to increase the flexibility of the SCS 10 and to reduce the commercial deployment cost of the system. The most presently preferred embodiment of the SCS 10 is described herein. The SCS 10, an overview of which is shown in Figure 2, includes digital receiver modules 10-2A through 10-2C; DSP modules 10-3A through 10-3C; a serial bus 10-4, a control and communications module 10-5; a GPS module 10-6; and a clock distribution module 10-7. The SCS 10 has the following external connections: power, fractional T1/E1 communications, RF connections to antennas, and a GPS antenna connection for the timing generation (or clock distribution) module 10-7. The architecture and packaging of the SCS 10 permit it to be physically collocated with cell sites (which is the most common installation place), located at other types of towers (such as FM, AM, two-way emergency communications, television, etc.), or located at other building structures (such as rooftops, silos, etc.).

Timing Generation

The Wireless Location System depends upon the accurate determination of time at all SCS's 10 contained within a network. Several different timing generation systems have been described in previous disclosures, however the most presently preferred embodiment is based upon an enhanced GPS receiver 10-6. The enhanced GPS receiver differs from most traditional GPS receivers in that the receiver contains algorithms that remove some of the timing instability of the GPS signals, and guarantees that any two SCS's 10 contained within a network can receive timing pulses that are within approximately ten nanoseconds of each other. These enhanced GPS receivers are now commercially available, and further reduce some of the time reference related errors that were observed in previous implementations of wireless location systems. While this enhanced GPS receiver can produce a very accurate time reference, the output of the receiver may still have an unacceptable phase noise. Therefore, the output of the receiver is input to a low phase noise, crystal oscillator-driven phase locked loop circuit that can now produce 10 MHz and one pulse per second (PPS) reference signals with less than 0.01 degrees RMS of phase noise, and with the pulse output at any SCS 10 in a Wireless Location System network within ten nanoseconds of any other pulse at another SCS 10. This combination of enhanced GPS receiver, crystal oscillator, and phase locked loop is now the most preferred method to produce stable time and frequency reference signals with low phase noise.

The SCS 10 has been designed to support multiple frequency bands and multiple carriers with equipment located at the same cell site. This can take place by using multiple receivers internal to a single SCS chassis, or by using multiple chassis each with separate receivers. In the event that multiple SCS chassis are placed at the same cell site, the SCS's 10 can share a single timing generation/clock distribution circuit 10-7 and thereby reduce overall system cost. The 10 MHz and one PPS output signals from the timing generation circuit are amplified and buffered internal to the SCS 10, and then made available via external connectors. Therefore a second SCS can receive its timing from a first SCS using the buffered output and the external connectors. These signals can also be made available to base station equipment collocated at the cell site. This might be useful to the base station, for example, in improving the frequency re-use pattern of a wireless communications system.

Receiver Module 10-2 (Wideband Embodiment)

When a wireless transmitter makes a transmission, the Wireless Location System must receive the transmission at multiple SCS's 10 located at multiple geographically dispersed cell sites. Therefore, each SCS 10 has the ability to receive a transmission on any RF channel on which the transmission may originate. Additionally, since the SCS 10 is capable of supporting multiple air interface protocols, the SCS 10 also supports multiple types of RF channels. This is in contrast to most current base station receivers, which typically receive only one type of channel and are usually capable of receiving only on select RF channels at each cell site. For example, a typical TDMA base station receiver will only support 30 KHz wide channels, and each receiver is programmed to receive signals on only a single channel whose frequency does not change often (i.e. there is a relatively fixed frequency plan). Therefore, very few TDMA base station receivers would receive a transmission on any given frequency. As another example, even though some GSM base station receivers are capable of frequency hopping, the receivers at multiple base stations are generally not capable of simultaneously tuning to a single frequency for the purpose of performing location processing. In fact, the receivers at GSM base stations are programmed to frequency hop to avoid using an RF channel that is being used by another transmitter so as to minimize interference.

The SCS receiver module 10-2 is preferably a dual wideband digital receiver that can receive the entire frequency band and all of the RF channels of an air interface. For cellular systems in the U.S., this receiver module is either 15 MHz wide or 25 MHz wide so that all of the channels of a single carrier or all of the channels of both carriers can be received. This receiver module has many of the characteristics of the receiver previously described in Patent Number 5,608,410, and Figure 2A is a block diagram of the currently preferred embodiment. Each receiver module contains an RF tuner section 10-2-1, a data interface and control section 10-2-2 and an analog to digital conversion section 10-2-3.

The RF tuner section 10-2-1 includes two full independent digital receivers (including Tuner #1 and Tuner #2) that convert the analog RF input from an external connector into a digitized data stream. Unlike most base station receivers, the SCS receiver module does not perform diversity combining or switching. Rather, the digitized signal from each independent receiver is made available to the location processing. The present inventors have determined that there is an advantage to the location processing, and especially the multipath mitigation processing, to independently process the signals from each antenna rather than perform combining on the receiver module.

The receiver module 10-2 performs, or is coupled to elements that perform, the following functions: automatic gain control (to support both nearby strong signals and far away weak signals), bandpass filtering to remove potentially interfering signals from outside of the RF band of interest, synthesis of frequencies needed for mixing with the RF signals to create an IF signal that can be sampled, mixing, and analog to digital conversion (ADC) for sampling the RF signals and outputting a digitized data stream having an appropriate bandwidth and bit resolution. The frequency synthesizer locks the synthesized frequencies to the 10 MHz reference signal from the clock distribution/timing generation module 10-7 (Figure 2). All of the circuits used in the receiver module maintain the low phase noise characteristics of the timing reference signal. The receiver module preferably has a spurious free dynamic range of at least 80 dB.

The receiver module 10-2 also contains circuits to generate test frequencies and calibration signals, as well as test ports where measurements can be made by technicians during installation or troubleshooting. Various calibration processes are described in further detail below. The internally generated test frequencies and test ports provide an easy method for engineers and technicians to rapidly test the receiver module and diagnose any suspected problems. This is also especially useful during the manufacturing process.

One of the advantages of the Wireless Location System described herein is that no new antennas are required at cell sites. The Wireless Location System can use the existing antennas already installed at most cell sites, including both omni-directional and sectored antennas. This feature can result in significant savings in the installation and maintenance costs of the Wireless Location System versus other approaches that have been described in the prior art. The SCS's digital receivers 10-2 can be connected to the existing antennas in two ways, as shown in Figures 2B and 2C, respectively. In Figure 2B, the SCS receivers 10-2 are connected to the existing cell site multi-coupler or RF splitter. In this manner, the SCS 10 uses the cell site's existing low noise pre-amplifier, band pass filter, and multi-coupler or RF splitter. This type of connection usually limits the SCS 10 to supporting the frequency band of a single carrier. For example, an A-side cellular carrier will typically use the band pass filter to block signals from customers of the B-side carrier, and vice versa.

In Figure 2C, the existing RF path at the cell site has been interrupted, and a new pre-amplifier, band pass filter, and RF splitter has been added as part of the Wireless Location System. The new band pass filter will pass multiple contiguous frequency bands, such as both the A-side and B-side cellular carriers, thereby allowing the Wireless Location System to locate wireless transmitters using both cellular systems but using the antennas from a single cell site. In this configuration, the Wireless Location System uses matched RF components at each cell site, so that the phase versus frequency responses are identical. This is in contrast to existing RF components, which may be from different manufacturers or using different model numbers at various cell sites. Matching the response characteristics of RF components reduces a possible source of error for the location processing, although the Wireless Location System has the capability to compensate for these sources of error. Finally, the new pre-amplifier installed with the Wireless Location System will have a very low noise figure to improve the sensitivity of the SCS 10 at a cell site. The overall noise figure of the SCS digital receivers 10-2 is dominated by the noise figure of the low noise amplifiers. Because the Wireless Location System can use weak signals in location processing, whereas the base station typically cannot process weak signals, the Wireless Location System can significantly benefit from a high quality, very low noise amplifier.

In order to improve the ability of the Wireless Location System to accurately determine TDOA for a wireless transmission, the phase versus frequency response of the cell site's RF components are determined at the time of installation and updated at other certain times and then stored in a table in the Wireless Location System. This can be important because, for example, the band pass filters and/or multi-couplers made by some manufacturers have a steep and non-linear phase versus frequency response near the edge of the pass band. If the edge of the pass band is very near to or coincident with the reverse control or voice channels, then the Wireless Location System would make incorrect measurements of the transmitted signal's phase characteristics if the Wireless Location System did not correct the measurements using the stored characteristics. This becomes even more important if a carrier has installed multi-couplers and/or band pass filters from more than one manufacturer, because the characteristics at each site may be different. In addition to measuring the phase versus frequency response, other environmental factors may cause changes to the RF path prior to the ADC. These factors require occasional and sometimes periodic calibration in the SCS 10.

Alternative Narrowband Embodiment of Receiver Module 10-2

In addition or as an alternative to the wideband receiver module, the SCS 10 also supports a narrowband embodiment of the receiver module 10-2. In contrast to the wideband receiver module that can simultaneously receive all of the RF channels in use by a wireless communications system, the narrowband receiver can only receive one or a few RF channels at a time. For example, the SCS 10 supports a 60 KHz narrowband receiver for use in AMPS/TDMA systems, covering two contiguous 30 KHz channels. This receiver is still a digital receiver as described for the wideband module, however the frequency synthesizing and mixing circuits are used to dynamically tune the receiver module to various RF channels on command. This dynamic tuning can typically occur in one millisecond or less, and the receiver can dwell on a specific RF channel for as long as required to receive and digitize RF data for location processing.

The purpose of the narrowband receiver is to reduce the implementation cost of a Wireless Location System from the cost that is incurred with wideband receivers. Of course, there is some loss of performance, but the availability of these multiple receivers permits wireless carriers to have more cost/performance options. Additional inventive functions and enhancements have been added to the Wireless Location System to support this new type of narrowband receiver. When the wideband receiver is being used, all RF channels are received continuously at all SCS's 10, and subsequent to the transmission, the Wireless Location System can use the DSP's 10-3 (Figure 2) to dynamically select any RF channel from the digital memory. With the narrowband receiver, the Wireless Location System must ensure *a priori* that the narrowband receivers at multiple cell sites are simultaneously tuned to the same RF channel so that all receivers can simultaneously receive, digitize and store the same wireless transmission. For this reason, the narrowband receiver is generally used only for locating voice channel transmissions, which can be known *a priori* to be making a transmission. Since control channel transmissions can occur asynchronously at any time, the narrowband receiver may not be tuned to the correct channel to receive the transmission.

When the narrowband receivers are used for locating AMPS voice channel transmissions, the Wireless Location System has the ability to temporarily change the modulation characteristics of the AMPS wireless transmitter to aid location processing. This may be necessary because AMPS voice channels are only FM modulated with the addition of a low level supervisory tone known as SAT. As is known in the art, the Cramer-Rao lower bound of AMPS FM modulation is significantly worse than the Manchester encoded FSK modulation used for AMPS reverse channels and "blank and burst" transmissions on the voice channel. Further, AMPS wireless transmitters may be transmitting with significantly reduced energy if there is no modulating input signal (i.e., no one is speaking). To improve the location estimate by improving the modulation characteristics without depending on the existence or amplitude of an input modulating signal, the Wireless Location System can cause an AMPS wireless transmitter to transmit a "blank and burst" message at a point in time when the narrowband receivers at multiple SCS's 10 are tuned to the RF channel on which the message will be sent. This is further described later.

The Wireless Location System performs the following steps when using the narrowband receiver module (see the flowchart of Figure 2C-1):

a first wireless transmitter is *a priori* engaged in transmitting on a particular RF channel;

the Wireless Location System triggers to make a location estimate of the first wireless transmitter (the trigger may occur either internally or externally via a command/response interface);

the Wireless Location System determines the cell site, sector, RF channel, timeslot, long code mask, and encryption key (all information elements may not be necessary for all air interface protocols) currently in use by the first wireless transmitter;

the Wireless Location System tunes an appropriate first narrowband receiver at an appropriate first SCS 10 to the RF channel and timeslot at the designated cell site and sector, where appropriate typically means both available and collocated or in closest proximity;

the first SCS 10 receives a time segment of RF data, typically ranging from a few microseconds to tens of milliseconds, from the first narrowband receiver and evaluates the transmission's power, SNR, and modulation characteristics;

if the transmission's power or SNR is below a predetermined threshold, the Wireless Location System waits a predetermined length of time and then returns to the above third step (where the Wireless Location System determines the cell site, sector, etc.);

if the transmission is an AMPS voice channel transmission and the modulation is below a threshold, then the Wireless Location System commands the wireless communications system to send a command to the first wireless transmitter to cause a "blank and burst" on the first wireless transmitter;

the Wireless Location System requests the wireless communications system to prevent hand-off of the wireless transmitter to another RF channel for a predetermined length of time;

the Wireless Location System receives a response from the wireless communications system indicating the time period during which the first wireless transmitter will be prevented from handing-off, and if commanded, the time period during which the wireless communications system will send a command to the first wireless transmitter to cause a "blank and burst";

the Wireless Location System determines the list of antennas that will be used in location processing (the antenna selection process is described below);

the Wireless Location System determines the earliest Wireless Location System timestamp at which the narrowband receivers connected to the selected antennas are available to begin simultaneously collecting RF data from the RF channel currently in use by the first wireless transmitter;

based upon the earliest Wireless Location System timestamp and the time periods in the response from the wireless communications system, the Wireless Location System commands the narrowband receivers connected to the antennas that will be used in location processing to tune to the cell site, sector, and RF channel currently in use by the first wireless transmitter and to receive RF data for a predetermined dwell time (based upon the bandwidth of the signal, SNR, and integration requirements);

the RF data received by the narrowband receivers are written into the dual port memory;

location processing on the received RF data commences, as described in Patent Nos. 5,327,144 and 5,608,410 and in sections below;

the Wireless Location System again determines the cell site, sector, RF channel, timeslot, long code mask, and encryption key currently in use by the first wireless transmitter;

if the cell site, sector, RF channel, timeslot, long code mask, and encryption key currently in use by the first wireless transmitter has changed between queries (i.e. before and after gathering the RF data) the Wireless Location System ceases location processing, causes an alert message that location processing failed because the wireless transmitter changed transmission status during the period of time in which RF data was being received, and re-triggers this entire process;

location processing on the received RF data completes in accordance with the steps described below.

The determination of the information elements including cell site, sector, RF channel, timeslot, long code mask, and encryption key (all information elements may not be necessary for all air interface protocols) is typically obtained by the Wireless Location System through a command / response interface between the Wireless Location System and the wireless communications system.

The use of the narrowband receiver in the manner described above is known as random tuning because the receivers can be directed to any RF channel on command from the system. One advantage to random tuning is that locations are processed only for those wireless transmitters for which the Wireless Location System is triggered. One disadvantage to random tuning is that various synchronization factors, including the interface between the wireless communications system and the Wireless Location System and the latency times in scheduling the necessary receivers throughout the system, can limit the total location processing throughput. For example, in a TDMA system, random tuning used throughout the Wireless Location System will typically limit location processing throughput to about 2.5 locations per second per cell site sector.

Therefore, the narrowband receiver also supports another mode, known as automatic sequential tuning, which can perform location processing at a higher throughput. For example, in a TDMA system, using similar assumptions about dwell time and setup time as for the narrowband receiver operation described above, sequential tuning can achieve a location processing throughput of about 41 locations per second per cell site sector, meaning that all 395 TDMA RF channels can be processed in about 9 seconds. This increased rate can be achieved by taking advantage of, for example, the two contiguous RF channels that can be received simultaneously, location processing all three TDMA timeslots in an RF channel, and eliminating the need for synchronization with the wireless communications system. When the Wireless Location System is using the narrowband receivers for sequential tuning, the Wireless Location System has no knowledge of the identity of the wireless transmitter because the Wireless Location System does not wait for a trigger, nor does the Wireless Location System query the wireless communications system for the identity information prior to receiving the transmission. In this method, the Wireless Location System sequences through every cell site, RF channel and time slot, performs location processing, and reports a location record identifying a time stamp, cell site, RF channel, time slot, and location. Subsequent to the location record report, the Wireless Location System and the wireless communications system match the location records to the wireless communications system's data indicating which wireless transmitters were in use at the time, and which cell sites, RF channels, and time slots were used by each wireless transmitter. Then, the Wireless Location System can retain the location records for wireless transmitters of interest, and discard those location records for the remaining wireless transmitters.

Digital Signal Processor Module 10-3

The SCS digital receiver modules 10-2 output a digitized RF data stream having a specified bandwidth and bit resolution. For example, a 15 MHz embodiment of the wideband receiver may output a data stream containing 60 million samples per second, at a resolution of 14 bits per sample. This RF data stream will contain all of the RF channels that are used by the wireless communications system. The DSP modules 10-3 receive the digitized data stream, and can extract any individual RF channel through digital mixing and filtering. The DSP's can also reduce the bit resolution upon command from the Wireless Location System, as needed to reduce the bandwidth requirements between the SCS 10 and TLP 12. The Wireless Location System can dynamically select the bit resolution at which to forward digitized baseband RF data, based upon the processing requirements for each location. DSP's are used for these functions to reduce the systemic errors that can occur from mixing and filtering with analog components. The use of DSP's allows perfect matching in the processing between any two SCS's 10.

A block diagram of the DSP module 10-3 is shown is Figure 2D, and the operation of the DSP module is depicted by the flowchart of Figure 2E. As shown in Figure 2D, the DSP module 10-3 comprises the following elements: a pair of DSP elements 10-3-1A and 10-3-1B, referred to collectively as a "first" DSP; serial to parallel converters 10-3-2; dual port memory elements 10-3-3; a second DSP 10-3-4; a parallel to serial converter; a FIFO buffer; a DSP 10-3-5 (including RAM) for detection, another DSP 10-3-6 for demodulation, and another DSP 10-3-7 for normalization and control; and an address generator 10-3-8. In a presently preferred embodiment, the DSP module 10-3 receives the wideband digitized data stream (Figure 2E, step S1), and uses the first DSP (10-3-1A and 10-3-1B) to extract blocks of channels (step S2). For example, a first DSP programmed to operate as a digital drop receiver can extract four blocks of channels, where each block includes at least 1.25 MHz of bandwidth. This bandwidth can include 42 channels of AMPS or TDMA, 6 channels of GSM, or 1 channel of CDMA. The DSP does not require the blocks to be contiguous, as the DSP can independently digitally tune to any set of RF channels within the bandwidth of the wideband digitized data stream. The DSP can also perform wideband or narrow band energy detection on all or any of the channels in the block, and report the power levels by channel to the TLP 12 (step S3). For example, every 10 ms, the DSP can perform wideband energy detection and create an RF spectral map for all channels for all receivers (see step S9). Because this spectral map can be sent from the SCS 10 to the TLP 12 every 10 ms via the communications link connecting the SCS 10 and the TLP 12, a significant data overhead could exist. Therefore, the DSP reduces the data overhead by companding the data into a finite number of levels. Normally, for example, 84 dB of dynamic range could require 14 bits. In the companding process implemented by the DSP, the data is reduced, for example, to only 4 bits by selecting 16 important RF spectral levels to send to the TLP 12. The choice of the number of levels, and therefore the number of bits, as well as the representation of the levels, can be automatically adjusted by the Wireless Location System. These adjustments are performed to maximize the information value of the RF spectral messages sent to the TLP 12 as well as to optimize the use of the bandwidth available on the communications link between the SCS 10 and the TLP 12.

After conversion, each block of RF channels (each at least 1.25 MHz) is passed through serial to parallel converter 10-3-2 and then stored in dual port digital memory 10-3-3 (step S4). The digital memory is a circular memory, which means that the DSP module begins writing data into the first memory address and then continues sequentially until the last memory address is reached. When the last memory address is reached, the DSP returns to the first memory address and continues to sequentially write data into memory. Each DSP module typically contains enough memory to store several seconds of data for each block of RF channels to support the latency and queuing times in the location process.

In the DSP module, the memory address at which digitized and converted RF data is written into memory is the time stamp used throughout the Wireless Location System and which the location processing references in determining TDOA. In order to ensure that the time stamps are aligned at every SCS 10 in the Wireless Location System, the address generator 10-3-8 receives the one pulse per second signal from the timing generation/clock distribution module 10-7 (Figure 2). Periodically, the address generator at all SCS's 10 in a Wireless Location System will simultaneously reset themselves to a known address. This enables the location processing to reduce or eliminate accumulated timing errors in the recording of time stamps for each digitized data element.

The address generator 10-3-8 controls both writing to and reading from the dual port digital memory 10-3-3. Writing takes places continuously since the ADC is continuously sampling and digitizing RF signals and the first DSP (10-3-1A and 10-3-1B) is continuously performing the digital drop receiver function. However, reading occurs in bursts as the Wireless Location System requests data for performing demodulation and location processing. The Wireless Location System may even perform location processing recursively on a single transmission, and therefore requires access to the same data multiple times. In order to service the many requirements of the Wireless Location System, the address generator allows the dual port digital memory to be read at a rate faster than the writing occurs. Typically, reading can be performed eight times faster than writing.

The DSP module 10-3 uses the second DSP 10-3-4 to read the data from the digital memory 10-3-3, and then performs a second digital drop receiver function to extract baseband data from the blocks of RF channels (step S5). For example, the second DSP can extract any single 30 KHz AMPS or TDMA channel from any block of RF channels that have been digitized and stored in the memory. Likewise, the second DSP can extract any single GSM channel. The second DSP is not required to extract a CDMA channel, since the channel bandwidth occupies the full bandwidth of the stored RF data. The combination of the first DSP 10-3-1A, 10-3-1B and the second DSP 10-3-4 allows the DSP module to select, store, and recover any single RF channel in a wireless communications system. A DSP module typically will store four blocks of channels. In a dual-mode AMPS/TDMA system, a single DSP module can continuously and simultaneously monitor up to 42 analog reverse control channels, up to 84 digital control channels, and also be tasked to monitor and locate any voice channel transmission. A single SCS chassis will typically support up to three receiver modules 10-2 (Figure 2), to cover three sectors of two antennas each, and up to nine DSP modules (three DSP modules per receiver permits an entire 15 MHz bandwidth to be simultaneously stored into digital memory). Thus, the SCS 10 is a very modular system than can be easily scaled to match any type of cell site configuration and processing load.

The DSP module 10-3 also performs other functions, including automatic detection of active channels used in each sector (step S6), demodulation (step S7), and station based location processing (step S8). The Wireless Location System maintains an active map of the usage of the RF channels in a wireless communications system (step S9), which enables the Wireless Location System to manage receiver and processing resources, and to rapidly initiate processing when a particular transmission of interest has occurred. The active map comprises a table maintained within the Wireless Location System that lists for each antenna connected to an SCS 10 the primary channels assigned to that SCS 10 and the protocols used in those channels. A primary channel is an RF control channel assigned to a collocated or nearby base station which the base station uses for communications with wireless transmitters. For example, in a typical cellular system with sectored cell sites, there will be one RF control channel frequency assigned for use in each sector. Those control channel frequencies would typically be assigned as primary channels for a collocated SCS 10.

The same SCS 10 may also be assigned to monitor the RF control channels of other nearby base stations as primary channels, even if other SCS's 10 also have the same primary channels assigned. In this manner, the Wireless Location System implements a system demodulation redundancy that ensures that any given wireless transmission has an infinitesimal probability of being missed. When this demodulation redundancy feature is used, the Wireless Location System will receive, detect, and demodulate the same wireless transmission two or more times at more than one SCS 10. The Wireless Location System includes means to detect when this multiple demodulation has occurred and to trigger location processing only once. This function conserves the processing and communications resources of the Wireless Location System, and is further described below. This ability for a single SCS 10 to detect and demodulate wireless transmissions occurring at cell sites not collocated with the SCS 10 permits operators of the Wireless Location System to deploy more efficient Wireless Location System networks. For example, the Wireless Location System may be designed such that the Wireless Location System uses much fewer SCS's 10 than the wireless communications system has base stations.

In the Wireless Location System, primary channels are entered and maintained in the table using two methods: direct programming and automatic detection. Direct programming comprises entering primary channel data into the table using one of the Wireless Location System user interfaces, such as the Network Operations Console 16 (Figure 1), or by receiving channel assignment data from the Wireless Location System to wireless communications system interface. Alternatively, the DSP module 10-3 also runs a background process known as automatic detection in which the DSP uses spare or scheduled processing capacity to detect transmissions on various possible RF channels and then attempt to demodulate those transmissions using probable protocols. The DSP module can then confirm that the primary channels directly programmed are correct, and can also quickly detect changes made to channels at base station and send an alert to the operator of the Wireless Location System.

The DSP module performs the following steps in automatic detection (see Figure 2E-1):

for each possible control and/or voice channel which may be used in the coverage area of the SCS 10, peg counters are established (step S7-1);

at the start of a detection period, all peg counters are reset to zero (step S7-2);

each time that a transmission occurs in a specified RF channel, and the received power level is above a particular pre-set threshold, the peg counter for that channel is incremented (step S7-3);

each time that a transmission occurs in a specified RF channel, and the received power level is above a second particular pre-set threshold, the DSP module attempts to demodulate a certain portion of the transmission using a first preferred protocol (step S7-4);

if the demodulation is successful, a second peg counter for that channel is incremented (step S7-5);

if the demodulation is unsuccessful, the DSP module attempts to demodulate a portion of the transmission using a second preferred protocol (step S7-6);

if the demodulation is successful, a third peg counter for that channel is incremented (step S7-7);

at the end of a detection period, the Wireless Location System reads all peg counters (step S7-8); and

the Wireless Location System automatically assigns primary channels based upon the peg counters (step S7-9).

The operator of the Wireless Location System can review the peg counters and the automatic assignment of primary channels and demodulation protocols, and override any settings that were performed automatically. In addition, if more than two preferred protocols may be used by the wireless carrier, then the DSP module 10-3 can be downloaded with software to detect the additional protocols. The architecture of the SCS 10, based upon wideband receivers 10-2, DSP modules 10-3, and downloadable software permits the Wireless Location System to support multiple demodulation protocols in a single system. There is a significant cost advantage to supporting multiple protocols within the single system, as only a single SCS 10 is required at a cell site. This is in contrast to many base station architectures, which may require different transceiver modules for different modulation protocols. For example, while the SCS 10 could support AMPS, TDMA, and CDMA simultaneously in the same SCS 10, there is no base station currently available that can support this functionality.

The ability to detect and demodulate multiple protocols also includes the ability to independently detect the use of authentication in messages transmitted over the certain air interface protocols. The use of authentication fields in wireless transmitters started to become prevalent within the last few years as a means to reduce the occurrence of fraud in wireless communications systems. However, not all wireless transmitters have implemented authentication. When authentication is used, the protocol generally inserts an additional field into the transmitted message. Frequently this field is inserted between the identity of the wireless transmitter and the dialed digits in the transmitted message. When demodulating a wireless transmission, the Wireless Location System determines the number of fields in the transmitted message, as well as the message type (i.e. registration, origination, page response, etc.). The Wireless Location System demodulates all fields and if extra fields appear to be present, giving consideration to the type of message transmitted, then the Wireless Location System tests all fields for a trigger condition. For example, if the dialed digits "911" appear in the proper place in a field, and the field is located either in its proper place without authentication or its proper place with authentication, then the Wireless Location System triggers normally. In this example, the digits "911" would be required to appear in sequence as "911" or "*911", with no other digits before or after either sequence. This functionality reduces or eliminates a false trigger caused by the digits "911" appearing as part of an authentication field.

The support for multiple demodulation protocols is important for the Wireless Location System to successfully operate because location processing must be quickly triggered when a wireless caller has dialed "911". The Wireless Location System can trigger location processing using two methods: the Wireless Location System will independently demodulate control channel transmissions, and trigger location processing using any number of criteria such as dialed digits, or the Wireless Location System may receive triggers from an external source such as the carrier's wireless communications system. The present inventors have found that independent demodulation by the SCS 10 results in the fastest time to trigger, as measured from the moment that a wireless user presses the "SEND" or "TALK" (or similar) button on a wireless transmitter.

Control and Communications Module 10-5

The control and communications module 10-5, depicted in Figure 2F, includes data buffers 10-5-1, a controller 10-5-2, memory 10-5-3, a CPU 10-5-4 and a T1/E1 communications chip 10-5-5. The module has many of the characteristics previously described in Patent Number 5,608,410. Several enhancements have been added in the present embodiment. For example, the SCS 10 now includes an automatic remote reset capability, even if the CPU on the control and communications module ceases to execute its programmed software. This capability can reduce the operating costs of the Wireless Location System because technicians are not required to travel to a cell site to reset an SCS 10 if it fails to operate normally. The automatic remote reset circuit operates by monitoring the communications interface between the SCS 10 and the TLP 12 for a particular sequence of bits. This sequence of bits is a sequence that does not occur during normal communications between the SCS 10 and the TLP 12. This sequence, for example, may consist of an all ones pattern. The reset circuit operates independently of the CPU so that even if the CPU has placed itself in a locked or other non-operating status, the circuit can still achieve the reset of the SCS 10 and return the CPU to an operating status.

This module now also has the ability to record and report a wide variety of statistics and variables used in monitoring or diagnosing the performance of the SCS 10. For example, the SCS 10 can monitor the percent capacity usage of any DSP or other processor in the SCS 10, as well as the communications interface between the SCS 10 and the TLP 12. These values are reported regularly to the AP 14 and the NOC 16, and are used to determine when additional processing and communications resources are required in the system. For example, alarm thresholds may be set in the NOC to indicate to an operator if any resource is consistently exceeding a preset threshold. The SCS 10 can also monitor the number of times that transmissions have been successfully demodulated, as well as the number of failures. This is useful in allowing operators to determine whether the signal thresholds for demodulation have been set optimally.

This module, as well as the other modules, can also self-report its identity to the TLP 12. As described below, many SCS's 10 can be connected to a single TLP 12. Typically, the communications between SCS's 10 and TLP's 12 is shared with the communications between base stations and MSC's. It is frequently difficult to quickly determine exactly which SCS's 10 have been assigned to particular circuits. Therefore, the SCS 10 contains a hard coded identity, which is recorded at the time of installation. This identity can be read and verified by the TLP 12 to positively determine which SCS 10 has been assigned by a carrier to each of several different communications circuits.

The SCS to TLP communications supports a variety of messages, including: commands and responses, software download, status and heartbeat, parameter download, diagnostic, spectral data, phase data, primary channel demodulation, and RF data. The communications protocol is designed to optimize Wireless Location System operation by minimizing the protocol overhead and the protocol includes a message priority scheme. Each message type is assigned a priority, and the SCS 10 and the TLP 12 will queue messages by priority such that a higher priority message is sent before a lower priority message is sent. For example, demodulation messages are generally set at a high priority because the Wireless Location System must trigger location processing on certain types of calls (i.e., E9-1-1) without delay. Although higher priority messages are queued before lower priority messages, the protocol generally does not preempt a message that is already in transit. That is, a message in the process of being sent across the SCS 10 to TLP 12 communications interface will be completed fully, but then the next message to be sent will be the highest priority message with the earliest time stamp. In order to minimize the latency of high priority messages, long messages, such as RF data, are sent in segments. For example, the RF data for a full 100-millisecond AMPS transmission may be separated into 10-millisecond segments. In this manner, a high priority message may be queued in between segments of the RF data.

Calibration and Performance Monitoring

The architecture of the SCS 10 is heavily based upon digital technologies including the digital receiver and the digital signal processors. Once RF signals have been digitized, timing, frequency, and phase differences can be carefully controlled in the various processes. More importantly, any timing, frequency, and phase differences can be perfectly matched between the various receivers and various SCS's 10 used in the Wireless Location System. However, prior to the ADC, the RF signals pass through a number of RF components, including antennas, cables, low noise amplifiers, filters, duplexors, multi-couplers, and RF splitters. Each of these RF components has characteristics important to the Wireless Location System, including delay and phase versus frequency response. When the RF and analog components are perfectly matched between the pairs of SCS's 10, such as SCS 10A and SCS 10B in Figure 2G, then the effects of these characteristics are automatically eliminated in the location processing. But when the characteristics of the components are not matched, then the location processing can inadvertently include instrumental errors resulting from the mismatch. Additionally, many of these RF components can experience instability with power, time, temperature, or other factors that can add instrumental errors to the determination of location. Therefore, several inventive techniques have been developed to calibrate the RF components in the Wireless Location System and to monitor the performance of the Wireless Location

System on a regular basis. Subsequent to calibration, the Wireless Location System stores the values of these delays and phases versus frequency response (i.e. by RF channel number) in a table in the Wireless Location System for use in correcting these instrumental errors. Figures 2G-2J are referred to below in explaining these calibration methods.

External Calibration Method

Referring to Figure 2G, the timing stability of the Wireless Location System is measured along baselines, where each baseline is comprised of two SCS's, 10A and 10B, and an imaginary line (A - B) drawn between them. In a TDOA / FDOA type of Wireless Location System, locations of wireless transmitters are calculated by measuring the differences in the times that each SCS 10 records for the arrival of the signal from a wireless transmitter. Thus, it is important that the differences in times measured by SCS's 10 along any baseline are largely attributed to the transmission time of the signal from the wireless transmitter and minimally attributed to the variations in the RF and analog components of the SCS's 10 themselves. To meet the accuracy goals of the Wireless Location System, the timing stability for any pair of SCS's 10 are maintained at much less than 100 nanoseconds RMS (root mean square). Thus, the components of the Wireless Location System will contribute less than 100 feet RMS of instrumentation error in the estimation of the location of a wireless transmitter. Some of this error is allocated to the ambiguity of the signal used to calibrate the system. This ambiguity can be determined from the well-known Cramer-Rao lower bound equation. In the case of an AMPS reverse control channel, this error is approximately 40 nanoseconds RMS. The remainder of the error budget is allocated to the components of the Wireless Location System, primarily the RF and analog components in the SCS 10.

In the external calibration method, the Wireless Location System uses a network of calibration transmitters whose signal characteristics match those of the target wireless transmitters. These calibration transmitters may be ordinary wireless telephones emitting periodic registration signals and/or page response signals. Each usable SCS-to-SCS baseline is preferably calibrated periodically using a calibration transmitter that has a relatively clear and unobstructed path to both SCS's 10 associated with the baseline. The calibration signal is processed identically to a signal from a target wireless transmitter. Since the TDOA values are known *a priori*, any errors in the calculations are due to systemic errors in the Wireless Location System. These systemic errors can then be removed in the subsequent location calculations for target transmitters.

Figure 2G illustrates the external calibration method for minimizing timing errors. As shown, a first SCS 10A at a point "A" and a second SCS 10A at a point "B" have an associated baseline A-B. A calibration signal emitted at time T_0 by a calibration transmitter at point "C" will theoretically reach first SCS 10A at time $T_0 + T_{AC}$. T_{AC} is a measure of the amount of time required for the calibration signal to travel from the antenna on the calibration transmitter to the dual port digital memory in a digital receiver. Likewise, the same calibration signal will reach second SCS 10B at a theoretical time $T_0 + T_{BC}$. Usually, however, the calibration signal will not reach the digital memory and the digital signal processing components of the respective SCS's 10 at exactly the correct times. Rather, there will be errors e1 and e2 in the amount of time (T_{AC}, T_{BC}) it takes the calibration signal to propagate from the calibration transmitter to the SCS's 10, respectively, such that the exact times of arrival are actually $T_0 + T_{AC} + e1$ and $T_0 + T_{BC} + e2$. Such errors will be due to some extent to delays in the signal propagation through the air, i.e., from the calibration transmitter's antenna to the SCS antennas; however, the errors will be due primarily to time varying characteristics in the SCS front end components. The errors e1 and e2 cannot be determined *per se* because the system does not know the exact time (T_0) at which the calibration signal was transmitted. The system can, however, determine the error in the *difference* in the time of arrival of the calibration signal at the respective SCS's 10 of any given pair of SCS's 10. This TDOA error value is defined as the difference between the measured TDOA value and the theoretical TDOA value τ_0, where τ_0 is the theoretical differences between the theoretical delay values T_{AC} and T_{BC}. Theoretical TDOA values for each pair of SCS's 10 and each calibration transmitter are known because the positions of the SCS's 10 and calibration transmitter, and the speed at which the calibration signal propagates, are known. The measured TDOA baseline ($TDOA_{A\text{-}B}$) can be represented as $TDOA_{A\text{-}B} = \tau_0 + \epsilon$, where $\epsilon = e1 - e2$. In a similar manner, a calibration signal from a second calibration transmitter at point "D" will have associated errors e3 and e4. The ultimate value of ϵ to be subtracted from TDOA measurements for a target transmitter will be a function (e.g., weighted average) of the ∈ values derived for one or more calibration transmitters. Therefore, a given TDOA measurement ($TDOA_{measured}$) for a pair of SCS's 10 at points "X" and "Y" and a target wireless transmitter at an unknown location will be corrected as follows:

$$TDOA_{X\text{-}Y} = TDOA_{measured} - \epsilon$$

$$\epsilon = k1\epsilon 1 + k2\epsilon 2 + \ldots kN\epsilon N,$$

where k1, k2, etc., are weighting factors and ∈1, ∈2, etc., are the errors determined by subtracting the measured TDOA values from the theoretical values for each calibration transmitter. In this example, error value ∈1 may the error value associated with the calibration transmitter at point "C" in the drawing. The weighting factors are determined by the operator of the Wireless Location System, and input into the configuration tables for each baseline. The operator will take into consideration the distance from each calibration transmitter to the SCS's 10 at points "X" and "Y", the empirically determined line of sight from each calibration transmitter to the SCS's 10 at points "X" and "Y", and the contribution that each SCS "X" and "Y" would have made to a location estimate of a wireless transmitter that might be located in the vicinity of each calibration transmitter. In general, calibration transmitters that are nearer to the SCS's 10 at points "X" and "Y" will be weighted higher than calibration transmitters that are farther away, and calibration transmitters with better line of sight to the SCS's 10 at points "X" and "Y" will be weighted higher than calibration transmitters with worse line of sight.

Each error component e1, e2, etc., and therefore the resulting error component ∈, can vary widely, and wildly, over time because some of the error component is due to multipath reflection from the calibration transmitter to each SCS 10. The multipath reflection is very much path dependent and therefore will vary from measurement to measurement and from path to path. It is not an object of this method to determine the multipath reflection for these calibration paths, but rather to determine the portion of the errors that are attributable to the components of the SCS's 10. Typically, therefore, error values e1 and e3 will have a common component since they relate to the same first SCS 10A. Likewise, error values e2 and e4 will also have a common component since they relate to the second SCS 10B. It is known that while the multipath components can vary wildly, the component errors vary slowly and typically vary sinusoidally. Therefore, in the external calibration method, the error values $\in$ are filtered using a weighted, time-based filter that decreases the weight of the wildly varying multipath components while preserving the relatively slow changing error components attributed to the SCS's 10. One such exemplary filter used in the external calibration method is the Kalman filter.

The period between calibration transmissions is varied depending on the error drift rates determined for the SCS components. The period of the drift rate should be much longer than the period of the calibration interval. The Wireless Location System monitors the period of the drift rate to determine continuously the rate of change, and may periodically adjust the calibration interval, if needed. Typically, the calibration rate for a Wireless Location System such as one in accordance with the present invention is between 10 and 30 minutes. This corresponds well with the typical time period for the registration rate in a wireless communications system. If the Wireless Location System were to determine that the calibration interval must be adjusted to a rate faster than the registration rate of the wireless communications system, then the AP 14 (Figure 1) would automatically force the calibration transmitter to transmit by paging the transmitter at the prescribed interval. Each calibration transmitter is individually addressable and therefore the calibration interval associated with each calibration transmitter can be different.

Since the calibration transmitters used in the external calibration method are standard telephones, the Wireless Location System must have a mechanism to distinguish those telephones from the other wireless transmitters that are being located for various application purposes. The Wireless Location System maintains a list of the identities of the calibration transmitters, typically in the TLP 12 and in the AP 14. In a cellular system, the identity of the calibration transmitter can be the Mobile Identity Number, or MIN. When the calibration transmitter makes a transmission, the transmission is received by each SCS 10 and demodulated by the appropriate SCS 10. The Wireless Location System compares the identity of the transmission with a pre-stored tasking list of identities of all calibration transmitters. If the Wireless Location System determines that the transmission was a calibration transmission, then the Wireless Location System initiates external calibration processing.

Internal Calibration Method

In addition to the external calibration method, it is an object of the present invention to calibrate all channels of the wideband digital receiver used in the SCS 10 of a Wireless Location System. The external calibration method will typically calibrate only a single channel of the multiple channels used by the wideband digital receiver. This is because the fixed calibration transmitters will typically scan to the highest-power control channel, which will typically be the same control channel each time. The transfer function of a wideband digital receiver, along with the other associated components, does not remain perfectly constant, however, and will vary with time and temperature. Therefore, even though the external calibration method can successfully calibrate a single channel, there is no assurance that the remaining channels will also be calibrated.

The internal calibration method, represented in the flowchart of Figure 2H, is particularly suited for calibrating an individual first receiver system (i.e., SCS 10) that is characterized by a time- and frequency-varying transfer function, wherein the transfer function defines how the amplitude and phase of a received signal will be altered by the receiver system and the receiver system is utilized in a location system to determine the location of a wireless transmitter by, in part, determining a difference in time of arrival of a signal transmitted by the wireless transmitter and received by the receiver system to be calibrated and another receiver system, and wherein the accuracy of the location estimate is dependent, in part, upon the accuracy of TDOA measurements made by the system. An example of a AMPS RCC transfer function is depicted in Figure 2I, which depicts how the phase of the transfer function varies across the 21 control channels spanning 630 KHz.

Referring to Figure 2H, the internal calibration method includes the steps of temporarily and electronically disconnecting the antenna used by a receiver system from the receiver system (step S-20); injecting an internally generated wideband signal with known and stable signal characteristics into the first receiver system (step S-21); utilizing the generated wideband signal to obtain an estimate of the manner in which the transfer function varies across the bandwidth of the first receiver system (step S-22); and utilizing the estimate to mitigate the effects of the variation of the first transfer function on the time and frequency measurements made by the first receiver system (step S-23). One example of a stable wideband signal used for internal calibration is a comb signal, which is comprised of multiple individual, equal-amplitude frequency elements at a known spacing, such as 5 KHz. An example of such a signal is shown in Figure 2I.

The antenna must be temporarily disconnected during the internal calibration process to prevent external signals from entering the wideband receiver and to guarantee that the receiver is only receiving the stable wideband signal. The antenna is electronically disconnected only for a few milliseconds to minimize the chance of missing too much of a signal from a wireless transmitter. In addition, internal calibration is typically performed immediately after external calibration to minimize the possibility that the any component in the SCS 10 drifts during the interval between external and internal calibration. The antenna is disconnected from the wideband receiver using two electronically controlled RF relays (not shown). An RF relay cannot provide perfect isolation between input and output even when in the "off" position, but it can provide up to 70 dB of isolation. Two relays may be used in series to increase the amount of isolation and to further assure that no signal is leaked from the antenna to the wideband receiver during calibration. Similarly, when the internal calibration function is not being used, the internal calibration signal is turned off, and the two RF relays are also turned off to prevent leakage of the internal calibration signals into the wideband receiver when the receiver is collecting signals from wireless transmitters.

The external calibration method provides an absolute calibration of a single channel and the internal calibration method then calibrates each other channel relative to the channel that had been absolutely calibrated. The comb signal is particularly suited as a stable wideband signal because it can be easily generated using a stored replica of the signal and a digital to analog converter.

External Calibration Using Wideband Calibration Signal

The external calibration method described next may be used in connection with an SCS 10 receiver system characterized by a time- and frequency-varying transfer function, which preferably includes the antennas, filters, amplifiers, duplexors, multi-couplers, splitters, and cabling associated with the SCS receiver system. The method includes the step of transmitting a stable, known wideband calibration signal from an external transmitter. The wideband calibration signal is then used to estimate the transfer function across a prescribed bandwidth of the SCS receiver system. The estimate of the transfer function is subsequently employed to mitigate the effects of variation of the transfer function on subsequent TDOA/FDOA measurements. The external transmission is preferably of short duration and low power to avoid interference with the wireless communications system hosting the Wireless Location System.

In the preferred method, the SCS receiver system is synchronized with the external transmitter. Such synchronization may be performed using GPS timing units. Moreover, the receiver system may be programmed to receive and process the entire wideband of the calibration signal only at the time that the calibration signal is being sent. The receiver system will not perform calibration processing at any time other than when in synchronization with the external calibration transmissions. In addition, a wireless communications link is used between the receiver system and the external calibration transmitter to exchange commands and responses. The external transmitter may use a directional antenna to direct the wideband signal only at the antennas of the SCS receiver system. Such as directional antenna may be a Yagi antenna (i.e. linear end-fire array). The calibration method preferably includes making the external transmission only when the directional antenna is aimed at the receiver system's antennas and the risk of multipath reflection is low.

Calibrating for Station Biases

Another aspect of the present invention concerns a calibration method to correct for station biases in a SCS receiver system. The "station bias" is defined as the finite delay between when an RF signal from a wireless transmitter reaches the antenna and when that same signal reached the wideband receiver. The inventive method includes the step of measuring the length of the cable from the antennas to the filters and determining the corresponding delays associated with the cable length. In addition, the method includes injecting a known signal into the filter, duplexor, multi-coupler, or RF splitter and measuring the delay and phase response versus frequency response from the input of each device to the wideband receiver. The delay and phase values are then combined and used to correct subsequent location measurements. When used with the GPS based timing generation described above, the method preferably includes correcting for the GPS cable lengths. Moreover, an externally generated reference signal is preferably used to monitor changes in station bias that may arise due to aging and weather. Finally, the station bias by RF channel and for each receiver system in the Wireless Location System is preferably stored in tabular form in the Wireless Location System for use in correcting subsequent location processing.

Performance Monitoring

The Wireless Location System uses methods similar to calibration for performance monitoring on a regular and ongoing basis. These methods are depicted in the flowcharts of Figure 2K and 2L. Two methods of performance monitoring are used: fixed phones and drive testing of surveyed points. The fixed phone method comprises the following steps (see Figure 2K):

standard wireless transmitters are permanently placed at various points within the coverage area of the Wireless Location System (these are then known as the fixed phones) (step S-30);

the points at which the fixed phones have been placed are surveyed so that their location is precisely known to within a predetermined distance, for example ten feet (step S-31);

the surveyed locations are stored in a table in the AP 14 (step S-32);

the fixed phones are permitted to register on the wireless communications system, at the rate and interval set by the wireless communications system for all wireless transmitters on the system (step S-33);

at each registration transmission by a fixed phone, the Wireless Location System locates the fixed phone using normal location processing (as with the calibration transmitters, the Wireless Location System can identify a transmission as being from a fixed phone by storing the identities in a table) (step S-34);

the Wireless Location System computes an error between the calculated location determined by the location processing and the stored location determined by survey (step S-35);

the location, the error value, and other measured parameters are stored along with a time stamp in a database in the AP 14 (step S-36);

the AP 14 monitors the instant error and other measured parameters (collectively referred to as an extended location record) and additionally computes various statistical values of the error(s) and other measured parameters (step S-37); and

if any of the error or other values exceed a pre-determined threshold or a historical statistical value, either instantaneously or after performing statistical filtering over a prescribed number of location estimates, the AP 14 signals an alarm to the operator of the Wireless Location System (step S-38).

The extended location record includes a large number of measured parameters usefully for analyzing the instant and historical performance of the Wireless Location System. These parameters include: the RF channel used by the wireless transmitter, the antenna port(s) used by the Wireless Location System to demodulate the wireless transmission, the antenna ports from which the Wireless Location System requested RF data, the peak, average, and variance in power of the transmission over the interval used for location processing, the SCS 10 and antenna port chosen as the reference for location processing, the correlation value from the cross-spectra correlation between every other SCS 10 and antenna used in location processing and the reference SCS 10 and antenna, the delay value for each baseline, the multipath mitigation parameters, and the residual values remaining after the multipath mitigation calculations. Any of these measured parameters can be monitored by the Wireless Location System for the purpose of determining how the Wireless Location System is performing. One example of the type of monitoring performed by the Wireless Location System may be the variance between the instant value of the correlation on a baseline and the historical range of the correlation value. Another may be the variance between the instant value of the received power at a particular antenna and the historical range of the received power. Many other statistical values can be calculated and this list is not exhaustive.

The number of fixed phones placed into the coverage area of the Wireless Location System can be determined based upon the density of the cell sites, the difficulty of the terrain, and the historical ease with which wireless communications systems have performed in the area. Typically the ratio is about one fixed phone for every six cell sites, however in some areas a ratio of one to one may be required. The fixed phones provide a continuous means to monitor the performance of the Wireless Location System, as well as the monitor any changes in the frequency plan that the carrier may have made. Many times, changes in the frequency plan will cause a variation in the performance of the Wireless Location System and the performance monitoring of the fixed phones provide an immediate indication to the Wireless Location System operator.

Drive testing of surveyed points is very similar to the fixed phone monitoring. Fixed phones typically can only be located indoors where access to power is available (i.e. the phones must be continuously powered on to be effective). To obtain a more complete measurement of the performance of the location performance, drive testing of outdoor test points is also performed. Referring to Figure 2L, as with the fixed phones, prescribed test points throughout the coverage area of the Wireless Location System are surveyed to within ten feet (step S-40). Each test point is assigned a code, where the code consists of either a "*" or a "#", followed by a sequence number (step S-41). For example, "*1001" through "*1099" may be a sequence of 99 codes used for test points. These codes should be sequences, that when dialed, are meaningless to the wireless communications system (i.e. the codes do not cause a feature or other translation to occur in the MSC, except for an intercept message). The AP 14 stores the code for each test point along with the surveyed location (step S-42). Subsequent to these initial steps, any wireless transmitter dialing any of the codes will be triggered and located using normal location processing (steps S-43 and S-44). The Wireless Location System automatically computes an error between the calculated location determined by the location processing and the stored location determined by survey, and the location and the error value are stored along with a time stamp in a database in the AP 14 (steps S-45 and S-46). The AP 14 monitors the instant error, as well as various historical statistical values of the error. If the error values exceed a pre-determined threshold or a historical statistical value, either instantaneously or after performing statistical filtering over a prescribed number of location estimates, the AP 14 signals an alarm to the operator of the Wireless Location System (step S-47).

TDOA Location Processor (TLP)

The TLP 12, depicted in Figures 1, 1A and 3, is a centralized digital signal processing system that manages many aspects of the Wireless Location System, especially the SCS's 10, and provides control over the location processing. Because location processing is DSP intensive, one of the major advantages of the TLP 12 is that the DSP resources can be shared among location processing initiated by transmissions at any of the SCS's 10 in a Wireless Location System. That is, the additional cost of DSP's at the SCS's 10 is reduced by having the resource centrally available. As shown in Figure 3, there are three major components of the TLP 12: DSP modules 12-1, T1/E1 communications modules 12-2 and a controller module 12-3.

The T1/E1 communications modules 12-2 provide the communications interface to the SCS's 10 (T1 and E1 are standard communications speeds available throughout the world). Each SCS 10 communicates to a TLP 12 using one or more DS0's (which are typically 56Kbps or 64 Kbps). Each SCS 10 typically connects to a fractional T1 or E1 circuit, using, e.g., a drop and insert unit or channel bank at the cell site. Frequently, this circuit is shared with the base station, which communicates with the MSC. At a central site, the DS0's assigned to the base station are separated from the DS0's assigned to the SCS's 10. This is typically accomplished external to the TLP 12 using a digital access and control system (DACS) 13A that not only separates the DS0's but also grooms the DS0's from multiple SCS's 10 onto full T1 or E1 circuits. These circuits then connect from the DACS 13A to the DACS 13B and then to the T1/E1 communications module on the TLP 12. Each T1/E1 communications module contains sufficient digital memory to buffer packets of data to and from each SCS 10 communicating with the module. A single TLP chassis may support one or more T1/E1 communications modules.

The DSP modules 12-1 provide a pooled resource for location processing. A single module may typically contain two to eight digital signal processors, each of which are equally available for location processing. Two types of location processing are supported: central based and station based, which are described in further detail below. The TLP controller 12-3 manages the DSP module(s) 12-1 to obtain optimal throughput. Each DSP module contains sufficient digital memory to store all of the data necessary for location processing. A DSP is not engaged until all of the data necessary to begin location processing has been moved from each of the involved SCS's 10 to the digital memory on the DSP module. Only then is a DSP given the specific task to locate a specific wireless transmitter. Using this technique, the DSP's , which are an expensive resource, are never kept waiting. A single TLP chassis may support one or more DSP modules.

The controller module 12-3 provides the real time management of all location processing within the Wireless Location System. The AP 14 is the top-level management entity within the Wireless Location System, however its database architecture is not sufficiently fast to conduct the real time decision making when transmissions occur. The controller module 12-3 receives messages from the SCS's 10, including: status, spectral energy in various channels for various antennas, demodulated messages, and diagnostics. This enables the controller to continuously determine events occurring in the Wireless Location System, as well as to send commands to take certain actions. When a controller module receives demodulated messages from SCS's 10, the controller module decides whether location processing is required for a particular wireless transmission. The controller module 12-3 also determines which SCS's 10 and antennas to use in location processing, including whether to use central based or station based location processing. The controller module commands SCS's 10 to return the necessary data, and commands the communications modules and DSP modules to sequentially perform their necessary roles in location processing. These steps are described below in further detail.

The controller module 12-3 maintains a table known as the Signal of Interest Table (SOIT). This table contains all of the criteria that may be used to trigger location processing on a particular wireless transmission. The criteria may include, for example, the Mobile Identity Number, the Mobile Station ID, the Electronic Serial Number, dialed digits, System ID, RF channel number, cell site number or sector number, type of transmission, and other types of data elements. Some of the trigger events may have higher or lower priority levels associated with them for use in determining the order of processing. Higher priority location triggers will always be processing before lower priority location triggers. However, a lower priority trigger that has already begun location processing will complete the processing before being assigned to a higher priority task. The master Tasking List for the Wireless Location System is maintained on the AP 14, and copies of the Tasking List are automatically downloaded to the Signal of Interest Table in each TLP 12 in the Wireless Location System. The full Signal of Interest Table is downloaded to a TLP 12 when the TLP 12 is reset or first starts. Subsequent to those two events, only changes are downloaded from the AP 14 to each TLP 12 to conserve communications bandwidth. The TLP 12 to AP 14 communications protocol preferably contains sufficient redundancy and error checking to prevent incorrect data from ever being entered into the Signal of Interest Table . When the AP 14 and TLP 12 periodically have spare processing capacity available, the AP 14 reconfirms entries in the Signal of Interest Table to ensure that all Signal of Interest Table entries in the Wireless Location System are in full synchronization.

Each TLP chassis has a maximum capacity associated with the chassis. For example, a single TLP chassis may only have sufficient capacity to support between 48 and 60 SCS's 10. When a wireless communications system is larger that the capacity of a single TLP chassis, multiple TLP chassis are connected together using Ethernet networking. The controller module 12-3 is responsible for inter-TLP communications and networking, and communicates with the controller modules in other TLP chassis and with Application Processors 14 over the Ethernet network. Inter-TLP communications is required when location processing requires the use of SCS's 10 that are connected to different TLP chassis. Location processing for each wireless transmission is assigned to a single DSP module in a single TLP chassis. The controller modules 12-3 in TLP chassis select the DSP module on which to perform location processing, and then route all of the RF data used in location processing to that DSP module. If RF data is required from the SCS's 10 connected to more that one TLP 12, then the controller modules in all necessary TLP chassis communicate to move the RF data from all necessary SCS's 10 to their respective connected TLP's 12 and then to the DSP module and TLP chassis assigned to the location processing. The controller module supports two fully independent Ethernet networks for redundancy. A break or failure in any one network causes the affected TLP's 12 to immediately shift all communications to the other network.

The controller modules 12-3 maintain a complete network map of the Wireless Location System, including the SCS's 10 associated with each TLP chassis. The network map is a table stored in the controller module containing a list of the candidate SCS/antennas that may be used in location processing, and various parameters associated with each of the SCS/antennas. The structure of an exemplary network map is depicted in Figure 3A. There is a separate entry in the table for each antenna connected to an SCS 10. When a wireless transmission occurs in an area that is covered by SCS's 10 communicating with more than one TLP chassis, the controller modules in the involved TLP chassis determine which TLP chassis will be the "master" TLP chassis for the purpose of managing location processing. Typically, the TLP chassis associated with the SCS 10 that has the primary channel assignment for the wireless transmission is assigned to be the master. However, another TLP chassis may be assigned instead if that TLP temporarily has no DSP resources available for location processing, or if most of the SCS's 10 involved in location processing are connected to another TLP chassis and the controller modules are minimizing inter-TLP communications. This decision making process is fully dynamic, but is assisted by tables in the TLP 12 that pre-determine the preferred TLP chassis for every primary channel assignment. The tables are created by the operator of the Wireless Location System, and programmed using the Network Operations Console.

The networking described herein functions for both TLP chassis associated with the same wireless carrier, as well as for chassis that overlap or border the coverage area between two wireless carriers. Thus it is possible for a TLP 12 belonging to a first wireless carrier to be networked and therefore receive RF data from a TLP 12 (and the SCS's 10 associated with that TLP 12) belonging to a second wireless carrier. This networking is particularly valuable in rural areas, where the performance of the Wireless Location System can be enhanced by deploying SCS's 10 at cell sites of multiple wireless carriers. Since in many cases wireless carriers do not collocate cell sites, this feature enables the

Wireless Location System to access more geographically diverse antennas than might be available if the Wireless Location System used only the cell sites from a single wireless carrier. As described below, the proper selection and use of antennas for location processing can enhance the performance of the Wireless Location System.

The controller module 12-3 passes many messages, including location records, to the AP 14, many of which are described below. Usually, however, demodulated data is not passed from the TLP 12 to the AP 14. If, however, the TLP 12 receives demodulated data from a particular wireless transmitter and the TLP 12 identifies the wireless transmitter as being a registered customer of a second wireless carrier in a different coverage area, the TLP 12 may pass the demodulated data to the first (serving) AP 14A. This will enable the first AP 14A to communicate with a second AP 14B associated with the second wireless carrier, and determine whether the particular wireless transmitter has registered for any type of location services. If so, the second AP 14B may instruct the first AP 14A to place the identity of the particular wireless transmitter into the Signal of Interest Table so that the particular wireless transmitter will be located for as long as the particular wireless transmitter is in the coverage area of the first Wireless Location System associated with the first AP 14A. When the first Wireless Location System has detected that the particular wireless transmitter has not registered in a time period exceeding a pre-determined threshold, the first AP 14A may instruct the second AP 14B that the identity of the particular wireless transmitter is being removed from the Signal of Interest Table for the reason of no longer being present in the coverage area associated with the first AP 14A.

Diagnostic Port

The TLP 12 supports a diagnostic port that is highly useful in the operation and diagnosis of problems within the Wireless Location System. This diagnostic port can be accessed either locally at a TLP 12 or remotely over the Ethernet network connecting the TLP's 12 to the AP's. The diagnostic port enables an operator to write to a file all of the demodulation and RF data received from the SCS's 10, as well as the intermediate and final results of all location processing. This data is erased from the TLP 12 after processing a location estimate, and therefore the diagnostic port provides the means to save the data for later post-processing and analysis. The inventor's experience in operating large scale wireless location systems is that a very small number of location estimates can occasionally have very large errors, and these large errors can dominate the overall operating statistics of the Wireless Location System over any measurement period. Therefore, it is important to provide the operator with a set of tools that enable the Wireless Location System to detect and trap the cause of the very large errors to diagnose and mitigate those errors. The diagnostic port can be set to save the above information for all location estimates, for location estimates from particular wireless transmitters or at particular test points, or for location estimates that meet a certain criteria. For example, for fixed phones or drive testing of surveyed points, the diagnostic port can determine the error in the location estimate in real time and then write the above described information only for those location estimates whose error exceeds a predetermined threshold. The diagnostic port determines the error in real time by storing the surveyed latitude, longitude coordinate of each fixed phone and drive test point in a table, and then calculating a radial error when a location estimate for the corresponding test point is made.

Redundancy

The TLP's 12 implement redundancy using several inventive techniques, allowing the Wireless Location System to support an M plus N redundancy method. M plus N redundancy means that N redundant (or standby) TLP chassis are used to provide full redundant backup to M online TLP chassis. For example, M may be ten and N may be two.

First, the controller modules in different TLP chassis continuously exchange status and "heartbeat" messages at pre-determined time intervals between themselves and with every AP 14 assigned to monitor the TLP chassis. Thus, every controller module has continuous and full status of every other controller module in the Wireless Location System. The controller modules in different TLP chassis periodically select one controller module in one TLP 12 to be the master controller for a group of TLP chassis. The master controller may decide to place a first TLP chassis into off-line status if the first TLP 12A reports a failed or degraded condition in its status message, or if the first TLP 12A fails to report any status or heartbeat messages within its assigned and pre-determined time. If the master controller places a first TLP 12A into off-line status, the master controller may assign a second TLP 12B to perform a redundant switchover and assume the tasks of the off-line first TLP 12A. The second TLP 12B is automatically sent the configuration that had been loaded into the first TLP 12A; this configuration may be downloaded from either the master controller or from an AP 14 connected to the TLP's 12. The master controller may be a controller module on any one of the TLP's 12 that is not in off-line status, however there is a preference that the master controller be a controller module in a stand-by TLP 12. When the master controller is the controller module in a stand-by TLP 12, the time required to detect a failed first TLP 12A, place the first TLP 12A into off-line status, and then perform a redundant switchover can be accelerated.

Second, all of the T1 or E1 communications between the SCS's 10 and each of the TLP T1/E1 communications modules 12-2 are preferably routed through a high-reliability DACS that is dedicated to redundancy control. The DACS 13B is connected to every groomed T1/E1 circuit containing DS0's from SCS's 10 and is also connected to every T1/E1 communications module 12-2 of every TLP 12. Every controller module at every TLP 12 contains a map of the DACS 13B that describes the DACS' connection list and port assignments. This DACS 13B is connected to the Ethernet network described above and can be controlled by any of the controller modules 12-3 at any of the TLP's 12. When a second TLP 12 is placed into off-line status by a master controller, the master controller sends commands to the DACS 13B to switch the groomed T1/E1 circuit communicating with the first TLP 12A to a second TLP 12B which had been in standby status. At the same time, the AP 14 downloads the complete configuration file that was being used by the second (and now off-line) TLP 12B to the third (and now online) TLP 12C. The time from the first detection of a failed first TLP chassis to the complete switch-over and assumption of processing responsibilities by a third TLP chassis is typically less than few seconds. In many cases, no RF data is lost by the SCS's 10 associated with the failed first TLP chassis, and location processing can continue without interruption. At the time of a TLP fail-over when a first TLP 12A is placed into off-line status, the NOC 16 creates an alert to notify the Wireless Location System operator that the event has occurred.

Third, each TLP chassis contains redundant power supplies, fans, and other components. A TLP chassis can also support multiple DSP modules, so that the failure of a single DSP module or even a single DSP on a DSP module reduces the overall amount of processing resources available but does not cause the failure of the TLP chassis. In all of the cases described in this paragraph, the failed component of the TLP 12 can be replaced without placing the entire TLP chassis into off-line status. For example, if a single power supply fails, the redundant power supply has sufficient capacity to singly support the load of the chassis. The failed power supply contains the necessary circuitry to remove itself from the load of the chassis and not cause further degradation in the chassis. Similarly, a failed DSP module can also remove itself from the active portions of the chassis, so as to not cause a failure of the backplane or other modules. This enables the remainder of the chassis, including the second DSP module, to continue to function normally. Of course, the total processing throughput of the chassis is reduced but a total failure is avoided.

Application Processor (AP) 14

The AP 14 is a centralized database system, comprising a number of software processes that manage the entire Wireless Location System, provide interfaces to external users and applications, store location records and configurations, and support various application-related functionality. The AP 14 uses a commercial hardware platform that is sized to match the throughput of the Wireless Location System. The AP 14 also uses a commercial relational database system (RDBMS), which has been significantly customized to provide the functionality described herein. While the SCS 10 and TLP 12 preferably operate together on a purely real time basis to determine location and create location records, the AP 14 can operate on both a real time basis to store and forward location records and a non-real time basis to post-process location records and provide access and reporting over time. The ability to store, retrieve, and post-process location records for various types of system and application analysis has proven to be a powerful advantage of the present invention. The main collection of software processes is known as the ApCore, which is shown in Figure 4 and includes the following functions:

The AP Performance Guardian (ApPerfGuard) is a dedicated software process that is responsible for starting, stopping, and monitoring most other ApCore processes as well as ApCore communications with the NOC 16. Upon receiving a configuration update command from the NOC, ApPerfGuard updates the database and notifies all other processes of the change. ApPerfGuard starts and stops appropriate processes when the NOC directs the ApCore to enter specific run states, and constantly monitors other software processes scheduled to be running to restart them if they have exited or stopping and restarting any process that is no longer properly responding. ApPerfGuard is assigned to one of the highest processing priorities so that this process cannot be blocked by another process that has "run away". ApPerfGuard is also assigned dedicated memory that is not accessible by other software processes to prevent any possible corruption from other software processes.

The AP Dispatcher (ApMnDsptch) is a software process that receives location records from the TLP's 12 and forwards the location records to other processes. This process contains a separate thread for each physical TLP 12 configured in the system, and each thread receives location records from that TLP 12. For system reliability, the ApCore maintains a list containing the last location record sequence number received from each TLP 12, and sends this sequence number to the TLP 12 upon initial connection. Thereafter, the AP 14 and the TLP 12 maintain a protocol whereby the TLP 12 sends each location record with a unique identifier. ApMnDsptch forwards location records to multiple processes, including Ap911, ApDbSend, ApDbRecvLoc, and ApDbFileRecv.

The AP Tasking Process (ApDbSend) controls the Tasking List within the Wireless Location System. The Tasking List is the master list of all of the trigger criteria that determines which wireless transmitters will be located, which applications created the criteria, and which applications can receive location record information. The ApDbSend process contains a separate thread for each TLP 12, over which the ApDbSend synchronizes the Tasking List with the Signal of Interest Table on each TLP 12. ApDbSend does not send application information to the Signal of Interest Table , only the trigger criteria. Thus the TLP 12 does not know why a wireless transmitter must be located. The Tasking List allows wireless transmitters to be located based upon Mobile Identity Number (MIN), Mobile Station Identifier (MSID), Electronic Serial Number (ESN) and other identity numbers, dialed sequences of characters and / or digits, home System ID (SID), originating cell site and sector, originating RF channel, or message type. The Tasking List allows multiple applications to receive location records from the same wireless transmitter. Thus, a single location record from a wireless transmitter that has dialed "911" can be sent, for example, to a 911 PSAP, a fleet management application, a traffic management application, and to an RF optimization application.

The Tasking List also contains a variety of flags and field for each trigger criteria, some of which are described elsewhere in this specification. One flag, for example, specifies the maximum time limit before which the Wireless Location System must provide a rough or final estimate of the wireless transmitter. Another flag allows location processing to be disabled for a particular trigger criteria such as the identity of the wireless transmitter. Another field contains the authentication required to make changes to the criteria for a particular trigger; authentication enables the operator of the Wireless Location System to specify which applications are authorized to add, delete, or make changes to any trigger criteria and associated fields or flags. Another field contains the Location Grade of Service associated with the trigger criteria; Grade of Service indicates to the Wireless Location System the accuracy level and priority level desired for the location processing associated with a particular trigger criteria. For example, some applications may be satisfied with a rough location estimate (perhaps for a reduced location processing fee), while other applications may be satisfied with low priority processing that is not guaranteed to complete for any given transmission (and which may be pre-empted for high priority processing tasks). The Wireless Location System also includes means to support the use of wildcards for trigger criteria in the Tasking List. For example, a trigger criteria can be entered as "MIN = 215555****". This will cause the Wireless Location System to trigger location processing for any wireless transmitter whose MIN begins with the six digits 215555 and ends with any following four digits. The wildcard characters can be placed into any position in a trigger criteria. This feature can save on the number of memory locations required in the Tasking List and Signal of Interest Table by grouping blocks of related wireless transmitters together.

ApDbSend also supports dynamic tasking. For example, the MIN, ESN, MSID, or other identity of any wireless transmitter that has dialed "911" will automatically be placed onto the Tasking List by ApDbSend for one hour. Thus, any further transmissions by the wireless transmitter that dialed "911" will also be located in case of further emergency.

For example, if a PSAP calls back a wireless transmitter that had dialed "911" within the last hour, the Wireless Location System will trigger on the page response message from the wireless transmitter, and can make this new location record available to the PSAP. This dynamic tasking can be set for any interval of time after an initiation event, and for any type of trigger criteria. The ApDbSend process is also a server for receiving tasking requests from other applications. These applications, such as fleet management, can send tasking requests via a socket connection, for example. These applications can either place or remove trigger criteria. ApDbSend conducts an authentication process with each application to verify that that the application has been authorized to place or remove trigger criteria, and each application can only change trigger criteria related to that application.

The AP 911 Process (Ap911) manages each interface between the Wireless Location System and E9-1-1 network elements, such as tandem switches, selective routers, ALI databases and/or PSAPs. The Ap911 process contains a separate thread for each connection to a E9-1-1 network element, and can support more than one thread to each network element. The Ap911 process can simultaneously operate in many modes based upon user configuration, and as described herein. The timely processing of E9-1-1 location records is one of the highest processing priorities in the AP 14, and therefore the Ap911 executes entirely out of random access memory (RAM) to avoid the delay associated with first storing and then retrieving a location record from any type of disk. When ApMnDsptch forwards a location record to Ap911, Ap911 immediately makes a routing determination and forwards the location record over the appropriate interface to a E9-1-1 network element. A separate process, operating in parallel, records the location record into the AP 14 database.

The AP 14, through the Ap911 process and other processes, supports two modes of providing location records to applications, including E9-1-1: "push" and "pull" modes. Applications requesting push mode receive a location record as soon as it is available from the AP 14. This mode is especially effective for E9-1-1 which has a very time critical need for location records, since E9-1-1 networks must route wireless 9-1-1 calls to the correct PSAP within a few seconds after a wireless caller has dialed "911". Applications requesting pull mode do not automatically receive location records, but rather must send a query to the AP 14 regarding a particular wireless transmitter in order to receive the last, or any other location record, about the wireless transmitter. The query from the application can specify the last location record, a series of location records, or all location records meeting a specific time or other criteria, such as type of transmission. An example of the use of pull mode in the case of a "911" call is the E9-1-1 network first receiving the voice portion of the "911" call and then querying the AP 14 to receive the location record associated with that call.

When the Ap911 process is connected to many E9-1-1 networks elements, Ap911 must determine to which E9-1-1 network element to push the location record (assuming that "push" mode has been selected). The AP 14 makes this determination using a dynamic routing table. The dynamic routing table is used to divide a geographic region into cells. Each cell, or entry, in the dynamic routing table contains the routing instructions for that cell. It is well known that one minute of latitude is 6083 feet, which is about 365 feet per millidegree. Additionally, one minute of longitude is cosine(latitude) times 6083 feet, which for the Philadelphia area is about 4659 feet, or about 280 feet per millidegree. A table of size one thousand by one thousand, or one million cells, can contain the routing instructions for an area that is about 69 miles by 53 miles, which is larger than the area of Philadelphia in this example, and each cell could contain a geographic area of 365 feet by 280 feet. The number of bits allocated to each entry in the table must only be enough to support the maximum number of routing possibilities. For example, if the total number of routing possibilities is sixteen or less, then the memory for the dynamic routing table is one million times four bits, or one-half megabyte. Using this scheme, an area the size of Pennsylvania could be contained in a table of approximately twenty megabytes or less, with ample routing possibilities available. Given the relatively inexpensive cost of memory, this inventive dynamic routing table provides the AP 14 with a means to quickly push the location records for "911" calls only to the appropriate E9-1-1 network element.

The AP 14 allows each entry in dynamic routing to be populated using manual or automated means. Using the automated means, for example, an electronic map application can create a polygon definition of the coverage area of a specific E9-1-1 network element, such as a PSAP. The polygon definition is then translated into a list of latitude, longitude points contained within the polygon. The dynamic routing table cell corresponding to each latitude, longitude point is then given the routing instruction for that E9-1-1 network element that is responsible for that geographic polygon.

When the Ap911 process receives a "911" location record for a specific wireless transmitter, Ap911 converts the latitude, longitude into the address of a specific cell in the dynamic routing table. Ap911 then queries the cell to determine the routing instructions, which may be push or pull mode and the identity of the E9-1-1 network element responsible for serving the geographic area in which the "911" call occurred. If push mode has been selected, then Ap911 automatically pushes the location record to that E9-1-1 network element. If pull mode has been selected, then Ap911 places the location record into a circular table of "911" location records and awaits a query.

The dynamic routing means described above entails the use of a geographically defined database that may be applied to other applications in addition to 911, and is therefore supported by other processes in addition to Ap911. For example, the AP 14 can automatically determine the billing zone from which a wireless call was placed for a Location Sensitive Billing application. In addition, the AP 14 may automatically send an alert when a particular wireless transmitter has entered or exited a prescribed geographic area defined by an application. The use of particular geographic databases, dynamic routing actions, any other location triggered actions are defined in the fields and flags associated with each trigger criteria. The Wireless Location System includes means to easily manage these geographically defined databases using an electronic map that can create polygons encompassing a prescribed geographic area. The Wireless Location System extracts from the electronic map a table of latitude, longitude points contained with the polygon. Each application can use its own set of polygons, and can define a set of actions to be taken when a location record for a triggered wireless transmission is contained within each polygon in the set.

The AP Database Receive Process (ApDbRecvLoc) receives all location records from ApMnDsptch via shared memory, and places the location records into the AP location database. ApDbRecvLoc starts ten threads that each retrieve location records from shared memory, validate each record before inserting the records into the database, and then inserts the records into the correct location record partition in the database. To preserve integrity, location records with any type of error are not written into the location record database but are instead placed into an error file that can be reviewed by the Wireless Location System operator and then manually entered into the database after error resolution. If the location database has failed or has been placed into off-line status, location records are written to a flat file where they can be later processed by ApDbFileRecv.

The AP File Receive Process (ApDbFileRecv) reads flat files containing location records and inserts the records into the location database. Flat files are a safe mechanism used by the AP 14 to completely preserve the integrity of the AP 14 in all cases except a complete failure of the hard disk drives. There are several different types of flat files read by ApDbFileRecv, including Database Down, Synchronization, Overflow, and Fixed Error. Database Down flat files are written by the ApDbRecvLoc process if the location database is temporarily inaccessible; this file allows the AP 14 to ensure that location records are preserved during the occurrence of this type of problem. Synchronization flat files are written by the ApLocSync process (described below) when transferring location records between pairs of redundant AP systems. Overflow flat files are written by ApMnDsptch when location records are arriving into the AP 14 at a rate faster than ApDbRecvLoc can process and insert the records into the location database. This may occur during very high peak rate periods. The overflow files prevent any records from being lost during peak periods. The Fixed Error flat files contain location records that had errors but have now been fixed, and can now be inserted into the location database.

Because the AP 14 has a critical centralized role in the Wireless Location System, the AP 14 architecture has been designed to be fully redundant. A redundant AP 14 system includes fully redundant hardware platforms, fully redundant RDBMS, redundant disk drives, and redundant networks to each other, the TLP's 12, the NOC's 16, and external applications. The software architecture of the AP 14 has also been designed to support fault tolerant redundancy. The following examples illustrate functionality supported by the redundant AP's. Each TLP 12 sends location records to both the primary and the redundant AP 14 when both AP's are in an online state. Only the primary AP 14 will process incoming tasking requests, and only the primary AP 14 will accept configuration change requests from the NOC 16. The primary AP 14 then synchronizes the redundant AP 14 under careful control. Both the primary and redundant AP's will accept basic startup and shutdown commands from the NOC. Both AP's constantly monitor their own system parameters and application health and monitor the corresponding parameters for the other AP 14, and then decide which AP 14 will be primary and which will be redundant based upon a composite score. This composite score is determined by compiling errors reported by various processes to a shared memory area, and monitoring swap space and disk space. There are several processes dedicated to supporting redundancy.

The AP Location Synchronization Process (ApLocSync) runs on each AP 14 and detects the need to synchronize location records between AP's, and then creates "sync records" that list the location records that need to be transferred from one AP 14 to another AP 14. The location records are then transferred between AP's using a socket connection. ApLocSync compares the location record partitions and the location record sequence numbers stored in each location database. Normally, if both the primary and redundant AP 14 are operating properly, synchronization is not needed because both AP's are receiving location records simultaneously from the TLP's 12. However, if one AP 14 fails or is placed in an off-line mode, then synchronization will later be required. ApLocSync is notified whenever ApMnDsptch connects to a TLP 12 so it can determine whether synchronization is required.

The AP Tasking Synchronization Process (ApTaskSync) runs on each AP 14 and synchronizes the tasking information between the primary AP 14 and the redundant AP 14. ApTaskSync on the primary AP 14 receives tasking information from ApDbSend, and then sends the tasking information to the ApTaskSync process on the redundant AP 14. If the primary AP 14 were to fail before ApTaskSync had completed replicating tasks, then ApTaskSync will perform a complete tasking database synchronization when the failed AP 14 is placed back into an online state.

The AP Configuration Synchronization Process (ApConfigSync) runs on each AP 14 and synchronizes the configuration information between the primary AP 14 and the redundant AP 14. ApConfigSync uses a RDBMS replication facility. The configuration information includes all information needed by the SCS's 10, TLP's 12, and AP's 14 for proper operation of the Wireless Location System in a wireless carrier's network.

In addition to the core functions described above, the AP 14 also supports a large number of processes, functions, and interfaces useful in the operation of the Wireless Location System, as well as useful for various applications that desire location information. While the processes, functions, and interfaces described herein are in this section pertaining to the AP 14, the implementation of many of these processes, functions, and interfaces permeates the entire Wireless Location System and therefore their inventive value should be not read as being limited only to the AP 14.

Roaming

The AP 14 supports "roaming" between wireless location systems located in different cities or operated by different wireless carriers. If a first wireless transmitter has subscribed to an application on a first Wireless Location System, and therefore has an entry in the Tasking List in the first AP 14 in the first Wireless Location System, then the first wireless transmitter may also subscribe to roaming. Each AP 14 and TLP 12 in each Wireless Location System contains a table in which a list of valid "home" subscriber identities is maintained. The list is typically a range, and for example, for current cellular telephones, the range can be determined by the NPA/NXX codes (or area code and exchange) associated with the MIN or MSID of cellular telephones. When a wireless transmitter meeting the "home" criteria makes a transmission, a TLP 12 receives demodulated data from one or more SCS's 10 and checks the trigger information in the Signal of Interest Table . If any trigger criterion is met, the location processing begins on that transmission; otherwise, the transmission is not processed by the Wireless Location System.

When a first wireless transmitter not meeting the "home" criterion makes a transmission in a second Wireless Location System, the second TLP 12 in the second Wireless Location

System checks the Signal of Interest Table for a trigger. One of three actions then occurs: (i) if the transmission meets an already existing criteria in the Signal of Interest Table , the transmitter is located and the location record is forwarded from the second AP 14 in the second Wireless Location System to the first AP 14 in the first Wireless Location System; (ii) if the first wireless transmitter has a "roamer" entry in the Signal of Interest Table indicating that the first wireless transmitter has "registered" in the second Wireless Location System but has no trigger criteria, then the transmission is not processed by the second Wireless Location System and the expiration timestamp is adjusted as described below; (iii) if the first wireless transmitter has no "roamer" entry and therefore has not "registered", then the demodulated data is passed from the TLP 12 to the second AP 14.

In the third case above, the second AP 14 uses the identity of the first wireless transmitter to identify the first AP 14 in the first Wireless Location System as the "home" Wireless Location System of the first wireless transmitter. The second AP 14 in the second Wireless Location System sends a query to the first AP 14 in the first Wireless Location System to determine whether the first wireless transmitter has subscribed to any location application and therefore has any trigger criteria in the Tasking List of the first AP 14. If a trigger is present in the first AP 14, the trigger criteria, along with any associated fields and flags, is sent from the first AP 14 to the second AP 14 and entered in the Tasking List and the Signal of Interest Table as a "roamer" entry with trigger criteria. If the first AP 14 responds to the second AP 14 indicating that the first wireless transmitter has no trigger criteria, then the second AP 14 "registers" the first wireless transmitter in the Tasking List and the Signal of Interest Table as a "roamer" with no trigger criteria. Thus both current and future transmissions from the first wireless transmitter can be positively identified by the TLP 12 in the second Wireless Location System as being registered without trigger criteria, and the second AP 14 is not required to make additional queries to the first AP 14.

When the second AP 14 registers the first wireless transmitter with a roamer entry in the Tasking List and the Signal of Interest Table with or without trigger criteria, the roamer entry is assigned an expiration timestamp. The expiration timestamp is set to the current time plus a predetermined first interval. Every time the first wireless transmitter makes a transmission, the expiration timestamp of the roamer entry in the Tasking List and the

Signal of Interest Table is adjusted to the current time of the most recent transmission plus the predetermined first interval. If the first wireless transmitter makes no further transmissions prior to the expiration timestamp of its roamer entry, then the roamer entry is automatically deleted. If, subsequent to the deletion, the first wireless transmitter makes another transmission, then the process of registering occurs again.

The first AP 14 and second AP 14 maintain communications over a wide area network. The network may be based upon TCP/IP or upon a protocol similar to the most recent version of IS-41. Each AP 14 in communications with other AP's in other wireless location systems maintains a table that provides the identity of each AP 14 and Wireless Location System corresponding to each valid range of identities of wireless transmitters.

Multiple Pass Location Records

Certain applications may require a very fast estimate of the general location of a wireless transmitter, followed by a more accurate estimate of the location that can be sent subsequently. This can be valuable, for example, for E9-1-1 systems that handle wireless calls and must make a call routing decision very quickly, but can wait a little longer for a more exact location to be displayed upon the E9-1-1 call-taker's electronic map terminal. The Wireless Location System supports these applications with an inventive multiple pass location processing mode, described later. The AP 14 supports this mode with multiple pass location records. For certain entries, the Tasking List in the AP 14 contains a flag indicating the maximum time limit before which a particular application must receive a rough estimate of location, and a second maximum time limit in which a particular application must receive a final location estimate. For these certain applications, the AP 14 includes a flag in the location record indicating the status of the location estimate contained in the record, which may, for example, be set to first pass estimate (i.e. rough) or final pass estimate. The Wireless Location System will generally determine the best location estimate within the time limit set by the application, that is the Wireless Location System will process the most amount of RF data that can be supported in the time limit. Given that any particular wireless transmission can trigger a location record for one or more applications, the Wireless Location System supports multiple modes simultaneously. For example, a wireless transmitter with a particular MIN can dial "911". This may trigger a two-pass location record for the E9-1-1 application, but a single pass location record for a fleet management application that is monitoring that particular MIN. This can be extended to any number of applications.

Multiple Demodulation and Triggers

In wireless communications systems in urban or dense suburban areas, frequencies or channels can be re-used several times within relatively close distances. Since the Wireless Location System is capable of independently detecting and demodulating wireless transmissions without the aid of the wireless communications system, a single wireless transmission can frequently be detected and successfully demodulated at multiple SCS's 10 within the Wireless Location System. This can happen both intentionally and unintentionally. An unintentional occurrence is caused by a close frequency re-use, such that a particular wireless transmission can be received above a predetermined threshold at more than one SCS 10, when each SCS 10 believes it is monitoring only transmissions that occur only within the cell site collocated with the SCS 10. An intentional occurrence is caused by programming more than one SCS 10 to detect and demodulate transmissions that occur at a particular cell site and on a particular frequency. As described earlier, this is generally used with adjacent or nearby SCS's 10 to provide system demodulation redundancy to further increase the probability that any particular wireless transmission is successful detected and demodulated.

Either type of event could potentially lead to multiple triggers within the Wireless Location System, causing location processing to be initiated several times for the same transmission. This causes an excess and inefficient use of processing and communications resources. Therefore, the Wireless Location System includes means to detect when the same transmission has been detected and demodulated more than once, and to select the best demodulating SCS 10 as the starting point for location processing. When the Wireless Location System detects and successfully demodulates the same transmission multiple times at multiple SCS/antennas, the Wireless Location System uses the following criteria to select the one demodulating SCS/antenna to use to continue the process of determining whether to trigger and possibly initiate location processing (again, these criteria may be weighted in determining the final decision): (i) an SCS/antenna collocated at the cell site to which a particular frequency has been assigned is preferred over another SCS/antenna, but this preference may be adjusted if there is no operating and on-line SCS/antenna collocated at the cell site to which the particular frequency has been assigned, (ii) SCS/antennas with higher average SNR are preferred over those with lower average SNR, and (iii) SCS/antennas with fewer bit errors in demodulating the transmission are preferred over those with higher bit errors. The weighting applied to each of these preferences may be adjusted by the operator of the Wireless Location System to suit the particular design of each system.

Interface to Wireless Communications System

The Wireless Location System contains means to communicate over an interface to a wireless communications system, such as a mobile switching center (MSC) or mobile positioning controller (MPC). This interface may be based, for example, on a standard secure protocol such as the most recent version of the IS-41 or TCP/IP protocols. The formats, fields, and authentication aspects of these protocols are well known. The Wireless Location System supports a variety of command / response and informational messages over this interface that are designed to aid in the successful detection, demodulation, and triggering of wireless transmissions, as well as providing means to pass location records to the wireless communications system. In particular, this interface provides means for the Wireless Location System to obtain information about which wireless transmitters have been assigned to particular voice channel parameters at particular cell sites. Example messages supported by the Wireless Location System over this interface to the wireless communications system include the following:

Query on MIN / MDN / MSID / IMSI / TMSI Mapping – Certain types of wireless transmitters will transmit their identity in a familiar form that can be dialed over the telephone network. Other types of wireless transmitters transmit an identity that cannot be dialed, but which is translated into a number that can be dialed using a table inside of the wireless communications system. The transmitted identity is permanent in most cases, but can also be temporary. Users of location applications connected to the AP 14 typically prefer to place triggers onto the Tasking List using identities that can be dialed. Identities that can be dialed are typically known as Mobile Directory Numbers

(MDN). The other types of identities for which translation may be required includes Mobile Identity Number (MIN), Mobile Subscriber Identity (MSID), International Mobile Subscriber Identity (IMSI), and Temporary Mobile Subscriber Identity (TMSI). If the wireless communications system has enabled the use of encryption for any of the data fields in the messages transmitted by wireless transmitters, the Wireless Location System may also query for encryption information along with the identity information. The Wireless Location System includes means to query the wireless communications system for the alternate identities for a trigger identity that has been placed onto the Tasking List by a location application, or to query the wireless communications system for alternate identities for an identity that has been demodulated by an SCS 10. Other events can also trigger this type of query. For this type of query, typically the Wireless Location System initiates the command, and the wireless communications system responds.

Query / Command Change on Voice RF Channel Assignment – Many wireless transmissions on voice channels do not contain identity information. Therefore, when the Wireless Location System is triggered to perform location processing on a voice channel transmission, the Wireless Location System queries the wireless communication system to obtain the current voice channel assignment information for the particular transmitter for which the Wireless Location System has been triggered. For an AMPS transmission, for example, the Wireless Location System preferably requires the cell site, sector, and RF channel number currently in use by the wireless transmitter. For a TDMA transmission, for example, the Wireless Location System preferably requires the cell site, sector, RF channel number, and timeslot currently in use by the wireless transmitter. Other information elements that may be needed includes long code mask and encryption keys. In general, the Wireless Location System will initiate the command, and the wireless communications system will respond. However, the Wireless Location System will also accept a trigger command from the wireless communications system that contains the information detailed herein.

The timing on this command / response message set is very critical since voice channel handoffs can occur quite frequently in wireless communications systems. That is, the Wireless Location System will locate any wireless transmitter that is transmitting on a particular channel – therefore the Wireless Location System and the wireless communications system must jointly be certain that the identity of the wireless transmitter and the voice channel assignment information are in perfect synchronization. The Wireless Location System uses several means to achieve this objective. The Wireless Location System may, for example, query the voice channel assignment information for a particular wireless transmitter, receive the necessary RF data, then again query the voice channel assignment information for that same wireless transmitter, and then verify that the status of the wireless transmitter did not change during the time in which the RF data was being collected by the Wireless Location System. Location processing is not required to complete before the second query, since it is only important to verify that the correct RF data was received. The Wireless Location System may also, for example, as part of the first query command the wireless communications system to prevent a handoff from occurring for the particular wireless transmitter during the time period in which the Wireless Location System is receiving the RF data. Then, subsequent to collecting the RF data, the Wireless Location System will again query the voice channel assignment information for that same wireless transmitter, command the wireless communications system to again permit handoffs for said wireless transmitter and then verify that the status of the wireless transmitter did not change during the time in which the RF data was being collected by the Wireless Location System.

For various reasons, either the Wireless Location System or the wireless communications system may prefer that the wireless transmitter be assigned to another voice RF channel prior to performing location processing. Therefore, as part of the command / response sequence, the wireless communications system may instruct the Wireless Location System to temporarily suspend location processing until the wireless communications system has completed a handoff sequence with the wireless transmitter, and the wireless communications system has notified the Wireless Location System that RF data can be received, and the voice RF channel upon which the data can be received. Alternately, the Wireless Location System may determine that the particular voice RF channel which a particular wireless transmitter is currently using is unsuitable for obtaining an acceptable location estimate, and request that the wireless communications system command the wireless transmitter to handoff. Alternately, the Wireless Location System may request that the wireless communications system command the wireless transmitter to handoff to a series of voice RF channels in sequence in order to perform a series of location estimates, whereby the Wireless Location System can improve upon the accuracy of the location estimate through the series of handoffs; this method is further described later.

The Wireless Location System can also use this command / response message set to query the wireless communications system about the identity of a wireless transmitter that had been using a particular voice channel (and timeslot, etc.) at a particular cell site at a particular time. This enables the Wireless Location System to first perform location processing on transmissions without knowing the identities, and then to later determine the identity of the wireless transmitters making the transmissions and append this information to the location record. This particular inventive feature enables the use of automatic sequential location of voice channel transmissions.

Receive Triggers – The Wireless Location System can receive triggers from the wireless communications system to perform location processing on a voice channel transmission without knowing the identity of the wireless transmitter. This message set bypasses the Tasking List, and does not use the triggering mechanisms within the Wireless Location System. Rather, the wireless communications system alone determines which wireless transmissions to locate, and then send a command to the Wireless Location System to collect RF data from a particular voice channel at a particular cell site and to perform location processing. The Wireless Location System responds with a confirmation containing a timestamp when the RF data was collected. The Wireless Location System also responds with an appropriate format location record when location processing has completed. Based upon the time of the command to Wireless Location System and the response with the RF data collection timestamp, the wireless communications system determines whether the wireless transmitter status changed subsequent to the command and whether there is a good probability of successful RF data collection.

Make Transmit – The Wireless Location System can command the wireless communications system to force a particular wireless transmitter to make a transmission at a particular time, or within a prescribed range of times. The wireless communications system responds with a confirmation and a time or time range in which to expect the transmission. The types of transmissions that the Wireless Location System can force include, for example, audit responses and page responses. Using this message set, the Wireless Location System can also command the wireless communications system to force the wireless transmitter to transmit using a higher power level setting. In many cases, wireless transmitters will attempt to use the lowest power level settings when transmitting in order to conserve battery life. In order improve the accuracy of the location estimate, the Wireless Location System may prefer that the wireless transmitter use a higher power level setting. The wireless communications system will respond to the Wireless Location System with a confirmation that the higher power level setting will be used and a time or time range in which to expect the transmission.

Delay Wireless Communications System Response to Mobile Access – Some air interface protocols, such as CDMA, use a mechanism in which the wireless transmitter initiates transmissions on a channel, such as an Access Channel, for example, at the lowest or a very low power level setting, and then enters a sequence of steps in which (i) the wireless transmitter makes an access transmission; (ii) the wireless transmitter waits for a response from the wireless communications system; (iii) if no response is received by the wireless transmitter from the wireless communications system within a predetermined time, the wireless transmitter increases its power level setting by a predetermined amount, and then returns to step (i); (iv) if a response is received by the wireless transmitter from the wireless communications system within a predetermined time, the wireless transmitter then enters a normal message exchange. This mechanism is useful to ensure that the wireless transmitter uses only the lowest useful power level setting for transmitting and does not further waste energy or battery life. It is possible, however, that the lowest power level setting at which the wireless transmitter can successfully communicate with the wireless communications system is not sufficient to obtain an acceptable location estimate. Therefore, the Wireless Location System can command the wireless communications system to delay its response to these transmissions by a predetermined time or amount. This delaying action will cause the wireless transmitter to repeat the sequence of steps (i) through (iii) one or more times than normal with the result that one or more of the access transmissions will be at a higher power level than normal. The higher power level may preferably enable the Wireless Location System to determine a more accurate location estimate. The Wireless Location System may command this type of delaying action for either a particular wireless transmitter, for a particular type of wireless transmission (for example, for all '911' calls), for wireless transmitters that are at a specified range from the base station to which the transmitter is attempting to communicate, or for all wireless transmitters in a particular area.

Send Confirmation to Wireless Transmitter – The Wireless Location System does not include means within to notify the wireless transmitter of an action because the Wireless Location System cannot transmit; as described earlier the Wireless Location System can only receive transmissions. Therefore, if the Wireless Location System desires to send, for example, a confirmation tone upon the completion of a certain action, the Wireless Location System commands the wireless communications system to transmit a particular message. The message may include, for example, an audible confirmation tone, spoken message, or synthesized message to the wireless transmitter, or a text message sent via a short messaging service or a page. The Wireless Location System receives confirmation from the wireless communications system that the message has been accepted and sent to the wireless transmitter. This command / response message set is important in enabling the Wireless Location System to support certain end-user application functions such as Prohibit Location Processing.

Report Location Records – The Wireless Location System automatically reports location records to the wireless communications system for those wireless transmitters tasked to report to the wireless communications system, as well as for those transmissions that the wireless communications system initiated triggers. The Wireless Location System also reports on any historical location record queried by the wireless communications system and which the wireless communications system is authorized to receive.

Monitor Internal Wireless Communications System Interfaces, State Table

In addition to this above interface between the Wireless Location System and the wireless communications system, the Wireless Location System also includes means to monitor existing interfaces within the wireless communications system for the purpose of intercepting messages important to the Wireless Location System for identifying wireless transmitters and the RF channels in use by these transmitters. These interfaces may include, for example, the "a-interface" and "a-bis interface" used in wireless communications systems employing the GSM air interface protocol. These interfaces are well-known and published in various standards. By monitoring the bi-directional messages on these interfaces between base stations (BTS), base station controllers (BSC), and mobile switching centers (MSC), and other points, the Wireless Location System can obtain the same information about the assignment of wireless transmitters to specific channels as the wireless communications system itself knows. The Wireless Location System includes means to monitor these interfaces at various points. For example, the SCS 10 may monitor a BTS to BSC interface. Alternately, a TLP 12 or AP 14 may also monitor a BSC where a number of BTS to BSC interfaces have been concentrated. The interfaces internal to the wireless communications system are not encrypted and the layered protocols are known to those familiar with the art. The advantage to the Wireless Location System to monitoring these interfaces is that the Wireless Location System may not be required to independently detect and demodulate control channel messages from wireless transmitters. In addition, the Wireless Location System may obtain all necessary voice channel assignment information from these interfaces.

Using these means for a control channel transmission, the SCS 10 receives the transmissions as described earlier and records the control channel RF data into memory without performing detection and demodulation. Separately, the Wireless Location System monitors the messages occurring over prescribed interfaces within the wireless communications system, and causes a trigger in the Wireless Location System when the Wireless Location System discovers a message containing a trigger event. Initiated by the trigger event, the Wireless Location System determines the approximately time at which the wireless transmission occurred, and commands a first SCS 10 and a second SCS 10B to each search its memory for the start of transmission. This first SCS 10A chosen is an SCS that is either collocated with the base station to which the wireless transmitter had communicated, or an SCS which is adjacent to the base station to which the wireless transmitter had communicated. That is, the first SCS 10A is an SCS which would have been assigned the control channel as a primary channel. If the first SCS 10A successfully determines and reports the start of the transmission, then location processing proceeds normally, using the means described below. If the first SCS 10A cannot successfully determine the start of transmission, then the second SCS 10B reports the start of transmission, and then location processing proceeds normally.

The Wireless Location System also uses these means for voice channel transmissions. For all triggers contained in the Tasking List, the Wireless Location System monitors the prescribed interfaces for messages pertaining to those triggers. The messages of interest include, for example, voice channel assignment messages, handoff messages, frequency hopping messages, power up / power down messages, directed re-try messages, termination messages, and other similar action and status messages. The Wireless Location System continuously maintains a copy of the state and status of these wireless transmitters in a State Table in the AP 14. Each time that the Wireless Location System detects a message pertaining to one of the entries in the Tasking List, the Wireless Location System updates its own State Table. Thereafter, the Wireless Location System may trigger to perform location processing, such as on a regular time interval, and access the State Table to determine precisely which cell site, sector, RF channel, and timeslot is presently being used by the wireless transmitter. The example contained herein described the means by which the Wireless Location System interfaces to a GSM based wireless communications system. The Wireless Location System also supports similar functions with systems based upon other air interfaces.

For certain air interfaces, such as CDMA, the Wireless Location System also keeps certain identity information obtained from Access bursts in the control channel in the State Table; this information is later used for decoding the masks used for voice channels. For example, the CDMA air interface protocol uses the Electronic Serial Number (ESN) of a wireless transmitter to, in part, determine the long code mask used in the coding of voice channel transmissions. The Wireless Location System maintains this information in the State Table for entries in the Tasking List because many wireless transmitters may transmit the information only once; for example, many CDMA mobiles will only transmit their ESN during the first Access burst after the wireless transmitter become active in a geographic area. This ability to independently determine the long code mask is very useful in cases where an interface between the Wireless Location System and the wireless communications system is not operative and/or the Wireless Location System is not able to monitor one of the interfaces internal to the wireless communications system. The operator of the Wireless Location System may optionally set the Wireless Location System to maintain the identity information for all wireless transmitters. In addition to the above reasons, the Wireless Location System can provide the voice channel tracking for all wireless transmitters that trigger location processing by calling "911". As described earlier, the Wireless Location System uses dynamic tasking to provide location to a wireless transmitter for a prescribed time after dialing "911", for example. By maintaining the identity information for all wireless transmitters in the State Table, the Wireless Location System is able to provide voice channel tracking for all transmitters in the event of a prescribed trigger event, and not just those with prior entries in the Tasking List.

Applications Interface

Using the AP 14, the Wireless Location System supports a variety of standards based interfaces to end-user and carrier location applications using secure protocols such as TCP/IP, X.25, SS-7, and IS-41. Each interface between the AP 14 and an external application is a secure and authenticated connection that permits the AP 14 to positively verify the identity of the application that is connected to the AP 14. This is necessary because each connected application is granted only limited access to location records on a real-time and/or historical basis. In addition, the AP 14 supports additional command / response, real-time, and post-processing functions that are further detailed below. Access to these additional functions also requires authentication. The AP 14 maintains a user list and the authentication means associated with each user. No application can gain access to location records or functions for which the application does not have proper authentication or access rights. In addition, the AP 14 supports full logging of all actions taken by each application in the event that problems arise or a later investigation into actions is required. For each command or function in the list below, the AP 14 preferably supports a protocol in which each action or the result of each is confirmed, as appropriate.

Edit Tasking List – This command permits external applications to add, remove, or edit entries in the Tasking List, including any fields and flags associated with each entry. This command can be supported on a single entry basis, or a batch entry basis where a list of entries is included in a single command. The latter is useful, for example, in a bulk application such as location sensitive billing whereby larger volumes of wireless transmitters are being supported by the external application, and it is desired to minimize protocol overhead. This command can add or delete applications for a particular entry in the Tasking List, however, this command cannot delete an entry entirely if the entry also contains other applications not associated with or authorized by the application issuing the command.

Set Location Interval – The Wireless Location System can be set to perform location processing at any interval for a particular wireless transmitter, on either control or voice channels. For example, certain applications may require the location of a wireless transmitter every few seconds when the transmitter is engaged on a voice channel. When the wireless transmitter make an initial transmission, the Wireless Location System initially triggers using a standard entry in the Tasking List. If one of the fields or flags in this entry specifies updated location on a set interval, then the Wireless Location System creates a dynamic task in the Tasking List that is triggered by a timer instead of an identity or other transmitted criteria. Each time the timer expires, which can range from 1 second to several hours, the Wireless Location System will automatically trigger to locate the wireless transmitter. The Wireless Location System uses its interface to the wireless communications system to query status of the wireless transmitter, including voice call parameters as described earlier.

If the wireless transmitter is engaged on a voice channel, then the Wireless Location System performs location processing. If the wireless transmitter is not engaged in any existing transmissions, the Wireless Location System will command the wireless communications system to make the wireless transmitter immediately transmit. When the dynamic task is set, the Wireless Location System also sets an expiration time at which the dynamic task ceases.

End-User Addition / Deletion – This command can be executed by an end-user of a wireless transmitter to place the identity of the wireless transmitter onto the Tasking List with location processing enabled, to remove the identity of the wireless transmitter from the Tasking List and therefore eliminate identity as a trigger, or to place the identity of the wireless transmitter onto the Tasking List with location processing disabled. When location processing has been disabled by the end-user, known as Prohibit Location Processing then no location processing will be performed for the wireless transmitter. The operator of the Wireless Location System can optionally select one of several actions by the Wireless Location System in response to a Prohibit Location Processing command by the end user: (i) the disabling action can override all other triggers in the Tasking List, including a trigger due to an emergency call such as "911", (ii) the disabling action can override any other trigger in the Tasking List, except a trigger due to an emergency call such as "911", (iii) the disabling action can be overridden by other select triggers in the Tasking List. In the first case, the end-user is granted complete control over the privacy of the transmissions by the wireless transmitter, as no location processing will be performed on that transmitter for any reason. In the second case, the end-user may still receive the benefits of location during an emergency, but at no other times. In an example of the third case, an employer who is the real owner of a particular wireless transmitter can override an end-user action by an employee who is using the wireless transmitter as part of the job but who may not desire to be located. The Wireless Location System may query the wireless communications system, as described above, to obtain the mapping of the identity contained in the wireless transmission to other identities.

The additions and deletions by the end-user are effected by dialed sequences of characters and digits and pressing the "SEND" or equivalent button on the wireless transmitter. These sequences may be optionally chosen and made known by the operator of the Wireless Location System. For example, one sequence may be "*55 SEND" to disable location processing. Other sequences are also possible. When the end-user can dialed this prescribed sequence, the wireless transmitter will transmit the sequence over one of the prescribed control channels of the wireless communications system. Since the Wireless Location System independently detects and demodulates all reverse control channel transmissions, the Wireless Location System can independently interpret the prescribed dialed sequence and make the appropriate feature updates to the Tasking List, as described above. When the Wireless Location System has completed the update to the Tasking List, the Wireless Location System commands the wireless communications system to send a confirmation to the end-user. As described earlier, this may take the form of an audible tone, recorded or synthesized voice, or a text message. This command is executed over the interface between the Wireless Location System and the wireless communications system.

Command Transmit – This command allows external applications to cause the Wireless Location System to send a command to the wireless communications system to make a particular wireless transmitter, or group of wireless transmitters, transmit. This command may contain a flag or field that the wireless transmitter(s) should transmit immediately or at a prescribed time. This command has the effort of locating the wireless transmitter(s) upon command, since the transmissions will be detected, demodulated, and triggered, causing location processing and the generation of a location record. This is useful in eliminating or reducing any delay in determining location such as waiting for the next registration time period for the wireless transmitter or waiting for an independent transmission to occur.

External Database Query and Update – The Wireless Location System includes means to access an external database, to query the said external database using the identity of the wireless transmitter or other parameters contained in the transmission or the trigger criteria, and to merge the data obtained from the external database with the data generated by the Wireless Location System to create a new enhanced location record. The enhanced location record may then be forwarded to requesting applications. The external database may contain, for example, data elements such as customer information, medical information, subscribed features, application related information, customer account information, contact information, or sets of prescribed actions to take upon a location trigger event. The Wireless Location System may also cause updates to the external database, for example, to increment or decrement a billing counter associated with the provision of location services, or to update the external database with the latest location record associated with the particular wireless transmitter. The Wireless Location System contains means to performed the actions described herein on more than one external database. The list and sequence of external databases to access and the subsequent actions to take are contained in one of the fields contained in the trigger criteria in the Tasking List.

Random Anonymous Location Processing – The Wireless Location System includes means to perform large scale random anonymous location processing. This function is valuable to certain types of applications that require the gathering of a large volume of data about a population of wireless transmitters without consideration to the specific identities of the individual transmitters. Applications of this type include: RF Optimization, which enables wireless carriers to measure the performance of the wireless communications system by simultaneously determining location and other parameters of a transmission; Traffic Management, which enables government agencies and commercial concerns to monitor the flow of traffic on various highways using statistically significant samples of wireless transmitters travelling in vehicles; and Local Traffic Estimation, which enables commercial enterprises to estimate the flow of traffic around a particular area which may help determine the viability of particular businesses.

Applications requesting random anonymous location processing optionally receive location records from two sources: (i) a copy of location records generated for other applications, and (ii) location records which have been triggered randomly by the Wireless Location System without regard to any specific criteria. All of the location records generated from either source are forwarded with all of the identity and trigger criteria information removed from the location records; however, the requesting application(s) can determine whether the record was generated from the fully random process or is a copy from another trigger criteria. The random location records are generated by a low priority task within the Wireless Location System that performs location processing on randomly selected transmissions whenever processing and communications resources are available and would otherwise be unused at a particular instant in time. The requesting application(s) can specify whether the random location processing is performed over the entire coverage area of a Wireless Location System, over specific geographic areas such as along prescribed highways, or by the coverage areas of specific cell sites. Thus, the requesting application(s) can direct the resources of the Wireless Location System to those area of greatest interest to each application. Depending on the randomness desired by the application(s), the Wireless Location System can adjust preferences for randomly selecting certain types of transmissions, for example, registration messages, origination messages, page response messages, or voice channel transmissions.

Anonymous Tracking of a Geographic Group – The Wireless Location System includes means to trigger location processing on a repetitive basis for anonymous groups of wireless transmitters within a prescribed geographic area. For example, a particular location application may desire to monitor the travel route of a wireless transmitter over a prescribed period of time, but without the Wireless Location System disclosing the particular identity of the wireless transmitter. The period of time may be many hours, days, or weeks. Using the means, the Wireless Location System: randomly selects a wireless transmitter that initiates a transmission in the geographic area of interest to the application; performs location processing on the transmission of interest; irreversibly translates and encrypts the identity of the wireless transmitter into a new coded identifier; creates a location record using only the new coded identifier as an identifying means; forwards the location record to the requesting location application(s); and creates a dynamic task in the Tasking List for the wireless transmitter, where the dynamic task has an associated expiration time. Subsequently, whenever the prescribed wireless transmitter initiates transmission, the Wireless

Location System shall trigger using the dynamic task, perform location processing on the transmission of interest, irreversibly translate and encrypt the identity of the wireless transmitter into the new coded identifier using the same means as prior such that the coded identifier is the same, create a location record using the coded identifier, and forward the location record to the requesting location application(s). The means described herein can be combined with other functions of the Wireless Location System to perform this type of monitoring use either control or voice channel transmissions. Further, the means described herein completely preserve the private identity of the wireless transmitter, yet enables another class of applications that can monitor the travel patterns of wireless transmitters. This class of applications can be of great value in determining the planning and design of new roads, alternate route planning, or the construction of commercial and retail space.

Location Record Grouping, Sorting, and Labeling – The Wireless Location System include means to post-process the location records for certain requesting applications to group, sort, or label the location records. For each interface supported by the Wireless Location System, the Wireless Location System stores a profile of the types of data for which the application is both authorized and requesting, and the types of filters or post-processing actions desired by the application. Many applications, such as the examples contained herein, do not require individual location records or the specific identities of individual transmitters. For example, an RF optimization application derives more value from a large data set of location records for a particular cell site or channel than it can from any individual location record. For another example, a traffic monitoring application requires only location records from transmitters that are on prescribed roads or highways, and additionally requires that these records be grouped by section of road or highway and by direction of travel. Other applications may request that the Wireless Location System forward location records that have been formatted to enhance visual display appeal by, for example, adjusting the location estimate of the transmitter so that the transmitter's location appears on an electronic map directly on a drawn road segment rather than adjacent to the road segment. Therefore, the Wireless Location System preferably "snaps" the location estimate to the nearest drawn road segment.

The Wireless Location System can filter and report location records to an application for wireless transmitters communicating only on a particular cell site, sector, RF channel, or group of RF channels. Before forwarding the record to the requesting application, the Wireless Location System first verifies that the appropriate fields in the record satisfy the requirements. Records not matching the requirements are not forwarded, and records matching the requirements are forwarded. Some filters are geographic and must be calculated by the Wireless Location System. For example, the Wireless Location System can process a location record to determine the closest road segment and direction of travel of the wireless transmitter on the road segment. The Wireless Location System can then forward only records to the application that are determined to be on a particular road segment, and can further enhance the location record by adding a field containing the determined road segment. In order to determine the closest road segment, the Wireless Location System is provided with a database of road segments of interest by the requesting application. This database is stored in a table where each road segment is stored with a latitude and longitude coordinate defining the end point of each segment. Each road segment can be modeled as a straight or curved line, and can be modeled to support one or two directions of travel. Then for each location record determined by the Wireless Location System, the Wireless Location System compares the latitude and longitude in the location record to each road segment stored in the database, and determines the shortest distance from a modeled line connecting the end points of the segment to the latitude and longitude of the location record. The shortest distance is a calculated imaginary line orthogonal to the line connecting the two end points of the stored road segment. When the closest road segment has been determined, the Wireless Location System can further determine the direction of travel on the road segment by comparing the direction of travel of the wireless transmitter reported by the location processing to the orientation of the road segment. The direction that produces the smallest error with respect to the orientation of the road segments is then reported by the Wireless Location System.

Network Operations Console (NOC) 16

The NOC 16 is a network management system that permits operators of the Wireless Location System easy access to the programming parameters of the Wireless Location System. For example, in some cities, the Wireless Location System may contain many hundreds or even thousands of SCS's 10. The NOC is the most effective way to manage a large Wireless Location System, using graphical user interface capabilities. The NOC will also receive real time alerts if certain functions within the Wireless Location System are not operating properly. These real time alerts can be used by the operator to take corrective action quickly and prevent a degradation of location service. Experience with trials of the Wireless Location System show that the ability of the system to maintain good location accuracy over time is directly related to the operator's ability to keep the system operating within its predetermined parameters.

Location Processing

The Wireless Location System is capable of performing location processing using two different methods known as central based processing and station based processing. Both techniques were first disclosed in Patent Number 5,327,144, and are further enhanced in this specification. Location processing depends in part on the ability to accurately determine certain phase characteristics of the signal as received at multiple antennas and at multiple SCS's 10. Therefore, it is an object of the Wireless Location System to identify and remove sources of phase error that impede the ability of the location processing to determine the phase characteristics of the received signal. One source of phase error is inside of the wireless transmitter itself, namely the oscillator (typically a crystal oscillator) and the phase lock loops that allow the phone to tune to specific channels for transmitting. Lower cost crystal oscillators will generally have higher phase noise. Some air interface specifications, such as IS-136 and IS-95A, have specifications covering the phase noise with which a wireless telephone can transmit. Other air interface specifications, such as IS-553A, do not closely specify phase noise. It is therefore an object of the present invention to automatically reduce and/or eliminate a wireless transmitter's phase noise as a source of phase error in location processing, in part by automatically selecting the use of central based processing or station based processing. The automatic selection will also consider the efficiency with which the communications link between the SCS 10 and the TLP 12 is used, and the availability of DSP resources at each of the SCS 10 and TLP 12.

When using central based processing, the TDOA and FDOA determination and the multipath processing are performed in the TLP 12 along with the position and speed determination. This method is preferred when the wireless transmitter has a phase noise that is above a predetermined threshold. In these cases, central based processing is most effective in reducing or eliminating the phase noise of the wireless transmitter as a source of phase error because the TDOA estimate is performed using a digital representation of the actual RF transmission from two antennas, which may be at the same SCS 10 or different SCS's 10. In this method, those skilled in the art will recognize that the phase noise of the transmitter is a common mode noise in the TDOA processing, and therefore is self-canceling in the TDOA determination process. This method works best, for example, with many very low cost AMPS cellular telephones that have a high phase noise. The basic steps in central based processing include the steps recited below and represented in the flowchart of Figure 6:

a wireless transmitter initiates a transmission on either a control channel or a voice channel (step S50);

the transmission is received at multiple antennas and at multiple SCS's 10 in the Wireless Location System (step S51);

the transmission is converted into a digital format in the receiver connected to each SCS/antenna (step S52);

the digital data is stored in a memory in the receivers in each SCS 10 (step S53);

the transmission is demodulated (step S54);

the Wireless Location System determines whether to begin location processing for the transmission (step S55);

if triggered, the TLP 12 requests copies of the digital data from the memory in receivers at multiple SCS's 10 (step S56);

digital data is sent from multiple SCS's 10 to a selected TLP 12 (step S57);

the TLP 12 performs TDOA, FDOA, and multipath mitigation on the digital data from pairs of antennas (step S58);

the TLP 12 performs position and speed determination using the TDOA data, and then creates a location record and forwards the location record to the AP 14 (step S59).

The Wireless Location System uses a variable number of bits to represent the transmission when sending digital data from the SCS's 10 to the TLP 12. As discussed earlier, the SCS receiver digitizes wireless transmissions with a high resolution, or a high number of bits per digital sample in order to achieve a sufficient dynamic range. This is especially required when using wideband digital receivers, which may be simultaneously receiving signals near to the SCS 10A and far from the SCS 10B. For example, up to 14 bits may be required to represent a dynamic range of 84 dB. Location processing does not always require the high resolution per digital sample, however. Frequently, locations of sufficient accuracy are achievable by the Wireless Location System using a fewer number of bits per digital sample. Therefore, to minimize the implementation cost of the Wireless Location System by conserving bandwidth on the communication links between each SCS 10 and TLP 12, the Wireless Location System determines the fewest number of bits required to digitally represent a transmission while still maintaining a desired accuracy level. This determination is based, for example, on the particular air interface protocol used by the wireless transmitter, the SNR of the transmission, the degree to which the transmission has been perturbed by fading and/or multipath, and the current state of the processing and communication queues in each SCS 10. The number of bits sent from the SCS 10 to the TLP 12 are reduced in two ways: the number of bits per sample is minimized, and the shortest length, or fewest segments, of the transmission possible is used for location processing. The TLP 12 can use this minimal RF data to perform location processing and then compare the result with the desired accuracy level. This comparison is performed on the basis of a confidence interval calculation. If the location estimate does not fall within the desired accuracy limits, the TLP 12 will recursively request additional data from selected SCS's 10. The additional data may include an additional number of bits per digital sample and/or may include more segments of the transmission. This process of requesting additional data may continue recursively until the TLP 12 has achieved the prescribed location accuracy.

There are additional details to the basic steps described above. These details are described in prior Patent Numbers 5,327,144 and 5,608,410 in other parts of this specification. One enhancement to the processes described in earlier patents is the selection of a single reference SCS/antenna that is used for each baseline in the location processing. In prior art, baselines were determined using pairs of antenna sites around a ring. In the present Wireless Location System, the single reference SCS/antenna used is generally the highest SNR signal, although other criteria are also used as described below. The use of a high SNR reference aids central based location processing when the other SCS/antennas used in the location processing are very weak, such as at or below the noise floor (i.e. zero or negative signal to noise ratio). When station based location processing is used, the reference signal is a re-modulated signal, which is intentionally created to have a very high signal to noise ratio, further aiding location processing for very weak signals at other SCS/antennas. The actual selection of the reference SCS/antenna is described below.

The Wireless Location System mitigates multipath by first recursively estimating the components of multipath received in addition to the direct path component and then subtracting these components from the received signal. Thus the Wireless Location System models the received signal and compares the model to the actual received signal and attempts to minimize the difference between the two using a weighted least square difference. For each transmitted signal x(t) from a wireless transmitter, the received signal y(t) at each SCS/antenna is a complex combination of signals:

$y(t) = \sum x(t - \tau_n) a_n e^{j\omega(t - \tau n)}$, for all n = 0 to N;

where x(t) is the signal as transmitted by the wireless transmitter;
a_n and τ_n are the complex amplitude and delays of the multipath components;
N is the total number of multipath components in the received signal; and
a_0 and τ_0 are constants for the most direct path component.

The operator of the Wireless Location System empirically determines a set of constraints for each component of multipath that applies to the specific environment in which each Wireless Location System is operating. The purpose of the constraints is to limit the amount of processing time that the Wireless Location System spends optimizing the results for each multipath mitigation calculation. For example, the Wireless Location System may be set to determine only four components of multipath: the first component may be assumed to have a time delay in the range τ_{1A} to τ_{1B}; the second component may be assumed to have a time delay in the range τ_{2A} to τ_{2B}; the third component may be assumed to have a time delay in the range τ_{3A} to τ_{3B}; and similar for the fourth component; however the fourth component is a single value that effectively represents a complex combination of many tens of individual (and somewhat diffuse) multipath components whose time delays exceed the range of the third component. For ease of processing, the Wireless Location System transforms the prior equation into the frequency domain, and then solves for the individual components such that a weighted least squares difference is minimized.

When using station based processing, the TDOA and FDOA determination and multipath mitigation are performed in the SCS's 10, while the position and speed determination are typically performed in the TLP 12. The main advantage of station based processing, as described in Patent Number 5,327,144, is reducing the amount of data that is sent on the communication link between each SCS 10 and TLP 12. However, there may be other advantages as well. One new objective of the present invention is increasing the effective signal processing gain during the TDOA processing. As pointed out earlier, central based processing has the advantage of eliminating or reducing phase error caused by the phase noise in the wireless transmitter. However, no previous disclosure has addressed how to eliminate or reduce the same phase noise error when using station based processing. The present invention reduces the phase error and increases the effective signal processing gain using the steps recited below and shown in Figure 6:

a wireless transmitter initiates a transmission on either a control channel or a voice channel (step S60);

the transmission is received at multiple antennas and at multiple SCS's 10 in the Wireless Location System (step S61);

the transmission is converted into a digital format in the receiver connected to each antenna (step S62);

the digital data is stored in a memory in the SCS 10 (step S63);

the transmission is demodulated (step S64);

the Wireless Location System determines whether to begin location processing for the transmission (step S65);

if triggered, a first SCS 10A demodulates the transmission and determines an appropriate phase correction interval (step S66);

for each such phase correction interval, the first SCS 10A calculates an appropriate phase correction and amplitude correction, and encodes this phase correction parameter and amplitude correction parameter along with the demodulated data (step S67);

the demodulated data and phase correction and amplitude correction parameters are sent from the first SCS 10A to a TLP 12 (step S68);

the TLP 12 determines the SCS's 10 and receiving antennas to use in the location processing (step S69);

the TLP 12 sends the demodulated data and phase correction and amplitude correction parameters to each second SCS 10B that will be used in the location processing (step S70);

the first SCS 10 and each second SCS 10B creates a first re-modulated signal based upon the demodulated data and the phase correction and amplitude correction parameters (step S71);

the first SCS 10A and each second SCS 10B performs TDOA, FDOA, and multipath mitigation using the digital data stored in memory in each SCS 10 and the first re-modulated signal (step S72);

the TDOA, FDOA, and multipath mitigation data are sent from the first SCS 10A and each second SCS 10B to the TLP 12 (step S73);

the TLP 12 performs position and speed determination using the TDOA data (step S74); and

the TLP 12 creates a location record, and forwards the location record to the AP 14 (step S75).

The advantages of determining phase correction and amplitude correction parameters are most obvious in the location of CDMA wireless transmitters based upon IS-95A. As is well known, the reverse transmissions from an IS-95A transmitter are sent using non-coherent modulation. Most CDMA base stations only integrate over a single bit interval because of the non-coherent modulation. For a CDMA Access Channel, with a bit rate of 4800 bits per second, there are 256 chips sent per bit, which permits an integration gain of 24 dB. Using the technique described above, the TDOA processing in each SCS 10 may integrate, for example, over a full 160 millisecond burst (196,608 chips) to produce an integration gain of 53 dB. This additional processing gain enables the present invention to detect and locate CDMA transmissions using multiple SCS's 10, even if the base stations collocated with the SCS's 10 cannot detect the same CDMA transmission.

For a particular transmission, if either the phase correction parameters or the amplitude correction parameters are calculated to be zero, or are not needed, then these parameters are not sent in order to conserve on the number of bits transmitted on the communications link between each SCS 10 and TLP 12. In another embodiment of the invention, the Wireless Location System may use a fixed phase correction interval for a particular transmission or for all transmissions of a particular air interface protocol, or for all transmissions made by a particular type of wireless transmitter. This may, for example, be based upon empirical data gathered over some period of time by the Wireless Location System showing a reasonable consistency in the phase noise exhibited by various classes of transmitters. In these cases, the SCS 10 may save the processing step of determining the appropriate phase correction interval.

Those skilled in the art will recognize that there are many ways of measuring the phase noise of a wireless transmitter. In one embodiment, a pure, noiseless re-modulated copy of the signal received at the first SCS 10A may be digitally generated by DSP's in the SCS, then the received signal may be compared against the pure signal over each phase correction interval and the phase difference may be measured directly. In this embodiment, the phase correction parameter will be calculated as the negative of the phase difference over that phase correction interval. The number of bits required to represent the phase correction parameter will vary with the magnitude of the phase correction parameter, and the number of bits may vary for each phase correction interval. It has been observed that some transmissions, for example, exhibit greater phase noise early in the transmission, and less phase noise in the middle of and later in the transmission.

Station based processing is most useful for wireless transmitters that have relatively low phase noise. Although not necessarily required by their respective air interface standards, wireless telephones that use the TDMA, CDMA, or GSM protocols will typically exhibit lower phase noise. As the phase noise of a wireless transmitter increases, the length of a phase correction interval may decrease and/or the number of bits required to represent the phase correction parameters increases. Station based processing is not effective when the number of bits required to represent the demodulated data plus the phase correction and amplitude parameters exceeds a predetermined proportion of the number of bits required to perform central based processing. It is therefore an object of the present invention to automatically determine for each transmission for which a location is desired whether to process the location using central based processing or station based processing. The steps in making this determination are recited below and shown in Figure 7:

a wireless transmitter initiates a transmission on either a control channel or a voice channel (step S80);

the transmission is received at a first SCS 10A (step S81);

the transmission is converted into a digital format in the receiver connected to each antenna (step S82);

the Wireless Location System determines whether to begin location processing for the transmission (step S83);

if triggered, a first SCS 10A demodulates the transmission and estimates an appropriate phase correction interval and the number of bits required to encode the phase correction and amplitude correction parameters (step S84);

the first SCS 10A then estimates the number of bits required for central based processing;

based upon the number of bits required for each respective method, the SCS 10 or the TLP 12 determine whether to use central based processing or station based processing to perform the location processing for this transmission (step S85).

In another embodiment of the invention, the Wireless Location System may always use central based processing or station based processing for all transmissions of a particular air interface protocol, or for all transmissions made by a particular kind of wireless transmitter. This may, for example, be based upon empirical data gathered over some period of time by the Wireless Location System showing a reasonable consistency in the phase noise exhibited by various classes of transmitters. In these cases, the SCS 10 and/or the TLP 12 may be saved the processing step of determining the appropriate processing method.

A further enhancement of the present invention, used for both central based processing and station based processing, is the use of threshold criteria for including baselines in the final determination of location and velocity of the wireless transmitter. For each baseline, the Wireless Location System calculates a number of parameters that include: the SCS/antenna port used with the reference SCS/antenna in calculating the baseline, the peak, average, and variance in the power of the transmission as received at the SCS/antenna port used in the baseline and over the interval used for location processing, the correlation value from the cross-spectra correlation between the SCS/antenna used in the baseline and the reference SCS/antenna, the delay value for the baseline, the multipath mitigation parameters, the residual values remaining after the multipath mitigation calculations, the contribution of the SCS/antenna to the weighted GDOP in the final location solution, and a measure of the quality of fit of the baseline if included in the final location solution. Each baseline is included in the final location solution is each meets or exceeds the threshold criteria for each of the parameters described herein. A baseline may be excluded from the location solution if it fails to meet one or more of the threshold criteria. Therefore, it is frequently possible that the number of SCS/antennas actually used in the final location solution is less than the total number considered.

Previous Patent Numbers 5,327,144 and 5,608,410 disclosed a method by which the location processing minimized the least square difference (LSD) value of the following equation:

$LSD = [Q_{12}(Delay\_T_{12}-Delay\_O_{12})^2 + Q_{13}(Delay\_T_{13}-Delay\_O_{13})^2 + \ldots + Q_{xy}(Delay\_T_{xy}-Delay\_O_{xy})^2$

In the present implementation, this equation has been rearranged to the following form in order to make the location processing code more efficient:

$LSD = \Sigma\ (TDOA_{0i} - \tau_i + \tau_0)^2 w_i^2$; over all i=1 to N-1

where N = number of SCS/antennas used in the location processing;
$TDOA_{0i}$ = the TDOA to the i[th] site from reference site 0;
τ_i = the theoretical line of sight propagation time from the wireless transmitter to the i[th] site;
τ_0 = the theoretical line of sight propagation time from the transmitter to the reference; and
w_i = the weight, or quality factor, applied to the i[th] baseline.

In the present implementation, the Wireless Location System also uses another alternate form of the equation that can aid in determining location solutions when the reference signal is not very strong or when it is likely that a bias would exist in the location solution using the prior form of the equation:

$LSD' = \Sigma\ (TDOA_{0i} - \tau_i)^2 w_i^2 - b^2\ \Sigma\ w_i^2$; over all i=0 to N-1

Where N = number of SCS/antennas used in the location processing;
$TDOA_{0i}$ = the TDOA to the i[th] site from reference site 0;
$TDOA_{00}$ = is assumed to be zero;
τ_i = the theoretical line of sight propagation time from the wireless transmitter to the i[th] site;
b = a bias that is separately calculated for each theoretical point that minimizes LSD' at that theoretical point; and
w_i = the weight, or quality factor, applied to the i[th] baseline.

The LSD' form of the equation offers an easier means of removing a bias in location solutions at the reference site by making w_0 equal to the maximum value of the other weights or basing w_0 on the relative signal strength at the reference site. Note that if w_0 is much larger than the other weights, then b is approximately equal to τ_0. In general, the weights, or quality factors are based on similar criteria to that discussed above for the threshold criteria in including baselines. That is, the results of the criteria calculations are used for weights and when the criteria falls below threshold the weight is then set to zero and is effectively not included in the determination of the final location solution.

Antenna Selection Process for Location Processing

Previous inventions and disclosures, such as those listed above, have described techniques in which a first, second, or possibly third antenna site, cell site, or base station are required to determine location. Patent number 5,608,410 further discloses a Dynamic Selection Subsystem (DSS) that is responsible for determining which data frames from which antenna site locations will be used to calculate the location of a responsive transmitter. In the DSS, if data frames are received from more than a threshold number of sites, the DSS determines which are candidates for retention or exclusion, and then dynamically organizes data frames for location processing. The DSS prefers to use more than the minimum number of antenna sites so that the solution is over-determined. Additionally, the DSS assures that all transmissions used in the location processing were received from the same transmitter and from the same transmission.

The preferred embodiments of the prior inventions had several limitations, however. First, either only one antenna per antenna site (or cell site) is used, or the data from two or four diversity antennas were first combined at the antenna site (or cell site) prior to transmission to the central site. Additionally, all antenna sites that received the transmission sent data frames to the central site, even if the DSS later discarded the data frames. Thus, some communications bandwidth may have been wasted sending data that was not used.

The present inventors have determined that while a minimum of two or three sites are required in order determine location, the actual selection of antennas and SCS's 10 to use in location processing can have a significant effect on the results of the location processing. In addition, it is advantageous to include the means to use more than one antenna at each SCS 10 in the location processing. The reason for using data from multiple antennas at a cell site independently in the location processing is that the signal received at each antenna is uniquely affected by multipath, fading, and other disturbances. It is well known in the field that when two antennas are separated in distance by more than one wavelength, then each antenna will receive the signal on an independent path. Therefore, there is frequently additional and unique information to be gained about the location of the wireless transmitter by using multiple antennas, and the ability of the Wireless Location System to mitigate multipath is enhanced accordingly.

It is therefore an object of the present invention to provide an improved method for using the signals received from more than one antenna at an SCS 10 in the location processing. It is a further object to provide a method to improve the dynamic process used to select the cooperating antennas and SCS's 10 used in the location processing. The first object is achieved by providing means within the SCS 10 to select and use any segment of data collected from any number of antennas at an SCS in the location processing. As described earlier, each antenna at a cell site is connected to a receiver internal to the SCS 10. Each receiver converts signals received from the antenna into a digital form, and then stores the digitized signals temporarily in a memory in the receiver. The TLP 12 has been provided with means to direct any SCS 10 to retrieve segments of data from the temporary memory of any receiver, and to provide the data for use in location processing. The second object is achieved by providing means within the Wireless Location System to monitor a large number of antennas for reception of the transmission that the Wireless Location System desires to locate, and then selecting a smaller set of antennas for use in location processing based upon a predetermined set of parameters. One example of this selection process is represented by the flowchart of Figure 8:

a wireless transmitter initiates a transmission on either a control channel or a voice channel (step S90);

the transmission is received at multiple antennas and at multiple SCS's 10 in the Wireless Location System (step S91);

the transmission is converted into a digital format in the receiver connected to each antenna (step S92);

the digital data is stored in a memory in each SCS 10 (step S93);

the transmission is demodulated at at least one SCS 10A and the channel number on which the transmission occurred and the cell site and sector serving the wireless transmitter is determined (step S94);

based upon the serving cell site and sector, one SCS 10A is designated as the 'primary' SCS 10 for processing that transmission (step S95);

the primary SCS 10A determines a timestamp associated with the demodulated data (step S96);

the Wireless Location System determines whether to begin location processing for the transmission (step S97);

if location processing is triggered, the Wireless Location System determines a candidate list of SCS's 10 and antennas to use in the location processing (step S98);

each candidate SCS/antenna measures and reports several parameters in the channel number of the transmission and at the time of the timestamp determined by the primary SCS 10A (step S99);

the Wireless Location System orders the candidate SCS/antennas using specified criteria and selects a reference SCS/antenna and a processing list of SCS/antennas to use in the location processing (step S100); and

the Wireless Location System proceeds with location processing as described earlier, using data from the processing list of SCS/antennas (step S101).

Selecting Primary SCS/Antenna

The process for choosing the 'primary' SCS/antenna is critical, because the candidate list of SCS's 10 and antennas 10-1 is determined in part based upon the designation of the primary SCS/antenna. When a wireless transmitter makes a transmission on a particular RF channel, the transmission frequently can propagate many miles before the signal attenuates below a level at which it can be demodulated. Therefore, there are frequently many SCS/antennas capable of demodulating the signal. This especially occurs is urban and suburban areas where the frequency re-use pattern of many wireless communications systems can be quite dense. For example, because of the high usage rate of wireless and the dense cell site spacing, the present inventors have tested wireless communications systems in which the same RF control channel and digital color code were used on cell sites spaced about one mile apart. Because the Wireless Location System is independently demodulating these transmissions, the Wireless Location System frequently can demodulate the same transmission at two, three, or more separate SCS/antennas. The Wireless Location System detects that the same transmission has been demodulated multiple times at multiple SCS/antennas when the Wireless Location System receives multiple demodulated data frames sent from different SCS/antennas, each with a number of bit errors below a predetermined bit error threshold, and with the demodulated data matching within an acceptable limit of bit errors, and all occurring within a predetermined interval of time.

When the Wireless Location System detects demodulated data from multiple SCS/antennas, it examines the following parameters to determine which SCS/antenna shall be designated the primary SCS: average SNR over the transmission interval used for location processing, the variance in the SNR over the same interval, correlation of the beginning of the received transmission against a pure pre-cursor (i.e. for AMPS, the dotting and Barker code), the number of bit errors in the demodulated data, and the magnitude and rate of change of the SNR from just before the on-set of the transmission to the on-set of the transmission, as well as other similar parameters. The average SNR is typically determined at each SCS/antenna either over the entire length of the transmission to be used for location processing, or over a shorter interval. The average SNR over the shorter interval can be determined by performing a correlation with the dotting sequence and/or Barker code and/or sync word, depending on the particular air interface protocol, and over a short range of time before, during, and after the timestamp reported by each SCS 10. The time range may typically be +/-200 microseconds centered at the timestamp, for example. The Wireless Location System will generally order the SCS/antennas using the following criteria, each of which may be weighted (multiplied by an appropriate factor) when combining the criteria to determine the final decision: SCS/antennas with a lower number of bit errors are preferred to SCS/antennas with a higher number of bit errors, average SNR for a given SCS/antenna must be greater than a predetermined threshold to be designated as the primary; SCS/antennas with higher average SNR are