Examiner-Initiated Interview Summary	**Application No.** 16/099,390	**Applicant(s)** DEENOO et al.	
	Examiner David M OVEISSI	**Art Unit** 2415	**AIA (FITF) Status** Yes

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

(1) David M. OVEISSI. (3) _____.

(2) David j Edmondson. (4) _____.

Date of Interview: 07 October 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: _____.

Identification of prior art discussed: _____.

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...)

See Continuation Sheet.

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

/MANSOUR OVEISSI/
Primary Examiner, Art Unit 2415

Continuation of Substance of Interview including description of the general nature of what was agreed to if an agreement was reached, or any other comments: The newly amended limitation "…wherein the one or more communication parameters include a frequency band of the transmission or a quality of a downlink signal…", raise new issues that would require further consideration and search. Examiner has found the reference Deng et al. (US 2019/0104549 A1), that examiner believes reads on the newly amended limitation (see paragraph [0138]).
[0138] When an mWTRU camps on an SCmB, it may subsequently receive a system information broadcast (SIB) specific to the mmW downlink beam configuration parameters that may include but are not limited to the following: mmW sector identity, the number of downlink transmit narrow beams per sector, BSRS frequency allocation, BSRS sequence configuration, BSRS periodicity, common PDDCCH transport format, common PDDCCH frequency allocation, common PDCCCH periodicity, and the like.

# AFCP 2.0 Decision	Application No.	Applicant(s)	
	16/099,390	DEENOO et al.	
	Examiner	**Art Unit**	**AIA (FITF) Status**
	David M OVEISSI	2415	Yes

This is in response to the After Final Consideration Pilot request filed 28 September 2020.

1. **Improper Request** – The AFCP 2.0 request is improper for the following reason(s) and the after final amendment submitted with the request will be treated under pre-pilot procedure.

   ☐ An AFCP 2.0 request form PTO/SB/434 (or equivalent document) was not submitted.

   ☐ A non-broadening amendment to at least one independent claim was not submitted.

   ☐ The request is not the first proper AFCP 2.0 request submitted in response to the most recent final rejection.

   ☐ Other: _____

2. **Proper Request**

   A. After final amendment submitted with the request will not be treated under AFCP 2.0.
   The after final amendment cannot be reviewed and a search conducted within the guidelines of the pilot program.

   ☐ The after final amendment will be treated under pre-pilot procedure.

   B. Updated search and/or completed additional consideration.
   The examiner performed an updated search and/or completed additional consideration of the after final amendment within the time authorized for the pilot program. The result(s) of the updated search and/or completed additional consideration are:

   ☐ 1. All of the rejections in the most recent final Office action are overcome and a Notice of Allowance is issued herewith.

   ☐ 2. The after final amendment would not overcome all of the rejections in the most recent final Office action . See attached interview summary for further details.

   ☑ 3. The after final amendment was reviewed, and it raises a new issue(s). See attached interview summary for further details.

   ☐ 4. The after final amendment raises new issues, but would overcome all of the rejections in the most recent final Office action. A decision on determining allowability could not be made within the guidelines of the pilot. See attached interview summary for further details, including any newly discovered prior art.

   ☐5. Other: _____

Examiner Note: Please attach an interview summary when necessary as described above.

DO NOT ENTER: /M.O/

10/07/2020

DOCKET NO: 11574US05

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

IN RE APPLICATION OF	:
YUGESWAR DEENOO	: EXAMINER: OVEISSI, MANSOUR
SERIAL NO: 16/099,390	:
FILED: NOVEMBER 6, 2018	: GROUP ART UNIT: 2415
FOR: DISTRIBUTED CONTROL IN WIRELESS SYSTEMS	:

AMENDMENT UNDER 37 C.F.R. § 1.116

COMMISSIONER FOR PATENTS
ALEXANDRIA, VIRGINIA 22313

Commissioner:

In response to the Office Action dated August 14, 2020, and pursuant to the AFCP 2.0 request filed herewith, the following is submitted in connection with the above-identified application.

Amendments to the claims begin on page 2 of this paper.

Remarks/arguments begin on page 13 of this paper.

Request for Continued Examination (RCE) Transmittal

Address to:
Mail Stop RCE
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Application Number	16/099,390
Filing Date	06 Nov 2018
First Named Inventor	Yugeswar DEENOO
Art Unit	2415 Confirmation No. 4717
Examiner Name	OVEISSI, MANSOUR
Attorney Docket Number	11574US05

This is a Request for Continued Examination (RCE) under 37 CFR 1.114 of the above-identified application.
Request for Continued Examination (RCE) practice under 37 CFR 1.114 does not apply to any utility or plant application filed prior to June 8, 1995, or to any design application. See Instruction Sheet for RCEs (not to be submitted to the USPTO) on page 2.

1. **Submission required under 37 CFR 1.114** Note: If the RCE is proper, any previously filed unentered amendments and amendments enclosed with the RCE will be entered in the order in which they were filed unless applicant instructs otherwise. If applicant does not wish to have any previously filed unentered amendment(s) entered, applicant must request non-entry of such amendment(s).
   - a. ☑ Previously submitted. If a final Office action is outstanding, any amendments filed after the final Office action may be considered as a submission even if this box is not checked.
     - i. ☐ Consider the arguments in the Appeal Brief or Reply Brief previously filed on ____________
     - ii. ☐ Other ____________
   - b. ☐ Enclosed
     - i. ☐ Amendment/Reply
     - ii. ☐ Affidavit(s)/ Declaration(s)
     - iii. ☐ Information Disclosure Statement (IDS)
     - iv. ☐ Other ____________
2. **Miscellaneous**
   - a. ☐ Suspension of action on the above-identified application is requested under 37 CFR 1.103(c) for a period of ______ months. (Period of suspension shall not exceed 3 months; Fee under 37 CFR 1.17(i) required)
   - b. ☐ Other ____________
3. **Fees** The RCE fee under 37 CFR 1.17(e) is required by 37 CFR 1.114 when the RCE is filed.
   - a. ☑ The Director is hereby authorized to charge the following fees, any underpayment of fees, or credit any overpayments, to Deposit Account No. 602325.
     - i. ☐ RCE fee required under 37 CFR 1.17(e)
     - ii. ☐ Extension of time fee (37 CFR 1.136 and 1.17)
     - iii. ☐ Other ____________
   - b. ☐ Check in the amount of $ ____________ enclosed
   - c. ☐ Payment by credit card (Form PTO-2038 enclosed)
   - d. ■ Payment by EFS-Web

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT REQUIRED

Signature	/david j edmondson/	Date	2020-11-24
Name (Print/Type)	David J. Edmondson	Registration No.	35,126

CERTIFICATE OF MAILING OR TRANSMISSION

I hereby certify that this correspondence is being EFS-Web transmitted to the United States Patent and Trademark Office (USPTO), deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Mail Stop RCE, Commissioner for Patents, P. O. Box 1450, Alexandria, VA 22313-1450 or facsimile transmitted to the USPTO on the date shown below.

Signature			
Name (Print/Type)		Date	

Electronic Patent Application Fee Transmittal

Application Number:	16099390
Filing Date:	06-Nov-2018
Title of Invention:	DISTRIBUTED CONTROL IN WIRELESS SYSTEMS
First Named Inventor/Applicant Name:	Yugeswar DEENOO
Filer:	Zachary S. Stern/Kelly Elam
Attorney Docket Number:	11574US05

Filed as Large Entity

Filing Fees for U.S. National Stage under 35 USC 371

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($)
Extension - 1 month with $0 paid	1251	1	220	220
Miscellaneous:				
RCE- 1ST REQUEST	1801	1	1360	1360
		Total in USD ($)		**1580**

Electronic Acknowledgement Receipt

EFS ID:	41220243
Application Number:	16099390
International Application Number:	
Confirmation Number:	4717
Title of Invention:	DISTRIBUTED CONTROL IN WIRELESS SYSTEMS
First Named Inventor/Applicant Name:	Yugeswar DEENOO
Customer Number:	154930
Filer:	Zachary S. Stern/Kelly Elam
Filer Authorized By:	Zachary S. Stern
Attorney Docket Number:	11574US05
Receipt Date:	24-NOV-2020
Filing Date:	06-NOV-2018
Time Stamp:	19:57:26
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$1580
RAM confirmation Number	E2020ANJ57424582
Deposit Account	602325
Authorized User	Kelly Elam

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

37 CFR 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		11574US05_RCE-EOT_signed.pdf	265370 792bd290296191f574caf13b512859094847a463	yes	2

Multipart Description/PDF files in .zip description

Document Description	Start	End
Extension of Time	2	2
Request for Continued Examination (RCE)	1	1

Warnings:

Information:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
2	Fee Worksheet (SB06)	fee-info.pdf	32678 ce77c3bc30273820a4b2bc1a2c9749780b430338	no	2

Warnings:

Information:

Total Files Size (in bytes): 298048

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.

PETITION FOR EXTENSION OF TIME UNDER 37 CFR 1.136(a)	Docket Number (Optional) 11574US05
Application Number 16/099,390	Filed 06 Nov 2018
For DISTRIBUTED CONTROL IN WIRELESS SYSTEMS	
Art Unit 2415	Examiner OVEISSI, MANSOUR

This is a request under the provisions of 37 CFR 1.136(a) to extend the period for filing a reply in the above-identified application.

The requested extension and fee are as follows (check time period desired and enter the appropriate fee below):

	Fee	Small Entity Fee	Micro Entity Fee	
☑ One month (37 CFR 1.17(a)(1))	$220	$110	$55	$ 220.00
☐ Two months (37 CFR 1.17(a)(2))	$640	$320	$160	$
☐ Three months (37 CFR 1.17(a)(3))	$1,480	$740	$370	$
☐ Four months (37 CFR 1.17(a)(4))	$2,320	$1,160	$580	$
☐ Five months (37 CFR 1.17(a)(5))	$3,160	$1,580	$790	$

☐ Applicant asserts small entity status. See 37 CFR 1.27.

☐ Applicant certifies micro entity status. See 37 CFR 1.29.
Form PTO/SB/15A or B or equivalent must either be enclosed or have been submitted previously.

☐ A check in the amount of the fee is enclosed.

☐ Payment by credit card. Form PTO-2038 is attached.

☐ The Director has already been authorized to charge fees in this application to a Deposit Account.

☑ The Director is hereby authorized to charge any fees which may be required, or credit any overpayment, to Deposit Account Number 602325.

☑ Payment made via EFS-Web.

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

I am the

☐ applicant.

☑ attorney or agent of record. Registration number 35,126.

☐ attorney or agent acting under 37 CFR 1.34. Registration number ______.

/david j edmondson/	2020-11-24
Signature	Date
David J. Edmondson	571-376-6333
Typed or printed name	Telephone Number

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. Submit multiple forms if more than one signature is required, see below*.

☑ * Total of ______ forms are submitted.

PTO/SB/06 (09-11)
Approved for use through 1/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 16/099,390	Filing Date 11/06/2018	☐ To be Mailed

ENTITY: ☑ LARGE ☐ SMALL ☐ MICRO

APPLICATION AS FILED - PART I

	(Column 1)	(Column 2)			
FOR	NUMBER FILED	NUMBER EXTRA		RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A		N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A		N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*		x $100 =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*		x $460 =	
☐ 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).				
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))					
* If the difference in column 1 is less than zero, enter "0" in column 2.				TOTAL	

APPLICATION AS AMENDED - PART II

		(Column 1)		(Column 2)	(Column 3)			
AMENDMENT	11/24/2020	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA		RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 40	Minus	** 40	= 0		x $100 =	0
	Independent (37 CFR 1.16(h))	* 4	Minus	*** 4	= 0		x $480 =	0
	☐ Application Size Fee (37 CFR 1.16(s))							
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							
							TOTAL ADD'L FEE	0

		(Column 1)		(Column 2)	(Column 3)			
AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA		RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=		x $0 =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=		x $0 =	
	☐ Application Size Fee (37 CFR 1.16(s))							
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							
							TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.	LIE
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".	/PEARLIE A FENNELL/
*** 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 number found in the appropriate box in column 1.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**		
	Application Number	16099390
	Filing Date	2018-11-06
	First Named Inventor	Yugeswar DEENOO
	Art Unit	2415
	Examiner Name	OVEISSI, MANSOUR
	Attorney Docket Number	11574US05

U.S.PATENTS

Remove

Examiner Initial*	Cite No	Patent Number	Kind Code1	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Patent citation information please click the Add button. Add

U.S.PATENT APPLICATION PUBLICATIONS

Remove

Examiner Initial*	Cite No	Publication Number	Kind Code1	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20150208443	A1	2015-07-23	Jung et al.	

If you wish to add additional U.S. Published Application citation information please click the Add button. Add

FOREIGN PATENT DOCUMENTS

Remove

Examiner Initial*	Cite No	Foreign Document Number3	Country Code2 i	Kind Code4	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T5
	1	2013/086164	WO	A1	2013-06-13	INTERDIGITAL PATENT HOLDINGS, INC.		
	2	2987276	EP	A1	2016-02-24	TELEFONAKTIEBOLAG ET LM ERICSSON (PUBL)		
	3	2419213	RU	C2	2011-05-20	QUALCOMM INC	English Translation attached	X

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number: 16099390
	Filing Date: 2018-11-06
	First Named Inventor: Yugeswar DEENOO
	Art Unit: 2415
	Examiner Name: OVEISSI, MANSOUR
	Attorney Docket Number: 11574US05

	4	2446575	RU	C2	2012-03-27	SAJBIM INK	English Translation attached	☒
	5	2254682	RU	C1	2005-06-20	AIRGAIN, INC.	English Translation attached	☒

If you wish to add additional Foreign Patent Document citation information please click the Add button Add

NON-PATENT LITERATURE DOCUMENTS Remove

Examiner Initials*	Cite No	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, pages(s), volume-issue number(s), publisher, city and/or country where published.	T5
	1	Office Action issued on August 13, 2020, in corresponding Russian patent Application No. 1811537, 15 pages.	☒

If you wish to add additional non-patent literature document citation information please click the Add button Add

EXAMINER SIGNATURE

Examiner Signature		Date Considered	

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

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16099390
	Filing Date	2018-11-06
	First Named Inventor	Yugeswar DEENOO
	Art Unit	2415
	Examiner Name	OVEISSI, MANSOUR
	Attorney Docket Number	11574US05

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

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. See 37 CFR 1.97(e)(1).

OR

☐ 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 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

See attached certification statement.

The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/david j edmondson/	Date (YYYY-MM-DD)	2020-11-25
Name/Print	David J. Edmondson	Registration Number	35,126

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 the Freedom of Information Act requires disclosure of these record s.

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 inspections 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.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
13 June 2013 (13.06.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/086164 A1

(51) International Patent Classification:
H04W 48/16 (2009.01) *H04W 36/00* (2009.01)
H04W 48/12 (2009.01) *H04W 36/14* (2009.01)

(21) International Application Number:
PCT/US2012/068206

(22) International Filing Date:
6 December 2012 (06.12.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/568,639 8 December 2011 (08.12.2011) US

(71) Applicant: **INTERDIGITAL PATENT HOLDINGS, INC.** [US/US]; 200 Bellevue Parkway, Suite 300, Wilmington, Delaware 19809 (US).

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(54) Title: METHOD AND APPARATUS FOR A MILLIMETER WAVE COMMUNICATION SYSTEM

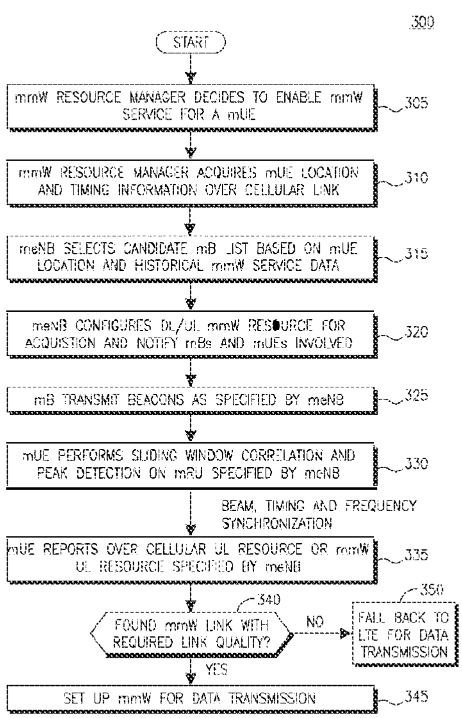

FIG. 3

(57) **Abstract**: Methods and apparatus for establishment of a milli-meter Wave (mmW) link communication include initial selection of candidate mmW Base stations (mBs) and configuration of mmW acquisition resources and procedures, both with the assistance of the cellular network. Further methods transmit mmW acquisition beacons, process mmW acquisition beacons to achieve mmW beam alignment and timing synchronization, and uplink (UL) reporting via cellular or mmW links. In an example, a mmW wireless transmit/receive unit (WTRU) transmits millimeter wave (mmW) WTRU (mmW WTRU) information over a cellular system to a base station, receives a candidate list of candidate mmW base stations (mB) including mmW acquisition start timing information and calculates correlation values around the received mmW acquisition start timing information for the mBs in the candidate list. The mmw WTRU performs sliding window correlations using signature sequences corresponding to mBs and beams in the candidate list.

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METHOD AND APPARATUS FOR A MILLIMETER WAVE COMMUNICATION SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. provisional application No. 61/568,639, filed December 8, 2011, the contents of which is hereby incorporated by reference herein.

BACKGROUND

[0002] The third generation partnership program (3GPP) introduced long term evolution (LTE) to increase cellular network bandwidth for anticipated mobile data demand. However, the projected mobile data demand growth may output the capacity of even LTE-Advanced (LTE-A). The delivery of high speed mobile data may be implemented using millimeter wave (mmW). For example, further generations of high speed mobile data may be delivered using 60 GHz mmW.

SUMMARY

[0003] Described herein are methods and systems for a millimeter wave (mmW) communication system. The methods include initial selection of candidate mmW Base stations (mBs) and configuration of mmW acquisition resources and procedures, both with the assistance of the cellular network. Further methods transmit mmW acquisition beacons, process mmW acquisition beacons to achieve mmW beam alignment and timing synchronization, and uplink (UL) reporting via cellular or mmW links. In an example, a mmW wireless transmit/receive unit (WTRU) transmits millimeter wave (mmW) WTRU (mmW WTRU) information over a cellular system to a base station, receives a candidate list of candidate mmW base stations (mB) including mmW acquisition start timing information and calculates correlation values around the received mmW acquisition start timing information for the mBs in the candidate list. The mmw WTRU performs sliding window correlations using signature sequences corresponding to mBs

and beams in the candidate list.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] A more detailed understanding may be had from the following description, given by way of example in conjunction with the accompanying drawings wherein:

[0005] FIG. 1A is a system diagram of an example communications system in which one or more disclosed embodiments may be implemented;

[0006] FIG. 1B is a system diagram of an example wireless transmit/receive unit (WTRU) that may be used within the communications system illustrated in FIG. 1A;

[0007] FIG. 1C is a system diagram of an example radio access network and an example core network that may be used within the communications system illustrated in FIG. 1A;

[0008] FIG. 2 is an example integrated millimeter wave (mmW) + long term evolution (LTE) (mmW+LTE) system;

[0009] FIG. 3 is an example mmW acquisition process flow;

[0010] FIG. 4A and 4B show an example mmW acquisition message flow sequence;

[0011] FIG. 5 is an example initial mmW acquisition procedure starting time configuration;

[0012] FIG. 6 is an example of beacon transmission schemes;

[0013] FIG. 7 is an example of an mmW base station/beam detection and time synchronization block for single stage modulation; and

[0014] FIG. 8 is an example of an mB/beam detection and time synchronization block for separately modulated beacons.

DETAILED DESCRIPTION

[0015] FIG. 1A is a diagram of an example communications system 100 in which one or more disclosed embodiments may be implemented. The communications system 100 may be a multiple access system that provides content, such as voice, data, video, messaging, broadcast, etc., to multiple wireless users. The communications system 100 may enable multiple wireless users to access such content through the sharing of system resources, including wireless bandwidth. For example, the communications systems 100 may employ one or more channel access methods, such as code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal FDMA (OFDMA), single-carrier FDMA (SC-FDMA), and the like.

[0016] As shown in FIG. 1A, the communications system 100 may include wireless transmit/receive units (WTRUs) 102a, 102b, 102c, 102d, a radio access network (RAN) 104, a core network 106, a public switched telephone network (PSTN) 108, the Internet 110, and other networks 112, though it will be appreciated that the disclosed embodiments contemplate any number of WTRUs, base stations, networks, and/or network elements. Each of the WTRUs 102a, 102b, 102c, 102d may be any type of device configured to operate and/or communicate in a wireless environment. By way of example, the WTRUs 102a, 102b, 102c, 102d may be configured to transmit and/or receive wireless signals and may include user equipment (UE), a mobile station, a fixed or mobile subscriber unit, a pager, a cellular telephone, a personal digital assistant (PDA), a smartphone, a laptop, a netbook, a personal computer, a wireless sensor, consumer electronics, and the like.

[0017] The communications systems 100 may also include a base station 114a and a base station 114b. Each of the base stations 114a, 114b may be any type of device configured to wirelessly interface with at least one of the WTRUs 102a, 102b, 102c, 102d to facilitate access to one or more communication networks, such as the core network 106, the Internet 110, and/or the networks 112. By way of example, the base stations 114a, 114b may be a base transceiver station (BTS), a Node-B, an eNode B, a Home Node B, a Home eNode B, a site controller, an access point (AP), a wireless router, and the like. While the base stations 114a, 114b are each depicted as a single element, it will be appreciated that the base stations 114a, 114b may include any number of interconnected base stations and/or network elements.

[0018] The base station 114a may be part of the RAN 104, which may also include other base stations and/or network elements (not shown), such as a base station controller (BSC), a radio network controller (RNC), relay nodes, etc. The base station 114a and/or the base station 114b may be configured to transmit and/or receive wireless signals within a particular geographic region, which may be referred to as a cell (not shown). The cell may further be divided into cell sectors. For example, the cell associated with the base station 114a may be divided into three sectors. Thus, in one embodiment, the base station 114a may include three transceivers, i.e., one for each sector of the cell. In another embodiment, the base station 114a may employ multiple-input multiple output (MIMO) technology and, therefore, may utilize multiple transceivers for each sector of the cell.

[0019] The base stations 114a, 114b may communicate with one or more of the WTRUs 102a, 102b, 102c, 102d over an air interface 116, which may be any suitable wireless communication link (e.g., radio frequency (RF), microwave, infrared (IR), ultraviolet (UV), visible light, etc.). The air interface 116 may be established using any suitable radio access technology (RAT).

[0020] More specifically, as noted above, the communications system 100 may be a multiple access system and may employ one or more channel access schemes, such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA, and the like. For example, the base station 114a in the RAN 104 and the WTRUs 102a, 102b, 102c may implement a radio technology such as Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (UTRA), which may establish the air interface 116 using wideband CDMA (WCDMA). WCDMA may include communication protocols such as High-Speed Packet Access (HSPA) and/or Evolved HSPA (HSPA+). HSPA may include High-

Speed Downlink Packet Access (HSDPA) and/or High-Speed Uplink Packet Access (HSUPA).

[0021] In another embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement a radio technology such as Evolved UMTS Terrestrial Radio Access (E-UTRA), which may establish the air interface 116 using Long Term Evolution (LTE) and/or LTE-Advanced (LTE-A).

[0022] In other embodiments, the base station 114a and the WTRUs 102a, 102b, 102c may implement radio technologies such as IEEE 802.16 (i.e., Worldwide Interoperability for Microwave Access (WiMAX)), CDMA2000, CDMA2000 1X, CDMA2000 EV-DO, Interim Standard 2000 (IS-2000), Interim Standard 95 (IS-95), Interim Standard 856 (IS-856), Global System for Mobile communications (GSM), Enhanced Data rates for GSM Evolution (EDGE), GSM EDGE (GERAN), and the like.

[0023] The base station 114b in FIG. 1A may be a wireless router, Home Node B, Home eNode B, or access point, for example, and may utilize any suitable RAT for facilitating wireless connectivity in a localized area, such as a place of business, a home, a vehicle, a campus, and the like. In one embodiment, the base station 114b and the WTRUs 102c, 102d may implement a radio technology such as IEEE 802.11 to establish a wireless local area network (WLAN). In another embodiment, the base station 114b and the WTRUs 102c, 102d may implement a radio technology such as IEEE 802.15 to establish a wireless personal area network (WPAN). In yet another embodiment, the base station 114b and the WTRUs 102c, 102d may utilize a cellular-based RAT (e.g., WCDMA, CDMA2000, GSM, LTE, LTE-A, etc.) to establish a picocell or femtocell. As shown in FIG. 1A, the base station 114b may have a direct connection to the Internet 110. Thus, the base station 114b may not be required to access the Internet 110 via the core network 106.

[0024] The RAN 104 may be in communication with the core network 106, which may be any type of network configured to provide voice, data, applications, and/or voice over internet protocol (VoIP) services to one or more of the WTRUs 102a, 102b, 102c, 102d. For example, the core network 106 may provide call control, billing services, mobile location-based services, pre-paid calling, Internet connectivity, video distribution, etc., and/or perform high-level security functions, such as user authentication. Although not shown in FIG. 1A, it will be appreciated that the RAN 104 and/or the core network 106 may be in direct or indirect communication with other RANs that employ the same RAT as the RAN 104 or a different RAT. For example, in addition to being connected to the RAN 104, which may be utilizing an E-UTRA radio technology, the core network 106 may also be in communication with another RAN (not shown) employing a GSM radio technology.

[0025] The core network 106 may also serve as a gateway for the WTRUs 102a, 102b, 102c, 102d to access the PSTN 108, the Internet 110, and/or other networks 112. The PSTN 108 may include circuit-switched telephone networks that provide plain old telephone service (POTS). The Internet 110 may include a global system of interconnected computer networks and devices that use common communication protocols, such as the transmission control protocol (TCP), user datagram protocol (UDP) and the internet protocol (IP) in the TCP/IP internet protocol suite. The networks 112 may include wired or wireless communications networks owned and/or operated by other service providers. For example, the networks 112 may include another core network connected to one or more RANs, which may employ the same RAT as the RAN 104 or a different RAT.

[0026] Some or all of the WTRUs 102a, 102b, 102c, 102d in the communications system 100 may include multi-mode capabilities, i.e., the WTRUs 102a, 102b, 102c, 102d may include multiple transceivers for communicating with different wireless networks over different wireless links. For example, the WTRU 102c shown in FIG. 1A may be configured to communicate with the base station 114a, which may employ a cellular-based radio technology, and with the base station 114b, which may employ an IEEE 802 radio technology.

[0027] FIG. 1B is a system diagram of an example WTRU 102. As shown in FIG. 1B, the WTRU 102 may include a processor 118, a transceiver

120, a transmit/receive element 122, a speaker/microphone 124, a keypad 126, a display/touchpad 128, non-removable memory 130, removable memory 132, a power source 134, a global positioning system (GPS) chipset 136, and other peripherals 138. It will be appreciated that the WTRU 102 may include any sub-combination of the foregoing elements while remaining consistent with an embodiment.

[0028] The processor 118 may be a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a microcontroller, Application Specific Integrated Circuits (ASICs), Field Programmable Gate Array (FPGAs) circuits, any other type of integrated circuit (IC), a state machine, and the like. The processor 118 may perform signal coding, data processing, power control, input/output processing, and/or any other functionality that enables the WTRU 102 to operate in a wireless environment. The processor 118 may be coupled to the transceiver 120, which may be coupled to the transmit/receive element 122. While FIG. 1B depicts the processor 118 and the transceiver 120 as separate components, it will be appreciated that the processor 118 and the transceiver 120 may be integrated together in an electronic package or chip.

[0029] The transmit/receive element 122 may be configured to transmit signals to, or receive signals from, a base station (e.g., the base station 114a) over the air interface 116. For example, in one embodiment, the transmit/receive element 122 may be an antenna configured to transmit and/or receive RF signals. In another embodiment, the transmit/receive element 122 may be an emitter/detector configured to transmit and/or receive IR, UV, or visible light signals, for example. In yet another embodiment, the transmit/receive element 122 may be configured to transmit and receive both RF and light signals. It will be appreciated that the transmit/receive element 122 may be configured to transmit and/or receive any combination of wireless signals.

[0030] In addition, although the transmit/receive element 122 is depicted in FIG. 1B as a single element, the WTRU 102 may include any number of transmit/receive elements 122. More specifically, the WTRU 102 may employ MIMO technology. Thus, in one embodiment, the WTRU 102 may include two or more transmit/receive elements 122 (e.g., multiple antennas) for transmitting and receiving wireless signals over the air interface 116.

[0031] The transceiver 120 may be configured to modulate the signals that are to be transmitted by the transmit/receive element 122 and to demodulate the signals that are received by the transmit/receive element 122. As noted above, the WTRU 102 may have multi-mode capabilities. Thus, the transceiver 120 may include multiple transceivers for enabling the WTRU 102 to communicate via multiple RATs, such as UTRA and IEEE 802.11, for example.

[0032] The processor 118 of the WTRU 102 may be coupled to, and may receive user input data from, the speaker/microphone 124, the keypad 126, and/or the display/touchpad 128 (e.g., a liquid crystal display (LCD) display unit or organic light-emitting diode (OLED) display unit). The processor 118 may also output user data to the speaker/microphone 124, the keypad 126, and/or the display/touchpad 128. In addition, the processor 118 may access information from, and store data in, any type of suitable memory, such as the non-removable memory 130 and/or the removable memory 132. The non-removable memory 130 may include random-access memory (RAM), read-only memory (ROM), a hard disk, or any other type of memory storage device. The removable memory 132 may include a subscriber identity module (SIM) card, a memory stick, a secure digital (SD) memory card, and the like. In other embodiments, the processor 118 may access information from, and store data in, memory that is not physically located on the WTRU 102, such as on a server or a home computer (not shown).

[0033] The processor 118 may receive power from the power source 134, and may be configured to distribute and/or control the power to the other components in the WTRU 102. The power source 134 may be any suitable device for powering the WTRU 102. For example, the power source 134 may include one or more dry cell batteries (e.g., nickel-cadmium (NiCd), nickel-zinc (NiZn), nickel metal hydride (NiMH), lithium-ion (Li-ion), etc.), solar cells, fuel cells, and the like.

[0034] The processor 118 may also be coupled to the GPS chipset 136, which may be configured to provide location information (e.g., longitude and latitude) regarding the current location of the WTRU 102. In addition to, or in lieu of, the information from the GPS chipset 136, the WTRU 102 may receive location information over the air interface 116 from a base station (e.g., base stations 114a, 114b) and/or determine its location based on the timing of the signals being received from two or more nearby base stations. It will be appreciated that the WTRU 102 may acquire location information by way of any suitable location-determination method while remaining consistent with an embodiment.

[0035] The processor 118 may further be coupled to other peripherals 138, which may include one or more software and/or hardware modules that provide additional features, functionality and/or wired or wireless connectivity. For example, the peripherals 138 may include an accelerometer, an e-compass, a satellite transceiver, a digital camera (for photographs or video), a universal serial bus (USB) port, a vibration device, a television transceiver, a hands free headset, a Bluetooth® module, a frequency modulated (FM) radio unit, a digital music player, a media player, a video game player module, an Internet browser, and the like.

[0036] FIG. 1C is a system diagram of the RAN 104 and the core network 106 according to an embodiment. As noted above, the RAN 104 may employ an E-UTRA radio technology to communicate with the WTRUs 102a, 102b, 102c over the air interface 116. The RAN 104 may also be in communication with the core network 106.

[0037] The RAN 104 may include eNode-Bs 140a, 140b, 140c, though it will be appreciated that the RAN 104 may include any number of eNode-Bs while remaining consistent with an embodiment. The eNode-Bs 140a, 140b, 140c may each include one or more transceivers for communicating with the WTRUs 102a, 102b, 102c over the air interface 116. In one embodiment, the eNode-Bs 140a, 140b, 140c may implement MIMO technology. Thus, the eNode-B 140a, for example, may use multiple antennas to transmit wireless signals to, and receive wireless signals from, the WTRU 102a.

[0038] Each of the eNode-Bs 140a, 140b, 140c may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the uplink and/or downlink, and the like. As shown in FIG. 1C, the eNode-Bs 140a, 140b, 140c may communicate with one another over an X2 interface.

[0039] The core network 106 shown in FIG. 1C may include a mobility management gateway (MME) 142, a serving gateway 144, and a packet data network (PDN) gateway 146. While each of the foregoing elements are depicted as part of the core network 106, it will be appreciated that any one of these elements may be owned and/or operated by an entity other than the core network operator.

[0040] The MME 142 may be connected to each of the eNode-Bs 140a, 140b, 140c in the RAN 104 via an S1 interface and may serve as a control node. For example, the MME 142 may be responsible for authenticating users of the WTRUs 102a, 102b, 102c, bearer activation/deactivation, selecting a particular serving gateway during an initial attach of the WTRUs 102a, 102b, 102c, and the like. The MME 142 may also provide a control plane function for switching between the RAN 104 and other RANs (not shown) that employ other radio technologies, such as GSM or WCDMA.

[0041] The serving gateway 144 may be connected to each of the eNode Bs 140a, 140b, 140c in the RAN 104 via the S1 interface. The serving gateway 144 may generally route and forward user data packets to/from the WTRUs 102a, 102b, 102c. The serving gateway 144 may also perform other functions, such as anchoring user planes during inter-eNode B handovers, triggering paging when downlink data is available for the WTRUs 102a, 102b, 102c, managing and storing contexts of the WTRUs 102a, 102b, 102c, and the like.

[0042] The serving gateway 144 may also be connected to the PDN gateway 146, which may provide the WTRUs 102a, 102b, 102c with access to packet-switched networks, such as the Internet 110, to facilitate communications between the WTRUs 102a, 102b, 102c and IP-enabled devices.

[0043] The core network 106 may facilitate communications with other networks. For example, the core network 106 may provide the WTRUs 102a, 102b, 102c with access to circuit-switched networks, such as the PSTN 108, to facilitate communications between the WTRUs 102a, 102b, 102c and traditional land-line communications devices. For example, the core network 106 may include, or may communicate with, an IP gateway (e.g., an IP multimedia subsystem (IMS) server) that serves as an interface between the core network 106 and the PSTN 108. In addition, the core network 106 may provide the WTRUs 102a, 102b, 102c with access to the networks 112, which may include other wired or wireless networks that are owned and/or operated by other service providers.

[0044] The Radio Network Evolution (RNE) described herein includes a new network node, a millimeter wave base station (mB). It may be used as mmW access links to mobiles units, or WTRUs and mmW backhaul (BH) links to other mBs and to the cellular base station. An mmW supported WTRU, (hereinafter referred to as an mWTRU for purposes of illustration), may be connected to the cellular layer before the mWTRU may receive data on the mmW layer. The mWTRUs may support mmW capabilities on a downlink (DL) with or without an uplink (UL). All mWTRUs may retain both UL and DL cellular capabilities with mmW channels assigned. The cellular layer may be used for one or more of mmW network control, connectivity and mobility management, and may carry L2/3 control messages thus alleviating the mB from the costs of these functions.

[0045] Described herein is the mmW channel description. A mmW link may be defined as the delivery of baseband symbols from a mmW beam forming capable transmitter to a mmW beam forming capable receiver. For example, the mmW DL link consists of an mB transmit beam forming with an mWTRU beam filtering on the reception side. Both mB and mWTRU have a transmitter as well as a receiver. A mmW resource unit (mRU) may include a specific combination of beam forming, (beamwidth and direction), and time slot, (a time slot is a fraction of a LTE subframe and is aligned to the LTE physical downlink control channel (PDCCH) frame timing). Each mRU may be dedicated to the controlling mB scheduling but the responsibility of mRU assignment to mWTRU resides with the meNB.

[0046] Described herein is mmW receive signal gain. A method to effectively increase the receive signal strength without increasing transmission power at the mB may be achieved by applying beam forming. The receiver gain may be increased by reducing the beam width of either or both the transmitter or receiver. One method affectively change the beam width is by applying phase shifting.

[0047] The RNE system capability may include one or more of: 1) location based service (LBS) or equivalent that provides sufficient accuracy to the meNB in locating the neighboring mB relative to a target mWTRU; 2) mmW resource assigned to mWTRU on demand; and 3) mB access link deactivation when no mWTRUs are assigned and activated on mWTRU acquisition.

[0048] FIG. 2 shows an example integrated millimeter wave (mmW) + long term evolution (LTE) (mmW+LTE) system 200 that includes an eNB1+ mB1A 205 having a link with a MME/S-GW 210 and an eNB2 220 through the X2 interface. Further the eNB2 200 may have a link with a MME/S-GW 225, where both the MME/S-GW 210 and 225 are in link with a P-GW 215. The eNB1+ mB1A 205 may have a link over the Xmb interface with an mB1B 230 and an mB1C 235 and the eNB2 220 may have a link with an mB2A 240, an mB2B 245 and an mB2C 250. An mWTRU 255 may be have links with the eNB1+ mB1A 205, mB1B 230 and mB1C 235.

[0049] In the mmW + LTE integrated system 200, the mWTRU 255 may remain connected to the cellular system, (e.g., LTE network), for the majority of the time. The mmW sub network may be utilized on demand when a service requiring mmW is requested such as high speed user data. The mmW link may be maintained only for the duration of the requested service. Therefore, each time a service is requested, an mmW acquisition procedure may be performed by the network to establish a mmW link for the target mWTRU.

[0050] The meNB that controls the mmW sub network may make the determination of when to initiate mmW service for a mWTRU. As shown in FIG. 2, the meNB 205 may select a target mB, (for example mB1C 235), based on mmW related information provided by the mWTRU, (such as mWTRU orientation and position, mmW capability, and the like), and available mB information, (such as available mB coordinates with or without historical mmW connection information), and then may trigger the mmW acquisition procedure.

[0051] During the acquisition process, the mWTRU may acquire an mB/beam combination that meets certain link quality requirements and achieve timing synchronization, (symbol, frame, slot, and the like), with the selected mB/beam combination. The acquisition process may then be performed on the mRU configured by the meNB. Upon completion of the acquisition procedure, the mWTRU may then be ready to transmit or receive user data on an assigned mmW link.

[0052] In conventional cellular systems operated in lower frequency bands, specialized channels are available cell-wide to facilitate system acquisition process. For example in LTE, symbol synchronization is achieved via primary synchronization channel (PSCH) and secondary synchronization channel (SSCH) and basic system information is broadcasted to all users in the coverage area via a broadcast channel (BCH). On the other hand, the mmW system link quality relies on high gain narrow beams from the transmitter and/or receiver, and proper alignment of the beam(s) due to its propagation property. A cell-wide channel is not available in the mmW system since the directionality of beam forming limits signal coverage to narrow beam areas corresponding to the beam width. The methods described herein below utilize readily available cellular systems to assist mmW acquisition, and various embodiments may provide faster acquisition, lower power consumption, and the like.

[0053] These methods address at least the following situations: 1) that the mmW acquisition procedure has to account for different path delays on the mWTRU-mB and mWTRU-meNB link in establishing timing synchronization; and 2) that the mmW acquisition procedure coordinates decisions and execution times on relevant nodes, (e.g., mWTRU, mB, and meNB). In addition, the sequence of triggering messages is also described herein below.

[0054] Described herein is a high level mmW acquisition procedure that leverages assistance from existing wireless systems. The 3GPP LTE cellular system may be referenced as an example system for description purposes to illustrate control plane support, but other systems may also be used, including UMTS, WIMAX, and the like.

[0055] FIG. 3 shows an example mmW acquisition procedure 300. The mmW acquisition procedure 300 acquires synchronization on several components of mmW communication properties for a transmitter and receiver pair to establish wireless communication. These mmW communication properties include at least the base carrier frequency, the directional alignment of transmitter and receiver beam forming, and timing. This synchronization allows reception of a user data packet over the mmW link.

[0056] Initially, the mmW resource management (MRM) function on an meNB may decide when an mmW link may be assigned to an mWTRU (305). The MRM may acquire some basic mWTRU information over the cellular system (310). The basic mWTRU information may include but is not limited to location, coarse timing, mmW capability of mWTRU and the like. The meNB may generate a candidate mB list based on the mWTRU information and a data base that maintains historical mmW link measurement statistics (if available) (315). The meNB may also consider other factors such as grouping of mWTRU with same mobility pattern at mB/eNB, the loading of the mBs, mBs resource availability, and the mBs ability to support the QoS requirements. For each mB in the candidate list, the meNB may also generate a preferred beam list.

[0057] The meNB may then notify both the mWTRU and the mB(s) in the candidate list of some or all of the information described herein below (320). For example, this information may include the physical layer mmW acquisition start time with reference to cellular timing. This may also be done using the coarse timing information obtained from the cellular underlay system. In another example, the information may include the number of beam sweeping repetitions, which may be derived from mWTRU mmW capability and its location. For instance, if an mWTRU is located near the edge of the mB coverage and likely needs receiver beamforming to establish a mmW link, multiple repetitions may be configured. On the other hand, if a mWTRU operate in omni antenna mode, then single repetition may be configured.

[0058] The information may further include, for example, mB and beam specific indices corresponding to signature sequences that may be used in beacon transmission as described herein below. In another example, the information may include the resources that may be used for mWTRU reporting. The mWTRU may feedback results of mmW acquisition over cellular channel or mmW channel. Multiple mWTRUs may be configured to perform mmW acquisition simultaneously. In such a case, different reporting resources may be assigned to each mWTRU so that reports may not collide. The resources may be differentiated by frequency, time, or code.

[0059] At the mmW acquisition start time, each mB may initiate transmitting acquisition beacons on the assigned mRU, and with sequential beams specified in the preferred beam list (325). The beacons may be modulated by each mB and beam specific sequences. In the meantime, the mWTRU may perform sliding window correlation around the specified mmW acquisition start time, using all sequences corresponding to the mBs and the beams in the candidate list (330). A peak detection module may be used to detect the best mB/beam combination and this may achieve timing and frequency synchronization at the same time.

[0060] The mWTRU may report to the network the following information described herein below (335). For example, the information may include the N highest received mmW signal strengths across all candidate mB/beam combinations and associated mB and beam indices. Based on the mWTRU report and along with other information such as the mB load status, the network may decide (340) to either setup an mmW link for the subsequent data transmission (345) or fall back to the cellular system (350). The eNB may also update its mmW link database from the received mUE reports.

[0061] FIG. 4A and 4B show an example mmW acquisition message flow sequence 400 to enable the mmW acquisition described herein above. The signaling for the mmW acquisition message flow sequence 400 may be between an eNB1 402, a target mB1B 404 and an LTE/mmW WTRU 406. Initially, the eNB1 402 and LTE/mmW WTRU 406 are connected to the LTE network (410 and 412). In a RNE system, this allows both the mB and mmW WTRU to use a meNB LTE time line as a common time reference.

[0062] The mB1B 404 may obtain basic information about the mmW WTRU, for example the LTE/mmW WTRU 406, from the cellular system to make an mmW beam allocation decision (416). This information may include mmW WTRU geographical information such as coordinates, which may be sent to the meNB from the mmW WTRU, (assuming global positioning system (GPS) capability), or may be derived by the network, which includes the cellular system and the mmW system, (i.e. the RNE). Using the mmW WTRU 406 coordinates, the meNB may generate a candidate mB list which includes mBs with the shortest distances. The meNB may also refine the candidate mB list according to a data base that collects historical mmW link data. For example, the data base may include ranges of received mmW power from given mB/beam combinations for each geographical zone, (as determined by the mmW WTRU coordinates). Using historical information from the data base, the meNB may possibly remove mBs from the candidate list if they do not have line-of sight (LOS) to the mmW WTRU or add a new mB with a prior successful connection. Additionally, the LOS information as well as other parameters that affect link establishment quality may be utilized to classify mB into different tiered priority candidate lists.

[0063] From the data base, the meNB may select preferred beams for each mB in the candidate list. In the case where historical data is not available, all possible beams available at the mB may be assigned as preferred beams. This may happen where there is a lack of historical data, such as when the network is newly deployed. In addition, for an mmW WTRU that is capable of reporting device orientation, (with the in-device gyro meter support), the preferred beam list may be further refined. The preferred beam list may be refined considering the current mB loading condition and the ability to satisfy quality of service (QoS) requirements for the mmW WTRU. In an example, the meNB may adopt predetermined filtering criteria to generate alternative (multiple) mB link candidate lists, each corresponding to specific system connectivity scenario filtered, (e.g. links with minimum backhaul hops, links with least backhaul delay, links incurring least system traffic load, links with least inter-cell-interference, links supported only with LOS, links supported by NLOS, and the like), to allow the meNB to make dynamic mmW candidate link selections corresponding to instantaneous link status feedback based on the information available, (e.g. user traffic QoS requirement, system load balancing input, LOS input, mmW WTRU location feedback (with/without orientation information)), or if configured, periodic mmW link measurements feedback.

[0064] The information may also include timing relationships between the mmW WTRU and the mB, which may be coarsely derived from the mmw WTRU-meNB timing and mB-meNB timing.

[0065] Once the allocation decision has been made, the eNB1 402 may initiate MMW link establishment (418). The eNB1 402 may send an mB configuration request message to a target mB1B 404 to reserve mRU (420). As part of mRU reservation, the acquisition mode and acquisition start time, (specified in the number of mmW symbol relatives to a LTE subframe), are determined by the eNB1 402. The target mB1B 404 may configure PHY assignment and update PHY scheduling assignment (422). The eNB1 402 may signal the set of information to the LTE/mmW WTRU 406 in an mmW configuration request message using the underlying cellular network (424). The target mB1B 404 may send an mB configuration confirmation (426).

[0066] The mmW acquisition process may then be executed (428). This may include target mB1B 404 downlink (DL) channel synchronization, which includes obtaining frequency, time and mmW frame synchronization, mB ID and a transmission beam index (430). This synchronization may be done by sending beacon transmissions (432 and 434) to the LTE/mmW WTRU 406.

[0067] An mmW uplink (UL) transmission procedure may be executed if mmW UL communication is configured (436). The LTE/mmW WTRU 406 may transmit multiple mmW alignment status messages 438 and 440 to the target mB1B 404. This may be repeated for multiple mB beam angles (442). The target mB1B 404 may transmit a mmW channel established success message to the eNB1 402 (444) and the eNB1 402, in turn, may transmit user data to the target mB1B 404 (446).

[0068] The LTE/mmW WTRU 406 may transmit an mmW configuration confirmation message to the eNB1 402, which may include an mmW alignment status message (448). The LTE/mmW WTRU 406 may then be connected to both the LTE and mmW networks (450) The eNB1 402 may transmit an initiate data transmission message to the target mB1b 404 (452). The target mB1b 404, in turn, may transmit user data to the LTE/mmW WTRU 406 (454).

[0069] FIG. 5 shows example RNE architecture 500 including an mmW WTRU 502, a mB 504 and a meNB 506, overlaid with a meNB LTE transmission timeline 508 and a mB mmW transmission time line 510. The mmW WTRU 502 may be communicating with the mB 504 using a mmW data link 512, the mB 504 may be communicating with the meNB 506 using a mmW backhaul (BH) link 514 and the meNB 506 may be communicating with the mmW WTRU 502 using a LTE control link 516.

[0070] As illustrated in FIG. 5, two different path delays: (1) LTE from meNB 506 to mmW WTRU 502; and (2) mmW from mB 504 to mmw WTRU 502 need to be considered in determining the mmW acquisition starting time. The mmW WTRU 502 may be connected to a LTE network of any cell size which may be up to 30 Km for a macro cell while the expected mB cell coverage may be in the range of pico or smaller (< 200m) size cells. The path delay on the mmW WTRU-mB link 512 at 200m is about 666 nano-seconds. This is insignificant when compared to the LTE path delay which may be up to 30 Km. The meNB to mmW WTRU 516 path delay on LTE is derived from the "timing advance" mechanism which may not be LOS. The path delay on the mmW link 512 is unknown during initial mmW acquisition. The inaccuracy in path delay on both mmW WTRU-meNB and mmW WTRU-mB links are considered and built into the "timing uncertainty". The inaccuracy is accounted for by extending the correlation sliding window length for peak detection to the detection length plus worst case timing uncertainty.

[0071] The "LTE time offset" 518 is the mmW acquisition start time and it is specified in terms of the number of mmW TTI delays from LTE frame N subframe n and takes into account the worst case signaling delay on the backhaul as well as an access link to configure the mmW WTRU to initiate mmW acquisition. This delay may be a default value per RNE deployment configuration and is adjustable by the meNB based on the dynamics of the backhaul latency monitored.

[0072] Also over the cellular link, the meNB may obtain the mmW specific capability of an mmW WTRU. Such capability information may include the number of mmW beams and beam widths the mmW WTRU may generate, and the number of transmission beams the mmW WTRU may simultaneously support. An mmW WTRU with multiple independent radio frequency (RF) chains may be able to mimic mB transmission (TX) beamforming by digital processing, and effectively have visibility to multiple TX beams simultaneously. Another method to allow multiple beam access is through filtering. The mmW WTRU may be able to separate signals from different subbands and each of the subbands may be beamformed differently. Shorter beam sweeping or faster acquisition may be achieved if the mmW WTRU is able to access multiple TX beams simultaneously.

[0073] Described herein is how to configure mmW acquisition. The meNB may inform both mB(s) and mmW WTRU of the preferred beam list, beam sweeping starting time, (probably with reference to cellular frame timing), and number of beam sweeping repetitions. The mmW WTRU may start measuring the mmW channels around the specified time, considering the timing inaccuracy obtained from the cellular system.

[0074] In some embodiments, the meNB also specifies the method and resources for mmW WTRU to send feedback information back to the network. In one embodiment, the mmW WTRU may be directed to send information to the meNB over the cellular link, and have the meNB relay the information to the mB. In an alternative embodiment, the mmW WTRU may be directed to send information over the mmW channels at a specified time/frequency and repetition.

[0075] The mmW WTRU may also be directed to feedback the highest received mmW signal strength and corresponding mB/beam indices, or feedback when the highest received mmW signal strength exceeds a certain predetermined threshold. The latter may be suitable when multiple mmW WTRUs contend for resources such as physical uplink control channel (PUCCH) in LTE. In such a case, the meNB may declare a failure after the mmW acquisition timer expires.

[0076] The meNB may also explicitly send mB and mmW WTRU the beacon sequences to be used for acquisition, or notify them to generate sequences based on mB and beam ID. The mB may verify if the resources requested by the meNB may be supported and provide the response in an mB configuration confirmation message 448 as shown in FIG. 4.

[0077] Described herein is beacon transmission and beacon frame design. Beacon transmission is over a specified time and frequency band as specified by the meNB. Beacon symbols may be modulated by the mB and beam specific sequences, which may be determined statically based on the mB and beam ID, or allocated semi-dynamically to avoid the need for large number sequences. The sequences should have good auto-correlation and cross-correlation properties. For example, sequences that may be suitable include Zadoff-Chu sequences or pseudo-random noise (PN) sequences that are used in WCDMA systems.

[0078] FIG. 6 shows embodiments (600) for modulating a beacon with mB and/or beam specific sequences. In one embodiment (A), single stage modulation is applied. A unique sequence is generated for each distinct mB/beam combination, and multiplied with a known pilot symbol sequence. In another embodiment (B), the modulation is done in two stages. The beacon is divided in two portions, for example, in time or frequency. The first portion is only modulated by an mB specific sequence (S1) and the second portion is modulated by a composite sequence of both mB (S1) and beam specific sequence (S2). The composite sequence is obtained by element-wise multiplication of the two sequences S1 and S2. The latter may reduce the total number of sequences and the mmW WTRU complexity and power consumption. In another embodiment (C), the beacon may be modulated by an mB specific sequence, (but not a beam specific sequence). In this embodiment, the mmW WTRU may first acquire beacon transmission timing, and then derive beam indices from it. Due to initial timing inaccuracy, the beacon frame should be long enough to overcome the initial timing inaccuracy.

[0079] Multiple beacons may also be transmitted simultaneously, but on different frequency bands. For example, mB may transmit beam A, C, E ,.... on frequency band 1, and beam B, D, F ,.... on frequency band 2.

[0080] Described herein is mmW WTRU processing. As described herein above, the mmW WTRU may obtain the acquisition start time from the LTE layer. Based on this information as well as the timing uncertainty guard interval, the mmW WTRU determines the time to start the procedure to detect beacons transmitted by the mBs. The detection procedure completes on mmW WTRU successfully synchronized in time with the mB providing the largest received beam energy, which is also the beam it wishes to establish the data transmission as described with respect to FIG. 3. In addition to the time synchronization achieved by this process, the mmW WTRU may also obtain the mB and beam identity, (i.e. cell and beam identity), that may be used to extract various cell specific properties.

[0081] Depending on the beacon transmission method, the detection of the beacons may take different forms. Common to all, the initial detection of the signals is performed via autocorrelation, i.e. a sliding window filtering procedure. With the knowledge of the mB/beam specific sequences provided by higher layer (e.g. radio resource control (RRC) signaling), the mmW WTRU autocorrelates the received signal with the candidate mB/beam specific signals. The mB and beam specific signals may be orthogonal to each other in order to minimize the autocorrelation among different mB and beam candidates. The output of the sliding window filtering gives the peak energy value, from which the mB beam transmission time, as well as the corresponding mB and its particular beam may be determined.

[0082] In the case of single stage modulation, the largest peak energy detected also determines the specific mB/beam pair with the largest received energy. FIG. 7 shows an example block diagram 700 of time synchronization and mB/beam selection. A received signal (710) is autocorrelated via sliding window filtering with the modulated beacon signals which are denoted as M_i, i=1,...,N (720). Note that each M_i, i=1,...,N, is uniquely modulated with the mB/Beam sequence (signature). The largest peak is selected and the time of the largest peak is obtained (730). The specific mB/beam pair is then determined (740) and the specific mB is time synchronized (750).

[0083] In embodiments having a beacon with multiple pieces, different parts are modulated with unique signatures such as mB specific, beam specific, or a combination of both. In embodiments with the beacon divided in time, the autocorrelation of the first part provides the timing synchronization and moreover, the location of the remaining split. However, the additional information extracted from the second part may give more detailed information such as beacon frame timing and the specific beam identity. FIG. 8 shows an example block diagram 800 for the mB and beam detection and time synchronization for separately modulation beacons. As opposed to the single stage modulation scheme 700 shown in FIG. 7, after receipt of the signal (810), the initial step employs sliding window filtering (820) in order to determine the particular mB ID (signature) from which the largest signal is received from (830). This initial filtering is carried by M_{pi}, i=1,2,..k unique signals that correspond to k number of mBs the mmW WTRU wishes to perform acquisition. As shown, after detecting the particular mB the mmW WTRU may synchronize with it in time (840). Moreover, since the location of the second beacon split is already known, the mmW WTRU is able to determine the location of the second beacon split (850). Another set of sliding window filtering is performed for this beacon, where the filtering signals are denoted as M_{si}, i=1,...,n (860). Here, n gives the possible beam signatures. The filtering operation outputs the particular beam of the already selected mB with the largest received power (870 and 880).

[0084] In embodiments where only mB specific sequences are carried by the beacons, mmW WTRU may derive the ID of the strongest beam from the timing relationship. If the mmW WTRU detects the strongest peak at time T, and assumes the beacon transmission starts at T_0 and the beacon interval is D, (both are known to the mmW WTRU in the mmW configuration phase), then the ID of the strongest beam is calculated as:

$$I = \text{round}((T-T_0)/D) \quad \text{(Equation 1)}$$

[0085] Due to timing inaccuracy, there is an offset between the beacon transmission time viewed by the mmW WTRU, which is To, and actual transmission time at mB. To ensure the correct detection of beam ID, the beacon interval should be at least two times the maximum timing offset.

[0086] Described herein is the mmW WTRU reporting. In some embodiments, once the mmW WTRU has detected the strongest mB/beam combination(s), and corresponding channel quality, the mmW WTRU reports the results, (which may include some or all of, but are not limited to: the mB/beam indices and corresponding channel quality indicator, timing offset between mmW and cellular system), back to the network using mmW or cellular channels specified by the meNB. If the cellular channels are specified, then the mmW WTRU feedback may be carried on the PUCCH or piggy backed on the mmW Configuration Confirm message carried on the physical uplink shared channel (PUSCH). The meNB may then decode the proper cellular uplink channel, and forward the information to the mB. If the mmW channel is specified, the mmW WTRU may then apply the proper coding and modulation which are specified by the meNB, and transmit the data package with the best receiver beam. The mmW feedback transmission is repeated multiple times, (number of repetitions having been specified), so that the target mB may try multiple beams to receive the feedback.

[0087] Described herein is the mB acquisition failure recovery. The mmW acquisition procedure may utilize command/respond protocols to synchronize procedure between nodes. To prevent communication dead lock for suspending the procedure, the mmW acquisition timer is utilized as the safety net to exit the acquisition procedure from failure condition. For example, the RNE system relies on two separate wireless signaling channels for communication. This creates the scenario where the mmW WTRU may be able to receive mmW configuration messages from the meNB on the LTE channel but not able to acquire mmW signals from the assigned mB. One such possible scenario is when a truck pulls up and blocks the LOS to the mB across the street. If there is no alternative mB or reflective path that may reach the target mmW WTRU, the mmW signal acquisition procedure will fail. In this scenario, if the mmW WTRU is not able to transmit mmW configuration failure messages back to the meNB on the UL LTE, the mmW acquisition timer expires triggering the meNB to abort the mmW acquisition procedure and revert back to LTE for data service.

[0088] In the case where the meNB receives mmW acquisition failure messages from the mB and/or mmW WTRU before mmW acquisition timer expires, the meNB may alternatively initiate another mmW acquisition procedure with the remaining (unattempted) mB/beam candidates before reverting back to LTE for data access.

[0089] Once the mmW acquisition timer times out, the meNB may temporarily suspend attempts to configure the mmW channel to the targeted mmW WTRU and configure the mmW WTRU for data access on the LTE network until new/updated mmW measurement data is received. The meNB may signal a new mmW measurement configuration message to the mmW WTRU upon mmW acquisition timer expiry.

[0090] Embodiments:

[0091] 1. A method, implemented at a wireless transmit/receive unit (WTRU), for millimeter wave (mmW) beam acquisition, comprising transmitting millimeter wave (mmW) WTRU (mmW WTRU) information over a cellular system to a base station.

[0092] 2. The method of embodiment 1, further comprising receiving a list of candidate mmW base stations (mB) including mmW acquisition start timing information.

[0093] 3. The method of any preceding embodiment, further comprising calculating correlation values around the received mmW acquisition start timing information for the mBs in the list.

[0094] 4. The method of any preceding embodiment, wherein the mmW acquisition start timing information includes coarse timing information relative to the cellular system timing.

[0095] 5. The method of any preceding embodiment, further comprising receiving at least one of a number of beam sweeping repetitions, mB and beam specific indices corresponding to signature sequences, and resource assignments for mmW WTRU reporting.

[0096] 6. The method of any preceding embodiment, wherein the mmw WTRU performs sliding window correlations using signature sequences corresponding to mBs and beams in the list.

[0097] 7. The method of any preceding embodiment, further comprising generating a message including the N highest received mmW signal strengths across the candidate mB and beam combinations and associated mB and beam indices.

[0098] 8. The method of any preceding embodiment, further comprising transmitting feedback information over at least one of a cellular link or an mmW link as directed by the base station.

[0099] 9. The method of any preceding embodiment, further comprising transmitting at least one of highest received mmW signal strength and corresponding mB/beam indices, and highest received mmW signal strength exceeding a predetermined threshold.

[0100] 10. The method of any preceding embodiment, further comprising detecting modulated beacons transmitted by mBs.

[0101] 11. The method of any preceding embodiment, further comprising correlating the modulated beacons with a sliding window filter.

[0102] 12. The method of any preceding embodiment, further comprising determining a specific mB and beam pair based on highest peak energy on a condition that single stage modulation is used.

[0103] 13. The method of any preceding embodiment, further comprising determining beacon frame timing and specific beam identity on a condition that multiple stage modulation is used.

[0104] 14. A method, implemented at a base station, for millimeter wave (mmW) beam acquisition, comprising obtaining millimeter wave (mmW) WTRU (mmW WTRU) information over a cellular system, wherein the mmW WTRU information includes at least one of location, coarse timing and mmW capability at the mmW WTRU.

[0105] 15. The method of any preceding embodiment, further comprising generating a candidate millimeter wave base station (mB) list using the mmW WTRU information and at least distance criteria.

[0106] 16. The method of any preceding embodiment, further comprising transmitting the candidate mB list and mmW acquisition start timing information to the mmW WTRU and candidate mBs;

[0107] 17. The method of any preceding embodiment, further comprising receiving N highest received mmW signal strengths across the candidate mB and beam combinations and associated mB and beam indices.

[0108] 18. The method of any preceding embodiment, further comprisingdetermining viability of mmW link based on the N highest received mmW signal strengths and mB load status.

[0109] 19. The method of any preceding embodiment, wherein the candidate mB list considers grouping of mmW WTRUs with same mobility pattern as candidate mBs and the base station.

[0110] 20. The method of any preceding embodiment, wherein the candidate mB list is obtained using historical data from a database.

[0111] 21. The method of any preceding embodiment, wherein a preferred beam list is determined from at least one of the database, reported mmW WTRU orientation, mB loading condition, and quality of service.

[0112] 22. The method of any preceding embodiment, wherein the candidate list is determined based on at least one of on line of sight (LOS) information, and prior successful connection.

[0113] 23. The method of any preceding embodiment, wherein the candidate mB list is determined using a predetermined filtering criteria to generate multiple candidate mB lists, each of the multiple candidate mB lists corresponding to different system connectivity scenarios that are filtered so that the base station can make a dynamic mmW candidate link selection corresponding to instantaneous link status feedback.

[0114] 24. The method of any preceding embodiment, wherein the acquisition mode and acquisition start time are specified in a number of mmW symbols relative to the cellular system radio frames.

[0115] 25. The method of any preceding embodiment, further comprising transmitting beacon sequence information to the mB and mmW WTRU, wherein the beacon sequence information includes one of beacon sequences or a notification to generate beacon sequences based on mB and beam ID.

[0116] 26. A method, implemented at a millimeter wave (mmW) base station (mB), for mmW beam acquisition, comprising receiving an mB configuration request from a base station including at least an acquisition start time and a preferred beam list.

[0117] 27. The method of any preceding embodiment, further comprising the acquisition start time, transmitting acquisition beacons on an assigned mmW resource unit (mRU) using sequential beams as listed in the preferred beam list.

[0118] 28. The method of any preceding embodiment, wherein the acquisition beacons are modulated by at least one of beam specific sequences and mB specific sequences.

[0119] 29. The method of any preceding embodiment, wherein the acquisition beacons are divided into parts and the parts are modulated by at least one of mB specific sequences and a combination of mB specific sequences and beam specific sequences.

[0120] 30. A method comprising at a user equipment (UE), acquiring millimeter wave (mmW) UE (mUE) information from a cellular system.

[0121] 31. The method of any preceding embodiment, further comprising receiving at the UE a candidate list of candidate mmW base stations (mB) including physical layer mmW acquisition start timing information.

[0122] 32. The method of any preceding embodiment, further comprising calculating correlation values based on the received mmW acquisition start timing information for the mBs in the candidate list.

[0123] 33. The method of any preceding embodiment, wherein the cellular system is LTE, UMTS, or WIMAX.

[0124] 34. The method of any preceding embodiment, wherein the mUE information includes one of the following location, coarse timing, mmW capability of mUE.

[0125] 35. The method of any preceding embodiment, wherein the acquisition start timing information includes coarse timing information relative to the cellular system timing.

[0126] 36. The method of any preceding embodiment, further comprising receiving at the UE a number of sweeping repetitions.

[0127] 37. The method of any preceding embodiment, wherein the number of sweeping repetitions is derived from mUE capability information and/or location information.

[0128] 38. The method of any preceding embodiment, wherein the UE also receives mB and beam specific indices corresponding to signature sequences.

[0129] 39. The method of any preceding embodiment, wherein the UE also receives mUE reporting resource assignments.

[0130] 40. The method of any preceding embodiment, wherein the UE performs sliding window correlations using signature sequences corresponding to mBs and beams in the candidate list.

[0131] 41. The method of any preceding embodiment, wherein the mUE generates a message including the N highest received mmW signal strength across the candidate mB/beam combinations and associated mB and beam indices.

[0132] 42. A method comprising receiving a mB configuration request from an e Node B (eNB).

[0133] 43. The method of any preceding embodiment, further comprising transmitting from a mB at an acquisition start time, acquisition beacons on the assigned mRU, and with sequential beams.

[0134] 44. The method of any preceding embodiment, wherein the beacons are modulated by a plurality of beam specific sequences.

[0135] 45. A method comprising obtaining at an e Node B (eNB) location information of a mUE.

[0136] 46. The method of any preceding embodiment, further comprising generating a candidate millimeter wave base station (mB) list using the location information and a distance criterion.

[0137] 47. The method of any preceding embodiment, further comprising acquisition mode and acquisition start time (specified in number of mmW symbol relative to LTE subframe) are determined

[0138] 48. The method of any preceding embodiment, wherein the location information comprises the UE's coordinates obtained from the UE, or is derived by the network.

[0139] 49. The method of any preceding embodiment, wherein the candidate list is obtained using historical data from a database.

[0140] 50. The method of any preceding embodiment, wherein the candidate list is determined based on line of sight (LOS) information.

[0141] 51. The method of any preceding embodiment, wherein the eNB also receives UE device orientation information.

[0142] Although features and elements are described above in particular combinations, one of ordinary skill in the art will appreciate that each feature or element can be used alone or in any combination with the other features and elements. In addition, the methods described herein may be implemented in a computer program, software, or firmware incorporated in a computer-readable medium for execution by a computer or processor. Examples of computer-readable media include electronic signals (transmitted over wired or wireless connections) and computer-readable storage media. Examples of computer-readable storage media include, but are not limited to, a read only memory (ROM), a random access memory (RAM), a register, cache memory, semiconductor memory devices, magnetic media such as internal hard disks and removable disks, magneto-optical media, and optical media such as CD-ROM disks, and digital versatile disks (DVDs). A processor in association with software may be used to implement a radio frequency transceiver for use in a WTRU, UE, terminal, base station, RNC, or any host computer.

CLAIMS

What is claimed is:

1. A method, implemented at a wireless transmit/receive unit (WTRU), for millimeter wave (mmW) beam acquisition, comprising:

transmitting millimeter wave (mmW) WTRU (mmW WTRU) information over a cellular system to a base station;

receiving a list of candidate mmW base stations (mB) including mmW acquisition start timing information; and

calculating correlation values around the received mmW acquisition start timing information for the mBs in the list.

2. The method of claim 1, wherein the mmW acquisition start timing information includes coarse timing information relative to the cellular system timing.

3. The method of claim 1, further comprising:

receiving at least one of a number of beam sweeping repetitions, mB and beam specific indices corresponding to signature sequences, and resource assignments for mmW WTRU reporting.

4. The method of claim 1, wherein the mmw WTRU performs sliding window correlations using signature sequences corresponding to mBs and beams in the list.

5. The method of claim 1, further comprising:

generating a message including the N highest received mmW signal strengths across the candidate mB and beam combinations and associated mB and beam indices.

6. The method of claim 1, further comprising:

transmitting feedback information over at least one of a cellular link or an mmW link as directed by the base station.

7. The method of claim 1, further comprising:

transmitting at least one of highest received mmW signal strength and corresponding mB/beam indices, and highest received mmW signal strength exceeding a predetermined threshold.

8. The method of claim 1, further comprising:

detecting modulated beacons transmitted by mBs;

correlating the modulated beacons with a sliding window filter;

determining a specific mB and beam pair based on highest peak energy on a condition that single stage modulation is used; and

determining beacon frame timing and specific beam identity on a condition that multiple stage modulation is used.

9. A method, implemented at a base station, for millimeter wave (mmW) beam acquisition, comprising:

obtaining millimeter wave (mmW) WTRU (mmW WTRU) information over a cellular system, wherein the mmW WTRU information includes at least one of location, coarse timing and mmW capability at the mmW WTRU;

generating a candidate millimeter wave base station (mB) list using the mmW WTRU information and at least distance criteria;

transmitting the candidate mB list and mmW acquisition start timing information to the mmW WTRU and candidate mBs;

receiving N highest received mmW signal strengths across the candidate mB and beam combinations and associated mB and beam indices; and

determining viability of mmW link based on the N highest received mmW signal strengths and mB load status.

10. The method of claim 9, wherein the candidate mB list considers grouping of mmW WTRUs with same mobility pattern as candidate mBs and the base station.

11. The method of claim 9, wherein the candidate mB list is obtained using historical data from a database.

12. The method of claim 11, wherein a preferred beam list is determined from at least one of the database, reported mmW WTRU orientation, mB loading condition, and quality of service.

13. The method of claim 9, wherein the candidate list is determined based on at least one of on line of sight (LOS) information, and prior successful connection.

14. The method of claim 9, wherein the candidate mB list is determined using a predetermined filtering criteria to generate multiple candidate mB lists, each of the multiple candidate mB lists corresponding to different system connectivity scenarios that are filtered so that the base station can make a dynamic mmW candidate link selection corresponding to instantaneous link status feedback.

15. The method of claim 9, wherein the acquisition mode and acquisition start time are specified in a number of mmW symbols relative to the cellular system radio frames.

16. The method of claim 9, further comprising:

transmitting beacon sequence information to the mB and mmW WTRU, wherein the beacon sequence information includes one of beacon sequences or a notification to generate beacon sequences based on mB and beam ID.

17. A method, implemented at a millimeter wave (mmW) base station (mB), for mmW beam acquisition, comprising:

receiving an mB configuration request from a base station including at least an acquisition start time and a preferred beam list; and

at the acquisition start time, transmitting acquisition beacons on an assigned mmW resource unit (mRU) using sequential beams as listed in the preferred beam list.

18. The method of claim 17, wherein the acquisition beacons are modulated by at least one of beam specific sequences and mB specific sequences.

19. The method of claim 17, wherein the acquisition beacons are divided into parts and the parts are modulated by at least one of mB specific sequences and a combination of mB specific sequences and beam specific sequences.

20. A wireless transmit/receive unit (WTRU) configured for millimeter wave (mmW) beam acquisition, comprising:

a transmitter configured to transmit millimeter wave (mmW) WTRU (mmW WTRU) information over a cellular system to a base station;

a receiver configured to receiv a list of candidate mmW base stations (mB) including mmW acquisition start timing information; and

a processor configured to calculate correlation values around the received mmW acquisition start timing information for the mBs in the list.

21. The WTRU of claim 20, wherein the mmW acquisition start timing information includes coarse timing information relative to the cellular system timing.

22. The WTRU of claim 20, wherein the receiver is configured to

receive at least one of a number of beam sweeping repetitions, mB and beam specific indices corresponding to signature sequences, and resource assignments for mmW WTRU reporting.

23. The WTRU of claim 20, wherein the mmw WTRU performs sliding window correlations using signature sequences corresponding to mBs and beams in the list.

24. The WTRU of claim 20, wherein the processor if configured to generate a message including the N highest received mmW signal strengths across the candidate mB and beam combinations and associated mB and beam indices.

25. The WTRU of claim 20, wherein the transmitter is configured to transmit feedback information over at least one of a cellular link or an mmW link as directed by the base station.

26. The WTRU of claim 20, wherein the transmitter is configured to transmit at least one of highest received mmW signal strength and corresponding mB/beam indices, and highest received mmW signal strength exceeding a predetermined threshold.

27. The WTRU of claim 20, wherein the processor is configured to:

detect modulated beacons transmitted by mBs;

correlate the modulated beacons with a sliding window filter;

determine a specific mB and beam pair based on highest peak energy on a condition that single stage modulation is used; and

determine beacon frame timing and specific beam identity on a condition that multiple stage modulation is used.

28. A base station configured for millimeter wave (mmW) beam acquisition, comprising:

a processor, a receiver and a transmitter;

the processor and receiver configured to obtain millimeter wave (mmW) WTRU (mmW WTRU) information over a cellular system, wherein the mmW WTRU information includes at least one of location, coarse timing and mmW capability at the mmW WTRU;

the processor configured to generate a candidate millimeter wave base station (mB) list using the mmW WTRU information and at least distance criteria;

the processor configured to transmit the candidate mB list and mmW acquisition start timing information to the mmW WTRU and candidate mBs;

the receiver configured to receiving N highest received mmW signal strengths across the candidate mB and beam combinations and associated mB and beam indices; and

the processor configured to determine viability of mmW link based on the N highest received mmW signal strengths and mB load status.

29. A millimeter wave (mmW) base station (mB) configured for mmW beam acquisition, comprising:

a receiver configured to receive an mB configuration request from a base station including at least an acquisition start time and a preferred beam list; and

a transmitter configured to, at the acquisition start time, transmit acquisition beacons on an assigned mmW resource unit (mRU) using sequential beams as listed in the preferred beam list.

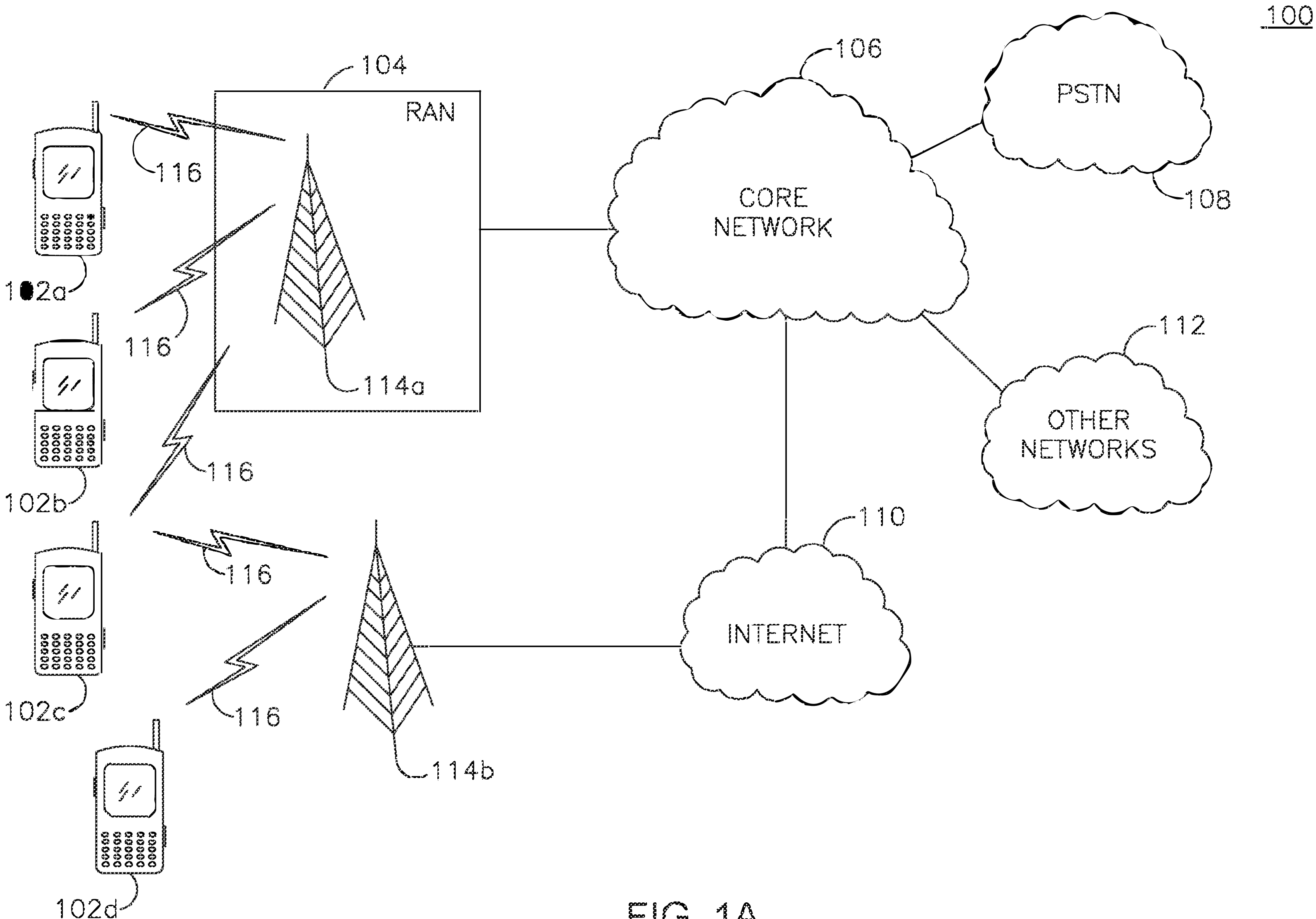

100
104
RAN
106
CORE NETWORK
PSTN
108
112
OTHER NETWORKS
110
INTERNET
116
116
116
116
116
114a
114b
102a
102b
102c
102d

FIG. 1A

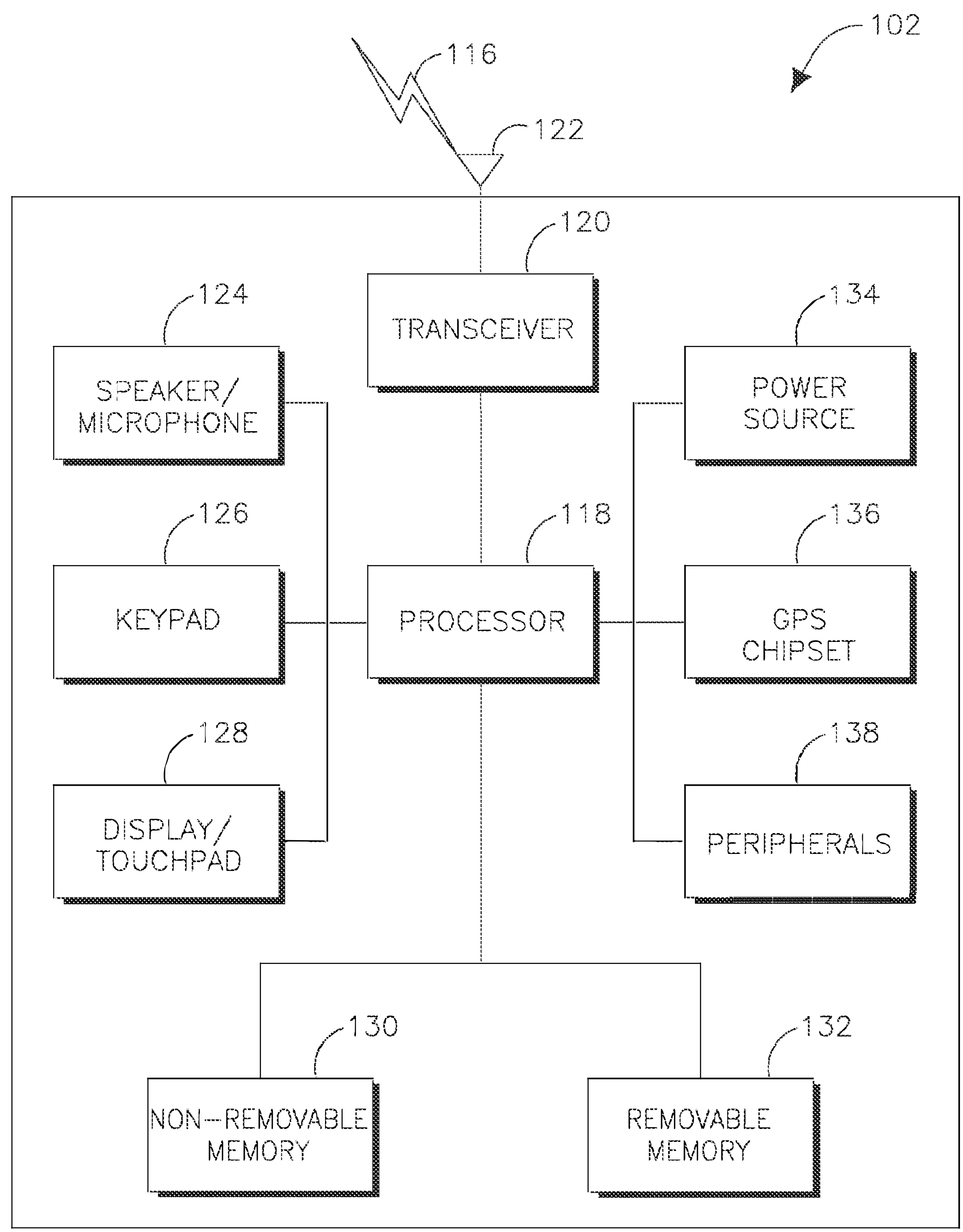

102
116
122
120
TRANSCEIVER
124
SPEAKER/
MICROPHONE
134
POWER
SOURCE
126
KEYPAD
118
PROCESSOR
136
GPS
CHIPSET
128
DISPLAY/
TOUCHPAD
138
PERIPHERALS
130
NON-REMOVABLE
MEMORY
132
REMOVABLE
MEMORY

FIG. 1B

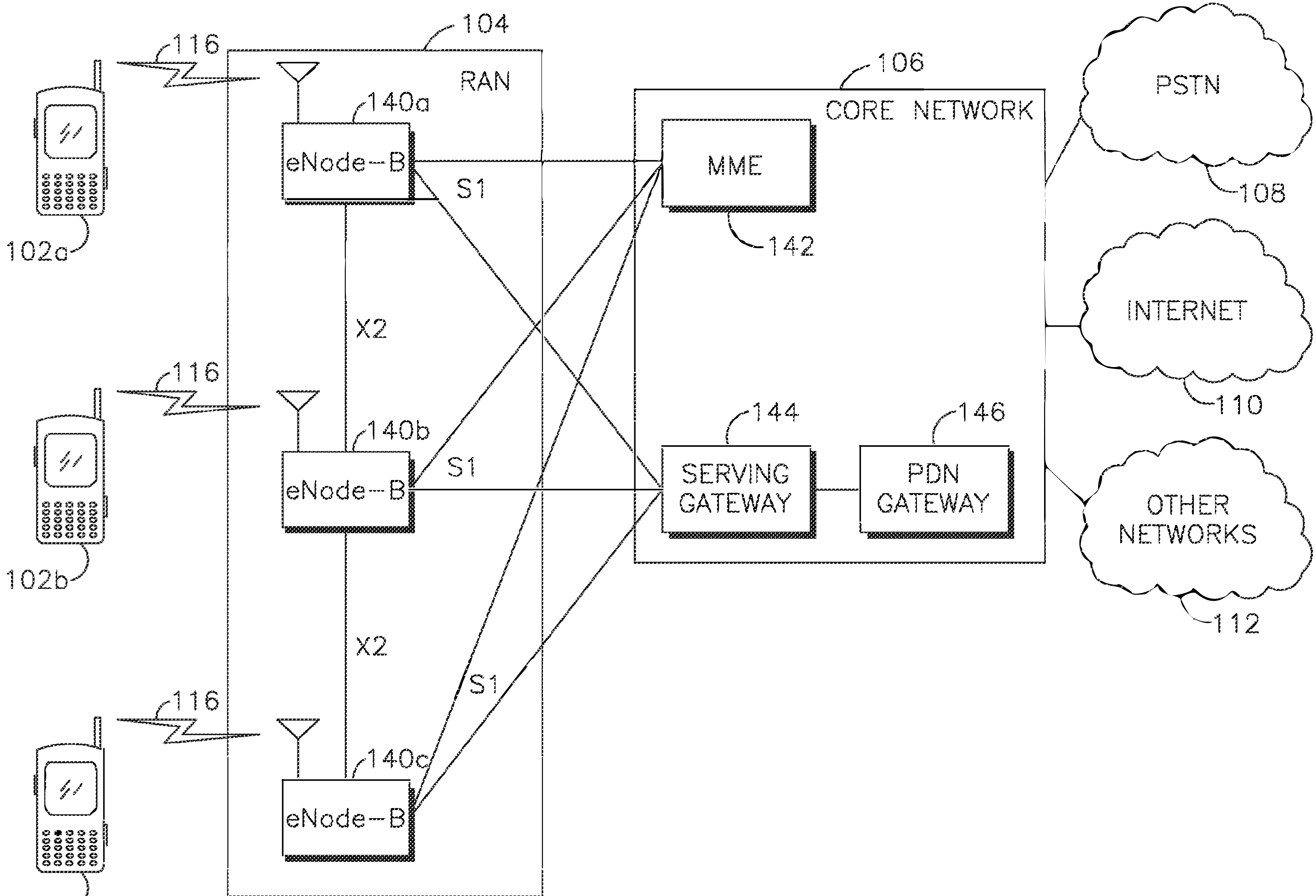

104
RAN
116
140a
eNode-B
S1
102a
X2
116
140b
eNode-B
S1
102b
X2
S1
116
140c
eNode-B
102c
106
CORE NETWORK
MME
142
144
SERVING GATEWAY
146
PDN GATEWAY
PSTN
108
INTERNET
110
OTHER NETWORKS
112

FIG. 1C

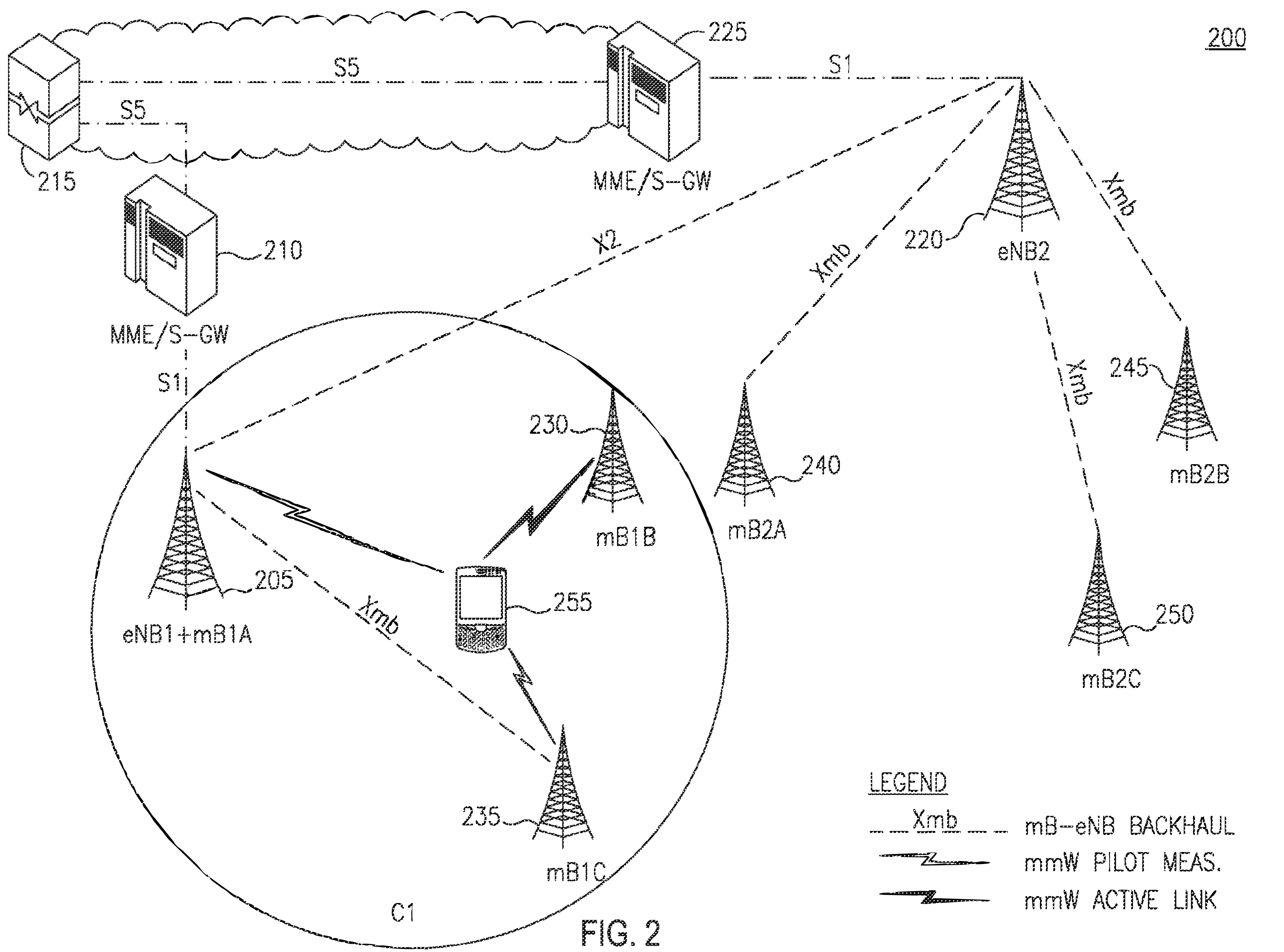

200
225
S5
S1
S5
215
MME/S-GW
210
X2
Xmb
220
eNB2
Xmb
MME/S-GW
S1
245
230
Xmb
240
mB2B
mB1B
mB2A
205
255
eNB1+mB1A
Xmb
250
mB2C
235
mB1C
C1
LEGEND
Xmb mB-eNB BACKHAUL
mmW PILOT MEAS.
mmW ACTIVE LINK

FIG. 2

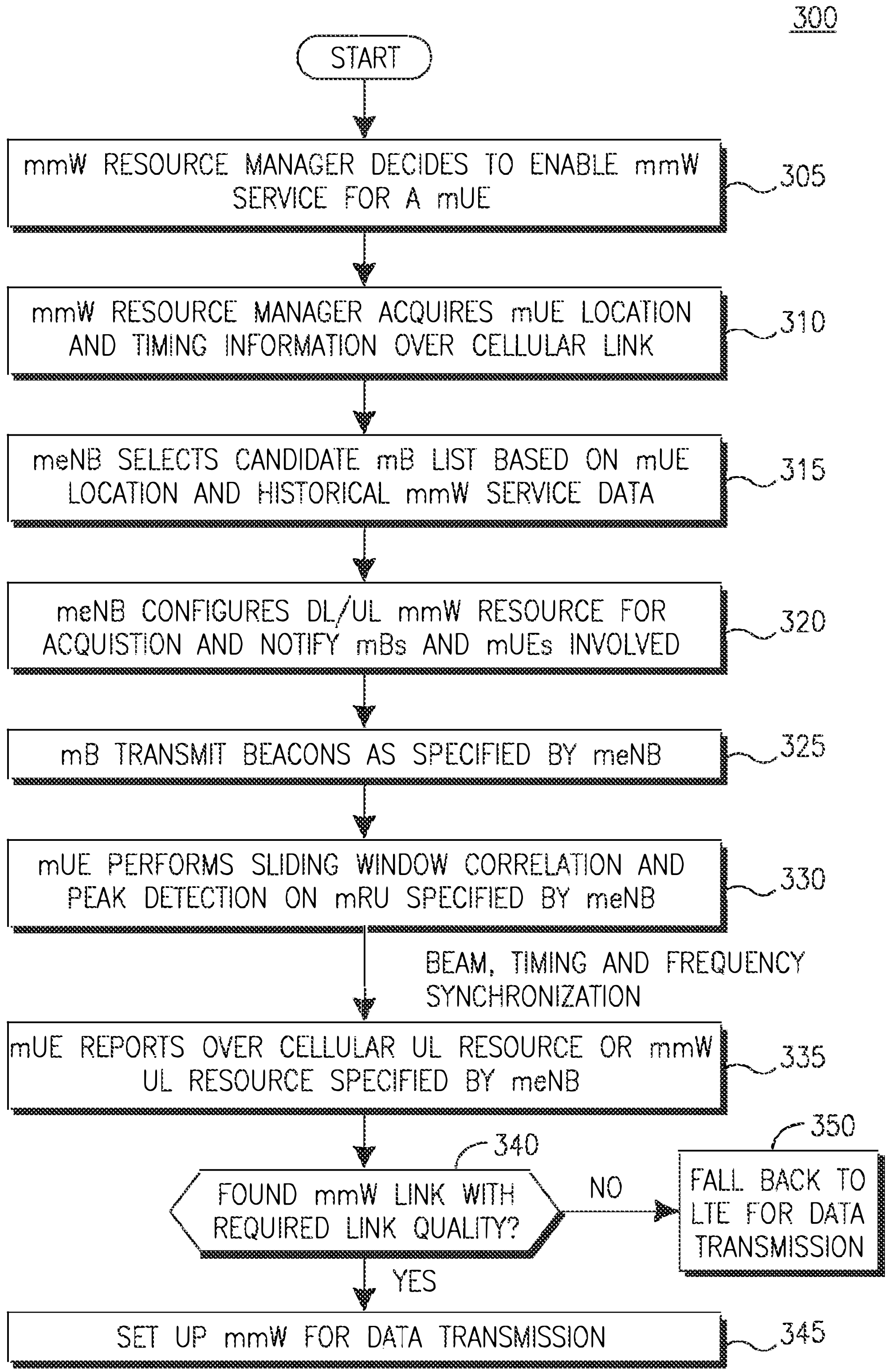
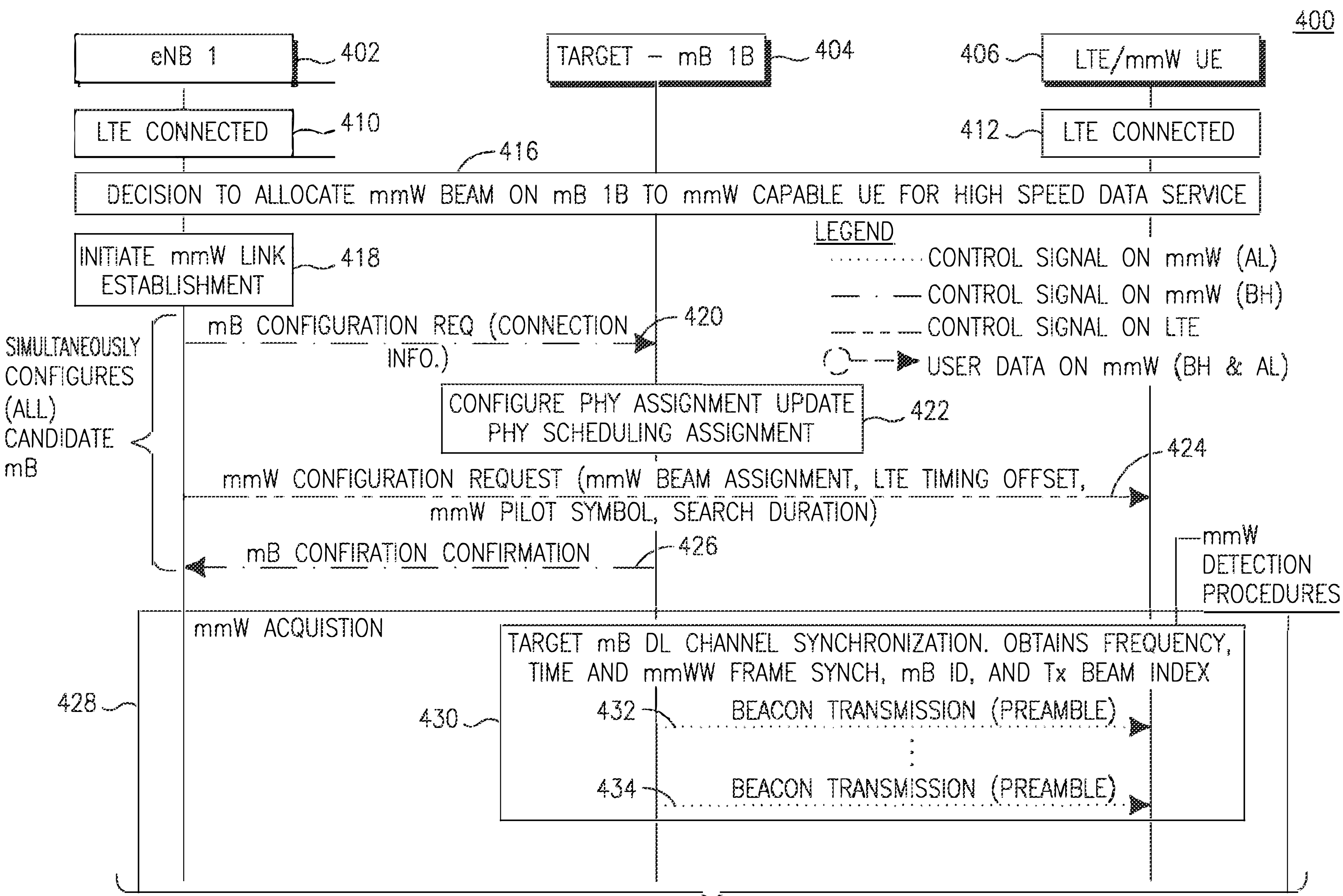

300
START
mmW RESOURCE MANAGER DECIDES TO ENABLE mmW SERVICE FOR A mUE
305
mmW RESOURCE MANAGER ACQUIRES mUE LOCATION AND TIMING INFORMATION OVER CELLULAR LINK
310
meNB SELECTS CANDIDATE mB LIST BASED ON mUE LOCATION AND HISTORICAL mmW SERVICE DATA
315
meNB CONFIGURES DL/UL mmW RESOURCE FOR ACQUISTION AND NOTIFY mBs AND mUEs INVOLVED
320
mB TRANSMIT BEACONS AS SPECIFIED BY meNB
325
mUE PERFORMS SLIDING WINDOW CORRELATION AND PEAK DETECTION ON mRU SPECIFIED BY meNB
330
BEAM, TIMING AND FREQUENCY SYNCHRONIZATION
mUE REPORTS OVER CELLULAR UL RESOURCE OR mmW UL RESOURCE SPECIFIED BY meNB
335
340
FOUND mmW LINK WITH REQUIRED LINK QUALITY?
NO
350
FALL BACK TO LTE FOR DATA TRANSMISSION
YES
SET UP mmW FOR DATA TRANSMISSION
345

FIG. 3



CONTINUED ON FIG. 4B

FIG. 4A

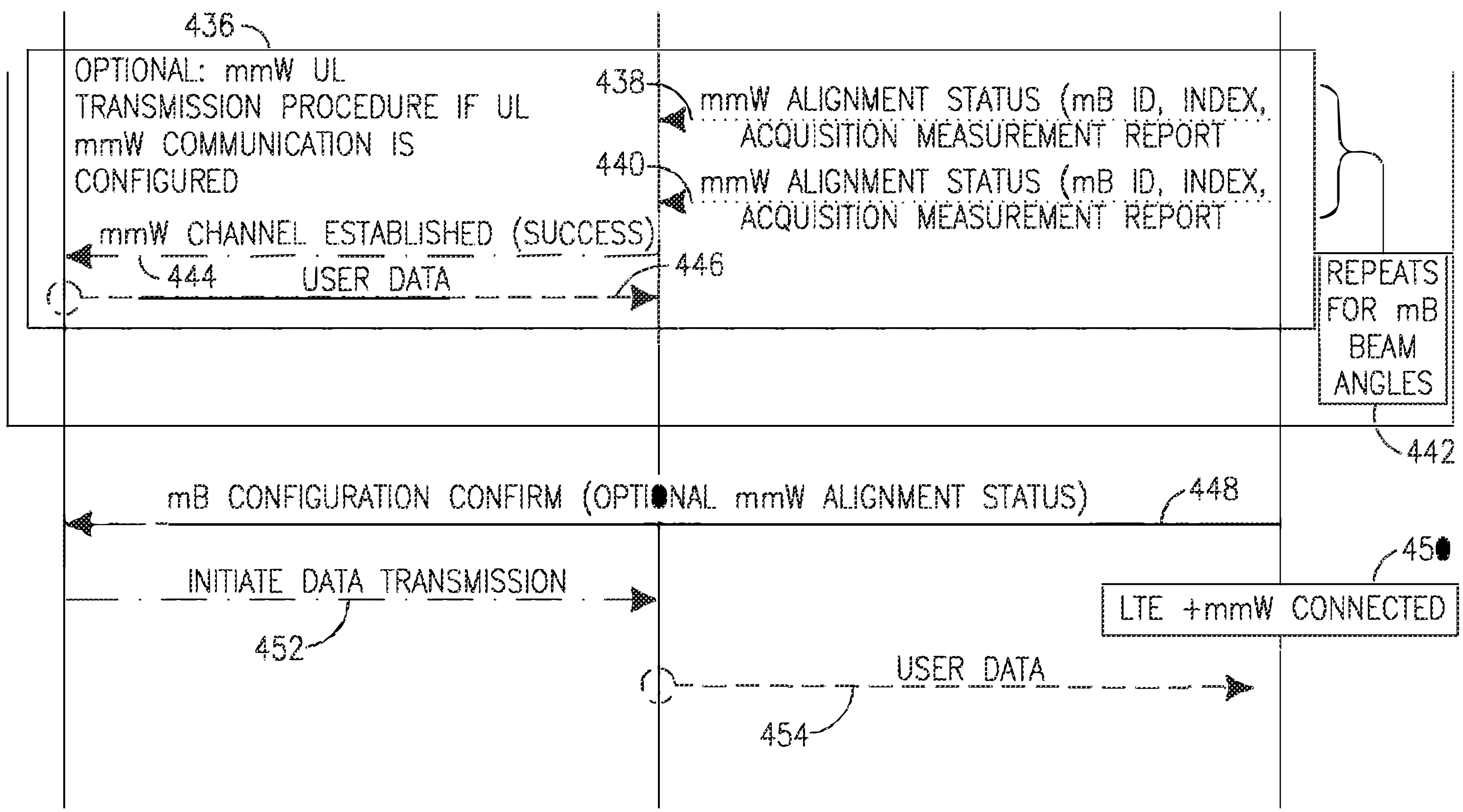

436
OPTIONAL: mmW UL TRANSMISSION PROCEDURE IF UL mmW COMMUNICATION IS CONFIGURED
438
mmW ALIGNMENT STATUS (mB ID, INDEX, ACQUISITION MEASUREMENT REPORT
440
mmW ALIGNMENT STATUS (mB ID, INDEX, ACQUISITION MEASUREMENT REPORT
mmW CHANNEL ESTABLISHED (SUCCESS)
444
USER DATA
446
REPEATS FOR mB BEAM ANGLES
442
mB CONFIGURATION CONFIRM (OPTIONAL mmW ALIGNMENT STATUS)
448
450
LTE +mmW CONNECTED
INITIATE DATA TRANSMISSION
452
USER DATA
454

FIG. 4B

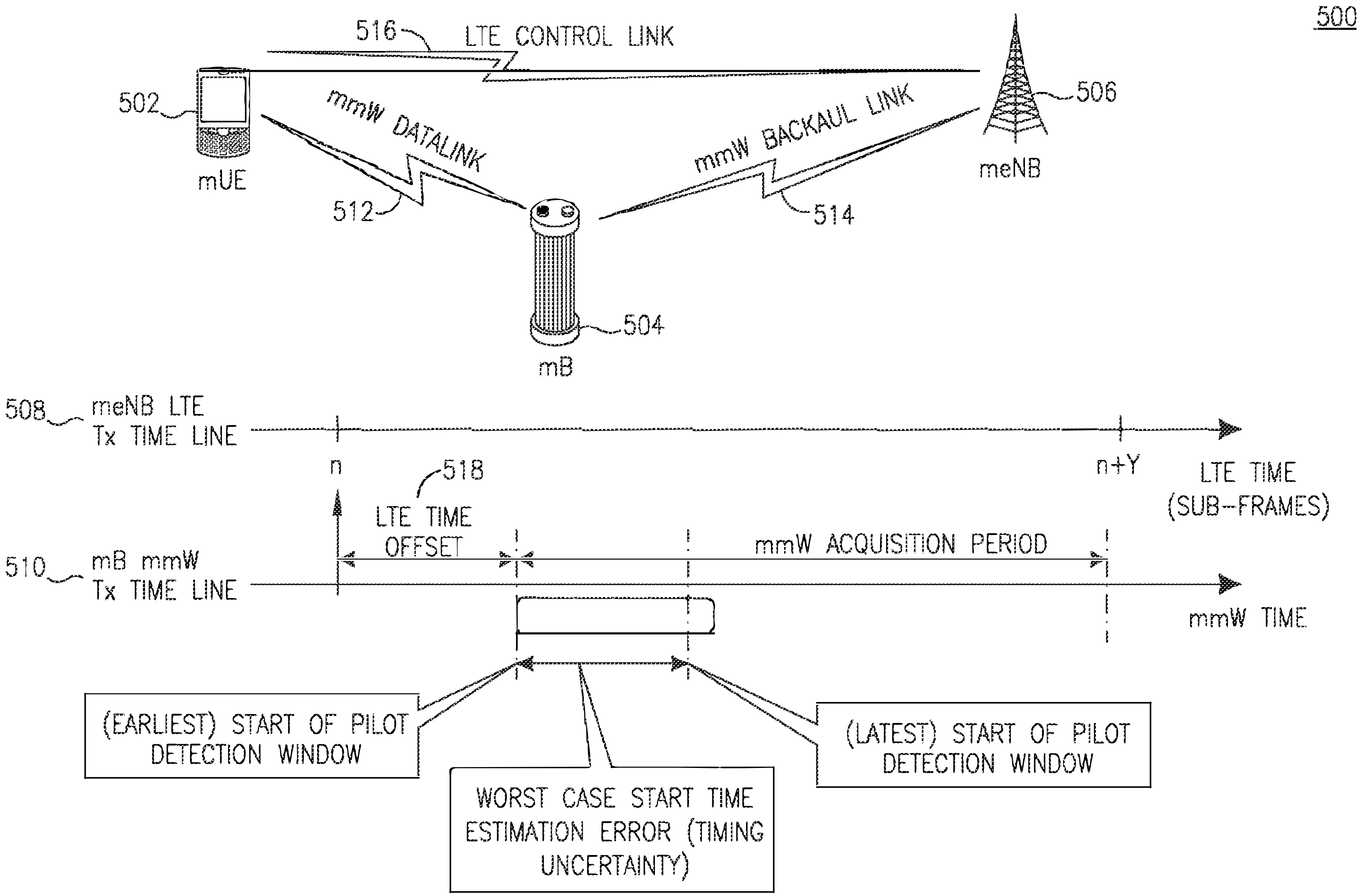

500
516
LTE CONTROL LINK
502
mUE
mmW DATALINK
512
mmW BACKAUL LINK
514
506
meNB
504
mB
508
meNB LTE
Tx TIME LINE
n
n+Y
LTE TIME
(SUB-FRAMES)
518
LTE TIME
OFFSET
mmW ACQUISITION PERIOD
510
mB mmW
Tx TIME LINE
mmW TIME
(EARLIEST) START OF PILOT
DETECTION WINDOW
WORST CASE START TIME
ESTIMATION ERROR (TIMING
UNCERTAINTY)
(LATEST) START OF PILOT
DETECTION WINDOW

FIG. 5

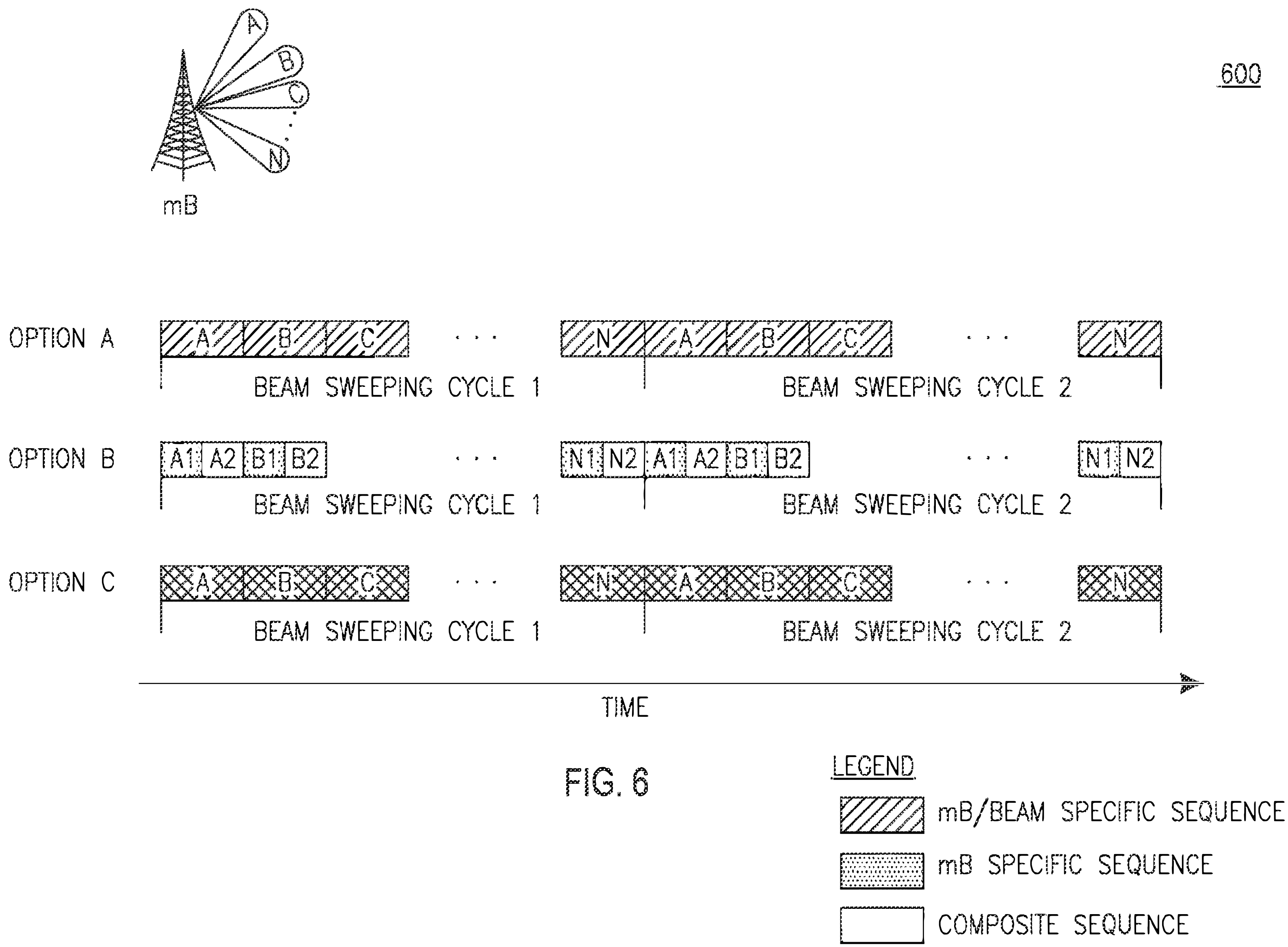

600
mB
A
B
C
N
OPTION A
BEAM SWEEPING CYCLE 1
BEAM SWEEPING CYCLE 2
OPTION B
A1 A2 B1 B2
N1 N2 A1 A2 B1 B2
N1 N2
OPTION C
TIME
LEGEND
mB/BEAM SPECIFIC SEQUENCE
mB SPECIFIC SEQUENCE
COMPOSITE SEQUENCE

FIG. 6

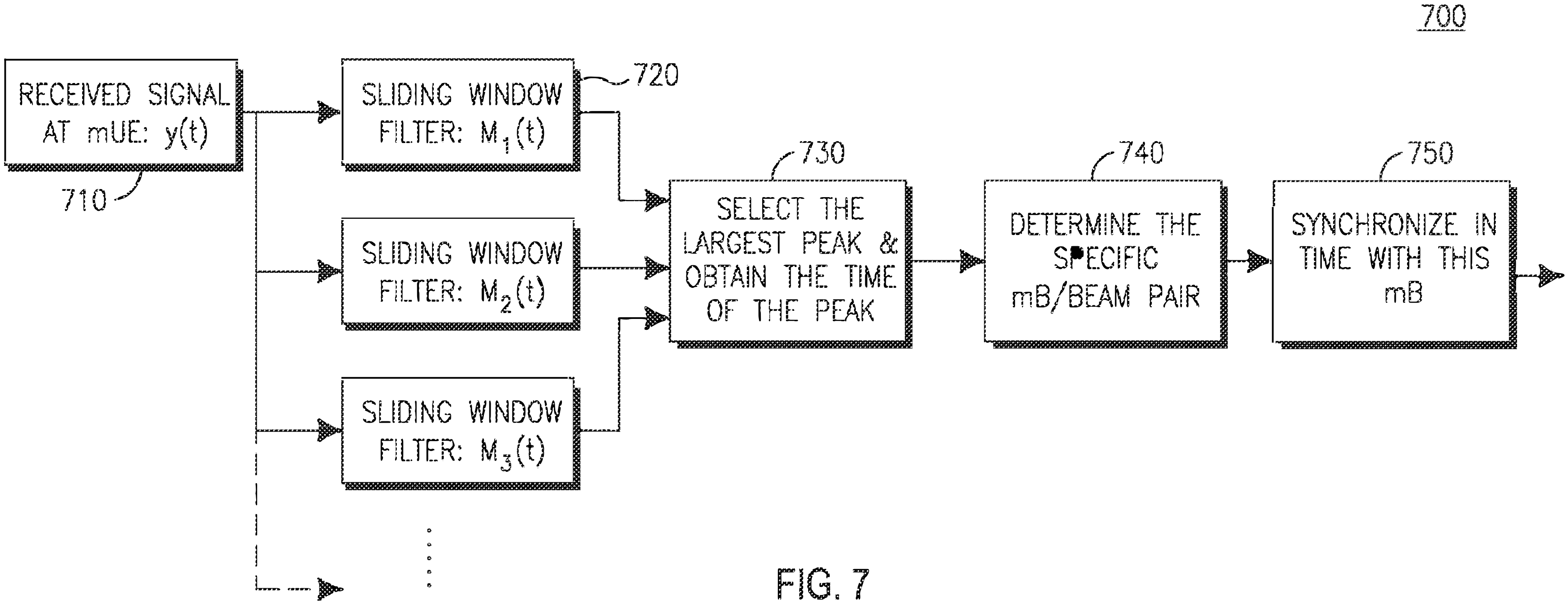

700
RECEIVED SIGNAL AT mUE: y(t)
710
SLIDING WINDOW FILTER: M1(t)
720
SLIDING WINDOW FILTER: M2(t)
SLIDING WINDOW FILTER: M3(t)
730
SELECT THE LARGEST PEAK & OBTAIN THE TIME OF THE PEAK
740
DETERMINE THE SPECIFIC mB/BEAM PAIR
750
SYNCHRONIZE IN TIME WITH THIS mB

FIG. 7

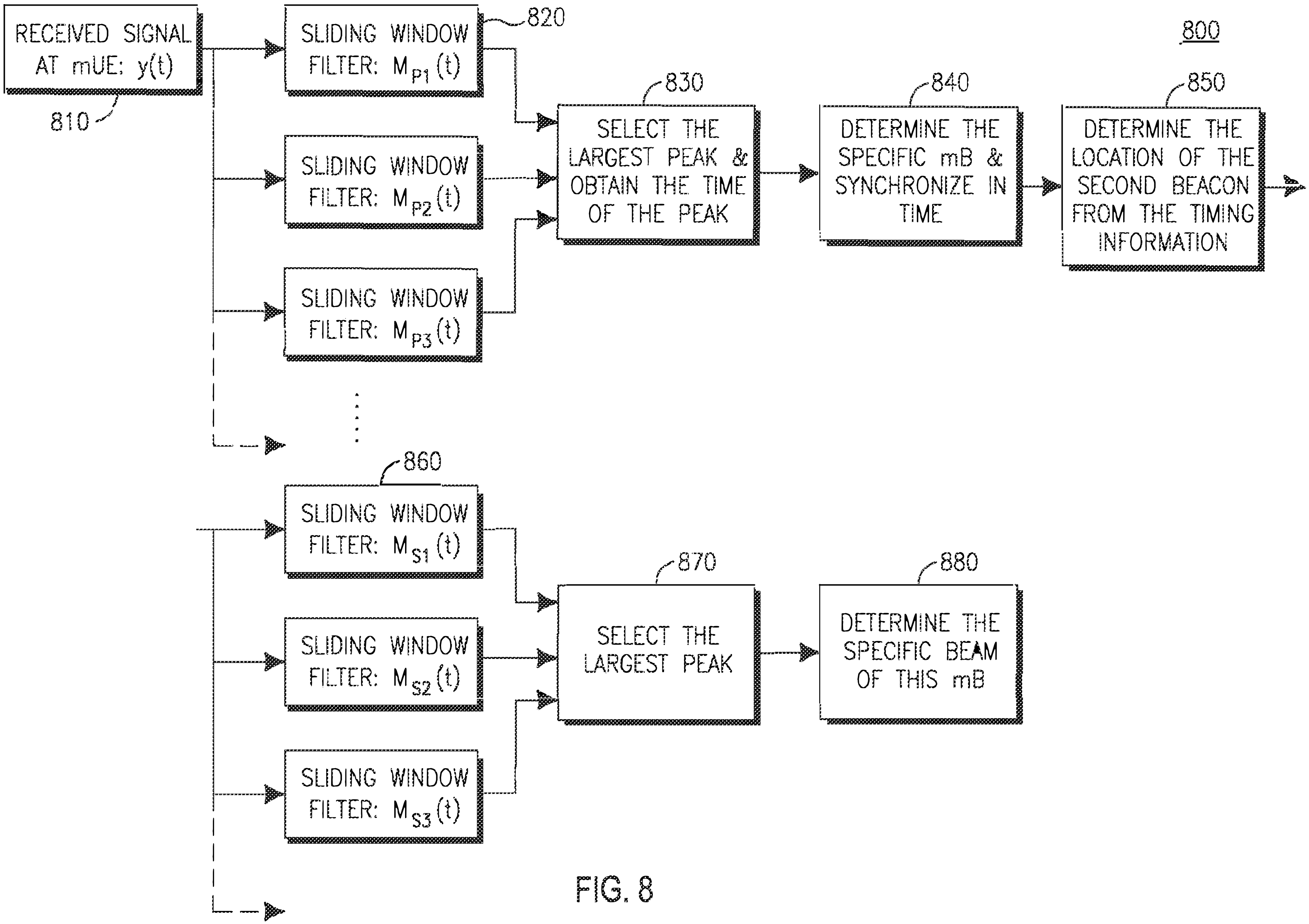

800
RECEIVED SIGNAL AT mUE: y(t)
810
SLIDING WINDOW FILTER: $M_{P1}(t)$
820
SLIDING WINDOW FILTER: $M_{P2}(t)$
SLIDING WINDOW FILTER: $M_{P3}(t)$
830
SELECT THE LARGEST PEAK & OBTAIN THE TIME OF THE PEAK
840
DETERMINE THE SPECIFIC mB & SYNCHRONIZE IN TIME
850
DETERMINE THE LOCATION OF THE SECOND BEACON FROM THE TIMING INFORMATION
860
SLIDING WINDOW FILTER: $M_{S1}(t)$
SLIDING WINDOW FILTER: $M_{S2}(t)$
SLIDING WINDOW FILTER: $M_{S3}(t)$
870
SELECT THE LARGEST PEAK
880
DETERMINE THE SPECIFIC BEAM OF THIS mB

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/068206

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W48/16
ADD. H04W48/12 H04W36/00 H04W36/14

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)
H04W

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)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2010/080197 A1 (KANELLAKIS KELLY G [CA] ET AL) 1 April 2010 (2010-04-01) paragraph [0005] - paragraph [0010] paragraph [0021] - paragraph [0042] -----	1-29
A	US 2010/074190 A1 (CORDEIRO CARLOS [US] ET AL) 25 March 2010 (2010-03-25) figures 1-3 paragraph [0011] paragraph [0013] - paragraph [0019] -----	1-29
	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] 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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"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
6 February 2013	27/02/2013

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, Fax: (+31-70) 340-3016	Bösch, Michael

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/068206

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2010/078590 A1 (QUALCOMM INC [US]; TENNY NATHAN EDWARD [US]) 8 July 2010 (2010-07-08) paragraph [0006] paragraph [0009] - paragraph [0011] paragraph [0045] - paragraph [0054] paragraphs [0061], [0062] paragraph [0074] - paragraph [0076] figures 3,5 -----	1-29
A	WO 2011/097416 A1 (QUALCOMM INC [US]; TAGHAVI NASRABADI MOHAMMAD HOSSEIN [US]; JAIN AVINA) 11 August 2011 (2011-08-11) paragraphs [0044], [0045] paragraph [0049] - paragraph [0053] paragraphs [0060], [0061], [0065] paragraph [0074] - paragraph [0091] figures 1,3A-3D,5-8 -----	1-29

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2012/068206

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 2010080197	A1	01-04-2010	CN	102165814	A	24-08-2011
			EP	2332372	A1	15-06-2011
			JP	2012504354	A	16-02-2012
			KR	20110066131	A	16-06-2011
			US	2010080197	A1	01-04-2010
			WO	2010034114	A1	01-04-2010
US 2010074190	A1	25-03-2010	CN	101714893	A	26-05-2010
			EP	2340669	A2	06-07-2011
			JP	2012503944	A	09-02-2012
			TW	201019748	A	16-05-2010
			US	2010074190	A1	25-03-2010
			WO	2010036595	A2	01-04-2010
WO 2010078590	A1	08-07-2010	CN	102273285	A	07-12-2011
			EP	2384597	A1	09-11-2011
			JP	2012514902	A	28-06-2012
			KR	20110102944	A	19-09-2011
			TW	201112705	A	01-04-2011
			US	2010172272	A1	08-07-2010
			WO	2010078590	A1	08-07-2010
WO 2011097416	A1	11-08-2011	CN	102742171	A	17-10-2012
			EP	2532095	A1	12-12-2012
			KR	20120123529	A	08-11-2012
			TW	201212555	A	16-03-2012
			US	2011211562	A1	01-09-2011
			WO	2011097416	A1	11-08-2011

Espacenet

Bibliographic data: EP2987276 (A1) — 2016-02-24

SIGNALING OF SYSTEM INFORMATION TO MTC-DEVICES

Inventor(s): FRENGER PÅL [SE]; DIMOU KONSTANTINOS [US]; BALDEMAIR ROBERT [SE]; BERGMAN JOHAN [SE]; ERIKSSON ERIK [SE] ± (FRENGER, PÅL, ; DIMOU, KONSTANTINOS, ; BALDEMAIR, ROBERT, ; BERGMAN, JOHAN, ; ERIKSSON, ERIK, ; FRENGER, Pål, ; DIMOU, Konstantinos, ; BALDEMAIR, Robert, ; BERGMAN, Johan, ; ERIKSSON, Erik)

Applicant(s): ERICSSON TELEFON AB L M [SE] ± (TELEFONAKTIEBOLAGET LM ERICSSON (PUBL), ; Telefonaktiebolaget LM Ericsson (publ))

Classification:
- international: *H04L12/24; H04L29/08; H04W16/08; H04W4/00; H04W48/02; H04W48/08; H04W48/10; H04W48/12; H04W56/00; H04W74/00; H04W74/08; H04W8/24; H04W48/18*
- cooperative: H04W16/08 (EP, RU); H04W28/0215 (RU); H04W48/12 (EP); H04W4/70 (EP); H04W48/18 (EP)

Application number: EP20130736995 20130620 Global Dossier

Priority number(s): US201361811903P 20130415 ; WO2013SE50745 20130620

Also published as: EP2987276 (B1) AU2013386897 (A1) AU2013386897 (B2) BR112015025960 (A2) CA2909666 (A1) CA2909666 (C) CN105122729 (A) CN105122729 (B) JP2016522605 (A) JP6196373 (B2) KR101771832 (B1) KR20150144330 (A) MX2015014410 (A) MX346771 (B) NZ712793 (A) PH12015501992 (A1) PH12015501992 (B1) RU2015148941 (A) RU2639660 (C2) SG11201507252S (A) WO2014171868 (A1) less

Abstract not available for EP2987276 (A1)
Abstract of corresponding document: WO2014171868 (A1)

Network node and UE, and methods therein for signaling system information, SI, to UEs. The method in the network node comprises transmitting SIto one or more UEs, where the SI comprisesmultiple alternative sets, where each set assigns different values to one or multiple radio system parameters. The method further comprises determining which set, out of the multiple alternative sets, that should currently be applied for a UE, and transmitting an SI selection signal to the UE, the SI selection signal indicating the determined set, thus enabling the UE to apply currently

appropriate radio system parametersalso in unfavorable radio conditions.The UE may be an MTC device (Machine Type Communication).

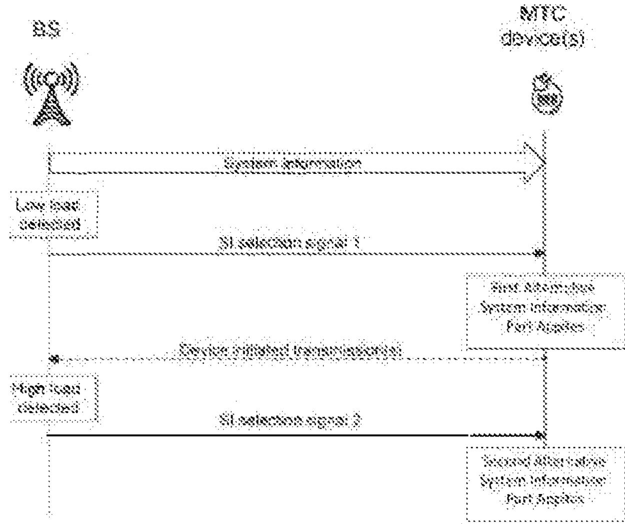

Figure 2

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Veröffentlichungsnummer:
(11) Publication number: EP 2 987 276 A0
(11) Numéro de publication:

Internationale Anmeldung veröffentlicht durch die Weltorganisation für geistiges Eigentum unter der Nummer:

WO 2014/171868 (Art. 153(3) EPÜ).

International application published by the World Intellectual Property Organization under number:

WO 2014/171868 (Art. 153(3) EPC).

Demande internationale publiée par l'Organisation Mondiale de la Propriété Intellectuelle sous le numéro:

WO 2014/171868 (art. 153(3) CBE).

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
23 October 2014 (23.10.2014)

WIPO | PCT

(10) International Publication Number
WO 2014/171868 A1

(51) International Patent Classification:
H04L 12/24 (2006.01) *H04W 74/08* (2009.01) *H04W 4/00* (2009.01) *H04W 56/00* (2009.01) *H04W 48/02* (2009.01) *H04W 48/12* (2009.01) *H04W 48/08* (2009.01) *H04W 74/00* (2009.01) *H04W 8/24* (2009.01) *H04W 48/10* (2009.01) *H04L 29/08* (2006.01)

(21) International Application Number: PCT/SE2013/050745

(22) International Filing Date: 20 June 2013 (20.06.2013)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/811,903 15 April 2013 (15.04.2013) US

(71) Applicant: TELEFONAKTIEBOLAGET L M ERICSSON (PUBL) [SE/SE]; SE-164 83 Stockholm (SE).

(72) Inventors: FRENGER, Pål; Enskiftesgatan 8, SE-583 34 Linköping (SE). DIMOU, Konstantinos; Norrbackagatan 11, 2nd floor, SE-113 41 Stockholm (SE). BALDEMAIR, Robert; Hornörsgatan 16, SE-17069 Solna (SE). BERGMAN, Johan; Kungsholmsgatan 9, SE-112 27 Stockholm (SE). ERIKSSON, Erik; Landeryd, Skogsstugan, SE-585 93 Linköping (SE).

(74) Agent: BOU FAICAL, Roger; Ericsson AB, Patent Unit Kista RAN 1, SE-164 80 Stockholm (SE).

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC,

[Continued on next page]

(54) Title: SIGNALING OF SYSTEM INFORMATION TO MTC-DEVICES

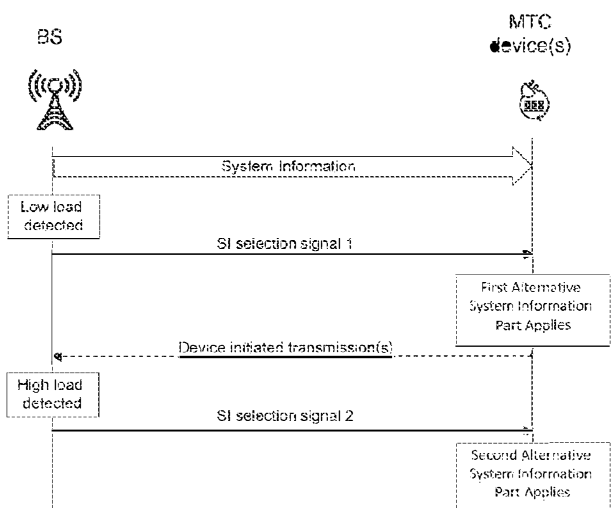

Figure 2

(57) Abstract: Network node and UE, and methods therein for signaling system information, SI, to UEs. The method in the network node comprises transmitting SIto one or more UEs, where the SI comprisesmultiple alternative sets, where each set assigns different values to one or multiple radio system parameters. The method further comprises determining which set, out of the multiple alternative sets, that should currently be applied for a UE, and transmitting an SI selection signal to the UE, the SI selection signal indicating the determined set, thus enabling the UE to apply currently appropriate radio system parametersalso in unfavorable radio conditions.The UE may be an MTC device (Machine Type Communication).

WO 2014/171868 A1

SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

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SIGNALING OF SYSTEM INFORMATION TO MTC-DEVICES

TECHNICAL FIELD

[01] The invention relates generally to system information in a wireless communications system, and in particular to signaling of system information to UEs (User Equipments), such as MTC-devices.

BACKGROUND

[02] Machine Type Communications (MTC or M2M) is expanding rapidly and has the potential to generate significant revenues for mobile network operators. MTC Devices are expected to outnumber voice subscribers by at least two orders of magnitude. Some predictions are much higher. MTC enables machines to communicate directly with one another M2M communication has the potential to radically change the world around us and the way that people interact with machines.

[03] As technology evolves, there are important changes in capabilities and costs. More computing power, memory and communication capabilities make it possible for machines to perform some tasks which were previously performed by human beings. The use of machines instead of human labor is often associated with lower costs. Increasing capabilities and lower costs together may open new opportunities for revenue generating services, which were not previously provided for economical reasons.

[04] MTC devices may be providing a wide variety of features. In the area of home automation, the MTC devices may be providing sensor capabilities such as, sensing temperature, humidity, open/closed/locked doors or windows, energy meters, water meters and similar, as well as various actuators such as for turning on heater/cooler, switching lights or pumps on/off, and similar applications related to home and workplace automation. Another area that can use machine to machine communication is security and surveillance related to homes and offices. Various sensors such as motion sensors, smoke detectors, cameras, etc, are connected to local or central security systems, which in turn are connected to actuators such as sirens, sprinklers, speakers, etc. Another area is automotive

where vehicles may include a wide range of different kind of sensors and actuates. Another area is transportation and logistics where both logistics centers as well as vehicles for transportation may contain both sensors and actuators for tracking of or creation of documents at certain toll gates. Material and goods may contain sensors and/or actuators, for example to monitor or control that certain quality requirements are fulfilled, such as temperature or mechanical shock.

[05] In a future "Networked society" scenario, there is expected to be a very large number of MTC devices in the wireless networks, as previously stated. Many of the MTC devices will transmit relatively small amounts of uplink data rather seldom, e.g. 100 bits once per hour. In LTE, there are plans of introducing a new solution for so-called "enhanced MTC coverage" with a target to enable MTC communication in areas where no communication is possible as of today. The target is formulated such as that the LTE link budget should be increased with approximately 20 dB, as compared to what is supported with the legacy LTE standard [3GPP Tdoc RP-121441]. Such a solution for enhanced MTC coverage is expected to make LTE even more attractive for MTC type of solutions, since it would imply that also MTC devices having very unfavorable radio conditions would be enabled to communicate in an LTE network. That is, devices which would not be able to communicate in an LTE network of today, herein called a "legacy" network, due e.g. to unfavorable radio conditions, could be able to communicate in an LTE network supporting enhanced MTC coverage. However, it is not yet clear how this improvement will be achieved. Further, it is not clear how MTC traffic and e.g. legacy data traffic should be coordinated in such a system.

SUMMARY

[06] The herein described technology enables an efficient sharing of in-band radio resources between a legacy LTE system and a system for extended coverage, such as an implementation of enhanced MTC coverage described above. Access parameters of the system for extended coverage can be changed quickly by means of changing e.g. a synchronization signal transmitted by a base station and received by the extended coverage UEs. This method is useful for devices which support delay tolerant traffic and for which the extra overhead and

complexity that this method exhibits are not prohibitive. It is an optimization method so as to allow devices with delay tolerant traffic to report their measurements in case the network is no longer congested e.g. by other high order priority users.

[07] According to a first aspect, a method for updating system information is provided, to be performed by a network node operable in a wireless communication system. The method comprises transmitting system information, SI, to one or more UEs, said SI comprising multiple alternative sets, where each set assigns different values to one or multiple radio system parameters. The method further comprises determining which set, out of the multiple alternative sets, that should currently be applied for a UE, and further transmitting an SI selection signal to the UE, the SI selection signal indicating the determined set, thus enabling the UE to apply currently appropriate radio system parameters.

[08] According to a second aspect, a method for updating system information is provided, to be performed by a UE operable in a wireless communication system. The method comprises receiving SI from a network node, said SI comprising multiple alternative sets, where each set assigns different values to one or multiple radio system parameters. The method further comprises receiving an SI selection signal from the network node, the SI selection signal indicating one of the alternative sets. The method further comprises applying the set indicated by the SI selection signal, thus enabling fast updating of system information in unfavorable radio conditions.

[09] According to a third aspect, a network node is provided for updating system information. The network node is operable in a wireless communication system and comprises a transmitting unit adapted to transmit SI to one or more UEs, said SI comprising multiple alternative sets, where each set assigns different values to one or multiple radio system parameters. The network node further comprises a control unit adapted to determine which set, out of the multiple alternative sets, that should currently be applied for a UE. The network node is further adapted to transmit an SI selection signal to the UE, the SI selection signal indicating the determined set.

[010] According to a fourth aspect, a UE for updating system information is provided. The UE is operable in a wireless communication system and comprises a receiving unit, adapted to receive SI from a network node, said SI comprising multiple alternative sets, where each set assigns different values to one or multiple radio system parameters. The receiving unit is further adapted to receive an SI selection signal from the network node, the SI selection signal indicating one of the alternative sets. The UE further comprises an applying unit, adapted to apply the set indicated by the SI selection signal.

BRIEF DESCRIPTION OF THE DRAWINGS

[011] The foregoing and other objects, features, and advantages of the technology disclosed herein will be apparent from the following more particular description of embodiments as illustrated in the accompanying drawings. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the technology disclosed herein.

Figure 1 shows signaling between a Base Station and a User Equipment in a wireless communication system, according to an exemplifying embodiment.

Figure 2 illustrates an exemplifying signaling scheme according to an exemplifying embodiment.

Figure 3 is a flow chart illustrating procedure in a BS, according to an exemplifying embodiment.

Figure 4 is a flow chart illustrating procedure in a UE, according to an exemplifying embodiment.

Figure 5 is a block chart, illustrating a BS, according to an exemplifying embodiment.

Figure 6 is a block chart, illustrating a UE, according to an exemplifying embodiment.

Figure 7 is a block chart illustrating an arrangement according to an exemplifying embodiment.

DETAILED DESCRIPTION

[012] Herein, it is referred to an extended coverage and an extended coverage mode. By extended coverage is here meant an extension, such as the so-called "enhanced MTC coverage", discussed in the LTE community, which will also be further described below. The extended coverage may herein alternatively be denoted "deep coverage". A device operating in an enhanced coverage mode may herein be referred to e.g. as a "deep coverage UE", or a "deep coverage MTC-device". In analogy, a service utilizing the enhanced coverage may herein be denoted e.g. "deep coverage service". An MTC device is considered to be, and will be referred to, as a type of UE.

[013] The solution described herein is primarily, but not exclusively, related to situations where a UE needs to communicate in an extended coverage mode. Communicating in an extended coverage mode is expected to consume more time and resources than communicating the same amount of information in a regular communication mode, at least if the extended coverage is achieved by use of repetition. In such a mode, it is expected that it will take a lot of time to receive e.g. system information. In excellent radio conditions, a UE will not need to use an extended coverage mode. The solution is herein described mainly in the context of MTC devices, since many MTC devices are expected to be located in places with unfavorable radio conditions, and are therefore expected to communicate in an extended coverage mode. However, there are examples where other UEs may benefit from communicating in an extended coverage mode. The solution may e.g. provide long range extended area coverage in wilderness areas.

[014] In a system supporting extended coverage, there will be devices, e.g. MTC devices, which communicate in an extended coverage mode, but there may also be devices, e.g. smartphones or MTC devices, which do not support extended coverage, or which do not use extended coverage mode for the moment. These different devices should preferably be able to co-exist in the network and share the available resources. In such a scenario, it may be desired to control which devices that should be allowed to communicate at a certain time, and which devices that should not be allowed to communicate at that time. This may be achieved e.g. by

updating certain parts of the system information (SI) of the devices. System information is information which enables a UE to access the network and to operate properly within the network and within a specific cell. System information is typically broadcasted repeatedly by a network. The system information includes, among other things, information about the downlink and uplink cell bandwidths, the uplink/downlink configuration in the case of TDD, detailed parameters related to random-access transmissions and uplink power control. The system information further comprises so-called "cell barring information", which is information regarding e.g. whether a cell may be accessed or not.

[015] In case there is a temporary capacity problem in a cell it may be desired to change the cell barring information for some devices. For example, it may be desired to temporarily prevent devices that use a large number of resources for transmitting a small number of bits, e.g. due to repetition, from using the cell resources. However, it may also be desired to make exceptions from the prevention, e.g. for very important information, or for devices of subscribers paying a large amount of money for the delivery of their small number of bits. Therefore it may be desired to have a possibility to be selective when changing e.g. the cell barring information.

[016] A coverage enhancement of 20 dB, as discussed for the "enhanced MTC coverage", is equivalent to achieving a 100 times higher signal-to-noise ratio. To achieve in the order of 20 dB coverage enhancements in LTE, multiple physical channels and physical signals will need to be improved. Since the required improvements are so large, and since LTE is already very good, i.e. there is no known flaw in LTE that can provide improvements anywhere near 100 times, it is likely that repetition will be used to provide most of the required coverage improvements. That is, the same information may need to be transmitted e.g. 100 times in order for a receiver to be able to decode the information correctly, due to that the received signal is so weak. Current LTE signals cannot easily be repeated approximately 100 times without consequences. Therefore, new signals may need to be defined for this purpose

[017] An outcome of the 3GPP work on enhanced coverage for MTC devices may therefore be a new set of signals and physical channels that are defined on top of the existing legacy LTE signals and physical channels. The new set of signals and channels may preferably be defined inside the data region of the current LTE carrier. That way, existing legacy UEs will simply ignore the new signals and channels, as they will appear to be data directed to some other UE, which is, in fact, the case, although the signaling format might be new.

[018] Assigning a separate set of radio resources, e.g. a frequency band, to be dedicated for the deep coverage MTC terminals could become very costly. Therefore, it is desirable that legacy services and deep coverage services are enabled to co-exist on the same carrier. Deep-coverage UEs, such as deep coverage MTC devices, may consume a large amount of radio resources while generating very low income per device. During peak traffic hours those radio resources are better used for e.g. normal, legacy, voice and mobile broadband services, which generate better incomes, and therefore it may be beneficial to be able to temporarily bar, i.e. exclude, some of the deep coverage traffic at those times. But, since resources that are not needed by the legacy services at a given point in time are wasted today, it would not cost much to assign such resources to deep coverage services, as long as the resources can be efficiently shared with legacy services.

[019] Below, the deep coverage devices will be referred to as MTC devices. As soon as the temporary capacity problem in a cell, as discussed above, is over, it will be desired to quickly inform the temporarily barred MTC devices that they are allowed back into the system again. However, changing the content of broadcasted system information (SI) normally takes a rather long time to perform. The system information can be updated only at specific radio frames or modification periods, as described in 3GPP TS 36.331 § 5.2.1.3. A sensible option for the SI modification period is that it should be at least higher than the maximum DRX cycle of devices in the cell. Upon consideration that DRX cycles in the orders of several minutes for MTC are currently under discussion, an idea on the required SI modification period can be obtained. Even under normal circumstances several

paging intervals are required for such a process. For low-rate devices with extremely poor link performance that are operating in an extended coverage mode, such as a power meter in an indoor basement, the reception of the system information is also a problem. Receiving a large amount of updated system information through a very poor radio link might require an extensive amount of time consuming signal repetition. Thus, changing the system information to MTC devices may take an even longer time, in comparison to UEs operating in a normal mode. This is a problem which needs a solution.

[020] In state-of-the-art systems it is not possible to change the system information fast enough. Cell barring information may be quite extensive, especially if it should be possible to differentiate the information such that different users have different cell barring parameters. At the same time, traffic fluctuations are happening at a millisecond time-scale. Therefore, there is a need for a new way of changing parts of the system information quickly and selectively. Herein, a solution to this problem is provided, which will be described in further detail below.

[021] Figure 1 shows an exemplifying embodiment of the solution. A base station transmits system information to an MTC device in need of coverage enhancement features, e.g. extensive repetition. The system information consists of an optional semi-static part and at least two alternative parts, a first and a second part in this example. That is, the system information, comprising different alternatives, is provided to the MTC device.

[022] It should be noted that the base station may also transmit other system information to other users that are not shown in the figure. For example, the MTC system information shown in the figure may be completely separated from the "normal" or "regular" system information, which is not shown in the figure, directed to and received by legacy UEs, which are not in need of coverage enhancement features. Alternatively, a subset of the system information may coincide with the regular system information. However, even in this case – due to difficult coverage conditions for MTC devices – the signaling scheme for MTC devices may differ from legacy procedures.

[023] In order for the MTC device to know which part of the optional system information to apply, the base station may also transmit an SI selection signal to the MTC device. The MTC device uses the SI selection signal to select which one of the alternative system information (SI) parts that currently applies. The MTC-device should at some point have been made aware of which part of the SI information that is indicated by a particular SI selection signal. Alternatively, the MTC-device could toggle between the alternatives, or change to a consecutive SI-part when detecting a change in SI selection signal.

[024] In one embodiment this SI selection signal may be a synchronization signal that is anyway transmitted from the base station to enable the MTC devices to acquire time and frequency synchronization. Please note that this MTC synchronization signal may be separate from the normal legacy synchronization signals transmitted to normal, non-extended coverage mode, legacy UEs.

[025] The SI selection signal may alternatively be some other signal than the synchronization signal, that is used also for other purposes, such as a demodulation reference signal that is anyway transmitted from the base station. It may also be a new signal designed explicitly for this purpose. The SI selection signal may be signaled in different ways. For example, it may be signaled as an information bit broadcasted over the whole coverage area or it may be sent only to a single user or a specific group of users. The SI selection signal may consist of one or more bits, and may be part of a protocol header, or, it may be transmitted e.g. as part of a so-called master information block (MIB).

[026] In case the synchronization signal is used to communicate the SI selection signal, it will be needed to consider the relation between the synchronization sequence transmitted and the physical cell identity (PCI) of the base station. Normally, the PCI has a one-to-one mapping towards the synchronization signal waveform. Once a UE has detected the synchronization signal, which in LTE Rel-8 consists of a primary (PSS) and a secondary (SSS) synchronization signal, then it also knows the physical cell ID of the cell. The PCI is a locally unique identifier used to identify the cell in signaling and measurement protocols, e.g. during handover, but it is also used to derive a large number of cell specific signals,

primarily uplink and downlink demodulation reference signals. If the synchronization signal waveform is to be used for indication of which system information part that currently applies, then it is important to clearly define how the MTC device should interpret a change of synchronization signal. One interpretation that should be avoided is that the MTC device thinks that the old cell is lost and that a new cell has entered. This could trigger an unnecessary attach procedure, where the MTC device tries to connect to the network via the cell corresponding to the newly found PCI. Instead, the MTC device should correctly understand that the new synchronization signal corresponds to the same cell as the old one. The MTC device may therefore keep its entire context in the base station, e.g. transmit and receive buffers, radio bearer configurations, cell-radio network temporary identifier (CRNTI), etc.

[027] One way to implement this is to de-couple the PCI from the synchronization signal for the MTC devices that require extended coverage. This might be beneficial if it is desired to avoid the risk of having cells associated with several PCIs in case separate synchronization signals are defined for legacy UEs and extended coverage MTC devices. In order to enable an MTC device to use the correct PCI in signaling and measurement protocols, the PCI could be explicitly signaled as part of the system information targeting the extended coverage devices.

[028] An alternative way is to design a several-to-one mapping between synchronization signals and the PCI. An MTC device may e.g. map the synchronization signal index to the PCI using a modulo operation which removes the ambiguity. In LTE the synchronization signal comprises two signals – the PSS (Primary Synchronization Signal), which has 3 different alternative realizations; and the SSS (Secondary Synchronization Signal), which has 168 different alternative realizations – and the cell ID is derived from their indices. Using such a multi-stage sync signal the cell could be determined by only one signal (e.g. SSS) and the SI selection signal could be the other signal, e.g. the PSS, which would enable selection of 1 out of 3 SI alternatives reusing current LTE numbers.

[029] The mapping may also be based e.g. on a table look-up, which could be fixed e.g. in the specification, grouping two or more synchronization signals to a PCI. It should be noted that it is not mandatory that an equal number of synchronizations signals map to each PCI. The mapping table between synchronization signal index and PCI may also be explicitly signaled as part of the system information targeting MTC devices. It should also be noted that the number of synchronization signals may be increased compared to current LTE standard.

[030] The existence of more than one synchronization signal/sequence might be hard coded at MTC devices, thus eliminating the risk of erroneous triggering of "lost cell", resulting in an unnecessary attach procedure, as indicated in the paragraph above.

[031] Figure 2 shows another example of the herein suggested technology. The base station "BS" transmits system information to many or all MTC devices in an extended coverage cell. At one time instant a low load is detected in the cell and hence there is no need to restrict some or all of the MTC devices from accessing the system. Therefore, as an example, the "SI selection signal 1" is transmitted. The MTC device detects this signal and understands, e.g. by consulting a mapping table, that the corresponding "first alternative system information part" applies. The MTC device may initiate one or more transmissions, illustrated as dashed line in figure 2, while this first system information part is valid or applied. At a later time instant, the base station detects a high load in the cell and it wants to restrict or prevent some of the MTC devices from accessing the network. It therefore sends out the "SI selection signal 2". The MTC device detects this signal and understands that the corresponding "second alternative system information part" now should be applied instead. In this example the MTC device is not allowed to initiate any transmissions when the second alternative system information part is valid or applied. The MTC device also understands that this signal is transmitted from the same network node as the old signal and that it (the MTC device) keeps its entire context in the network node.

[032] The different alternative system information parts, e.g. first and second part as illustrated in figure 1, may also control the rate at which the MTC devices send

their reports. In a normal situation, corresponding to e.g. the first alternative system information part, the MTC device may be allowed to access the network according to its default configuration, which may be e.g. once per 15 minutes. However, this rate may be reduced e.g. by a pre-defined fraction, when an overload situation occurs. For example, the MTC device may instead be allowed to access the network once every 30 minutes or once every hour during the overload situation. This new, reduced, configuration may be signaled or indicated to the MTC device e.g. by the transmission of "SI selection signal 2", as illustrated in figure 2. When applying a reduced access rate or frequency, the network can inform MTC devices e.g. to skip some of their upcoming measurement reports altogether, or to postpone them so that they can be combined into less frequent transmissions containing several measurement reports each.

[033] Whether to skip or to postpone individual measurement reports can e.g. be configurable by RRC signaling or indicated through the choice of synchronization signal. The latter case may require that additional synchronization signals are defined. It could be determined in advance or on the fly based on different factors, e.g. the priority of the data or on UE subscription information. For example, when the access restrictions apply, it may be desired to allow certain types of information without delay, e.g. different kinds of alarms, while other information, e.g. electricity meter readings, can either be skipped altogether or reported with reduced periodicity, where the reports with reduced periodicity could possibly, as already mentioned, contain measurement reports from more than one measurement occasion.

[034] The system information can either be transmitted via broadcast or dedicated transmission. Transmission via broadcast has the merit of reduced overhead when the system is fully loaded, while dedicated signaling has the merit of allowing for more flexible configurations, e.g. as when some important MTC devices should be allowed to transmit despite high load. Such important MTC devices could e.g. be configured with multiple identical alternative SI alternatives or just a single one, which must then always be used, independent of the SI selection signal. Thereby, such MTC devices could have e.g. a high access rate even when using broadcast

of different SI selection signals. Further, this on/off grouping dedicated signaling allows a more fine granular approach, e.g. that some MTC devices are not allowed to transmit at all during high loads, some MTC devices are allowed to transmit with reduced periodicity during high loads, and some MTC devices are not impacted at all. To avoid the high overhead associated with dedicated signaling the "baseline", where "baseline" here refers to that it is valid for many or most MTCs, system information configuration, including the baseline alternative sets, may be broadcasted, and "deviating", referring to "valid for few" or "exceptions to the baseline version", MTC behavior may be signaled to concerned MTC devices via dedicated signaling

[035] The new SI and SI Selection Signals, according to embodiments of the herein presented solution, directed to MTC devices, can be transmitted in the same time and frequency resources as used for the current, legacy, SI and SIBs, and they can be separated e.g. by using different codes for the different signals.

[036] The herein described method and messages may be applied for MTC devices whose traffic can tolerate delay. Information on the traffic type supported by different MTC devices can be provided to the network according to the prior art. The method and signaling structure described herein may be supported e.g. by devices which can handle the extra energy consumption which may be needed for reading the extra SI related messages and for using more than one synchronization sequences.

[037] As previously mentioned, even though the solution herein is primarily described for MTC devices, other types of UEs could also use and benefit from the solution. For example, in very large cells, where a UE, such as a smartphone, could have problems with initial access due to that the UE signals do not reach the base station, the UE could use an extended coverage procedure for accessing the cell. When having accessed the cell, and e.g. when more data needs to be transmitted in the uplink, beamforming could be used to enable regular communication between the UE and the base station.

[038] In a general manner, the herein suggested solution could be described as a first radio communication node transmitting system information, SI, to a second radio communication node, where the system information contains multiple, alternative, sets, where each set assigns different values to one or multiple radio system parameters. For example, the one or multiple radio system parameters could be access related parameters such as cell barring information, while other states and parameters remains unaffected when applying a different SI set. Such other states and parameters could be related to e.g. UE context, CRNTI, system bandwidth etc. Embodiments of the herein suggested solution may further comprise that a radio communication node (the first transmitting node, or another) transmits a signal, which may be denoted an "SI selection signal", indicating the set currently applicable in the radio communication system. The second radio communication node may receive the SI, including the multiple alternative sets, and may then receive the signal indicating the currently applicable set. Based on the received signal, the second radio communication node may determine which set to apply. The first radio communication node may be a base station such as an eNB, and the second radio communication node may be a UE, such as an MTC-device, e.g. located in a basement in a building The SI selection signal may be a synchronization signal, which may be dedicated to MTC devices, or be a signal which is directed both to legacy UEs and to UEs operating in an extended. coverage mode

[039] The SI is assumed to be transmitted, or otherwise provided, to devices very seldom, or at least be received by the MTC devices very seldom, e.g. once at setup and then possibly when the whole or parts of the SI information need to be replaced due to some major change.

[040] An exemplifying procedure in a network node, such as an eNB in an LTE network, is illustrated in figure 3a. The network node is operable to support an extended coverage mode, such as an implementation of "enhanced MTC coverage", as described above. The network node transmits SI to one or more UEs in an action 301. The UEs also support the extended coverage mode. The SI comprises at least one part for which a number of alternatives are provided. That

is, the SI comprises multiple alternative sets, where each set assigns different values to one or multiple radio system parameters. The network node then determines 303 which set, out of the multiple alternative sets, that should currently be applied for a UE. This action could, for example, be implemented by the two actions 303:1 and 303:2, as illustrated in figure 3b, which will be further described below.

[041] The network node then transmits an SI selection signal to the UE, where the SI selection signal indicates the determined set, in accordance with the determining in the action 303. Thereby, the UE is enabled to apply currently appropriate radio system parameters, i.e. the parameters in the determined system information set.

[042] The UEs could be MTC devices, such as power meters or alarm sensors, but could alternatively be e.g. smartphones, tablets, computers or other devices,. The UEs could be experiencing unfavorable radio conditions, and be in need of features associated with the extended coverage mode, such as e.g. extensive repetition. The SI could be broadcasted or transmitted in a dedicated manner, as previously described. The part or parts of the SI for which alternative sets are provided may be related to different things, which will be further described below.

[043] The determining of which set, out of the multiple alternative sets, that should currently be applied for a UE could be performed in different ways. For example, the network node could determine the current load in a cell associated with the network node. The determined cell load could be compared with a threshold value, representing a boundary e.g. between a load defined as high load, and a load defined as normal load. Depending on the comparison, it could be determined whether the current load is e.g. "high" or "normal", and a set, out of the plurality of alternative sets, corresponding to the determined current conditions could be determined or identified, and be indicated to a concerned UE via the associated SI selection signal. The SI selection signal could be implemented or realized in different ways, as previously described.

[044] For example, at one point in time, the load may be determined by the network node to be "high". The network node then selects alternative SI set_2, which is to be used by a certain type of UE during high load. "Certain type of UE" could refer e.g. to a low priority MTC device. The SI selection signal associated with, and indicating, alternative SI set_2 is then transmitted to a UE, which is of the certain type. At a later point in time, the load in the cell may have changed, and be determined to be "normal". Then, at normal load, there may be another set out of the alternative sets that should be applied for UEs of the certain type, e.g. alternative SI set_1. Then, the SI selection signal associated with, and indicating, alternative SI set_1 may be transmitted to the UE. The transmitting of different SI selection signals based on the determined load in the cell is illustrated as actions 304 and 305 in figure 3b. There may be more than two alternative SI selection signals and alternative SI sets. The decision criterion may also be different than the example given in figure 3b.

[045] The one or multiple radio system parameters may be related to cell access. That is, the system parameter comprised in the alternative sets may control e.g. whether the UE is allowed to access a cell or not, or to which extent the UE is allowed to access the cell. For example, the one or multiple radio system parameters may be related to so-called cell barring.

[046] The SI selection signal may be a synchronization signal. By synchronization signal is meant a reference signal or sequence which is used by UEs for synchronization. It could be a synchronization signal which is used for synchronization by legacy UEs and/or by UEs, such as MTC devices, which are in need of an extended coverage mode. Alternatively, one or more dedicated signals could be used as SI selection signals.

[047] A procedure for updating system information, performed by a UE is illustrated in figure 4. The UE may be e.g. an MTC device or a smartphone, which supports and is operable in an extended coverage mode, such as an implementation of so-called "enhanced MTC coverage". System Information, SI, is received 401 from a network node. The SI comprises multiple alternative sets, where each set assigns different values to one or multiple radio system

parameters. Further, an SI selection signal is received 402 from the network node. The SI selection signal indicates one of the alternative sets. Then, the UE applies 404, 405 the set, out of the multiple alternative sets, which corresponds to the SI selection signal. Thereby, fast updating of system information is enabled, also in unfavorable radio conditions.

[048] The SI, may be received from a base station over an air interface. Alternatively, the SI and the associated alternative parts thereof may be provided to the UE in some other way, e.g. during installation using e.g. a portable storage device, such as a USB memory. The received SI may be stored in the UE, e.g. in a memory.

[049] The receiving of the SI may take a long time, e.g. when the UE is located in unfavorable radio conditions. For example, if the extended coverage mode relies on repetition, the SI may need to be received e.g. 100 times for the UE to be able to decode it correctly. The SI selection signal may also need to be received a large number of times for the same reasons, but since the SI selection signal only comprises a fraction of the amount of data as compared to the SI information, the time is takes to receive the SI selection signal is small in comparison.

[050] The applying of the set indicated by the SI selection signal may comprise determining which alternative SI set that is indicated by the received SI selection signal. This determining may comprise use of a mapping table or other interpretation scheme stored in, or at least accessible to, the UE. The mapping table could be provided to the UE e.g. as part of the received SI or in some other therefore suitable way. At a later time instant, the UE may receive a second SI selection signal, indicating that another one of the alternative SI sets of the received SI should be used, instead of the one determined/selected based on the received first SI selection signal. The UE may then determine, based on the second SI selection signal, which alternative SI set that should be applied. This applying of different SI sets based on the SI selection signal is illustrated as actions 404 and 405 in figure 4. It should be noted that there may be more than two alternative SI selection signals and sets.

[051] As described above, the one or multiple radio system parameters may be related to cell access, such as cell barring.

[052] The SI selection signal, which may be e.g. a synchronization signal, has been described above, and will therefore not be described in more detail here.

[053] Embodiments described herein also relate to a network node operable in a wireless communication system. The network node is adapted to perform at least one embodiment of the method described above. The network node is associated with the same technical features, objects and advantages as the method described above. The network node will be described in brief in order to avoid unnecessary repetition.

[054] Below, an exemplifying network node, 501, adapted to enable the performance of the above described procedure in a network node, will be described with reference to figure 5. The network node supports an extended coverage mode such as an implementation of the enhanced MTC coverage mode described above.

[055] The part of the network node which is most affected by the adaptation to the herein described method is illustrated as an arrangement 501, surrounded by a dashed line. The network node could be a base station such as an eNB in an LTE communication system. The network node 500 and arrangement 501 is further illustrated as to communicate with other entities via a communication unit 502 which may be regarded as part of the arrangement 501. The communication unit comprises means for communication, such as e.g. a receiver 509 and a transmitter 508, or a transceiver. The communication unit may alternatively be denoted "interface". The arrangement or network node may further comprise other functional units 507, such as e.g. functional units providing regular eNB functions, and may further comprise one or more storage units 506.

[056] The arrangement 501 could be implemented e.g. by one or more of: a processor or a micro processor and adequate software and memory for storing thereof, a Programmable Logic Device (PLD) or other electronic component(s) or

processing circuitry configured to perform the actions described above, e.g. in any of the figures 3a-3b.

[057] The arrangement part of the network node may be implemented and/or described as follows:
The network node comprises a transmitting unit 503, adapted to transmit system information, SI, to one or more UEs, said SI comprising multiple alternative sets, where each set assigns different values to one or multiple radio system parameters. The network node further comprises a control unit, 504, adapted to determine which set, out of the multiple alternative sets, that should currently be applied for a UE. The control unit, or some other unit in the arrangement, is further adapted to transmit an SI selection signal to the UE, the SI selection signal indicating the determined set. The term "transmit" also covers triggering transmission of the SI selection signal.

[058] As described above, the one or multiple radio system parameters may be related to cell access, e.g. to cell barring. Further, the SI selection signal may be a synchronization signal, as previously described.

[059] Embodiments described herein also relate to a UE operable in a wireless communication system. The UE is adapted to perform at least one embodiment of the method described above. The UE is associated with the same technical features, objects and advantages as the method, performed by a UE, described above. The network node will be described in brief in order to avoid unnecessary repetition.

[060] Below, an exemplifying UE 601, adapted to enable the performance of the above described procedure performed by a UE will be described with reference to figure 6. The UE 600 is operable in a wireless communication system. The UE supports an extended coverage mode, such as an implementation of the enhanced MTC coverage mode described above.

[061] The part of the UE which is most affected by the adaptation to the herein described method is illustrated as an arrangement 601, surrounded by a dashed

line. The network node could be a UE such as an MTC device or a smartphone in an LTE communication system. The UE 600 and arrangement 601 is further illustrated as to communicate with other entities via a communication unit 602 which may be regarded as part of the arrangement 601. The communication unit comprises means for communication, such as e.g. a receiver 609 and a transmitter 608, or a transceiver. The communication unit may alternatively be denoted "interface". The arrangement or UE may further comprise other functional units 607, such as e.g. functional units providing regular UE functions, and may further comprise one or more storage units 606.

[062] The arrangement 601 could be implemented e.g by one or more of: a processor or a micro processor and adequate software and memory for storing thereof, a Programmable Logic Device (PLD) or other electronic component(s) or processing circuitry configured to perform the actions described above, e.g. in figure 4.

[063] The arrangement part of the UE may be implemented and/or described as follows:
The UE comprises a receiver unit 603, adapted to receive system information, SI, from a network node, said SI comprising multiple alternative sets, where each set assigns different values to one or multiple radio system parameters, and further adapted to receive an SI selection signal from the network node, the SI selection signal indicating one of the alternative sets. The UE further comprises an applying unit 605, adapted to apply the set indicated by the SI selection signal.

[064] As described above, the one or multiple radio system parameters may be related to cell access, e.g. to cell barring. Further, the SI selection signal may be e.g. a synchronization signal, as previously described.

[065] The UE may further comprise a determining unit 604, which could alternatively be denoted "selecting unit" and/or "identifying unit". The determining unit may be adapted to determine which SI selection signal that has been received, and which set, of the multiple alternative sets of SI, that should be applied, based on the received SI selection signal. The determining could be

based on different things, such as a mapping table or other decision scheme, stored in the UE, as previously described. Alternatively, the applying unit could be adapted to perform this step.

[066] Figure 7 schematically shows a possible embodiment of an arrangement 700, which also can be an alternative way of disclosing an embodiment of the arrangement 501 or 601 illustrated in any of figures 5 or 6. Comprised in the arrangement 700 are here a processing unit 706, e.g. with a DSP (Digital Signal Processor). The processing unit 706 may be a single unit or a plurality of units to perform different actions of procedures described herein. The arrangement 700 may also comprise an input unit 702 for receiving signals from other entities, and an output unit 704 for providing signal(s) to other entities. The input unit 702 and the output unit 704 may be arranged as an integrated entity.

[067] Furthermore, the arrangement 700 may comprise at least one computer program product 708 in the form of a non-volatile or volatile memory, e.g. an EEPROM (Electrically Erasable Programmable Read-Only Memory), a flash memory and/or a hard drive. The computer program product 708 may comprise a computer program 710, which comprises code means, which when executed in the processing unit 706 in the arrangement 700 causes the arrangement and/or a node in which the arrangement is comprised to perform the actions e.g. of the procedures described earlier in conjunction with figure 3a, 3b or 4.

[068] The computer program 710 may be configured as a computer program code structured in computer program modules. Hence, in an exemplifying embodiment for use in a network node, the code means in the computer program 710 of the arrangement 700 comprises a transmitter module 710a for transmitting System Information. The computer program 710 may further comprise a determining module 710b, for determining a cell load. The computer program 710 further comprises a selecting module 710c, for selecting or determining which set out of multiple sets related to the SI, to apply, e.g. based on the cell load, and thereby determining, which SI selection signal to transmit to a UE. The computer program may further comprise additional computer program modules 710d, adapted to

provide some or all of the different actions of the embodiments described above in conjunction with the procedure in a network node.

[069] A corresponding arrangement in a UE could be described in a similar manner, with the necessary changes made, which changes may be derived from other parts of this document.

[070] The modules 710a-c could essentially perform the actions of the flow illustrated in figure 3a or 3b, to emulate the arrangement 501 illustrated in figure 5.

[071] Although the code means in the embodiment disclosed above in conjunction with figure 7 are implemented as computer program modules which when executed in the processing unit causes the decoder to perform the actions described above in the conjunction with figures mentioned above, at least one of the code means may in alternative embodiments be implemented at least partly as hardware circuits.

[072] The processor may be a single CPU (Central processing unit), but could also comprise two or more processing units. For example, the processor may include general purpose microprocessors; instruction set processors and/or related chips sets and/or special purpose microprocessors such as ASICs (Application Specific Integrated Circuit). The processor may also comprise board memory for caching purposes. The computer program may be carried by a computer program product connected to the processor. The computer program product may comprise a computer readable medium on which the computer program is stored. For example, the computer program product may be a flash memory, a RAM (Random-access memory) ROM (Read-Only Memory) or an EEPROM, and the computer program modules described above could in alternative embodiments be distributed on different computer program products in the form of memories within the network node or within the UE.

[073] The above description of various embodiments of the herein suggested technology, while not limited to use in LTE systems, may be read and understood in the context of the existing 3GPP standards and revisions thereto, and may be

understood to reflect adaptations of well-known physical structures and devices to carry out the described techniques.

[074] Examples of several embodiments of the herein suggested technology have been described in detail above. Those skilled in the art will appreciate that the herein suggested technology can be implemented in other ways than those specifically set forth herein, without departing from essential characteristics of the suggested technology.

[075] The solution suggested by the inventors is herein mostly described in terms of EPS/LTE. It should, however, be noted that the general concepts of the solution are applicable also at least to UMTS/WCDMA/HSPA, and other systems having an extended coverage mode to support e.g. MTC devices in unfavorable radio conditions.

[076] It is to be understood that the choice of interacting units or modules, as well as the naming of the units are only for exemplifying purpose, and nodes suitable to execute any of the methods described above may be configured in a plurality of alternative ways in order to be able to execute the suggested process actions.

[077] It should also be noted that the units or modules described in this disclosure are to be regarded as logical entities and not with necessity as separate physical entities.

ABBREVIATIONS

3GPP	3rd Generation Partnership Project
BS	Base Station, e.g. eNB
C-RNTI	Cell Radio Network Temporary Identifier
eNB, eNodeB	evolved (E-UTRAN) NodeB
EPS	Evolved Packet System
E-UTRAN	Evolved UTRAN
HSPA	High Speed Packet Access
LTE	Long Term Evolution

MTC	Machine Type Communication
RRC	Radio Resource Control
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
UTRAN	Universal Terrestrial Radio Access Network

CLAIMS

1. Method for updating system information, performed by a network node in a wireless communication system, the method comprising:

   -transmitting system information, SI, to one or more User Equipments, UEs, said SI comprising multiple alternative sets, where each set assigns different values to one or multiple radio system parameters;
   -determining which set, out of the multiple alternative sets, that should currently be applied for a UE;
   -transmitting an SI selection signal to the UE, the SI selection signal indicating the determined set,
   thus enabling the UE to apply currently appropriate radio system parameters.

2. Method according to claim 1, wherein the one or multiple radio system parameters are related to cell access.

3. Method according to claim 1 or 2, wherein the one or multiple radio system parameters are related to cell barring.

4. Method according to any of the preceding claims, wherein the SI selection signal is a synchronization signal.

5. Method according to any of the preceding claims, wherein the UE is a Machine Type Communication, MTC, device.

6. Method for updating system information performed by a User equipment, UE, in a wireless communication system, the method comprising:

   -receiving system information, SI, from a network node, said SI comprising multiple alternative sets, where each set assigns different values to one or multiple radio system parameters;
   -receiving an SI selection signal from the network node, the SI selection signal indicating one of the alternative sets;

-applying the set indicated by the SI selection signal,
thus enabling fast updating of system information.

7. Method according to claim 6, wherein the one or multiple radio system parameters are related to cell access.

8. Method according to claim 6 or 7, wherein the one or multiple radio system parameters are related to cell barring.

9. Method according to any of claims 6-8, wherein the SI selection signal is a synchronization signal.

10. Method according to any of any of claims 6-9, wherein the UE is a Machine Type Communication, MTC, device.

11. Network node for updating system information, being operable in a wireless communication system, the network node comprising:

-a transmitting unit (503), adapted to transmit system information, SI, to one or more User Equipments, UEs, said SI comprising multiple alternative sets, where each set assigns different values to one or multiple radio system parameters;
-a control unit (504), adapted to determine which set, out of the multiple alternative sets, that should currently be applied for a UE; and further adapted to transmit an SI selection signal to the UE, the SI selection signal indicating the determined set.

12. Network node according to claim 11, wherein the one or multiple radio system parameters are related to cell access.

13. Network node according to claims 11 or 12, wherein the one or multiple radio system parameters are related to cell barring.

14. Network node according to any of claims 11-13, wherein the SI selection signal is a synchronization signal.

15. User Equipment, UE, for updating system information, being operable in a wireless communication system, the UE comprising:

-a receiving unit (603), adapted to receive system information, SI, from a network node, said SI comprising multiple alternative sets, where each set assigns different values to one or multiple radio system parameters; and further adapted to receive an SI selection signal from the network node, the SI selection signal indicating one of the alternative sets; and
-an applying unit (605), adapted to apply the set indicated by the SI selection signal.

16. User Equipment, UE according to claim 15, wherein the one or multiple radio system parameters are related to cell access.

17. User Equipment, UE according to claim 15 or 16, wherein the one or multiple radio system parameters are related to cell barring.

18. User Equipment, UE according to any of claims 15-17, wherein the SI selection signal is a synchronization signal.

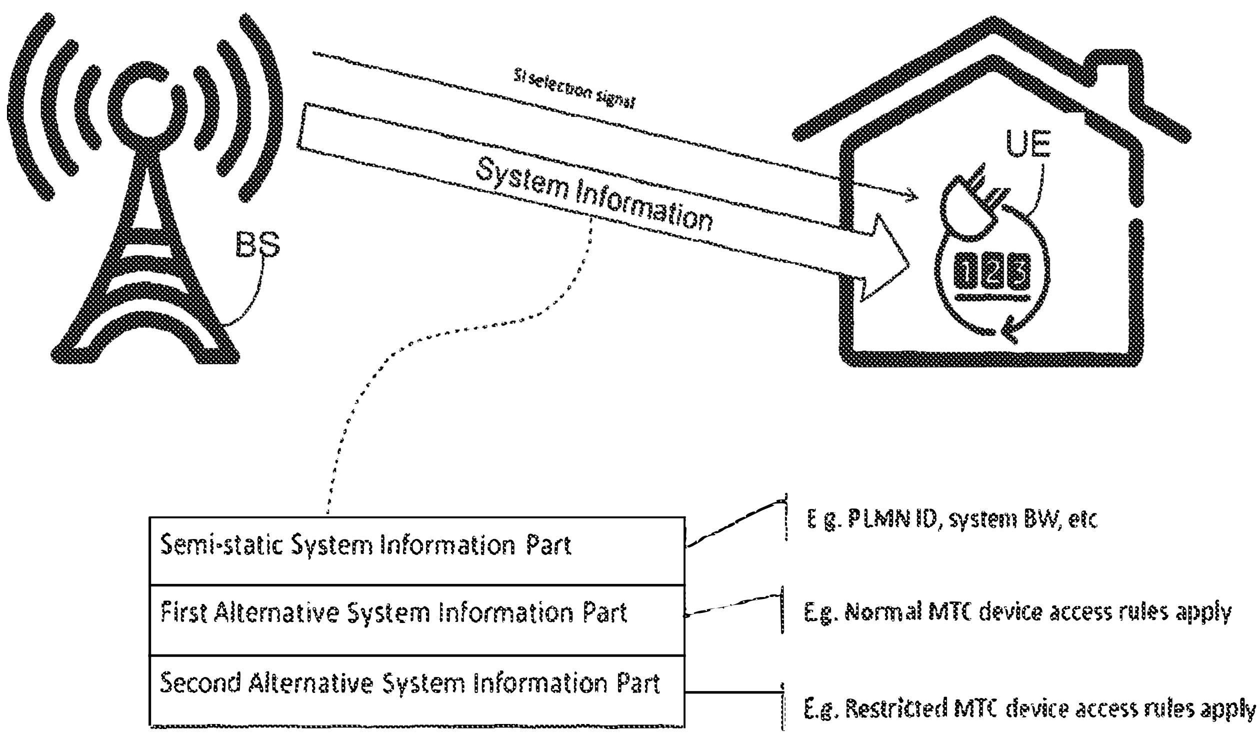
SI selection signal
System Information
BS
UE
Semi-static System Information Part
First Alternative System Information Part
Second Alternative System Information Part
E.g. PLMN ID, system BW, etc
E.g. Normal MTC device access rules apply
E.g. Restricted MTC device access rules apply

Figure 1

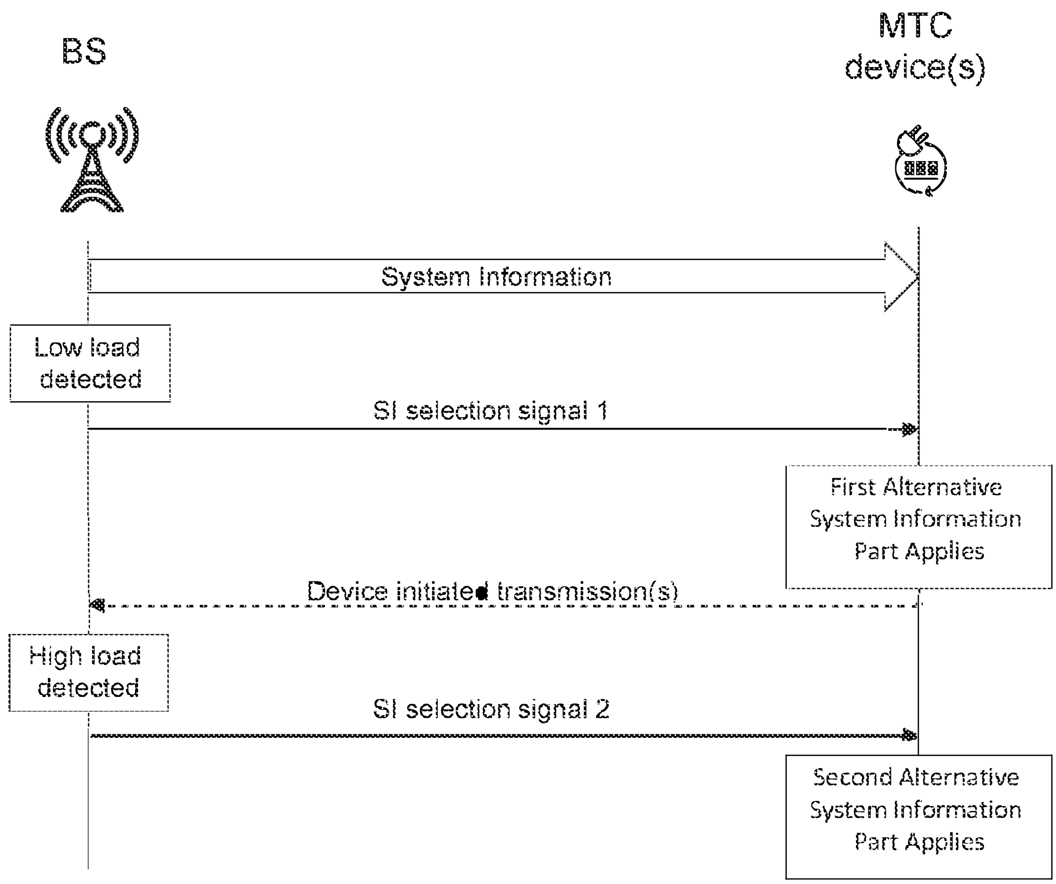
BS
MTC device(s)
System Information
Low load detected
SI selection signal 1
First Alternative System Information Part Applies
Device initiated transmission(s)
High load detected
SI selection signal 2
Second Alternative System Information Part Applies

Figure 2

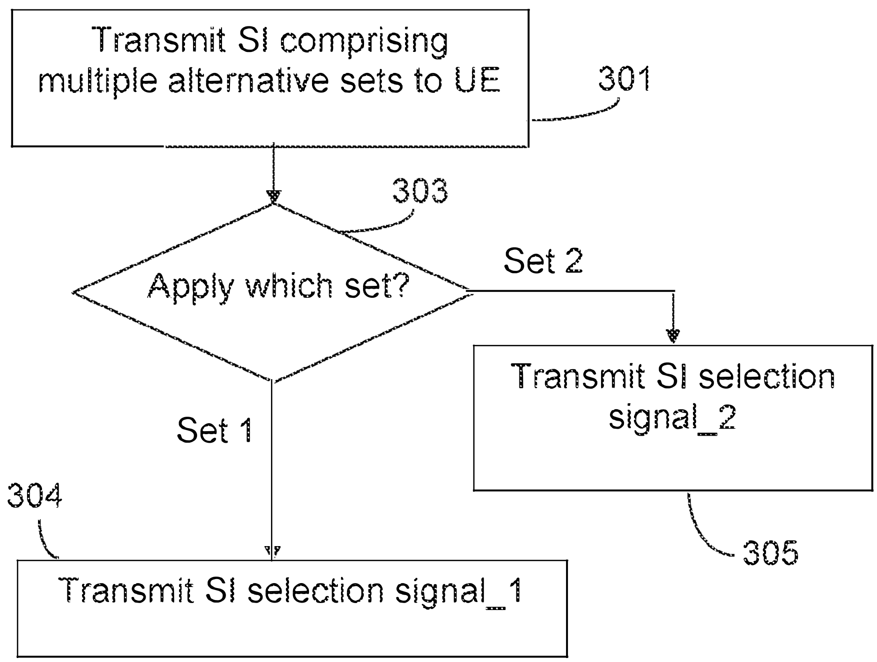

Figure 3a

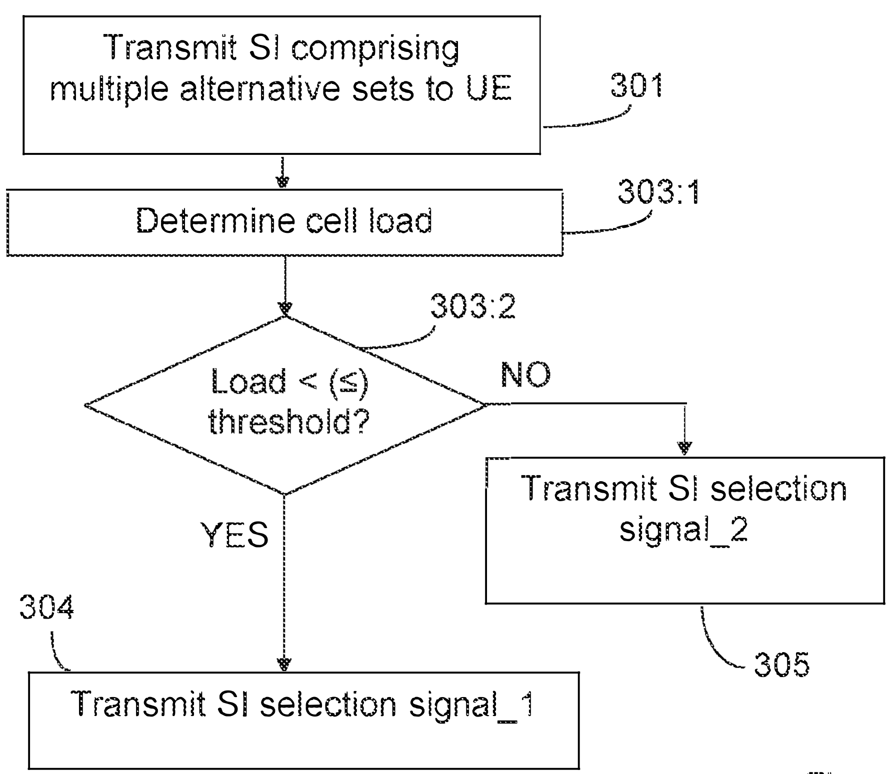

Figure 3b

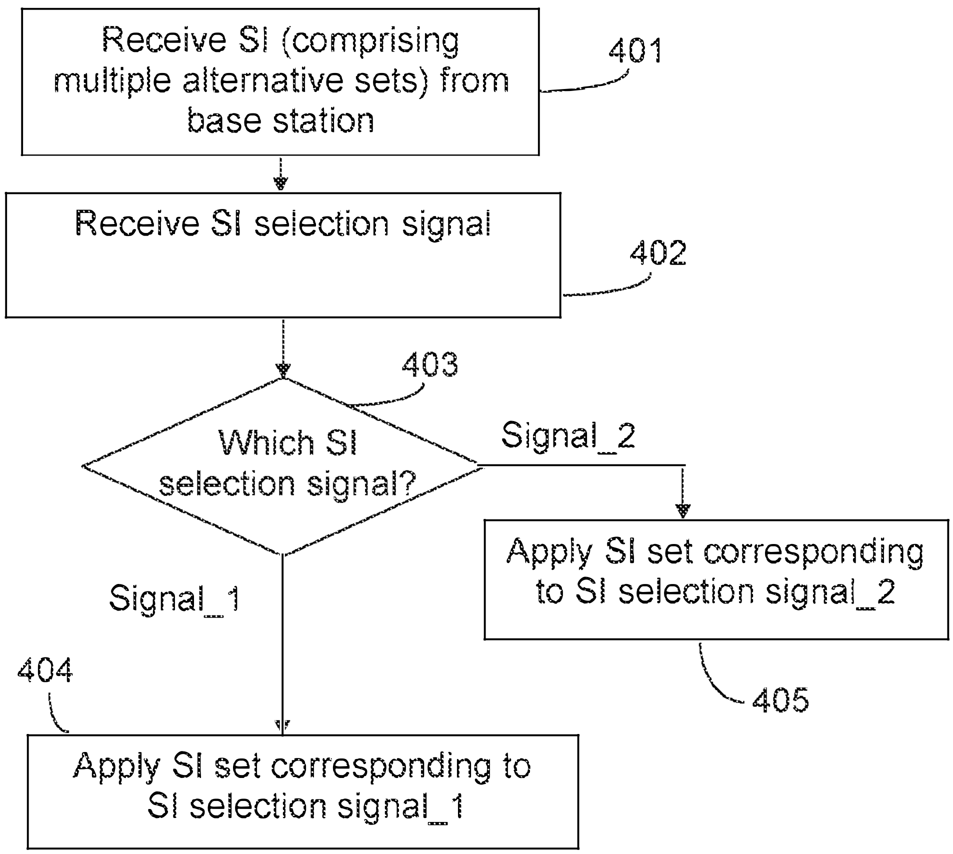
Receive SI (comprising multiple alternative sets) from base station
401
Receive SI selection signal
402
403
Which SI selection signal?
Signal_2
Apply SI set corresponding to SI selection signal_2
Signal_1
405
404
Apply SI set corresponding to SI selection signal_1

Figure 4

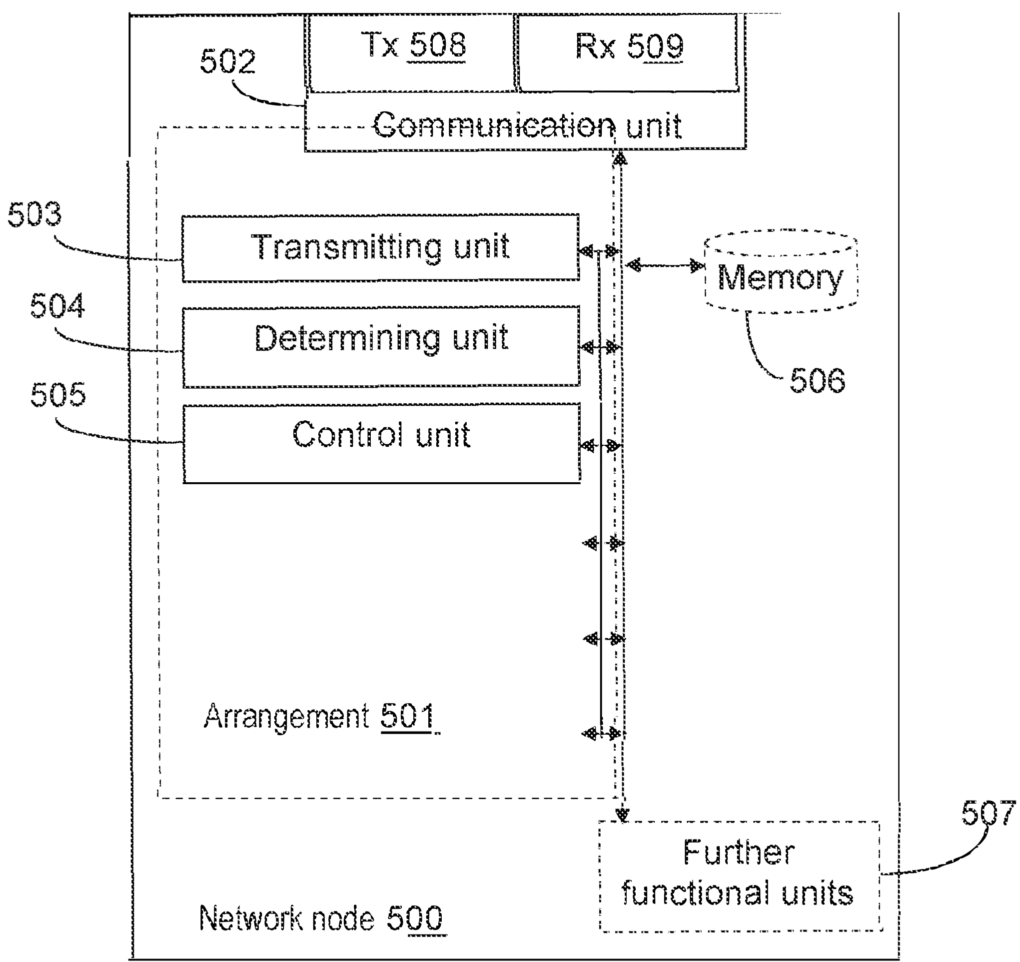
Tx 508
Rx 509
502
Communication unit
503
Transmitting unit
504
Determining unit
505
Control unit
Memory
506
Arrangement 501
507
Further functional units
Network node 500

Figure 5

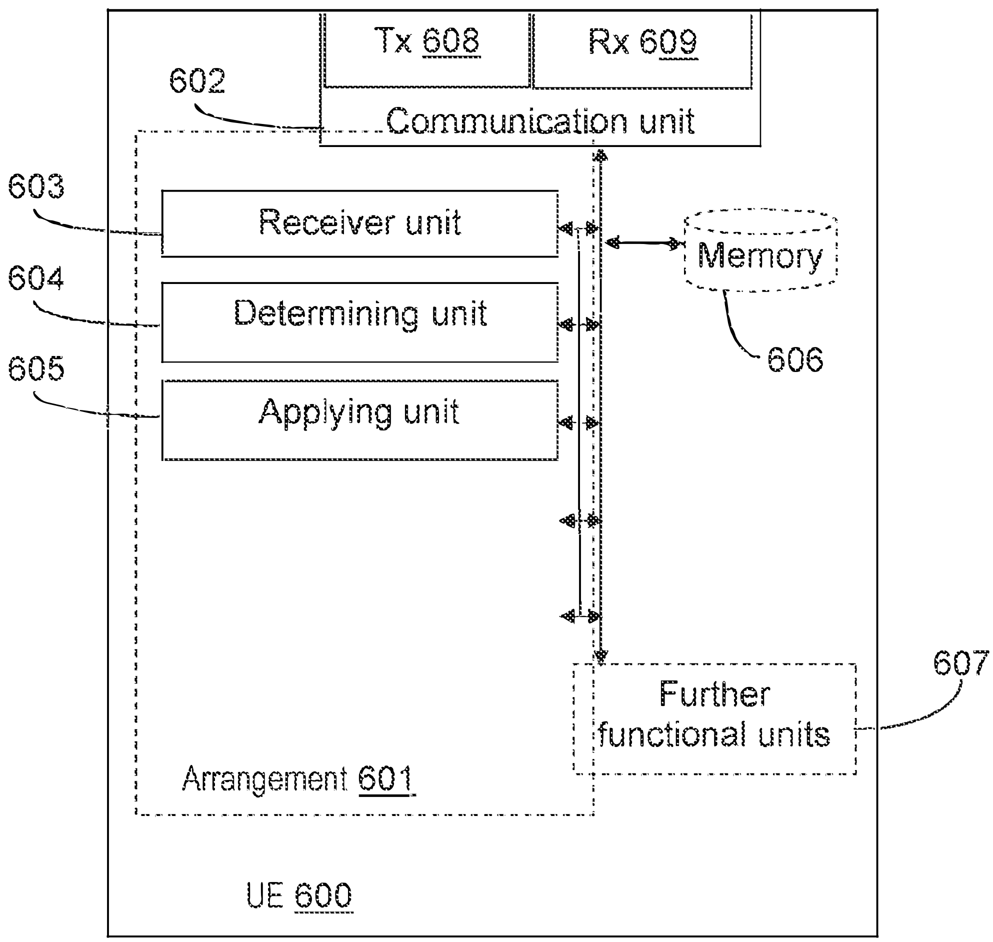
Tx 608
Rx 609
602
Communication unit
603
Receiver unit
604
Determining unit
605
Applying unit
Memory
606
607
Further functional units
Arrangement 601
UE 600

Figure 6

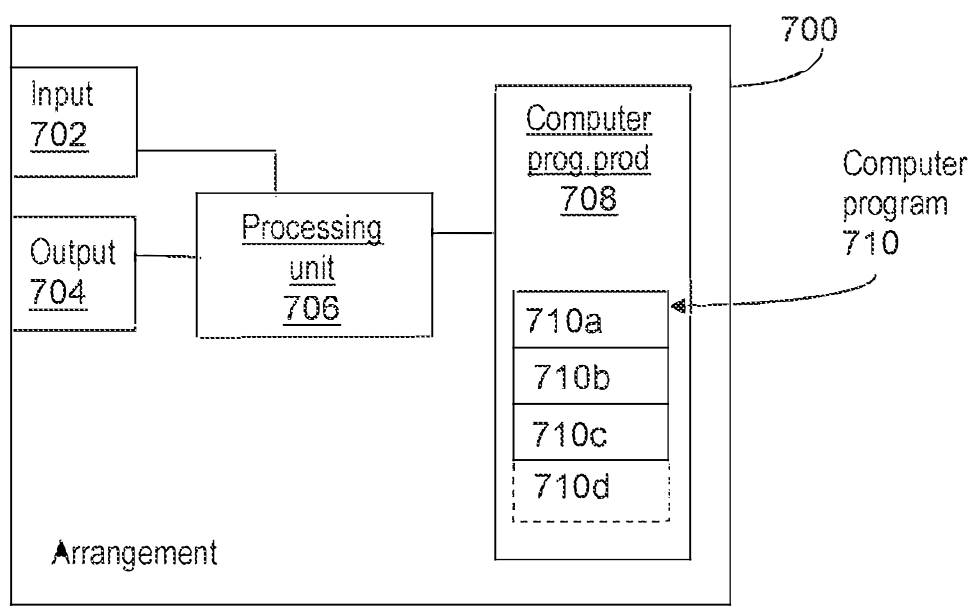
700
Input
702
Output
704
Processing
unit
706
Computer
prog.prod
708
Computer
program
710
710a
710b
710c
710d
Arrangement

Figure 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/SE2013/050745

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L12/24 H04W4/00 H04W48/02 H04W48/08 H04W8/24 H04L29/08
ADD. H04W74/08 H04W56/00 H04W48/12 H04W74/00 H04W48/10

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)
H04L H04W

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)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2008/075043 A1 (WANG JIN [US] ET AL) 27 March 2008 (2008-03-27) paragraphs [0003] - [0024] paragraphs [0030] - [0044]	1-18
A	ANNA LARMO ET AL: "RAN overload control for Machine Type Communications in LTE", GLOBECOM WORKSHOPS (GC WKSHPS), 2012 IEEE, IEEE, 3 December 2012 (2012-12-03), pages 1626-1631, XP032341629, DOI: 10.1109/GLOCOMW.2012.6477829 ISBN: 978-1-4673-4942-0 Section I Section II	1-18

-/--

[X] Further documents are listed in the continuation of Box C.

[X] 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 application or patent 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
13 December 2013	20/12/2013

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, Fax: (+31-70) 340-3016	Krause, Sven

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PUNEET JAIN ET AL: "Machine type communications in 3GPP systems", IEEE COMMUNICATIONS MAGAZINE, IEEE SERVICE CENTER, PISCATAWAY, US, vol. 50, no. 11, 1 November 2012 (2012-11-01), pages 28-35, XP011472332, ISSN: 0163-6804, DOI: 10.1109/MCOM.2012.6353679 page 31, column 2, line 42 - page 33, column 2, line 32 page 34, column 1, line 9 - column 2, line 6 page 35, column 1, lines 15-33 -----	1-18
E	WO 2013/170424 A1 (NOKIA SIEMENS NETWORKS OY [FI]; DU LEI [CN]; SEBIRE BENOIST PIERRE [JP) 21 November 2013 (2013-11-21) page 3, line 28 - page 4, line 2 page 6, lines 11-20 page 8, lines 27-31 page 20, lines 5-18 page 22, lines 4-20 page 24, lines 6-22 page 25, lines 23-27 -----	1-18

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/SE2013/050745

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2008075043 A1	27-03-2008	AR 062876 A1	10-12-2008
		AU 2007294766 A1	20-03-2008
		BR PI0715008 A2	28-05-2013
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		RU 2009114160 A	20-10-2010
		TW 200818936 A	16-04-2008
		TW 201038102 A	16-10-2010
		US 2008075043 A1	27-03-2008
		WO 2008033463 A1	20-03-2008
WO 2013170424 A1	21-11-2013	NONE	

Espacenet

Bibliographic data: RU2419213 (C2) — 2011-05-20

METHOD AND SYSTEM TO PROVIDE FEEDBACK FOR GENERATION OF BEAM IN WIRELESS COMMUNICATION SYSTEMS

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Applicant(s): QUALCOMM INC [US] ± (КВЭЛКОММ ИНКОРПОРЕЙТЕД (US), ; KVEHLKOMM INKORPOREJTED)

Classification: - international: ***H04B7/06***
- cooperative: **H04B7/0421 (KR); H04B7/0617 (EP, KR, US); H04B7/0634 (EP, KR, US); H04B7/0636 (EP, KR, US); H04B7/0643 (EP, KR, US); H04L25/0204 (KR); H04L25/0228 (KR); H04L25/03343 (EP, KR, US);** H04B7/0421 (EP, US); H04L2025/03414 (EP, KR, US); H04L2025/03426 (EP, KR, US); H04L2025/03802 (EP, KR, US); H04L25/0204 (EP, US); H04L25/0228 (EP, US)

Application number: RU20090102533 20070627

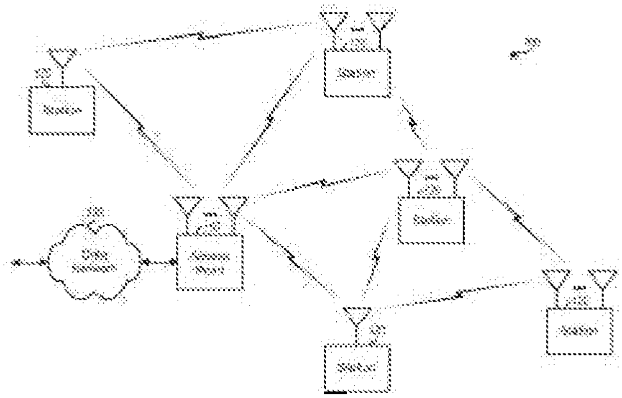
Priority number(s): US20060816988P 20060627

Also published as: BRPI0712995 (A2) CA2654573 (A1) CN101479958 (A) EP2039022 (A2) JP2009543471 (A) JP2012199943 (A) JP2013062844 (A) JP5612020 (B2) JP5619849 (B2) KR101096383 (B1) KR20090031434 (A) RU2009102533 (A) SG173324 (A1) TW200812283 (A) TWI343729 (B) US2007298742 (A1) US2012127899 (A1) US8665795 (B2) US8787841 (B2) WO2008002972 (A2) WO2008002972 (A3) less

Abstract of RU2419213 (C2)

FIELD: information technologies. ^ SUBSTANCE: method to support beam generation includes stages, at which a testing request is received, and the first probing frame is sent in response to the testing request. Then the request is received for explicit feedback to generate a beam, the second probing frame is received, the explicit feedback is generated on the basis of the second probing frame, and the explicit

feedback is sent in response to the explicit feedback. ^ EFFECT: generation of beam with low complexity, both for a transmitter and for a receiver. ^ 59 cl, 28 dwg, 3 tbl



Notice

DESCRIPTION RU2419213C2

METHOD AND SYSTEM FOR PROVIDING FEEDBACK FOR BEAM FORMATION IN WIRELESS COMMUNICATION SYSTEMS

[0001]

This application claims priority in accordance with US Provisional Application No. 60 / 816,988 entitled "METHOD AND SYSTEM FOR PROVIDING BEAMFORMING FEEDBACK IN WIRELESS COMMUNICATION SYSTEMS", filed 27 June 2006, assigned to the assignee of this application and incorporated herein by reference.

[0002]

State of the art

[0003]

Technical field to which the invention relates

[0004]

The present disclosure relates generally to the field of communications, and more specifically to techniques for transmitting feedback information for beamforming in wireless communication systems.

[0005]

Description of the prior art

[0006]

In a wireless communication system, a transmitter may use multiple (T) transmit antennas to transmit data to a receiver equipped with multiple (R) receive antennas. The multiple transmit and receive antennas form a multiple-input multiple-output (MIMO) channel that can be used to improve throughput and / or improve reliability. For example, a transmitter can transmit up to T data streams simultaneously via T transmit antennas to improve throughput. Alternatively, the transmitter can transmit a single data stream across all T transmit antennas to improve receiver reception.

[0007]

Good performance (eg good throughput) can be obtained by transmitting one or more beamforming data streams. For beamforming, the transmitter can obtain a channel estimate for the MIMO channel, derive steering matrices based on the channel estimate, and perform spatial processing on the transmission using steering matrices. The transmitter can obtain the channel estimate in several ways, depending on the duplexing scheme used by the system and the capabilities of the transmitter and receiver. It is desirable to maintain beamforming with as little complexity as possible for both the transmitter and receiver.

[0008]

The essence of the invention

[0009]

Beamforming support technologies for stations in wireless networks are described herein. In one aspect, a station can support implicit feedback or explicit feedback beamforming, being able to transmit and receive sounding frames, respond to a test request by transmitting a sounding frame, and respond to an explicit feedback request. Implicit feedback and explicit feedback are two ways to obtain MIMO channel information and are described below. The station must be able to perform implicit or explicit beamforming with another station with the same capabilities.

[0010]

In another aspect, a station can perform beamforming using explicit feedback and zero data burst (NDP) sounding. The station can transmit the first frame with a request for explicit feedback and can also transmit an NDP having at least one test field but no data field. The station can receive the second frame with explicit feedback, which can be derived from the NDP. The station may output control information (eg, steering matrices) based on explicit feedback and may then transmit a controlled beamforming frame based on the control information.

[0011]

87 In yet another aspect, a station can perform implicit feedback beamforming and NDP sounding. The station may transmit the first frame with a test request and may receive an NDP in response.

90 The station may output control information based on the NDP and may then transmit a controlled beamforming frame based on the control information.

[0012]

95 In yet another aspect, a station can perform bi-directional beamforming with implicit feedback and NDP sensing.

97 The station can transmit the first frame with the test request and can also transmit the first NDP either before or after the first frame. The station may receive the first controlled beamforming frame based on the first control information that may be derived from the first NDP. The station may also receive the second NDP in response to the test request and may output the second control information based on the second NDP. The station may then transmit a second steered beamforming frame based on the second control information.

[0013]

106 The station can also perform MPDU sensing beamforming, which uses frames having both test fields and data fields.

108 Such a frame can carry a data unit (MPDU) in accordance with a medium access control (MAC) protocol. Various aspects and properties of the disclosure are described in more detail below.

[0014]

114 Brief Description of Drawings

[0015]

118 Figure 1 shows a wireless communication network.

[0016]

122 On figa, 2B and 3C shows three PPDU formats in accordance with IEEE 802.11n.

[0017]

126 3 shows a MAC frame format according to IEEE 802.11n.

[0018]

130 4 shows unidirectional explicit beamforming with NDP sensing.

[0019]

134 5 shows implicit unidirectional beamforming with NDP sensing.

[0020]

138 6 shows implicit bi-directional beamforming with NDP sensing.

[0021]

142 7 shows unidirectional explicit beamforming with MPDU sounding.

[0022]

146 8 shows implicit unidirectional beamforming with MPDU sounding.

[0023]

150 Figure 9 shows implicit bidirectional beamforming with MPDU sounding.

[0024]

154 10 shows a calibration with NDP sensing.

[0025]

158 Figure 11 shows the MPDU probed calibration.

[0026]

162 12 shows a calibration with simultaneous sensing of NDP and MPDU.

[0027]

166 13 shows a control frame for transmitting channel state information (CSI) on a feedback channel.

[0028]

171 14 and 15 show beamforming by a station.

[0029]

175 Figures 16 and 17 show explicit beamforming with NDP sensing.

[0030]

179 Figures 18 and 19 show implicit beamforming with NDP sensing.

[0031]

183 Figures 20 and 21 show bi-directional implicit beamforming with NDP sensing.

[0032]

187 Figures 22 and 23 show a calibration with NDP sensing.

[0033]

191 Figures 24 and 25 show CSI feedback transmission for calibration.

[0034]

195 Fig. 26 shows a block diagram of two stations.

[0035]

199 Detailed description of the invention

[0036]

203 The technologies described here can be used in a variety of wireless networks and systems such as wireless local area networks (LANs), wireless metropolitan area networks (WMANs), wireless regional area networks (WWANs), etc.

206 The terms "networks" and "systems" are often used interchangeably.

[0037]

210 Any of the radio technologies from the IEEE 802.11 family of standards, Hiperlan, etc. can be implemented in WLAN.

212 WMAN can implement the IEEE 802.16 standard, etc.

213 WWAN may be a cellular network, such as a code division multiple access (CDMA) network, a time division multiple access (TDMA) network, a frequency division multiple access (FDMA) network, an orthogonal FDMA network (OFDMA), an FDMA network single carrier (SC-FDMA), etc.

217 For clarity, certain aspects of the technologies are described below for a WLAN that implements the IEEE 802.11n standard.

[0038]

222 The IEEE 802.11n standard uses Orthogonal Frequency Division Multiplexing (OFDM), which is a modulation technology that partitions the bandwidth of a system into multiple (K) orthogonal subcarriers.

225 For operation within 20 MHz, in accordance with IEEE 802.11n, a total number of K = 64 subcarriers is defined using OFDM and assigned indices from -32 to +31.

227 The total number of 64 subcarriers includes 52 data subcarriers with indices ± {1 ..., 6, 8 ..., 20, 22 ..., 28} and four pilot subcarriers with indices ± {7, 21}.

229 The DC (direct current) subcarrier with index 0 of the remaining subcarriers is not used.

230 For operation in the 40 MHz band in accordance with IEEE 802.11n, the total number of subcarriers K = 128 with indices from -64 to +63 is determined, and they include 108 data subcarriers with indices ± {2, 10, 12, 24, 26 ... , 52, 54 ..., 58} and six pilot subcarriers with indices ± {11, 25, 54}.

234 IEEE 802.11n also supports MIMO transmission over multiple transmit antennas to multiple receive antennas.

236 IEEE 802.11n is described in IEEE P802.11n ™ / D1.0 entitled "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Enhancements for Higher Throughput" dated March 2006 and in IEEE P802. 11n ™ / D2.00 entitled "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Amendment: Enhancements for Higher Throughput" dated February 2007.

[0039]

244 1 shows a wireless network 100 with an access point 110 and multiple stations 120.

245 In general, a wireless network can include any number of access points and any number of stations.

247 A station is a device that communicates with another station over a wireless medium / channel.

248 A station may also be called a terminal, mobile station, user equipment, subscriber unit, etc., and may contain some or all of their functions.

250 The station can be a cell phone, portable device, wireless device, personal digital assistant (PDA), laptop, wireless modem, cordless telephone, and so on.

252 An access point is a station that provides access to services distributed over a wireless medium for stations associated with that access point.

254 An access point may also be called a base station, base transmitting station (BTS), Node B, etc., and may contain some or all of their functions.

256 Stations 120 can communicate with access point 110 and / or with each other using peer to peer communication.

258 The access point 110 can be connected to the data network 130 and can communicate with other devices via the data network.

260 Data network 130 may be the Internet, intranet, and / or any other wired or wireless network.

[0040]

264 The technologies described herein can be used for MIMO transmission on the downlink, uplink, and peer to peer.

266 For downlink communication, access point 110 can be a transmitter and station 120 can be receivers.

268 For uplink data transmission, stations 120 can be transmitters and access point 110 can be a receiver.

270 In peer-to-peer transmission, one of the stations 120 may be a transmitter and the other station 120 may be a receiver.

[0041]

275 A MIMO channel formed by multiple (T) transmit antennas at a transmitter and multiple (R) receive antennas at a receiver may be characterized by an Hk matrix of R × T channels for each subcarrier k or each subcarrier group of interest.

278 The channel matrix Hk can be diagonalized by performing an eigenvalue decomposition of the correlation matrix for Hk as follows.

[0043]

283 where Rk is the T × T correlation matrix for Hk,

[0044]

287 V

288 k is a unitary T × T matrix whose columns are eigenvectors Rk,

[0045]

282 Λ

283 k is a T × T diagonal matrix of eigenvalues of Rk, and

[0046]

287 "H" denotes the result of conjugate transposition.

[0047]

301 The unitary matrix Vk is characterized by the property VH k

302 V

303 k = I, where I is the identity matrix.

304 The columns of the unitary matrix are orthogonal to each other, and each column has unit cardinality.

306 Vk is also called a beamforming matrix.

307 The diagonal matrix Λk contains possible nonzero values along the diagonal and zeros elsewhere.

308 Diagonal elements Λk are eigenvalues representing the power amplification factors of the eigenmodes Rk.

[0048]

314 The transmitter (or beamformer) can perform beamforming transmit spatial processing for the receiver (or beamforming receiver) as follows:

[0049]

319 Lvl. (2)

[0050]

323 where xk is a vector of up to T data symbols intended for transmission of subcarrier k,

[0051]

327 Q

328 k is a steering matrix for subcarrier k that can be derived based on Vk, and

[0052]

332 Z
333 k is a vector with T output symbols for the T transmit antennas for subcarrier k.

[0053]

337 During beamforming, equation (2) controls or shapes the beams transmitted from the transmitter to the receiver.
339 For effective beamforming, the transmitter must have an accurate estimate of the MIMO channel response from the transmitter to the receiver.
341 This MIMO channel information can be used to derive appropriate steering matrices for spatial processing of the transmission, for directing beams from the transmitter to the receiver.

[0054]

346 Beamforming can be done in a variety of ways and can be supported by different protocol data units (PDUs).
348 For clarity, the PDU beamforming defined in IEEE 802.11n is described below.

[0055]

352 In IEEE 802.11n, the MAC protocol treats data as a MAC PDU (MPDU).
353 The Physical Layer Convergence Protocol (PLCP) then processes the MPDU to generate a PLCP PDU (PPDU).
355 PPDU can also be referred to as packet, frame, etc.
356 The physical layer (PHY) then processes and transmits each PPDU over the wireless medium.
357 In IEEE 802.11n, high-throughput PPDUs (HT-PPDUs) can be used to transmit MIMO from multiple transmit antennas to multiple receive antennas.

[0056]

362 2A shows the structure of HT-PPDU 210 with mixed HT format in IEEE 802.11n.
363 The HT-PPDU 210 includes a mixed mode preamble followed by a data field.
364 The mixed mode preamble includes (i) an inheritance preamble consisting of an inheritance short test field (L-STF) and an inheritance long test field (L-LTF), (ii) an inheritance signal field (L-SIG), (iii), an HT signal field (HT-SIG); and (iv) an HT preamble consisting of a short HT test field (HT-STF) and one or more long HT test fields (HT-LTF).
368 The number of HT-LTFs is equal to or greater than the number of data streams transmitted simultaneously. Long and short test fields can carry well-known test symbols that can be used for frame detection, timing, frequency estimation and equalization, automatic gain control (AGC), channel estimation, etc. The L-SIG and HT-SIG fields can carry signaling information for the HT-PPDU. For example, the HT-SIG field carries (i) a Length field, which denotes the length of the data field, and (ii) a Not Sounding field, which denotes whether or not the HT-

PPDU is a sounding PPDU. The probe PPDU is a PPDU carrying known test symbols that can be used for channel estimation. The data field carries the payload of the HT-PPDU, which can be one or more MPDUs and can be of variable length, indicated by the Length field.

[0057]

380 2B shows the structure of an HT-PPDU 220 with a new greenfield HT format (HT) according to IEEE 802.11n.

382 The HT-PPDU 220 includes a format preamble on a new basis followed by a data field. The preamble of the format on the new basis includes a short field of testing the format on a new basis of HT (HT-GF-STF), a long testing field of HT (HT-LTF1, VP-RTP1), an HT-SIG field and one or more HT-LTF fields ...

[0058]

389 The HT-PPDU 210 and 220 can be used as sounding PPDUs by setting 0 in the Not Sounding field and enabling enough HT-LTF. The probe PPDU that carries the data is called the probe MPDU.

[0059]

395 2C shows the structure of a null data packet (NDP) 230 with a preamble format on a new basis in accordance with IEEE 802.11n.

397 The NDP 230 is a probing PPDU that does not carry data and may also be called a zero length frame (ZLF), etc.

399 The NDP 230 can be generated by setting 0 in the Length field, setting 0 in the Not Sounding field, including enough HT-LTFs, and excluding the Data data field.

[0060]

404 HT-PPDU 210, 220 and 230 are some of the PPDU formats supported by IEEE 802.11n.

405 PPDU formats supported by IEEE 802.11n are described in the above IEEE 802.11n documents.

[0061]

410 3 shows the structure of a MAC frame 300 in accordance with IEEE 802.11n.

411 The MAC frame 300 includes various fields such as an HT Control field, a Frame Body field, and a frame check sequence (FCS) field. The Frame Body field carries data for the MAC frame. The FCS field carries an FCS value that is generated based on the contents of the other fields of the MAC frame and is used to detect MAC frame errors. The HT Control field includes various fields such as a Link Adaptation Control field, a CSI / Steering field, an NDP

Announcement field, and a Reverse Direction Grant (RDG) / More PPDU field. The Link Adaptation Control field includes a Test Request (TRQ) field and an MCS request or Antenna Selection Indication (MAI) field. The MAI field includes a request (MRQ) field for a modulation coding scheme (MCS). Table 1 presents the various MAC fields shown in FIG. 3 and provides a description for each MAC field. The frame and MAC field formats and various types of explicit feedback indicated by the CSI / Steering field are described in the IEEE 802.11n documents cited above.

[0062]

Table 1

MAC field

Description

TRQ

0 = Transponder transmitter did not receive a request to send a Probing PPDU, 1 = Transponder transmitter received a request to transmit a Probing PPDU.

MRQ

0 = no MCS feedback requested, 1 = MCS feedback requested.

CSI / Steering

0 = no feedback required, 1 = request for CSI feedback, 2 = request for uncompressed beamforming feedback matrix, 3 = request for compressed beamforming feedback matrix.

NDP Announcement

0 = no further NDP, 1 = no further NDP.

RDG / More PPDU

0 = PPDU carrying the MAC frame is the last transmission, 1 = PPDU carrying the MAC frame is followed by another PPDU, 0 = no reverse grant sent, 1 = reverse grant present.

[0063]

Table 2 lists the two sounding types and provides a short description of each sounding type.

NDP does not carry a MAC frame and thus does not contain the HT Control field.

Therefore, there may be certain restrictions on the use of NDP, as well as on the way the NDP can be transmitted.

[0064]

table 2

Sensing type

Description

MPDU sounding

Using data carrying Probing PPDU and HT Control field.

NDP Probing

Using a probing PPDU that does not carry data and does not contain an HT Control field.

[0065]

Table 3 lists the two types of beamforming / feedback circuits supported by IEEE 802.11n and provides a short description of each type of feedback.

[0066]

Table 3

Feedback type

Description

Implicit feedback

The beamforming receiver transmits the sounding PPDU. The beamformer derives the MIMO channel estimate from the sounding PPDU and calculates steering matrices based on the MIMO channel estimate.

Explicit feedback

The beamformer transmits the probe PPDU. The beamformer derives the MIMO channel estimate from the probe PPDU and feeds back to the beamformer.

The beamformer calculates the steering matrices based on the feedback.

[0067]

Implicit feedback can be used in time division duplexing (TDD) networks in which transmissions between stations are carried out on a single time division frequency channel.

In this case, the channel response for one connection can be assumed to be the mutual channel response for the other connection.

Explicit feedback can be used for both TDD and Frequency Division Duplex (FDD) networks.

[0068]

Beamforming can be used if the transmitting station and the receiving station both support the same type of feedback, which can be implicit feedback or explicit feedback.

If one station only supports implicit feedback and the other station only supports explicit feedback, then beamforming may not be available to those stations due to interaction problems between the two types of feedback.

The two types of feedback are incompatible for several reasons.

First, a station that only supports implicit feedback may not be able to transmit appropriate feedback to a station that only supports explicit feedback.

Second, there may not be a mechanism to stimulate a station that only supports explicit feedback to transmit a probing PPDU. In addition, the two types of probing may not be compatible.

[0069]

503 In one aspect, a station can be designed with the following capabilities to support both implicit feedback and explicit feedback for beamforming:

[0070]

508 1) transmitting and receiving a sounding PPDU,

[0071]

512 2) a test request (TRQ) response by transmitting a Probing PPDU, and

[0072]

516 3) responding to a request for explicit feedback.

[0073]

520 By supporting this set of capabilities presented above, a station may be able to perform implicit or explicit beamforming with another station supporting the same set of capabilities.

[0074]

525 In one design, a station can support only NDP sounding, or only MPDU sounding, or both NDP sounding and MPDU sounding. A station may notify its sensing capability using a transmit beamforming (TxBF) Capability field that is included in certain frames, such as a beacon frame, an association request frame, an association response, a probe request frame, and a probe response frame.

530 In another design, the beamformer may support NDP sensing transmission and offset sensing reception, and the beamforming receiver may support NDP sensing reception and offset sensing transmission.

533 In IEEE 802.11n, the reference to multiple dimensions is extended to multiple test symbols using a specific orthonormal matrix.

535 When using biased sensing, this propagation is performed separately for test symbols associated with data dimensions and test symbols associated with additional spatial dimensions (extension of spatial streams in 802.11n).

538 Thus, soundings for spatial expansion streams can be time-sliced from soundings for data dimensions.

540 Offset sounding can be used when the number of dimensions to sound exceeds the number of data dimensions or space-time streams (NSTS).

542 Offset sounding can only be available for MPDU soundings and can be used for additional dimension sounding for MPDU soundings. The beamforming receiver can respond to the CSI feedback request sent by the NDP beamformer.

545 The beamformer can respond to a beamforming receiver sensing request.

[0075]

549 Beamforming can be performed with implicit feedback or explicit feedback, which can be supported by NDP sensing and / or MPDU sensing. Beamforming can also be performed for unidirectional transmission from one station to another station, or for bi-directional transmission between two stations.

553 There can be exchanges between different sequences of frames for different beamforming scenarios.

555 For clarity, examples of framing for some beamforming scenarios are described below.

[0076]

559 4 shows an example of a frame exchange for unidirectional explicit beamforming with NDP sounding. Station A may transmit an uncontrolled frame 410 requesting feedback for one of the feedback types shown in Table 1.

562 An unsteered frame is a frame transmitted without beamforming, and a steered frame is a frame transmitted with beamforming.

564 Frame 410 may be a request to send (RTS) frame containing a requested duration for the time required to transmit pending transmissions of data and associated signals.

566 The NDP Announcement field of frame 410 may be set to 1 to indicate that an NDP will follow. Station B may receive an RTS frame 410, satisfy the request, and transmit an uncontrolled Clear to Send (CTS) frame 412, which may carry any data that Station B may have for Station A. The RTS and CTS frames are control frames that can be exchanged for wireless redundancy and to eliminate mutual interference from implicit stations.

571 RTS and CTS frames can also be dropped.

[0077]

575 Station A may transmit NDP 414 and an unmanaged frame 416, which may represent a data frame or some other frame.

577 NDP 414 may be transmitted in a short inter-frame time (SIFS) at the end of frame 412.

578 The RDG field of frame 416 may be set to 1 to indicate a reverse direction grant that can transfer wireless media control to station B. Station B may estimate the MIMO channel response based on NDP 414 and generate explicit feedback of the type requested by station A. Station B can then transmit an uncontrolled frame 418 with explicit feedback.

582 Station A can receive explicit feedback, can derive steering matrices based on the feedback, and transmit a steered data frame 420 using the steering matrices for beamforming.

[0078]

587 Unidirectional explicit beamforming with NDP sensing can also be accomplished in other ways.

588 For example, RTS and CTS frames may be omitted or replaced with other types of frames.

589 NDP 414 may be transmitted within SIFS time after frame 416, whose NDP Announcement field may be set to 1 to indicate that NDP follows.

[0079]

594 5 shows an example of a frame exchange for unidirectional implicit beamforming with NDP sounding. Station A may transmit an uncontrolled RTS frame 510 and station B may return an uncontrolled CTS frame 512. Station A may then transmit an uncontrolled frame 514 whose TRQ field may be set to 1 to indicate a test request and whose RDG field may be set to 1 to indicate a reverse direction grant.

599 Station B may then transmit an uncontrolled frame 516, an NDP 518, and an uncontrolled frame 520 based on the reverse direction grant in the frame 514.

601 The NDP Announcement field of frame 516 may be set to 1 to indicate that an NDP will follow, and the More PPDU field may be set to 1 to indicate that another frame follows.

603 NDP 518 may be transmitted within SIFS time after frame 516.

604 The More PPDU field of frame 520 may be set to 0 to indicate that no more frame follows.

605 Station A may estimate the MIMO channel response based on the NDP 518, derive steering matrices based on the MIMO channel estimate, and transmit a steered data frame 522 using the beamforming steering matrices.

[0080]

611 Unidirectional implicit beamforming with NDP sensing can also be accomplished in other ways.

612 For example, RTS and CTS frames can be deleted or replaced with other types of frames.

613 The NDP Announcement field of frame 516 may be set to 1 and frame 518 may be omitted.

[0081]

617 6 shows an example of a frame exchange for bidirectional implicit beamforming with NDP sounding. Station A may transmit an uncontrolled RTS frame 610 and station B may return an uncontrolled CTS frame 612. Station A may then transmit an unmanaged frame 614, an NDP 616, and an unmanaged frame 618.

621 The MRQ field of frame 614 may be set to 1 for an MCS request. The TRQ field of frame 618 may be set to 1 to indicate a test request, and the RDG field may be set to 1 to indicate a reverse direction grant.

624 Station B may estimate the MIMO channel response based on NDP 616 and may derive a steering matrix based on the MIMO channel estimate. Station B may then transmit steered

frame 620, NDP 622, and steered frame 624 using steering matrices for beamforming.

627 Frame 620 may respond to the RDG and its More PPDU field may be set to 1 to indicate that another frame will follow.

629 The TRQ field of frame 624 may be set to 1 to request testing, and its More PPDU field may be set to 0 to indicate that no other frames follow.

631 Frame 620 and / or 624 may carry any data that station B may transmit to station A.

[0082]

635 Station A may estimate the MIMO channel response based on NDP 622 and may derive steering matrices based on the MIMO channel estimate. Station A may then transmit steered frame 626, NDP 628 in response to TRQ in frame 624 and steered frame 630.

638 The TRQ field of frame 630 may be set to 1 to indicate a test request, and its RDG field may be set to 1 to indicate a reverse direction grant.

640 Each station can transmit additional beamforming frames in a similar manner.

[0083]

644 Bi-directional implicit beamforming with NDP sensing can also be accomplished in other ways.

645 For example, RTS and CTS frames can be deleted or replaced with other types of frames.

646 The NDP Announcement field of each of frames 614, 620, and / or 626 may be set to 1, and frames 618, 624, and / or 630 may be dropped.

[0084]

651 Bidirectional explicit beamforming with NDP sensing may be implemented based on a combination of FIGS. 4 and 6.

653 Both stations A and B can transmit NDP as shown in FIG. 6.

654 Each station can output explicit feedback based on the NDP received from the other station, and can transmit explicit feedback to the other station.

656 Each station can derive steering matrices based on explicit feedback received from the other station and can transmit steered frames with steering matrices.

[0085]

661 7 shows an example of framing for unidirectional explicit beamforming with MPDU sounding. Station A may transmit an uncontrolled RTS frame 710 in the sounding PPDU. Frame 710 can include a request for feedback for one of the types of feedback shown in Table 1.

664 Station B can estimate the MIMO channel response based on the sounding PPDU and can generate explicit feedback of the type that station A requests. Station B can then transmit an uncontrolled CTS frame 712 that can carry explicit feedback information.

667 Station A may derive steering matrices based on explicit feedback received from station B and

may transmit a steered data frame 714 using the steering matrices for beamforming.

669 Frame 714 may be sent in a sounding PPDU and may include a request for feedback for updated feedback.

671 Station B can estimate the MIMO channel response based on the sounding PPDU and can generate explicit feedback of the type that station A requests. Station B can then transmit an uncontrolled frame 716 that carries explicit feedback and block acknowledgment (BA) for data. transmitted in frame 714.

[0086]

678 8 shows an example of framing for unidirectional implicit beamforming with MPDU sounding. Station A may transmit an uncontrolled RTS frame 810, whose TRQ field may be set to 1 to indicate a test request.

681 Station B may then transmit an uncontrolled CTS frame 812 in the sounding PPDU. Frame 812 can carry any data station B may have for transmission to station A. Station A can derive steering matrices based on the sounding PPDU received from station B and can transmit a steered data frame 814 using the steering matrix for beamforming ...

685 The TRQ field of frame 814 may be set to 1 to indicate a test request.

686 Station B may then transmit an unsteered frame 816 in the sounding PPDU. Frame 816 may carry an Ack block for data transmitted in frame 814.

[0087]

691 9 shows an example of a frame exchange for bidirectional implicit beamforming with MPDU sounding. Station A may transmit an uncontrolled RTS frame 910 in the sounding PPDU. The TRQ field of frame 910 may be set to 1 to indicate a test request.

694 Station B may estimate the MIMO channel response based on the sounding PPDU from station B and may derive steering matrices based on the MIMO channel estimate. Station B may then transmit a controlled CTS frame 912 in the sounding PPDU. The TRQ field of frame 912 may be set to 1 to indicate a test request, and the frame may carry any data that station B may have for transmission to station A. Station A may derive steering matrices based on the sounding PPDU received from station B, and can transmit a steered data frame 914 using steering matrices for beamforming.

701 Frame 914 may carry an Ack block for any data transmitted in frame 912, and its TRQ field may be set to 1 to indicate a test request.

703 Station B may derive steering matrices based on the sounding PPDU received from station A and can transmit a controlled data frame 918 in the sounding PPDU. Frame 918 may carry an Ack block for data transmitted in frame 914, a test request, and data.

[0088]

709 The MPDU sensing beamforming shown in FIGS. 7, 8 and 9 can also be performed in other

ways.

711 For example, RTS and CTS frames can be replaced with other types of frames.

[0089]

715 Bi-directional explicit beamforming with MPDU sensing can be implemented based on a combination of FIGS. 7 and 9.

717 Both stations A and B can transmit a sounding PPDU as shown in FIG. 9.

718 Each station can derive explicit feedback based on the sounding PPDU received from another station, and can transmit explicit feedback to the other station.

720 Each station can derive steering matrices based on explicit feedback received from the other station and can transmit steered frames with steering matrices.

[0090]

725 Implicit feedback beamforming involves a mutual MIMO channel between stations A and B. This allows station A (i) to estimate the MIMO channel response to a connection from station B to station A based on the sounding PPDU received from station B and (ii) use this estimate the MIMO channel as an estimate of the MIMO channel response for another connection from station A to station B. However, if the responses of the transmission chains are different from the responses of the receive chains in station A or station B, then the differences will affect the mutual use of the MIMO channel.

[0091]

735 Stations A and B can calibrate to determine the difference between their transmit and receive chains and to output correction vectors that can be applied to account for the differences to restore reciprocity.

738 Calibration is not required for beamforming, but if done can improve beamforming performance.

739 Stations A and B may calibrate at association and / or at other times.

[0092]

743 10 shows an example of a frame exchange for calibration with explicit CSI feedback and NDP sounding. Station A may transmit an uncontrolled RTS frame 1010 and station B may return an uncontrolled CTS frame 1012. Station A may then transmit an unmanaged frame 1014, an NDP 1016, and an unmanaged frame 1018.

747 The CSI / Steering field of frame 1014 may be set to 1 to request CSI feedback, and this may indicate that full fidelity CSI feedback should be sent back.

749 The TRQ field of frame 1018 may be set to 1 to request a test, and the RDG field may be set to 1 to indicate a reverse direction grant.

[0093]

754 Station B may estimate the MIMO channel response based on NDP 1016 and may generate CSI feedback as described in the IEEE 802.11n documents mentioned above.

756 Station B may then transmit an unmanaged frame 1020, an NDP 1022, and an unmanaged frame 1024.

758 Frame 1020 may carry CSI feedback and its More PPDU field may be set to 1 to indicate that another frame will follow.

760 Frame 1024 may also provide CSI feedback, and its More PPDU field may be set to 0 to indicate that no other frames follow.

[0094]

765 Station A can estimate the MIMO channel response based on NDP 1022 from station B. Station A can then calculate reciprocity correction vectors based on the MIMO channel estimate determined by station A and the CSI feedback received by station B. Station A can apply reciprocity correction vectors when future transfer of station B.

[0095]

772 11 shows an example of a frame exchange for calibration with explicit CSI feedback and MPDU sounding. Station A may transmit an uncontrolled RTS frame 1110 in the sounding PPDU. The CSI / Steering field of frame 1110 may be set to 1 to request CSI feedback, and its TRQ field may be set to 1 to indicate a test request.

776 Station B can estimate the MIMO channel response based on the sounding PPDU received from station A and can generate CSI feedback. Station B may then transmit an uncontrolled CTS frame 1112, which may carry CSI feedback in the sounding PPDU. Station A may estimate the MIMO channel response based on the sounding PPDU received from station B and may calculate reciprocity correction vectors based on the MIMO channel estimate and explicit feedback.

[0096]

785 12 shows an example of a frame exchange for calibration with explicit CSI feedback and simultaneous NDP and MPDU probing. Station A may transmit an unsteered RTS frame 1210, whose CSI / Steering field may be set to 1 to request CSI feedback. Station B may return an uncontrolled CTS frame 1212. Station A may then transmit NDP 1214 and an uncontrolled frame 1216.

790 The TRQ field of frame 1216 may be set to 1 to request testing, and the RDG field may be set to 1 to indicate a reverse direction.

792 Station B can estimate the MIMO channel response based on NDP 1214 from station A and can generate CSI feedback. Station B may then transmit an unsteered frame 1218 in the

probe PPDU. Frame 1218 may carry CSI feedback, and its More PPDU field may be set to 0 to indicate that no other frames follow.

796 Station A may estimate the MIMO channel response based on the sounding PPDU received from station B and may calculate reciprocity correction vectors based on the MIMO channel estimate and explicit feedback.

[0097]

802 Calibration can also be done in other ways.

803 For example, RTS and CTS frames can be replaced with data frames or other types of frames.

804 The NDP Announcement field of frame 1014 and / or frame 1020 in FIG. 10 may be set to 1, and frame 1018 and / or frame 1024 may be omitted.

806 Station B may transmit an NDP or probe PPDU as soon as possible after a test request from station A. Station B may transmit CSI feedback either in conjunction with the NDP or probe PPDU, or at a later time.

[0098]

812 As shown in FIGS. 10, 11 and 12, calibration can be supported without the use of calibration specific messages and frame exchanges.

814 For calibration, a CSI feedback request may be sent using the CSI / Steering field in the HT Control field, as shown in FIG. 3 and Table 1.

816 In one design, when a test request is included in the same frame as a CSI feedback request, full fidelity CSI matrices can be fed back for use to derive reciprocity correction vectors.

818 In another design, dedicated fields can be used to indicate the start of the calibration and to identify the frames submitted for calibration.

[0099]

823 13 shows the structure of a control frame 1300 that can be used to transmit CSI feedback for calibration.

825 Frame 1300 includes various fields such as a MIMO Control field and a CSI MIMO Matrices Report field.

827 The MIMO Control field includes various fields such as the Grouping (Ng) field and the Coefficient Size field.

829 For calibration, the Grouping field can be set to 0 for Ng = 1, which means there is no grouping of subcarriers, so that a CSI matrix will be provided for each of the subcarriers {-28, -1, + 1 ... + 28}, which can be used for transmission.

832 The Coefficient Size field can be set to 3 for Nb = 8, which means that eight bits of precision (or full precision) will be used for each element of each CSI matrix. The CSI MIMO Matrices Report field can carry a CSI matrix for each subcarrier that can be used for transmission, with each matrix element being represented with full fidelity.

[0100]

14 is a diagram of a process 1400 for supporting beamforming by a station. The station may receive a test request (block 1412) and may transmit the first probe frame in response to the test request (block 1414). The station may receive a request for explicit feedback for beamforming (block 1416) and may also receive a second probe frame (block 1418). The station may generate explicit feedback based on the second probe frame (block 1420) and may transmit explicit feedback in response to a request for explicit feedback (block 1422). Processing in blocks 1412-1422 may be performed for one or more independent frame exchanges. The processing in blocks 1412-1422 may use the capabilities described above to support both implicit feedback and explicit feedback for beamforming. In particular, the transmission and reception of the probe PPDU is reflected in blocks 1414 and 1418, respectively. The response to the test request by transmitting a probe PPDU is reflected in blocks 1412 and 1414. The response to a request for explicit feedback is reflected in blocks 1416-1422.

[0101]

Each frame can correspond to PPDUs in IEEE 802.11 or some other PDU type. Each probe frame can be (i) an NDP having at least one test field but no data field, or (ii) a frame having both a test field and a data field. Explicit feedback may include CSI matrices, uncompressed beamforming feedback matrices, despread beamforming feedback matrices, etc.

[0102]

The station may be an explicit explicit beamforming receiver and may receive a steered frame transmitted using beamforming based on the explicit feedback returned at block 1422. The station may be an implicit beamforming receiver and may receive a steered frame transmitted in beamforming based on the implicit feedback obtained from the first probe frame transmitted at block 1414. The station may be an explicit beamformer and may receive explicit feedback generated from the first sensing frame, may obtain control information (eg, steering matrix) based on the received explicit feedback, and may transmit a controlled beamforming frame based on the control information. The station can be an implicit beamformer and can transmit a third sensing frame, output control information based on the third sensing frame, and transmit a controlled beamforming frame based on the control information.

[0103]

881 15 is a schematic diagram of an apparatus 1500 for supporting beamforming.

882 Apparatus 1500 includes means for receiving a test request (module 1512), means for transmitting a first probe frame in response to a test request (module 1514), means for receiving an explicit feedback request for beamforming (module 1516), means for receiving a second sounding frame (module 1518), means for generating explicit feedback based on the second probe frame (module 1520), and means for transmitting explicit feedback in response to a request for explicit feedback (module 1522).

[0104]

891 FIG. 16 is a flow diagram of processing 1600 for explicit feedback beamforming with NDP sensing. The station may transmit the first frame (eg, frame 410 in FIG. 4) requesting explicit feedback (block 1612).

894 A station may transmit an NDP (eg, NDP 414) having at least one test field but no data field (block 1614).

896 The station may receive the second frame with explicit feedback derived from the NDP, eg, frame 418 (block 1616).

898 The station may output control information based on explicit feedback (block 1618) and may transmit a control frame (eg, frame 420) beamforming based on the control information (block 1620).

[0105]

904 The station may transmit an RTS frame as the first frame, receive a CTS frame in response to the RTS frame, and transmit NDP within STFS time for the CTS frame. A station may transmit a third RDG frame (eg, frame 416) within the SIFS time for NDP and may receive a second frame after the third frame.

908 A station can include either in the first frame or in the third frame a notification that an NDP will follow.

[0106]

913 17 is a schematic diagram of an apparatus 1700 for explicit feedback beamforming and NDP sensing.

915 Apparatus 1700 includes means for transmitting a first frame with a request for explicit feedback (module 1712), means for transmitting an NDP having at least one test field, but not having a data field (module 1714), means for receiving a second frame with an explicit feedback derived from the NDP (module 1716), means for outputting control information based on explicit feedback (module 1718) and means for transmitting a controlled frame in

beamforming based on the control information (module 1720).

[0107]

924 FIG. 18 shows a flow diagram of processing 1800 for beamforming implicit feedback and NDP sensing.

926 The station may transmit the first frame (eg, frame 514 in FIG. 5) with a test request (block 1812).

928 The station may receive an NDP (eg, NDP 518) having at least one test field but no data field (block 1814).

930 The station may output NDP-based control information (block 1816) and may transmit a controlled frame (eg, frame 522) beamforming based on the control information (block 1818).

[0108]

935 A station may transmit an RTS frame (eg, frame 510), receive a CTS frame (eg, frame 512) in response to the RTS frame, and transmit the first frame after the CTS frame. A station may include RDG in the first frame, receive a second frame (eg, frame 516) in response to the first frame, and receive NDP after the second frame.

939 The second frame may include an announcement that an NDP will follow. The second frame may also include a notification that another frame will follow, and the station may then receive a third frame (eg, frame 520) with the notification that no further frame will follow.

[0109]

945 FIG. 19 is a schematic diagram of an apparatus 1900 for implicit feedback beamforming with NDP sensing.

947 The device 1900 includes means for transmitting a first frame with a test request (module 1912), means for receiving an NDP having at least one test field, but no data field (module 1914), means for outputting NDP-based control information (module 1916) and a means for transmitting a controlled frame with beamforming based on the control information (module 1918).

[0110]

955 On Fig shows a processing scheme 2000 for bi-directional beamforming with implicit feedback and NDP sensing.

957 The station may transmit the first frame (eg, frame 614 or 618 of FIG. 6) with a test request (block 2012).

959 A station may transmit a first NDP (eg, NDP 616) having at least one test field but no data field, either before or after the first frame (block 2014).

961 The station may receive the first controlled frame (eg, frame 620) with beamforming based on

the first control information output from the first NDP (block 2016).
963 The station may receive a second NDP (eg, NDP 622) in response to a test request (block 2018) and may output second control information based on the second NDP (block 2020).
965 The station may then transmit a second steered frame (eg, frame 626) with beamforming based on the second control information (block 2022).

[0111]
970 A station may transmit an RTS frame (eg, 610 frame), receive a CTS frame (eg, 612 frame) in response to the RTS frame, and transmit the first frame after the CTS frame. The first frame and / or the first controlled frame may include a notification that an NDP will follow.

[0112]
976 21 is a schematic diagram of an apparatus 2100 for bi-directional beamforming with implicit feedback and NDP sensing.
978 Apparatus 2100 includes means for transmitting a first frame with a test request (module 2112), means for transmitting a first NDP having at least one test field but no data field, either before or after the first frame (module 2114), means for receiving a first controlled frame with beamforming based on the first control information outputted from the first NDP (module 2116), means for receiving a second NDP in response to a test request (module 2118), means for outputting second control information based on the second NDP (module 2120) and means for transmitting a second controllable frame with beamforming based on the second control information (module 2122).

[0113]
989 FIG. 22 shows a design of NDP sensing calibration processing 2200.
990 The station may transmit the first frame (eg, frame 1014 in FIG. 10 or frame 1210 in FIG. 12) requesting explicit feedback for calibration (block 2212).
992 The station may also transmit an NDP (eg, NDP 1016 or 1214) having at least one test field but no data field (block 2214).
994 The station may receive a second frame (eg, frame 1020 in FIG. 10 or frame 1218 in FIG. 12) with explicit feedback (block 2216).
996 The station can also receive a probe frame, which can be either an NDP such as NDP 1022 in FIG. 10 or a frame having both a test field and a data field, such as frame 1218 in FIG. 12 (block 2218).
999 The station may derive a channel estimate based on the probing frames (block 2220).
1000 The station may then perform a calibration (eg, may derive reciprocity correction vectors) based on the channel estimate and explicit feedback (block 2222).

[0114]

1005 The first frame may include a test request and a notification that an NDP will follow. Alternatively, the station may transmit a third frame (eg, frame 1018 in FIG. 10 or frame 1216 in FIG. 12) with a test request after NDP. In either case, a probe frame can be transmitted in response to a test request.

[0115]

1012 On Fig shows the structure of the device 2300 for NDP sensing calibration.

1013 The device 2300 includes means for transmitting a first frame with a request for explicit feedback for calibration (module 2312), means for transmitting an NDP having at least one test field but no data field (module 2314), means for receiving a second frame with explicit feedback (module 2316), means for receiving a sounding frame (module 2318), means for deriving a channel estimate based on a sounding frame (module 2320), means for performing calibration based on a channel estimate and explicit feedback (module 2322).

[0116]

1022 24 shows a flow chart of processing 2400 for transmitting CSI feedback for calibration.

1023 A station may receive a request for CSI feedback for calibration, for example, at frame 1014 in FIG. 10, frame 1110 in FIG. 11, or frame 1210 in FIG. 12 (block 2412).

1025 The station may also receive a sounding frame, such as NDP 1016 in FIG. 10, frame 1110 in FIG. 11, or NDP 1214 in FIG. 12 (block 2414).

1027 The station may generate CSI feedback based on the probe frame (block 2416) and may transmit CSI feedback without subcarrier grouping and with full accuracy (block 2418).

[0117]

1032 A station can provide CSI feedback in an administration frame that has a grouping field and a coefficient size field as shown in FIG. 13.

1034 The station may set the grouping field to 0 to indicate no subcarrier grouping (Ng = 1) and may set the coefficient size field to 3 to indicate 8 bits (Nb = 8) for full CSI feedback accuracy. The CSI feedback can comprise a CSI matrix for each of a plurality of subcarriers usable for transmission.

[0118]

1041 25 shows a flowchart of processing 2500 for transmitting CSI feedback for calibration.

1042 Apparatus 2500 includes means for receiving a CSI feedback request for calibration (module 2512), means for receiving a probing frame (module 2514), means for generating CSI feedback based on the probing frame (module 2516), and means for transmitting CSI feedback without subcarrier grouping and with full accuracy (module 2518).

[0119]

1049 The modules in FIGS. 15, 17, 19, 21, 23, and 25 may contain processors, electronic devices, hardware devices, electronic components, logic circuits, memory devices, etc. or any combination of them.

[0120]

1055 FIGS. 14-25 illustrate the processing performed by station A in FIGS. 4, 5, 6, 10, 11 and 12.

1056 The processing performed by station B is complementary to the processing performed by station A and may be described by a set of drawings complementary to FIGS. 14-25.

1058 The processing performed by stations A and B of FIGS. 7, 8 and 9 can also be performed as shown in these figures.

[0121]

1063 FIG. 26 is a block diagram of stations A and B, each of which may be an access point 110 or one of stations 120 in FIG. 1.

1065 Station A is equipped with multiple (T) antennas 2624a through 2624t that can be used to transmit and receive data.

1067 Station B is equipped with multiple (R) antennas 2652a-2652r that can be used to transmit and receive data.

[0122]

1072 At station A, a transmit (TX) data processor 2614 may receive traffic data from a data source 2612 and / or other data from a controller / processor 2630.

1074 A TX data processor 2614 can process (eg, format, encode, interleave, and symbol map) the received data and generate data symbols, which are modulation symbols for the data.

1076 A TX spatial processor 2620 can multiplex the data symbols with the test symbols, perform transmission spatial processing using steering matrices, and provide T output symbol streams to T modulators (MODs) 2622a-2622t.

1079 Test symbols are also commonly referred to as pilot symbols.

1080 Each modulator 2622 may process its own output symbol stream (eg, for OFDM) to generate an output chip stream.

1082 Each modulator 2622 may additionally perform post-processing (eg, analog, amplify, filter, and up-convert) its output chip stream to generate a modulated signal.

1084 T modulated signals from modulators 2622a through 2622t may be transmitted via antennas 2624a through 2624t, respectively.

[0123]

1089 At station B, R antennas 2652a through 2652r may receive modulated signals from station A, and each antenna 2652 may provide the received signal to a corresponding demodulator (DEMOD) 2654.

1092 Each demodulator 2654 can perform processing complementary to the processing performed by the modulators 2622 to obtain received symbols.

1094 A receive (RX) spatial processor 2660 may perform spatial matched filtering on received symbols from all demodulators 2654a through 2654r and provide data symbol estimates that are estimates of data symbols transmitted by station A. RX data processor 2670 may further process (e.g., reverse mapping symbols, deinterleaving and decode) estimates of the data symbols, and provide the decoded data to a data sink 2672 and / or to a controller / processor 2680.

[0124]

1103 Channel processor 2678 can process the test symbols received from station A and can estimate the MIMO channel response. Processor 2678 may decompose the channel matrix for each subcarrier or each group of subcarriers of interest, eg, as shown in equation (1), to obtain a corresponding beamforming matrix.

1107 Processor 2678 can generate feedback information for channel matrices or (for uncompressed or compressed) beamforming matrices.

1109 Processor 2678 may provide feedback information to controller / processor 2680 for transmission back to station A. Processor 2678 may also derive a spatial filter matrix for each subcarrier or each group of subcarriers of interest based on the corresponding channel and / or beamforming matrix.

1113 Processor 2678 may provide spatial filter matrices to RX spatial processor 2660 for spatial matched filtering.

[0125]

1118 Processing for transmission from station B to station A may be performed in the same way as processing for transmission from station A to station B, or differently.

1120 Traffic data from data source 2686 and / or other data (e.g., feedback information) from controller / processor 2680 can be processed (e.g., encoded, interleaved, and modulated) by data processor 2688 TX and are optionally multiplexed with test symbols and spatially processed using a 2690 TX spatial processor with steering matrices.

1124 The output symbols from the 2690 TX spatial processor can be further processed by modulators 2654a through 2654r to generate R modulated signals that can be transmitted via antennas 2652a through 2652r.

[0126]

1130 At station A, the modulated signals from station B may be received by antennas 2624a through 2624t and processed by demodulators 2622a through 2622t to obtain received symbols.
1133 An RX spatial processor 2640 may perform spatial matched filtering on the received symbols and provide estimates of the data symbols.
1135 An RX data processor 2642 may further process data symbol estimates, provide decoded data to a data sink 2644, and provide feedback information to a controller / processor 2630.
1137 Processor 2630 may derive steering matrices based on the feedback information.

[0127]

1141 Channel processor 2628 can process the test symbols received from station B and can estimate the MIMO channel response. Processor 2628 may decompose the channel matrix for each subcarrier or each group of subcarriers of interest to obtain a corresponding beamforming matrix.
1145 Processor 2628 may also derive a spatial filter matrix for each subcarrier or each group of subcarriers of interest.
1147 Processor 2628 can provide spatial filter matrices to RX spatial processor 2640 for spatial matched filtering, and can provide channel matrices or beamforming matrices to controller / processor 2630 for feedback to Station B.

[0128]

1153 Controllers / processors 2630 and 2680 can control stations A and B, respectively.
1154 Memories 2632 and 2682 can store data and program codes for stations A and B, respectively.
1156 Processors 2628, 2630, 2678, 2680 and / or other processors may perform the processing and functions described herein, such as processing 1400 in FIG. 14, processing 1600 in FIG. 16, processing 1800 in FIG. 18, processing 2000 in FIG. , processing 2200 in FIG. 22, processing 2400 in FIG. 24, and so on.

[0129]

1163 The technologies described here can be implemented using various means.
1164 For example, these technologies can be implemented as hardware, firmware, software, or a combination of both.
1166 For hardware implementation, the processing modules used to perform these technologies may be embodied in one or more application specific integrated circuits (ASICs), digital signal processors (DSPs), digital signal processing devices (DSPDs), programmable logic devices (PLDs) , field programmable gate arrays (FPGA), processors, controllers, microcontrollers, microprocessors, electronic devices, other electronic modules designed to perform the functions described herein, a computer, or a combination thereof.

[0130]

1175 For implementation in firmware and / or software, technologies may be implemented with modules (eg, procedures, functions, etc.) that perform the functions described herein.

1177 Firmware and / or software instructions may be stored in a memory (eg, memory 2632 or 2682 of FIG. 26) and may be executed by a processor (eg, processor 2630 or 2680).

1179 The storage device can be embodied as a processor, or can be external to the processor.

1180 Firmware and / or software instructions may also be stored in other processor-readable media such as random access memory (RAM), read-only memory (ROM), non-volatile random access memory (NVRAM), programmable read-only memory (PROM), electrically erasable PROM (EEPROM), flash memory, compact disk (CD), magnetic or optical storage device, etc.

[0131]

1188 The foregoing description of the disclosure is presented to enable any person skilled in the art to make use of the disclosure.

1190 Various modifications of such disclosure will be obvious to a person skilled in the art, and the general principles defined herein may be applied in other embodiments without departing from the spirit or scope of the disclosure.

1193 Thus, the disclosure should not be limited to the examples and constructions described herein, but should conform to the broadest scope consistent with the principles and novel features disclosed herein.

Notice

CLAIMS RU2419213C2

1.

13 An apparatus for supporting beamforming in a wireless communication network, comprising: at least one processor configured to receive a test request, transmit a first probe frame in response to a test request, receive a request for explicit feedback for beamforming, receive a second probe frame generate explicit feedback based on the second probe frame, and transmit explicit feedback in response to the explicit feedback request; and a memory device coupled to at least one processor.

2.

22 The apparatus of claim 1, wherein the at least one processor is configured to receive a controlled frame transmitted based on explicit feedback.

3.

27 The apparatus of claim 1, wherein the at least one processor is configured to receive a controlled frame transmitted based on implicit feedback derived from the first probe frame.

4.

32 The apparatus of claim 1, wherein the at least one processor is configured to receive explicit feedback derived from the first probe frame, output control information based on the received explicit feedback, and transmit a controlled frame based on the control information.

5.

38 The apparatus of claim 1, wherein the at least one processor is configured to receive a third probe frame, output control information based on the third probe frame, and transmit a controlled frame based on the control information.

6.

44 The apparatus of claim 1, wherein each of the first and second probe frames comprises test and data fields.

7.

49 The apparatus of claim 1, wherein each of the first and second probe frames comprises a null data packet (NDP) having at least one test field but no data field.

8.

54 The apparatus of claim 1, wherein each of the first and second probe frames comprises a frame having test and data fields or a null data packet (NDP) having at least one test field but no data field.

9.

60 The apparatus of claim 1, wherein the explicit feedback comprises channel state information (CSI) matrices, uncompressed beamforming feedback matrices, or compressed beamforming feedback matrices.

10.

66 The apparatus of claim 1, wherein the first and second probe frames comprise protocol data units (PPDUs) for a physical layer convergence protocol (PLCP) in accordance with the IEEE 802.11 standard.

11.

72 A method for supporting beamforming in a wireless communication network, comprising the steps of: receiving a test request; transmitting a first probe frame in response to a test request; receiving a request for explicit feedback for beamforming; receiving a second sounding frame; generating explicit feedback based on the second probe frame; and transmitting explicit feedback in response to a request for explicit feedback.

12.

80 The method of claim 11, further comprising: receiving a controlled frame transmitted based on either explicit feedback or implicit feedback derived from the first probe frame.

13.

85 The method of claim 11, further comprising the steps of: receiving explicit feedback derived from the first probe frame; outputting control information based on the received explicit feedback; and transmitting a controlled frame based on the control information.

14.

91 The method according to claim 11, further comprising the steps of: receiving a third sounding frame; outputting control information based on the third sounding frame; and transmitting a controlled frame based on the control information.

15.

97 An apparatus for supporting beamforming in a wireless communication network, comprising: means for receiving a test request; means for transmitting a first probe frame in response to a test request; means for receiving a request for explicit feedback for beamforming; means for receiving a second sounding frame; means for generating explicit feedback based on the second probe frame; means for transmitting explicit feedback in response to a request for explicit feedback.

16.

106 The apparatus of claim 15, further comprising: means for receiving a controlled frame transmitted based on either explicit feedback or implicit feedback obtained from the first probe frame.

17.

112 The apparatus of claim 15, further comprising: means for receiving explicit feedback derived based on the first probe frame; means for outputting control information based on the received explicit feedback; and a means for transmitting a controlled frame based on the control information.

18.

119 The device according to claim 15, further comprising: means for receiving the third sounding frame; means for outputting control information based on the third sounding frame; and a means for transmitting a controlled frame based on the control information.

19.

125 A processor-readable medium including instructions stored therein, comprising: a first set of instructions for receiving a test request; a second set of instructions for transmitting a first probe frame in response to a test request; a third set of instructions for receiving an explicit feedback request for beamforming ; a fourth set of instructions for receiving the second probe frame; a fifth set of instructions for generating explicit feedback based on the second probe frame; and a sixth set of instructions for providing explicit feedback in response to a request for explicit feedback.

20.

135 An explicit feedback beamforming apparatus, comprising: at least one processor configured to transmit a first explicit feedback request frame, transmit a null data packet (NDP) having at least one test field, but containing no data field, and receive a second frame with explicit feedback derived from the NDP; and a memory device coupled to at least one processor.

21.

142 The apparatus of claim 20, wherein the at least one processor is configured to output control information based on explicit feedback and transmit a controlled frame based on the control information.

22.

148 The apparatus of claim 20, wherein the first frame comprises a Request to Send (RTS) frame, and wherein the at least one processor is configured to receive a Clear to Send (CTS) frame, and transmit NDP during short inter-frame interval time (SIFS) of the CTS frame.

23.

154 The apparatus of claim 20, wherein the at least one processor is configured to transmit a third frame with a reverse direction during an NDP short inter-frame interval (SIFS) time and receive a second frame after the third frame.

24.

160 The apparatus of claim 23, wherein the at least one processor is configured to include in the first frame or in the third frame a notification that an NDP will follow.

25.

165 An explicit feedback beamforming method comprising: transmitting a first explicit feedback request frame; transmitting a null data packet (NDP) having at least one test field but not having a data field; and a second frame is received with explicit feedback derived from the NDP.

26.

172 The method according to claim 25, further comprising the steps of: outputting control information based on explicit feedback; and transmitting a controlled frame based on the control information.

27.

178 The method of claim 25, further comprising: receiving a Clear to Send (CTS) frame in response to a Request to Send (RTS) frame in the first frame, and in which the NDP is sent to the duration of the short inter-frame interval (SIFS) of the CTS frame.

28.

184 The method of claim 25, further comprising: transmitting the third frame with reverse resolution during an NDP short inter-frame interval (SIFS) time, and wherein the second frame is received after the third frame.

29.

190 The method according to claim 28, further comprising the step of: including in the first frame or in the third frame a notification that NDP will follow.

30.

195 An apparatus for supporting beamforming in a wireless communication network, comprising: at least one processor configured to receive a null data packet (NDP) having at least one test field but not containing a data field, output control information to based on NDP and transmit a controlled frame based on the control information; and a memory device coupled to at least one processor.

31.

203 The apparatus of claim 30, wherein the at least one processor is configured to transmit the first test request frame and receive an NDP in response to the test request.

32.

208 The apparatus of claim 31, wherein the at least one processor is configured to transmit the reverse direction grant in the first frame, receive the second frame after the first frame, and receive the NDP after the second frame.

33.

214 The apparatus of claim 32, wherein the second frame includes a notification that an NDP will follow.

34.

219 The apparatus of claim 32, wherein the second frame includes an indication that another frame follows and in which at least one processor is configured to: receive a third frame after the second frame, the third frame including an indication that that no other frame follows.

35.

225 The apparatus of claim 30, wherein the at least one processor is configured to transmit a Request to Send (RTS) frame, receive a Clear to Send (CTS) frame in response to the RTS frame and transmit the first frame after the CTS frame.

36.

231 A method for supporting beamforming in a wireless communication network, comprising: receiving a null data packet (NDP) having at least one test field but not containing a data field; outputting control information based on the NDP; and transmitting a controlled frame based on the control information.

37.

238 The method of claim 36, further comprising: transmitting the first test request frame, and wherein the NDP is received in response to the test request.

38.

243 The method according to claim 37, further comprising the steps of: transmitting a reverse direction grant in the first frame; and a second frame is received after the first frame, the NDP being received after the second frame.

39.

249 An apparatus for supporting beamforming in a wireless communication network, comprising: at least one processor configured to transmit a first frame with a test request, transmit a first null data packet (NDP) having at least one test field, but not containing a data field, and receive a second NDP in response to a test request; and a memory device coupled to at least one processor.

40.

257 The apparatus of claim 39, wherein the at least one processor is configured to receive a controlled frame based on control information derived from the first NDP.

41.

262 The apparatus of claim 39, wherein the at least one processor is configured to output control information based on the second NDP and transmit the controlled frame based on the second control information.

42.

268 The apparatus of claim 39, wherein the first frame includes an announcement that an NDP will follow.

43.

273 The apparatus of claim 39, wherein the at least one processor is configured to transmit a Request to Send (RTS) frame, receive a Clear to Send (CTS) frame in response to the RTS frame and transmit the first frame after the CTS frame.

44.

279 A method for implementing beamforming in a wireless communication network, comprising: transmitting a first frame with a test request; transmitting a first null data packet (NDP) having at least one test field but not containing a data field; and receiving a second NDP in response to a test request.

45.

286 The method according to claim 44, further comprising the step of: receiving the controlled frame based on the control information output from the first NDP.

46.

291 The method of claim 44, further comprising the steps of: outputting control information based on the second NDP; and transmitting a controlled frame based on the second control information.

47.

297 A device for calibration during beamforming in a wireless communication network, comprising: at least one processor configured to transmit a first frame with a request for explicit feedback for calibration, transmit a null data packet (NDP) having at least one a test field, but not containing a data field, receive a second explicit feedback frame, receive a probe frame, derive a channel estimate based on the probe frame, and perform a calibration based on the channel estimate and explicit feedback; and a storage device connected at least with one processor.

48.

306 The apparatus of claim 47, wherein the probe frame comprises an NDP.

49.

310 The apparatus of claim 47, wherein the probe frame comprises test and data fields.

50.

314 The apparatus of claim 47, wherein the first frame comprises a test request and a notification that an NDP will follow, wherein the probe frame is transmitted in response to the test request.

51.

319 The apparatus of claim 47, wherein the at least one processor is configured to transmit a third test request frame after the NDP, wherein the probe frame is transmitted in response to the test request.

52.

325 A method for performing beamforming calibration in a wireless communication network, comprising: transmitting a first frame with a request for explicit feedback for calibration; transmitting a null data packet (NDP) having at least one test field but not containing a data field; receive a second explicit feedback frame; receive a probe frame; derive a channel estimate based on the probe frame; and performing calibration based on the channel estimate and explicit feedback.

53.

334 The method of claim 52, wherein the first frame includes a test request and notification that an NDP will follow, wherein the probe frame is transmitted in response to the test request.

54.

339 The method of claim 52, further comprising the step of: transmitting a third test request frame after NDP, wherein the probe frame is transmitted in response to the test request.

55.

344 An apparatus for transmitting feedback, comprising: at least one processor configured to receive a feedback request with channel state information (CSI) for calibration, receive a probe frame to generate CSI feedback based on the probe frame, and transmit CSI feedback no subcarrier grouping and with full precision; and a memory device coupled to at least one processor.

56.

352 The apparatus of claim 55, wherein the at least one processor is configured to transmit CSI feedback in the administration frame having a grouping field and a coefficient size field, set in the grouping field 0 to indicate no subcarrier grouping, and set in the coefficient size field 3 to denote 8 bits for full CSI feedback accuracy.

57.

359 The apparatus of claim 55, wherein the CSI feedback comprises a CSI matrix for each of the plurality of transmittable subcarriers.

58.

364 A method for transmitting feedback, comprising: receiving a feedback request for channel state information (CSI) for calibration; receiving a probe frame; generating CSI feedback based on the probe frame; and transmitting CSI feedback without subcarrier grouping and with full fidelity.

59.

371 The method of claim 58, wherein transmitting CSI feedback comprises: transmitting CSI feedback in an administration frame having a grouping field and a coefficient size field, set in a grouping field of 0 to indicate no subcarrier grouping, and set in a coefficient size field 3 to

denote 8 bits for full CSI feedback accuracy.

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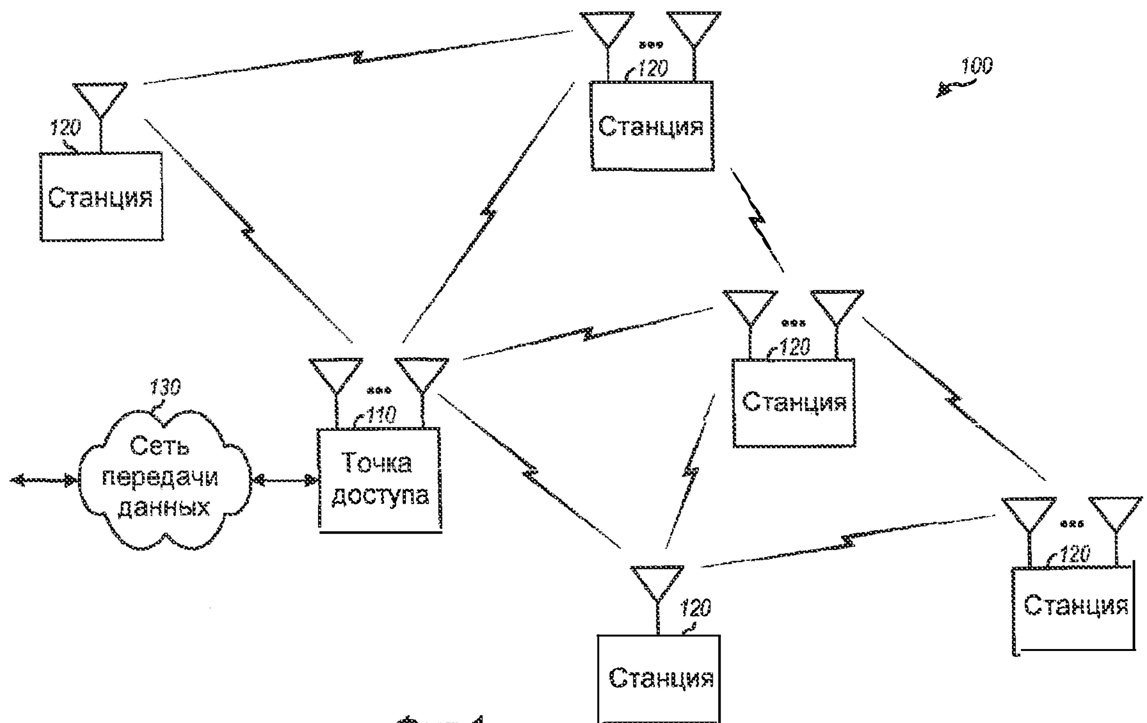
(54) СПОСОБ И СИСТЕМА ОБЕСПЕЧЕНИЯ ОБРАТНОЙ СВЯЗИ ДЛЯ ФОРМИРОВАНИЯ ЛУЧА В СИСТЕМАХ БЕСПРОВОДНОЙ СВЯЗИ

(57) Реферат:

Изобретение относится к технологиям передачи информации обратной связи для формирования луча в системах беспроводной связи. Технический результат заключается в формировании луча с малой сложностью как для передатчика, так и для приемника. Для этого способ поддержки формирования луча содержит этапы, на которых принимают запрос тестирования и передают первый зондирующий кадр в ответ на запрос тестирования. Затем принимают запрос на явную обратную связь для формирования луча, принимают второй зондирующий кадр,

генерируют явную обратную связь на основе второго зондирующего кадра и передают явную обратную связь в ответ на запрос на явную обратную связь. 14 н. и 45 з.п. ф-лы, 28 ил., 3 табл.



Фиг.1

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(54) METHOD AND SYSTEM TO PROVIDE FEEDBACK FOR GENERATION OF BEAM IN WIRELESS COMMUNICATION SYSTEMS

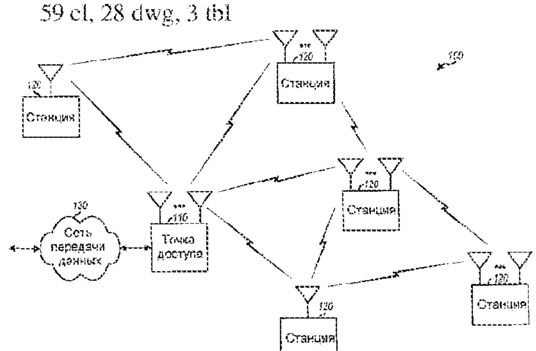
(57) Abstract:

FIELD: information technologies.

SUBSTANCE: method to support beam generation includes stages, at which a testing request is received, and the first probing frame is sent in response to the testing request. Then the request is received for explicit feedback to generate a beam, the second probing frame is received, the explicit feedback is generated on the basis of the second probing frame, and the explicit feedback is sent in response to the explicit feedback.

EFFECT: generation of beam with low complexity, both for a transmitter and for a receiver.

59 cl, 28 dwg, 3 tbl



Фиг.1

По настоящей заявке испрашивается приоритет в соответствии с предварительной заявкой США №60/816,988 под названием «Способ и система обеспечения обратной связи для формирования луча в системах беспроводной связи» ("METHOD AND SYSTEM FOR PROVIDING BEAMFORMING FEEDBACK IN WIRELESS COMMUNICATION SYSTEMS"), поданной 27 июня 2006 года, переуступленной правопреемнику настоящей заявки и включенной в настоящий документ посредством ссылки.

Уровень техники

Область техники, к которой относится изобретение

Настоящее раскрытие, в общем, относится к области связи и, более конкретно, к технологиям передачи информации обратной связи для формирования луча в системах беспроводной связи.

Описание предшествующего уровня техники

В системе беспроводной связи в передатчике может использоваться множество (T) передающих антенн для передачи данных в приемник, оборудованный множеством (R) приемных антенн. Множество передающих и приемных антенн формируют канал с множеством входов и множеством выходов (MIMO), который можно использовать для повышения пропускной способности и/или улучшения надежности. Например, передатчик может передавать вплоть до T потоков данных одновременно через T передающих антенн для улучшения пропускной способности. В качестве альтернативы передатчик может передавать одиночный поток данных через все T передающих антенн для улучшения приема приемником.

Хорошие характеристики (например, хорошая пропускная способность) могут быть получены при передаче одного или больше потоков данных с формированием луча. Для формирования луча, передатчик может получать оценку канала для канала MIMO, выводить матрицы управления на основе оценки канала и выполнять пространственную обработку передачи с помощью матриц управления. Передатчик может получать оценку канала несколькими способами в зависимости от схемы дуплексирования, используемой системой, и возможностей передатчика и приемника. Желательно поддерживать формирование луча с насколько это возможно малой сложностью как для передатчика, так и для приемника.

Сущность изобретения

Здесь описаны технологии поддержки формирования луча для станций в сетях беспроводной связи. В одном аспекте станция может поддерживать формирование луча с неявной обратной связью или явной обратной связью, обладая возможностью передавать и принимать кадры зондирования, отвечать на запрос тестирования путем передачи кадра зондирования и отвечать на запрос явной обратной связи. Неявная обратная связь и явная обратная связь представляют собой два способа получения информации о канале MIMO и описаны ниже. Станция должна обладать способностью выполнять неявное или явное формирование луча с другой станцией, обладающей такими же возможностями.

В другом аспекте станция может осуществлять формирование луча, используя явную обратную связь и зондирование с нулевым пакетом данных (NDP). Станция может передавать первый кадр с запросом на явную обратную связь и может также передавать NDP, имеющий, по меньшей мере, одно поле тестирования, но не имеющий поле данных. Станция может принимать второй кадр с явной обратной связью, которая может быть выведена на основе NDP. Станция может выводить информацию управления (например, матрицы управления) на основе явной обратной связи и может затем передавать управляемый кадр с формированием луча на основе информации управления.

В еще одном другом аспекте станция может выполнять формирование луча с неявной обратной связью и зондирование NDP. Станция может передавать первый кадр с запросом тестирования и может принимать NDP в ответ. Станция может выводить информацию управления на основе NDP и может затем передавать управляемый кадр с формированием луча на основе информации управления.

В еще одном другом аспекте станция может выполнять двунаправленное формирование луча с неявной обратной связью и NDP зондированием. Станция может передавать первый кадр с запросом тестирования и может также передавать первый NDP либо до, либо после первого кадра. Станция может принимать первый управляемый кадр с формированием луча на основе первой информации управления, которая может быть выведена из первого NDP. Станция может также принимать второй NDP в ответ на запрос тестирования и может выводить вторую информацию управления на основе второго NDP. Станция может затем передавать второй управляемый кадр с формированием луча на основе второй информации управления.

Станция может также выполнять формирование луча с зондированием MPDU, в котором используют кадры, имеющие как поля тестирования, так и поля данных. Такой кадр может переносить модуль данных (MPDU) в соответствии с протоколом управления доступом к среде передачи (MAC). Различные аспекты и свойства раскрытия более подробно описаны ниже.

Краткое описание чертежей

На фиг.1 показана сеть беспроводной связи.

На фиг.2А, 2В и 3С показаны три формата PPDU в соответствии с IEEE 802.11n.

На фиг.3 показан формат кадра MAC в соответствии с IEEE 802.11n.

На фиг.4 показано однонаправленное явное формирование луча с зондированием NDP.

На фиг.5 показано неявное однонаправленное формирование луча с зондированием NDP.

На фиг.6 показано неявное двунаправленное формирование луча с зондированием NDP.

На фиг.7 показано однонаправленное явное формирование луча с зондированием MPDU.

На фиг.8 показано неявное однонаправленное формирование луча с зондированием MPDU.

На фиг.9 показано неявное двунаправленное формирование луча с зондированием MPDU.

На фиг.10 показана калибровка с зондированием NDP.

На фиг.11 показана калибровка с зондированием MPDU.

На фиг.12 показана калибровка с одновременным зондированием NDP и MPDU.

На фиг.13 показан кадр управления для передачи информации о состоянии канала (CSI, ИСК) по каналу обратной связи.

На фиг.14 и 15 показано формирование луча станцией.

На фиг.16 и 17 показано явное формирование луча с зондированием NDP.

На фиг.18 и 19 показано неявное формирование луча с зондированием NDP.

На фиг.20 и 21 показано двунаправленное неявное формирование луча с зондированием NDP.

На фиг.22 и 23 показана калибровка с зондированием NDP.

На фиг.24 и 25 показана передача обратной связи с CSI для калибровки.

На фиг.26 показана блок-схема двух станций.

Подробное описание изобретения

Технологии, описанные здесь, можно использовать в различных сетях и системах беспроводной связи, таких как беспроводные локальные вычислительные сети (LAN), беспроводные городские сети мегаполиса (WMAN), беспроводные региональные вычислительные сети (WWAN) и т.д. Термины "сети" и "системы" часто используют взаимозаменяемо.

Во WLAN может быть воплощена любая из радиотехнологий из семейства стандартов IEEE 802.11, Hiperlan и т.д. В WMAN может быть воплощен стандарт IEEE 802.16 и т.д. WWAN может представлять собой сотовую сеть, такую как сеть множественного доступа с кодовым разделением каналов (CDMA), сеть множественного доступа с временным разделением каналов (TDMA), сеть множественного доступа с частотным разделением (FDMA), сеть ортогонального FDMA (OFDMA), сеть FDMA с одной несущей (SC-FDMA) и т.д. Для ясности определенные аспекты технологий описаны ниже для WLAN, в которой воплошен стандарт IEEE 802.11n.

В стандарте IEEE 802.11n используется мультиплексирование с ортогональным частотным разделением сигналов (OFDM), которое представляет собой технологию модуляции, которая разделяет полосы пропускания системы на множество (K) ортогональных поднесущих. Для работы в пределах 20 МГц в соответствии с IEEE 802.11n определено общее количество поднесущих K = 64 с использованием OFDM, и им назначены индексы от -32 до +31. Общее количество 64 поднесущих включает в себя 52 поднесущие данных с индексами ±{1..., 6, 8..., 20, 22..., 28} и четыре пилотных поднесущих с индексами ±{7, 21}. Поднесущую DC (постоянного тока) с индексом 0 из остальных поднесущих не используют. Для работы в полосе 40 МГц в соответствии с IEEE 802.11n определено суммарное количество поднесущих K = 128 с индексами от -64 до +63, и они включают в себя 108 поднесущих данных с индексами ±{2, 10, 12, 24, 26..., 52, 54..., 58} и шесть пилотных поднесущих с индексами ±{11, 25, 54}. IEEE 802.11n также поддерживает передачу MIMO через множество передающих антенн в множество приемных антенн. IEEE 802.11n описан в IEEE P802.11n™/D1.0 под названием "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Enhancements for Higher Throughput" от марта 2006 года и в IEEE P802.11n™/D2.00 под названием "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Amendment: Enhancements for Higher Throughput" от февраля 2007 года.

На фиг.1 показана беспроводная сеть 100 с точкой 110 доступа и множеством станций 120. В общем случае беспроводная сеть может включать в себя любое количество точек доступа и любое количество станций. Станция представляет собой устройство, которое связывается с другой станцией через беспроводную среду/канал. Станцию также можно называть терминалом, мобильной станцией, оборудованием пользователя, модулем абонента и т.д., и она может содержать некоторые или все их функции. Станция может представлять собой сотовый телефон, переносное устройство, беспроводное устройство, карманный персональный компьютер (PDA), переносной компьютер, беспроводный модем, беспроводный телефон и т.д. Точка доступа представляет собой станцию, которая обеспечивает доступ к услугам, распределяемым через беспроводную среду, для станций, ассоциированных с этой точкой доступа. Точку доступа также можно называть базовой станцией, базовой передающей станцией (BTS), узлом B и т.д., и она может содержать некоторые или все их функции. Станции 120 могут связываться с точкой 110 доступа и/или друг с другом, используя передачу данных между одноранговыми узлами сети. Точка 110 доступа может быть соединена с сетью 130 данных и может связываться с другими устройствами через сеть данных. Сеть 130 данных может представлять собой Интернет, интранет и/или любую другую кабельную или беспроводную сеть.

Технологии, описанные здесь, можно использовать для MIMO передачи по нисходящему каналу передачи, восходящему каналу передачи и между одноранговыми узлами сети. Для нисходящей передачи данных точка 110 доступа может представлять собой передатчик и станция 120 может представлять собой приемники. Для восходящей передачи данных станции 120 могут представлять собой передатчики и точка 110 доступа может представлять собой приемник. При передаче между одноранговыми узлами сети одна из станций 120 может представлять собой передатчик и другая станция 120 может представлять собой приемник.

Канал MIMO, сформированный множеством (T) передающих антенн в передатчике и множеством (R) приемных антенн в приемнике, может быть охарактеризован матрицей $\underline{H}_k$, состоящей из R × T каналов, для каждой поднесущей k или каждой группы поднесущих, представляющей интерес. Матрица $\underline{H}_k$ каналов может быть диагонализирована в результате выполнения разложения по собственному значению матрицы корреляции для $\underline{H}_k$ следующим образом.

$$\underline{R}_k = \underline{H}_k^H \underline{H}_k = \underline{V}_k \underline{\Lambda}_k \underline{V}_k^H, \qquad \text{Ур.(1)}$$

где $\underline{R}_k$ представляет собой матрицу корреляции T × T для $\underline{H}_k$,

$\underline{V}_k$ представляет собой унитарную матрицу T × T, столбцы которой представляют собой собственные векторы $\underline{R}_k$,

$\underline{\Lambda}_k$ представляет собой диагональную матрицу T × T собственных значений $\underline{R}_k$, и "H" обозначает результат сопряженного транспонирования.

Унитарная матрица $\underline{V}_k$ характеризуется свойством $\underline{V}^H{}_k\, \underline{V}_k = \underline{I}$, где $\underline{I}$ представляет собой матрицу тождественности. Столбцы унитарной матрицы ортогональны друг другу, и каждый столбец имеет единичную мощность. $\underline{V}_k$ также называется матрицей формирования луча. Диагональная матрица $\underline{\Lambda}_k$ содержит возможные ненулевые значения вдоль диагонали и нули во всех других местах. Диагональные элементы $\underline{\Lambda}_k$ представляют собой собственные значения, представляющие коэффициенты усиления мощности собственных мод $\underline{R}_k$.

Передатчик (или формирователь луча) может выполнять пространственную обработку передачи для формирования луча для приемника (или получателя формируемого луча) следующим образом:

$$\underline{z}_k = \underline{Q}_k\, \underline{x}_k \qquad \text{Ур. (2)}$$

где $\underline{x}_k$ представляет собой вектор, содержащий вплоть до T символов данных, предназначенный для передачи поднесущей k,

$\underline{Q}_k$ представляет собой матрицу управления для поднесущей k, которая может быть выведена на основе $\underline{V}_k$, и

$\underline{z}_k$ представляет собой вектор с T выходными символами для T передающих антенн для поднесущей k.

В ходе формирования луча в соответствии с уравнением (2) управляют или формуют лучи, передаваемые из передатчика в приемник. Для эффективного формирования луча передатчик должен иметь точную оценку отклика канала MIMO из передатчика в приемник. Эту информацию канала MIMO можно использовать для вывода соответствующих матриц управления для пространственной обработки передачи, для направления лучей из передатчика к приемнику.

Формирование луча может осуществляться различными способами и может поддерживаться различными модулями данных протокола (PDU). Для ясности ниже описано формирование луча с использованием PDU, определенное в IEEE 802.11n.

В IEEE 802.11n протокол MAC обрабатывает данные как MAC PDU (MPDU). Затем протокол сходимости физического уровня (PLCP) обрабатывает MPDU для генерирования PLCP PDU (PPDU). PPDU также может называться пакетом, кадром и т.д. Физический уровень (PHY) затем обрабатывает и передает каждый PPDU через беспроводную среду. В IEEE 802.11n можно использовать PPDU с высокой пропускной способностью (HT-PPDU) для передачи MIMO из множества передающих антенн в множество приемных антенн.

На фиг.2А показана структура HT-PPDU 210 со смешанным форматом HT в IEEE 802.11n. HT-PPDU 210 включает в себя преамбулу смешанного режима, после чего следует поле данных. Преамбула смешанного режима включает в себя (i) преамбулу наследования, состоящую из короткого тестового поля наследования (L-STF) и длинного поля тестирования наследования (L-LTF), (ii) поле сигнала наследования (L-SIG), (iii), поле сигнала HT (HT-SIG) и (iv) HT-преамбулу, состоящую из короткого поля тестирования HT, (HT-STF) и одного или больше длинных полей тестирования HT (HT-LTF). Количество HT-LTF равно или больше количеству потоков данных, передаваемых одновременно. Длинные и короткие поля тестирования могут переносить известные символы тестирования, которые можно использовать для детектирования кадра, получения времени, оценки частоты и коррекции, автоматической регулировки усиления (AGC), оценки канала и т.д. Поля L-SIG и HT-SIG могут переносить информацию сигналов для HT-PPDU. Например, поле HT-SIG переносит (i) поле Length (Длина), которое обозначает длину поля данных и (ii) поле Not Sounding (Отсутствие зондирования), которое обозначает, является или нет HT-PPDU зондирующим PPDU. Зондирующий PPDU представляет собой PPDU, переносящий известные символы тестирования, которые можно использовать для оценки канала. Поле данных переносит полезную нагрузку HT-PPDU, которая может представлять собой один или больше MPDU и может иметь переменную длину, обозначенную полем Length.

На фиг.2В показана структура HT-PPDU 220 с форматом HT (ВП) на новой основе (greenfield) в соответствии с IEEE 802.11n. HT-PPDU 220 включает в себя преамбулу формата на новой основе, после которой следует поле данных. Преамбула формата на новой основе включает в себя короткое поле тестирования формата на новой основе HT (HT-GF-STF), длинное поле тестирования HT (HT-LTF1, ВП-ДТП1), поле HT-SIG и одно или больше полей HT-LTF.

HT-PPDU 210 и 220 можно использовать как зондирующие PPDU путем установки 0 в поле отсутствия зондирования (Not Sounding) и включения достаточного количества HT-LTF. Зондирующий PPDU, который переносит данные, называется зондирующим MPDU.

На фиг.2С показана структура пакета 230 нулевых данных (NDP) с преамбулой формата на новой основе в соответствии с IEEE 802.11n. NDP 230 представляет собой зондирующий PPDU, который не переносит данные и который также может называться кадром нулевой длины (ZLF) и т.д. NDP 230 может быть сформирован путем установки 0 в поле Length, установки 0 в поле Not Sounding, включения достаточного количества HT-LTF и исключения поля данных Data.

HT-PPDU 210, 220 и 230 представляют собой некоторые форматы PPDU, поддерживаемые IEEE 802.11n. Форматы PPDU, поддерживаемые IEEE 802.11n, описаны в указанных выше документах IEEE 802.11n.

На фиг.3 показана структура кадра 300 MAC в соответствии с IEEE 802.11n. Кадр 300 MAC включает в себя различные поля, такие как поле HT Control (управление HT), поле Frame Body (тело кадра) и поле последовательности проверки кадра (FCS). Поле Frame Body переносит данные для кадра MAC. Поле FCS переносит значение FCS, которое генерируют на основе содержания других полей кадра MAC и используют для детектирования ошибок кадра MAC. Поле HT Control включает в себя различные поля, такие как поле Link Adaptation Control (управление адаптацией соединения), поле CSI/Steering (CSI/управление), поле NDP Announcement (ТВЗ уведомление) и поле предоставления обратного направления (RDG)/More PPDU. Поле Link Adaptation Control включает в себя поле запроса тестирования (TRQ) и запрос MCS или поле Antenna Selection Indication (индикации выбора антенны) (MAI). Поле MAI включает в себя поле запроса (MRQ) схемы (MCS) кодирования модуляции. В Таблице 1 представлены различные поля MAC, показанные на фиг.3, и представлено описание для каждого поля MAC. Форматы кадра и полей MAC и различных типов явной обратной связи, обозначенные полем CSI/Steering, описаны в указанных выше документах IEEE 802.11n.

Таблица 1

Поле MAC	Описание
TRQ	0 = передатчик ответчика не получил запрос передать зондирующий PPDU, 1 = передатчик ответчика получил запрос передать зондирующий PPDU.
MRQ	0 = не запрошена обратная связь MCS, 1 = запрошена обратная связь MCS.
CSI/Steering	0 = обратная связь не требуется, 1 = запрос на обратную связь CSI, 2 = запрос на несжатую матрицу обратной связи формирования луча, 3 = запрос на сжатую матрицу обратной связи формирования луча.
NDP Announcement	0 = далее не следует NDP, 1 = далее следует NDP.
RDG/More PPDU	0 = PPDU, переносящий кадр MAC, представляет собой последнюю передачу, 1 = после PPDU, переносящего кадр MAC, следует другой PPDU, 0 = не передано предоставление обратного направления, 1 = присутствует предоставление обратного направления.

В Таблице 2 представлено два типа зондирования и в ней представлено короткое описание каждого типа зондирования. NDP не переносит кадр MAC и, таким образом, не содержит поле HT Control. Следовательно, могут существовать определенные ограничения по использованию NDP, а также по способу возможной передачи NDP.

Таблица 2

Тип зондирования	Описание
Зондирование MPDU	Использование данных, переносящих зондирующий PPDU и поле HT Control.
Зондирование NDP	Использование зондирующего PPDU, который не переносит данные и не содержит поле HT Control.

В Таблице 3 представлены два типа схем/обратной связи для формирования луча, поддерживаемых IEEE 802.11n, и предоставлено короткое описание каждого типа обратной связи.

Таблица 3

Тип обратной связи	Описание

Неявная обратная связь	Получатель формирования луча передает зондирующий PPDU. Формирователь луча выводит оценку канала MIMO из зондирующего PPDU и рассчитывает матрицы управления на основе оценки канала MIMO.
Явная обратная связь	Формирователь луча передает зондирующий PPDU. Получатель формирования луча выводит оценку канала MIMO из зондирующего PPDU и передает сигнал обратной связи в формирователь луча. Формирователь луча рассчитывает матрицы управления на основе обратной связи.

Неявную обратную связь можно использовать в сетях дуплексирования с временным разделением (TDD), в которых передачу между станциями осуществляют по одному частотному каналу с временным разделением. В этом случае отклик канала для одного соединения, как можно предположить, представляет собой взаимный отклик канала для другого соединения. Явную обратную связь можно использовать как для сетей TDD, так и для сетей дуплексирования с частотным разделением (FDD).

Формирование луча можно использовать, если передающая станция и приемная станция обе поддерживают одинаковый тип обратной связи, который может представлять собой неявную обратную связью или явную обратную связь. Если одна станция поддерживает только неявную обратную связь и другая станция поддерживает только явную обратную связь, то формирование луча может быть недоступным для этих станций из-за проблем взаимодействия между двумя типами обратной связи. Два типа обратной связи являются несовместимыми по нескольким причинам. Во-первых, станция, которая поддерживает только неявную обратную связь, может не быть способной передавать соответствующие сигналы обратной связи для станции, которая поддерживает только явную обратную связь. Во-вторых, может не быть доступен механизм стимуляции станции, которая поддерживает только явную обратную связь, передать зондирующий PPDU. Кроме того, два типа зондирования могут быть несовместимыми.

В одном аспекте станция может быть разработана со следующими возможностями для поддержания как неявной обратной связи, так и явной обратной связи для формирования луча:

1) передача и прием зондирующего PPDU,

2) отклик на запрос тестирования (TRQ) путем передачи зондирующего PPDU и

3) отклик на запрос на явную обратную связь.

Благодаря поддержке этого набора возможностей, представленных выше, станция может быть способна выполнять неявное или явное формирование луча с другой станцией, поддерживающей тот же набор возможностей.

В одной схеме станция может поддерживать только зондирование NDP или только зондирование MPDU или как зондирование NDP, так и зондирование MPDU. Станция может уведомлять о своей возможности зондирования с помощью поля Capability (Возможность) формирования луча передачи (TxBF), которое включено в определенные кадры, такие как кадр маяка, кадр запроса ассоциации, ответа ассоциации, кадр запроса зондирования и кадр ответа зондирования. В другой схеме формирователь луча может поддерживать передачу зондирования NDP и прием смещенного зондирования, и получатель формирования луча может поддерживать прием зондирования NDP и передачу смещенного зондирования. В IEEE 802.11n ссылка на множество размерностей распространена на множество символов тестирования с использованием определенной ортонормированной матрицы. При использовании смещенного зондирования такое распространение выполняется отдельно для символов тестирования, ассоциированных с размерностями данных, и символов тестирования, ассоциированных с дополнительными пространственными размерностями (расширение пространственных потоков в 802.11n). Таким образом, зондирование для потоков пространственного расширения может быть разделено по времени от зондирования для размерностей данных. Зондирование со смещением можно использовать, когда количество размерностей для зондирования превышает количество размерностей данных или пространственно-временных потоков (N_{STS}). Зондирование со смещением может быть доступно только для зондирования MPDU и может использоваться для зондирования дополнительных размерностей при зондировании MPDU. Получатель формируемого луча может отвечать на запрос обратной связи CSI, переданный с NDP формирователем луча. Формирователь луча может отвечать на запрос зондирования получателя формирования луча.

Формирование луча может быть выполнено с неявной обратной связью или с явной обратной связью, которые могут поддерживаться с помощью зондирования NDP и/или зондирования MPDU. Формирование луча также может осуществляться для однонаправленной передачи из одной станции в другую станцию или для двунаправленной передачи между двумя станциями. Может осуществляться обмен между различными последовательностями кадров для различных сценариев формирования луча. Для ясности ниже описаны примеры обмена кадрами для некоторых сценариев формирования луча.

На фиг.4 показан пример обмена кадрами для однонаправленного явного формирования луча с зондированием NDP. Станция A может передать неуправляемый кадр 410 с запросом обратной связи для одного из типов обратной связи, представленных в Таблице 1. Неуправляемый кадр представляет собой кадр, переданный без формирования луча, и управляемый кадр представляет собой кадр, переданный с формированием луча. Кадр 410 может представлять собой кадр запроса на передачу (RTS), содержащий запрашиваемую длительность для времени, требуемого для передачи ожидающих передачи данных и соответствующих сигналов. Поле NDP Announcement кадра 410 может быть установлено на 1 для обозначения того, что далее следует NDP. Станция B может принимать кадр 410 RTS, может удовлетворять этот запрос и передавать неуправляемый кадр 412 Clear to Send (Готов к передаче) (CTS), который может переносить любые данные, которые станция B может иметь для станции A. Кадры RTS и CTS представляют собой кадры управления, обмен которыми может осуществляться для резервирования беспроводной среды и для исключения взаимных помех от неявных станций. Кадры RTS и CTS также могут быть исключены.

Станция A может передавать NDP 414 и неуправляемый кадр 416, который может представлять кадр данных или некоторый другой кадр. NDP 414 может быть передан в течение короткого промежутка времени между кадрами (SIFS) в конце кадра 412. Поле RDG кадра 416 может быть установлено на 1 для обозначения предоставления обратного направления, которое может передавать управление беспроводной среды передачи в станцию B. Станция B может оценивать ответ канала MIMO на основе NDP 414 и генерировать явную обратную связь типа, запрашиваемого станцией A. Станция B может затем передавать неуправляемый кадр 418 с явной обратной связью. Станция A может принимать явную обратную связь, может выводить матрицы управления на основе обратной связи и передать управляемый кадр 420 данных, используя матрицы управления для формирования луча.

Однонаправленное явное формирование луча с зондированием NDP также может осуществляться другими способами. Например, кадры RTS и CTS могут быть опущены или заменены кадрами других типов. NDP 414 может быть передан в пределах времени SIFS после кадра 416, в поле NDP Announcement которого может быть установлена 1 для обозначения того, что далее следует NDP.

На фиг.5 показан пример обмена кадрами для однонаправленного неявного формирования луча с зондированием NDP. Станция A может передать неуправляемый кадр 510 RTS, и станция B может возвращать неуправляемый кадр 512 CTS. Станция A может затем передавать неуправляемый кадр 514, в поле TRQ которого может быть установлена 1 для обозначения запроса тестирования и в поле RDG которого может быть установлена 1 для обозначения предоставления обратного направления. Станция B может затем передавать неуправляемый кадр 516, NDP 518 и неуправляемый кадр 520 на основе предоставления обратного направления в кадре 514. В поле NDP Announcement кадра 516 может быть установлена 1 для обозначения того, что далее следует NDP, и в поле More PPDU может быть установлена 1 для обозначения того, что далее следует другой кадр. NDP 518 может быть передан в пределах времени SIFS после кадра 516. В поле More PPDU кадра 520 может быть установлен 0 для обозначения того, что больше не следует никакого кадра. Станция A может оценивать ответ канала MIMO на основе NDP 518, выводить матрицы управления на основе оценки канала MIMO и передать управляемый кадр 522 данных, используя матрицы управления для формирования луча.

Однонаправленное неявное формирование луча с зондированием NDP также может осуществляться другими способами. Например, кадры RTS и CTS могут быть исключены или заменены кадрами других типов. В поле NDP Announcement кадра 516 может быть установлена 1, и кадр 518 может быть опущен.

На фиг.6 показан пример обмена кадрами для двунаправленного неявного формирования луча с зондированием NDP. Станция A может передать неуправляемый кадр 610 RTS, и станция B может возвращать неуправляемый кадр 612 CTS. Станция A может затем передавать неуправляемый кадр 614, NDP 616 и неуправляемый кадр 618. В поле MRQ кадра 614 может быть установлена 1 для запроса MCS. В поле TRQ кадра 618 может быть установлена 1 для обозначения запроса тестирования, и в поле RDG может быть установлена 1 для обозначения предоставления обратного направления. Станция B может оценивать отклик канала MIMO на основе NDP 616 и может выводить матрицу управления на основе оценки канала MIMO. Станция B может затем передавать управляемый кадр 620, NDP 622 и управляемый кадр 624, используя матрицы управления для формирования луча. Кадр 620 может отвечать на RDG, и в его поле More PPDU может быть установлена 1 для обозначения того, что другой кадр будет следовать после этого. В поле TRQ кадра 624 может быть установлена 1 для запроса тестирования, и в его поле More PPDU быть установлен 0 для обозначения того, что другие кадры не следуют после этого. Кадр 620 и/или 624 может переносить любые данные, которые станция B может передавать в станцию A.

Станция A может оценивать ответ канала MIMO на основе NDP 622 и может выводить матрицы управления на основе оценки канала MIMO. Станция A может затем передавать управляемый кадр 626, NDP 628 в ответ на TRQ в кадре 624 и управляемый кадр 630. В поле TRQ кадра 630 может быть установлена 1 для обозначения запроса тестирования, и в его поле RDG может быть установлена 1 для обозначения предоставления обратного направления. Каждая станция может передавать дополнительные кадры с формированием луча аналогичным образом.

Двунаправленное неявное формирование луча с зондированием NDP также может осуществляться другими способами. Например, кадры RTS и CTS могут быть исключены или заменены кадрами других типов. В поле NDP Announcement каждого из кадров 614, 620 и/или 626 может быть установлена 1, и кадры 618, 624 и/или 630 могут быть исключены.

Двунаправленное явное формирование луча с зондированием NDP может осуществляться на основе комбинации фиг.4 и 6. Обе станции A и B могут передать NDP, как показано на фиг.6. Каждая станция может выводить явную обратную связь на основе NDP, принятого из другой станции, и может передавать явную обратную связь в другую станцию. Каждая станция может выводить матрицы управления на основе явной обратной связи, принятой из другой станции, и может передавать управляемые кадры с матрицами управления.

На фиг.7 показан пример обмена кадрами для однонаправленного явного формирования луча с зондированием MPDU. Станция A может передать неуправляемый кадр 710 RTS в зондирующем PPDU. Кадр 710 может включать в себя запрос на обратную связь для одного из типов обратной связи, представленных в Таблице 1. Станция B может оценивать ответ канала MIMO на основе зондирующего PPDU и может генерировать явную обратную связь такого типа, который запрашивает станция A. Станция B может затем передать неуправляемый кадр 712 CTS, который может нести информацию явной обратной связи. Станция A может выводить матрицы управления на основе явной обратной связи, принятой из станции B, и может передать управляемый кадр 714 данных, используя матрицы управления для формирования луча. Кадр 714 может быть передан в зондирующем PPDU и может включать в себя запрос на обратную связь для обновленной обратной связи. Станция B может оценивать ответ канала MIMO на основе зондирующего PPDU и может генерировать явную обратную связь такого типа, который запрашивает станция A. Станция B затем может передать неуправляемый кадр 716, который переносит явную обратную связь и подтверждение блока (BA, ПБ) для данных, переданных в кадре 714.

На фиг.8 показан пример обмена кадрами для однонаправленного неявного формирования луча с зондированием MPDU. Станция A может передавать неуправляемый кадр 810 RTS, в поле TRQ которого может быть установлена 1 для обозначения запроса тестирования. Станция B может затем передавать неуправляемый кадр 812 CTS в зондирующем PPDU. Кадр 812 может переносить любые данные, которые может иметь станция B, предназначенные для передачи в станцию A. Станция A может выводить матрицы управления на основе зондирующего PPDU, принятого из станции B, и может передать управляемый кадр 814 данных, используя матрицу управления для формирования луча. В поле TRQ кадра 814 может быть установлена 1 для обозначения запроса тестирования. Станция B может затем передавать неуправляемый кадр 816 в зондирующем PPDU. Кадр 816 может переносить блок Ack для данных, переданных в кадре 814.

На фиг.9 показан пример обмена кадрами для двунаправленного неявного формирования луча с зондированием MPDU. Станция A может передавать неуправляемый кадр 910 RTS в зондирующем PPDU. В поле TRQ кадра 910 может быть установлена 1 для обозначения запроса тестирования. Станция B может выполнять оценку ответа канала MIMO на основе зондирующего PPDU из станции B и может выводить матрицы управления на основе оценки канала MIMO. Станция B может затем передать управляемый кадр 912 CTS в зондирующем PPDU. В поле TRQ кадра 912 может быть установлена 1 для обозначения запроса тестирования, и кадр может переносить любые данные, которые могут иметься в станции B для передачи в станцию A. Станция A может выводить матрицы управления на основе зондирующего PPDU, принятого из станции B, и может передать управляемый кадр 914 данных с использованием матриц управления для формирования луча. Кадр 914 может переносить блок Ack для любых данных, переданных в кадре 912, и в его поле TRQ может быть установлена 1 для обозначения запроса тестирования. Станция B может выводить матрицы управления на основе зондирующего PPDU, принятого из станции A, и может передать управляемый кадр 918 данных в зондирующем PPDU. Кадр 918 может переносить блок Ack для данных, переданных в кадре 914, запрос тестирования и данные.

Формирование луча с зондированием MPDU, показанное на фиг.7, 8 и 9, также может осуществляться другими способами. Например, кадры RTS и CTS могут быть заменены кадрами других типов.

Двунаправленное явное формирование луча с зондированием MPDU может осуществляться на основе комбинации фиг.7 и 9. Обе станции A и B могут передавать зондирующий PPDU, как показано на фиг.9. Каждая станция может выводить явную обратную связь на основе зондирующего PPDU, принятого из другой станции, и может передавать явную обратную связь в другую станцию. Каждая станция может выводить матрицы управления на основе явной обратной связи, принятой из другой станции, и может передать управляемые кадры с матрицами управления.

Формирование луча с неявной обратной связью предусматривает взаимный канал MIMO между станциями A и B. Это позволяет станции A (i) оценивать отклик канала MIMO на соединение из станции B в станцию A на основе зондирующего PPDU, принятого из станции B и (ii) использовать эту оценку канала MIMO как оценку отклика канала MIMO для другого соединения из станции A в станцию B. Однако если отклики цепочек передач будут отличаться от откликов цепочек приема в станции A или в станции B, тогда различия будут влиять на возможность взаимного использования канала MIMO.

Станции A и B могут выполнять калибровку для определения различия между их цепочками передачи и приема и для вывода векторов коррекции, которые можно применять для учета различий для восстановления взаимности. Калибровка не требуется для формирования луча, но если ее выполняют, она может улучшить характеристику формирования луча. Станции A и B могут выполнять калибровку при ассоциировании и/или в другие моменты времени.

На фиг.10 показан пример обмена кадрами для калибровки при явной обратной связи CSI и с зондированием NDP. Станция A может передавать неуправляемый кадр 1010 RTS, и станция B может возвращать неуправляемый кадр 1012 CTS. Станция A может затем передавать неуправляемый кадр 1014, NDP 1016 и неуправляемый кадр 1018. В поле CSI/Steering кадра 1014 может быть установлена 1 для запроса обратной связи CSI, и это может обозначать, что обратная связь CSI полной точности должна быть передана обратно. В поле TRQ кадра 1018 может быть установлена 1 для запроса тестирования, и в поле RDG может быть установлена 1 для обозначения предоставления обратного направления.

Станция B может оценивать отклик канала MIMO на основе NDP 1016 и может генерировать обратную связь CSI, как описано в упомянутых выше документах IEEE 802.11n. Станция B может затем передавать неуправляемый кадр 1020, NDP 1022 и неуправляемый кадр 1024. Кадр 1020 может переносить обратную связь CSI, и в его поле More PPDU может быть установлена 1 для обозначения того, что другой кадр будет следовать дальше. Кадр 1024 также может осуществлять обратную связь CSI, и в его поле More PPDU может быть установлен 0 для обозначения того, что другие кадры не следуют после него.

Станция A может оценивать отклик канала MIMO на основе NDP 1022 из станции B. Станция A затем может рассчитывать векторы коррекции взаимности на основе оценки канала MIMO, определенной станцией A, и обратной связи CSI, принятой станцией B. Станция A может применять векторы коррекции взаимности при будущей передаче станции B.

На фиг.11 показан пример обмена кадрами для калибровки с явной обратной связью CSI и зондированием MPDU. Станция A может передавать неуправляемый кадр 1110 RTS в зондирующем PPDU. В поле CSI/Steering кадра 1110 может быть установлена 1 для запроса обратной связи CSI, и в его поле TRQ может быть установлена 1 для обозначения запроса тестирования. Станция B может оценивать отклик канала MIMO на основе зондирующего PPDU, принятого из станции A, и может генерировать обратную связь CSI. Станция B может затем передавать неуправляемый кадр 1112 CTS, который может переносить обратную связь CSI в зондирующем PPDU. Станция A может оценивать отклик канала MIMO на основе зондирующего PPDU, принятого из станции B, и может рассчитывать векторы коррекции взаимности на основе оценки канала MIMO и явной обратной связи.

На фиг.12 показан пример обмена кадрами для калибровки с явной обратной связью CSI и с одновременным зондированием NDP и MPDU. Станция A может передавать неуправляемый кадр 1210 RTS, в поле CSI/Steering которого может быть установлена 1 для запроса обратной связи CSI. Станция B может возвращать неуправляемый кадр 1212 CTS. Станция A может затем передавать NDP 1214 и неуправляемый кадр 1216. В поле TRQ кадра 1216 может быть установлена 1 для запроса тестирования, и в поле RDG может быть установлена 1 для обозначения разрешения на обратное направление. Станция B может оценивать отклик канала MIMO на основе NDP 1214 из станции A и может генерировать обратную связь CSI. Станция B может затем передавать неуправляемый кадр 1218 в зондирующем PPDU. Кадр 1218 может переносить обратную связь CSI, и в его поле More PPDU может быть установлен 0 для обозначения того, что другие кадры не следуют после этого. Станция A может оценивать отклик канала MIMO на основе зондирующего PPDU, принятого из станции B, и может рассчитывать векторы коррекции взаимности на основе оценки канала MIMO и явной обратной связи.

Калибровка также может осуществляться другими способами. Например, кадры RTS и CTS могут быть заменены кадрами данных или кадрами других типов. В поле NDP Announcement кадра 1014 и/или кадра 1020 на фиг.10 может быть установлена 1, и кадр 1018 и/или кадр 1024 может быть опущен. Станция B может передавать NDP или зондирующий PPDU как можно скорее после запроса тестирования из станции A. Станция B может передавать обратную связь CSI либо совместно с NDP, либо с зондирующим PPDU, либо в более позднее время.

Как показано на фиг.10, 11 и 12, калибровка может поддерживаться без использования сообщений, специфичных для калибровки, и обмена кадрами. Для калибровки может быть передан запрос на обратную связь CSI с использованием поля CSI/Steering в поле HT Control, как показано на фиг.3 и в Таблице 1. В одной схеме, когда запрос тестирования включен в тот же кадр, что и запрос на обратную связь CSI, матрицы CSI полной точности могут быть переданы обратно для использования для вывода векторов коррекции взаимности. В другой конструкции можно использовать специально выделенные поля для обозначения начала калибровки и для идентификации кадров, переданных для калибровки.

На фиг.13 показана структура кадра 1300 управления, который можно использовать для передачи обратной связи CSI для калибровки. Кадр 1300 включает в себя различные поля, такие как поле MIMO Control (управление MBMB) и поле CSI MIMO Matrices Report (сообщение матриц). Поле MIMO Control включает в себя различные поля, такие как поле Grouping (группировка) (Ng) и поле Coefficient Size (размер коэффициента). Для калибровки в поле Grouping может быть установлено 0 для Ng = 1, что означает отсутствие группировки поднесущих, таким образом, что матрица CSI будет предусмотрена для каждой из поднесущих {-28, -1, +1…+28}, которую можно использовать для передачи. В поле Coefficient Size может быть установлено значение 3 для Nb = 8, что означает, что восемь битов точности (или полная точность) будут использоваться для каждого элемента каждой матрицы CSI. Поле CSI MIMO Matrices Report может переносить матрицу CSI для каждой поднесущей, которая может использоваться для передачи, при этом каждый элемент матрицы представлен с полной точностью.

На фиг.14 показана схема процесса 1400 для поддержки формирования луча станцией. Станция может принимать запрос тестирования (блок 1412) и может передавать первый кадр зондирования в ответ на запрос тестирования (блок 1414). Станция может принимать запрос на явную обратную связь для формирования луча (блок 1416) и может также принимать второй кадр зондирования (блок 1418). Станция может генерировать явную обратную связь на основе второго кадра зондирования (блок 1420) и может передавать явную обратную связь в ответ на запрос на явную обратную связь (блок 1422). Обработка в блоках 1412-1422 может осуществляться для одного или больше независимых обменов кадра. При обработке в блоках 1412 - 1422 могут использоваться возможности, описанные выше, для поддержки как неявной обратной связи, так и явной обратной связи, для формирования луча. В частности, передача и прием зондирующего PPDU отражены в блоках 1414 и 1418 соответственно. Ответ на запрос тестирования путем передачи зондирующего PPDU отражен в блоках 1412 и 1414. Ответ на запрос на явную обратную связь отражен в блоках 1416-1422.

Каждый кадр может соответствовать PPDU в IEEE 802.11 или некоторым другим типам PDU. Каждый кадр зондирования может быть (i) NDP, имеющим, по меньшей мере, одно поле тестирования, но не имеющим поле данных, или (ii) кадром, имеющим как поле тестирования, так и поле данных. Явная обратная связь может содержать матрицы CSI, несжатые матрицы обратной связи, формирующие луч, сжатые матрицы обратной связи, формирующие луч, и т.д.

Станция может представлять собой явный выраженный получатель формирования луча и может принимать управляемый кадр, переданный при использовании формирования луча, на основе явной обратной связи, возвращенной в блоке 1422. Станция может представлять собой неявный получатель формирования луча и может принимать управляемый кадр, переданный при формировании луча, на основе неявной обратной связи, полученной из первого кадра зондирования, переданного в блоке 1414. Станция может представлять собой явный формирователь луча и может принимать явную обратную связь, генерируемую из первого кадра зондирования, может получать информацию управления (например, матрицы управления) на основе принятой явной обратной связи и может передавать управляемый кадр с формированием луча на основе информации управления. Станция может представлять собой неявный формирователь луча и может передавать третий кадр зондирования, выводить информацию управления на основе третьего кадра зондирования и передавать управляемый кадр с формированием луча на основе информации управления.

На фиг.15 показана схема устройства 1500 для поддержки формирования луча. Устройство 1500 включает в себя средство приема запроса тестирования (модуль 1512), средство передачи первого кадра зондирования в ответ на запрос тестирования (модуль 1514), средство приема запроса на явную обратную связь для формирования луча (модуль 1516), средство приема второго кадра зондирования (модуль 1518), средство генерирования явной обратной связи на основе второго кадра зондирования (модуль 1520) и средство передачи явной обратной связи в ответ на запрос на явную обратную связь (модуль 1522).

На фиг.16 представлена схема обработки 1600 для формирования луча с явной обратной связью и зондированием NDP. Станция может передавать первый кадр (например, кадр 410 на фиг.4) с запросом на явную обратную связь (блок 1612). Станция может передавать NDP (например, NDP 414), имеющий, по меньшей мере, одно поле тестирования, но без поля данных (блок 1614). Станция может принимать второй кадр с явной обратной связью, выведенной на основе NDP, например кадр 418 (блок 1616). Станция может выводить информацию управления на основе явной обратной связи (блок 1618) и может передавать кадр управления (например, кадр 420) с формированием луча на основе информации управления (блок 1620).

Станция может передавать кадр RTS в качестве первого кадра, принимать кадр CTS в ответ на кадр RTS и передавать NDP в пределах времени STFS для кадра CTS. Станция может передавать третий кадр с RDG (например, кадр 416) в пределах времени SIFS для NDP и может принимать второй кадр после третьего кадра. Станция может включать либо в первый кадр, либо в третий кадр уведомление о том, что далее следует NDP.

На фиг.17 показана схема устройства 1700 для формирования луча с явной обратной связью и NDP зондирования. Устройство 1700 включает в себя средство передачи первого кадра с запросом на явную обратную связь (модуль 1712), средство передачи NDP, имеющее, по меньшей мере, одно поле тестирования, но не имеющее поля данных (модуль 1714), средство приема второго кадра с явной обратной связью, выведенного на основе NDP (модуль 1716), средство вывода информации управления на основе явной обратной связи (модуль 1718) и средство передачи управляемого кадра при формировании луча на основе информации управления (модуль 1720).

На фиг.18 показана схема обработки 1800 для формирования луча при неявной обратной связи и NDP зондировании. Станция может передавать первый кадр (например, кадр 514 на фиг.5) с запросом тестирования (блок 1812). Станция может принимать NDP (например, NDP 518), имеющий, по меньшей мере, одно поле тестирования, но без поля данных (блок 1814). Станция может выводить информацию управления на основе NDP (блок 1816) и может передавать управляемый кадр (например, кадр 522) с формированием луча на основе информации управления (блок 1818).

Станция может передавать кадр RTS (например, кадр 510), принимать кадр CTS (например, кадр 512) в ответ на кадр RTS и передавать первый кадр после кадра CTS. Станция может включать RDG в первый кадр, принимать второй кадр (например, кадр 516) в ответ на первый кадр и принимать NDP после второго кадра. Второй кадр может включать в себя объявление о том, что далее следует NDP. Второй кадр также может включать в себя уведомление о том, что дальше будет следовать другой кадр, и станция может затем принимать третий кадр (например, кадр 520) с уведомлением о том, что далее не следует никакой другой кадр.

На фиг.19 показана схема устройства 1900 для формирования луча с неявной обратной связью и NDP зондированием. Устройство 1900 включает в себя средство передачи первого кадра с запросом тестирования (модуль 1912), средство приема NDP, имеющее, по меньшей мере, одно поле тестирования, но без поля данных (модуль 1914), средство вывода информации управления на основе NDP (модуль 1916) и средство передачи управляемого кадра с формированием луча на основе информации управления (модуль 1918).

На фиг.20 показана схема обработки 2000 для двунаправленного формирования луча с неявной обратной связью и NDP зондированием. Станция может передавать первый кадр (например, кадр 614 или 618 по фиг.6) с запросом тестирования (блок 2012). Станция может передавать первый NDP (например, NDP 616), имеющий, по меньшей мере, одно поле тестирования, но без поля данных, либо перед, либо после первого кадра (блок 2014). Станция может принимать первый управляемый кадр (например, кадр 620) с формированием луча на основе первой информации управления, выведенной из первого NDP (блок 2016). Станция может принимать второй NDP (например, NDP 622) в ответ на запрос тестирования (блок 2018) и может выводить вторую информацию управления на основе второго NDP (блок 2020). Станция может затем передавать второй управляемый кадр (например, кадр 626) с формированием луча на основе второй информации управления (блок 2022).

Станция может передавать кадр RTS (например, кадр 610), принимать кадр CTS (например, кадр 612) в ответ на кадр RTS и передавать первый кадр после кадра CTS. Первый кадр и/или первый управляемый кадр может включать в себя уведомление о том, что далее следует NDP.

На фиг.21 показана схема устройства 2100 для двунаправленного формирования луча с неявной обратной связью и NDP зондированием. Устройство 2100 включает в себя средство для передачи первого кадра с запросом тестирования (модуль 2112), средство передачи первого NDP, имеющего, по меньшей мере, одно поле тестирования, но без поля данных, либо перед, либо после первого кадра (модуль 2114), средство приема первого управляемого кадра с формированием луча на основе первой информации управления, выведенной из первого NDP (модуль 2116), средство приема второго NDP в ответ на запрос тестирования (модуль 2118), средство вывода второй информации управления на основе второго NDP (модуль 2120) и средство передачи второго управляемого кадра с формированием луча на основе второй информации управления (модуль 2122).

На фиг.22 показана конструкция обработки 2200 для калибровки с NDP зондированием. Станция может передавать первый кадр (например, кадр 1014 на фиг.10 или кадр 1210 на фиг.12) с запросом на явную обратную связь для калибровки (блок 2212). Станция также может передавать NDP (например, NDP 1016 или 1214), имеющий, по меньшей мере, одно поле тестирования, но без поля данных (блок 2214). Станция может принимать второй кадр (например, кадр 1020 по фиг.10 или кадр 1218 по фиг.12) с явной обратной связью (блок 2216). Станция также может принимать кадр зондирования, который может представлять собой либо NDP, такой как NDP 1022 на фиг.10, либо кадр, имеющий как поле тестирования, так и поле данных, такой как кадр 1218 на фиг.12 (блок 2218). Станция может выводить оценку канала на основе кадров зондирования (блок 2220). Станция может затем выполнять калибровку (например, может выводить векторы коррекции взаимности) на основе оценки канала и явной обратной связи (блок 2222).

Первый кадр может включать в себя запрос тестирования и уведомление о том, что далее следует NDP. В качестве альтернативы станция может передавать третий кадр (например, кадр 1018 по фиг.10 или кадр 1216 по фиг.12) с запросом тестирования после NDP. В любом случае кадр зондирования может быть передан в ответ на запрос тестирования.

На фиг.23 показана конструкция устройства 2300 для калибровки с NDP зондированием. Устройство 2300 включает в себя средство для передачи первого кадра с запросом на явную обратную связь для калибровки (модуль 2312), средство передачи NDP, имеющее, по меньшей мере, одно поле тестирования, но без поля данных (модуль 2314), средство приема второго кадра с явной обратной связью (модуль 2316), средство приема кадра зондирования (модуль 2318), средство вывода оценки канала на основе кадра зондирования (модуль 2320), средство выполнения калибровки на основе оценки канала и явной обратной связи (модуль 2322).

На фиг.24 показана схема обработки 2400 для передачи обратной связи CSI для калибровки. Станция может принимать запрос на обратную связь CSI для калибровки, например, в кадре 1014 на фиг.10, кадре 1110 на фиг.11, или кадре 1210 на фиг.12 (блок 2412). Станция также может принимать кадр зондирования, например, NDP 1016 на фиг.10, кадр 1110 на фиг.11 или NDP 1214 на фиг.12 (блок 2414). Станция может генерировать обратную связь CSI на основе кадра зондирования (блок 2416) и может передавать обратную связь CSI без группирования поднесущих и с полной точностью (блок 2418).

Станция может передавать обратную связь CSI в кадре администрирования, который имеет поле группировки и поле размера коэффициента, как показано на фиг.13. Станция может устанавливать в поле группировки значение 0 для обозначения отсутствия группировки поднесущих (Ng = 1) и может устанавливать в поле размера коэффициента значение 3 для обозначения 8 битов (Nb = 8) для полной точности обратной связи CSI. Обратная связь CSI может содержать матрицу CSI для каждой из множества поднесущих, пригодных для передачи.

На фиг.25 показана схема обработки 2500 для передачи обратной связи CSI для калибровки. Устройство 2500 включает в себя средство приема запроса на обратную связь CSI для калибровки (модуль 2512), средство приема кадра зондирования (модуль 2514), средство генерирования обратной связи CSI на основе кадра зондирования (модуль 2516) и средство передачи обратной связи CSI без группировки поднесущих и с полной точностью (модуль 2518).

Модули на фиг.15, 17, 19, 21, 23 и 25 могут содержать процессоры, электронные устройства, аппаратные устройства, электронные компоненты, логические схемы, запоминающие устройства и т.д. или любую их комбинацию.

На фиг.14-25 иллюстрируется обработка, выполняемая станцией A, по фиг.4, 5, 6, 10, 11 и 12. Обработка, выполняемая станцией B, является взаимодополняющей для обработки, выполняемой станцией A, и может быть описана набором чертежей, взаимодополняющих фиг.14-25. Обработка, выполняемая станциями A и B по фиг.7, 8 и 9, также может выполняться, как показано на этих чертежах.

На фиг.26 показана блок-схема станций A и B, каждая из которых может представлять собой точку 110 доступа или одну из станций 120 на фиг.1. Станция A оборудована множеством (T) антенн 2624a-2624t, которые можно использовать для передачи и приема данных. Станция B оборудована множеством (R) антенн 2652a-2652r, которые можно использовать для передачи и приема данных.

В станции A, процессор 2614 данных передачи (TX) может принимать данные трафика из источника 2612 данных и/или другие данные из контроллера/процессора 2630. Процессор 2614 TX данных может обрабатывать (например, форматировать, кодировать, выполнять перемежение и отображение символов) принимаемые данные и генерировать символы данных, которые представляют собой символы модуляции для данных. Пространственный процессор 2620 TX может мультиплексировать символы данных с символами тестирования, выполнять пространственную обработку передачи с использованием матриц управления и предоставлять T потоков выходных символов в T модуляторов (MOD) 2622a-2622t. Символы тестирования также обычно обозначают, как пилотные символы. Каждый модулятор 2622 может обрабатывать свой собственный выходной поток символов (например, для OFDM) для генерирования выходного потока элементарных сигналов. Каждый модулятор 2622 может дополнительно выполнять окончательную обработку (например, преобразовывать в аналоговую форму, усиливать, фильтровать и преобразовывать с повышением частоты) своего выходного потока элементарных сигналов для генерирования модулированного сигнала. T модулированных сигналов из модуляторов 2622a-2622t могут быть переданы через антенны 2624a-2624t соответственно.

В станции B R антенн 2652a-2652r могут принимать модулированные сигналы из станции A, и каждая антенна 2652 может предоставлять принятый сигнал в соответствующий демодулятор (DEMOD) 2654. Каждый демодулятор 2654 может выполнять обработку, взаимодополняющую обработку, выполненную модуляторами 2622, для получения принятых символов. Пространственный процессор 2660 приема (RX) может выполнять пространственную согласованную фильтрацию по принимаемым символам от всех демодуляторов 2654a-2654r и предоставлять оценки символов данных, которые представляют собой оценки символов данных, переданных станцией A. Процессор 2670 данных RX может дополнительно обрабатывать (например, выполнять обратное отображение символов, устранять перемежение и декодировать) оценки символов данных и предоставлять декодированные данные в потребитель 2672 данных и/или в контроллер/процессор 2680.

Процессор 2678 канала может обрабатывать символы тестирования, принятые из станции A, и может оценивать отклик канала MIMO. Процессор 2678 может выполнять разложение матрицы канала для каждой поднесущей или каждой группы поднесущих, представляющих интерес, например, как показано в уравнении (1), для получения соответствующей матрицы формирования луча. Процессор 2678 может генерировать информацию обратной связи для матриц канала или (для несжатых или сжатых) матриц формирования луча. Процессор 2678 может предоставлять информацию обратной связи в контроллер/процессор 2680 для передачи обратно в станцию A. Процессор 2678 может также выводить матрицу пространственного фильтра для каждой поднесущей или каждой группы поднесущих, представляющих интерес, на основе соответствующей матрицы канала и/или матрицы формирования луча. Процессор 2678 может предоставлять матрицы пространственного фильтра в пространственный процессор 2660 RX для пространственной согласованной фильтрации.

Обработка для передачи из станции B в станцию A может осуществляться так же, как обработка для передачи из станции A в станцию B, или по-другому. Данные трафика из источника 2686 данных и/или другие данные (например, информация обратной связи) из контроллера/процессора 2680 могут обрабатываться (например, могут быть кодированы, в них может быть выполнено перемежение, и они могут быть модулированы) с помощью процессора 2688 данных TX и дополнительно мультиплексированы с символами тестирования и пространственно обработаны с помощью пространственного процессора 2690 TX с управляющими матрицами. Выходные символы из пространственного процессора 2690 TX могут быть дополнительно обработаны с помощью модуляторов 2654a-2654r для генерирования R модулированных сигналов, которые могут быть переданы через антенны 2652a-2652r.

В станции A модулированные сигналы из станции B могут быть приняты с помощью антенн 2624a-2624t и обработаны демодуляторами 2622a-2622t для получения принятых символов. Пространственный процессор 2640 RX может выполнять пространственную согласованную фильтрацию по принятым символам и обеспечивать оценки символов данных. Процессор 2642 данных RX может дополнительно обрабатывать оценки символов данных, предоставлять декодированные данные в потребитель 2644 данных и предоставлять информацию обратной связи в контроллер/процессор 2630. Процессор 2630 может выводить матрицы управления на основе информации обратной связи.

Процессор 2628 канала может обработать символы тестирования, принятые из станции B, и может оценивать отклик канала MIMO. Процессор 2628 может выполнять разложение матрицы канала для каждой поднесущей или каждой группы поднесущих, представляющих интерес, для получения соответствующей матрицы формирования луча. Процессор 2628 также может выводить матрицу пространственного фильтра для каждой поднесущей или каждой группы поднесущих, представляющей интерес. Процессор 2628 может предоставлять матрицы пространственного фильтра в пространственный процессор 2640 RX для пространственной согласованной фильтрации и может предоставлять матрицы канала или матрицы формирования луча в контроллер/процессор 2630 для обратной связи в станцию B.

Контроллеры/процессоры 2630 и 2680 могут управлять работой станций A и B соответственно. Запоминающие устройства 2632 и 2682 могут сохранять данные и программные коды для станций A и B соответственно. Процессоры 2628, 2630, 2678, 2680 и/или другие процессоры могут выполнять обработку и функции, описанные здесь, например обработку 1400 по фиг.14, обработку 1600 по фиг.16, обработку 1800 по фиг.18, обработку 2000 по фиг.20, обработку 2200 по фиг.22, обработку 2400 по фиг.24 и т.д.

Технологии, описанные здесь, могут быть воплощены с помощью различных средств. Например, эти технологии могут быть воплощены в виде аппаратных средств, встроенных программных средств, программного обеспечения или их комбинации. Для воплощения в виде аппаратных средств модули обработки, используемые для выполнения этих технологий, могут быть воплощены в одной или больше специализированных интегральных микросхем (ASIC), цифровых процессоров сигнала (DSP), устройств обработки цифрового сигнала (DSPD), программируемых логических устройств (PLD), программируемых пользователем вентильных матриц (FPGA), процессоров, контроллеров, микроконтроллеров, микропроцессоров, электронных устройств, других электронных модулей, разработанных для выполнения функций, описанных здесь, компьютера или их комбинации.

Для воплощения в виде встроенных программных средств и/или программного обеспечения технологии могут быть воплощены с помощью модулей (например, процедур, функций и т.д.), которые выполняют описанные здесь функции. Инструкции в виде встроенных программных средств и/или программного обеспечения могут быть сохранены в запоминающем устройстве (например, в запоминающем устройстве 2632 или 2682 по фиг.26) и могут выполняться с помощью процессора (например, процессора 2630 или 2680). Запоминающее устройство может быть воплощено в виде процессора или может быть внешним относительно процессора. Инструкции в виде встроенных программных средств и/или программного обеспечения также могут быть сохранены в другом считываемом процессором носителе, таком как оперативное запоминающее устройство (RAM), постоянное запоминающее устройство (ROM), энергонезависимое оперативное запоминающее устройство (NVRAM), программируемое постоянное запоминающее устройство (PROM), электрически стираемое PROM (EEPROM), флэш-память, компакт-диск (CD), магнитное или оптическое устройство - накопитель данных и т.д.

Приведенное выше описание раскрытия представлено для того, чтобы обеспечить любому специалисту в данной области техники возможность использования этого раскрытия. Различные модификации такого раскрытия будут очевидно понятными для специалиста в данной области техники, и общие принципы, определенные здесь, можно применять в других вариантах без выхода за пределы сущности или объема раскрытия. Таким образом, раскрытие не должно быть ограничено описанными здесь примерами и конструкциями, но должно соответствовать самому широкому объему, соответствующему принципам и новым свойствам, раскрытым здесь.

Формула изобретения

1. Устройство для поддержки формирования луча в сети беспроводной связи, содержащее:

по меньшей мере, один процессор, выполненный с возможностью принимать запрос тестирования, передавать первый зондирующий кадр в ответ на запрос тестирования, принимать запрос на явную обратную связь для формирования луча, принимать второй зондирующий кадр, генерировать явную обратную связь на основе второго зондирующего кадра и передавать явную обратную связь в ответ на запрос на явную обратную связь; и

запоминающее устройство, соединенное с, по меньшей мере, одним процессором.

2. Устройство по п.1, в котором, по меньшей мере, один процессор выполнен с возможностью принимать управляемый кадр, переданный на основе явной обратной связи.

3. Устройство по п.1, в котором, по меньшей мере, один процессор выполнен с возможностью принимать управляемый кадр, переданный на основе неявной обратной связи, выведенной из первого зондирующего кадра.

4. Устройство по п.1, в котором, по меньшей мере, один процессор выполнен с возможностью принимать явную обратную связь, выведенную на основе первого зондирующего кадра, выводить информацию управления на основе принятой явной обратной связи и передавать управляемый кадр на основе информации управления.

5. Устройство по п.1, в котором, по меньшей мере, один процессор выполнен с возможностью принимать третий зондирующий кадр, выводить информацию управления на основе третьего зондирующего кадра и передавать управляемый кадр на основе информации управления.

6. Устройство по п.1, в котором каждый из первого и второго зондирующих кадров содержит поля тестирования и данных.

7. Устройство по п.1, в котором каждый из первого и второго зондирующих кадров содержит пакет нулевых данных (NDP), имеющий, по меньшей мере, одно поле

тестирования, но не содержащий поле данных.

8. Устройство по п.1, в котором каждый из первого и второго зондирующих кадров содержит кадр, имеющий поля тестирования и данных или пакет нулевых данных (NDP), имеющий, по меньшей мере, одно поле тестирования, но не содержащий поле данных.

9. Устройство по п.1, в котором явная обратная связь содержит матрицы информации состояния канала (CSI), несжатые матрицы обратной связи формирования луча или сжатые матрицы обратной связи формирования луча.

10. Устройство по п.1, в котором первый и второй зондирующие кадры содержат модули данных протокола (PPDU) для протокола схождения физического уровня (PLCP) в соответствии со стандартом IEEE 802.11.

11. Способ поддержки формирования луча в сети беспроводной связи, содержащий этапы, на которых:

принимают запрос тестирования;

передают первый зондирующий кадр в ответ на запрос тестирования;

принимают запрос на явную обратную связь для формирования луча;

принимают второй зондирующий кадр;

генерируют явную обратную связь на основе второго зондирующего кадра; и

передают явную обратную связь в ответ на запрос на явную обратную связь.

12. Способ по п.11, дополнительно содержащий этап, на котором:

принимают управляемый кадр, переданный на основе либо явной обратной связи, либо неявной обратной связи, выведенной из первого зондирующего кадра.

13. Способ по п.11, дополнительно содержащий этапы, на которых:

принимают явную обратную связь, выведенную на основе первого зондирующего кадра;

выводят информацию управления на основе принятой явной обратной связи; и

передают управляемый кадр на основе информации управления.

14. Способ по п.11, дополнительно содержащий этапы, на которых:

принимают третий зондирующий кадр;

выводят информацию управления на основе третьего зондирующего кадра; и

передают управляемый кадр на основе информации управления.

15. Устройство для поддержки формирования луча в сети беспроводной связи, содержащее:

средство приема запроса тестирования;

средство передачи первого зондирующего кадра в ответ на запрос тестирования;

средство приема запроса на явную обратную связь для формирования луча;

средство приема второго зондирующего кадра;

средство генерирования явной обратной связи на основе второго зондирующего кадра;

средство передачи явной обратной связи в ответ на запрос на явную обратную связь.

16. Устройство по п.15, дополнительно содержащее:

средство приема управляемого кадра, переданного на основе либо явной обратной связи, либо неявной обратной связи, полученной из первого зондирующего кадра.

17. Устройство по п.15, дополнительно содержащее:

средство приема явной обратной связи, выведенной на основе первого зондирующего кадра;

средство вывода информации управления на основе принятой явной обратной связи; и

средство передачи управляемого кадра на основе информации управления.

18. Устройство по п.15, дополнительно содержащее:

средство приема третьего зондирующего кадра;

средство вывода информации управления на основе третьего зондирующего кадра; и

средство передачи управляемого кадра на основе информации управления.

19. Считываемый процессором носитель, включающий в себя инструкции, сохраненные в нем, содержащий:

первый набор инструкций для приема запроса тестирования;

второй набор инструкций для передачи первого зондирующего кадра в ответ на запрос тестирования;

третий набор инструкций для приема запроса на явную обратную связь для формирования луча;

четвертый набор инструкций для приема второго зондирующего кадра;

пятый набор инструкций для генерирования явной обратной связи на основе второго зондирующего кадра; и

шестой набор инструкций для передачи явной обратной связи в ответ на запрос на явную обратную связь.

20. Устройство для формирования луча с явной обратной связью, содержащее:

по меньшей мере, один процессор, выполненный с возможностью передавать первый кадр с запросом на явную обратную связь, передавать пакет нулевых данных (NDP), имеющий, по меньшей мере, одно поле тестирования, но не содержащий поле данных, и принимать второй кадр с явной обратной связью, выведенной на основе NDP; и

запоминающее устройство, соединенное с, по меньшей мере, одним процессором.

21. Устройство по п.20, в котором, по меньшей мере, один процессор выполнен с возможностью выводить информацию управления на основе явной обратной связи и передавать управляемый кадр на основе информации управления.

22. Устройство по п.20, в котором первый кадр содержит кадр Request to Send (запрос на передачу) (RTS) и в котором, по меньшей мере, один процессор выполнен с возможностью принимать кадр Clear to Send (готов к передаче) (CTS) и передавать NDP в течение времени короткого промежутка между кадрами (SIFS) кадра CTS.

23. Устройство по п.20, в котором, по меньшей мере, один процессор выполнен с возможностью передавать третий кадр с предоставлением обратного направления в течение времени короткого промежутка между кадрами (SIFS) NDP и принимать второй кадр после третьего кадра.

24. Устройство по п.23, в котором, по меньшей мере, один процессор выполнен с возможностью включать в первый кадр или в третий кадр уведомление о том, что далее следует NDP.

25. Способ формирования луча с явной обратной связью, содержащий этапы, на которых:

передают первый кадр с запросом на явную обратную связь;

передают пакет нулевых данных (NDP), имеющий, по меньшей мере, одно поле тестирования, но не имеющий поле данных; и

принимают второй кадр с явной обратной связью, выведенной на основе NDP.

26. Способ по п.25, дополнительно содержащий этапы, на которых:

выводят информацию управления на основе явной обратной связи; и передают управляемый кадр на основе информации управления.

27. Способ по п.25, дополнительно содержащий этап, на котором:

принимают кадр Clear to Send (готов к передаче) (CTS) в ответ на кадр Request to Send (запрос на передачу) (RTS) в первом кадре и в котором NDP передают в течение времени короткого промежутка между кадрами (SIFS) кадра CTS.

28. Способ по п.25, дополнительно содержащий этап, на котором:

передают третий кадр с разрешением на обратное направление в течение времени короткого промежутка между кадрами (SIFS) NDP и в котором второй кадр принимают после третьего кадра.

29. Способ по п.28, дополнительно содержащий этап, на котором:

включают в первый кадр или в третий кадр уведомление о том, что далее следует NDP.

30. Устройство для поддержки формирования луча в сети беспроводной связи, содержащее:

по меньшей мере, один процессор, выполненный с возможностью принимать пакет нулевых данных (NDP), имеющий, по меньшей мере, одно поле тестирования, но не содержащий поле данных, выводить информацию управления на основе NDP и передавать управляемый кадр на основе информации управления; и

запоминающее устройство, соединенное, по меньшей мере, с одним процессором.

31. Устройство по п.30, в котором, по меньшей мере, один процессор выполнен с возможностью передавать первый кадр с запросом тестирования и принимать NDP в ответ на запрос тестирования.

32. Устройство по п.31, в котором, по меньшей мере, один процессор выполнен с возможностью передавать предоставление обратного направления в первом кадре, принимать второй кадр после первого кадра и принимать NDP после второго кадра.

33. Устройство по п.32, в котором второй кадр включает в себя уведомление о том, что далее следует NDP.

34. Устройство по п.32, в котором второй кадр включает в себя обозначение того, что далее следует другой кадр и в котором, по меньшей мере, один процессор выполнен с возможностью:

принимать третий кадр после второго кадра, причем третий кадр включает в себя обозначение того, что далее не следует никакой другой кадр.

35. Устройство по п.30, в котором, по меньшей мере, один процессор выполнен с возможностью передавать кадр Request to Send (запрос на передачу) (RTS), принимать кадр Clear to Send (готов к передаче) (CTS) в ответ на кадр RTS и передавать первый кадр после кадра CTS.

36. Способ поддержки формирования луча в сети беспроводной связи, содержащий этапы, на которых:

принимают пакет нулевых данных (NDP), имеющий, по меньшей мере, одно поле тестирования, но не содержащий поле данных;

выводят информацию управления на основе NDP; и передают управляемый кадр на основе информации управления.

37. Способ по п.36, дополнительно содержащий этап, на котором:

передают первый кадр с запросом тестирования и в котором NDP принимают в ответ на запрос тестирования.

38. Способ по п.37, дополнительно содержащий этапы, на которых:

передают предоставление обратного направления в первом кадре; и принимают второй кадр после первого кадра, причем NDP принимают после второго кадра.

39. Устройство для поддержки формирования луча в сети беспроводной связи, содержащее:

по меньшей мере, один процессор, выполненный с возможностью передавать первый кадр с запросом тестирования, передавать первый пакет нулевых данных (NDP), имеющий, по меньшей мере, одно поле тестирования, но не содержащий поле данных, и принимать второй NDP в ответ на запрос тестирования; и

запоминающее устройство, соединенное, по меньшей мере, с одним процессором.

40. Устройство по п.39, в котором, по меньшей мере, один процессор выполнен с возможностью принимать управляемый кадр на основе информации управления, выведенной из первого NDP.

41. Устройство по п.39, в котором, по меньшей мере, один процессор выполнен с возможностью выводить информацию управления на основе второго NDP и передавать управляемый кадр на основе второй информации управления.

42. Устройство по п.39, в котором первый кадр включает в себя объявление о том, что далее следует NDP.

43. Устройство по п.39, в котором, по меньшей мере, один процессор выполнен с возможностью передавать кадр Request to Send (запрос на передачу) (RTS), принимать кадр Clear to Send (готов к передаче) (CTS) в ответ на кадр RTS и передавать первый кадр после кадра CTS.

44. Способ осуществления формирования луча в сети беспроводной связи, содержащий этапы, на которых:

передают первый кадр с запросом тестирования;

передают первый пакет нулевых данных (NDP), имеющий, по меньшей мере, одно поле тестирования, но не содержащий поле данных; и принимают второй NDP в ответ на запрос тестирования.

45. Способ по п.44, дополнительно содержащий этап, на котором:

принимают управляемый кадр на основе информации управления, выведенной из первого NDP.

46. Способ по п.44, дополнительно содержащий этапы, на которых:

выводят информацию управления на основе второго NDP; и

передают управляемый кадр на основе второй информации управления.

47. Устройство для калибровки при формировании луча в сети беспроводной связи, содержащее:

по меньшей мере, один процессор, выполненный с возможностью передавать первый кадр с запросом на явную обратную связь для калибровки, передавать пакет нулевых данных (NDP), имеющий, по меньшей мере, одно поле тестирования, но не содержащий поле данных, принимать второй кадр с явной обратной связью, принимать зондирующий кадр, выводить оценку канала на основе зондирующего кадра и выполнять калибровку на основе оценки канала и явной обратной связи;

и запоминающее устройство, соединенное, по меньшей мере, с одним процессором.

48. Устройство по п.47, в котором зондирующий кадр содержит NDP.

49. Устройство по п.47, в котором зондирующий кадр содержит поля тестирования и данных.

50. Устройство по п.47, в котором первый кадр содержит запрос тестирования и уведомление о том, что далее следует NDP, причем зондирующий кадр передается в ответ на запрос тестирования.

51. Устройство по п.47, в котором, по меньшей мере, один процессор выполнен с возможностью передавать третий кадр с запросом тестирования после NDP, причем зондирующий кадр передается в ответ на запрос тестирования.

52. Способ выполнения калибровки при формировании луча в сети беспроводной связи, содержащий этапы, на которых:

передают первый кадр с запросом на явную обратную связь для калибровки;

передают пакет нулевых данных (NDP), имеющий, по меньшей мере, одно поле тестирования, но не содержащий поле данных;

принимают второй кадр с явной обратной связью;

принимают зондирующий кадр;

выводят оценку канала на основе зондирующего кадра; и выполняют калибровку на основе оценки канала и явной обратной связи.

53. Способ по п.52, в котором первый кадр включает в себя запрос тестирования и уведомление о том, что далее следует NDP, при этом зондирующий кадр передают в ответ на запрос тестирования.

54. Способ по п.52, дополнительно содержащий этап, на котором:

передают третий кадр с запросом тестирования после NDP, при этом зондирующий кадр передают в ответ на запрос тестирования.

55. Устройство для передачи обратной связи, содержащее:

по меньшей мере, один процессор, выполненный с возможностью принимать запрос на обратную связь с информацией состояния канала (CSI) для калибровки, принимать зондирующий кадр для генерирования обратной связи CSI на основе зондирующего кадра и передавать обратную связь CSI без группировки поднесущих и с полной точностью: и

запоминающее устройство, соединенное, по меньшей мере, с одним процессором.

56. Устройство по п.55, в котором, по меньшей мере, один процессор выполнен с возможностью передавать обратную связь CSI в кадре администрирования, имеющем поле группировки и поле размера коэффициента, устанавливать в поле группировки 0 для обозначения отсутствия группировки поднесущих и устанавливать в поле размера коэффициента 3 для обозначения 8 битов для полной точности обратной связи CSI.

57. Устройство по п.55, в котором обратная связь CSI содержит матрицу CSI для каждой из множества поднесущих, пригодных для передачи.

58. Способ передачи обратной связи, содержащий этапы, на которых:

принимают запрос на обратную связь для получения информации о состоянии канала (CSI) для калибровки;

принимают зондирующий кадр;

генерируют обратную связь CSI на основе зондирующего кадра; и

передают обратную связь CSI без группировки поднесущих и с полной точностью.

59. Способ по п.58, в котором передача обратной связи CSI содержит этапы, на которых:

передают обратную связь CSI в кадре администрирования, имеющем поле группировки и поле размера коэффициента, устанавливают в поле группировки 0 для обозначения отсутствия группировки поднесущих и устанавливают в поле размера коэффициента 3 для обозначения 8 битов для полной точности обратной связи CSI.