US007079499B1

(12) **United States Patent**
Akhtar et al.

(10) **Patent No.: US 7,079,499 B1**
(45) **Date of Patent: Jul. 18, 2006**

(54) **INTERNET PROTOCOL MOBILITY ARCHITECTURE FRAMEWORK**

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(73) Assignee: **Nortel Networks Limited**, St. Laurent (CA)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/657,351**

(22) Filed: **Sep. 7, 2000**

Related U.S. Application Data

(60) Provisional application No. 60/192,411, filed on Mar. 27, 2000, provisional application No. 60/157,449, filed on Oct. 4, 1999, provisional application No. 60/157,289, filed on Oct. 1, 1999, provisional application No. 60/156,669, filed on Sep. 29, 1999, provisional application No. 60/152,916, filed on Sep. 8, 1999.

(51) **Int. Cl.**
H04L 12/56 (2006.01)

(52) **U.S. Cl.** **370/310**; 370/389

(58) **Field of Classification Search** ..... 370/310, 370/338, 465, 466, 469; 707/100, 103 R, 707/103 X; 717/100, 106, 108, 116
See application file for complete search history.

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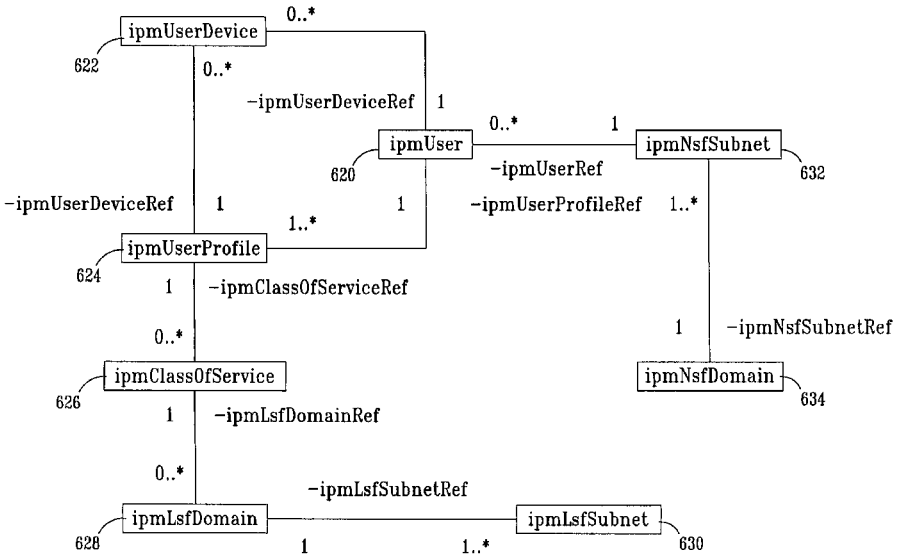
Primary Examiner—Chi Pham
Assistant Examiner—Derrick W Ferris
(74) *Attorney, Agent, or Firm*—Carr LLP

(57) **ABSTRACT**

A communications architecture for enabling IP-based mobile communications includes a Local Service Function (LSF) component configured to serve as an IP-based serving area network for a set of x-Access Networks, and a Network Service Function (NSF) component configured to serve as an IP-based home network by managing a MN's subscription and associated profile so that the MN is authorized to use the resources of the LSF. An x-Access Network (xAN) is interconnected to the LSF and NSF for providing heterogeneous Layer 2 access for MNs irrespective of access technology.

4 Claims, 110 Drawing Sheets



Ex. 1013
Apple v. MPH Techs. Oy
IPR2019-00819

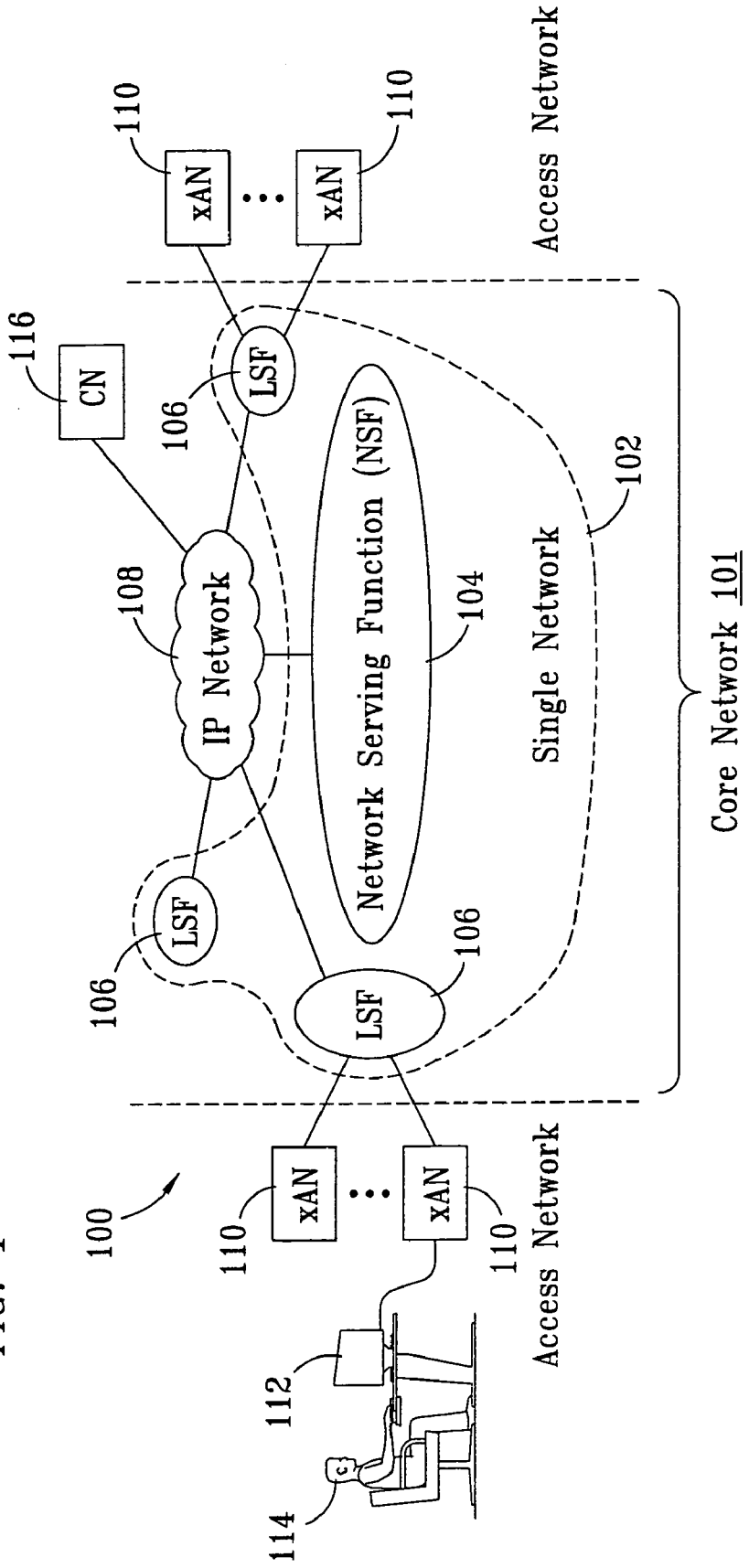

Access Network
110
xAN
xAN
110
116
CN
106
LSF
Network Serving Function (NSF)
102
Single Network
108
IP Network
104
Core Network 101
LSF
106
106
LSF
100
110
xAN
xAN
110
Access Network
112
114

FIG. 1

FIG. 2

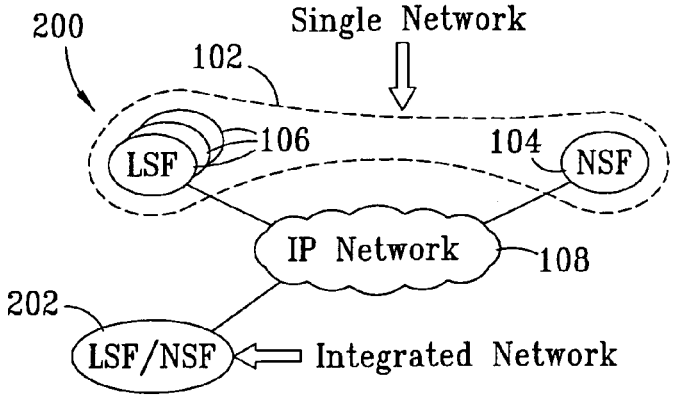

200
Single Network
102
106
LSF
104
NSF
IP Network
108
202
LSF/NSF
Integrated Network

FIG. 3

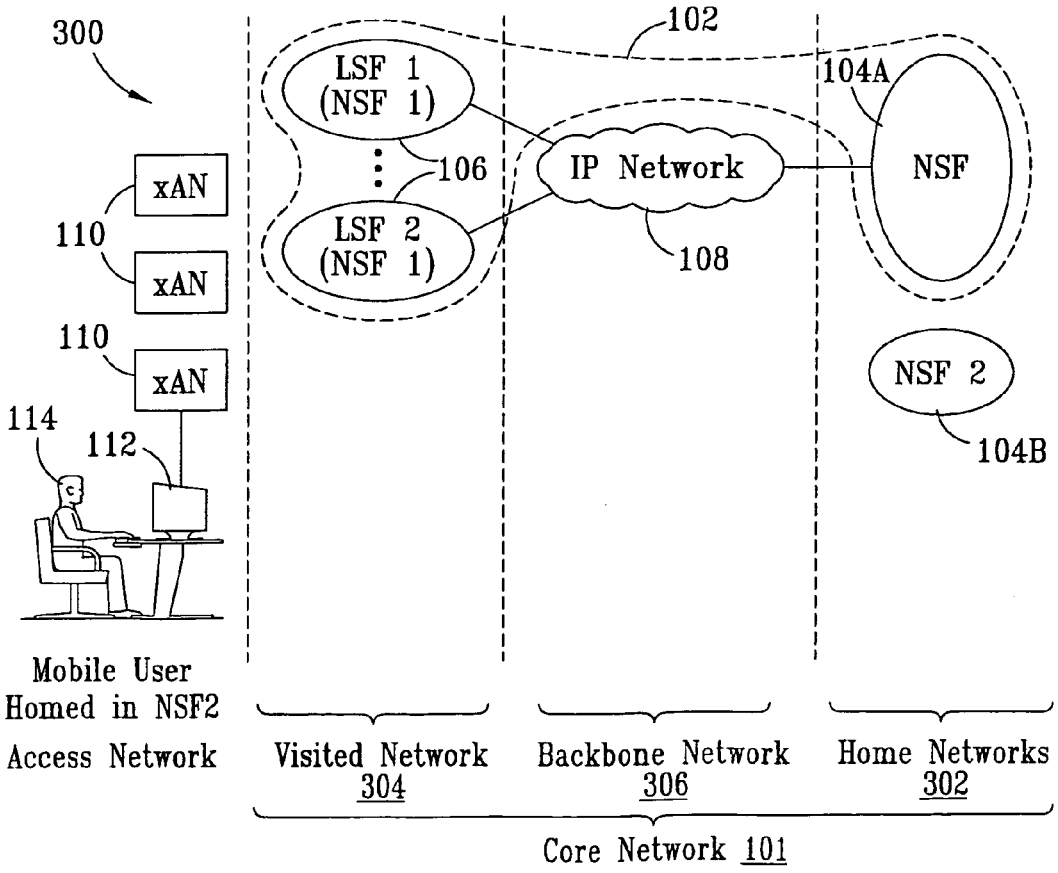

300
102
LSF 1
(NSF 1)
106
LSF 2
(NSF 1)
IP Network
108
104A
NSF
NSF 2
104B
xAN
110
xAN
110
xAN
114
112
Mobile User
Homed in NSF2
Access Network
Visited Network
304
Backbone Network
306
Home Networks
302
Core Network 101

FIG. 4A

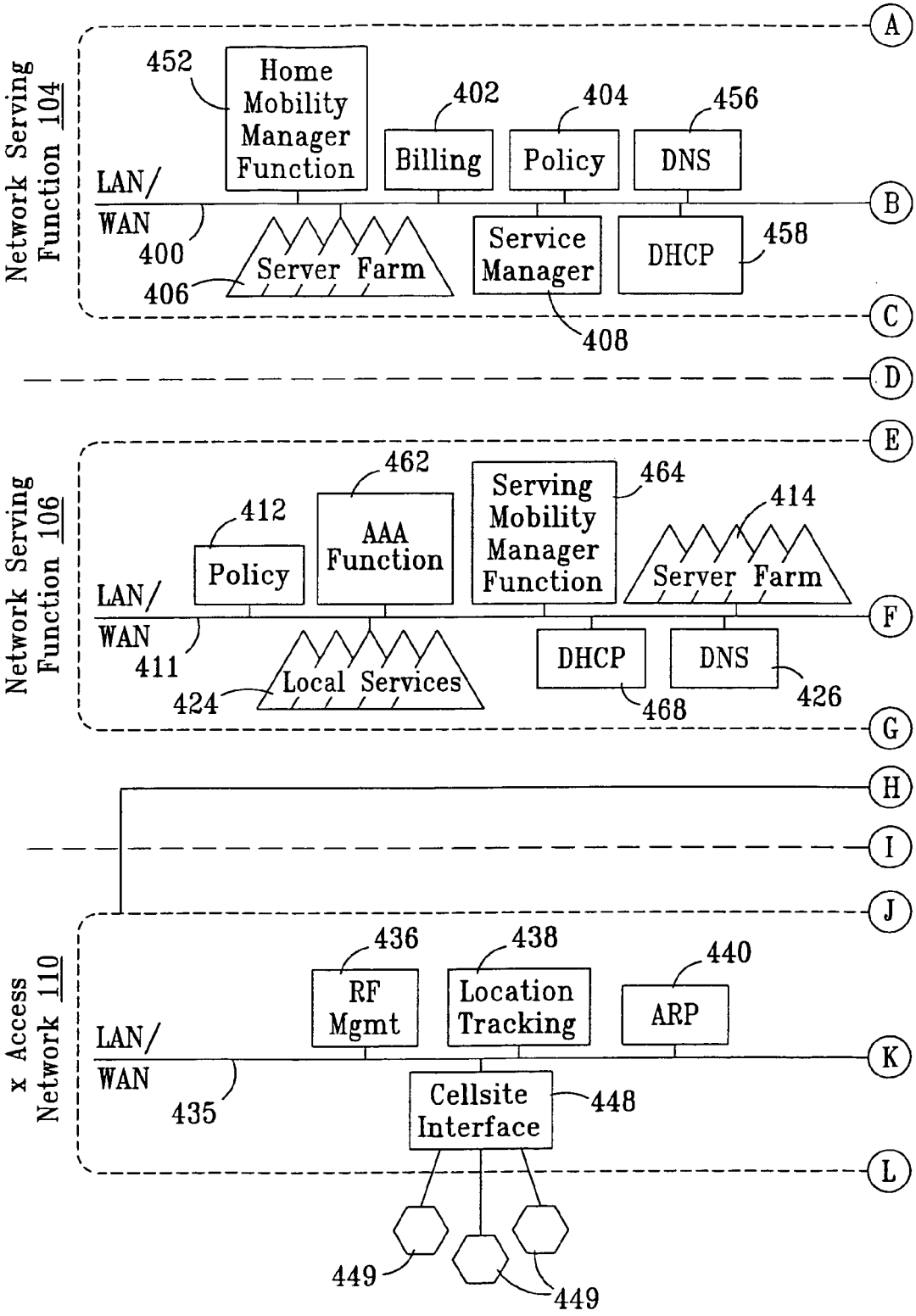

A
B
C
D
E
F
G
H
I
J
K
L
Network Serving Function 104
452
Home Mobility Manager Function
402
Billing
404
Policy
456
DNS
LAN/ WAN
400
406
Server Farm
Service Manager
408
DHCP
458
Network Serving Function 106
462
AAA Function
412
Policy
Serving Mobility Manager Function
464
414
Server Farm
LAN/ WAN
411
424
Local Services
DHCP
468
DNS
426
x Access Network 110
436
RF Mgmt
438
Location Tracking
440
ARP
LAN/ WAN
435
Cellsite Interface
448
449
449

FIG. 4B

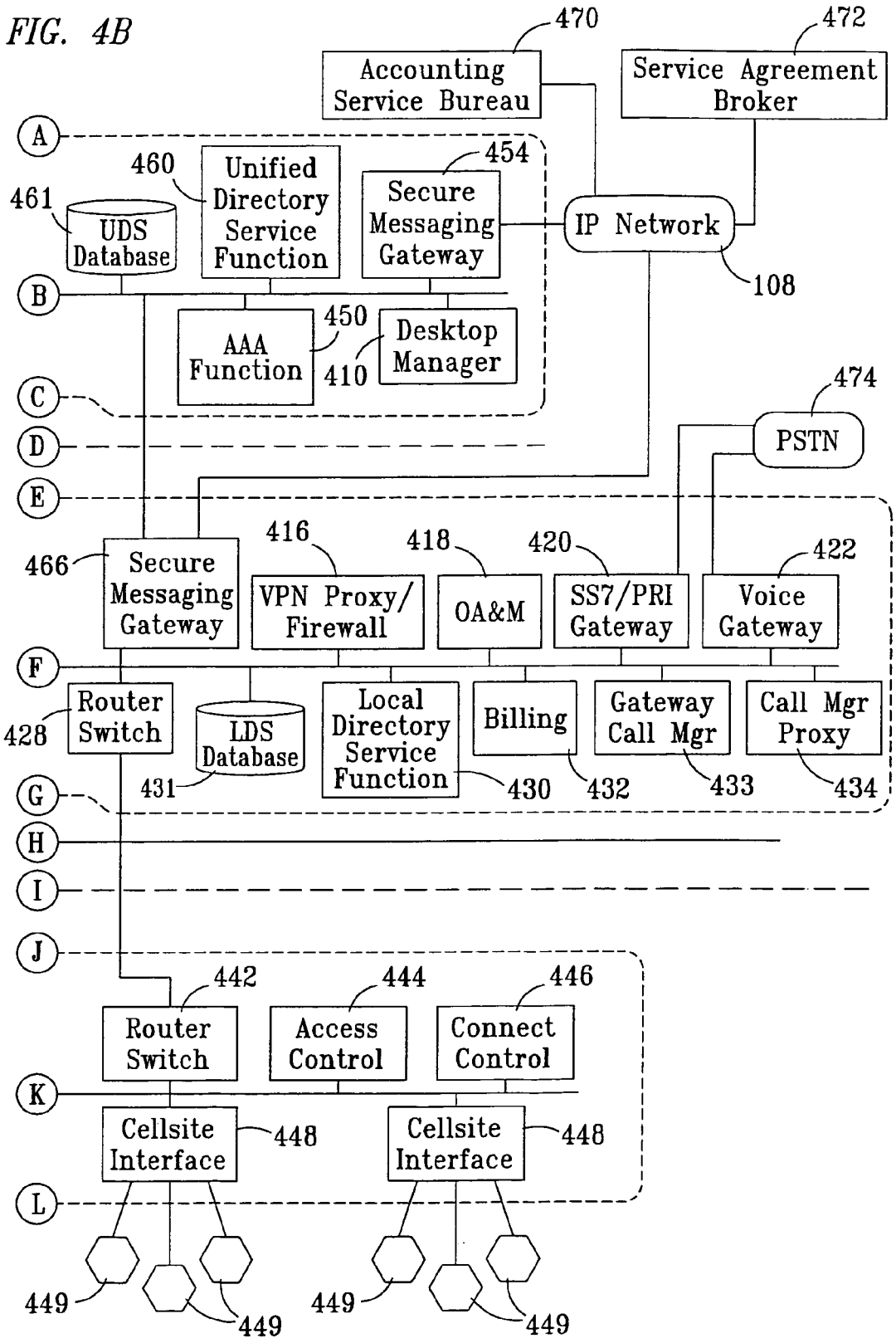

470
Accounting Service Bureau
472
Service Agreement Broker
A
460
Unified Directory Service Function
454
Secure Messaging Gateway
461
UDS Database
IP Network
108
B
450
AAA Function
410
Desktop Manager
C
474
PSTN
D
E
466
Secure Messaging Gateway
416
VPN Proxy/ Firewall
418
OA&M
420
SS7/PRI Gateway
422
Voice Gateway
F
428
Router Switch
LDS Database
431
Local Directory Service Function
430
Billing
432
Gateway Call Mgr
433
Call Mgr Proxy
434
G
H
I
J
442
Router Switch
444
Access Control
446
Connect Control
K
Cellsite Interface
448
Cellsite Interface
448
L
449
449
449
449

FIG. 4C

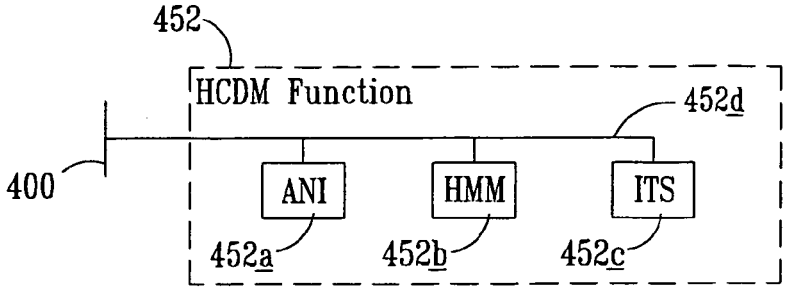


FIG. 4D

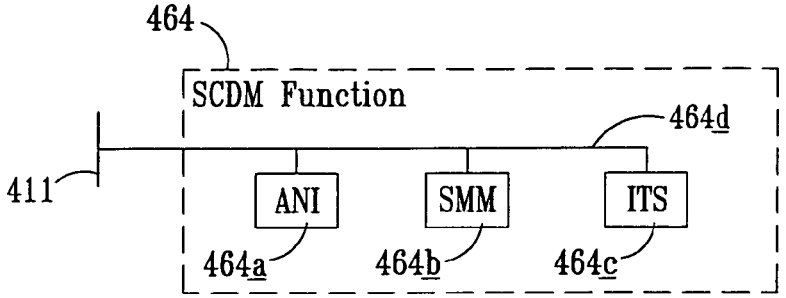


FIG. 4E

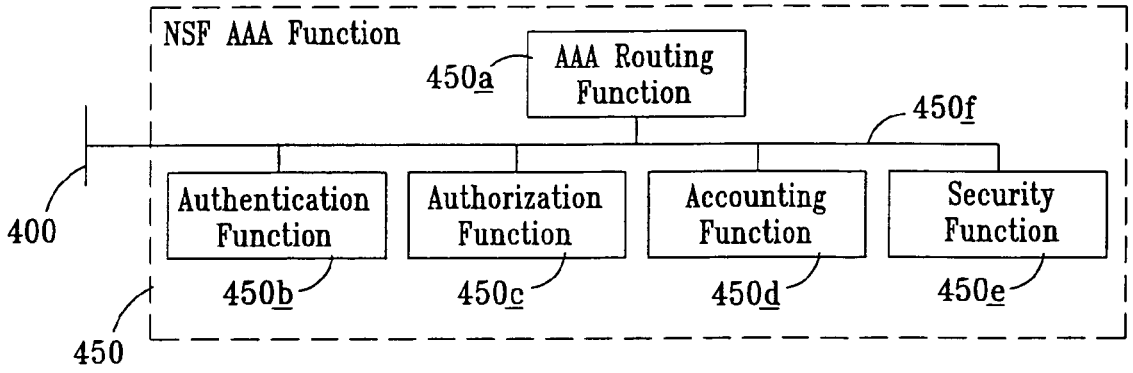
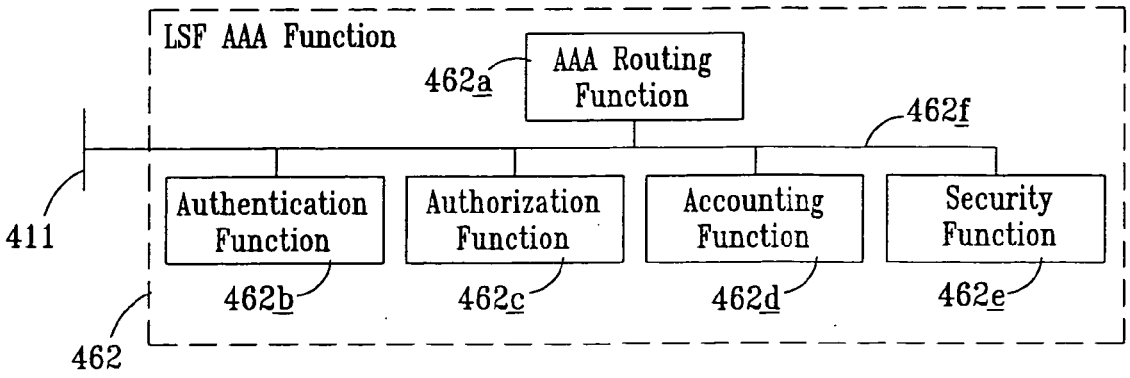


FIG. 4F



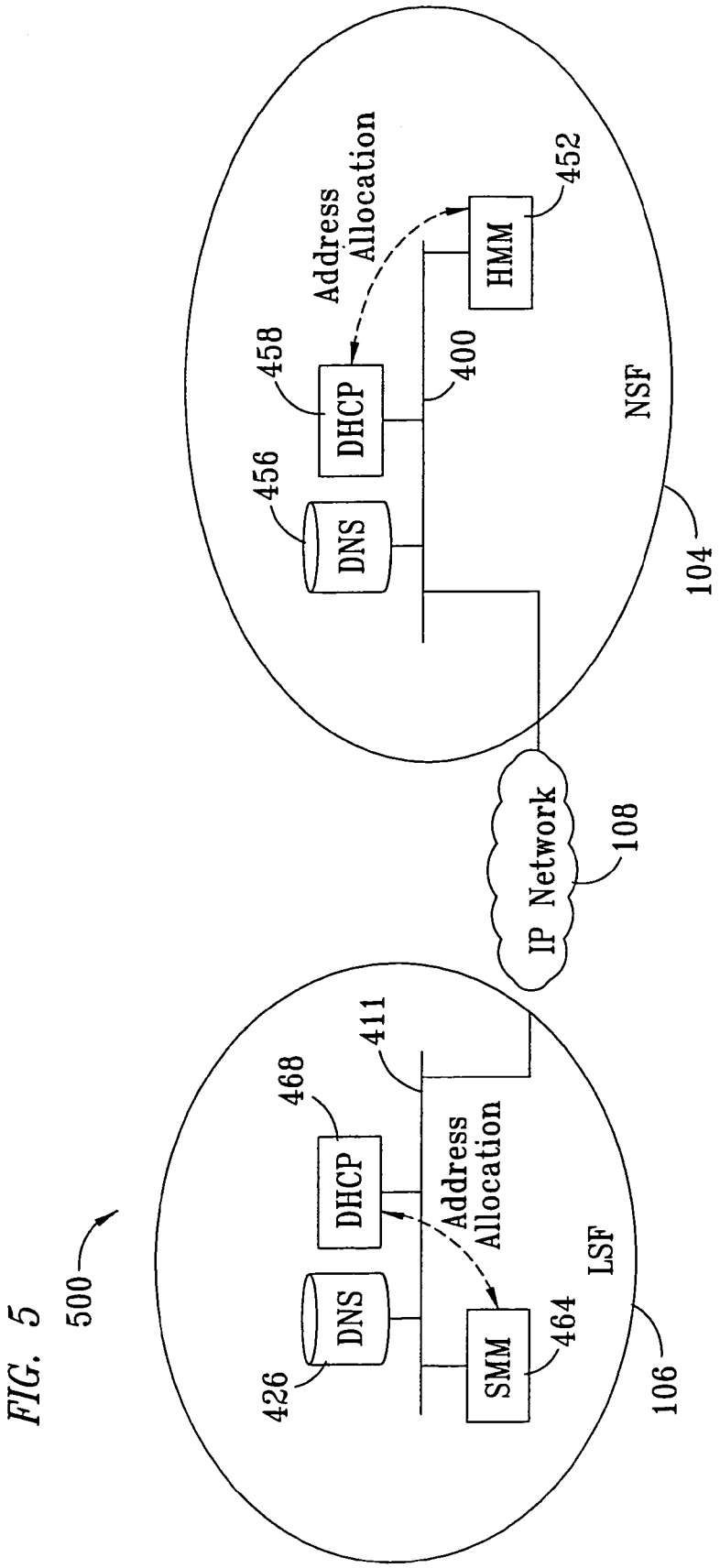

500
NSF
104
HMM
452
Address Allocation
458
DHCP
400
456
DNS
IP Network
108
LSF
106
411
468
DHCP
Address Allocation
DNS
426
SMM
464

FIG. 5

FIG. 5A

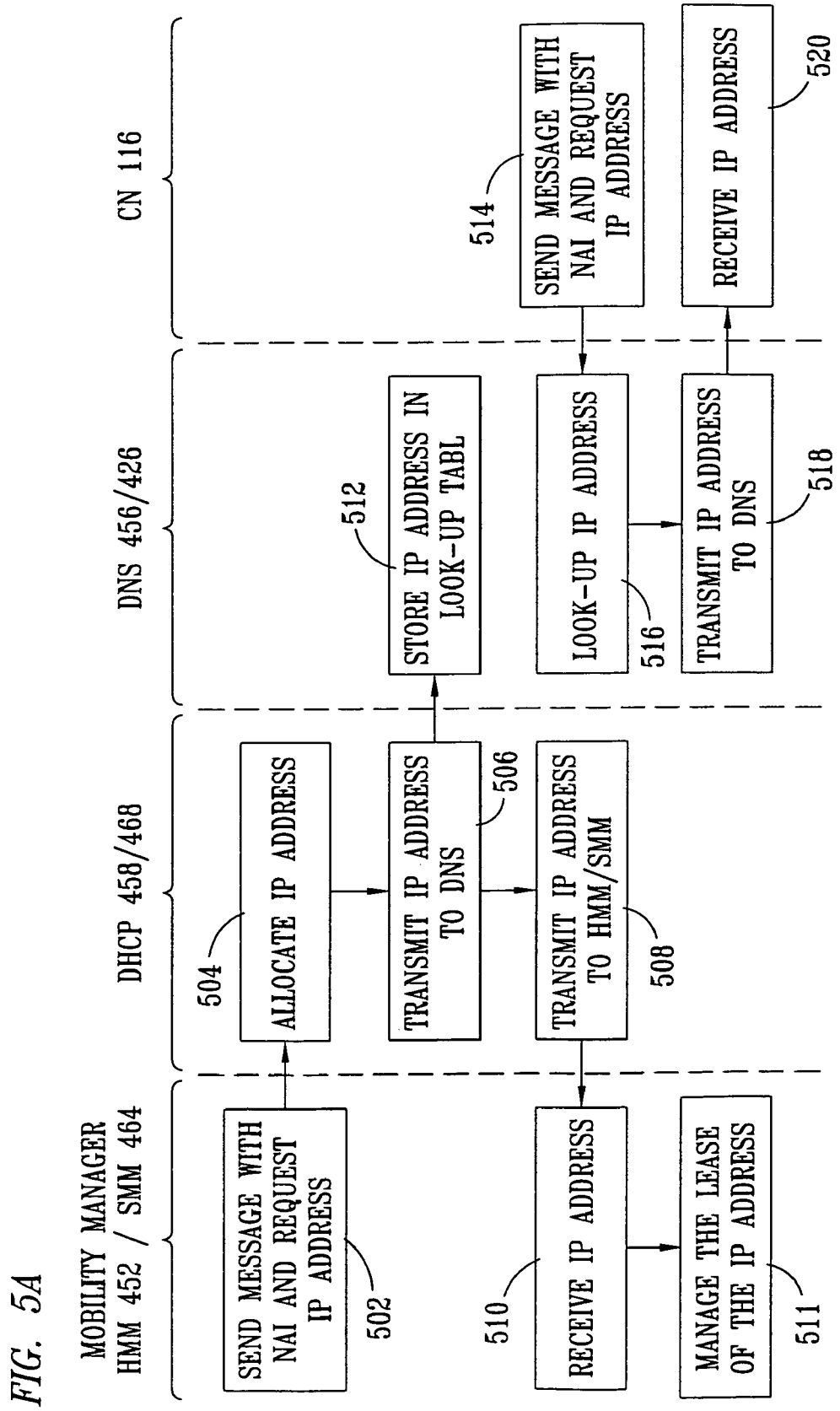
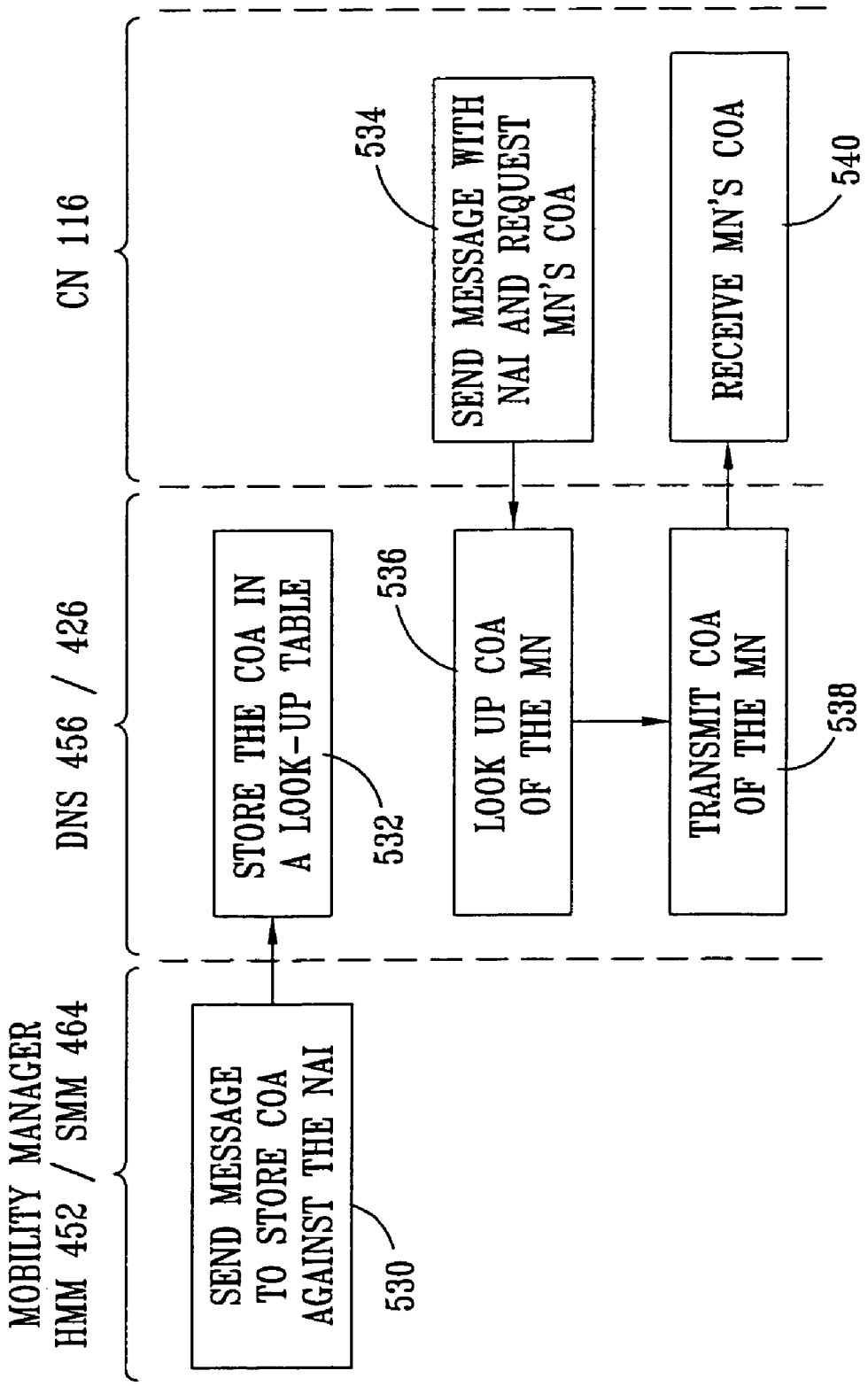

MOBILITY MANAGER
HMM 452 / SMM 464
DHCP 458/468
DNS 456/426
CN 116
SEND MESSAGE WITH NAI AND REQUEST IP ADDRESS
502
ALLOCATE IP ADDRESS
504
TRANSMIT IP ADDRESS TO DNS
506
TRANSMIT IP ADDRESS TO HMM/SMM
508
STORE IP ADDRESS IN LOOK-UP TABL
512
RECEIVE IP ADDRESS
510
MANAGE THE LEASE OF THE IP ADDRESS
511
SEND MESSAGE WITH NAI AND REQUEST IP ADDRESS
514
LOOK-UP IP ADDRESS
516
TRANSMIT IP ADDRESS TO DNS
518
RECEIVE IP ADDRESS
520

FIG. 5B


MOBILITY MANAGER
HMM 452 / SMM 464
DNS 456 / 426
CN 116
SEND MESSAGE TO STORE COA AGAINST THE NAI
530
STORE THE COA IN A LOOK-UP TABLE
532
SEND MESSAGE WITH NAI AND REQUEST MN'S COA
534
LOOK UP COA OF THE MN
536
TRANSMIT COA OF THE MN
538
RECEIVE MN'S COA
540

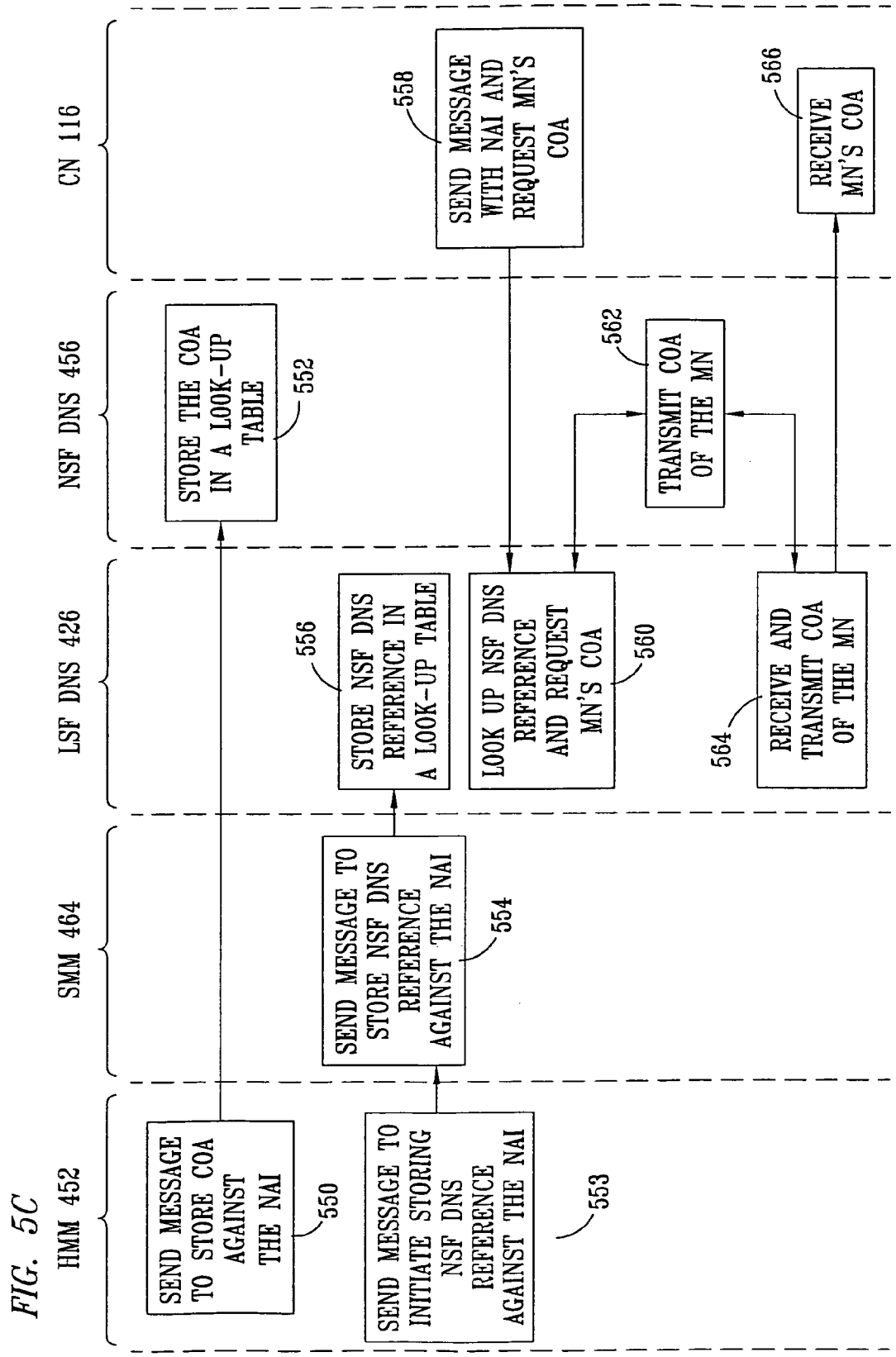

HMM 452
SMM 464
LSF DNS 426
NSF DNS 456
CN 116
SEND MESSAGE TO STORE COA AGAINST THE NAI
550
SEND MESSAGE TO INITIATE STORING NSF DNS REFERENCE AGAINST THE NAI
553
SEND MESSAGE TO STORE NSF DNS REFERENCE AGAINST THE NAI
554
STORE NSF DNS REFERENCE IN A LOOK-UP TABLE
556
STORE THE COA IN A LOOK-UP TABLE
552
SEND MESSAGE WITH NAI AND REQUEST MN'S COA
558
LOOK UP NSF DNS REFERENCE AND REQUEST MN'S COA
560
TRANSMIT COA OF THE MN
562
RECEIVE AND TRANSMIT COA OF THE MN
564
RECEIVE MN'S COA
566

FIG. 5C

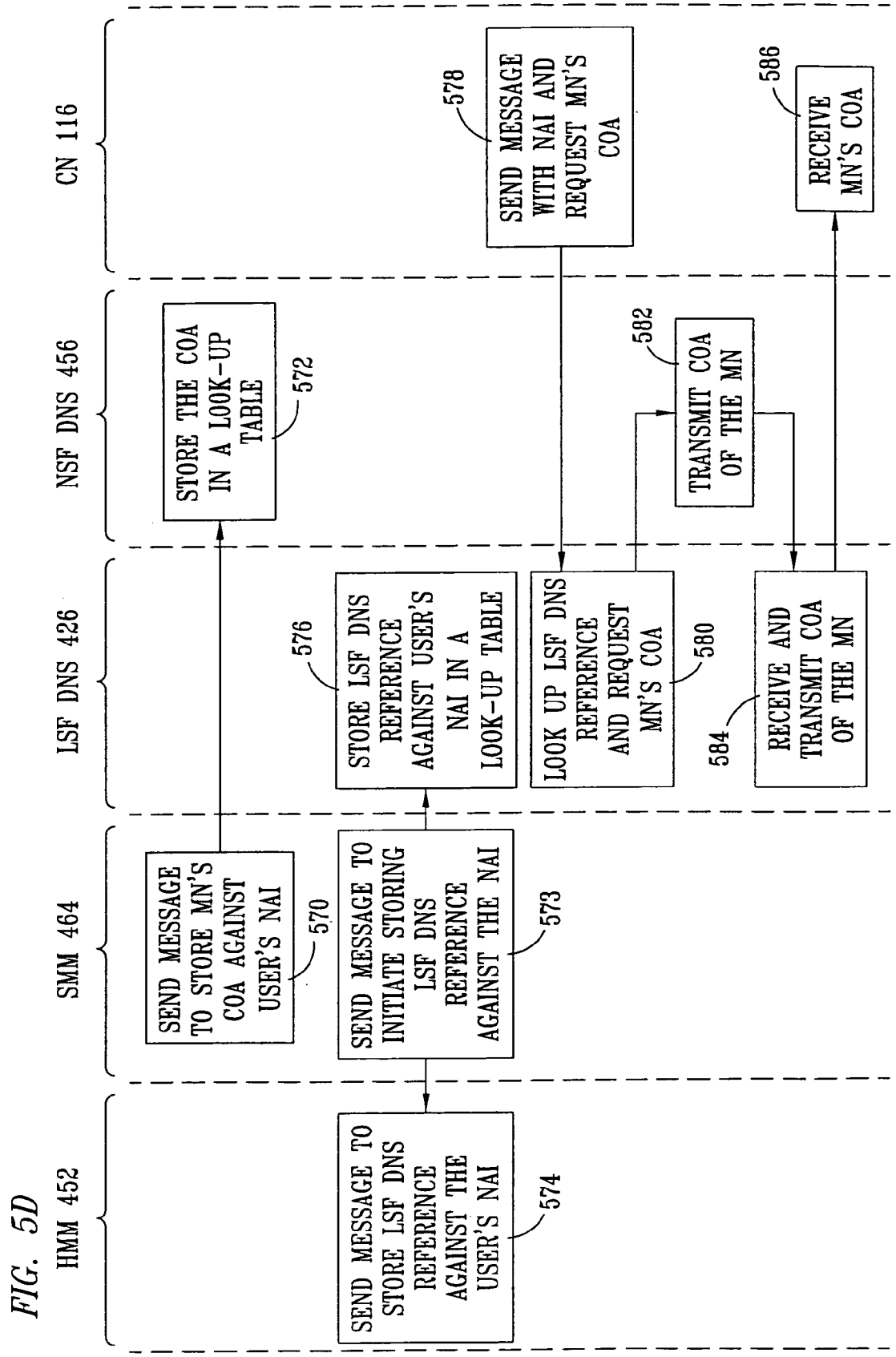
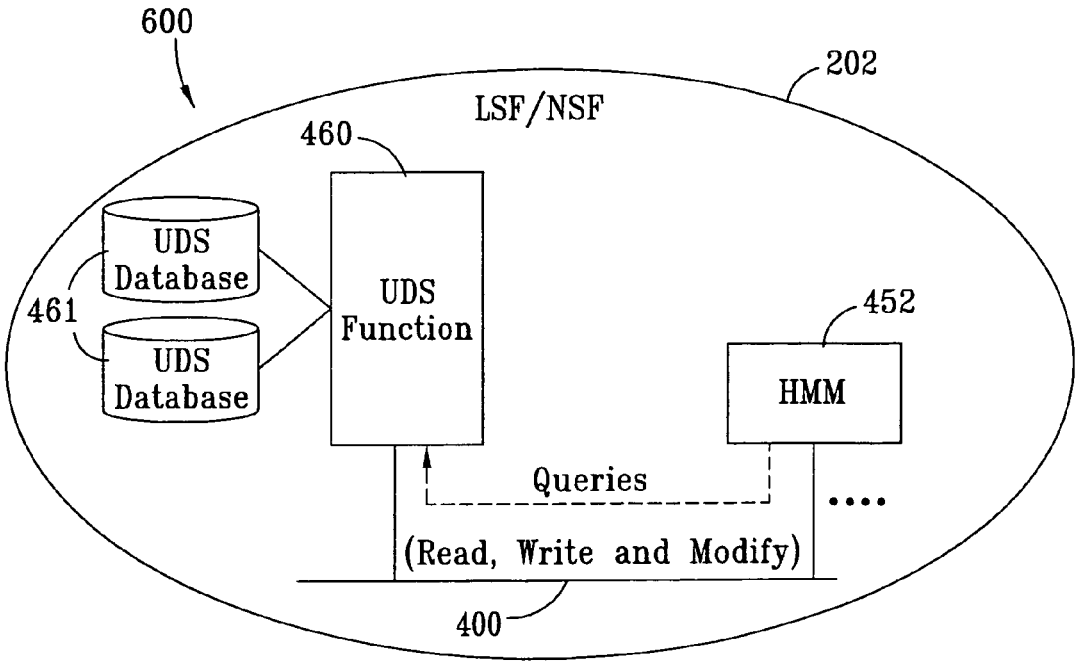

CN 116
NSF DNS 456
LSF DNS 426
SMM 464
HMM 452
SEND MESSAGE TO STORE MN'S COA AGAINST USER'S NAI
570
SEND MESSAGE TO INITIATE STORING LSF DNS REFERENCE AGAINST THE NAI
573
SEND MESSAGE TO STORE LSF DNS REFERENCE AGAINST THE USER'S NAI
574
STORE THE COA IN A LOOK-UP TABLE
572
STORE LSF DNS REFERENCE AGAINST USER'S NAI IN A LOOK-UP TABLE
576
SEND MESSAGE WITH NAI AND REQUEST MN'S COA
578
LOOK UP LSF DNS REFERENCE AND REQUEST MN'S COA
580
TRANSMIT COA OF THE MN
582
RECEIVE AND TRANSMIT COA OF THE MN
584
RECEIVE MN'S COA
586

FIG. 5D

FIG. 6


600
202
LSF/NSF
460
UDS Database
461
UDS Database
UDS Function
452
HMM
Queries
....
(Read, Write and Modify)
400

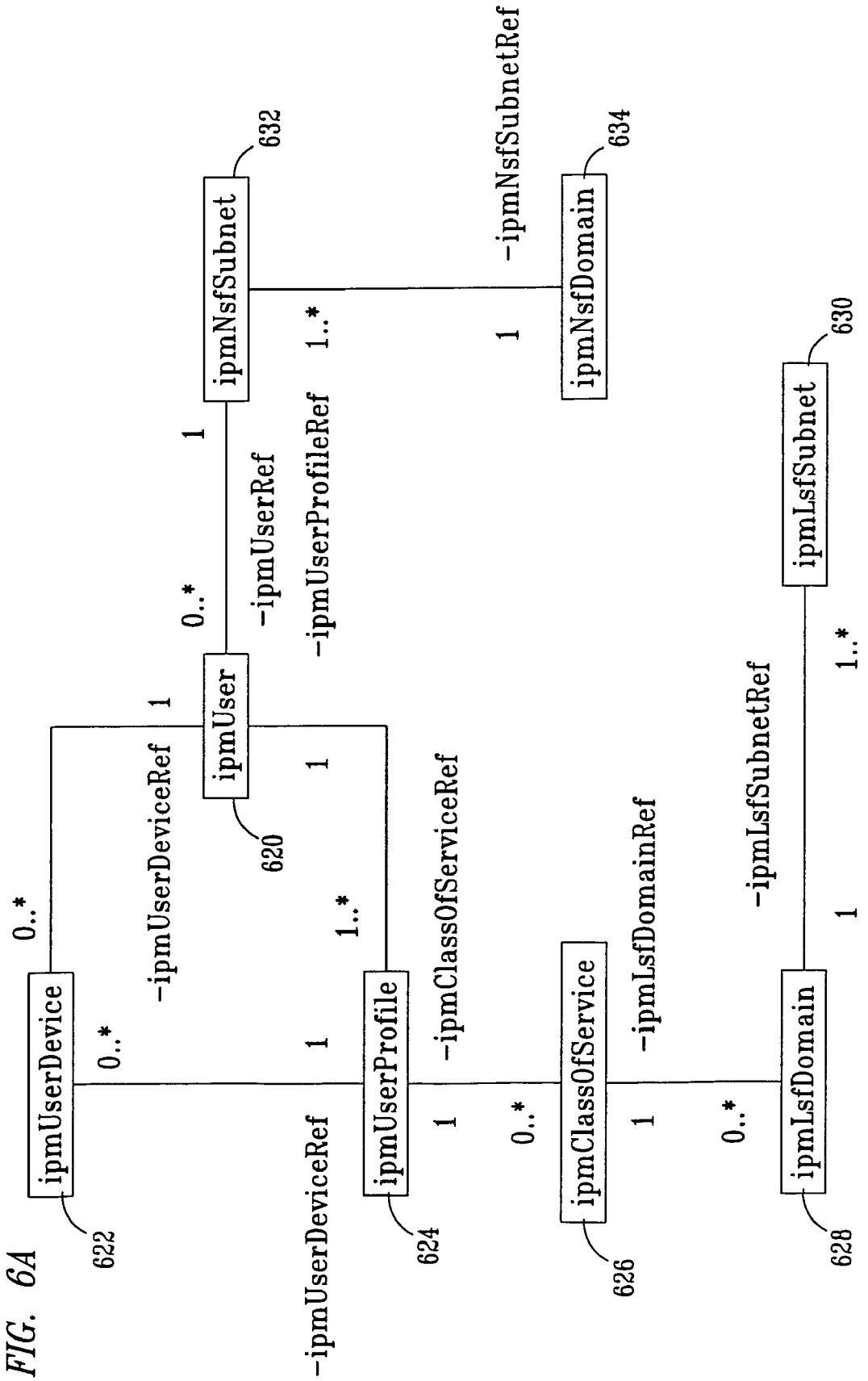

ipmUserDevice
622
ipmUser
620
ipmUserProfile
624
ipmClassOfService
626
ipmLsfDomain
628
ipmLsfSubnet
630
ipmNsfSubnet
632
ipmNsfDomain
634
-ipmUserDeviceRef
-ipmUserRef
-ipmUserProfileRef
-ipmNsfSubnetRef
-ipmClassOfServiceRef
-ipmLsfDomainRef
-ipmLsfSubnetRef
0..*
1..*
1

FIG. 6A

FIG. 6B(a)

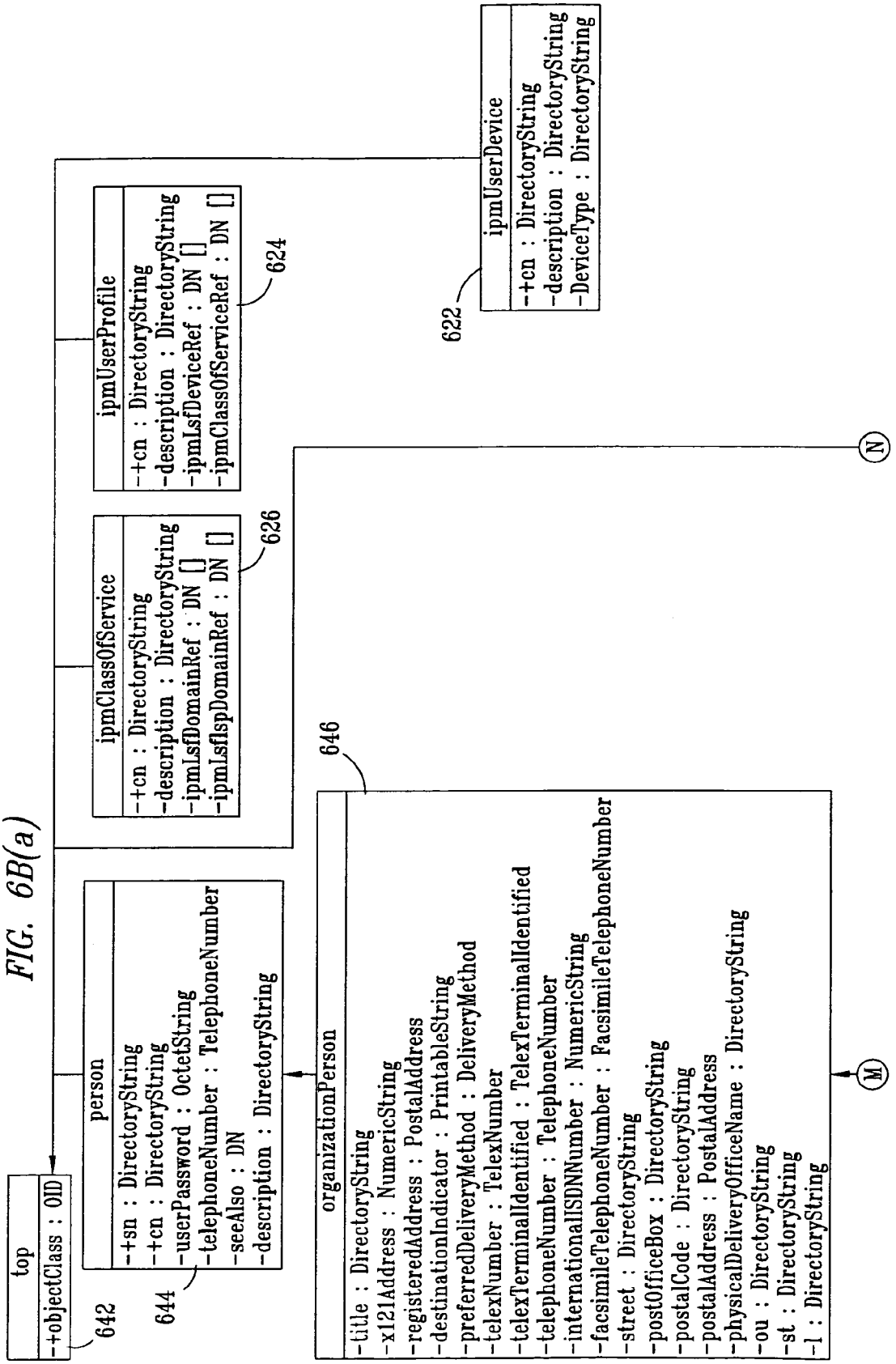

top
-+objectClass : OID
642
person
-+sn : DirectoryString
-+cn : DirectoryString
-userPassword : OctetString
644
-telephoneNumber : TelephoneNumber
-seeAlso : DN
-description : DirectoryString
ipmClassOfService
-+cn : DirectoryString
-description : DirectoryString
-ipmLsfDomainRef : DN []
-ipmLsflspDomainRef : DN []
626
ipmUserProfile
-+cn : DirectoryString
-description : DirectoryString
-ipmLsfDeviceRef : DN []
-ipmClassOfServiceRef : DN []
624
ipmUserDevice
-+cn : DirectoryString
-description : DirectoryString
-DeviceType : DirectoryString
622
organizationPerson
646
-title : DirectoryString
-x121Address : NumericString
-registeredAddress : PostalAddress
-destinationIndicator : PrintableString
-preferredDeliveryMethod : DeliveryMethod
-telexNumber : TelexNumber
-telexTerminalIdentified : TelexTerminalIdentified
-telephoneNumber : TelephoneNumber
-internationalISDNNumber : NumericString
-facsimileTelephoneNumber : FacsimileTelephoneNumber
-street : DirectoryString
-postOfficeBox : DirectoryString
-postalCode : DirectoryString
-postalAddress : PostalAddress
-physicalDeliveryOfficeName : DirectoryString
-ou : DirectoryString
-st : DirectoryString
-l : DirectoryString
M
N

FIG. 6B(b)

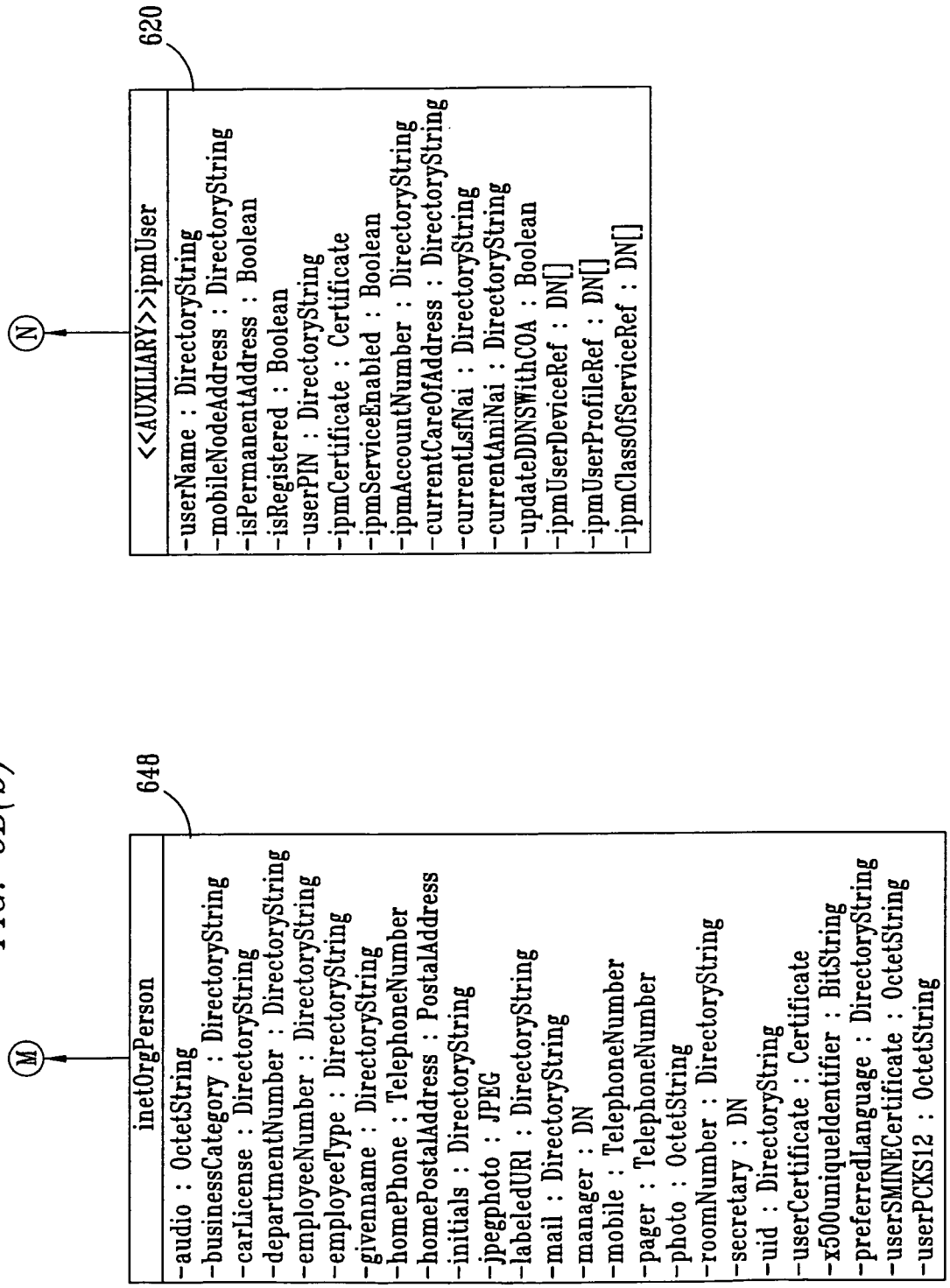

M
inetOrgPerson
648
-audio : OctetString
-businessCategory : DirectoryString
-carLicense : DirectoryString
-departmentNumber : DirectoryString
-employeeNumber : DirectoryString
-employeeType : DirectoryString
-givenname : DirectoryString
-homePhone : TelephoneNumber
-homePostalAddress : PostalAddress
-initials : DirectoryString
-jpegphoto : JPEG
-labeledURI : DirectoryString
-mail : DirectoryString
-manager : DN
-mobile : TelephoneNumber
-pager : TelephoneNumber
-photo : OctetString
-roomNumber : DirectoryString
-secretary : DN
-uid : DirectoryString
-userCertificate : Certificate
-x500uniqueIdentifier : BitString
-preferredLanguage : DirectoryString
-userSMINECertificate : OctetString
-userPCKS12 : OctetString
N
<<AUXILIARY>>ipmUser
620
-userName : DirectoryString
-mobileNodeAddress : DirectoryString
-isPermanentAddress : Boolean
-isRegistered : Boolean
-userPIN : DirectoryString
-ipmCertificate : Certificate
-ipmServiceEnabled : Boolean
-ipmAccountNumber : DirectoryString
-currentCareOfAddress : DirectoryString
-currentIsfNai : DirectoryString
-currentAniNai : DirectoryString
-updateDDNSWithCOA : Boolean
-ipmUserDeviceRef : DN[]
-ipmUserProfileRef : DN[]
-ipmClassOfServiceRef : DN[]

FIG. 6C

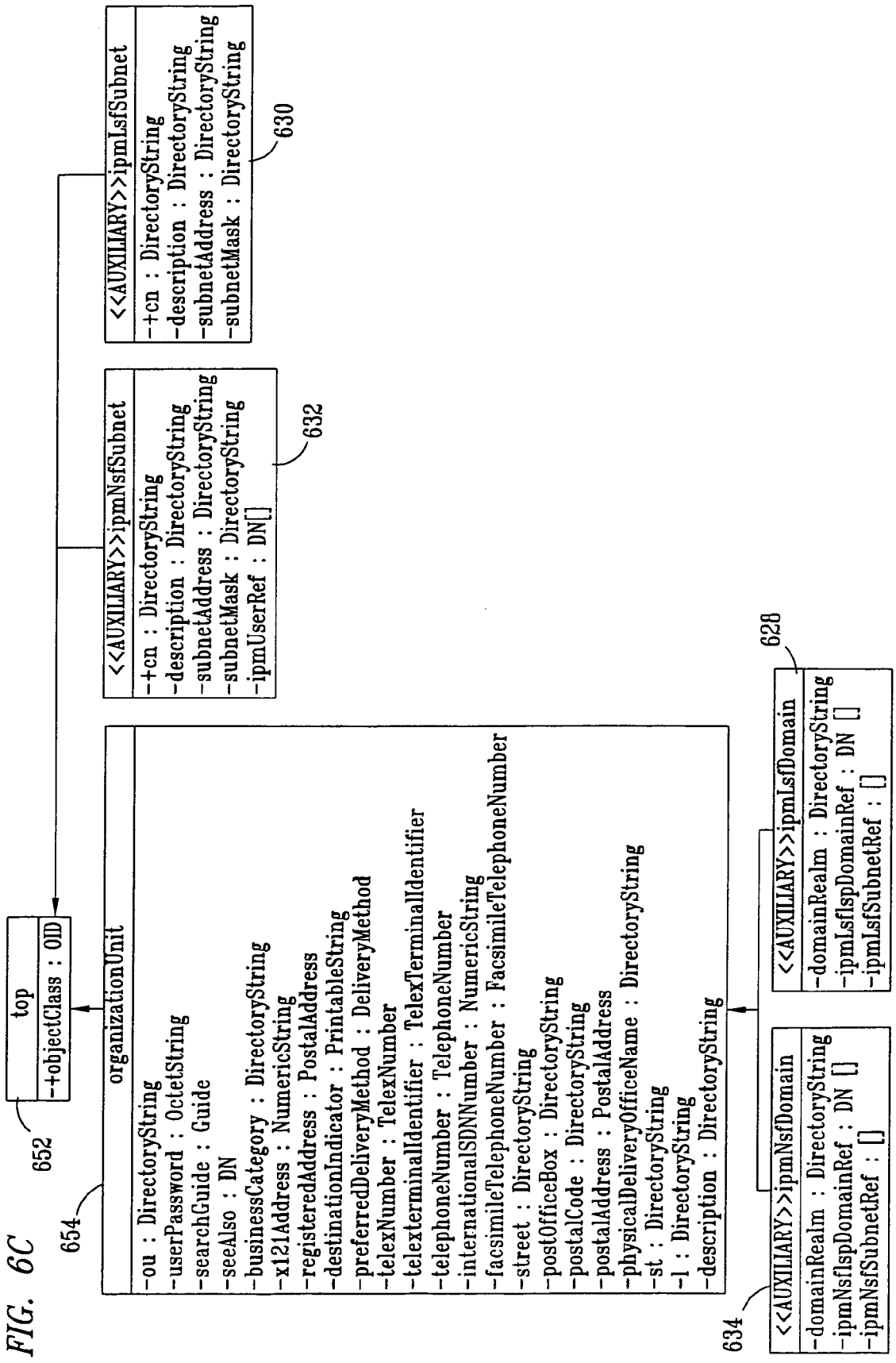

top
-+objectClass : OID
652
organizationUnit
-ou : DirectoryString
-userPassword : OctetString
-searchGuide : Guide
-seeAlso : DN
-businessCategory : DirectoryString
-x121Address : NumericString
-registeredAddress : PostalAddress
-destinationIndicator : PrintableString
-preferredDeliveryMethod : DeliveryMethod
-telexNumber : TelexNumber
-telexterminalIdentifier : TelexTerminalIdentifier
-telephoneNumber : TelephoneNumber
-internationalSDNNumber : NumericString
-facsimileTelephoneNumber : FacsimileTelephoneNumber
-street : DirectoryString
-postOfficeBox : DirectoryString
-postalCode : DirectoryString
-postalAddress : PostalAddress
-physicalDeliveryOfficeName : DirectoryString
-st : DirectoryString
-l : DirectoryString
-description : DirectoryString
654
<<AUXILIARY>>ipmNsfSubnet
-+cn : DirectoryString
-description : DirectoryString
-subnetAddress : DirectoryString
-subnetMask : DirectoryString
-ipmUserRef : DN[]
632
<<AUXILIARY>>ipmLsfSubnet
-+cn : DirectoryString
-description : DirectoryString
-subnetAddress : DirectoryString
-subnetMask : DirectoryString
630
<<AUXILIARY>>ipmNsfDomain
-domainRealm : DirectoryString
-ipmNsflspDomainRef : DN []
-ipmNsfSubnetRef : []
634
<<AUXILIARY>>ipmLsfDomain
-domainRealm : DirectoryString
-ipmLsflspDomainRef : DN []
-ipmLsfSubnetRef : []
628

FIG. 6D

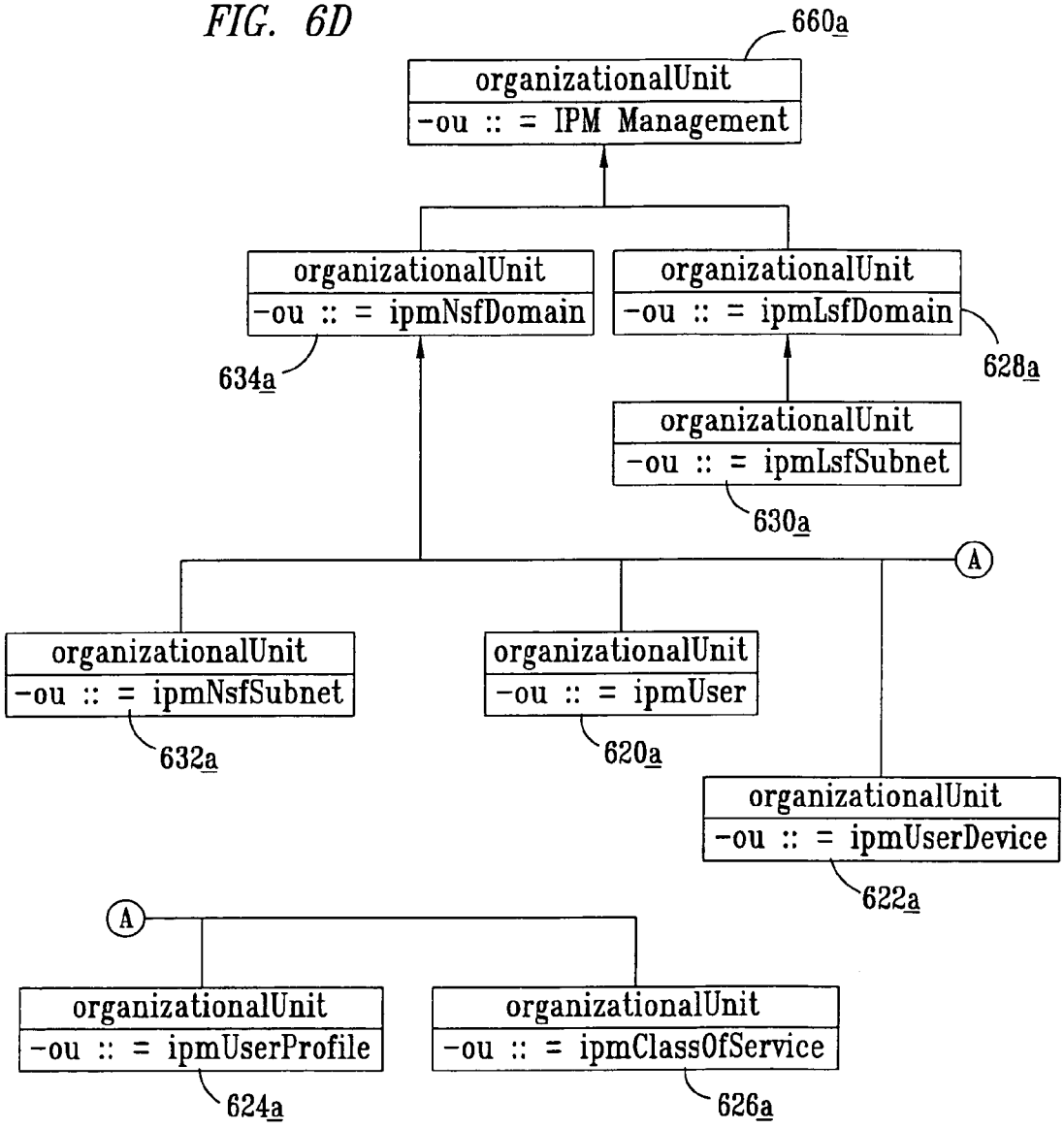

660a
organizationalUnit
-ou :: = IPM Management
organizationalUnit
-ou :: = ipmNsfDomain
634a
organizationalUnit
-ou :: = ipmLsfDomain
628a
organizationalUnit
-ou :: = ipmLsfSubnet
630a
A
organizationalUnit
-ou :: = ipmNsfSubnet
632a
organizationalUnit
-ou :: = ipmUser
620a
organizationalUnit
-ou :: = ipmUserDevice
622a
A
organizationalUnit
-ou :: = ipmUserProfile
624a
organizationalUnit
-ou :: = ipmClassOfService
626a

FIG. 6E(a)

Name	Type	MatchingRule	Multi-Valued	Purpose	Example
userName	Directory String	CaseIgnoreString	No	The name of the User (subscriber)	johndoe
MobileNodeAddress	Directory String	CaseIgnoreString	No	Mobile Node's home IP address	100.150.128.1
IsAddressPermanent	Booleam	CaseIgnoreString	No	Flag signifying whether the Mobile Node's home IP address was permanently provisioned or allocated (e.g. by DHCP)	FALSE
IsRegistered	Boolean	CaseIgnoreString	No	Flag signifying whether the Mobile Node is presently registered	TRUE
currentLsfNai	Directory String	CaseIgnoreString	No	NAI of the LSF at which the Mobile Node is registered	smm1@southwesternbell.com
currentAniNai	Directory String	Integer	No	4 byte code identifying the Mobile Node's routing area (i.e. as is GPRS routing area)	95

(P)

0018

FIG. 6E(b)

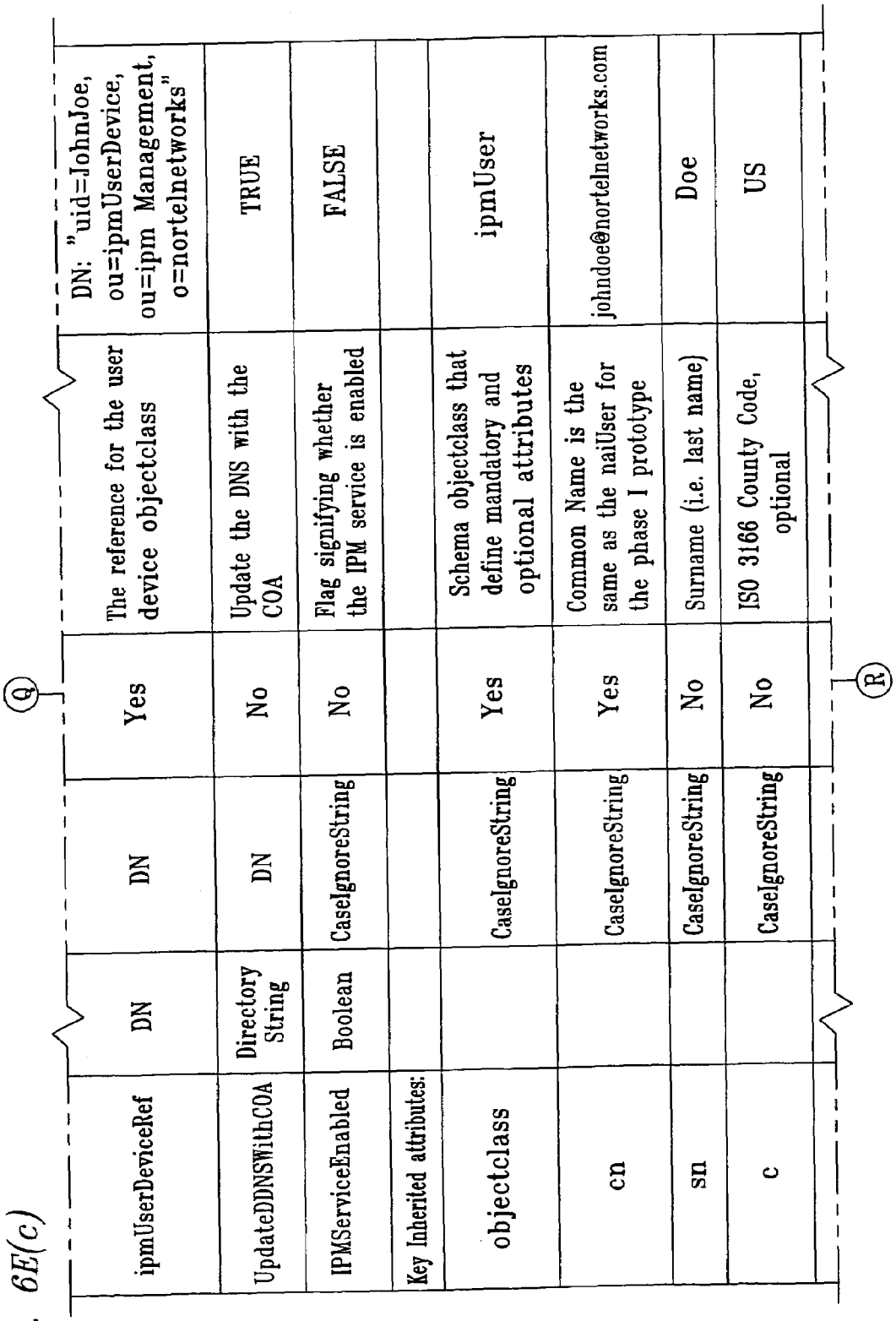
(P)

currentCareOfAddress	Certificate	CaseIgnoreString	No	IP Care of Address for the roaming Mobile Node	240.240.10.66
ipmAccountNumber	Directory String	CaseIgnoreString	No	User's account number assigned by the IPM security center	12345678
ipmCertificate	Certificate	CaseIgnoreString	No	User's Certificate generated by IPM Security Center	
userPIN	Directory String	CaseIgnoreString	No	User PIN number. It is an integer selected by the user to secure the access to his account	123decx456
ipmUserProfileRef	DN	DN	Yes	The reference for the user profile objectclass	DN: "uid=JohnJoe, ou=ipmUserProfile, ou=ipm Management, o=nortelnetworks"
ipmClassOfServiceRef	DN	DN	Yes	The reference for the user class of service objectclass	DN: "uid=JohnJoe, ou=ipmClassOfService, iu=ipm Management, o=nortelnetworks"

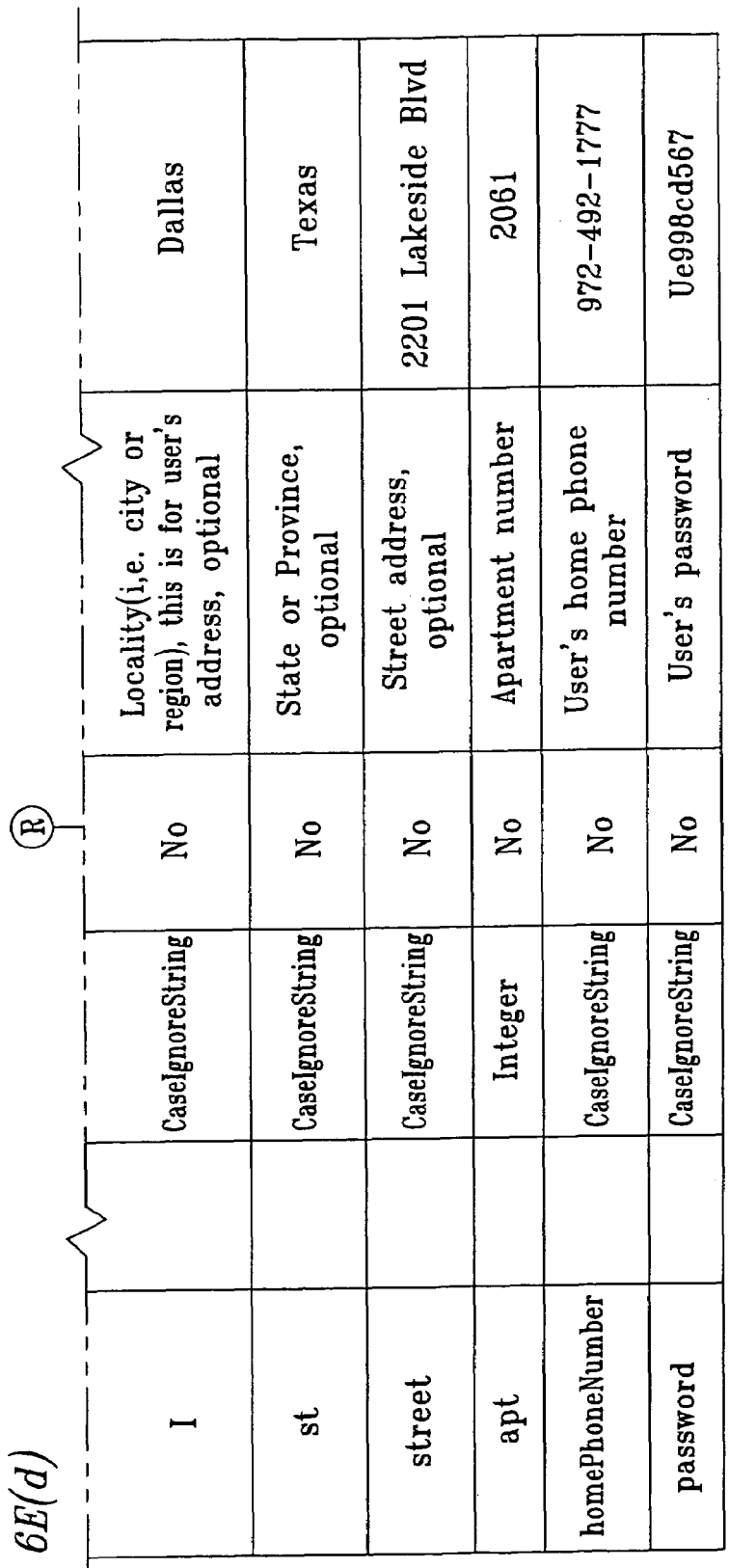
(Q)

0019

FIG. 6E(c)



ipmUserDeviceRef	DN	DN	Yes	The reference for the user device objectclass	DN: "uid=JohnJoe, ou=ipmUserDevice, ou=ipm Management, o=nortelnetworks"
UpdateDDNSWithCOA	Directory String	DN	No	Update the DNS with the COA	TRUE
IPMServiceEnabled	Boolean	CaseIgnoreString	No	Flag signifying whether the IPM service is enabled	FALSE
Key Inheriten attributes:					
objectclass		CaseIgnoreString	Yes	Schema objectclass that define mandatory and optional attributes	ipmUser
cn		CaseIgnoreString	Yes	Common Name is the same as the naiUser for the phase I prototype	johndoe@nortelnetworks.com
sn		CaseIgnoreString	No	Surname (i.e. last name)	Doe
c		CaseIgnoreString	No	ISO 3166 County Code, optional	US



l		CaseIgnoreString	No	Locality(i,e. city or region), this is for user's address, optional
st		CaseIgnoreString	No	State or Province, optional
street		CaseIgnoreString	No	Street address, optional
apt		Integer	No	Apartment number
homePhoneNumber		CaseIgnoreString	No	User's home phone number
password		CaseIgnoreString	No	User's password

Dallas
Texas
2201 Lakeside Blvd
2061
972-492-1777
Ue998cd567

FIG. 6E(d)

FIG. 6F

Name	Type	MatchingRule	Multi-Valued	Purpose	Example
cn	Directory String	CaseIgnoreString	No	Common name for the ipmUserDevice	johndoe@nortelnetworks.com
description	Directory String	CaseIgnoreString	No	The description list the device vendor, device model, the device version...	e.g.(Qualcomm QCP-2700)
deviceType	Directory String	CaseIgnoreString	No	There are two device types, devices used by a mobile subscriber to access the network and devices that are logically the user, e.g. mobile routers	e.g.(notebook, mobile)

FIG. 6G

Name	Type	MatchingRule	Multi-Valued	Purpose	Example
cn	Directory String	CaseIgnoreString	No	The common name for the ipmUserProfile objectclass	bob@nortelworks.com
description	Directory String	CaseIgnoreString	No	List all the information about the ipmUserProfile objectclass	e.g.(home, office)
ipmUserDeviceRef	DN	CaseIgnoreString	No	The reference for ipmUserDevice	DN: "uid=JohnJoe, ou=ipmUserDevice, ou=ipm Management, o=nortelnetworks"
ipmClassOfServiceRef	DN	CaseIgnoreString	No	The reference for ipmClassOfService	DN: "uid=JohnJoe, ou=ipmClassOfService, ou=ipm Management, o=nortelnetworks"

FIG. 6H

Name	Type	MatchingRule	Multi-Valued	Purpose	Example
cn	Directory String	CaseIgnoreString	No	The common name for the ipmClassOfService	bob@nortelworks.com
description	Directory String	CaseIgnoreString	No		e.g.(gold)
ipmLsfDomainRef	DN	DN	Yes	The reference for ipmLsfDomain	DN: "cn=ipmLsfDomain, ou=ipm Management, o=nortelnetworks"

FIG. 6I

Name	Type	MatchingRule	Multi-Valued	Purpose	Example
domainRealm	Directory String	CaseIgnoreString	No	Realm component of the IETF Network Access Identifier for the home network	John.Doe@ISPabe.com
ipmNsfSubnetRef	DN	DN	Yes	The reference of the NSFsubnet	DN: "cn=ipmNsfSubnet, ou=ipm Management, o=nortelnetworks"

FIG. 6J

Name	Type	MatchingRule	Multi-Valued	Purpose	Example
cn	Directory String	CaseIgnoreString	No	The common name for the ipmClassOfService	ip10@nortelworks.com
description	Directory String	CaseIgnoreString	No	The description for the ipmLsfSubnet	
subnetMask	Directory String	CaseIgnoreString	No	32 bit value help the devices understand the limits or boundaries of the network and subnet	255.255.255.0
subnetAddress	Directory String	CaseIgnoreString	No	The IP address of the LSFsubnet	47.456.70.80

FIG. 6K

Name	Type	MatchingRule	Multi-Valued	Purpose	Example
cn	Directory String	CaseIgnoreString	No	The common name for the ipmClassOfService	ip10@nortelworks.com
description	Directory String	CaseIgnoreString	No	The description for the ipmNsfSubnet	
subnetMask	Directory String	CaseIgnoreString	No	32 bit value help the devices understand the limits or boundaries of the network and subnet	255.255.255.0
subnetAddress	Directory String	CaseIgnoreString	No	The IP address of the NSFsubnet	47.456.70.80

FIG. 6L

Name	Type	MatchingRule	Multi-Valued	Purpose	Example
domainRealm	Directory String	CaseIgnoreString	No	Realm component of the IETF Network Access Identifier for the home network	John.Doe@ISPabc.com
ipmLsfSubnetRef	DN	DN	Yes	The reference of the LSFsubnet	DN: "cn=ipmLsfSubnet, ou=ipm Management, o=nortelnetworks"

FIG. 6M

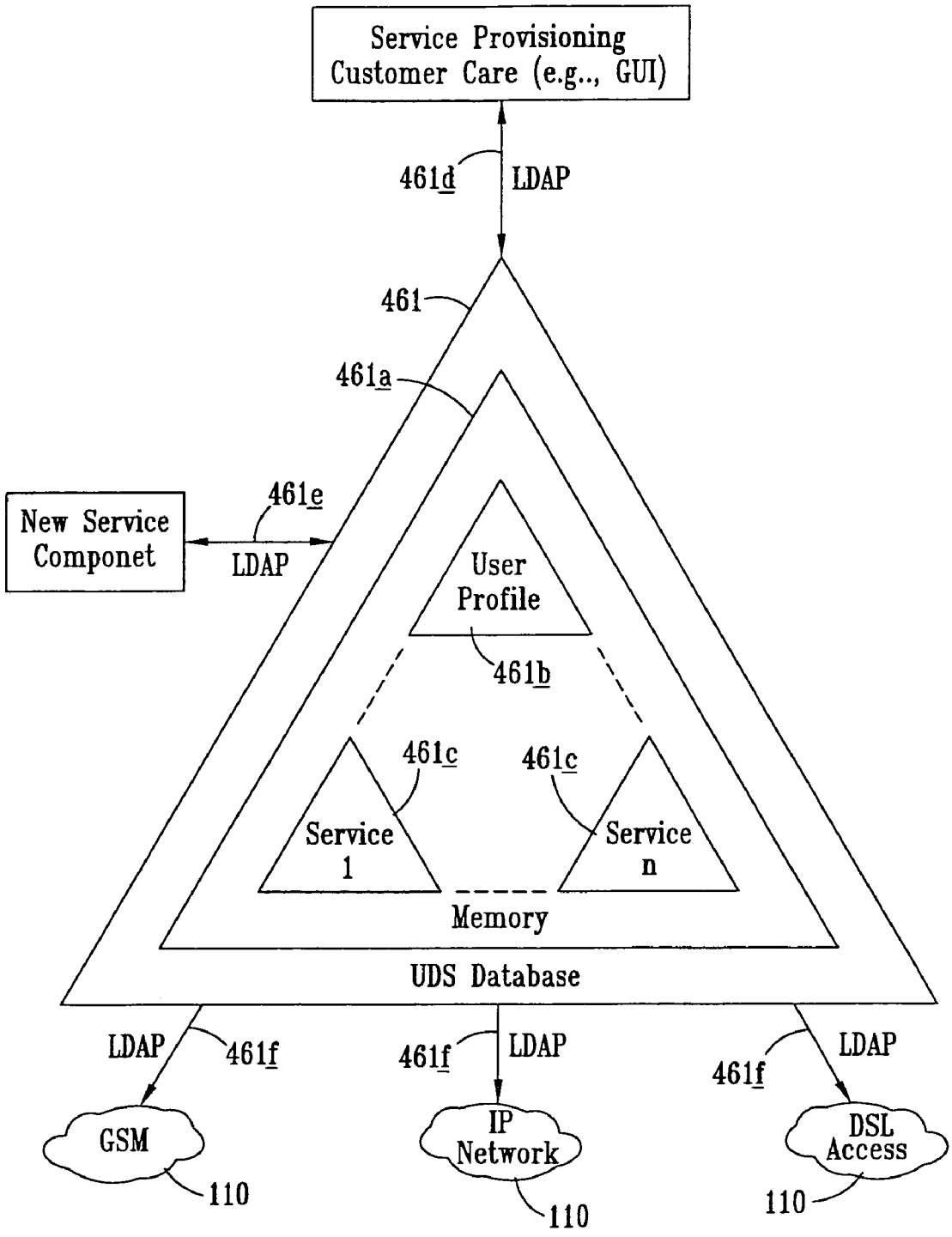

Service Provisioning
Customer Care (e.g.., GUI)
461d
LDAP
461
461a
461e
New Service
Componet
LDAP
User
Profile
461b
461c
461c
Service
1
Service
n
Memory
UDS Database
LDAP
461f
461f
LDAP
461f
LDAP
GSM
110
IP
Network
110
DSL
Access
110

FIG. 7

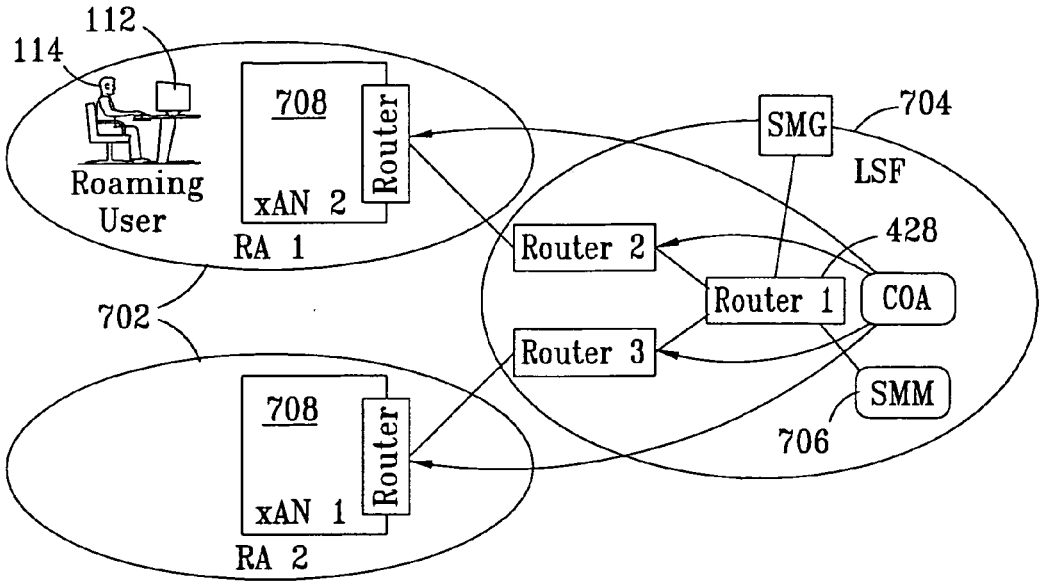

112
114
Roaming User
708
xAN 2
Router
RA 1
702
708
xAN 1
Router
RA 2
SMG
704
LSF
Router 2
428
Router 1
COA
Router 3
SMM
706

FIG. 8

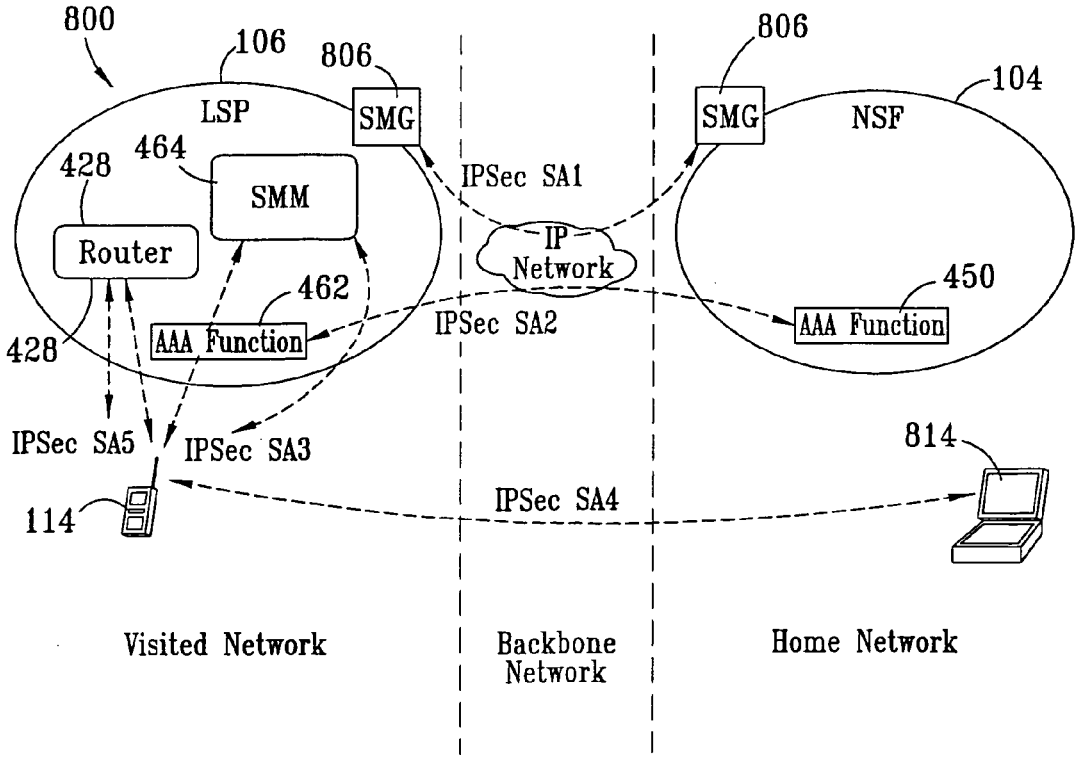

800
106
806
LSP
SMG
464
428
SMM
Router
462
AAA Function
428
IPSec SA1
IP Network
IPSec SA2
806
SMG
104
NSF
450
AAA Function
IPSec SA5
IPSec SA3
114
IPSec SA4
814
Visited Network
Backbone Network
Home Network

FIG. 9

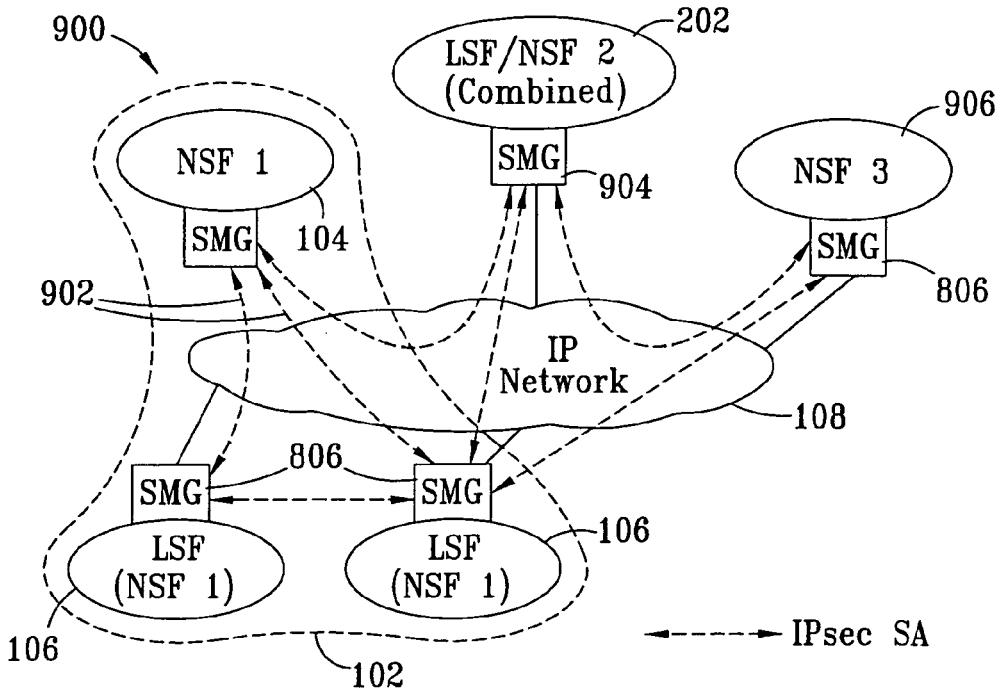

900
LSF/NSF 2
(Combined)
202
SMG
904
906
NSF 1
SMG
104
NSF 3
SMG
806
902
IP
Network
108
806
SMG
SMG
106
LSF
(NSF 1)
LSF
(NSF 1)
106
102
IPsec SA

FIG. 10

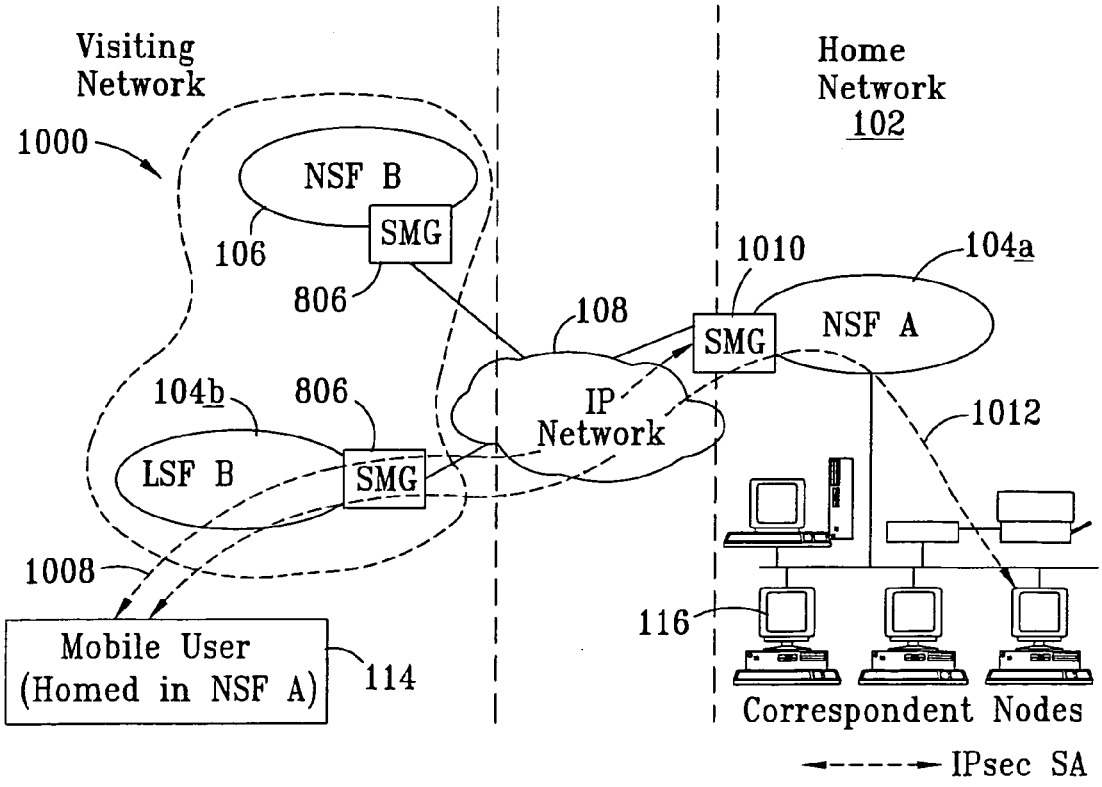
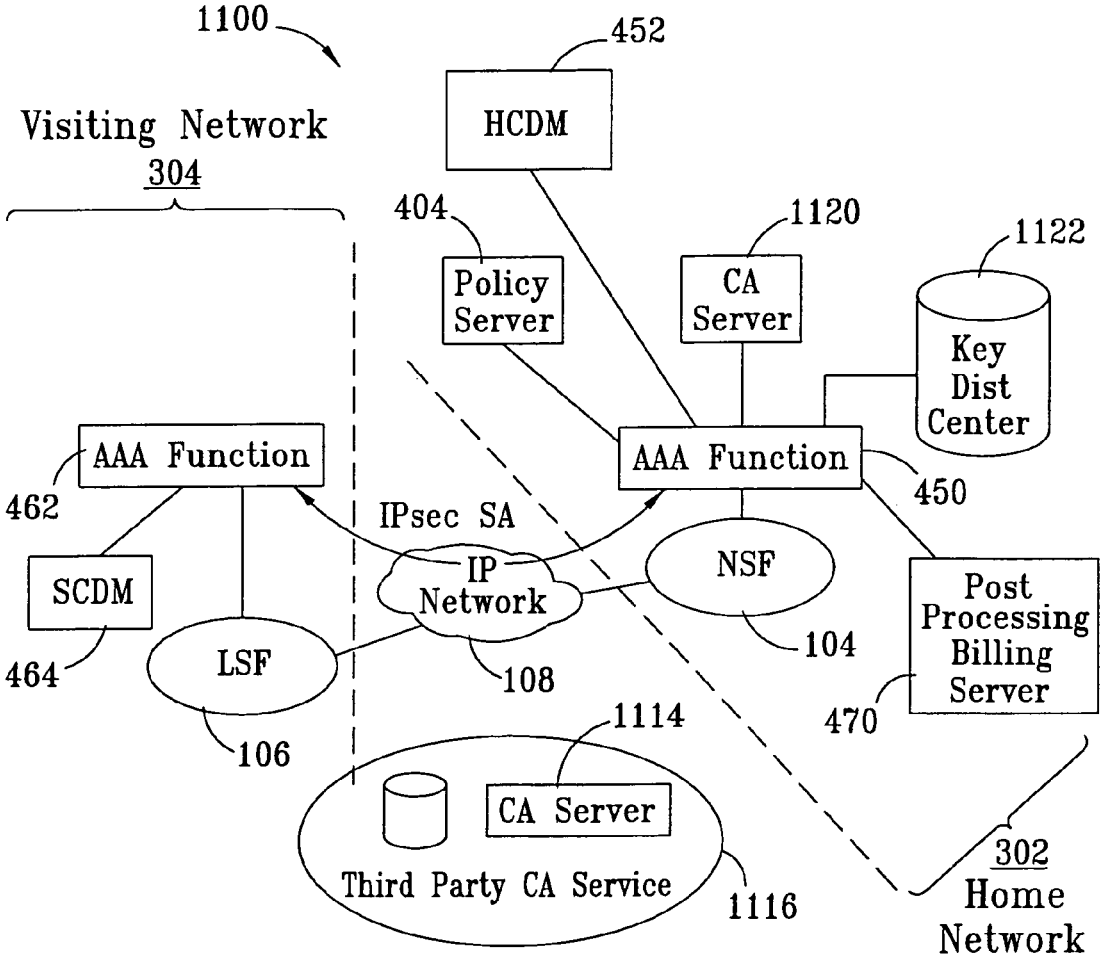

Visiting
Network
Home
Network
102
1000
NSF B
SMG
106
806
1010
104a
NSF A
SMG
108
IP
Network
104b
806
LSF B
SMG
1012
1008
116
Mobile User
(Homed in NSF A)
114
Correspondent Nodes
IPsec SA

FIG. 11


1100
Visiting Network
304
452
HCDM
404
Policy Server
1120
CA Server
1122
Key Dist Center
AAA Function
462
AAA Function
450
IPsec SA
IP Network
NSF
104
SCDM
464
LSF
106
108
Post Processing Billing Server
470
1114
CA Server
Third Party CA Service
1116
302
Home Network

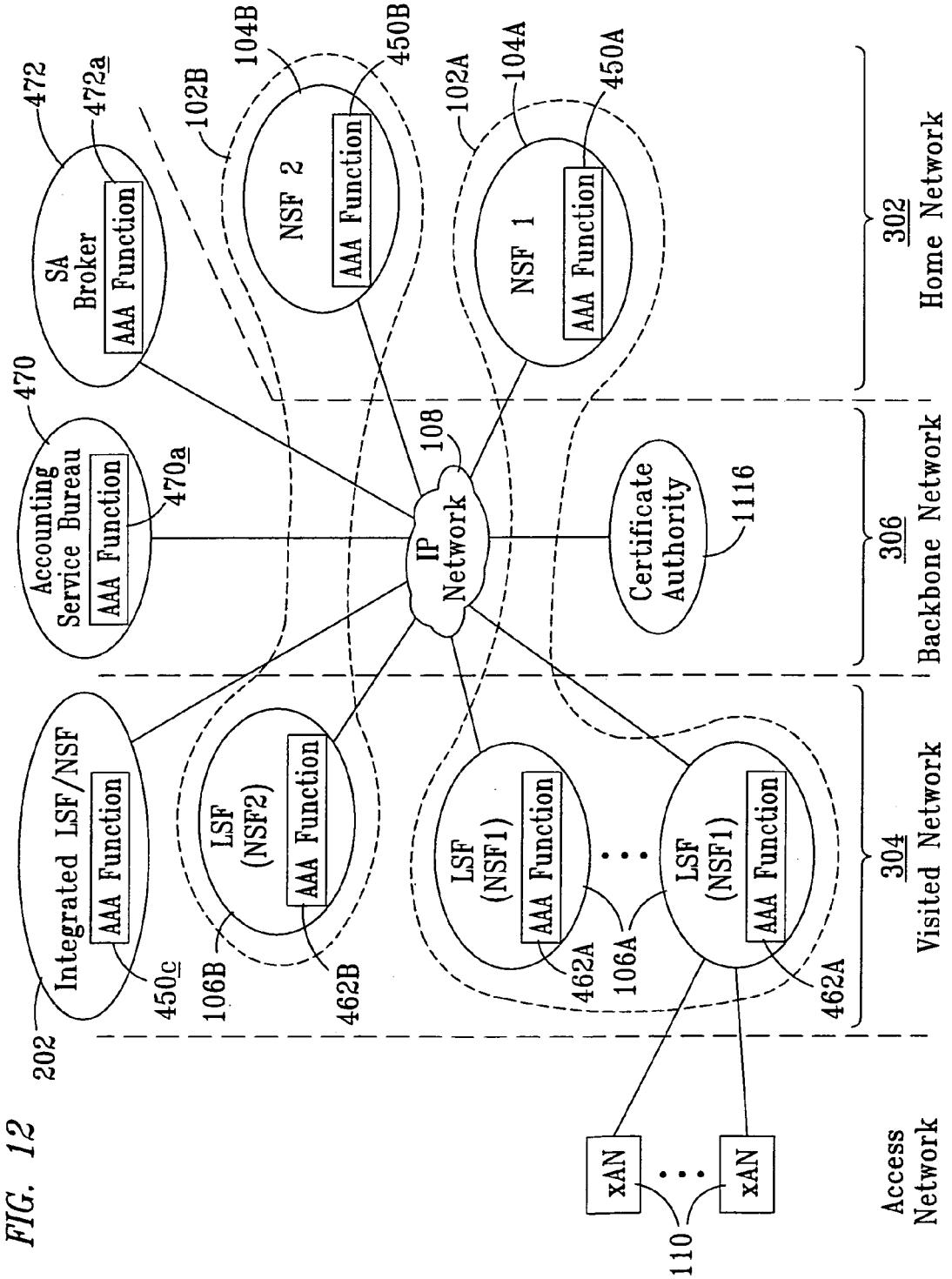

472
472a
SA Broker
AAA Function
102B
104B
450B
NSF 2
AAA Function
102A
104A
450A
NSF 1
AAA Function
302
Home Network
470
Accounting Service Bureau
AAA Function
470a
IP Network
108
Certificate Authority
1116
306
Backbone Network
Integrated LSF/NSF
AAA Function
450c
202
106B
LSF (NSF2)
AAA Function
462B
LSF (NSF1)
AAA Function
462A
106A
LSF (NSF1)
AAA Function
462A
304
Visited Network
xAN
xAN
110
Access Network

FIG. 12

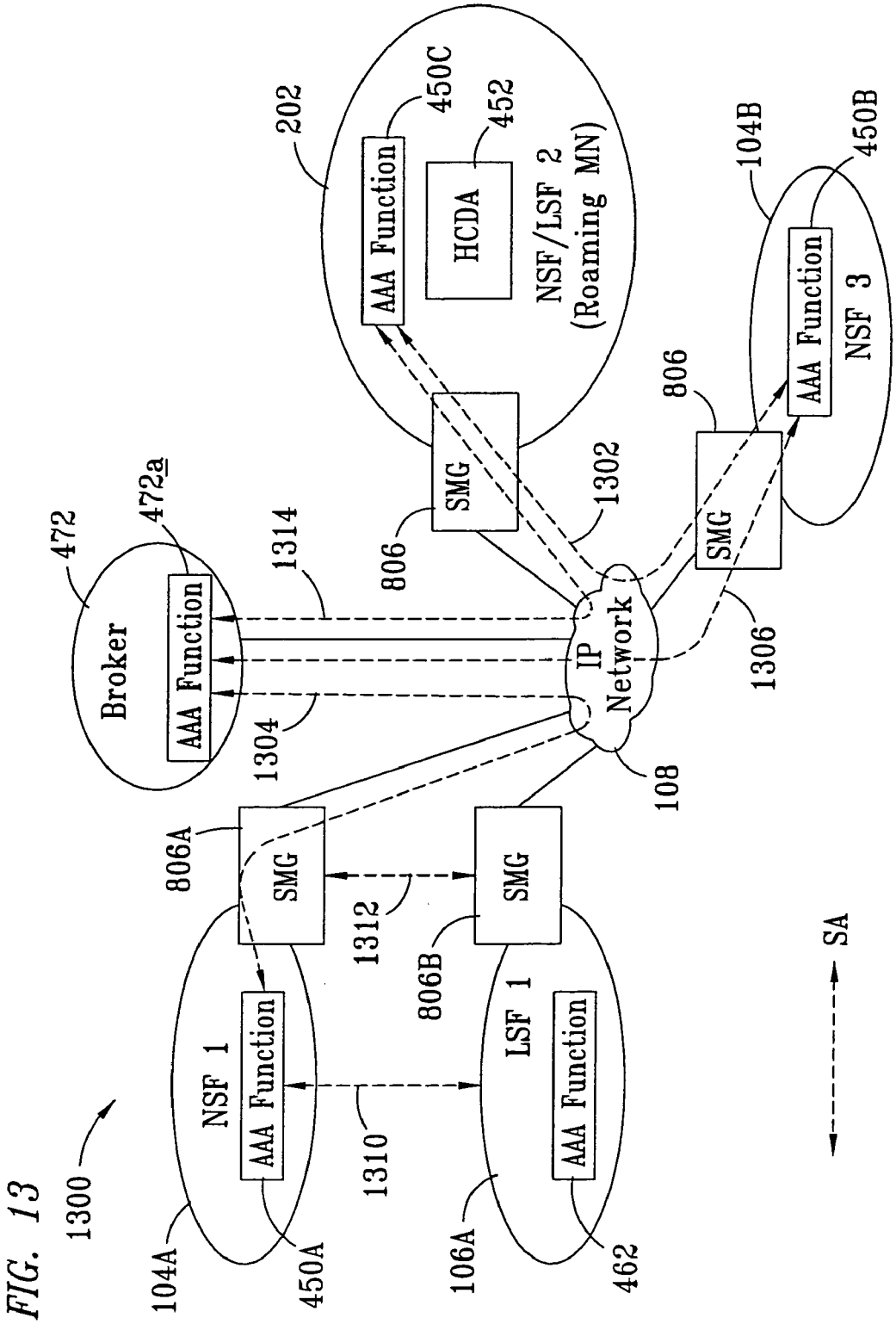

1300
104A
NSF 1
AAA Function
450A
106A
LSF 1
AAA Function
462
1310
806A
SMG
1312
806B
SMG
108
IP Network
1304
1314
472
Broker
472a
AAA Function
806
SMG
1302
202
NSF/LSF 2 (Roaming MN)
AAA Function
450C
HCDA
452
806
SMG
1306
104B
NSF 3
AAA Function
450B
SA

FIG. 13

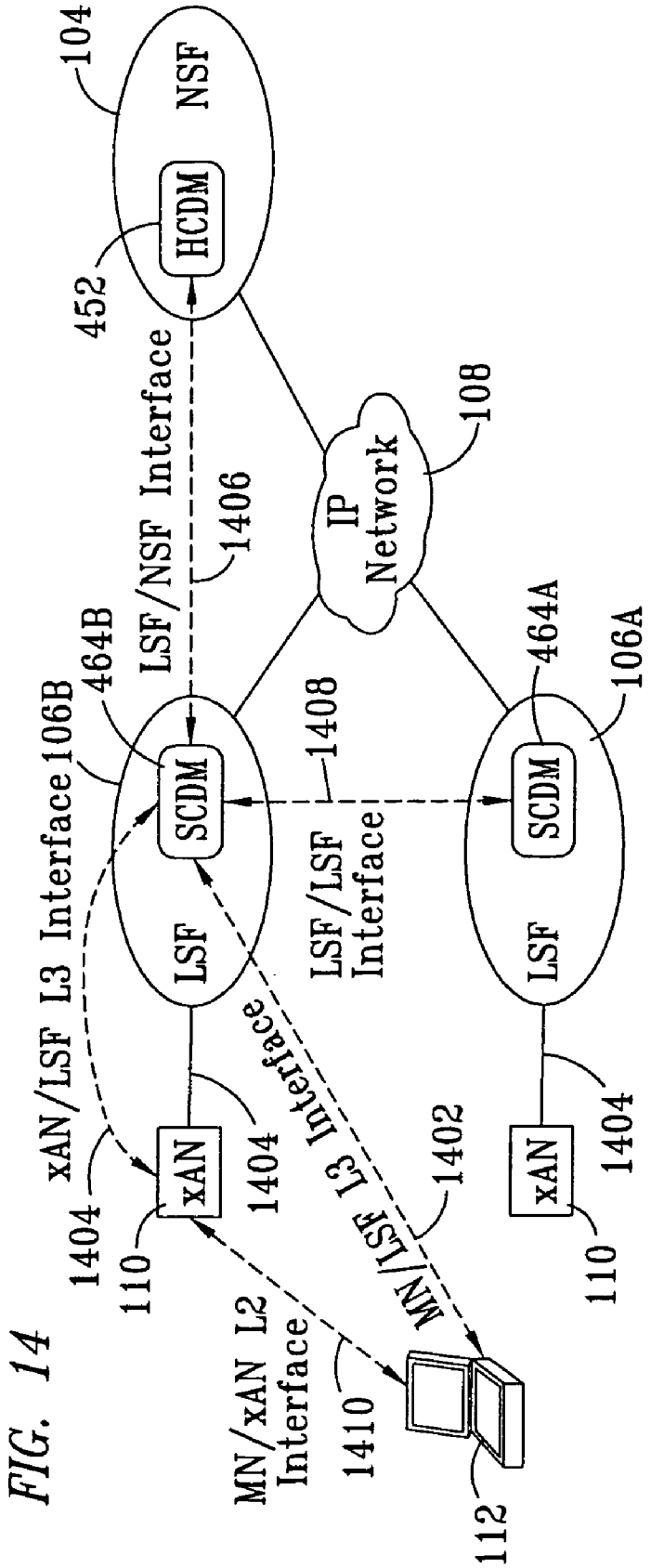

104
NSF
HCDM
452
LSF/NSF Interface
1406
IP Network
108
464B
106B
xAN/LSF L3 Interface
SCDM
1408
LSF/LSF Interface
464A
106A
SCDM
LSF
LSF
1404
xAN
110
1404
MN/xAN L2 Interface
1410
MN/LSF L3 Interface
1402
xAN
1404
110
112

FIG. 14

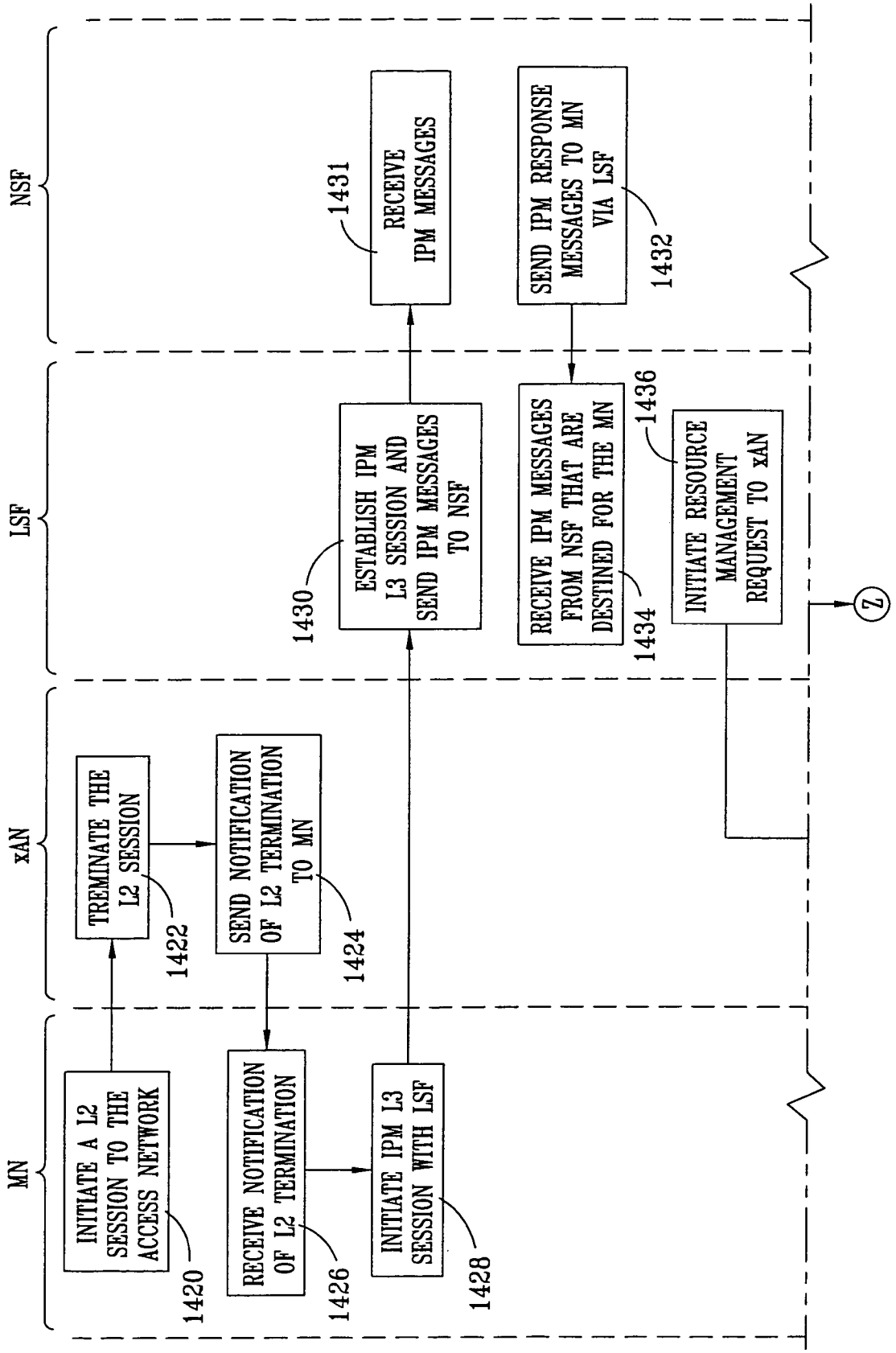

NSF
LSF
xAN
MN
INITIATE A L2 SESSION TO THE ACCESS NETWORK
1420
TREMINATE THE L2 SESSION
1422
SEND NOTIFICATION OF L2 TERMINATION TO MN
1424
RECEIVE NOTIFICATION OF L2 TERMINATION
1426
INITIATE IPM L3 SESSION WITH LSF
1428
ESTABLISH IPM L3 SESSION AND SEND IPM MESSAGES TO NSF
1430
RECEIVE IPM MESSAGES
1431
SEND IPM RESPONSE MESSAGES TO MN VIA LSF
1432
RECEIVE IPM MESSAGES FROM NSF THAT ARE DESTINED FOR THE MN
1434
INITIATE RESOURCE MANAGEMENT REQUEST TO xAN
1436
Z

FIG. 14A

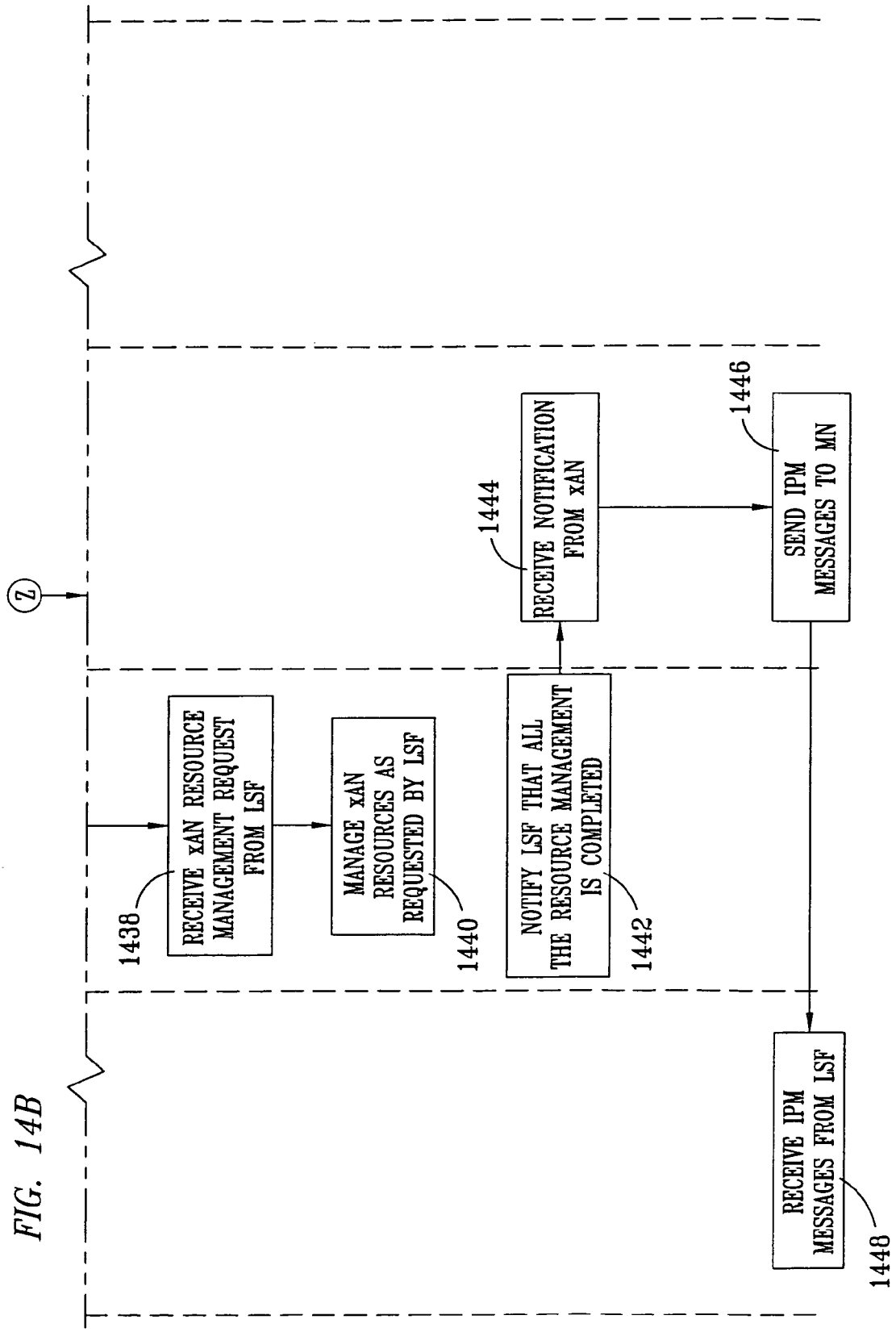

Z
RECEIVE xAN RESOURCE MANAGEMENT REQUEST FROM LSF
1438
MANAGE xAN RESOURCES AS REQUESTED BY LSF
1440
NOTIFY LSF THAT ALL THE RESOURCE MANAGEMENT IS COMPLETED
1442
RECEIVE NOTIFICATION FROM xAN
1444
SEND IPM MESSAGES TO MN
1446
RECEIVE IPM MESSAGES FROM LSF
1448

FIG. 14B

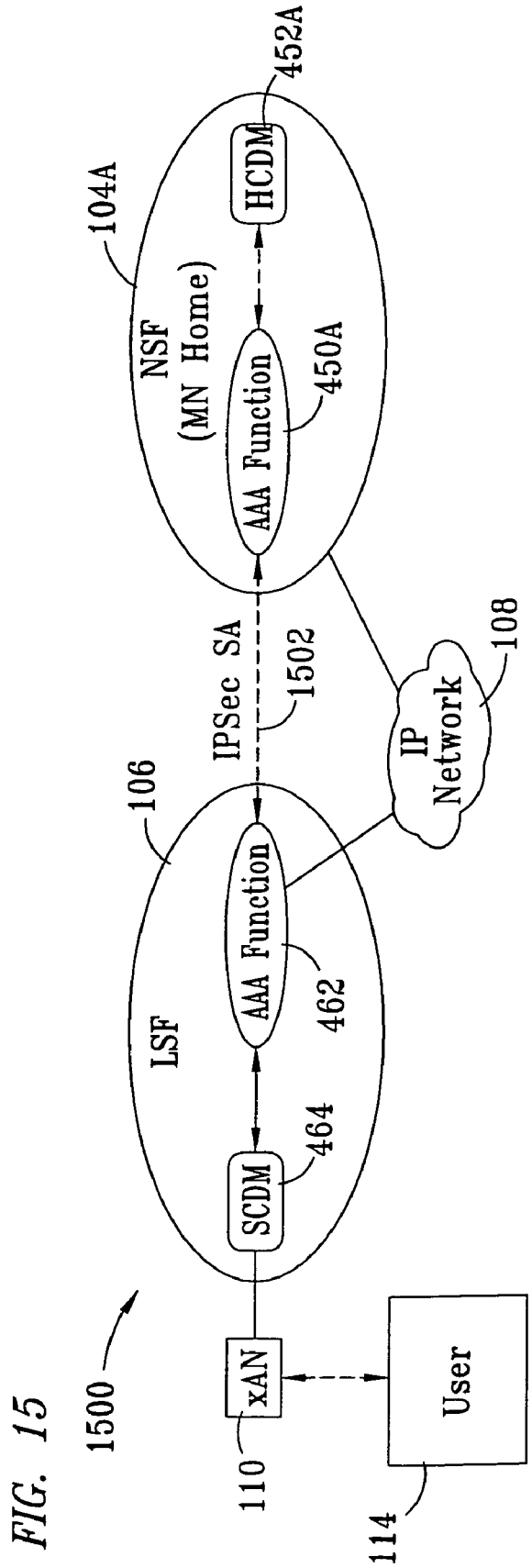

1500
104A
NSF
(MN Home)
HCDM
452A
AAA Function
450A
IPSec SA
1502
IP
Network
108
106
LSF
AAA Function
462
SCDM
464
xAN
110
User
114

FIG. 15

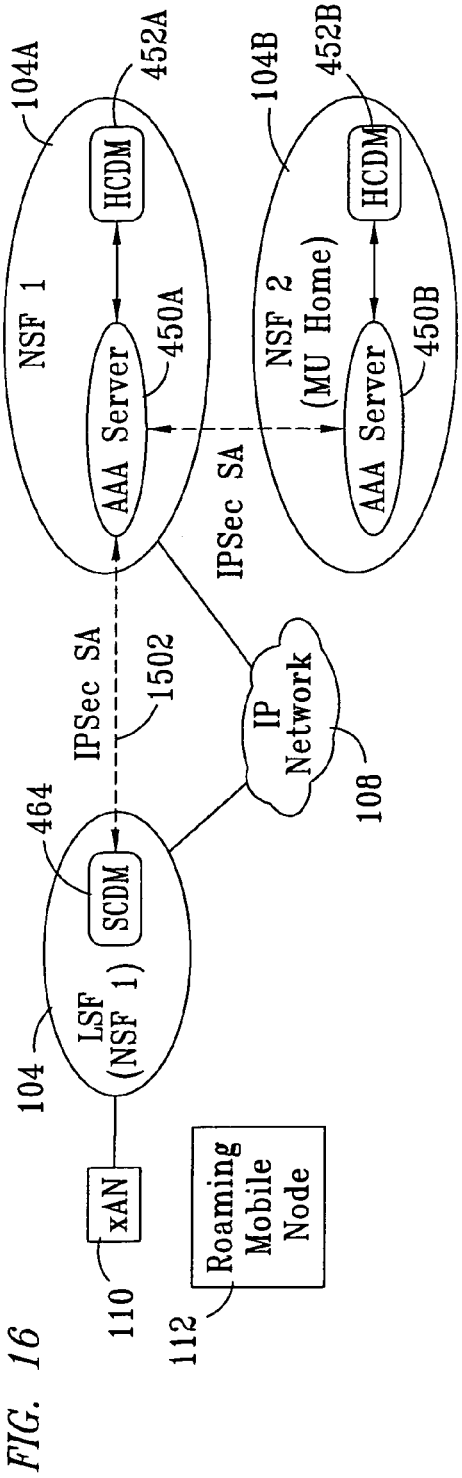

104A
NSF 1
HCDM
452A
AAA Server
450A
104B
NSF 2
(MU Home)
HCDM
452B
AAA Server
450B
IPSec SA
IPSec SA
1502
464
SCDM
LSF
(NSF 1)
104
IP
Network
108
xAN
110
Roaming
Mobile
Node
112

FIG. 16

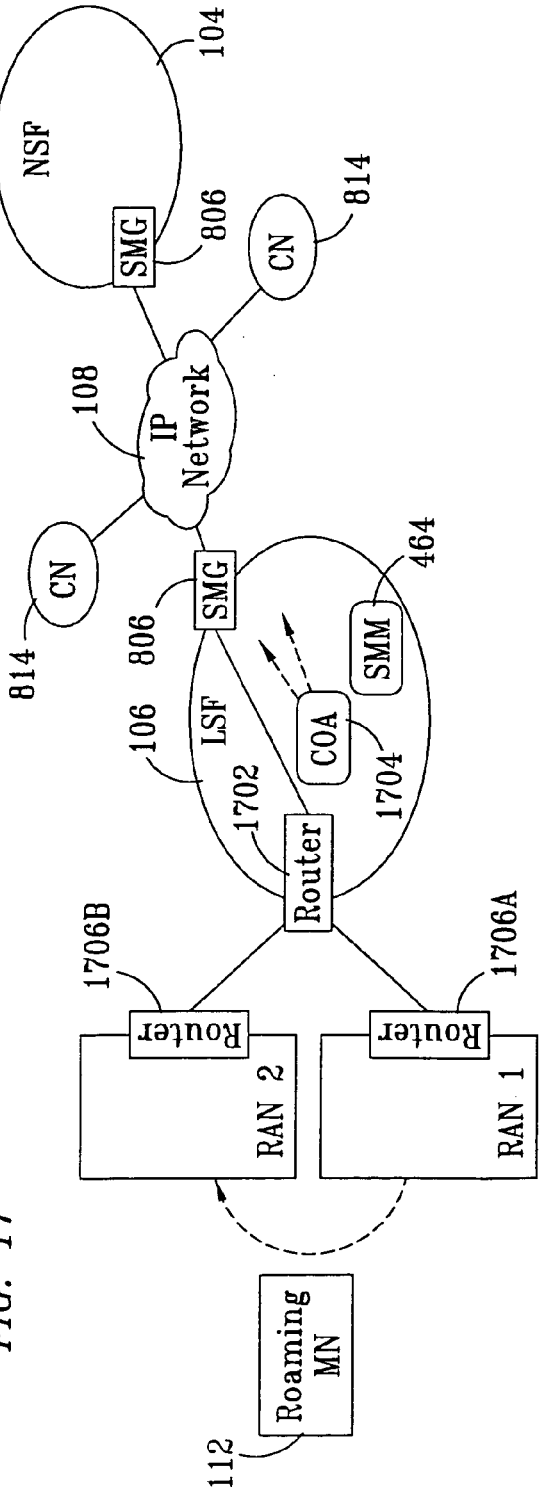

NSF
104
SMG
806
CN
814
108
IP
Network
814
CN
806
SMG
464
SMM
106
LSF
1702
COA
1704
Router
1706B
1706A
Router
Router
RAN 2
RAN 1
112
Roaming
MN

FIG. 17

FIG. 18

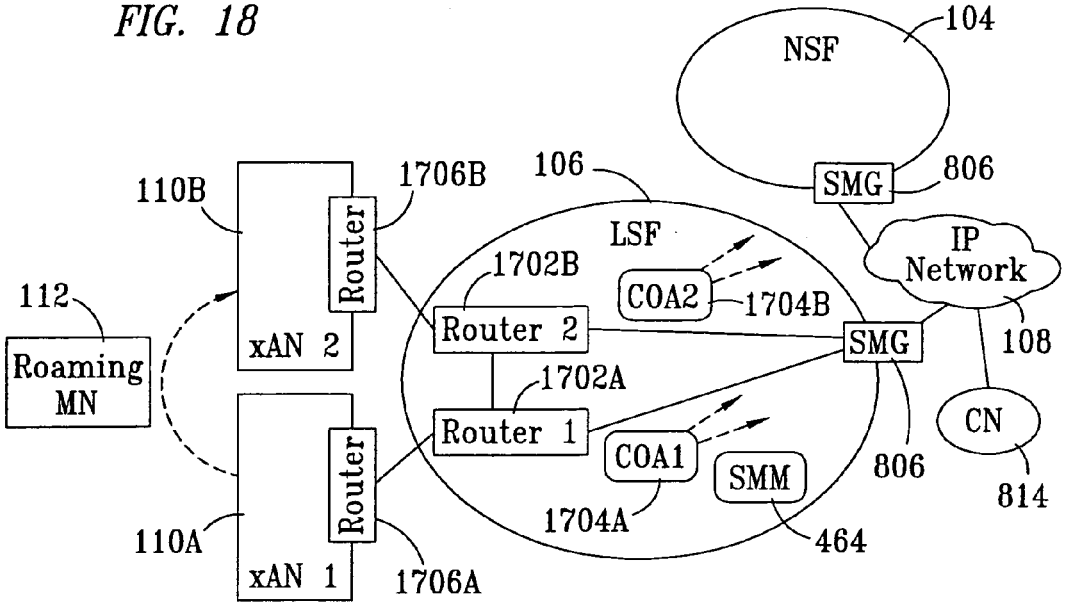

NSF
104
SMG
806
110B
1706B
106
LSF
IP
Network
Router
1702B
COA2
1704B
112
Roaming
MN
xAN 2
Router 2
SMG
108
1702A
Router 1
CN
COA1
806
SMM
814
110A
1704A
464
xAN 1
1706A

FIG. 19

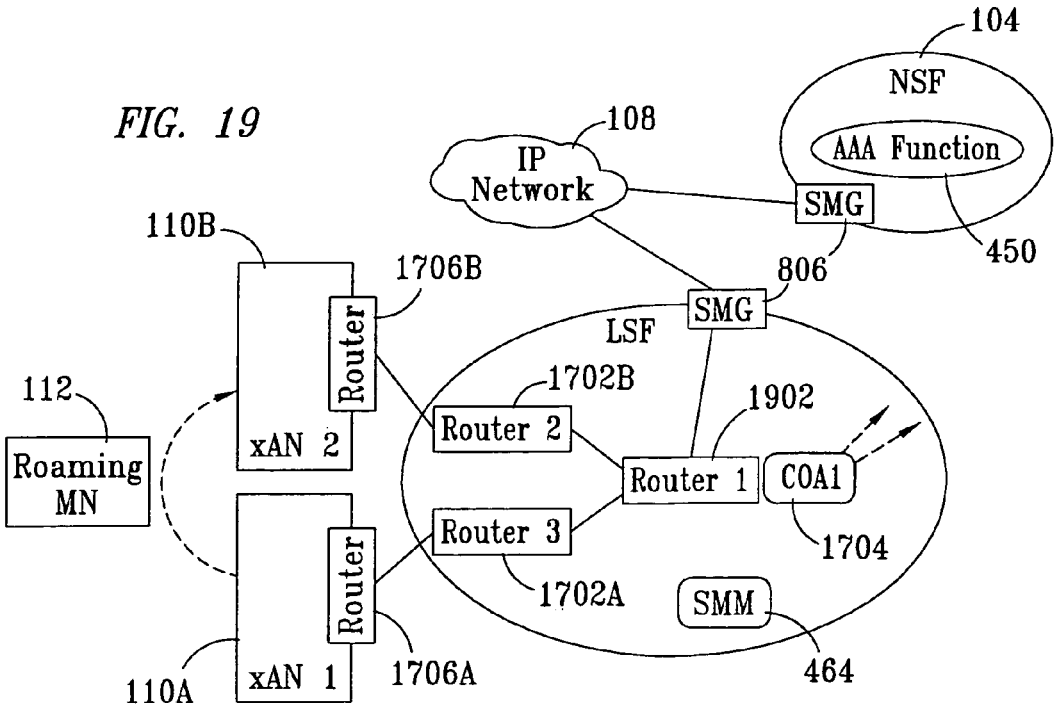

104
NSF
AAA Function
108
IP
Network
SMG
450
110B
806
1706B
SMG
LSF
Router
1702B
1902
112
Roaming
MN
xAN 2
Router 2
Router 1
COA1
Router 3
1704
1702A
SMM
110A
xAN 1
1706A
464

FIG. 20

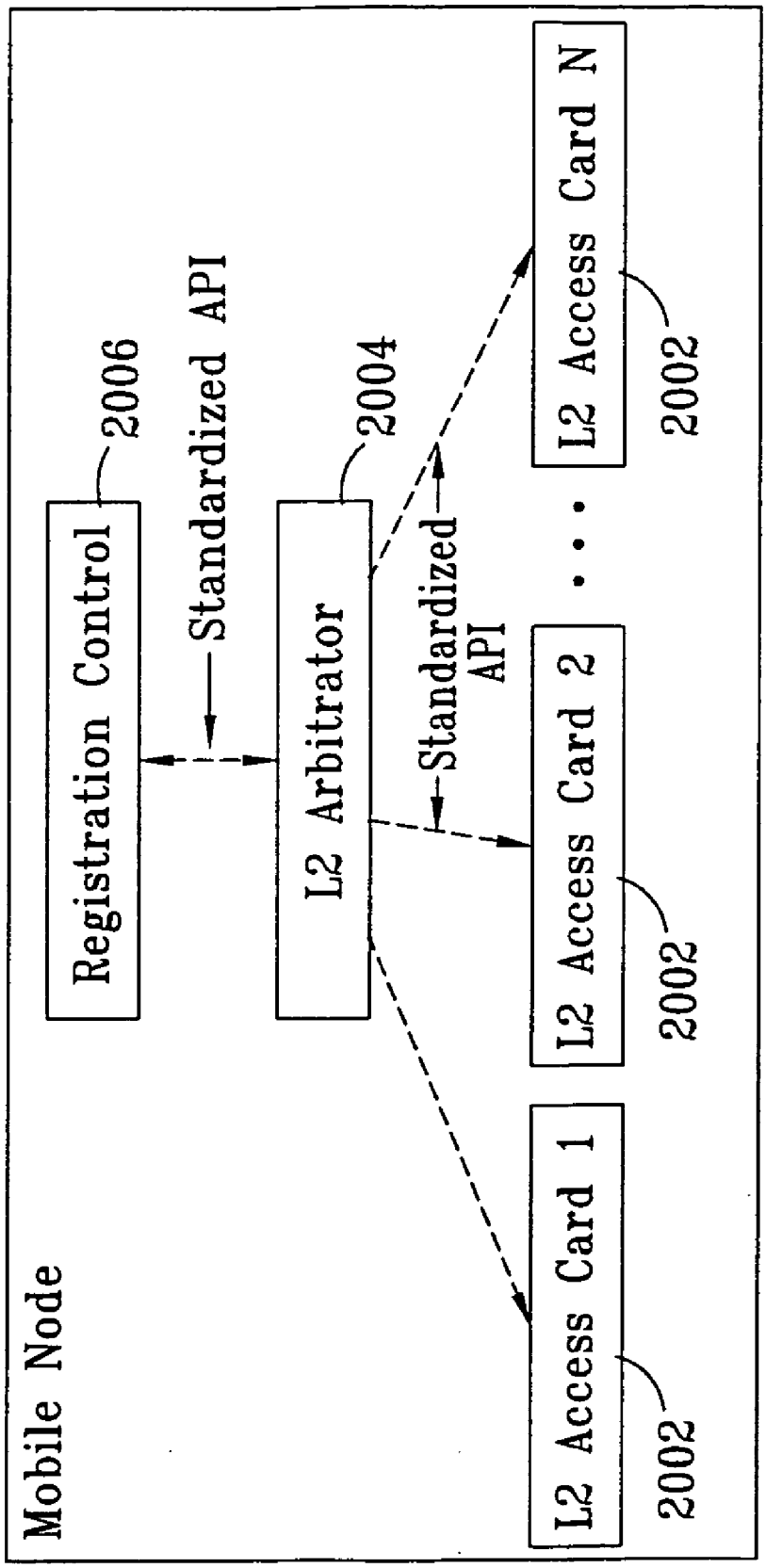

Mobile Node
Registration Control
2006
Standardized API
L2 Arbitrator
2004
Standardized API
L2 Access Card 1
2002
L2 Access Card 2
2002
• • •
L2 Access Card N
2002

FIG. 20A

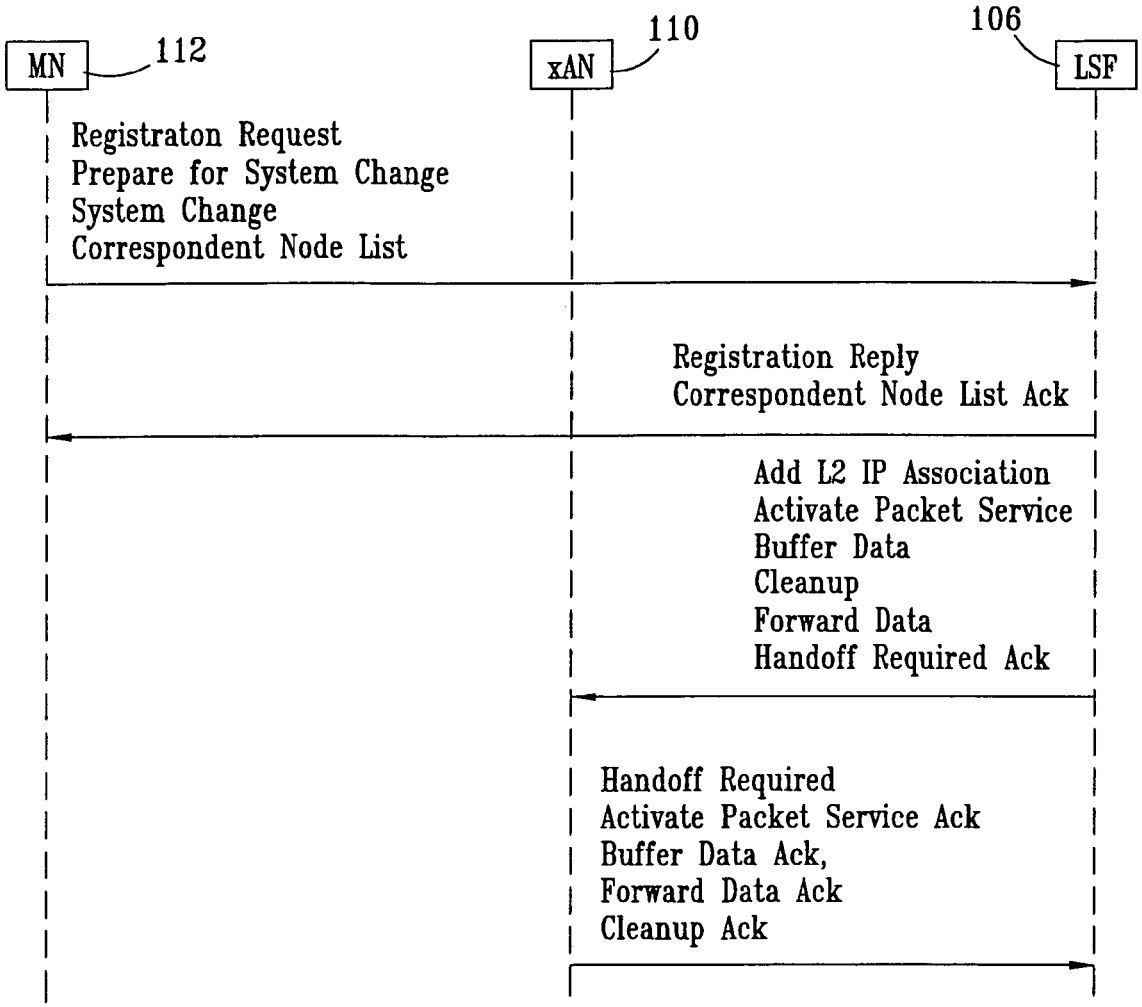


FIG. 20B

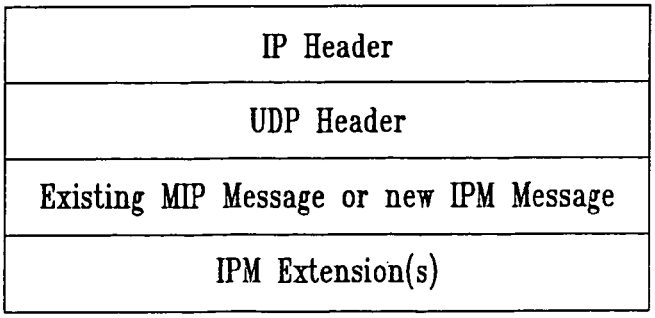
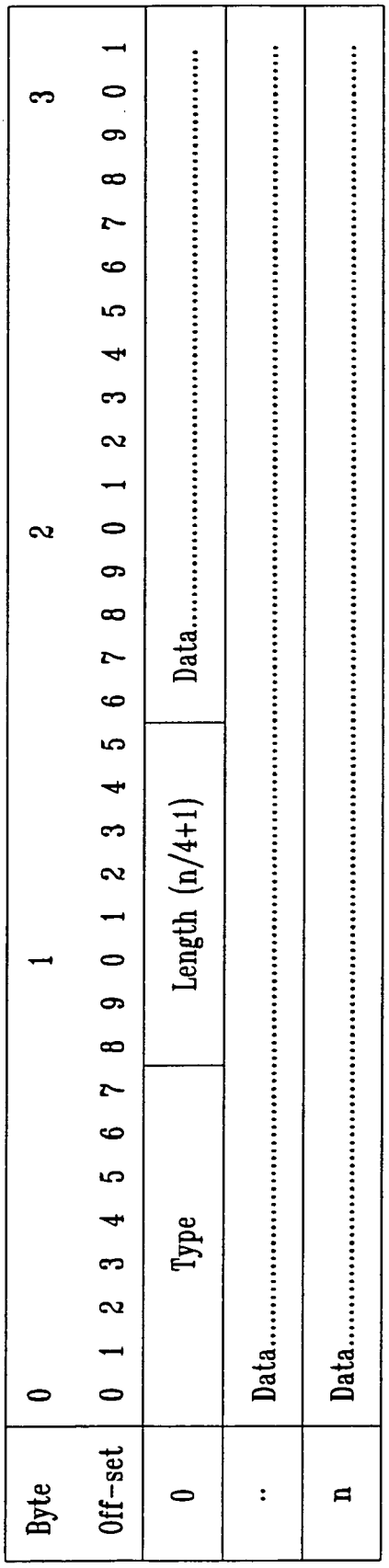
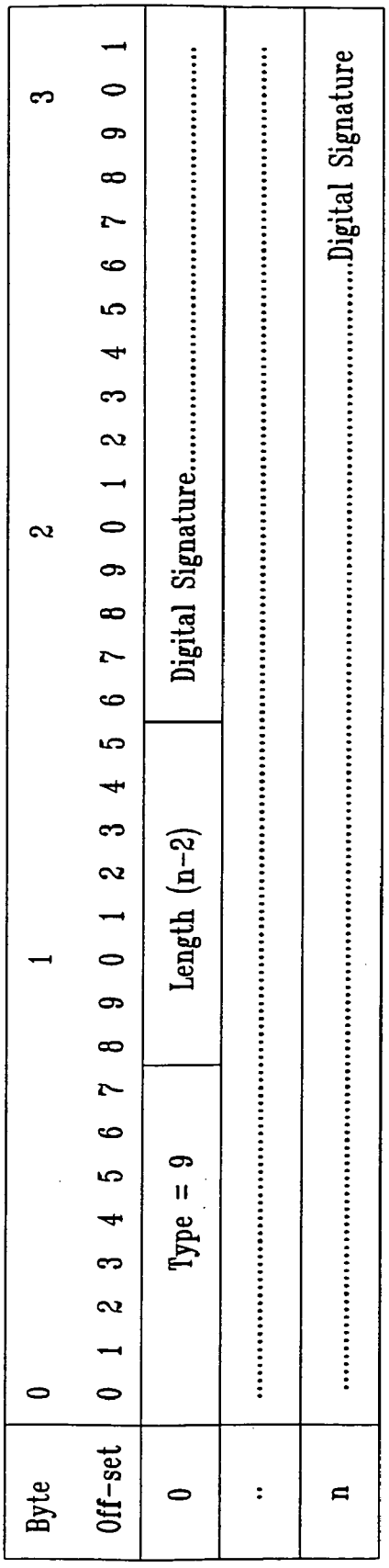


Fig. 20C



Byte	0								1								2								3							
Off-set	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
0	Type								Length (n/4+1)								Data.....															
..	Data.....																															
n	Data.....																															

Fig. 20D



Byte	0								1								2								3							
Off-set	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
0	Type = 9								Length (n-2)								Digital Signature.....															
..	.....																															
n	.....Digital Signature																															

Fig. 20E

Byte Off-set	0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
0	Type = 10 | Length (n-2) | Reserved
..	<User NAI 1+ User IP Address 1+ Service Definition for User>++ <User NAI 2+ User IP Address 2+ Service Definition for User>++.....
n	.....<User NAI n+ User IP Address n+ Service Definition for User>

Fig. 20F

Byte Off-set	0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
0	Type = 11 | Length (n-2) | <CN 1 IP Address> + <CN 2 IP Address>+.....
..	.....
n	.....<CN n IP Address>

FIG. 20G

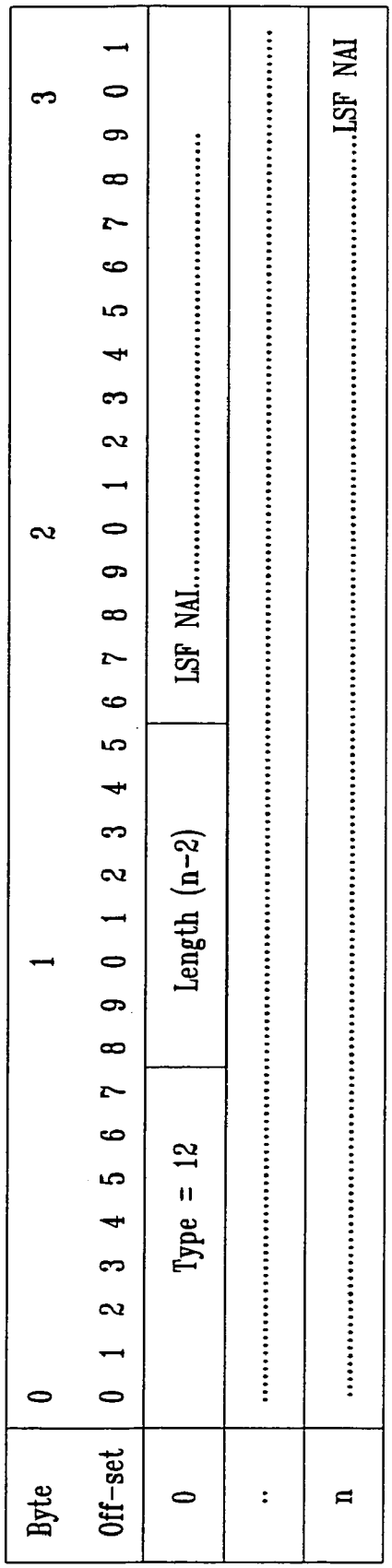


FIG. 20H

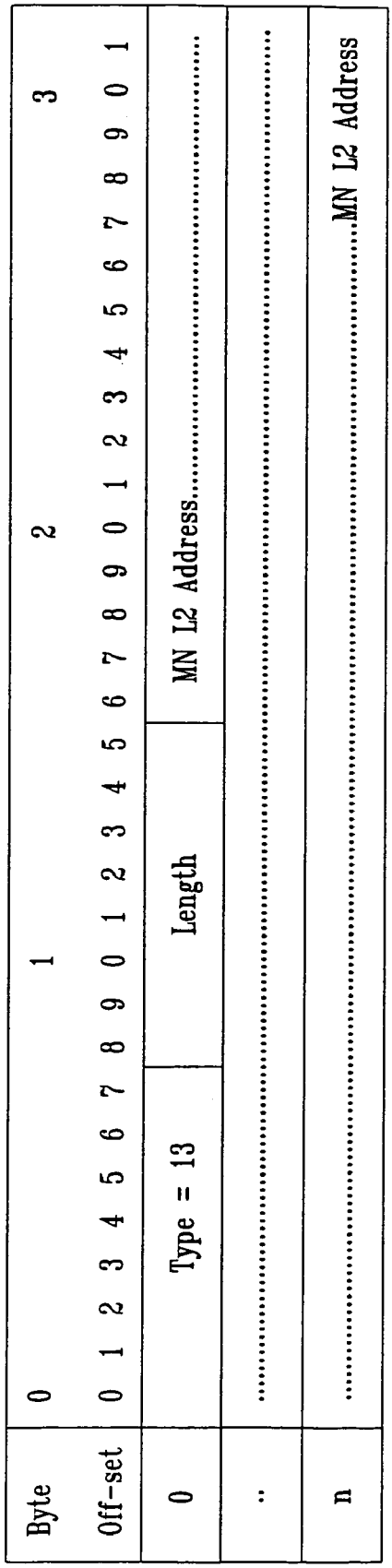


FIG. 20I

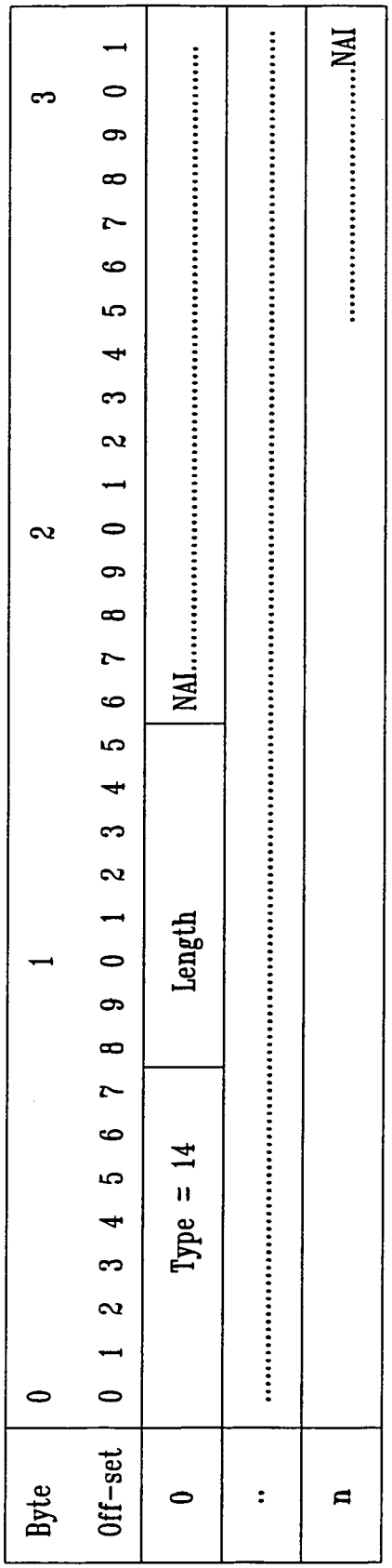


FIG. 20J

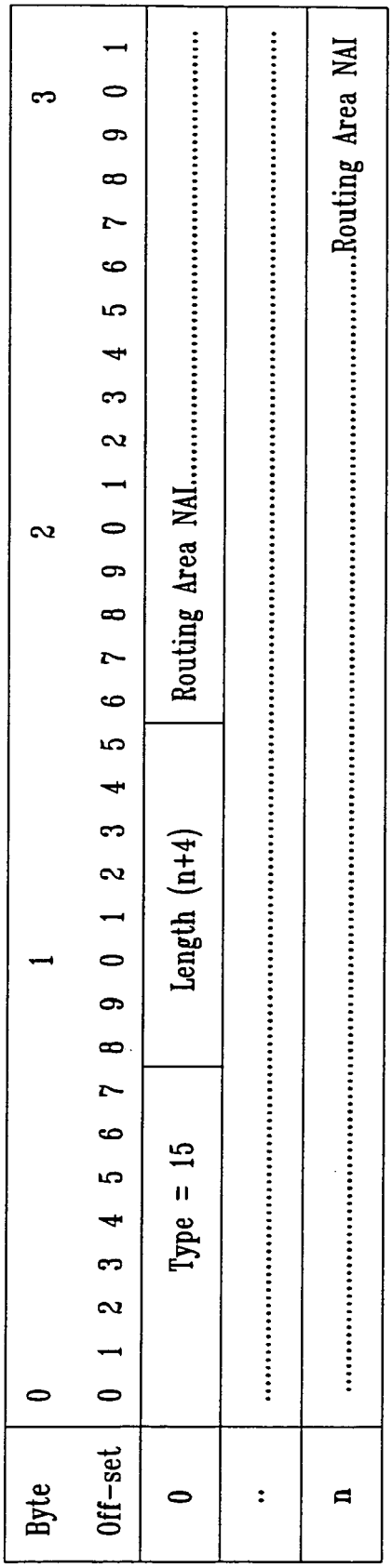


FIG. 20K

Byte Off-set	0 1 2 3 4 5 6 7	8 9 0 1 2 3 4 5 6 7	8 9 0 1 2 3 4 5 6 7	8 9 0 1
0	Type = 16	Length (n-2)	<Protocol Name 1> + <Protocol Name 2>+.....	
..	.....			
n	.....			<Protocol Name n>

FIG. 20L

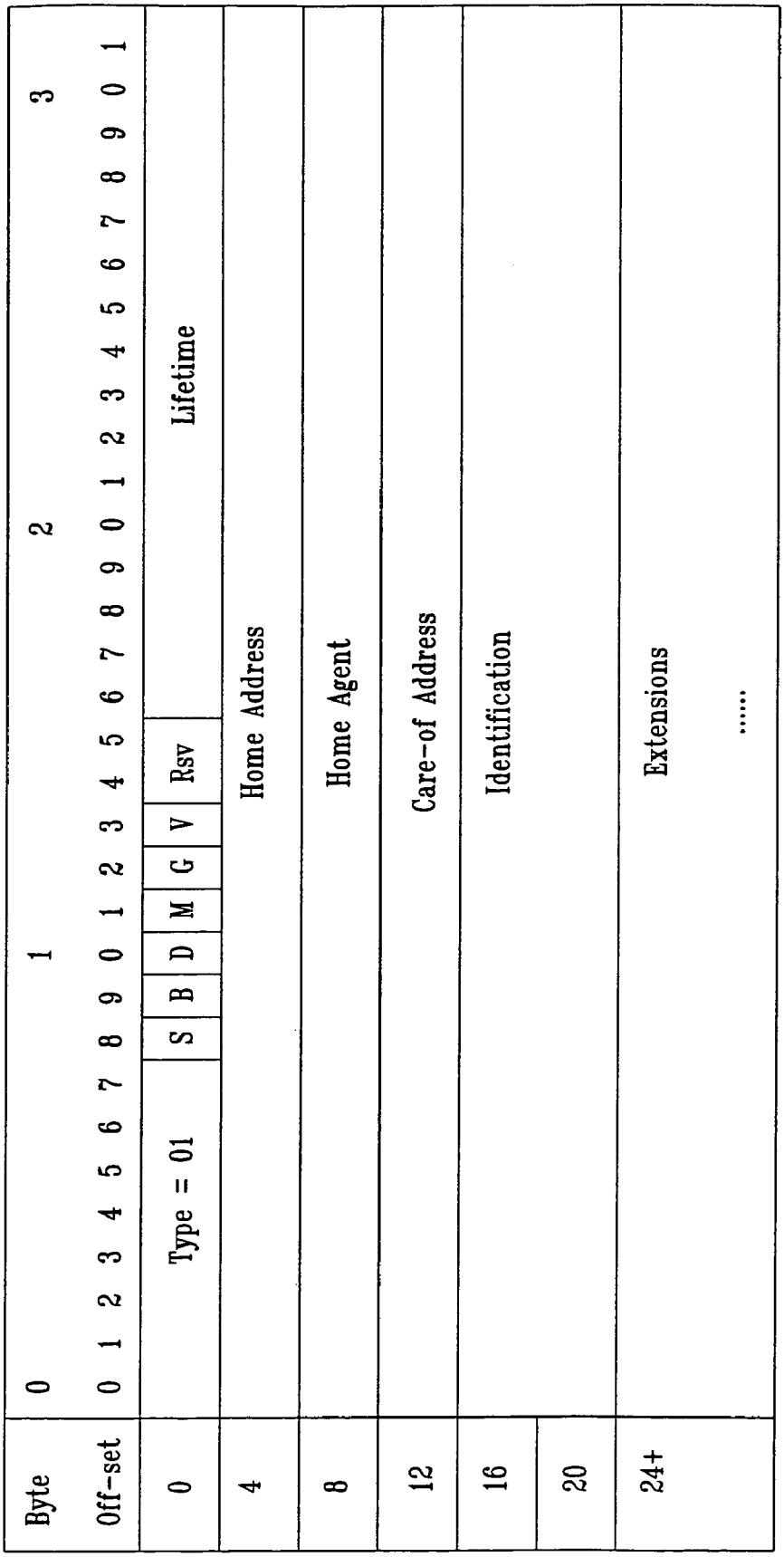

Byte
Off-set
0
1
2
3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
Type = 01
S
B
D
M
G
V
Rsv
Lifetime
Home Address
Home Agent
Care-of Address
Identification
Extensions
.....

FIG. 20M

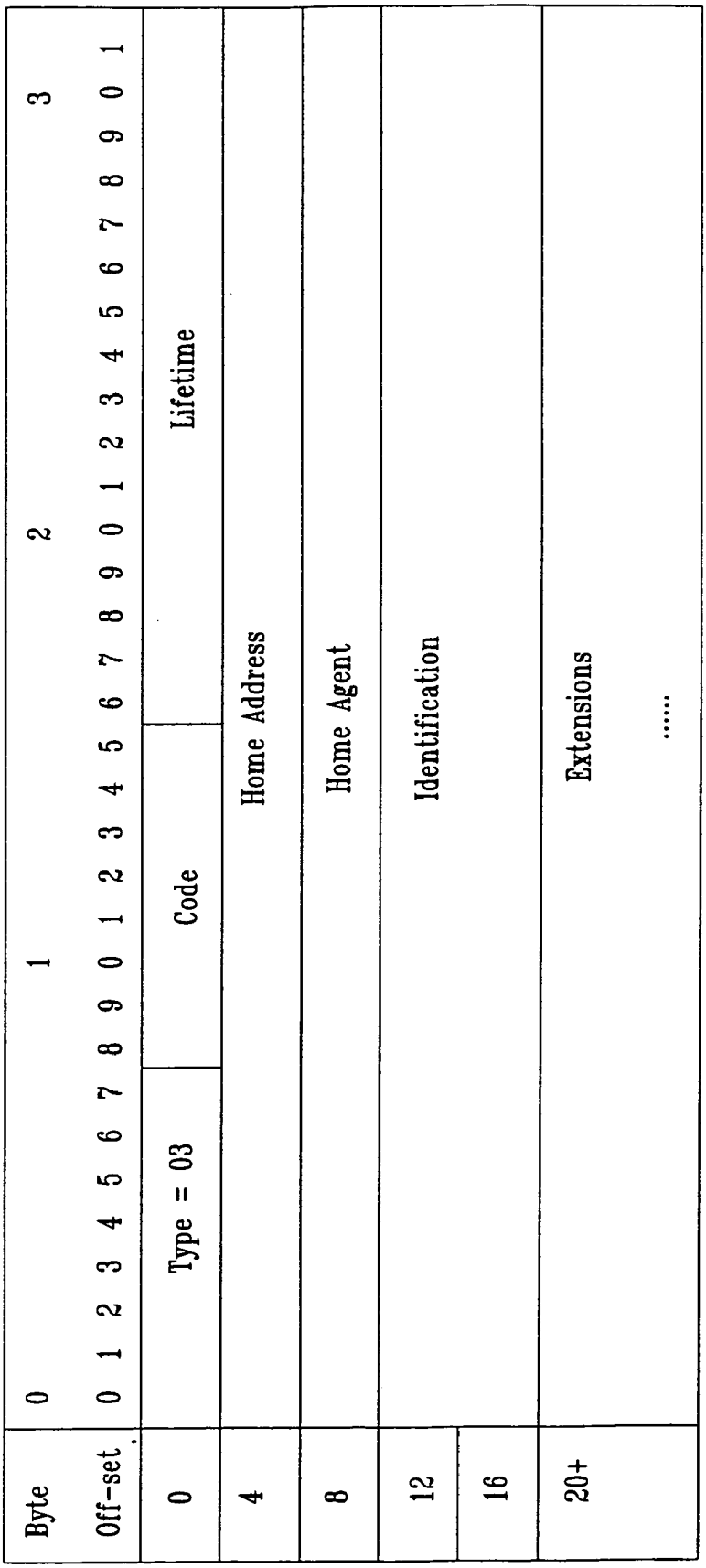

Byte Off-set
0
1
2
3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
Type = 03
Code
Lifetime
Home Address
Home Agent
Identification
Extensions
.....
0
4
8
12
16
20+

FIG. 20N

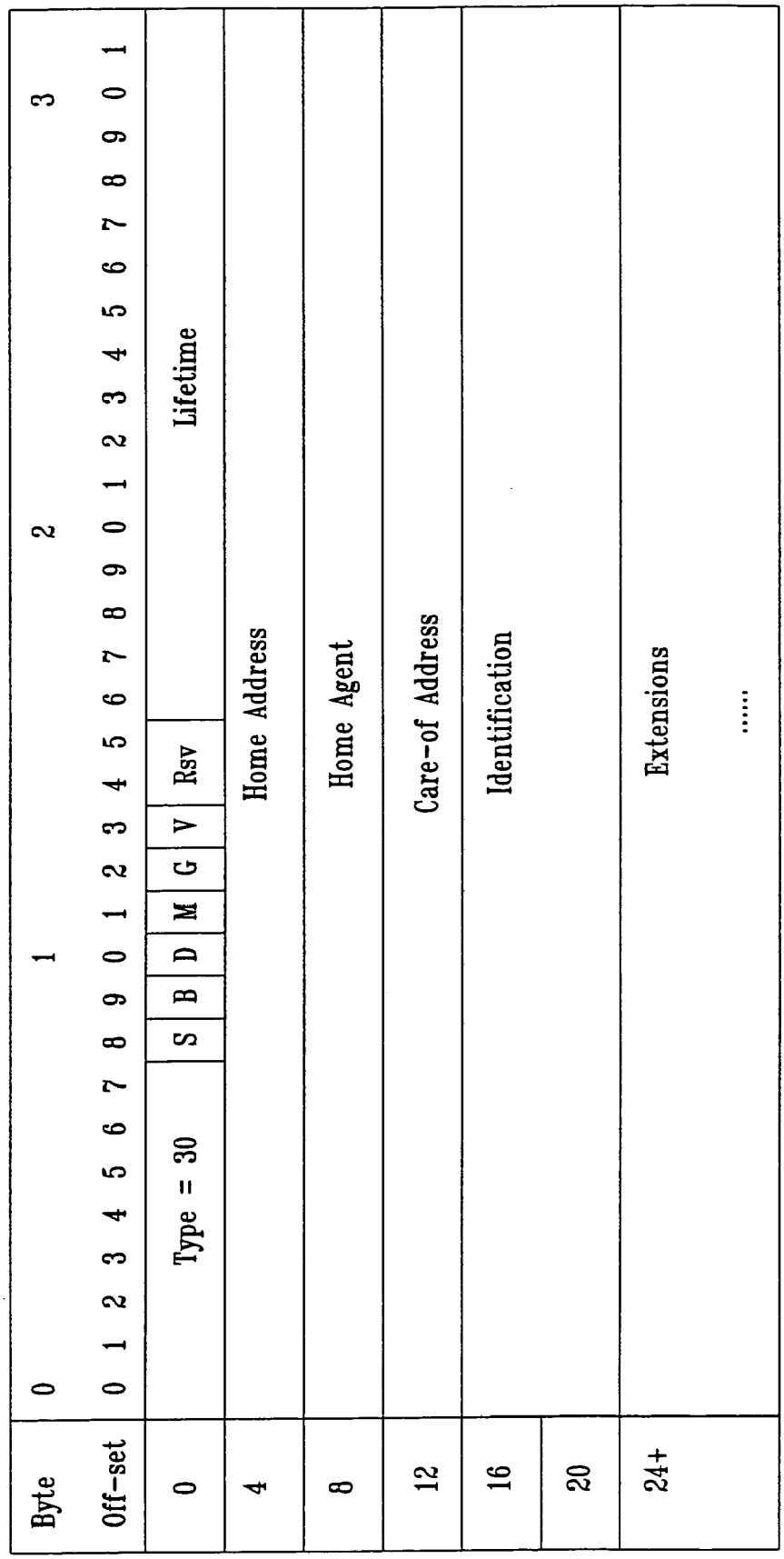

Byte
Off-set
0
1
2
3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
Type = 30
S
B
D
M
G
V
Rsv
Lifetime
Home Address
Home Agent
Care-of Address
Identification
Extensions
.....

FIG. 20O

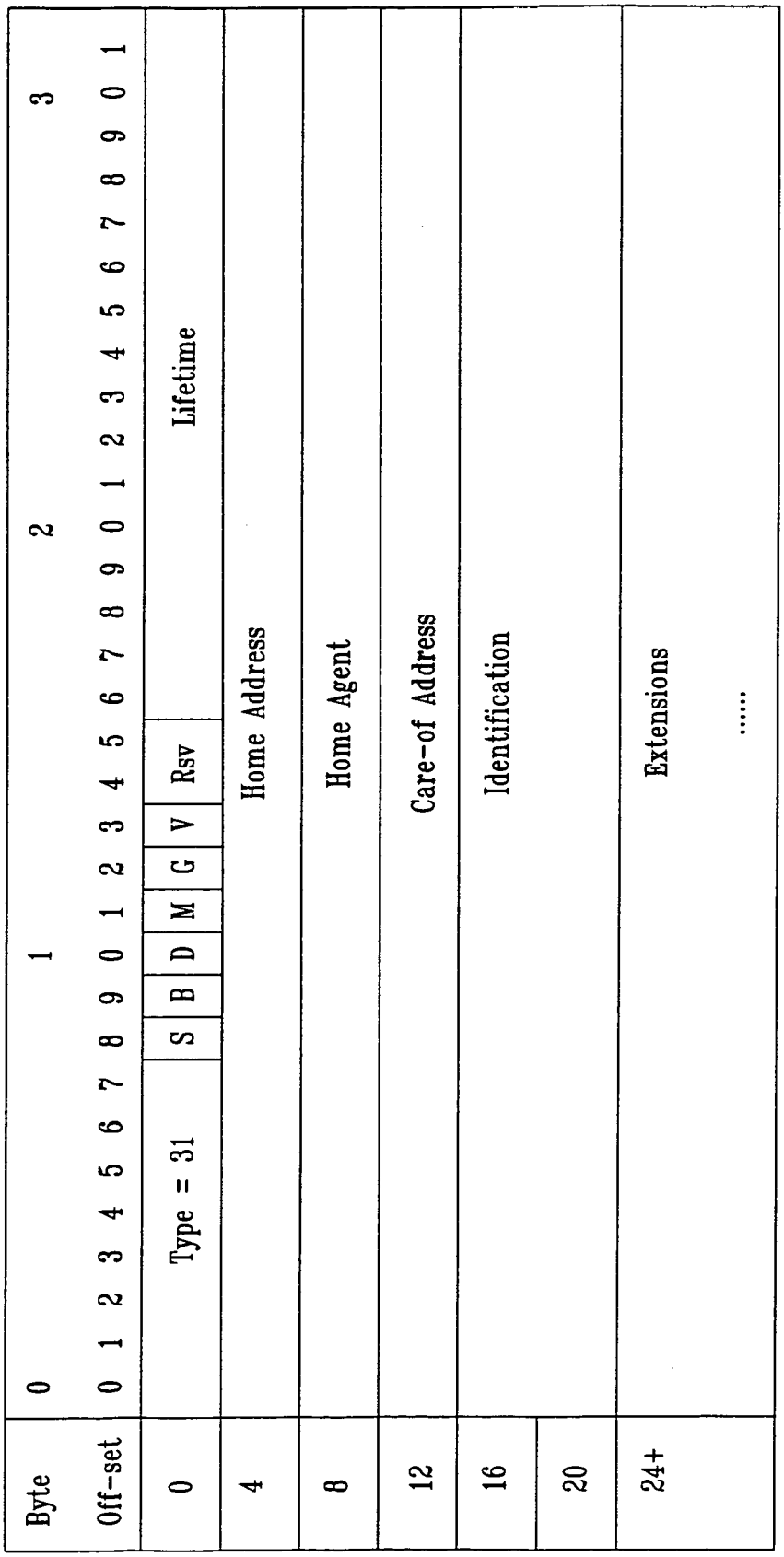

Byte
Off-set
0
1
2
3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
Type = 31
S
B
D
M
G
V
Rsv
Lifetime
Home Address
Home Agent
Care-of Address
Identification
Extensions
.....

FIG. 20P

Byte Off-set	0 1 2 3 4 5 6 7	8 9 10 11 12 13 14 15	16 17 18 19 20 21 22 23	24 25 26 27 28 29 30 31
0	Type	Length (n/4+1)	Data.....	
..	Data.....			
n	Data.....			

FIG. 20Q

Byte Off-set	0 1 2 3 4 5 6 7	8 9 10 11 12 13 14 15	16 17 18 19 20 21 22 23	24 25 26 27 28 29 30 31
0	Type = 40	Length	Reserved	
4+	Extensions			

FIG. 20R

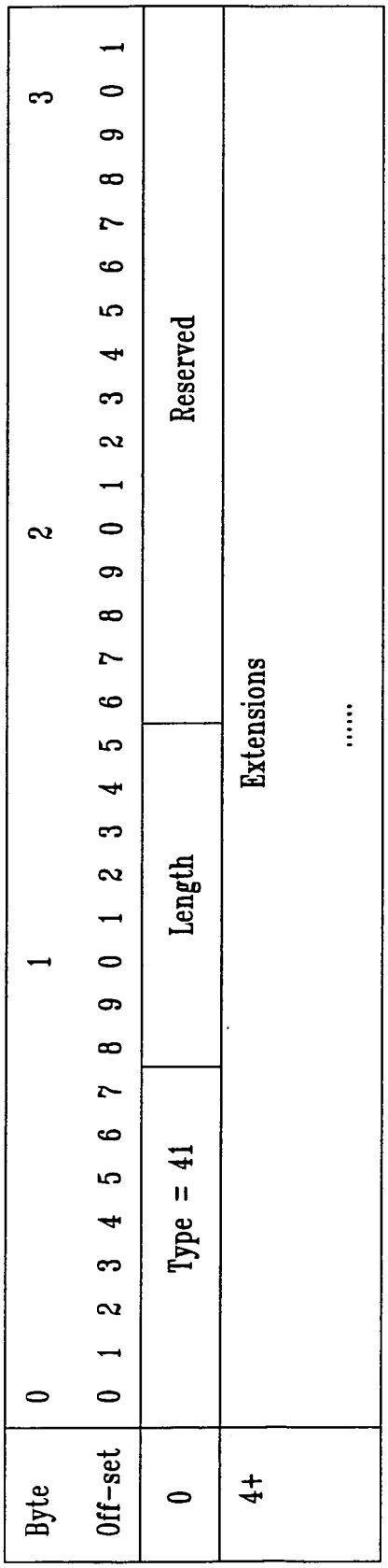


FIG. 20S

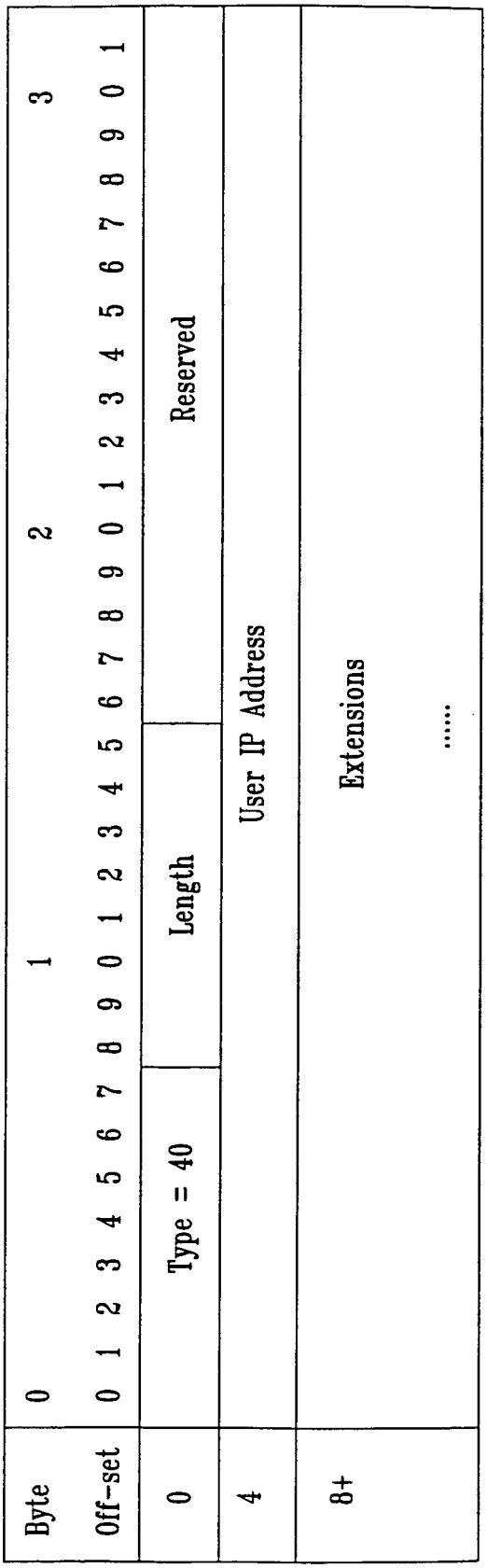


FIG. 20T

Byte	0								1								2								3			
Off-set	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
0	Type = 42								Length								Reserved															
4	User IP Address																															

FIG. 20U

Byte	0								1								2								3			
Off-set	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
0	Type = 43								Length								Result Code								Reserved							
4	User IP Address																															

FIG. 20V

Byte	0								1								2								3			
Off-set	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
0	Type = 44								Length								Reserved															
4	User IP Address																															

FIG. 20W

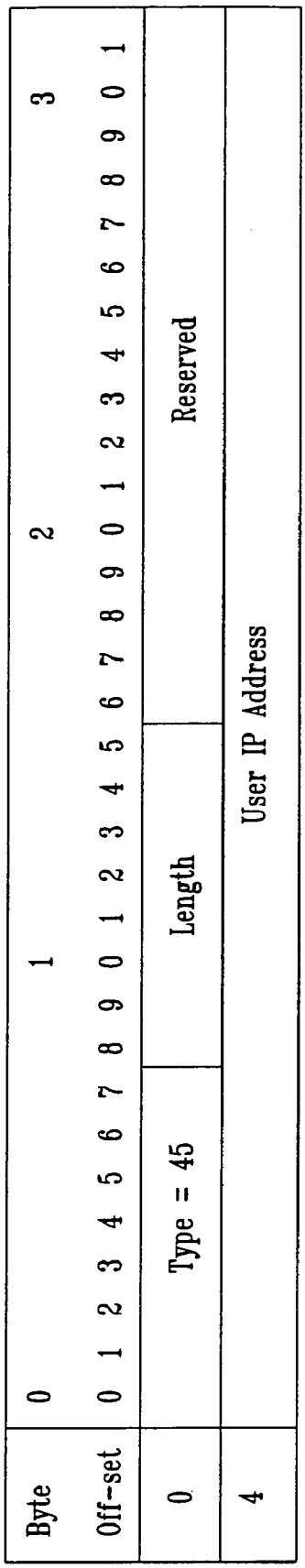


FIG. 20X

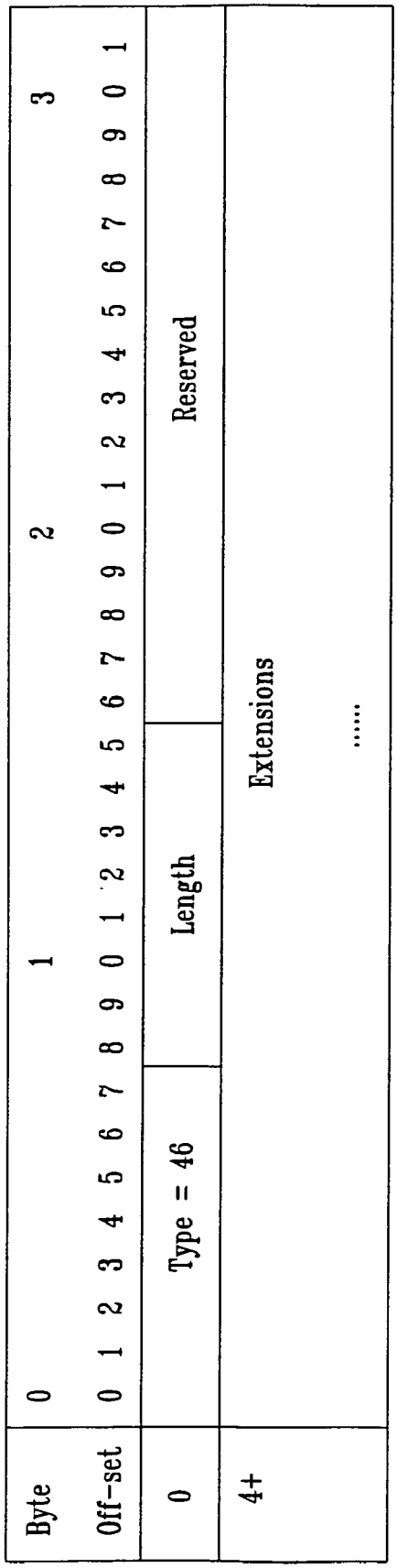
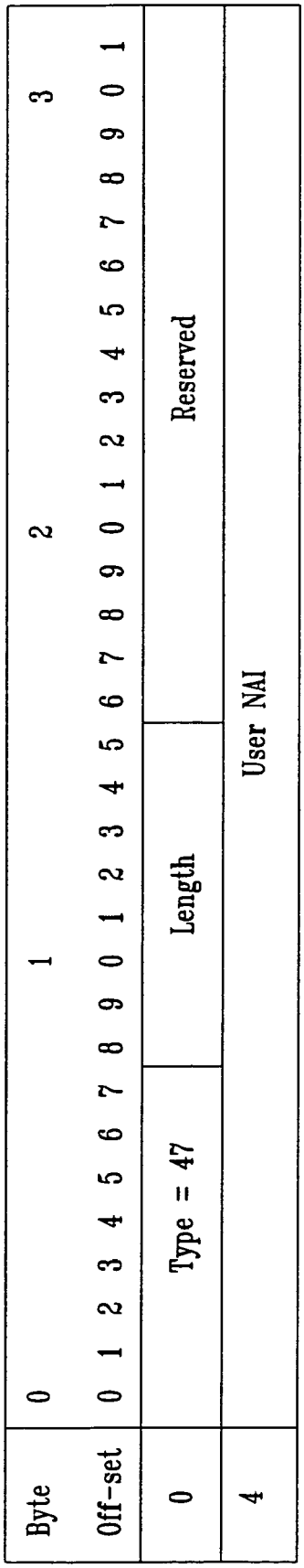
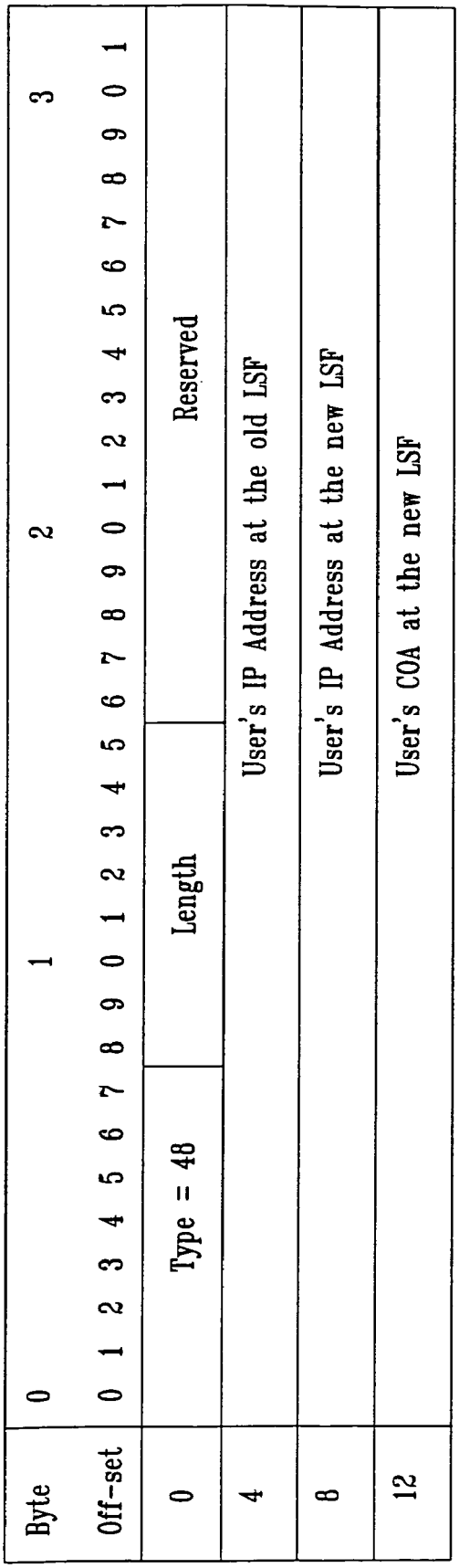


FIG. 20Y



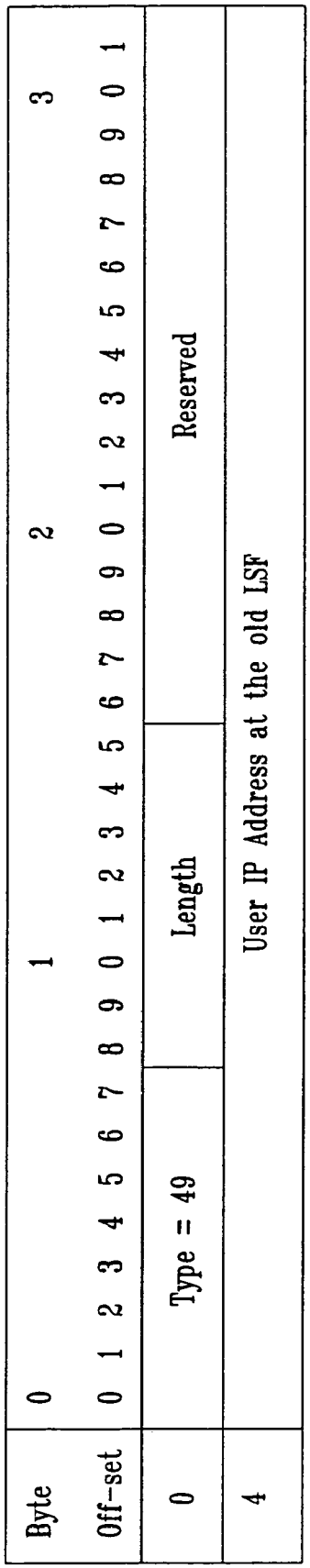
Byte Off-set	0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
0	Type = 47 / Length / Reserved
4	User NAI

FIG. 20Z



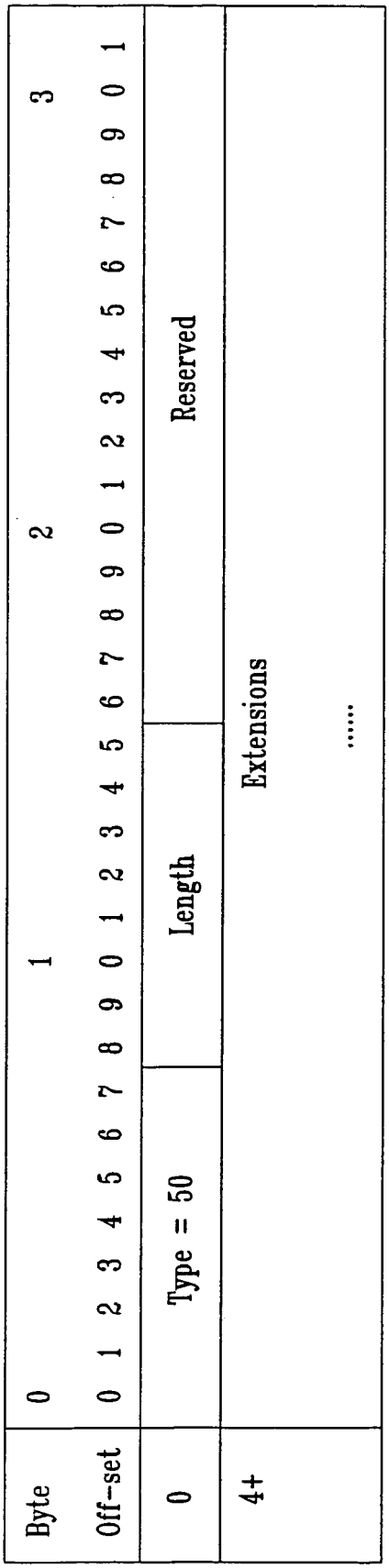
Byte Off-set	0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
0	Type = 48 / Length / Reserved
4	User's IP Address at the old LSF
8	User's IP Address at the new LSF
12	User's COA at the new LSF

FIG. 20AA



Byte Off-set	0 1 2 3 4 5 6 7 8 9 0 1	2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
0	Type = 49	Length / Reserved
4	User IP Address at the old LSF	

FIG. 20AB



Byte Off-set	0 1 2 3 4 5 6 7 8 9 0 1	2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
0	Type = 50	Length / Reserved
4+	Extensions	

FIG. 20AC

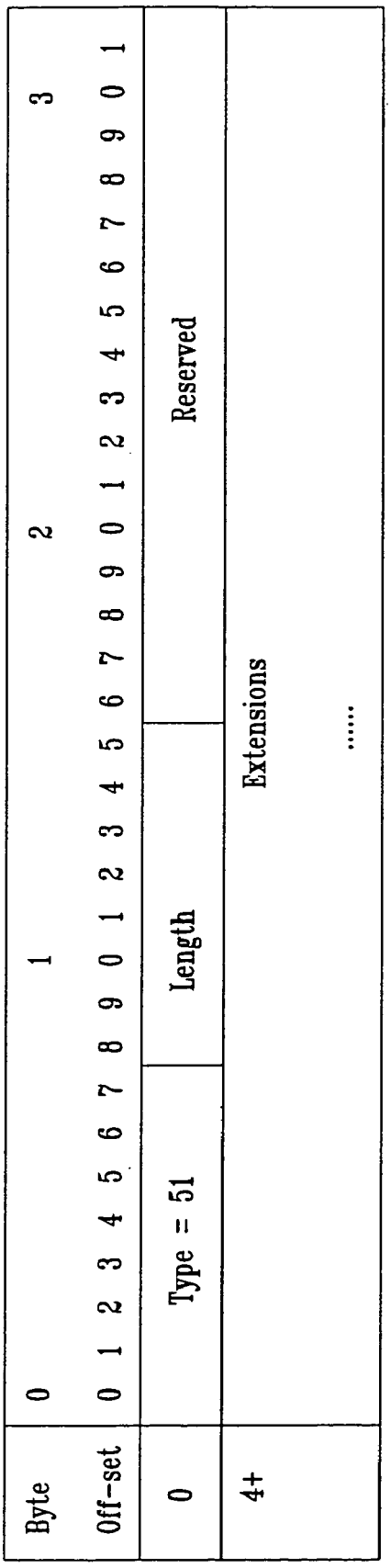
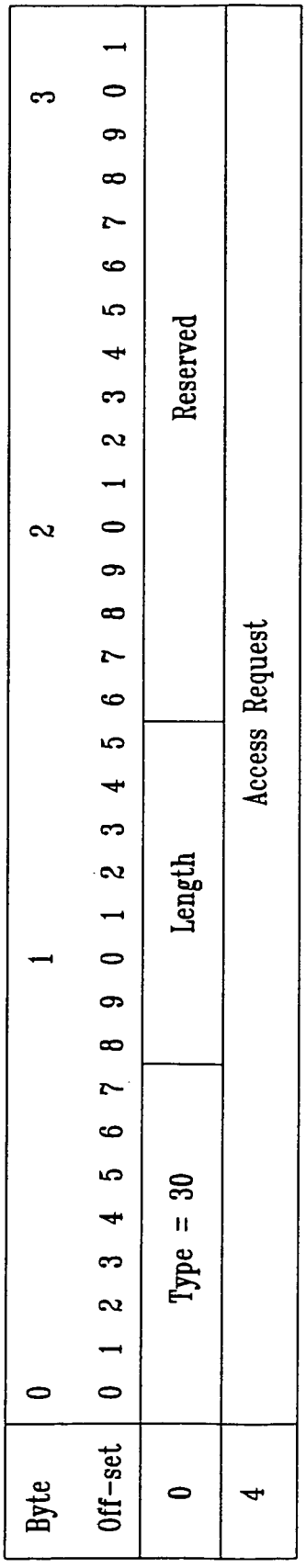


FIG. 20AD



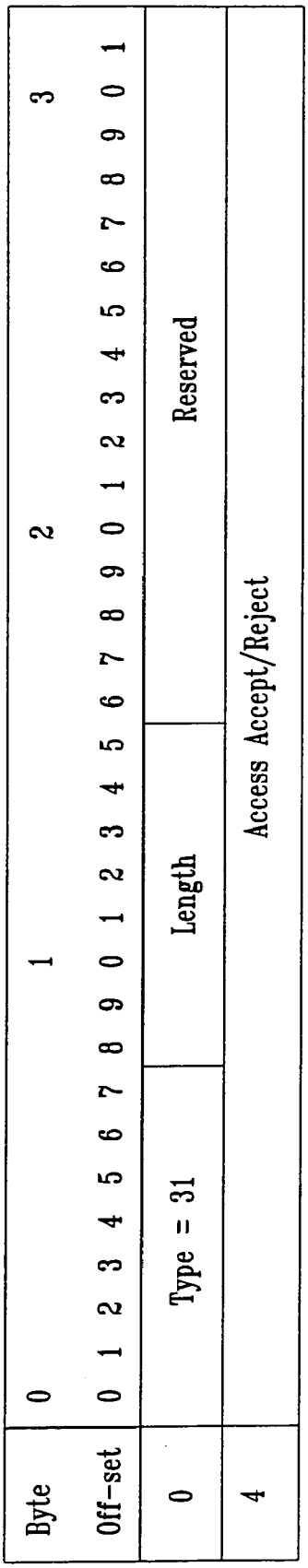

Byte
Off-set
0
1
2
3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
0
Type = 31
Length
Reserved
4
Access Accept/Reject

FIG. 20AE

FIG. 20AF

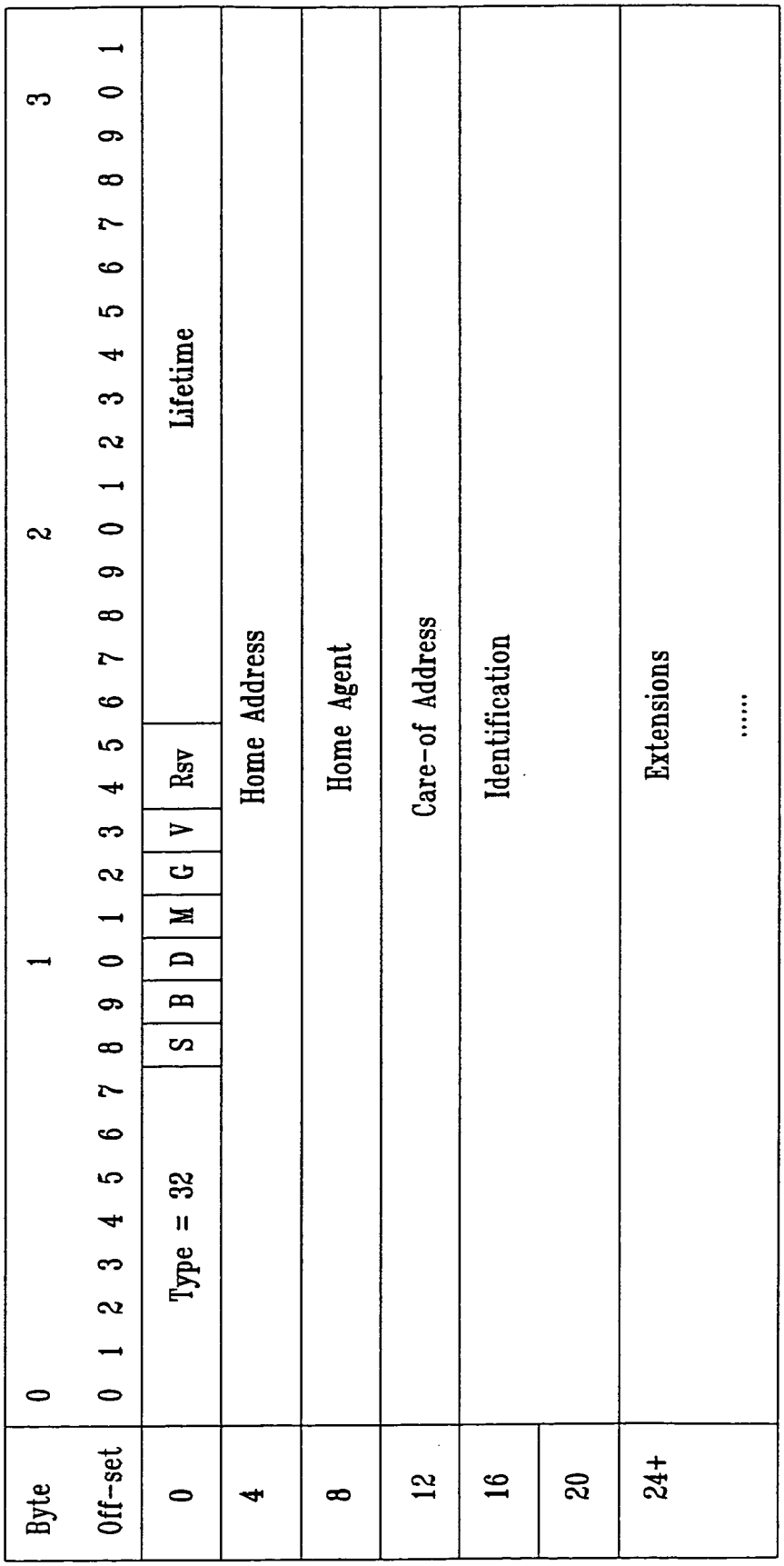

Byte Off-set
0 1 2 3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
Type = 32
S B D M G V Rsv
Lifetime
Home Address
Home Agent
Care-of Address
Identification
Extensions
.....
0
4
8
12
16
20
24+

FIG. 20AG

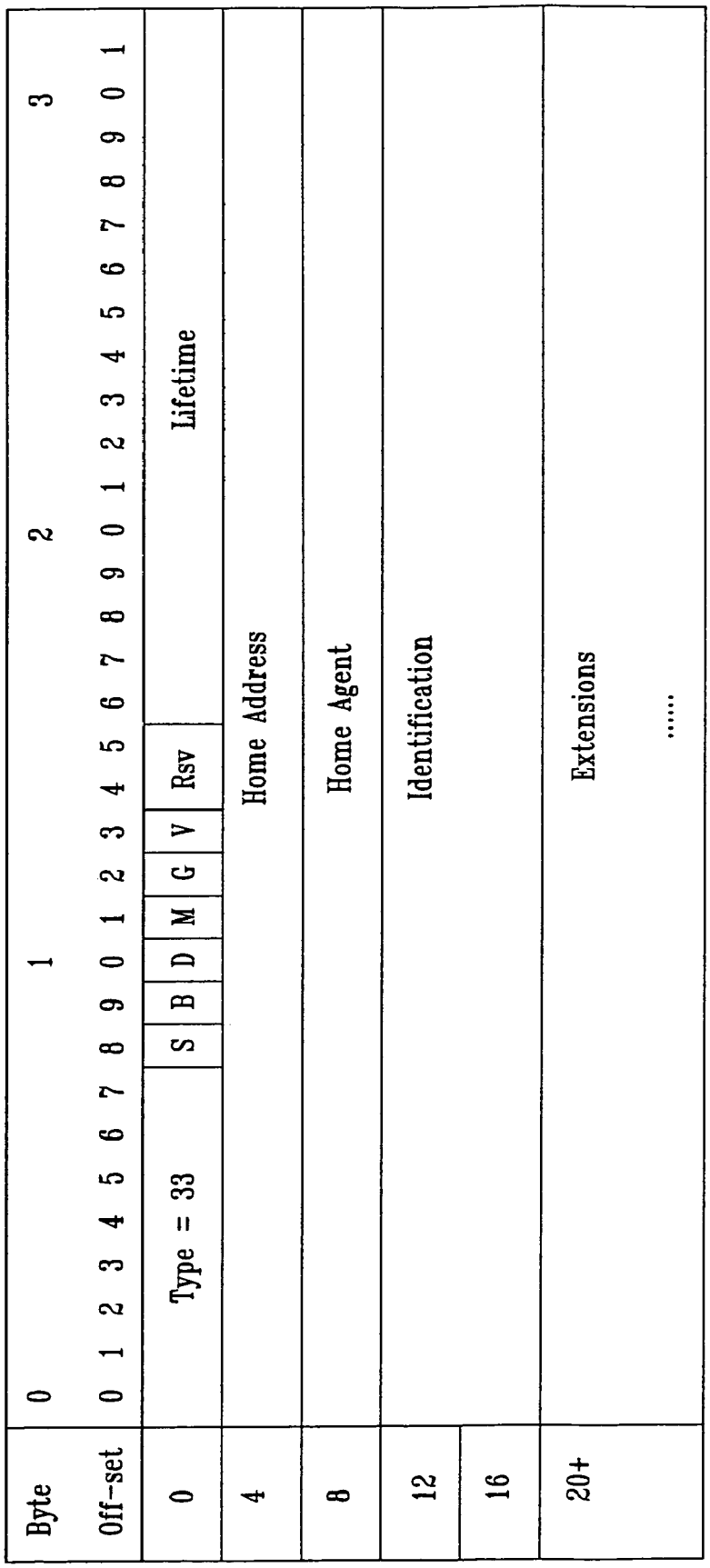

Byte
Off-set
0
1
2
3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
Type = 33
S
B
D
M
G
V
Rsv
Lifetime
Home Address
Home Agent
Identification
Extensions
.....
0
4
8
12
16
20+

FIG. 21

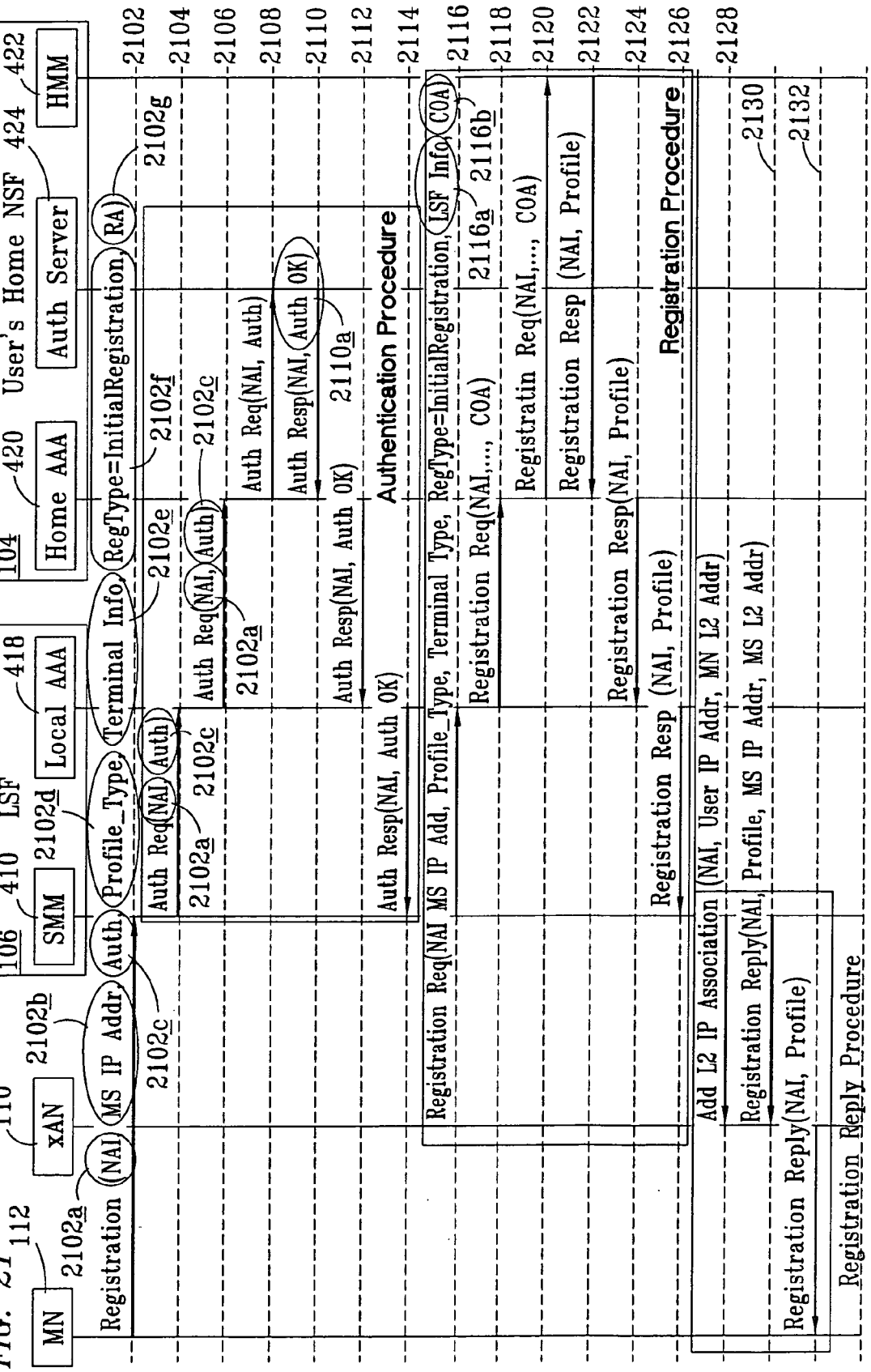

MN
112
2102a
xAN
110
2102b
106
SMM
410
LSF
2102d
Local AAA
418
104
Home AAA
420
User's Home NSF
Auth Server
424
HMM
422
Registration (NAI)
MS IP Addr
Auth
Profile_Type
Terminal Info
RegType=InitialRegistration
RA
2102c
2102e
2102f
2102g
Auth Req(NAI, Auth)
2102a
2102c
Auth Req(NAI, Auth)
2102a
Auth Req(NAI, Auth)
Auth Resp(NAI, Auth OK)
2110a
Auth Resp(NAI, Auth OK)
Auth Resp(NAI, Auth OK)
Authentication Procedure
Registration Req(NAI MS IP Add, Profile_Type, Terminal Type, RegType=InitialRegistration, LSF Info, COA)
Registration Req(NAI,..., COA)
2116a
2116b
Registratin Req(NAI,..., COA)
Registration Resp (NAI, Profile)
Registration Resp(NAI, Profile)
Registration Resp (NAI, Profile)
Registration Procedure
Add L2 IP Association (NAI, User IP Addr, MN L2 Addr)
Registration Reply(NAI, Profile, MS IP Addr, MS L2 Addr)
Registration Reply(NAI, Profile)
Registration Reply Procedure
2102
2104
2106
2108
2110
2112
2114
2116
2118
2120
2122
2124
2126
2128
2130
2132

FIG. 22

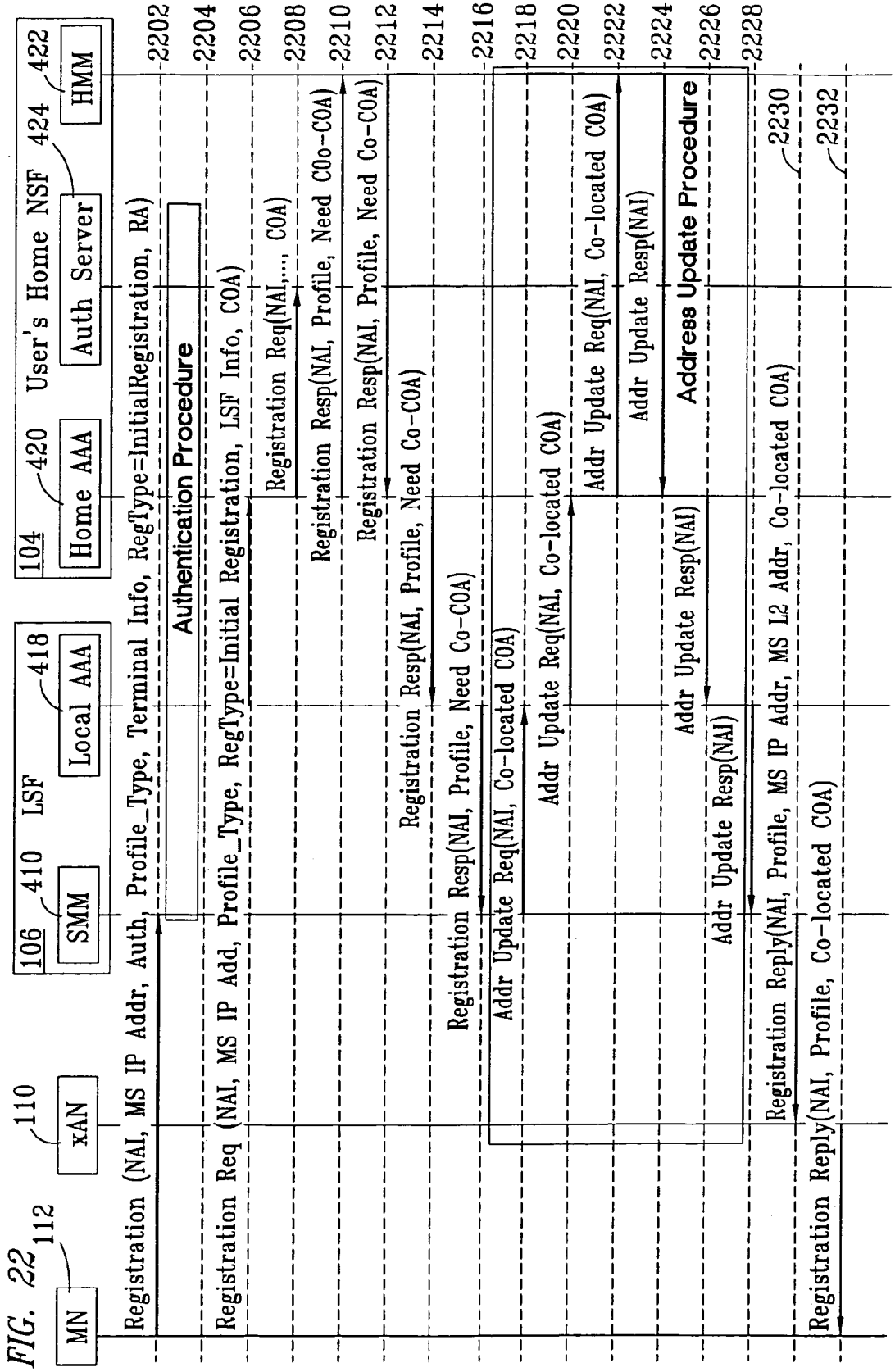
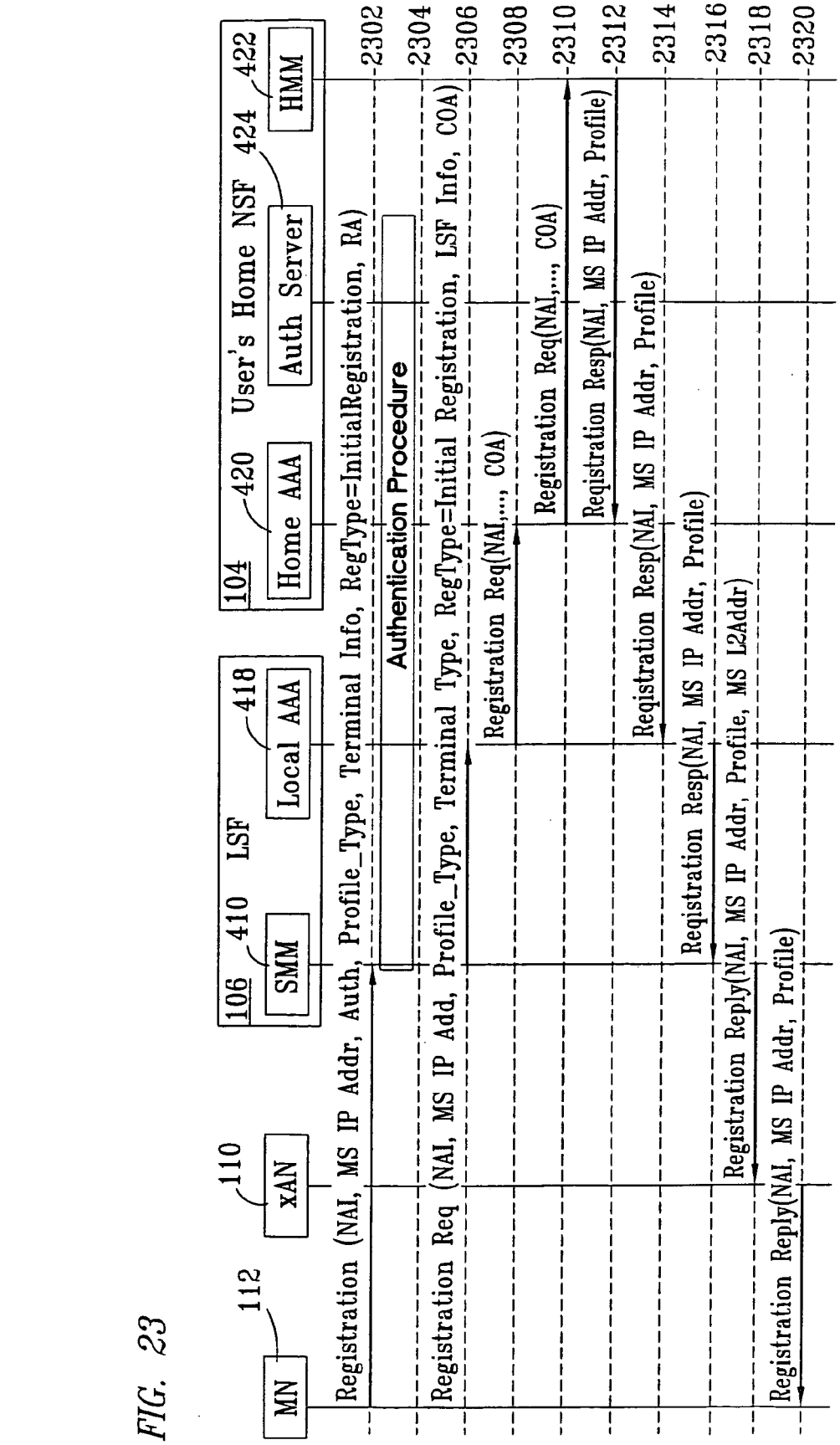

MN
112
xAN
110
SMM
106
410
LSF
Local AAA
418
Home AAA
420
User's Home NSF
Auth Server
424
HMM
422
Registration (NAI, MS IP Addr, Auth, Profile_Type, Terminal Info, RegType=InitialRegistration, RA)
2202
Authentication Procedure
2204
Registration Req (NAI, MS IP Add, Profile_Type, RegType=Initial Registration, LSF Info, COA)
2206
Registration Req(NAI,..., COA)
2208
Registration Resp(NAI, Profile, Need COo-COA)
2210
Registration Resp(NAI, Profile, Need Co-COA)
2212
Registration Resp(NAI, Profile, Need Co-COA)
2214
Registration Resp(NAI, Profile, Need Co-COA)
2216
Addr Update Req(NAI, Co-located COA)
2218
Addr Update Req(NAI, Co-located COA)
2220
Addr Update Req(NAI, Co-located COA)
2222
Addr Update Resp(NAI)
2224
Addr Update Resp(NAI)
Address Update Procedure
2226
Addr Update Resp(NAI)
2228
Registration Reply(NAI, Profile, MS IP Addr, MS L2 Addr, Co-located COA)
2230
Registration Reply(NAI, Profile, Co-located COA)
2232

FIG. 23


MN
112
xAN
110
106
SMM
410
LSF
Local AAA
418
104
Home AAA
420
User's Home NSF
Auth Server
424
HMM
422
Registration (NAI, MS IP Addr, Auth, Profile_Type, Terminal Info, RegType=InitialRegistration, RA)
2302
Authentication Procedure
2304
Registration Req (NAI, MS IP Add, Profile_Type, Terminal Type, RegType=Initial Registration, LSF Info, COA)
2306
Registration Req(NAI,..., COA)
2308
Registration Req(NAI,..., COA)
2310
Registration Resp(NAI, MS IP Addr, Profile)
2312
Registration Resp(NAI, MS IP Addr, Profile)
2314
Registration Resp(NAI, MS IP Addr, Profile)
2316
Registration Reply(NAI, MS IP Addr, Profile, MS L2Addr)
2318
Registration Reply(NAI, MS IP Addr, Profile)
2320

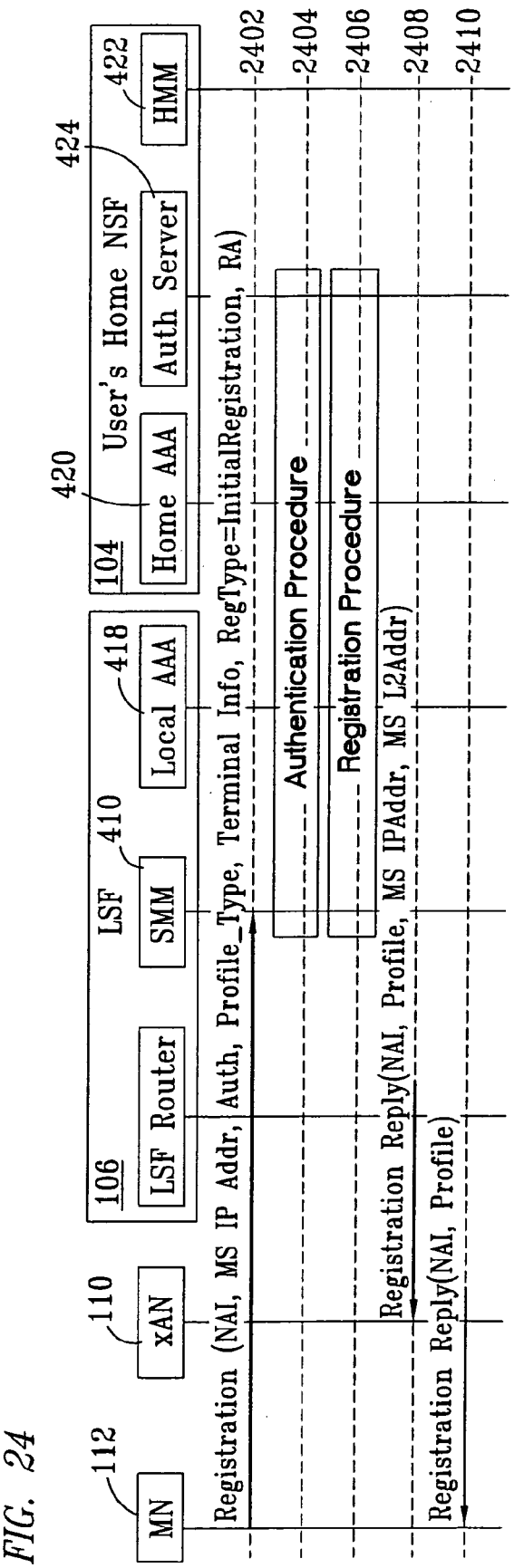
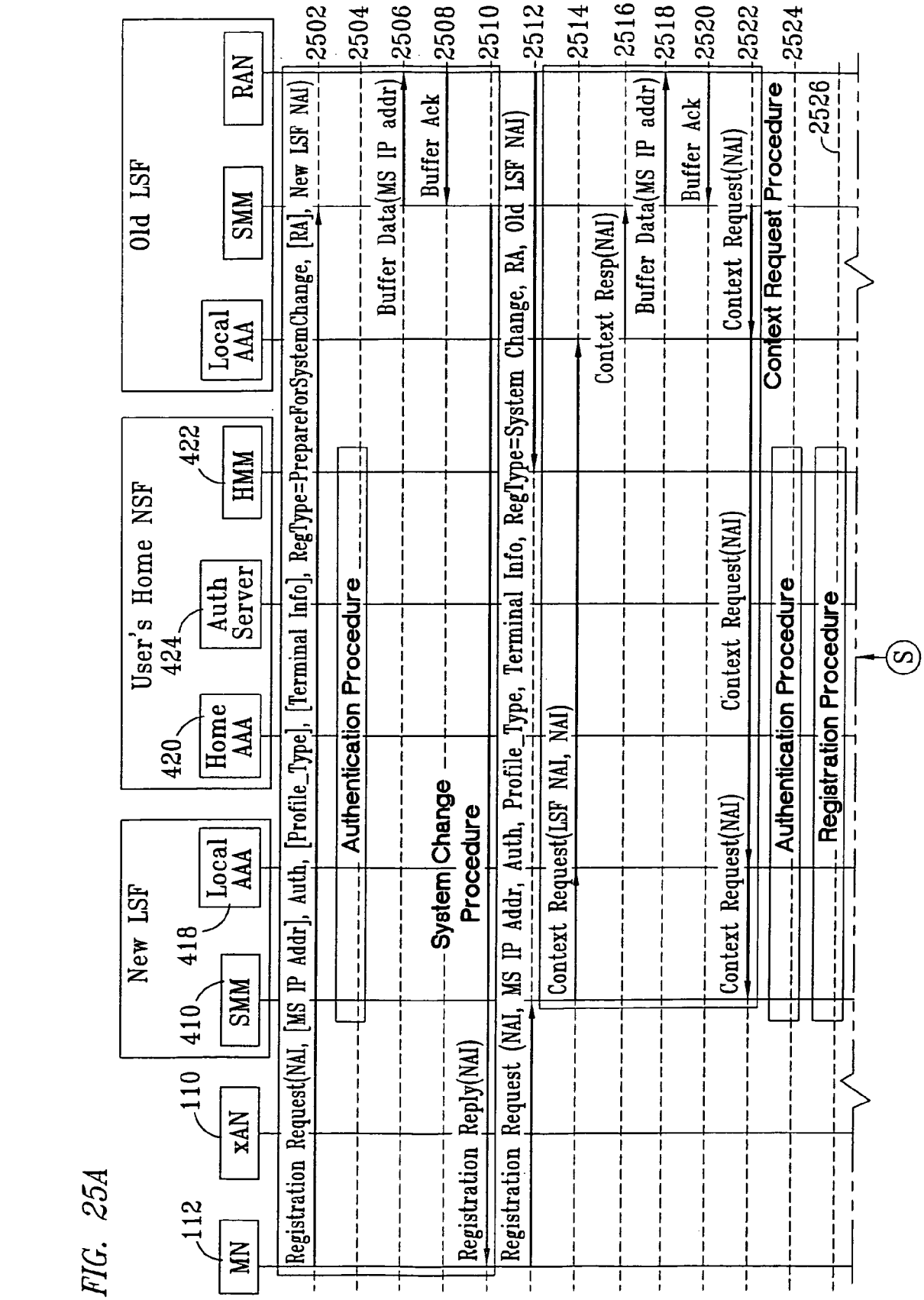

MN
112
xAN
110
106
LSF
LSF Router
SMM
410
Local AAA
418
104
Home AAA
420
User's Home NSF
Auth Server
424
HMM
422
2402
2404
2406
2408
2410
Registration (NAI, MS IP Addr, Auth, Profile_Type, Terminal Info, RegType=InitialRegistration, RA)
Authentication Procedure
Registration Procedure
Registration Reply(NAI, Profile, MS IPAddr, MS L2Addr)
Registration Reply(NAI, Profile)

FIG. 24

FIG. 25A


MN
112
xAN
110
New LSF
SMM
410
Local AAA
418
User's Home NSF
Home AAA
420
Auth Server
424
HMM
422
Old LSF
Local AAA
SMM
RAN
2502
2504
2506
2508
2510
2512
2514
2516
2518
2520
2522
2524
2526
Registration Request(NAI, [MS IP Addr], Auth, [Profile_Type], [Terminal Info], RegType=PrepareForSystemChange, [RA], New LSF NAI)
Authentication Procedure
Buffer Data(MS IP addr)
Buffer Ack
System Change Procedure
Registration Reply(NAI)
Registration Request (NAI, MS IP Addr, Auth, Profile_Type, Terminal Info, RegType=System Change, RA, Old LSF NAI)
Context Request(LSF NAI, NAI)
Context Resp(NAI)
Buffer Data(MS IP addr)
Buffer Ack
Context Request(NAI)
Context Request(NAI)
Context Request Procedure
Authentication Procedure
Registration Procedure
S

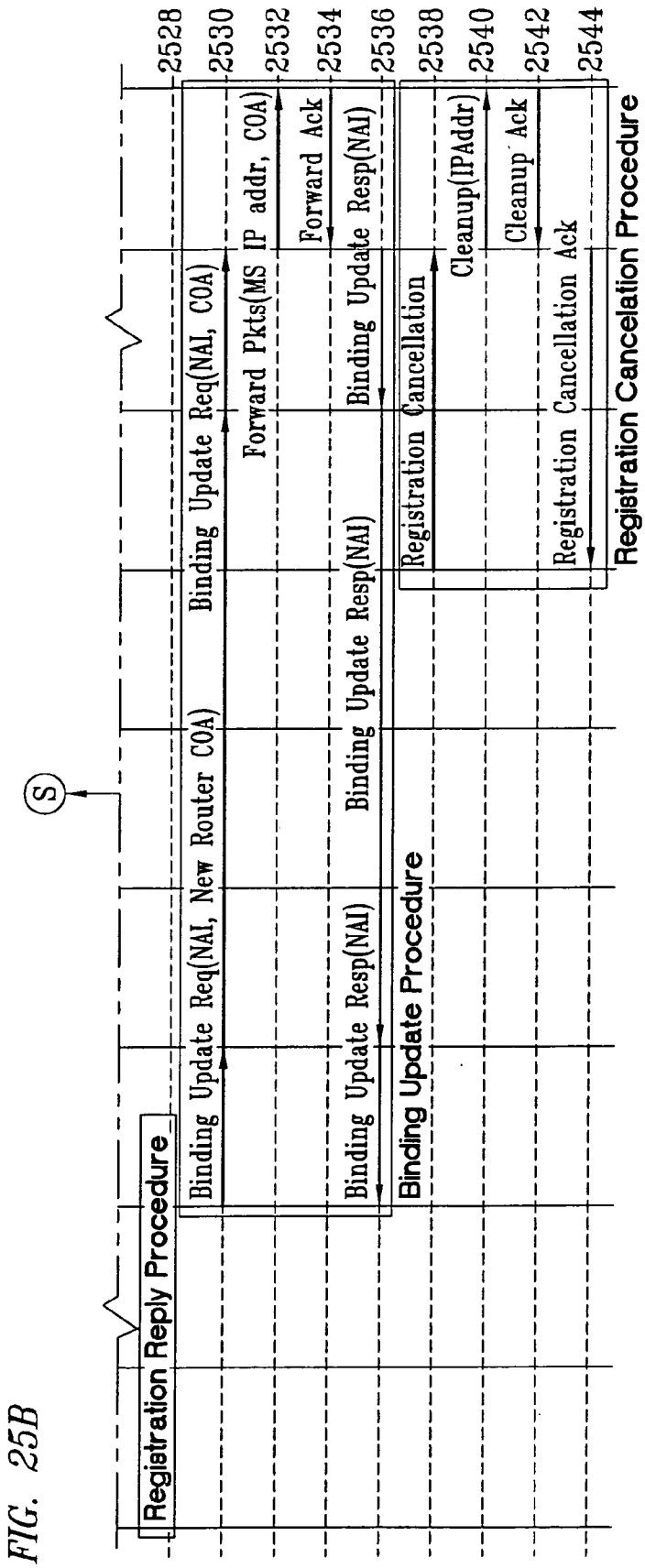

2528
2530
2532
2534
2536
2538
2540
2542
2544
S
Registration Reply Procedure
Binding Update Req(NAI, New Router COA)
Binding Update Req(NAI, COA)
Forward Pkts(MS IP addr, COA)
Forward Ack
Binding Update Resp(NAI)
Binding Update Resp(NAI)
Binding Update Procedure
Registration Cancellation
Cleanup(IPAddr)
Cleanup Ack
Registration Cancellation Ack
Registration Cancelation Procedure

FIG. 25B

FIG. 26

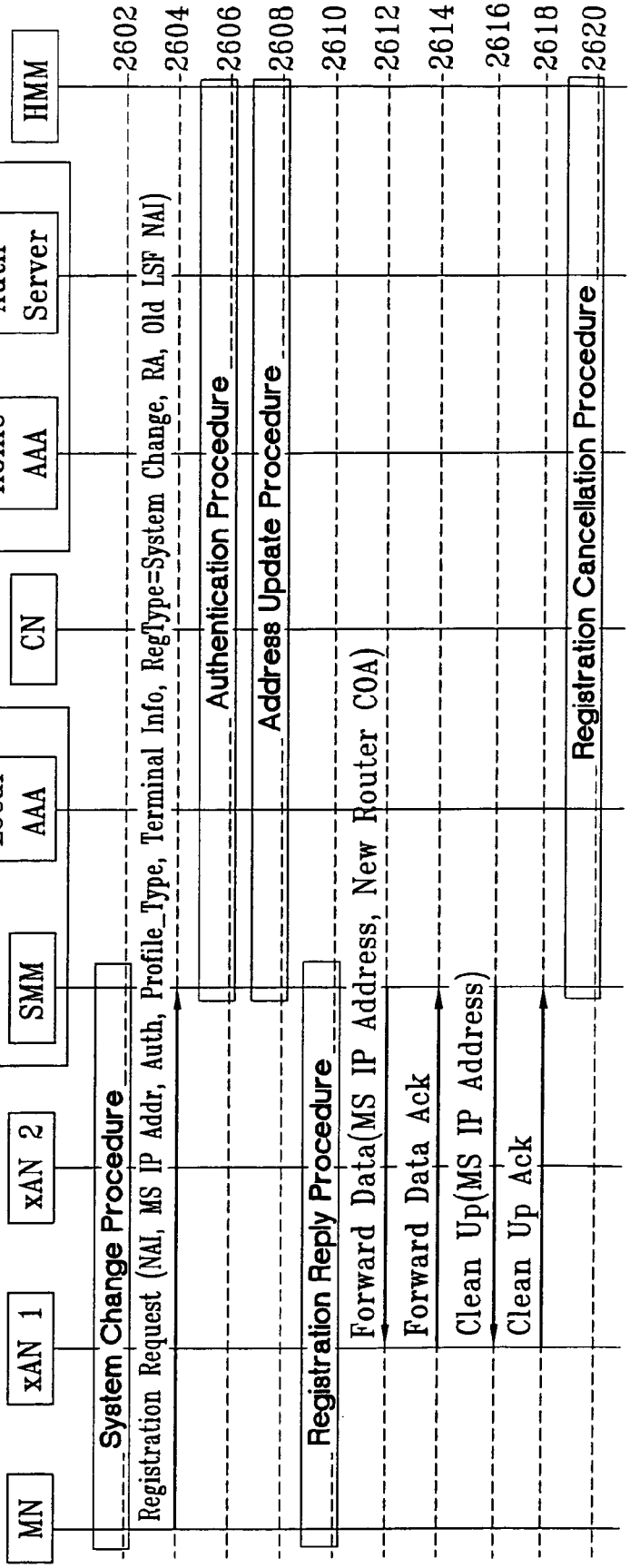
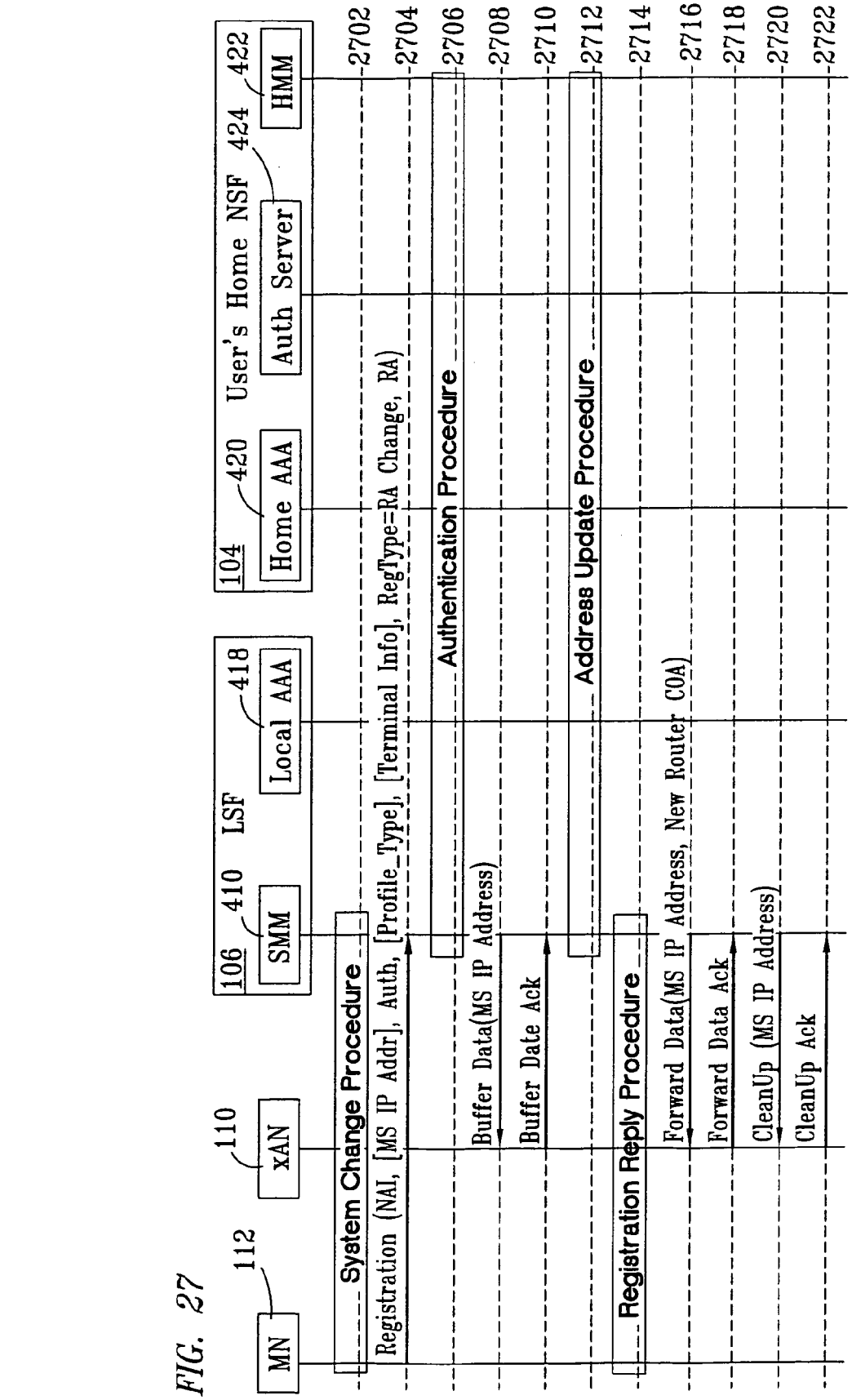

MN
xAN 1
xAN 2
LSF
SMM
Local AAA
CN
User's Home NSF
Home AAA
Auth Server
HMM
2602
2604
2606
2608
2610
2612
2614
2616
2618
2620
System Change Procedure
Registration Request (NAI, MS IP Addr, Auth, Profile_Type, Terminal Info, RegType=System Change, RA, Old LSF NAI)
Authentication Procedure
Address Update Procedure
Registration Reply Procedure
Forward Data(MS IP Address, New Router COA)
Forward Data Ack
Clean Up(MS IP Address)
Clean Up Ack
Registration Cancellation Procedure

FIG. 27


MN
112
xAN
110
106
SMM
410
LSF
Local AAA
418
104
Home AAA
420
User's Home NSF
Auth Server
424
HMM
422
System Change Procedure
Registration (NAI, [MS IP Addr], Auth, [Profile_Type], [Terminal Info], RegType=RA Change, RA)
Authentication Procedure
Buffer Data(MS IP Address)
Buffer Date Ack
Address Update Procedure
Registration Reply Procedure
Forward Data(MS IP Address, New Router COA)
Forward Data Ack
CleanUp (MS IP Address)
CleanUp Ack
2702
2704
2706
2708
2710
2712
2714
2716
2718
2720
2722

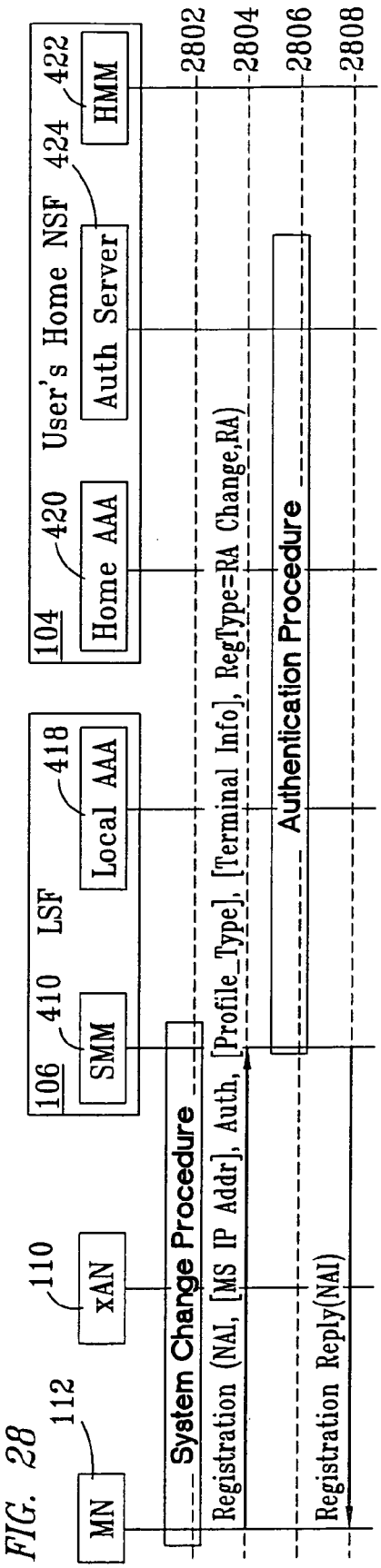

MN
112
xAN
110
106
SMM
410
LSF
418
Local AAA
104
Home AAA
420
User's Home NSF
424
Auth Server
422
HMM
2802
2804
2806
2808
System Change Procedure
Registration (NAI, [MS IP Addr], Auth, [Profile_Type], [Terminal Info], RegType=RA Change,RA)
Authentication Procedure
Registration Reply(NAI)

FIG. 28

FIG. 29

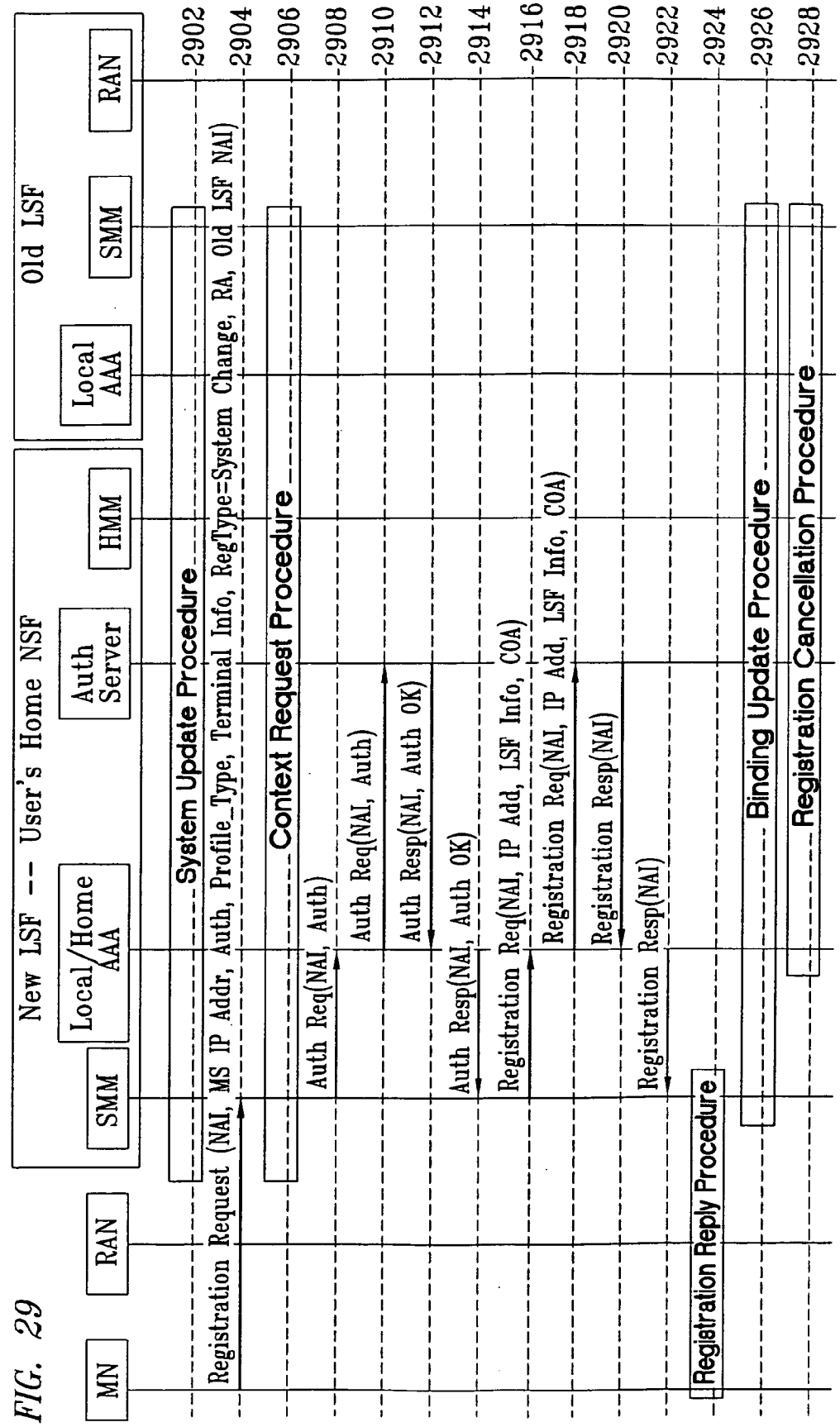

MN
RAN
New LSF -- User's Home NSF
SMM
Local/Home AAA
Auth Server
HMM
Old LSF
Local AAA
SMM
RAN
2902
2904
2906
2908
2910
2912
2914
2916
2918
2920
2922
2924
2926
2928
System Update Procedure
Registration Request (NAI, MS IP Addr, Auth, Profile_Type, Terminal Info, RegType=System Change, RA, Old LSF NAI)
Context Request Procedure
Auth Req(NAI, Auth)
Auth Req(NAI, Auth)
Auth Resp(NAI, Auth OK)
Auth Resp(NAI, Auth OK)
Registration Req(NAI, IP Add, LSF Info, COA)
Registration Req(NAI, IP Add, LSF Info, COA)
Registration Resp(NAI)
Registration Resp(NAI)
Registration Reply Procedure
Binding Update Procedure
Registration Cancellation Procedure

FIG. 30

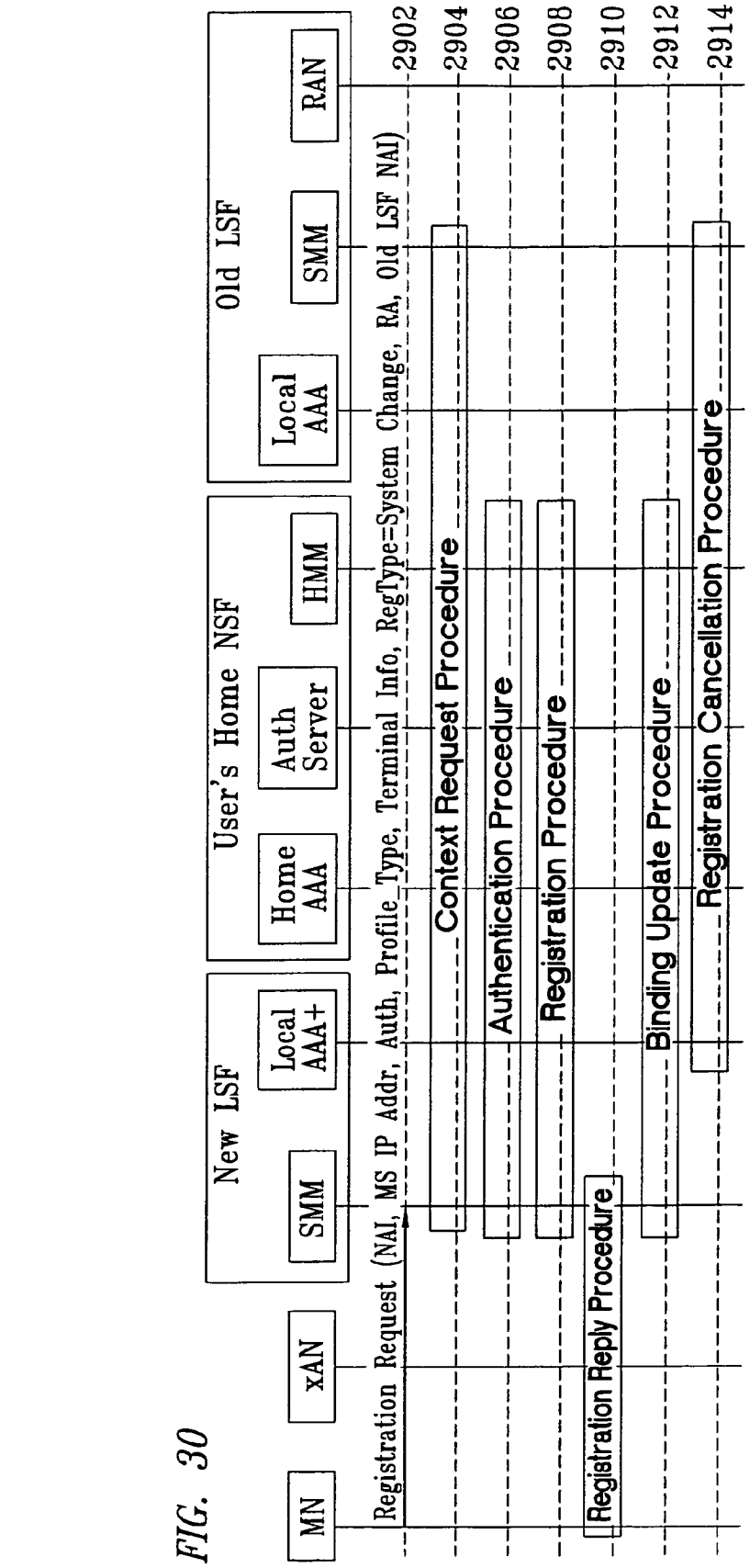

MN
xAN
New LSF
SMM
Local AAA+
User's Home NSF
Home AAA
Auth Server
HMM
Old LSF
Local AAA
SMM
RAN
Registration Request (NAI, MS IP Addr, Auth, Profile_Type, Terminal Info, RegType=System Change, RA, Old LSF NAI)
2902
Context Request Procedure
2904
Authentication Procedure
2906
Registration Procedure
2908
Registration Reply Procedure
2910
Binding Update Procedure
2912
Registration Cancellation Procedure
2914

FIG. 31

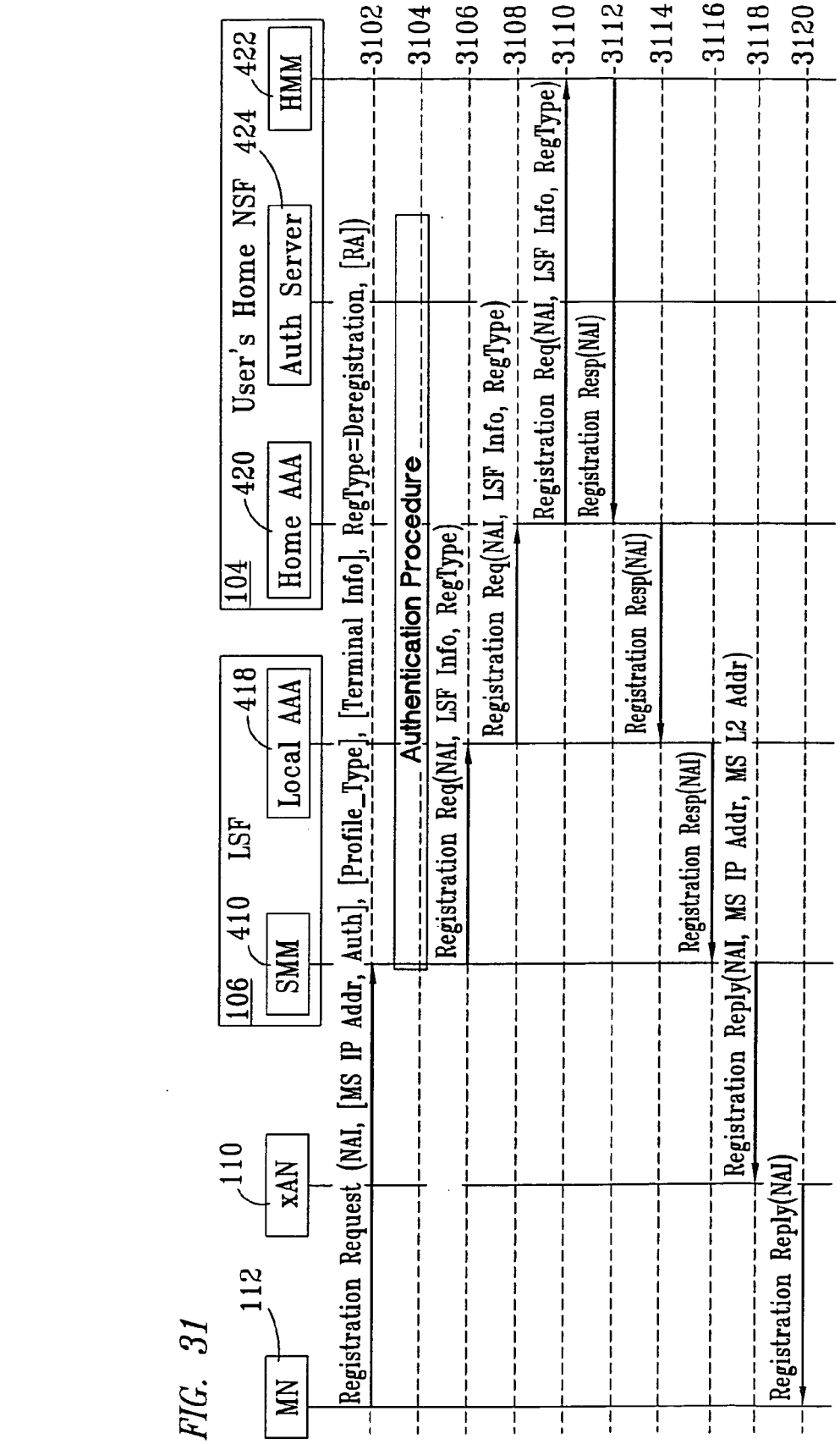
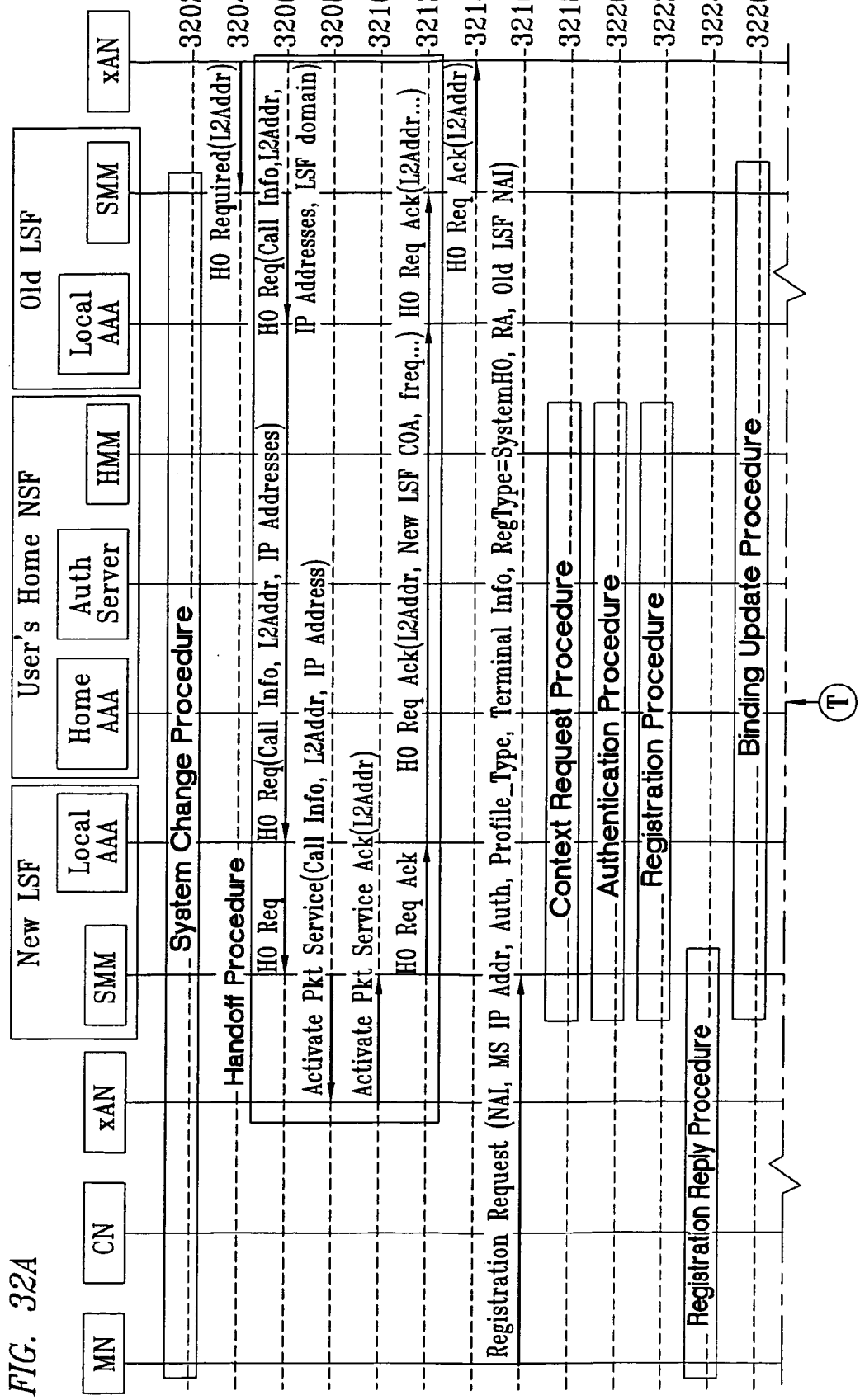

MN
112
xAN
110
106
SMM
410
LSF
Local AAA
418
104
Home AAA
420
User's Home NSF
Auth Server
424
HMM
422
Registration Request (NAI, [MS IP Addr, Auth], [Profile_Type], [Terminal Info], RegType=Deregistration, [RA])
3102
Authentication Procedure
3104
Registration Req(NAI, LSF Info, RegType)
3106
Registration Req(NAI, LSF Info, RegType)
3108
Registration Req(NAI, LSF Info, RegType)
3110
Registration Resp(NAI)
3112
Registration Resp(NAI)
3114
Registration Resp(NAI)
3116
Registration Reply(NAI, MS IP Addr, MS L2 Addr)
3118
Registration Reply(NAI)
3120

FIG. 32A


MN
CN
xAN
New LSF
SMM
Local AAA
User's Home NSF
Home AAA
Auth Server
HMM
Old LSF
Local AAA
SMM
xAN
3202
3204
3206
3208
3210
3212
3214
3216
3218
3220
3222
3224
3226
System Change Procedure
HO Required(L2Addr)
Handoff Procedure
HO Req
HO Req(Call Info, L2Addr, IP Addresses)
HO Req(Call Info,L2Addr, IP Addresses, LSF domain)
Activate Pkt Service(Call Info, L2Addr, IP Address)
Activate Pkt Service Ack(L2Addr)
HO Req Ack
HO Req Ack(L2Addr, New LSF COA, freq...)
HO Req Ack(L2Addr...)
HO Req Ack(L2Addr)
Registration Request (NAI, MS IP Addr, Auth, Profile_Type, Terminal Info, RegType=SystemHO, RA, Old LSF NAI)
Context Request Procedure
Authentication Procedure
Registration Procedure
Registration Reply Procedure
Binding Update Procedure
T

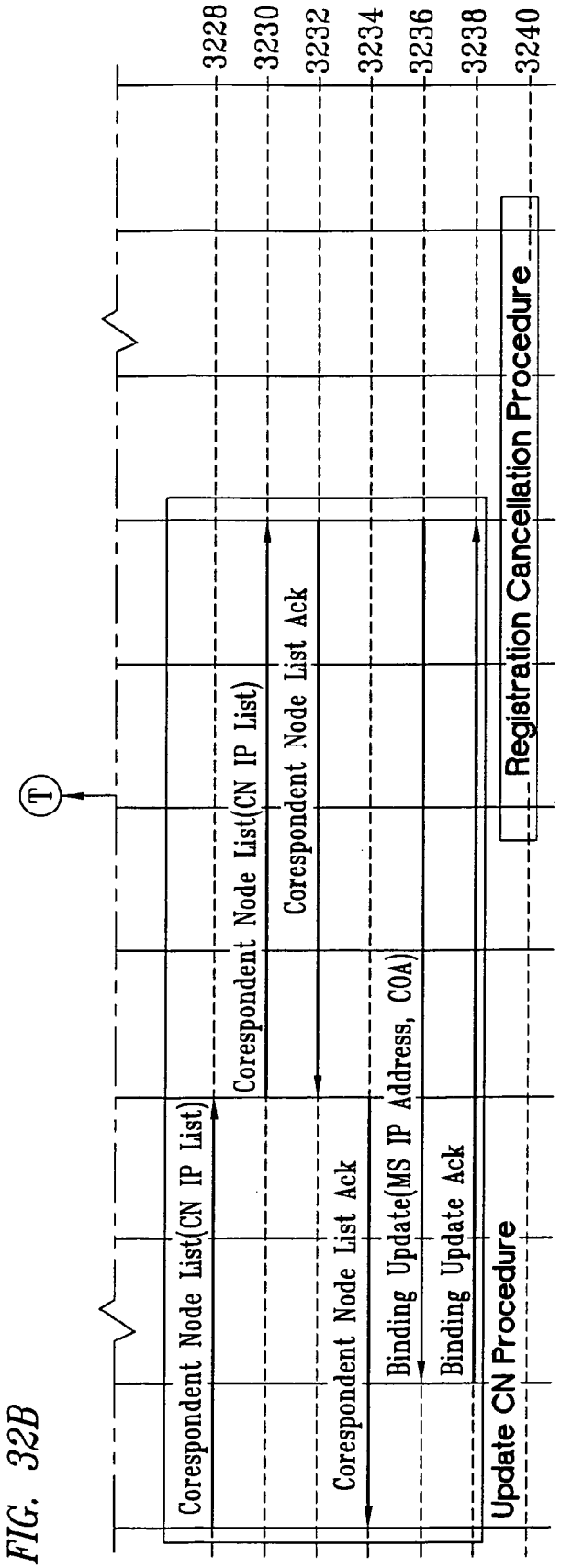

3228
3230
3232
3234
3236
3238
3240
T
Corespondent Node List(CN IP List)
Corespondent Node List(CN IP List)
Corespondent Node List Ack
Corespondent Node List Ack
Binding Update(MS IP Address, COA)
Binding Update Ack
Update CN Procedure
Registration Cancellation Procedure

FIG. 32B

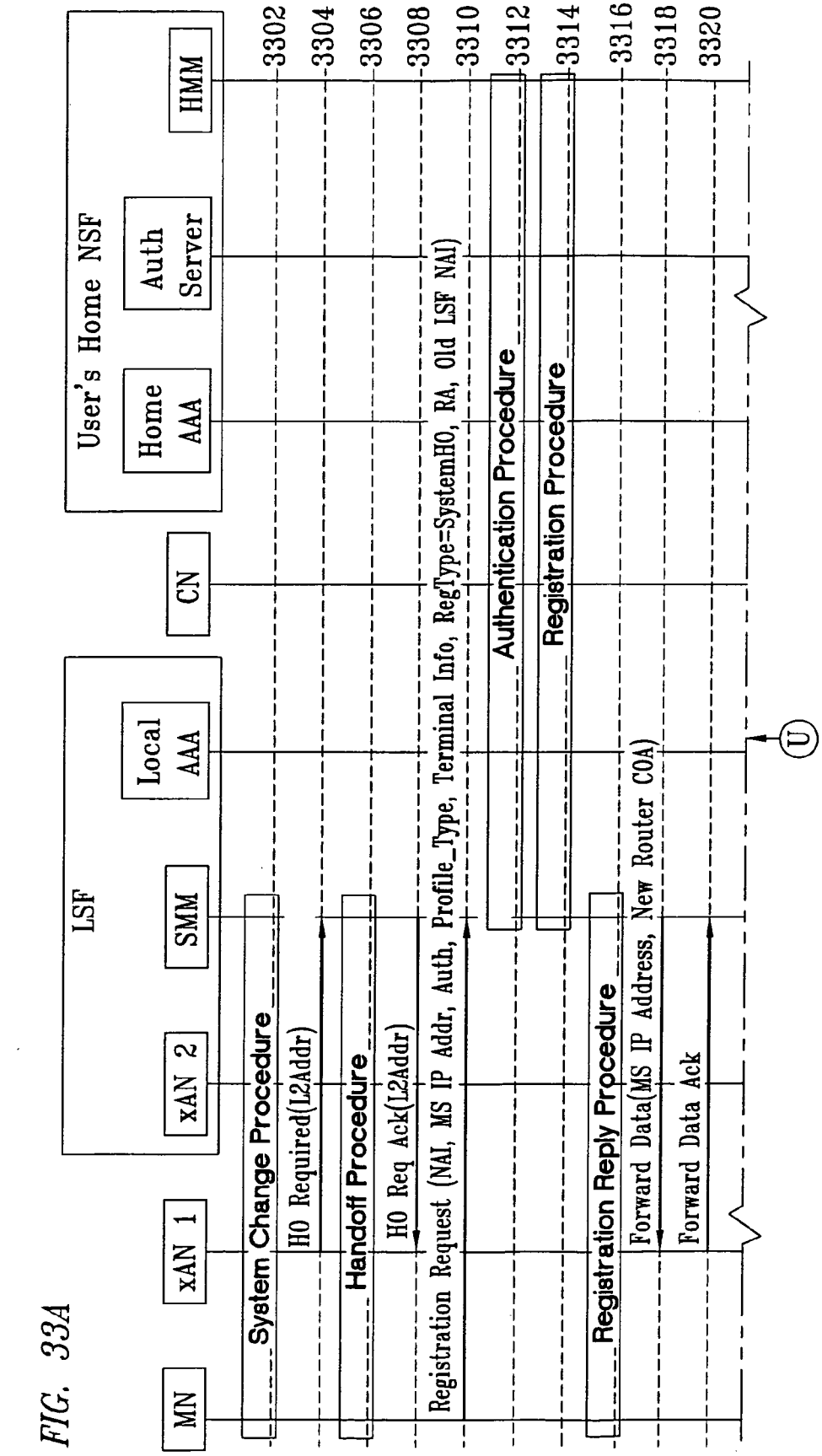

MN
xAN 1
LSF
xAN 2
SMM
Local AAA
CN
User's Home NSF
Home AAA
Auth Server
HMM
3302
3304
3306
3308
3310
3312
3314
3316
3318
3320
System Change Procedure
HO Required(L2Addr)
Handoff Procedure
HO Req Ack(L2Addr)
Registration Request (NAI, MS IP Addr, Auth, Profile_Type, Terminal Info, RegType=SystemHO, RA, Old LSF NAI)
Authentication Procedure
Registration Procedure
Registration Reply Procedure
Forward Data(MS IP Address, New Router COA)
Forward Data Ack
U

FIG. 33A

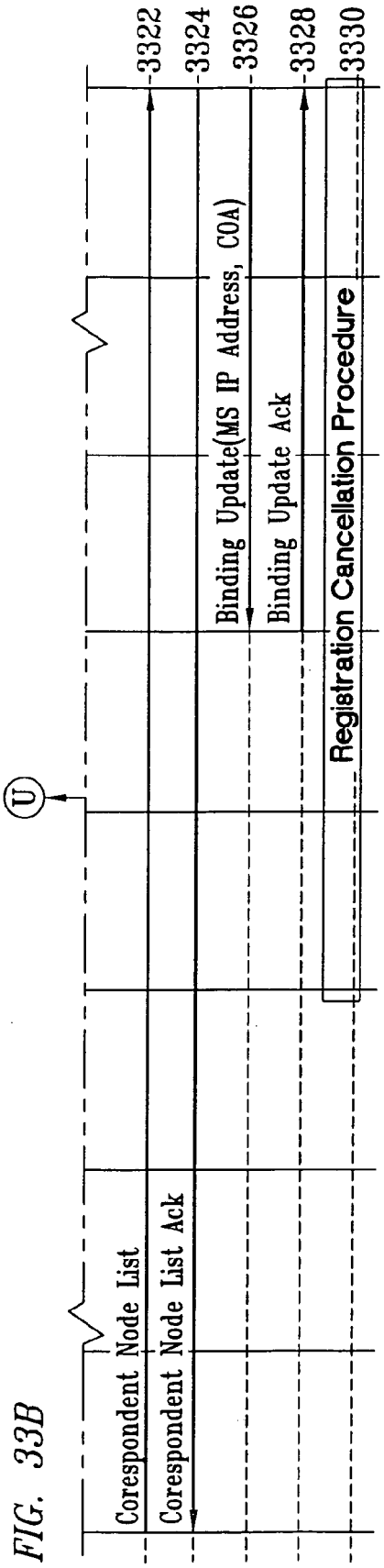

3322
3324
3326
3328
3330
Corespondent Node List
Corespondent Node List Ack
Binding Update(MS IP Address, COA)
Binding Update Ack
Registration Cancellation Procedure
U

FIG. 33B

FIG. 34

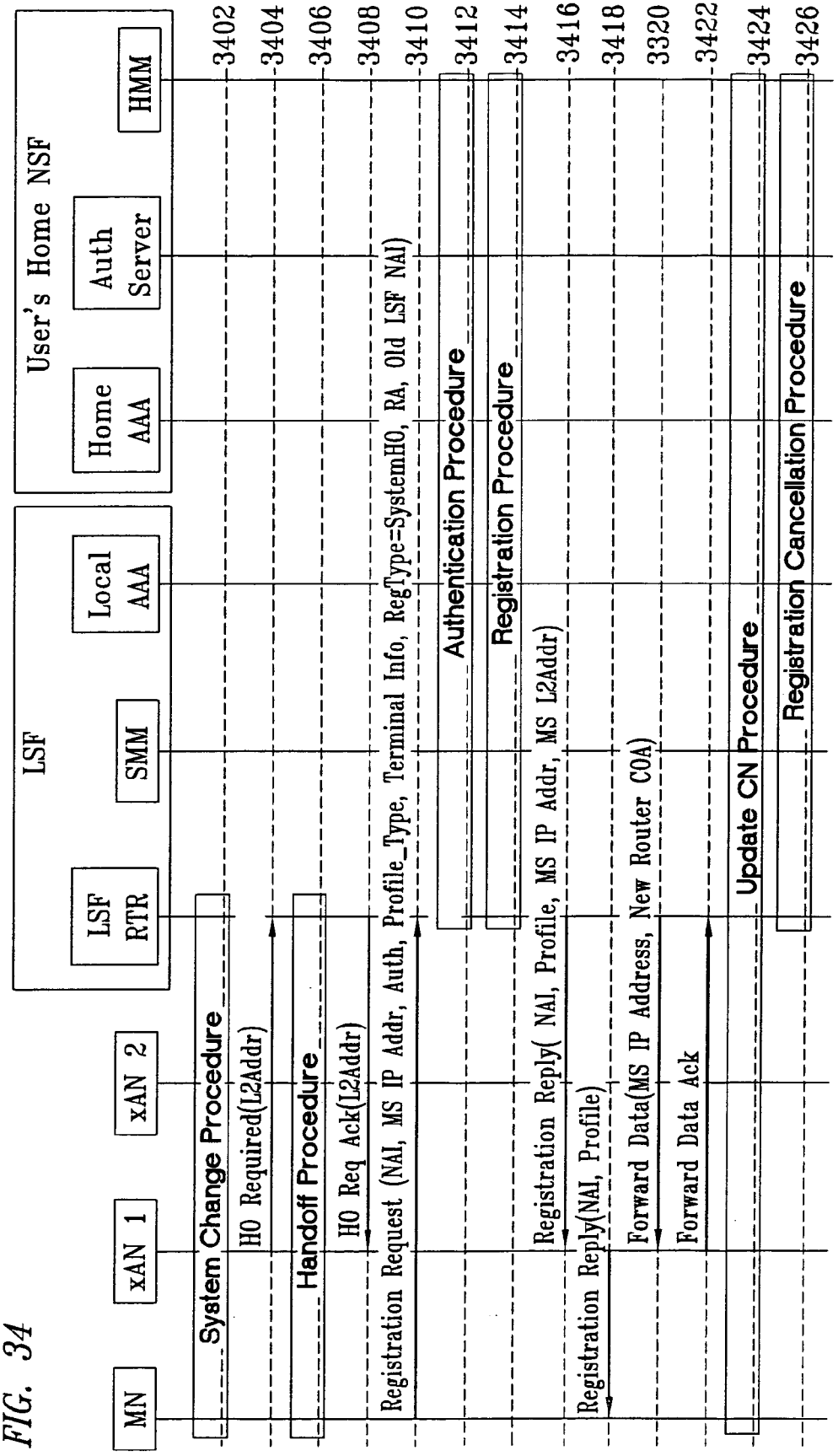
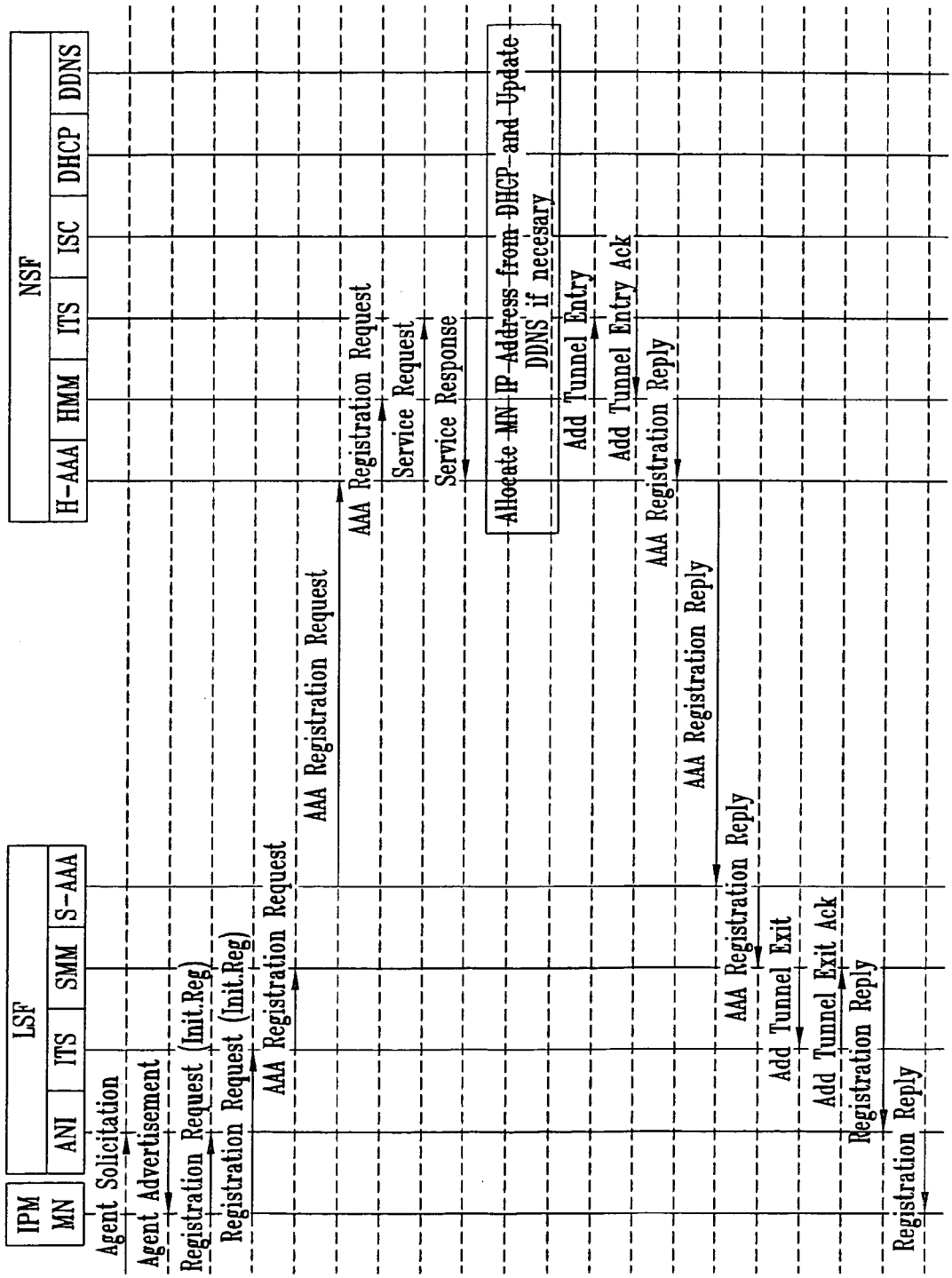

MN
xAN 1
xAN 2
LSF
LSF RTR
SMM
Local AAA
User's Home NSF
Home AAA
Auth Server
HMM
System Change Procedure
HO Required(L2Addr)
Handoff Procedure
HO Req Ack(L2Addr)
Registration Request (NAI, MS IP Addr, Auth, Profile_Type, Terminal Info, RegType=SystemHO, RA, Old LSF NAI)
Authentication Procedure
Registration Procedure
Registration Reply(NAI, Profile, MS IP Addr, MS L2Addr)
Registration Reply(NAI, Profile)
Forward Data(MS IP Address, New Router COA)
Forward Data Ack
Update CN Procedure
Registration Cancellation Procedure
3402
3404
3406
3408
3410
3412
3414
3416
3418
3320
3422
3424
3426

FIG. 35


IPM
MN
LSF
ANI
ITS
SMM
S-AAA
NSF
H-AAA
HMM
ITS
ISC
DHCP
DDNS
Agent Solicitation
Agent Advertisement
Registration Request (Init.Reg)
Registration Request (Init.Reg)
AAA Registration Request
AAA Registration Request
AAA Registration Request
Service Request
Service Response
Allocate MN IP Address from DHCP and Update DDNS if necesary
Add Tunnel Entry
Add Tunnel Entry Ack
AAA Registration Reply
AAA Registration Reply
AAA Registration Reply
Add Tunnel Exit
Add Tunnel Exit Ack
Registration Reply
Registration Reply
3502
3504
3506
3508
3510
3512
3514
3516
3518
3520
3522
3524
3526
3528
3530
3532
3534
3536
3538
3540

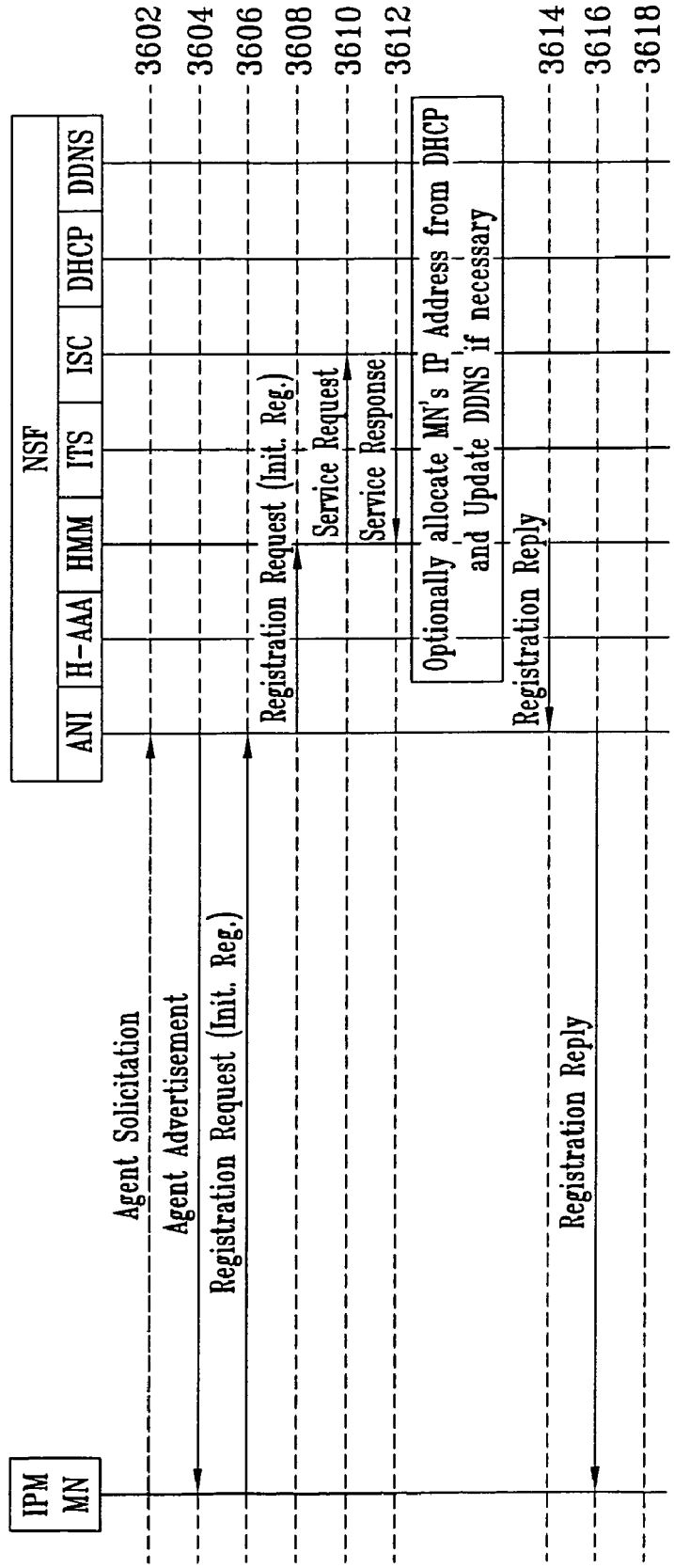
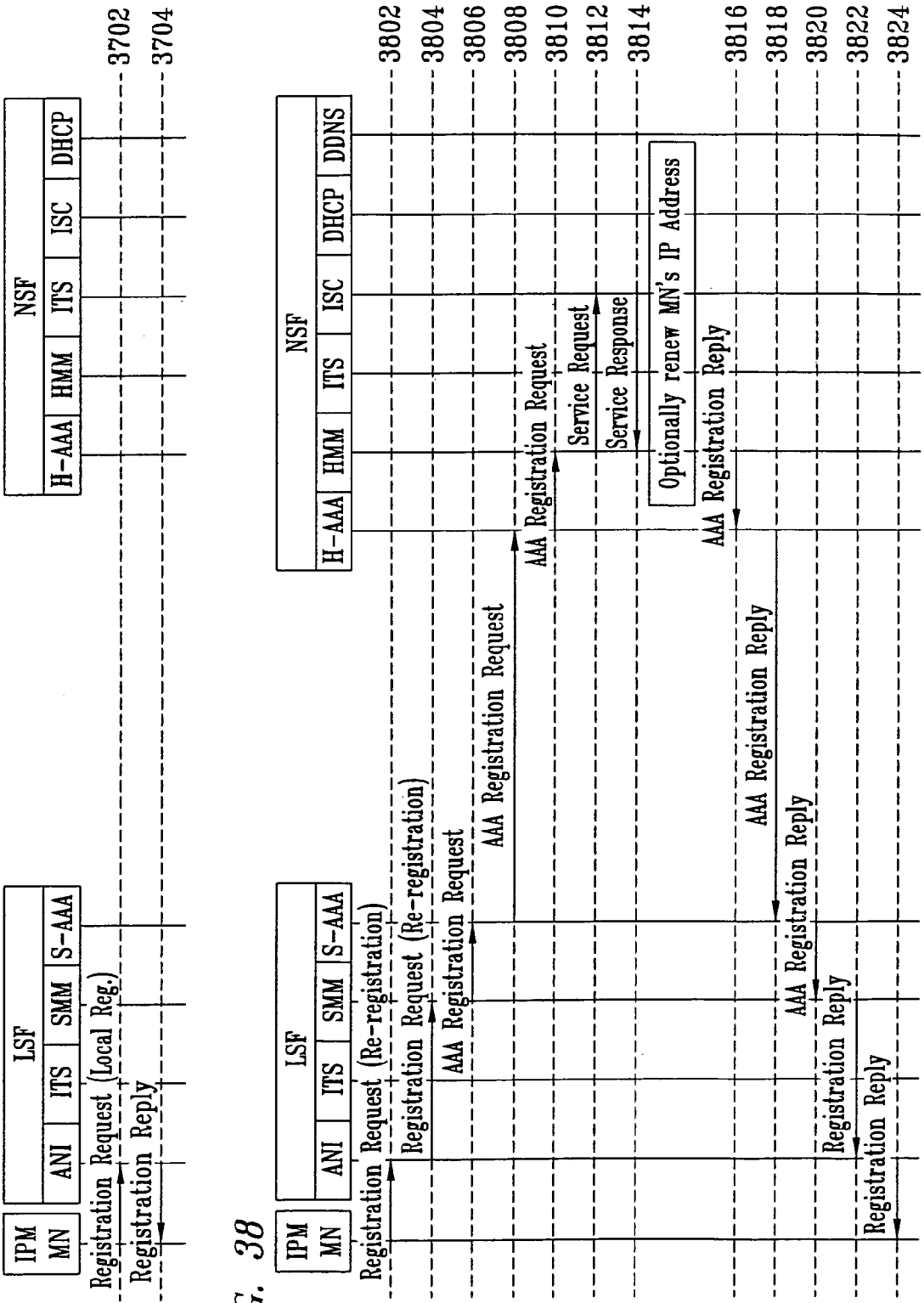

IPM
MN
NSF
ANI
H-AAA
HMM
ITS
ISC
DHCP
DDNS
3602
3604
3606
3608
3610
3612
3614
3616
3618
Agent Solicitation
Agent Advertisement
Registration Request (Init. Reg.)
Registration Request (Init. Reg.)
Service Request
Service Response
Optionally allocate MN's IP Address from DHCP and Update DDNS if necessary
Registration Reply
Registration Reply

FIG. 36

FIG. 37

IPM
MN
LSF
ANI
ITS
SMM
S-AAA
NSF
H-AAA
HMM
ITS
ISC
DHCP
Registration Request (Local Reg.)
Registration Reply
3702
3704

FIG. 38


IPM
MN
LSF
ANI
ITS
SMM
S-AAA
NSF
H-AAA
HMM
ITS
ISC
DHCP
DDNS
Registration Request (Re-registration)
Registration Request (Re-registration)
AAA Registration Request
AAA Registration Request
AAA Registration Request
Service Request
Service Response
Optionally renew MN's IP Address
AAA Registration Reply
AAA Registration Reply
AAA Registration Reply
Registration Reply
Registration Reply
3802
3804
3806
3808
3810
3812
3814
3816
3818
3820
3822
3824

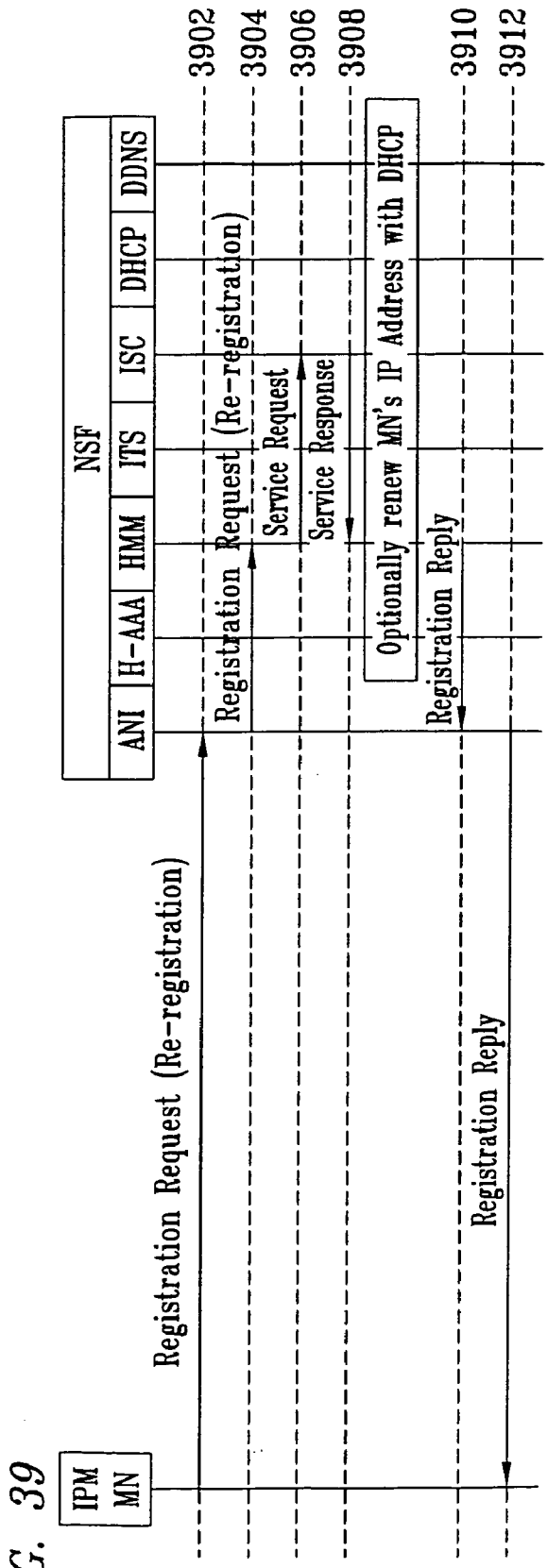
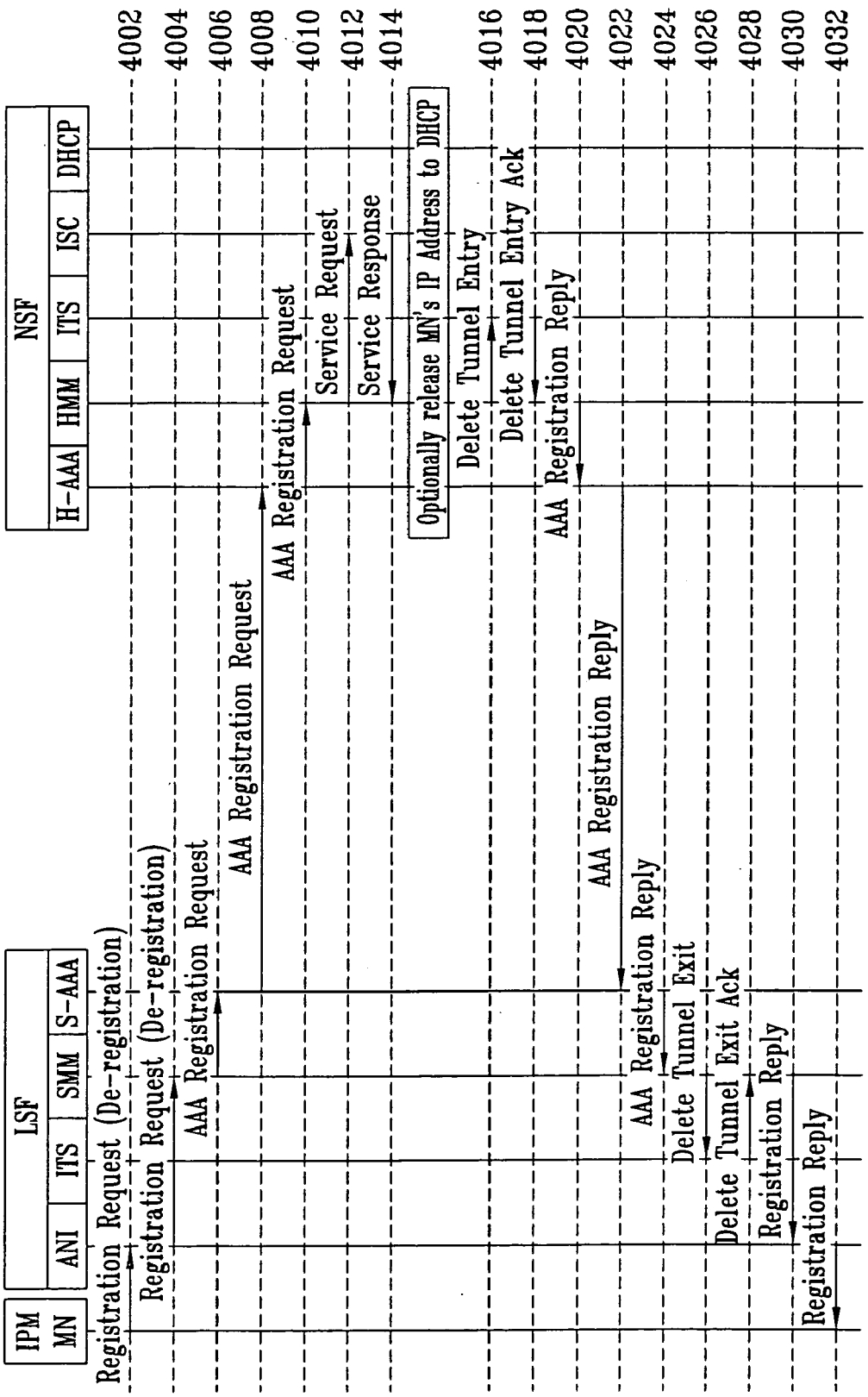

IPM MN
NSF
ANI
H-AAA
HMM
ITS
ISC
DHCP
DDNS
3902
3904
3906
3908
3910
3912
Registration Request (Re-registration)
Registration Request (Re-registration)
Service Request
Service Response
Optionally renew MN's IP Address with DHCP
Registration Reply
Registration Reply

FIG. 39

FIG. 40


IPM
MN
LSF
ANI
ITS
SMM
S-AAA
NSF
H-AAA
HMM
ITS
ISC
DHCP
Registration Request (De-registration)
Registration Request (De-registration)
AAA Registration Request
AAA Registration Request
AAA Registration Request
Service Request
Service Response
Optionally release MN's IP Address to DHCP
Delete Tunnel Entry
Delete Tunnel Entry Ack
AAA Registration Reply
AAA Registration Reply
AAA Registration Reply
Delete Tunnel Exit
Delete Tunnel Exit Ack
Registration Reply
Registration Reply
4002
4004
4006
4008
4010
4012
4014
4016
4018
4020
4022
4024
4026
4028
4030
4032

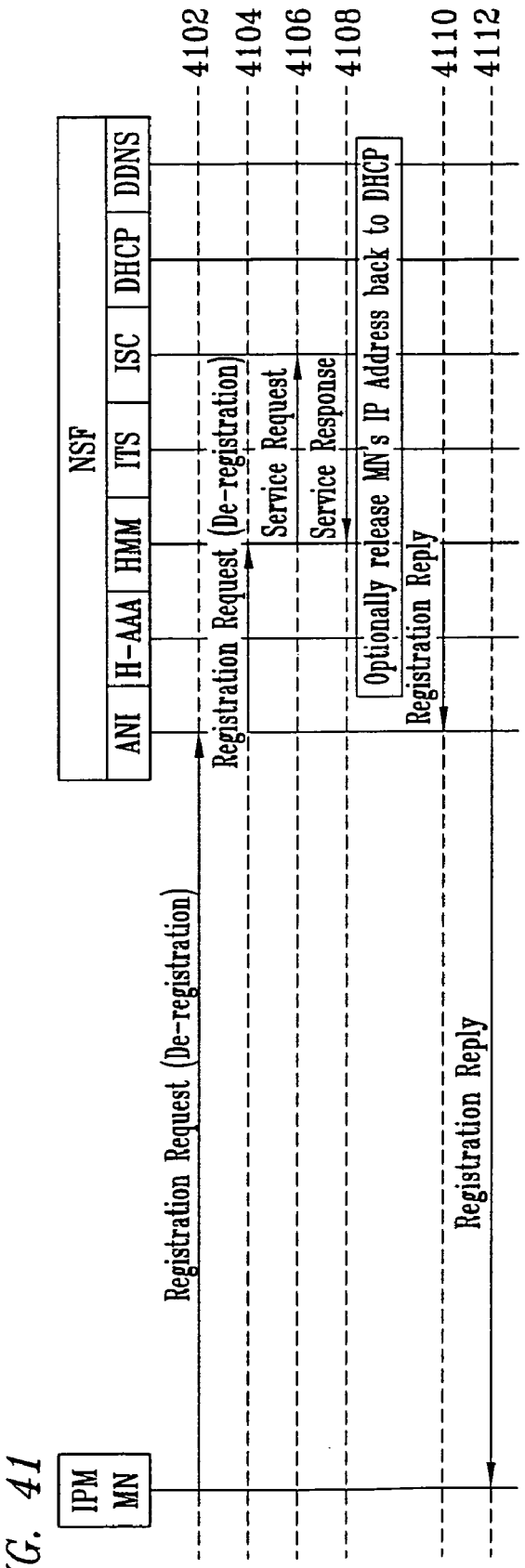

IPM MN
NSF
ANI
H-AAA
HMM
ITS
ISC
DHCP
DDNS
4102
4104
4106
4108
4110
4112
Registration Request (De-registration)
Registration Request (De-registration)
Service Request
Service Response
Optionally release MN's IP Address back to DHCP
Registration Reply
Registration Reply

FIG. 41

FIG. 42

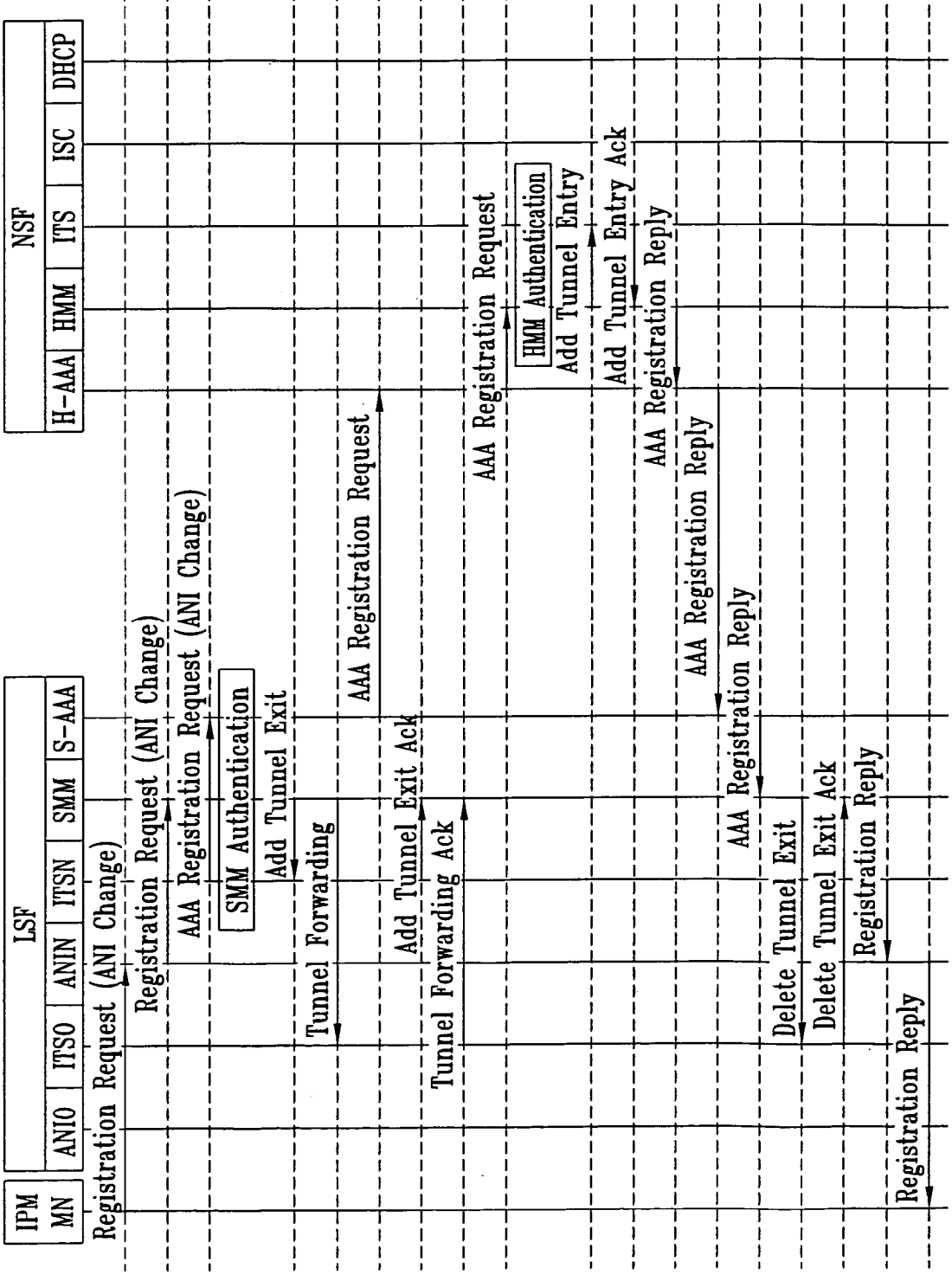
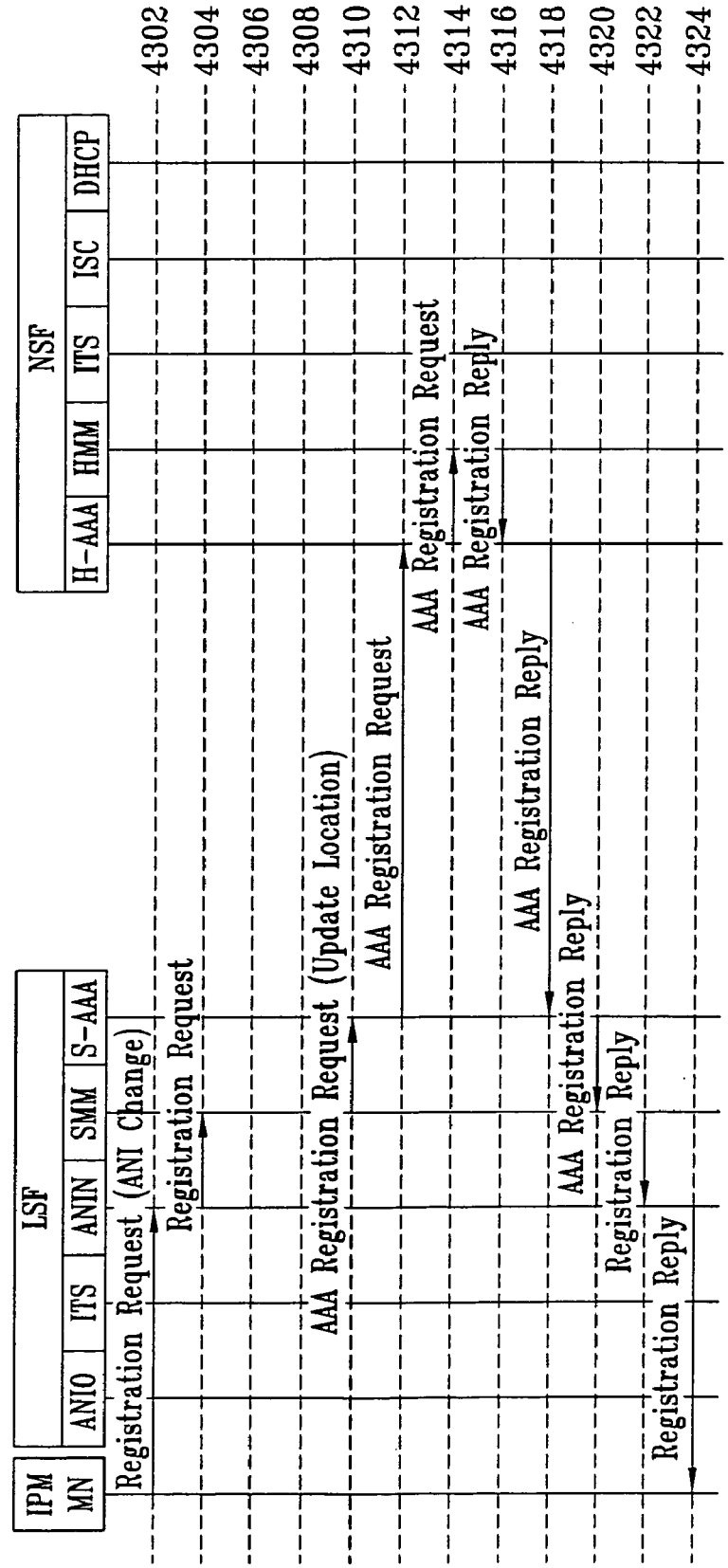

IPM
MN
LSF
AN10
ITSO
ANIN
ITSN
SMM
S-AAA
NSF
H-AAA
HMM
ITS
ISC
DHCP
Registration Request (ANI Change)
Registration Request (ANI Change)
AAA Registration Request (ANI Change)
SMM Authentication
Add Tunnel Exit
Tunnel Forwarding
AAA Registration Request
Add Tunnel Exit Ack
Tunnel Forwarding Ack
AAA Registration Request
HMM Authentication
Add Tunnel Entry
Add Tunnel Entry Ack
AAA Registration Reply
AAA Registration Reply
AAA Registration Reply
Delete Tunnel Exit
Delete Tunnel Exit Ack
Registration Reply
Registration Reply
4202
4204
4206
4208
4210
4212
4214
4216
4218
4220
4222
4224
4226
4228
4230
4232
4234
4236

FIG. 43


IPM
MN
LSF
ANIO
ITS
ANIN
SMM
S-AAA
NSF
H-AAA
HMM
ITS
ISC
DHCP
4302
4304
4306
4308
4310
4312
4314
4316
4318
4320
4322
4324
Registration Request (ANI Change)
Registration Request
AAA Registration Request (Update Location)
AAA Registration Request
AAA Registration Request
AAA Registration Reply
AAA Registration Reply
AAA Registration Reply
AAA Registration Reply
Registration Reply
Registration Reply

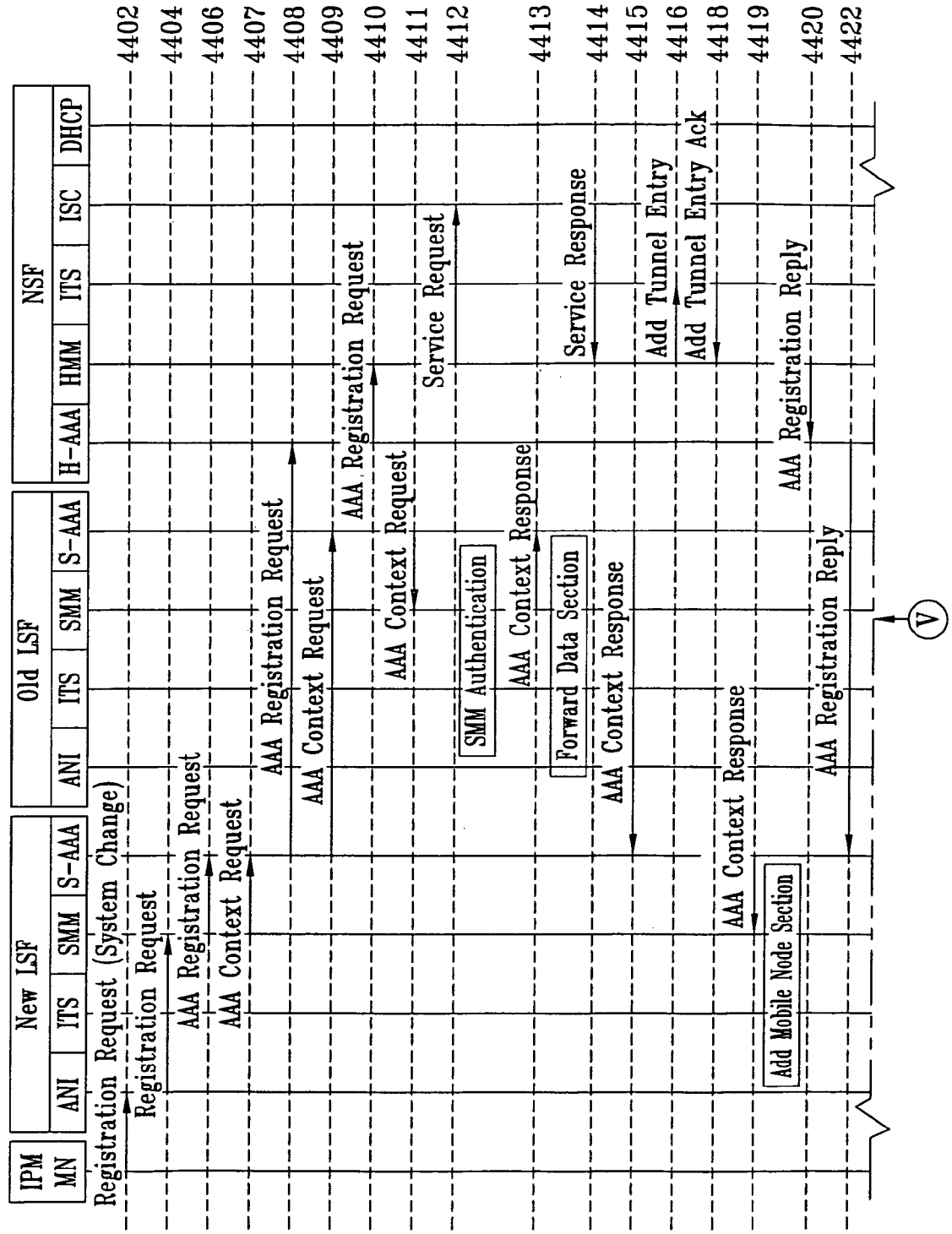

IPM
MN
New LSF
ANI
ITS
SMM
S-AAA
Old LSF
ANI
ITS
SMM
S-AAA
NSF
H-AAA
HMM
ITS
ISC
DHCP
4402
4404
4406
4407
4408
4409
4410
4411
4412
4413
4414
4415
4416
4418
4419
4420
4422
Registration Request (System Change)
Registration Request
AAA Registration Request
AAA Context Request
AAA Registration Request
AAA Context Request
AAA Context Request
AAA Registration Request
AAA Context Request
Service Request
SMM Authentication
AAA Context Response
Forward Data Section
Service Response
AAA Context Response
Add Tunnel Entry
Add Tunnel Entry Ack
AAA Context Response
Add Mobile Node Section
AAA Registration Reply
AAA Registration Reply
V

FIG. 44A

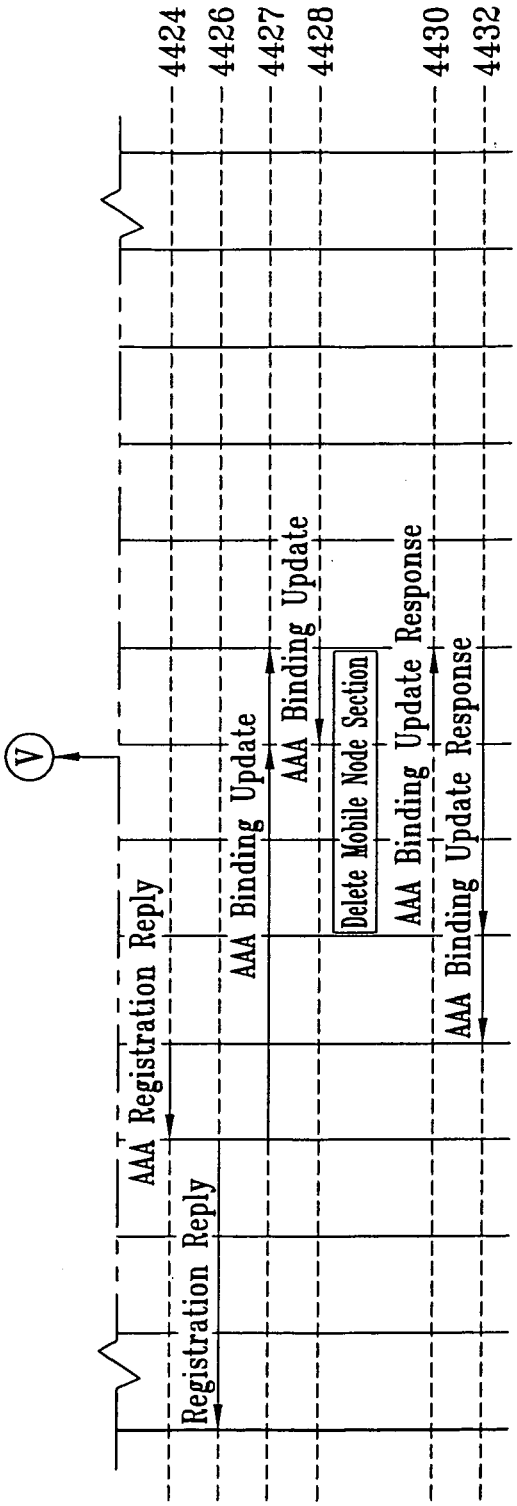

4424
4426
4427
4428
4430
4432
V
AAA Registration Reply
Registration Reply
AAA Binding Update
AAA Binding Update
Delete Mobile Node Section
AAA Binding Update Response
AAA Binding Update Response

FIG. 44B

FIG. 45

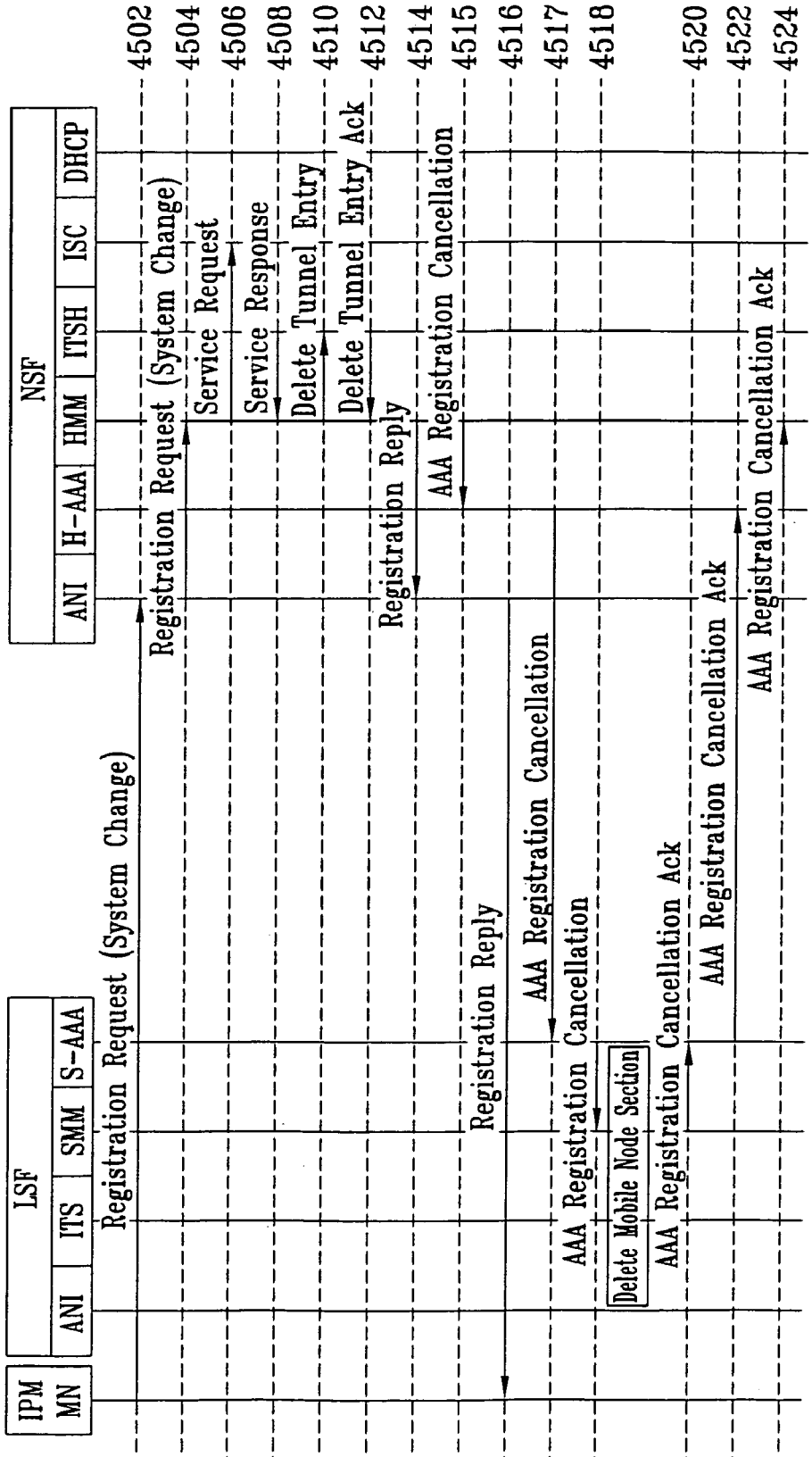

IPM
MN
LSF
ANI
ITS
SMM
S-AAA
NSF
ANI
H-AAA
HMM
ITSH
ISC
DHCP
Registration Request (System Change)
Registration Request (System Change)
Service Request
Service Response
Delete Tunnel Entry
Delete Tunnel Entry Ack
Registration Reply
AAA Registration Cancellation
Registration Reply
AAA Registration Cancellation
AAA Registration Cancellation
Delete Mobile Node Section
AAA Registration Cancellation Ack
AAA Registration Cancellation Ack
AAA Registration Cancellation Ack
4502
4504
4506
4508
4510
4512
4514
4515
4516
4517
4518
4520
4522
4524

FIG. 46

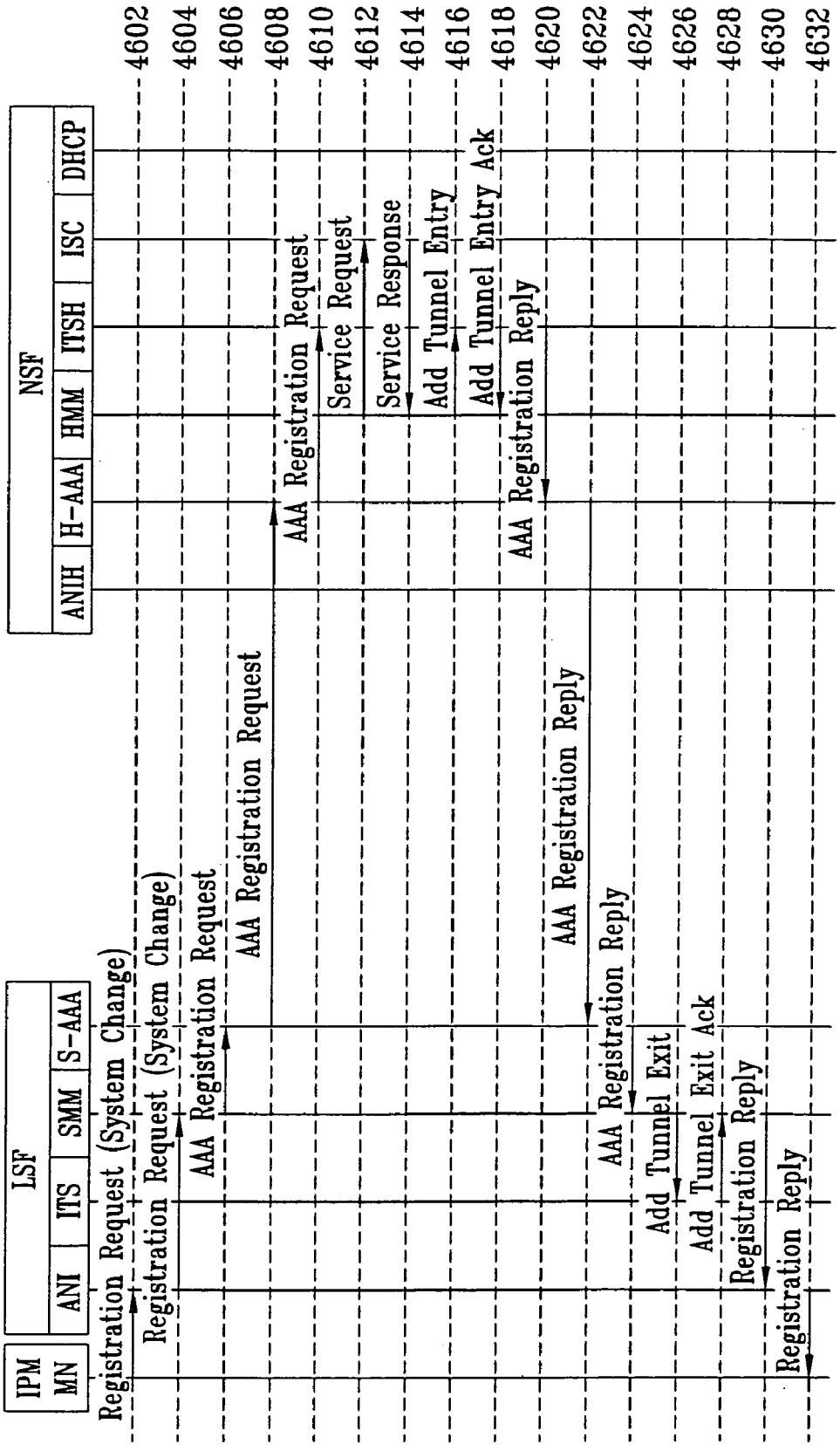

IPM
MN
LSF
ANI
ITS
SMM
S-AAA
NSF
ANIH
H-AAA
HMM
ITSH
ISC
DHCP
Registration Request (System Change)
Registration Request (System Change)
AAA Registration Request
AAA Registration Request
AAA Registration Request
Service Request
Service Response
Add Tunnel Entry
Add Tunnel Entry Ack
AAA Registration Reply
AAA Registration Reply
AAA Registration Reply
Add Tunnel Exit
Add Tunnel Exit Ack
Registration Reply
Registration Reply
4602
4604
4606
4608
4610
4612
4614
4616
4618
4620
4622
4624
4626
4628
4630
4632

FIG. 47

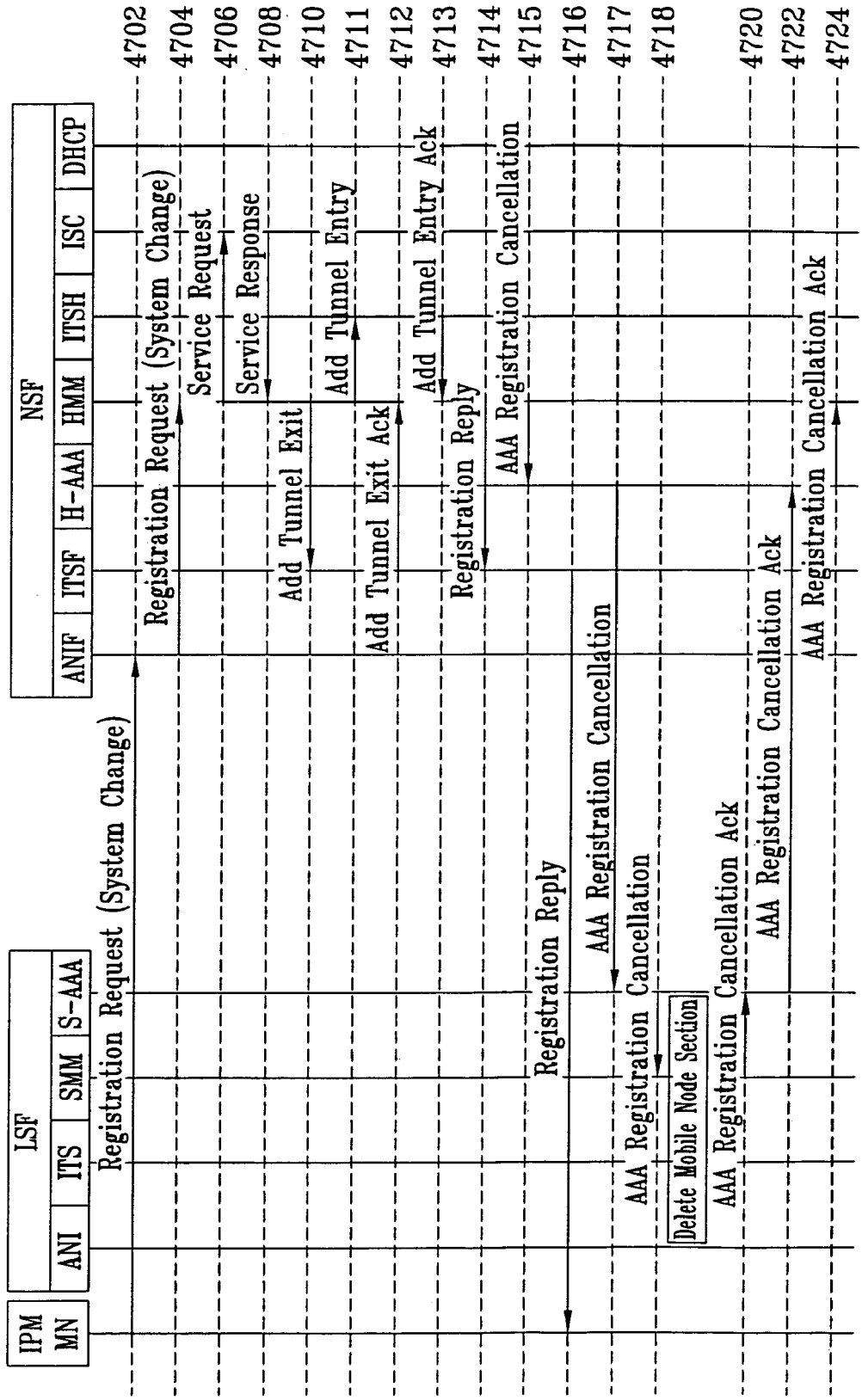

IPM
MN
LSF
ANI
ITS
SMM
S-AAA
NSF
ANIF
ITSF
H-AAA
HMM
ITSH
ISC
DHCP
Registration Request (System Change)
Registration Request (System Change)
Service Request
Service Response
Add Tunnel Exit
Add Tunnel Entry
Add Tunnel Exit Ack
Add Tunnel Entry Ack
Registration Reply
AAA Registration Cancellation
Registration Reply
AAA Registration Cancellation
AAA Registration Cancellation
Delete Mobile Node Section
AAA Registration Cancellation Ack
AAA Registration Cancellation Ack
AAA Registration Cancellation Ack
4702
4704
4706
4708
4710
4711
4712
4713
4714
4715
4716
4717
4718
4720
4722
4724

FIG. 48

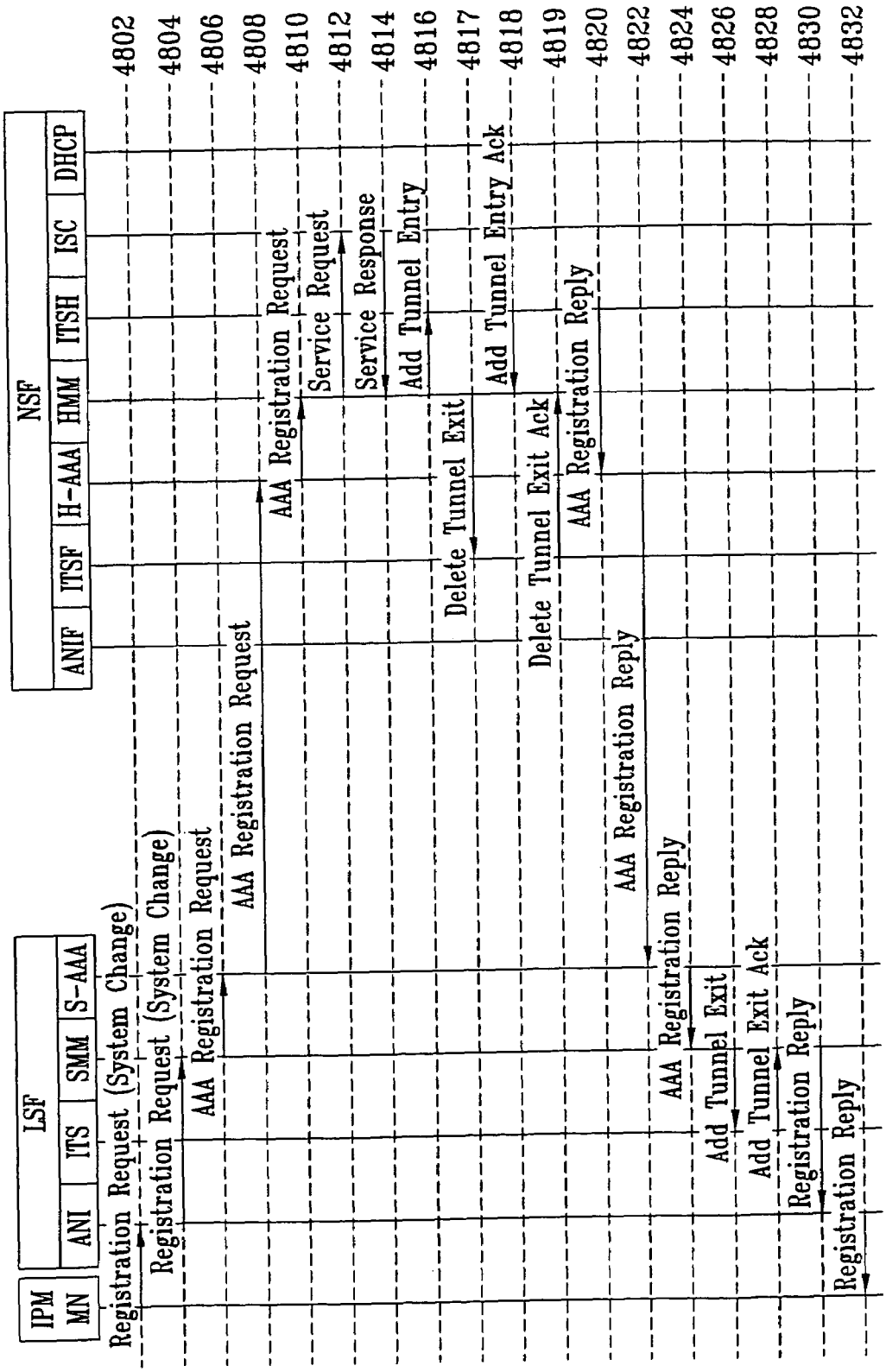
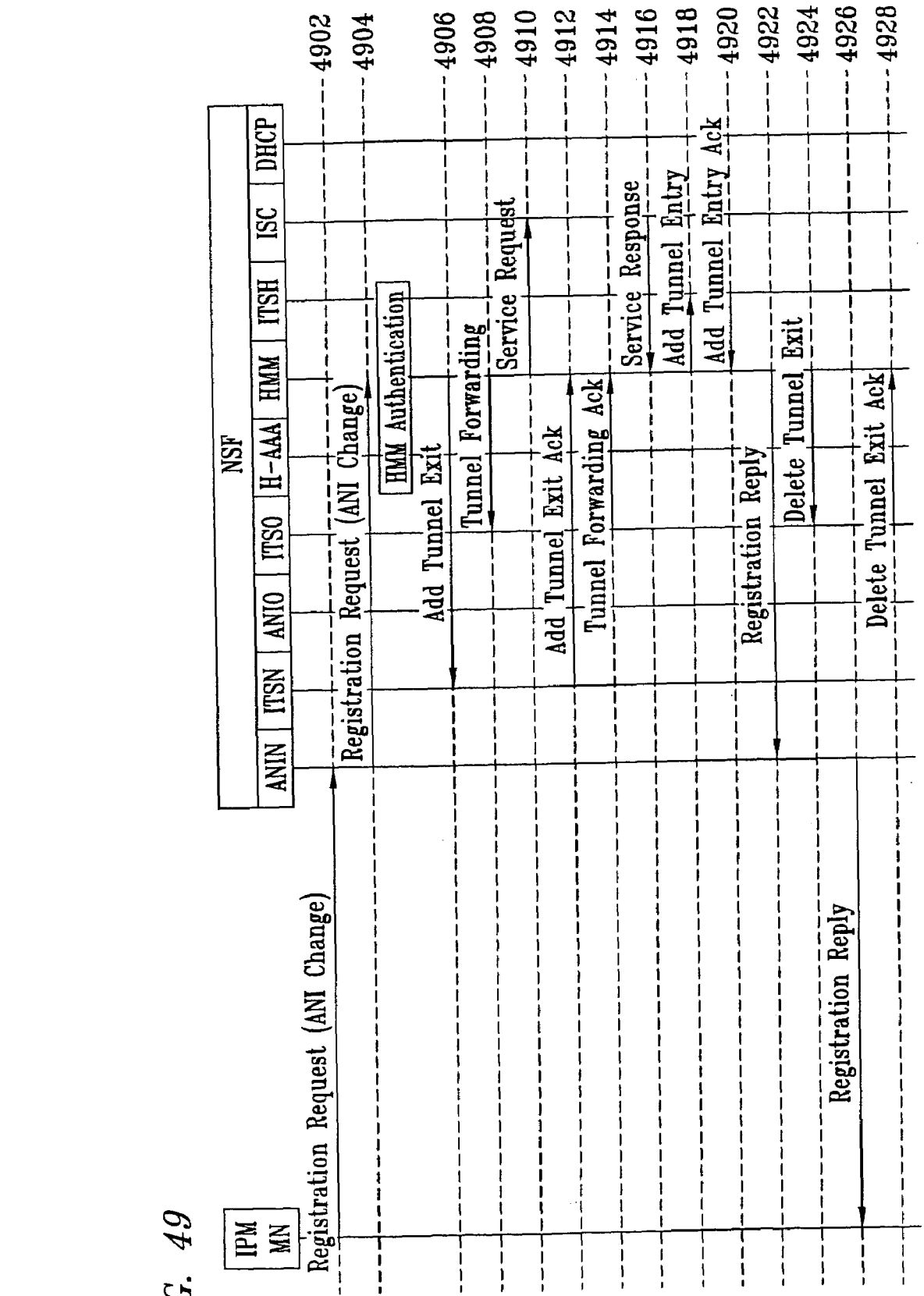

IPM
MN
LSF
ANI
ITS
SMM
S-AAA
NSF
ANIF
ITSF
H-AAA
HMM
ITSH
ISC
DHCP
Registration Request (System Change)
Registration Request (System Change)
AAA Registration Request
AAA Registration Request
AAA Registration Request
Service Request
Service Response
Add Tunnel Entry
Delete Tunnel Exit
Add Tunnel Entry Ack
Delete Tunnel Exit Ack
AAA Registration Reply
AAA Registration Reply
AAA Registration Reply
Add Tunnel Exit
Add Tunnel Exit Ack
Registration Reply
Registration Reply
4802
4804
4806
4808
4810
4812
4814
4816
4817
4818
4819
4820
4822
4824
4826
4828
4830
4832

FIG. 49


IPM
MN
NSF
ANIN
ITSN
ANIO
ITSO
H-AAA
HMM
ITSH
ISC
DHCP
Registration Request (ANI Change)
Registration Request (ANI Change)
HMM Authentication
Add Tunnel Exit
Tunnel Forwarding
Service Request
Add Tunnel Exit Ack
Tunnel Forwarding Ack
Service Response
Add Tunnel Entry
Add Tunnel Entry Ack
Registration Reply
Delete Tunnel Exit
Registration Reply
Delete Tunnel Exit Ack
4902
4904
4906
4908
4910
4912
4914
4916
4918
4920
4922
4924
4926
4928

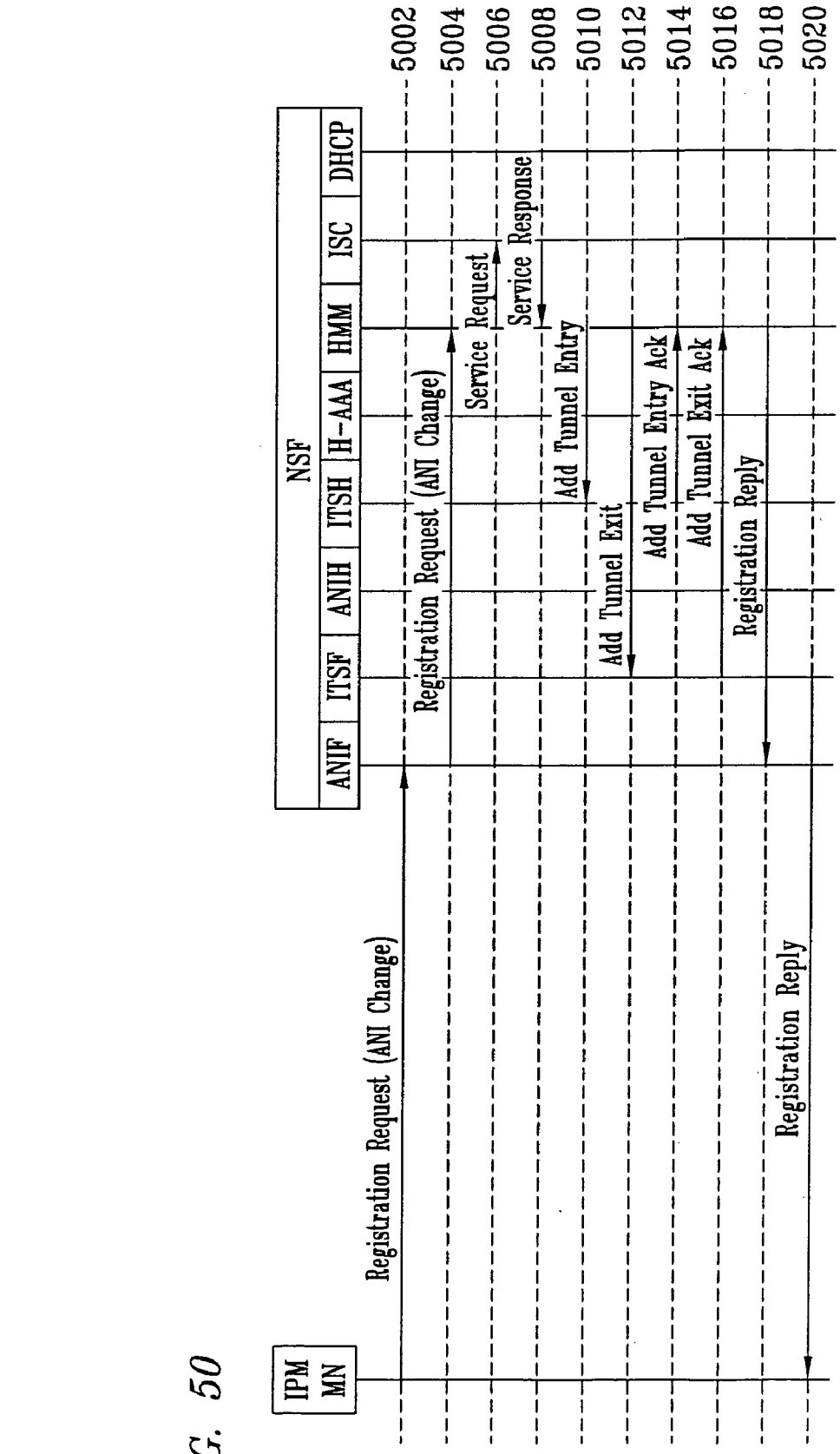

IPM MN
NSF
ANIF
ITSF
ANIH
ITSH
H-AAA
HMM
ISC
DHCP
5002
5004
5006
5008
5010
5012
5014
5016
5018
5020
Registration Request (ANI Change)
Registration Request (ANI Change)
Service Request
Service Response
Add Tunnel Entry
Add Tunnel Exit
Add Tunnel Entry Ack
Add Tunnel Exit Ack
Registration Reply
Registration Reply

FIG. 50

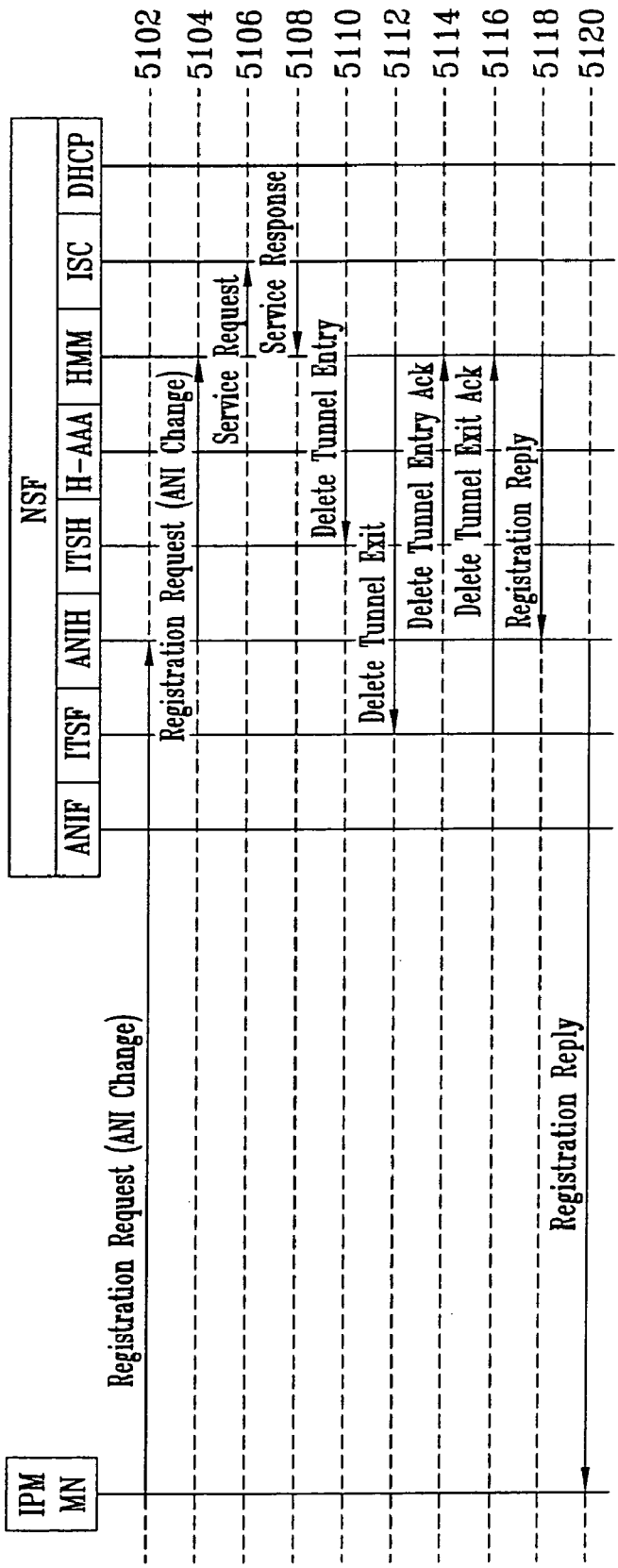

IPM MN
NSF
ANIF
ITSF
ANIH
ITSH
H-AAA
HMM
ISC
DHCP
5102
5104
5106
5108
5110
5112
5114
5116
5118
5120
Registration Request (ANI Change)
Registration Request (ANI Change)
Service Request
Service Response
Delete Tunnel Entry
Delete Tunnel Exit
Delete Tunnel Entry Ack
Delete Tunnel Exit Ack
Registration Reply
Registration Reply

FIG. 51

FIG. 52

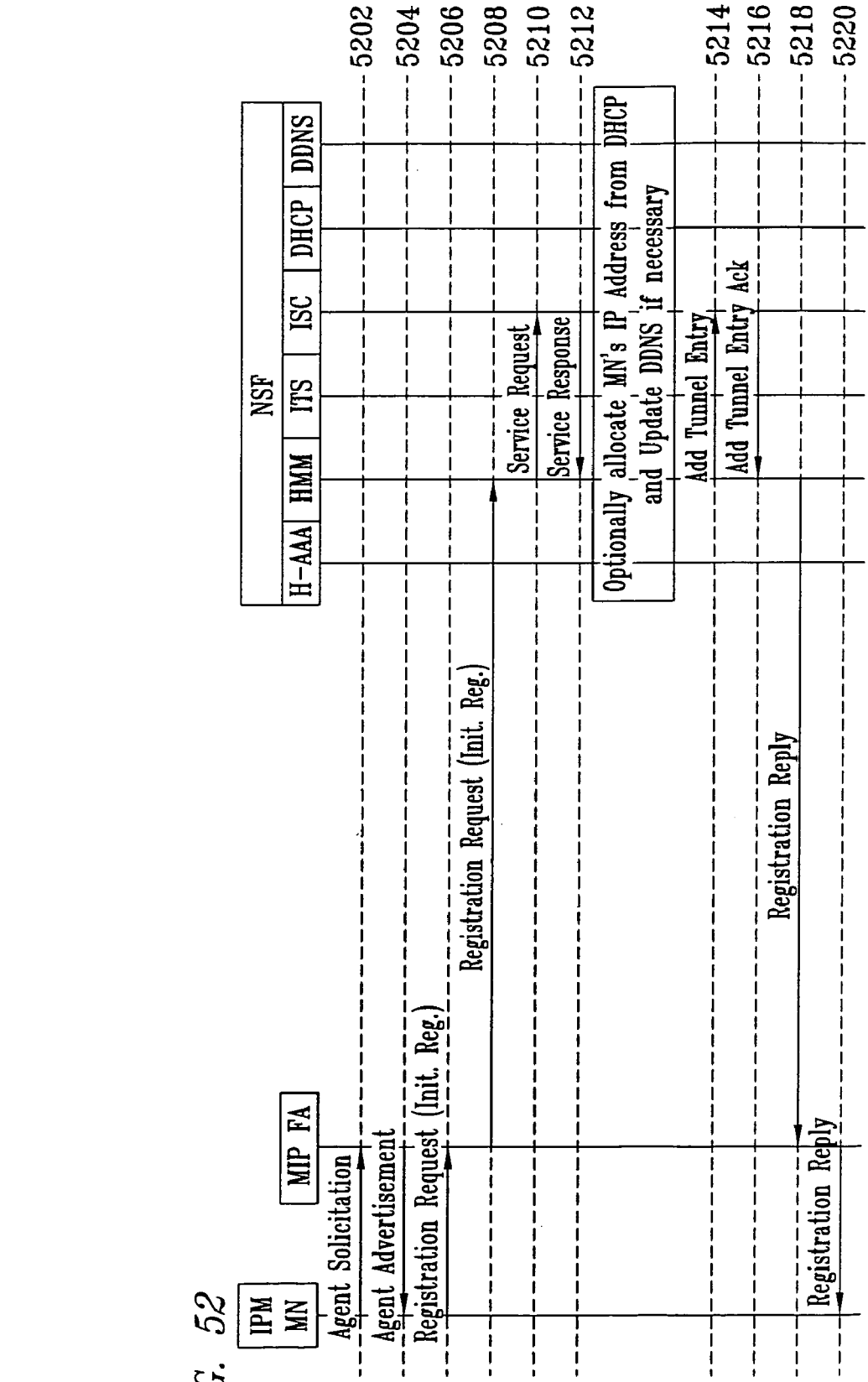
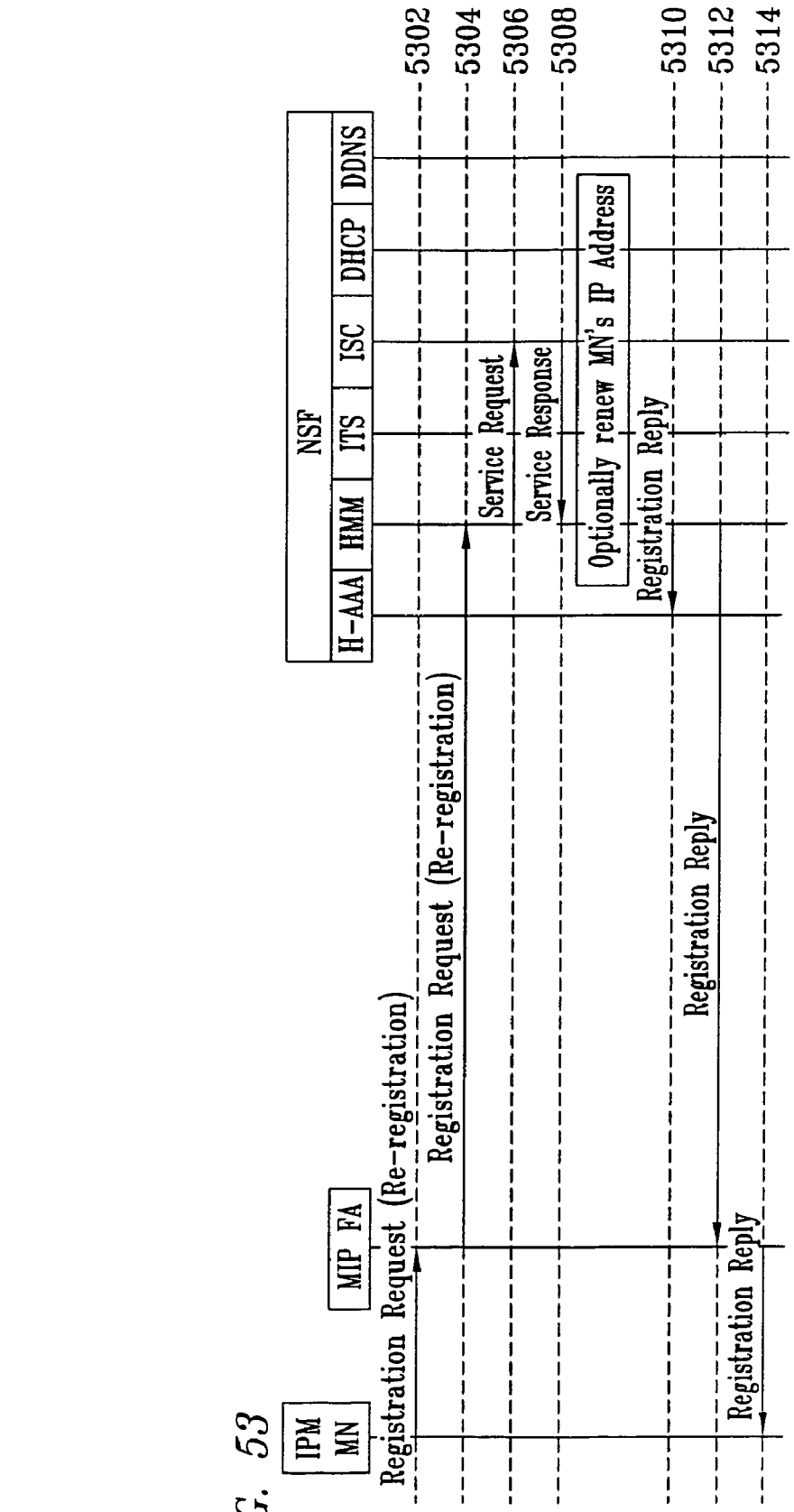

IPM MN
MIP FA
NSF
H-AAA
HMM
ITS
ISC
DHCP
DDNS
5202
5204
5206
5208
5210
5212
5214
5216
5218
5220
Agent Solicitation
Agent Advertisement
Registration Request (Init. Reg.)
Registration Request (Init. Reg.)
Service Request
Service Response
Optionally allocate MN's IP Address from DHCP and Update DDNS if necessary
Add Tunnel Entry
Add Tunnel Entry Ack
Registration Reply
Registration Reply

FIG. 53


IPM
MN
MIP FA
NSF
H-AAA
HMM
ITS
ISC
DHCP
DDNS
5302
5304
5306
5308
5310
5312
5314
Registration Request (Re-registration)
Registration Request (Re-registration)
Service Request
Service Response
Optionally renew MN's IP Address
Registration Reply
Registration Reply
Registration Reply

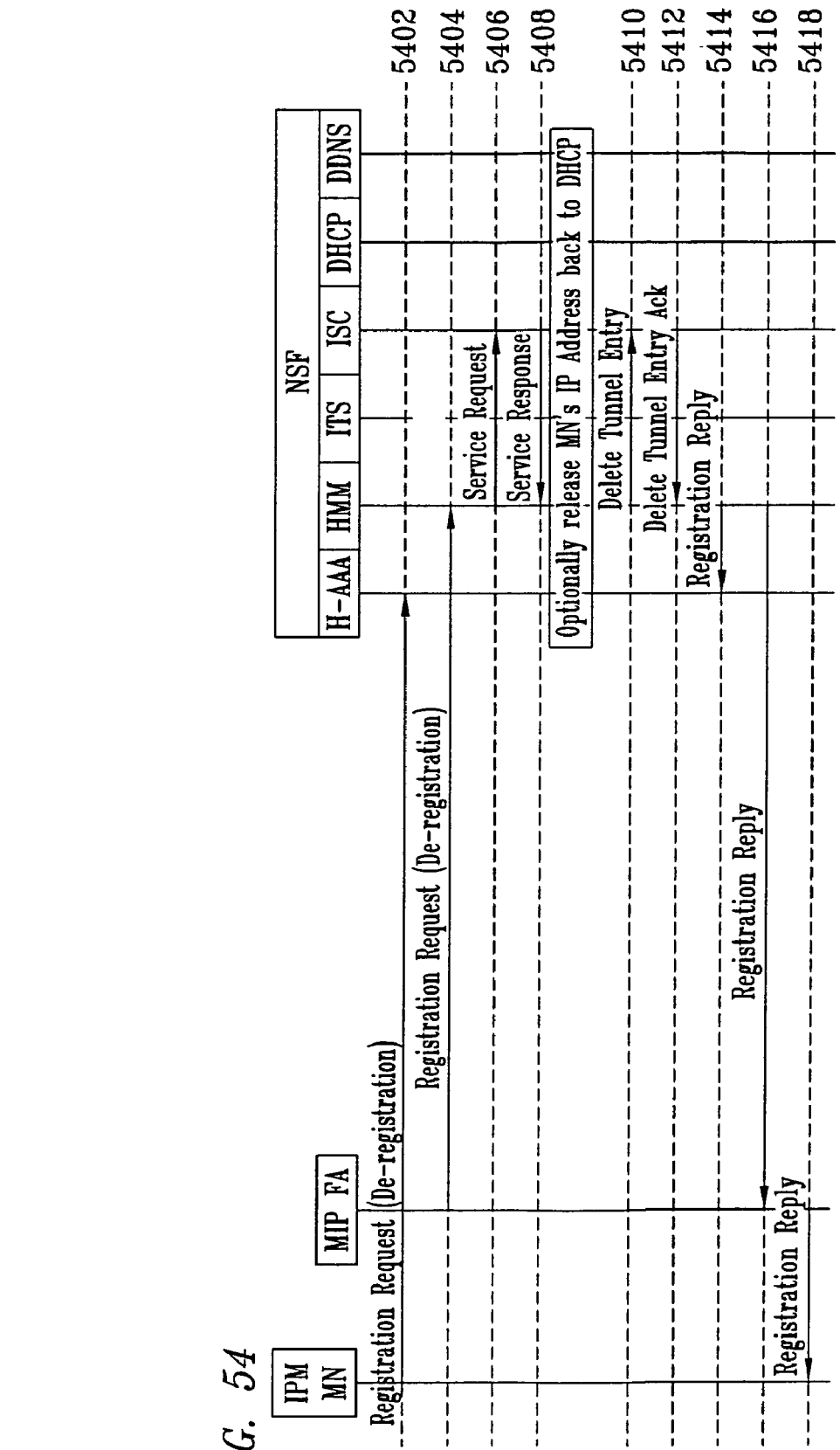

IPM MN
MIP FA
NSF
H-AAA
HMM
ITS
ISC
DHCP
DDNS
Registration Request (De-registration)
Registration Request (De-registration)
Service Request
Service Response
Optionally release MN's IP Address back to DHCP
Delete Tunnel Entry
Delete Tunnel Entry Ack
Registration Reply
Registration Reply
Registration Reply
5402
5404
5406
5408
5410
5412
5414
5416
5418

FIG. 54

FIG. 55

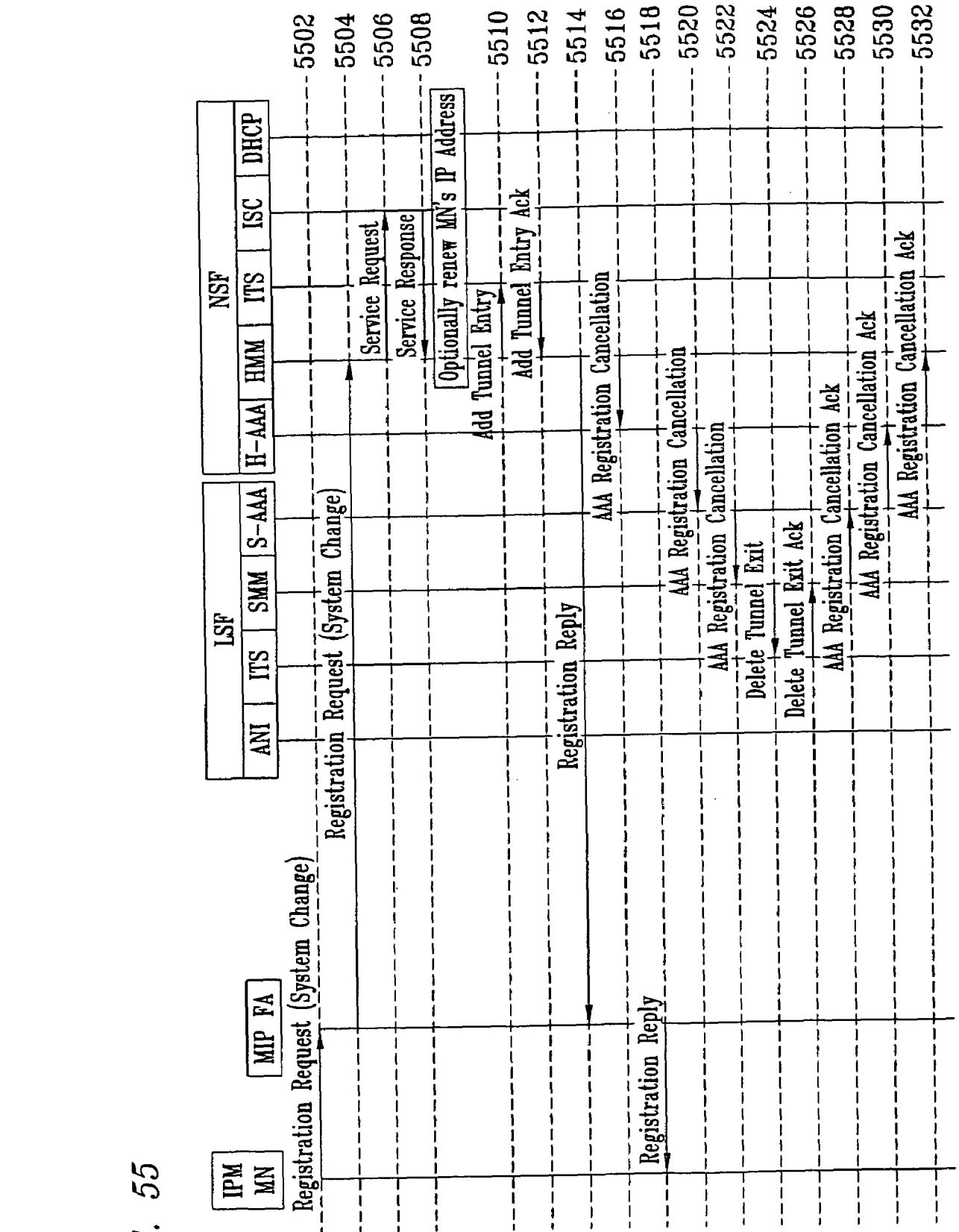
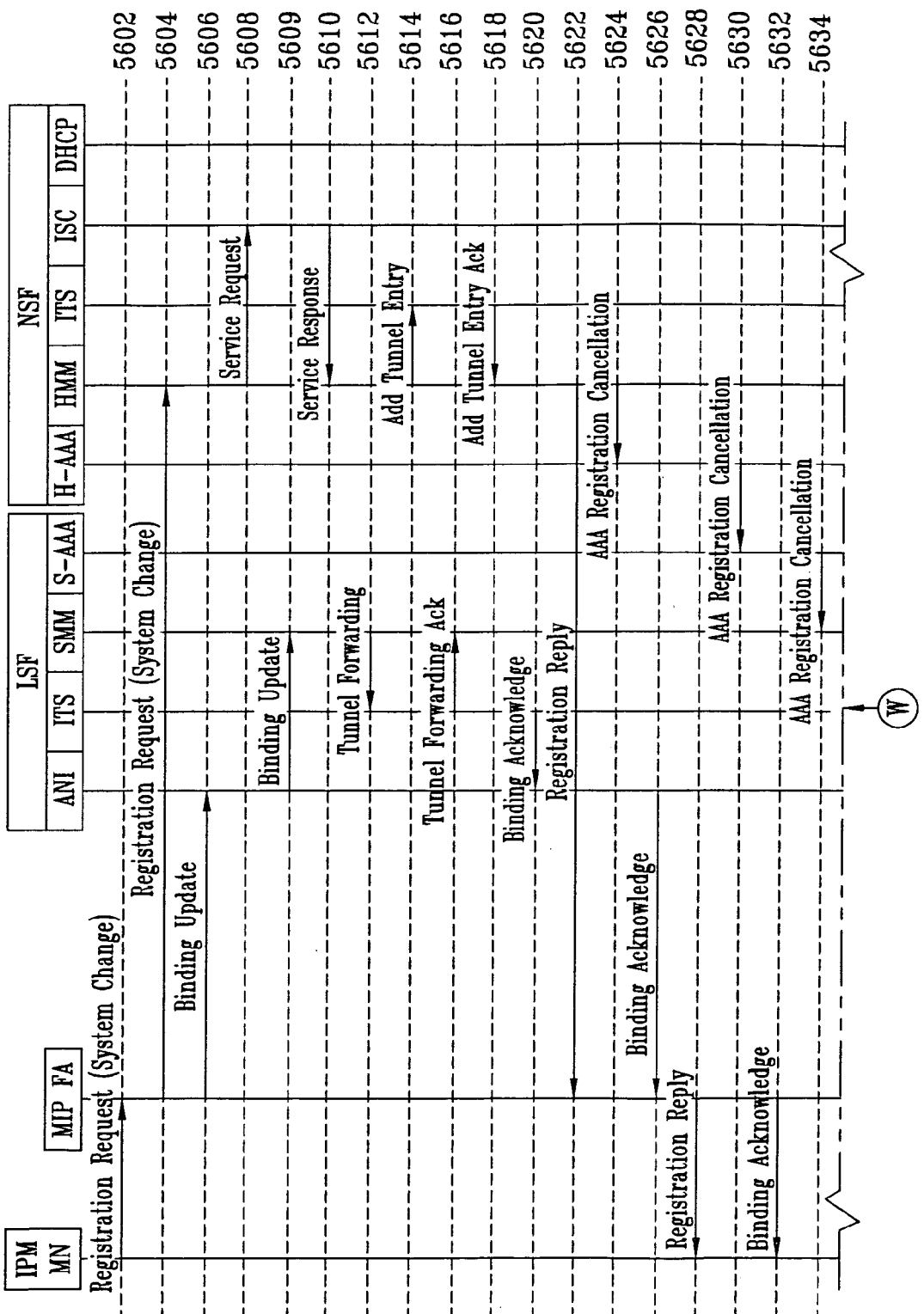

IPM MN
MIP FA
LSF
ANI
ITS
SMM
S-AAA
NSF
H-AAA
HMM
ITS
ISC
DHCP
Registration Request (System Change)
Registration Request (System Change)
Service Request
Service Response
Optionally renew MN's IP Address
Add Tunnel Entry
Add Tunnel Entry Ack
Registration Reply
AAA Registration Cancellation
Registration Reply
AAA Registration Cancellation
AAA Registration Cancellation
Delete Tunnel Exit
Delete Tunnel Exit Ack
AAA Registration Cancellation Ack
AAA Registration Cancellation Ack
AAA Registration Cancellation Ack
5502
5504
5506
5508
5510
5512
5514
5516
5518
5520
5522
5524
5526
5528
5530
5532

FIG. 56A


IPM MN
MIP FA
LSF
ANI
ITS
SMM
S-AAA
NSF
H-AAA
HMM
ITS
ISC
DHCP
5602
5604
5606
5608
5609
5610
5612
5614
5616
5618
5620
5622
5624
5626
5628
5630
5632
5634
Registration Request (System Change)
Registration Request (System Change)
Binding Update
Service Request
Binding Update
Service Response
Tunnel Forwarding
Add Tunnel Entry
Tunnel Forwarding Ack
Add Tunnel Entry Ack
Binding Acknowledge
Registration Reply
AAA Registration Cancellation
Binding Acknowledge
Registration Reply
AAA Registration Cancellation
Binding Acknowledge
AAA Registration Cancellation
W

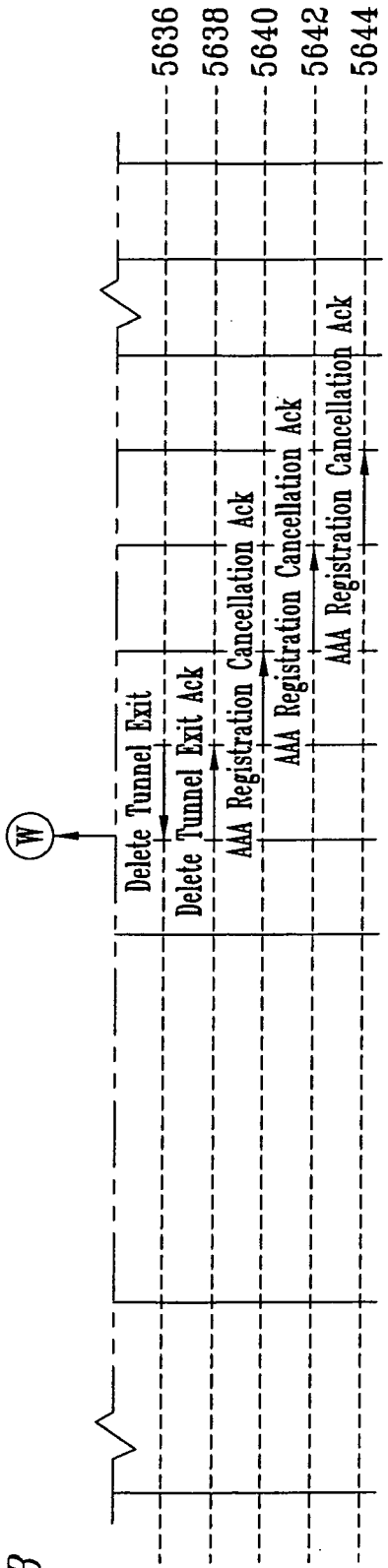

5636
5638
5640
5642
5644
W
Delete Tunnel Exit
Delete Tunnel Exit Ack
AAA Registration Cancellation Ack
AAA Registration Cancellation Ack
AAA Registration Cancellation Ack

FIG. 56B

FIG. 57

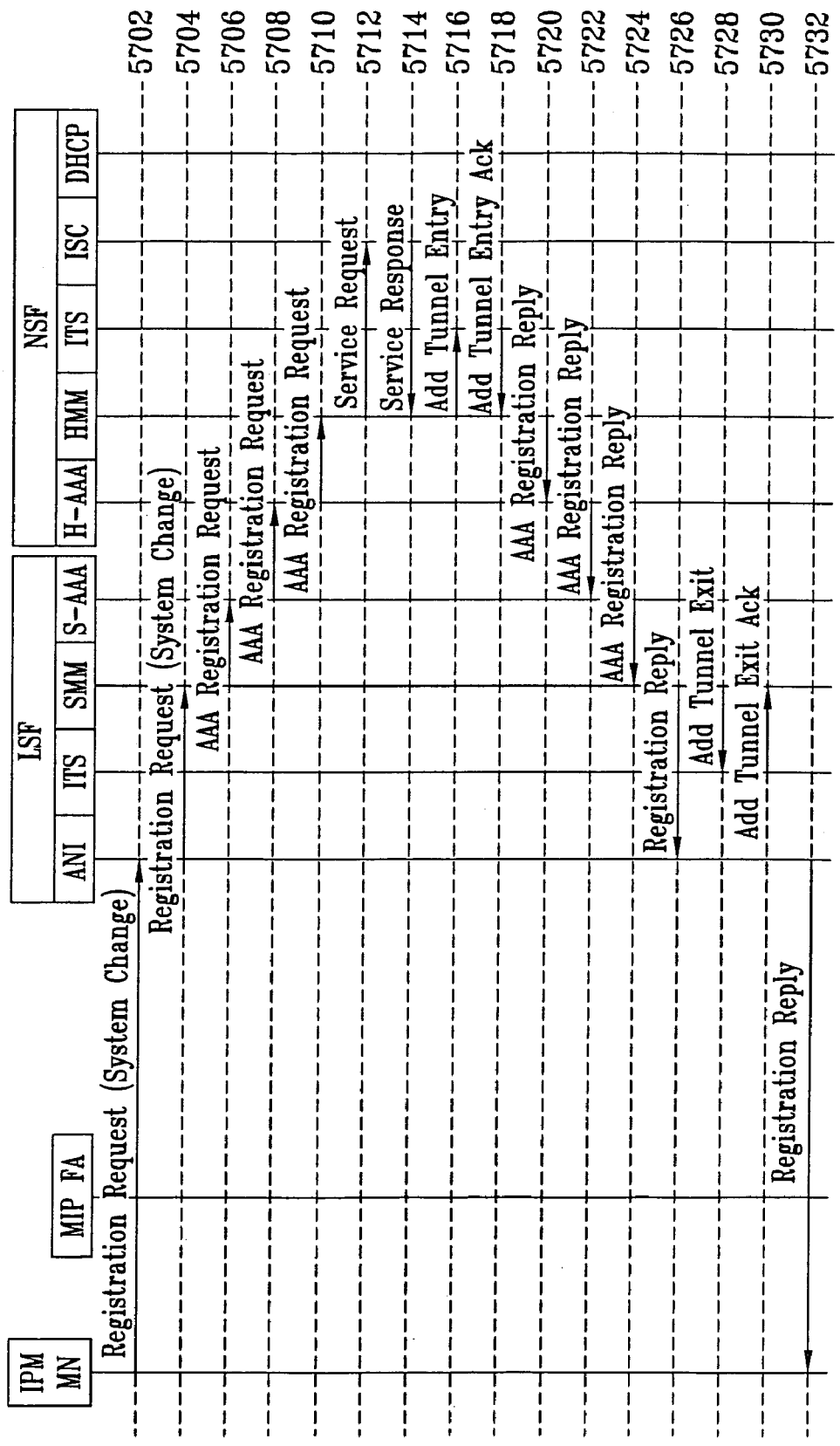

IPM
MN
MIP FA
LSF
ANI
ITS
SMM
S-AAA
NSF
H-AAA
HMM
ITS
ISC
DHCP
5702
5704
5706
5708
5710
5712
5714
5716
5718
5720
5722
5724
5726
5728
5730
5732
Registration Request (System Change)
Registration Request (System Change)
AAA Registration Request
AAA Registration Request
AAA Registration Request
Service Request
Service Response
Add Tunnel Entry
Add Tunnel Entry Ack
AAA Registration Reply
AAA Registration Reply
AAA Registration Reply
Registration Reply
Add Tunnel Exit
Add Tunnel Exit Ack
Registration Reply

FIG. 58

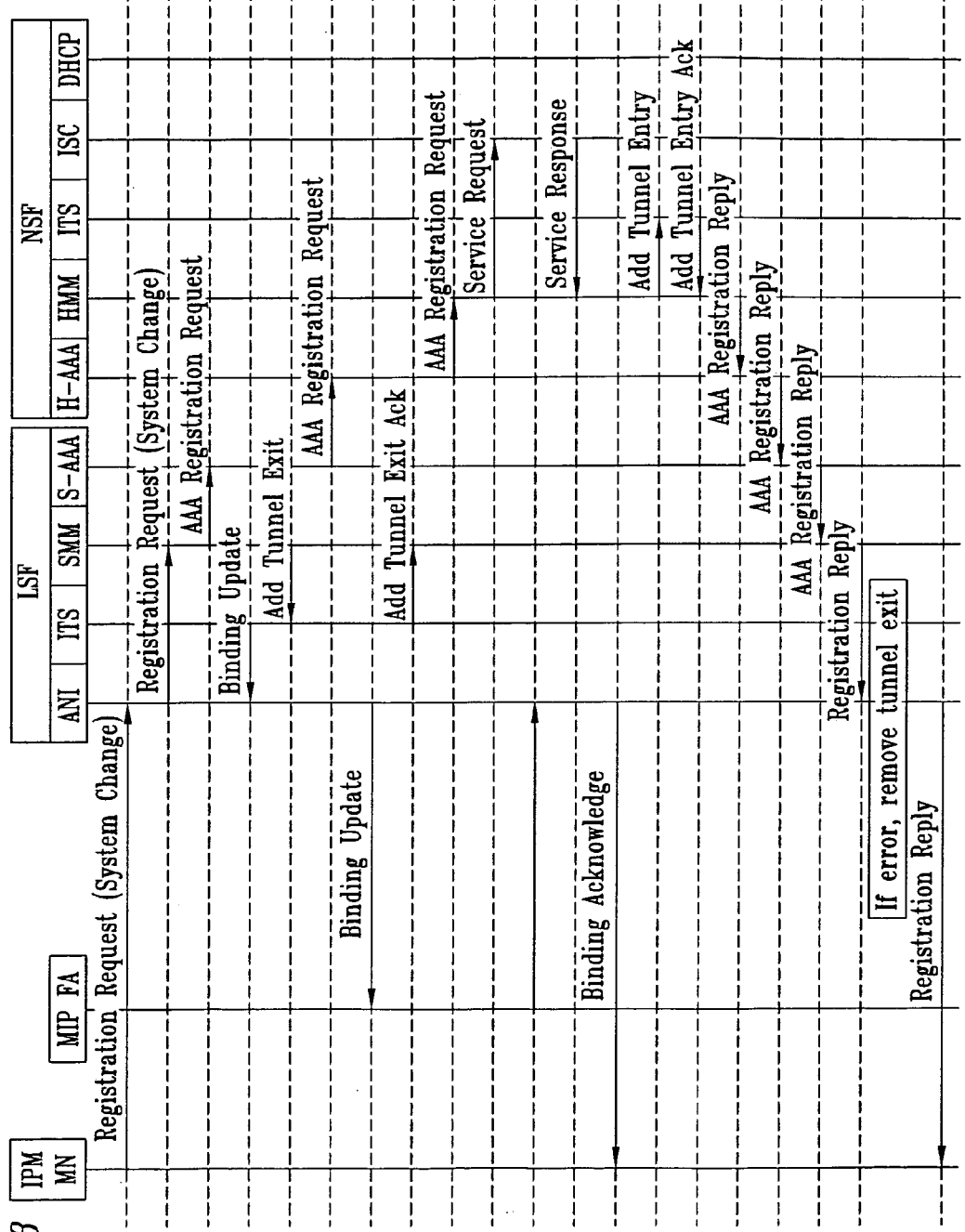
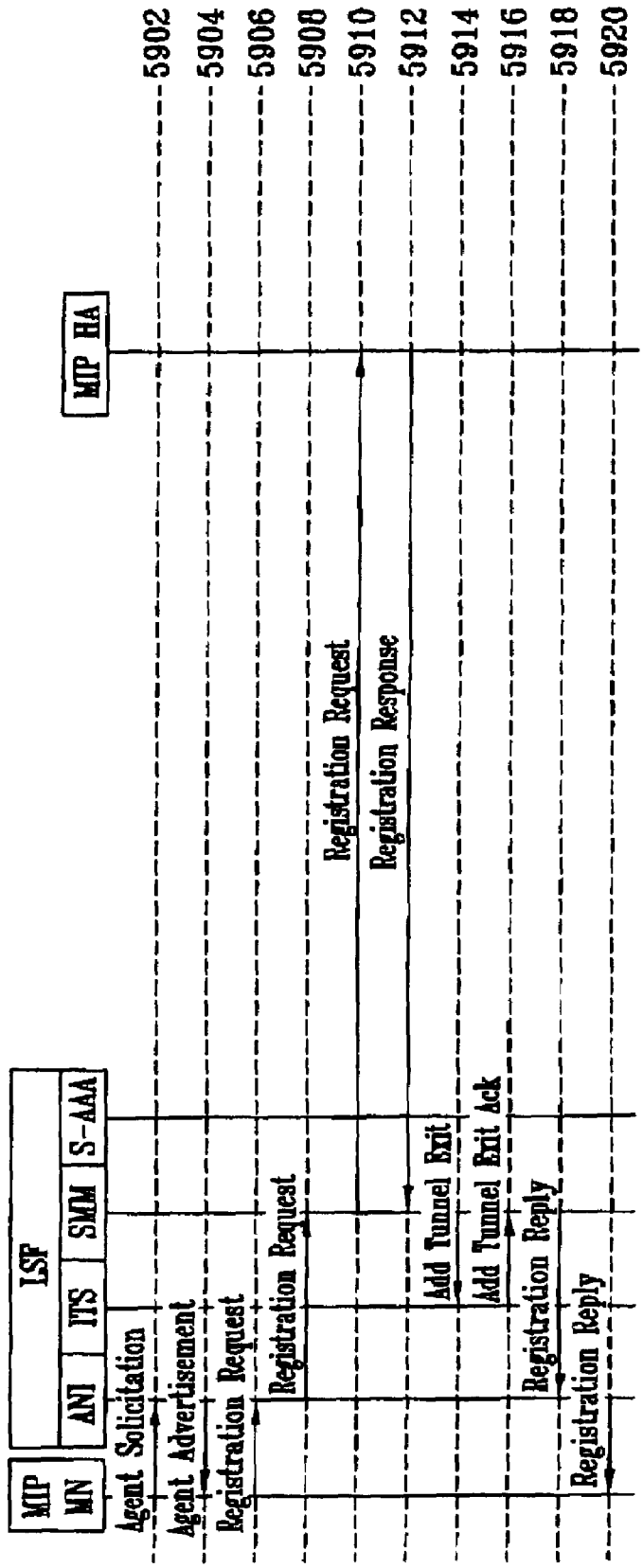

IPM MN
MIP FA
LSF
ANI
ITS
SMM
S-AAA
NSF
H-AAA
HMM
ITS
ISC
DHCP
Registration Request (System Change)
Registration Request (System Change)
AAA Registration Request
Binding Update
Add Tunnel Exit
AAA Registration Request
Add Tunnel Exit Ack
AAA Registration Request
Service Request
Service Response
Binding Acknowledge
Add Tunnel Entry
Add Tunnel Entry Ack
AAA Registration Reply
AAA Registration Reply
AAA Registration Reply
Registration Reply
If error, remove tunnel exit
Registration Reply
5802
5804
5806
5808
5810
5812
5814
5816
5818
5820
5822
5824
5826
5828
5830
5832
5834
5836
5838
5840

FIG. 59


MIP
MN
LSF
ANI
ITS
SMM
S-AAA
MIP HA
5902
5904
5906
5908
5910
5912
5914
5916
5918
5920
Agent Solicitation
Agent Advertisement
Registration Request
Registration Request
Registration Request
Registration Response
Add Tunnel Bnit
Add Tunnel Bnit Ack
Registration Reply
Registration Reply

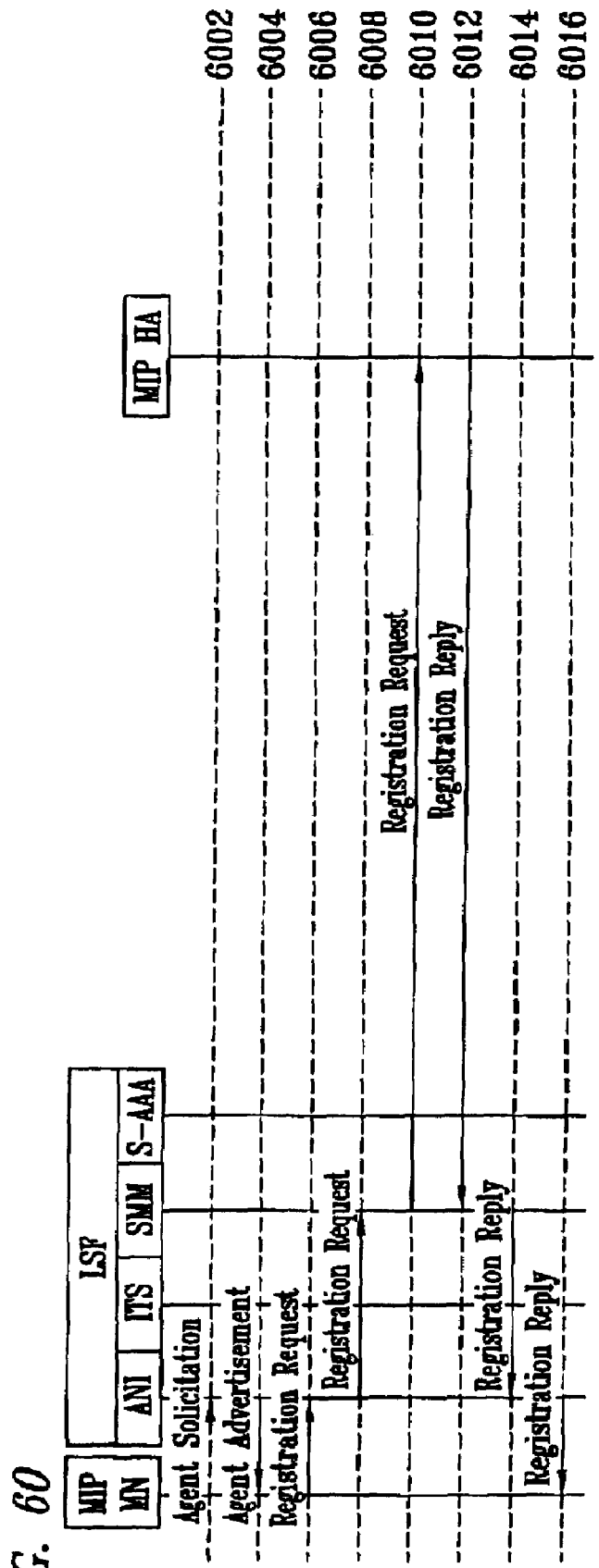

MIP
MN
LSP
ANI
ITS
SMM
S-AAA
MIP HA
6002
6004
6006
6008
6010
6012
6014
6016
Agent Solicitation
Agent Advertisement
Registration Request
Registration Request
Registration Request
Registration Reply
Registration Reply
Registration Reply

FIG. 60

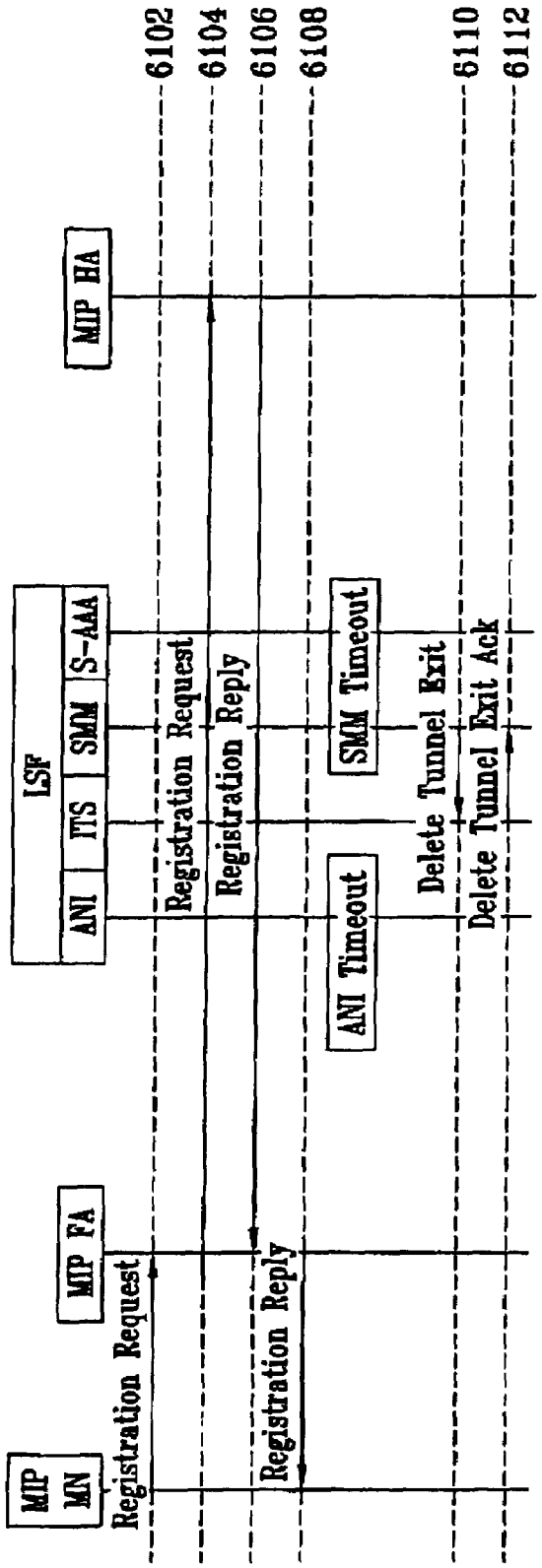
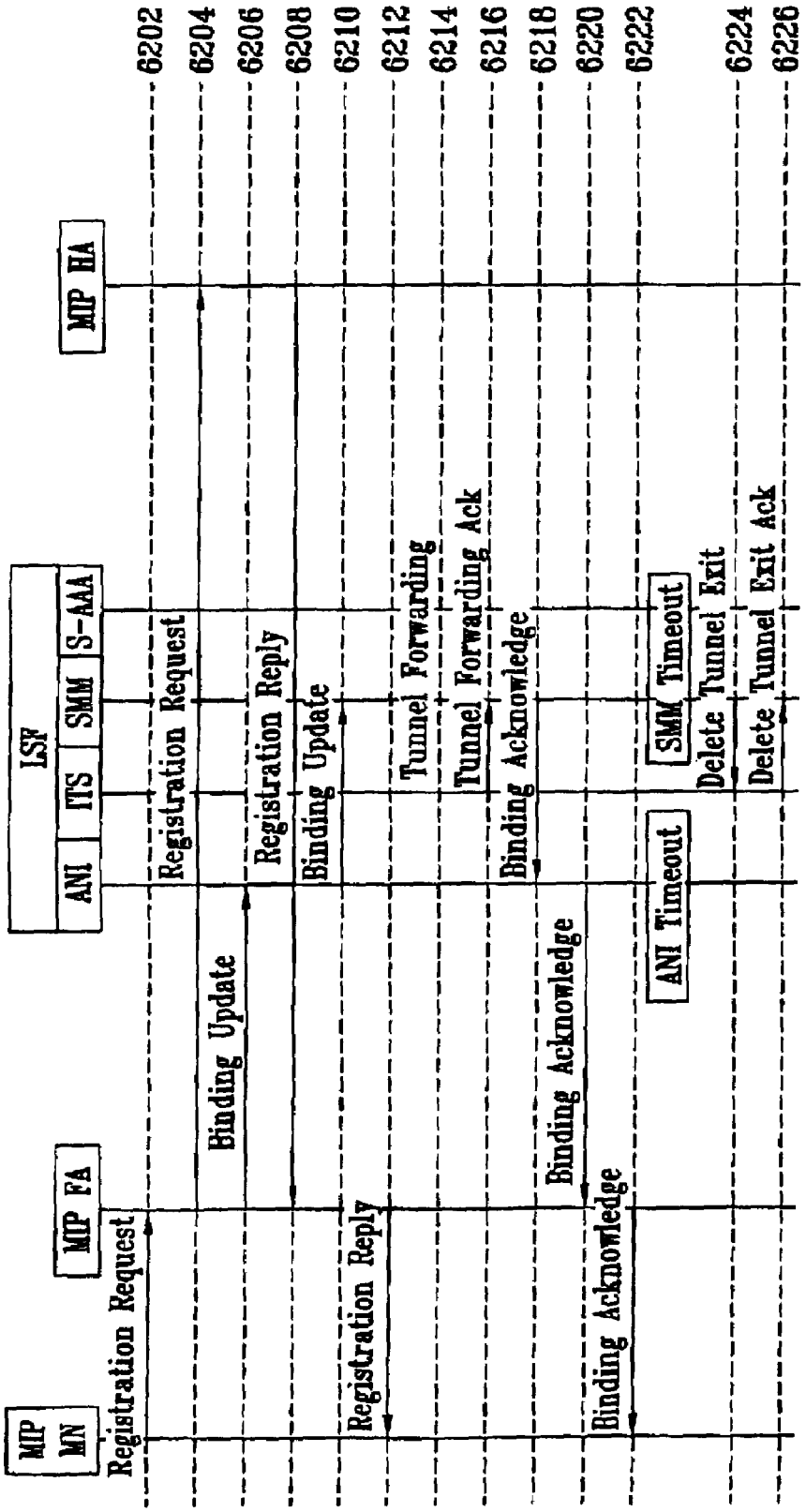

6102
6104
6106
6108
6110
6112
MIP MN
MIP FA
LSF
ANI
ITS
SMM
S-AAA
MIP HA
Registration Request
Registration Reply
Registration Reply
ANI Timeout
SMM Timeout
Delete Tunnel Exit
Delete Tunnel Exit Ack

FIG. 61

FIG. 62


MIP MN
MIP FA
LSF
ANI
ITS
SMM
S-AAA
MIP HA
6202
6204
6206
6208
6210
6212
6214
6216
6218
6220
6222
6224
6226
Registration Request
Registration Request
Binding Update
Registration Reply
Registration Reply
Binding Update
Tunnel Forwarding
Tunnel Forwarding Ack
Binding Acknowledge
Binding Acknowledge
Binding Acknowledge
ANI Timeout
SMM Timeout
Delete Tunnel Exit
Delete Tunnel Exit Ack

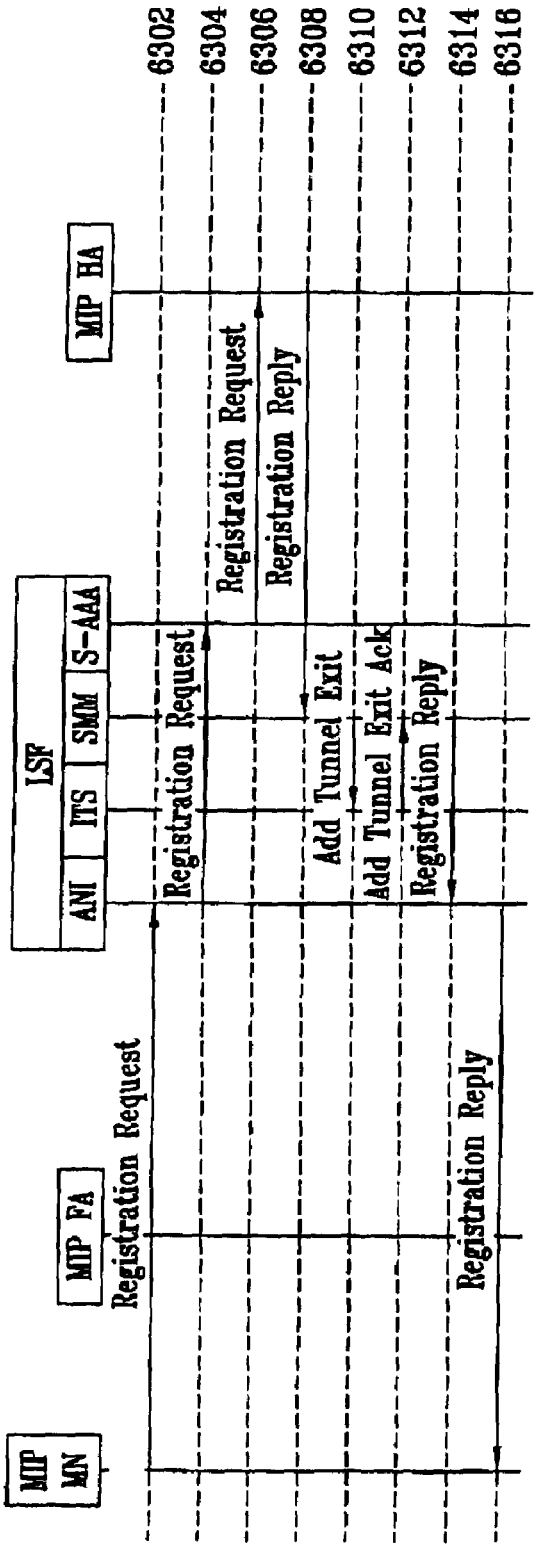

MIP MN
MIP FA
LSF
ANI
ITS
SMM
S-AAA
MIP HA
6302
6304
6306
6308
6310
6312
6314
6316
Registration Request
Registration Request
Registration Request
Registration Reply
Add Tunnel Exit
Add Tunnel Exit Ack
Registration Reply
Registration Reply

FIG. 63

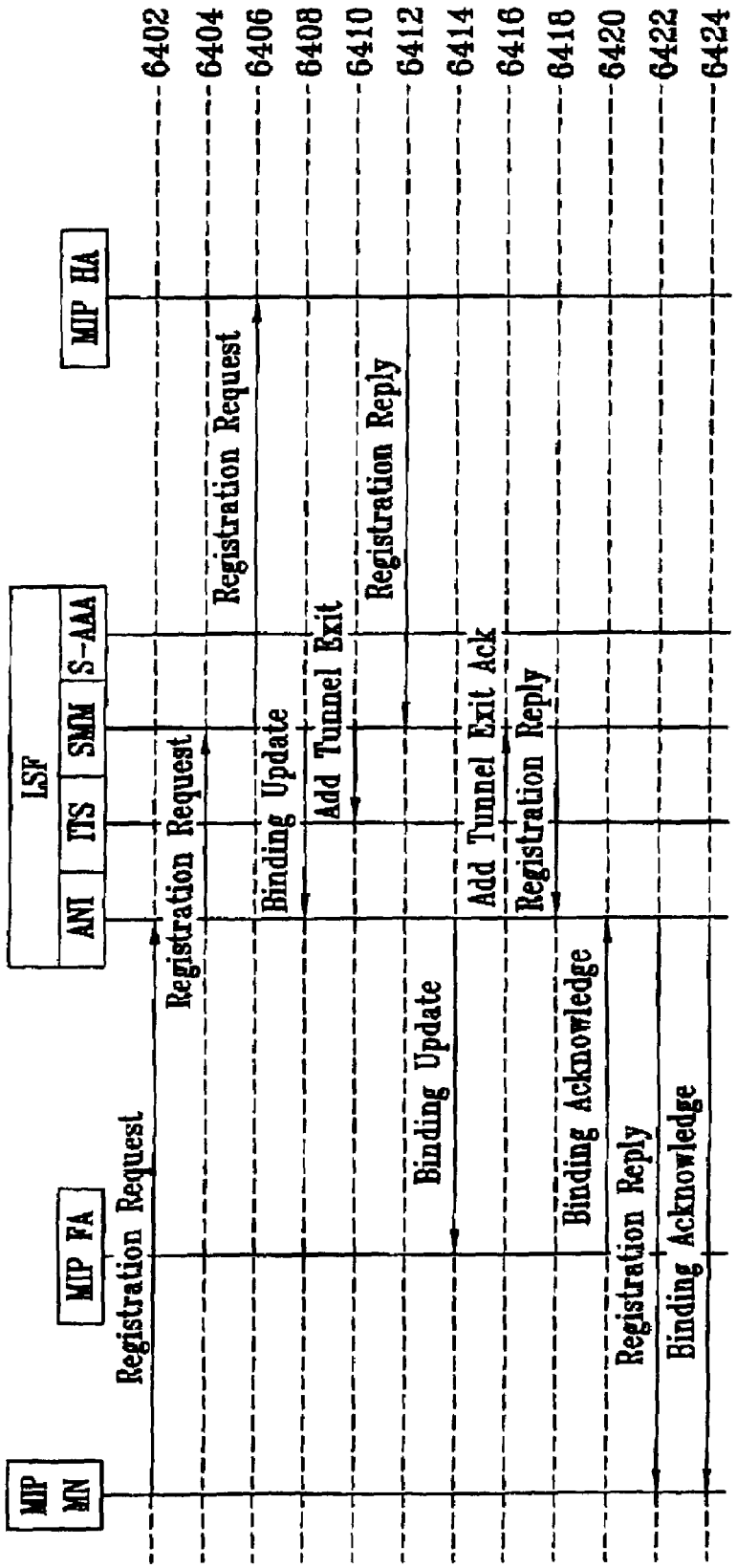

MIP MN
MIP FA
LSF
ANI
ITS
SMM
S-AAA
MIP HA
Registration Request
Registration Request
Registration Request
Binding Update
Add Tunnel Exit
Registration Reply
Binding Update
Add Tunnel Exit Ack
Registration Reply
Binding Acknowledge
Registration Reply
Binding Acknowledge
6402
6404
6406
6408
6410
6412
6414
6416
6418
6420
6422
6424

FIG. 64

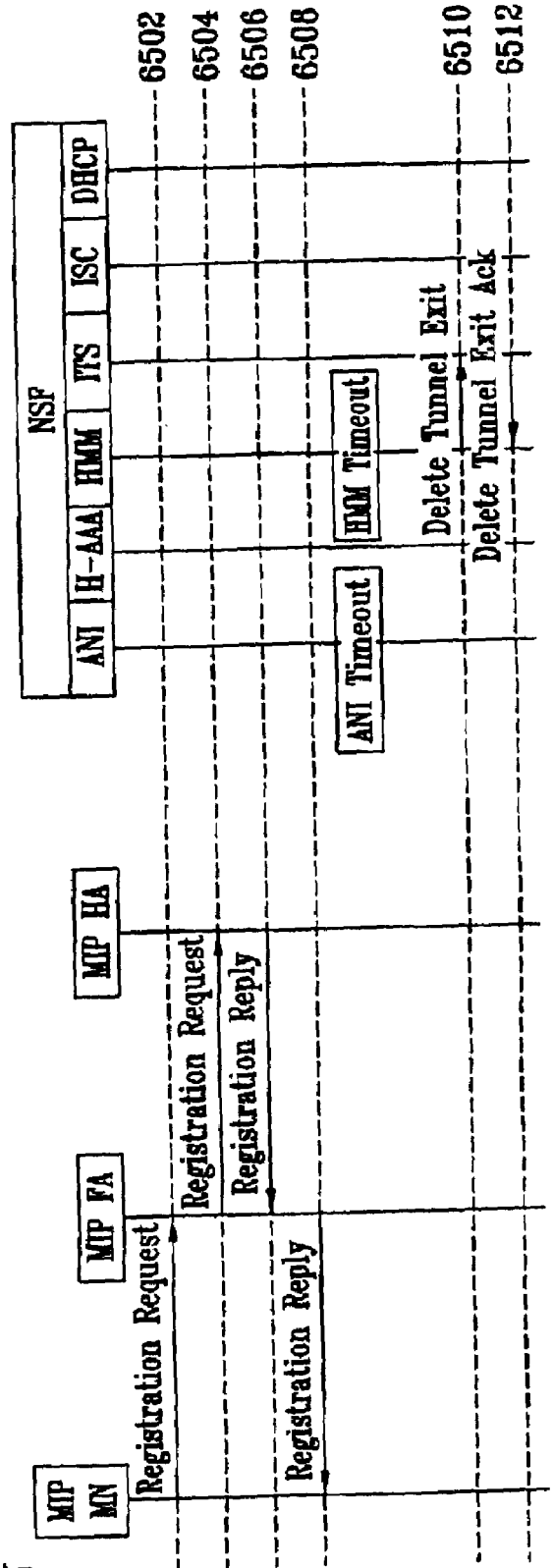
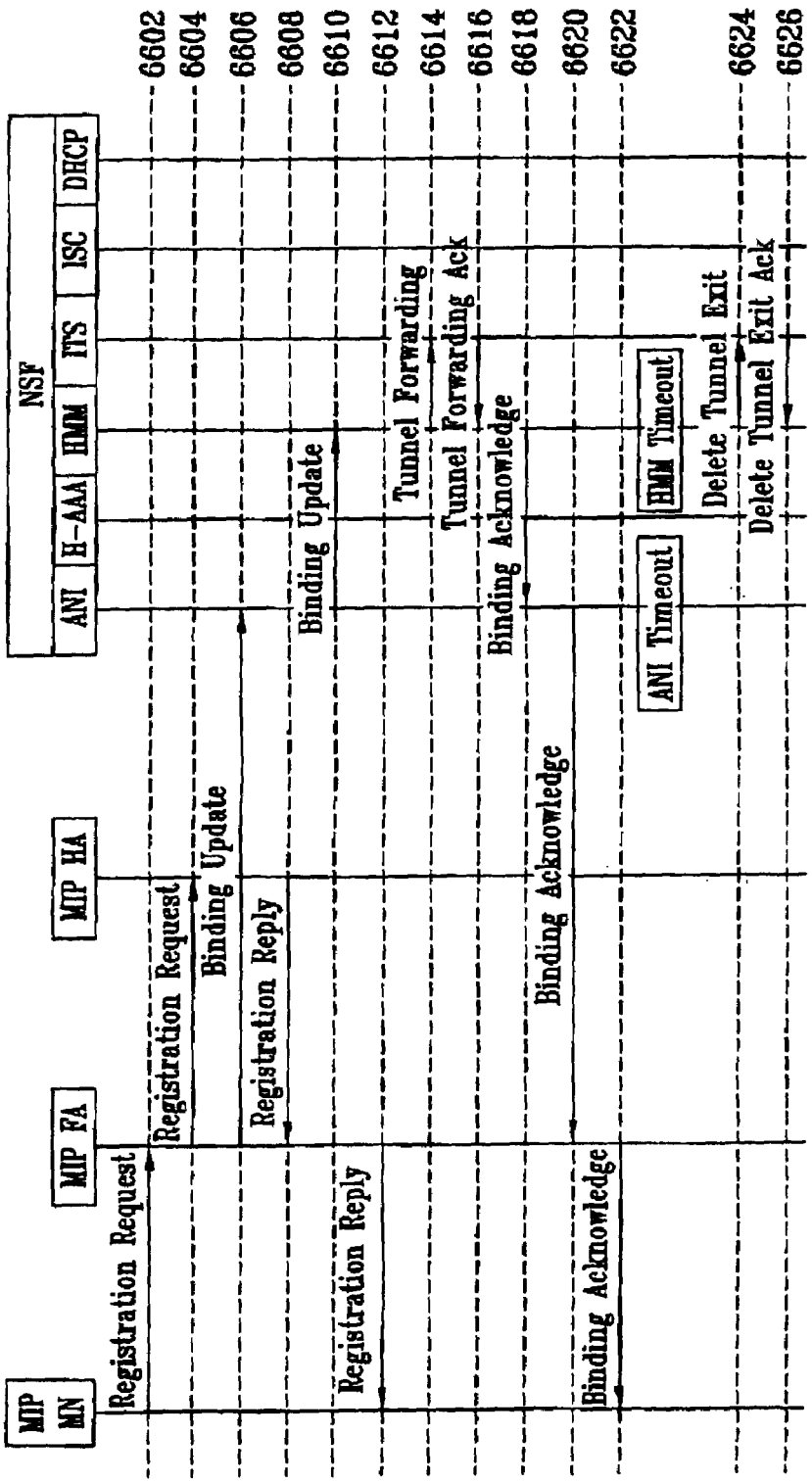

MIP MN
MIP FA
MIP HA
NSF
ANI
H-AAA
HMM
ITS
ISC
DHCP
Registration Request
Registration Request
Registration Reply
Registration Reply
ANI Timeout
HMM Timeout
Delete Tunnel Exit
Delete Tunnel Exit Ack
6502
6504
6506
6508
6510
6512

FIG. 65

FIG. 66


MIP MN
MIP FA
MIP HA
NSF
ANI
H-AAA
HMM
ITS
ISC
DHCP
Registration Request
Registration Request
Binding Update
Registration Reply
Registration Reply
Binding Update
Tunnel Forwarding
Tunnel Forwarding Ack
Binding Acknowledge
Binding Acknowledge
Binding Acknowledge
ANI Timeout
HMM Timeout
Delete Tunnel Exit
Delete Tunnel Exit Ack
6602
6604
6606
6608
6610
6612
6614
6616
6618
6620
6622
6624
6626

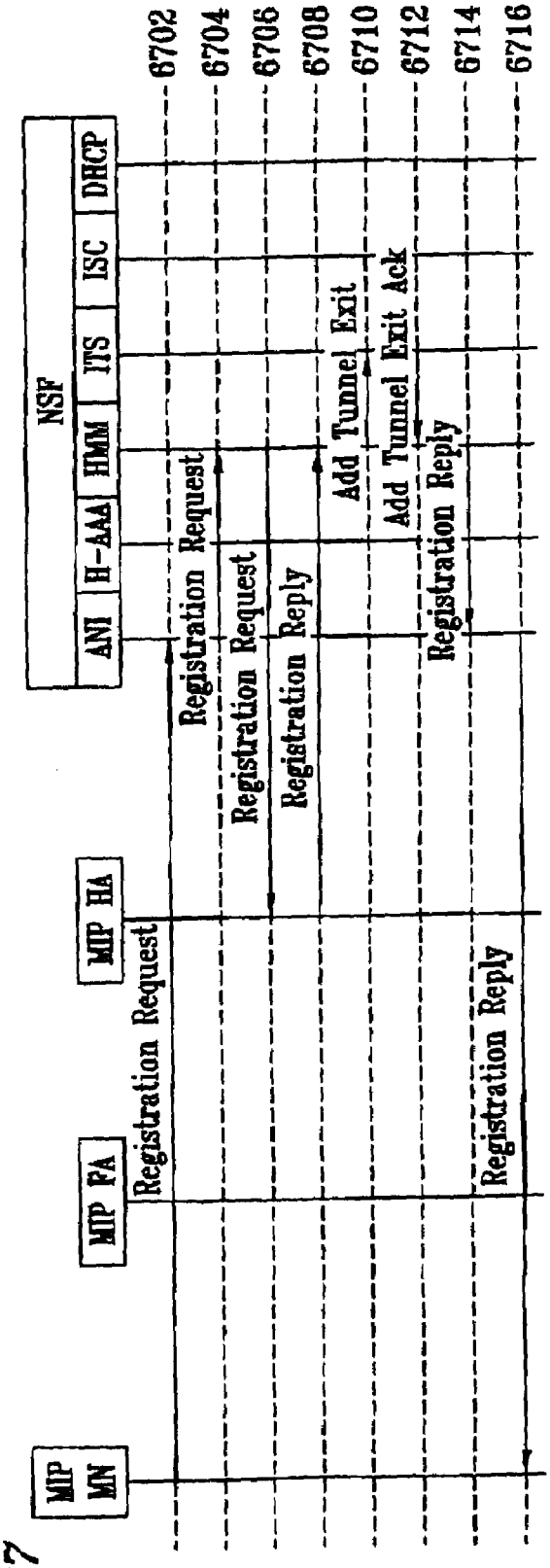

MIP MN
MIP FA
MIP HA
NSF
ANI
H-AAA
HMM
ITS
ISC
DHCP
Registration Request
Registration Request
Registration Reply
Add Tunnel Exit
Add Tunnel Exit Ack
Registration Reply
Registration Reply
6702
6704
6706
6708
6710
6712
6714
6716

FIG. 67

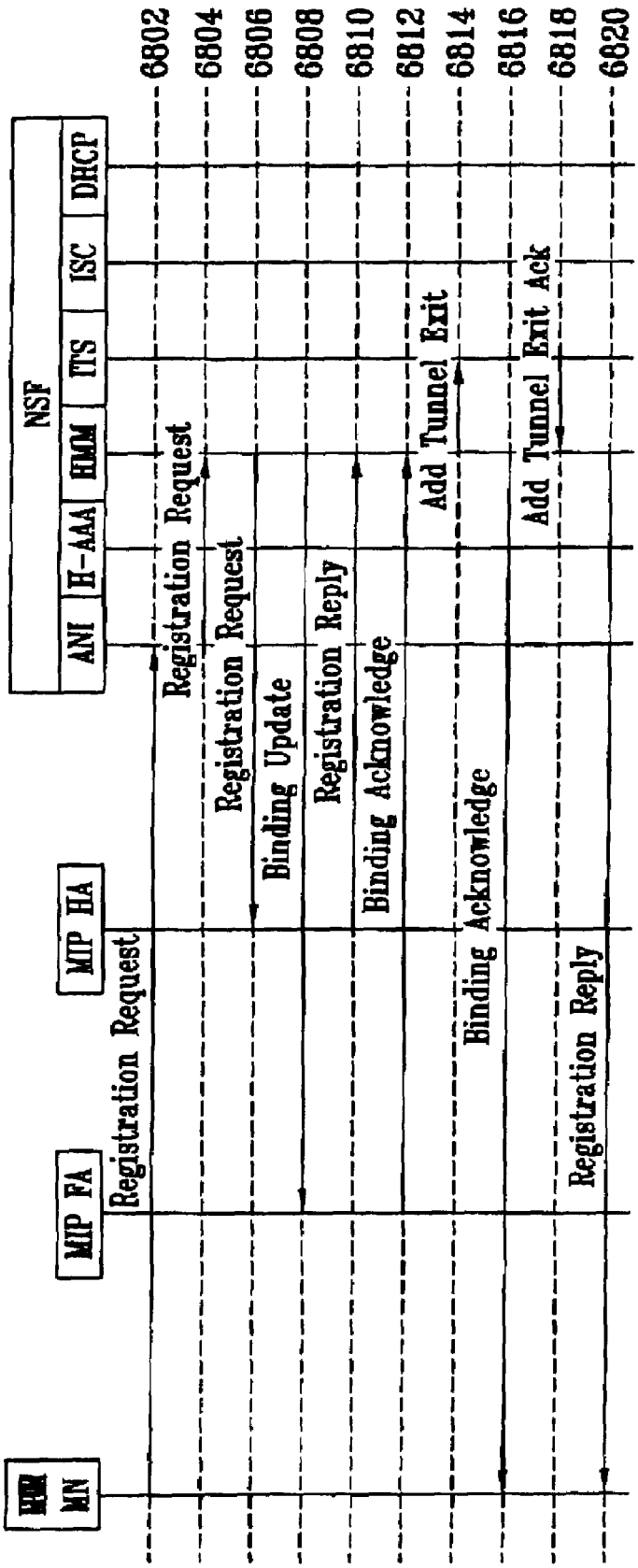

HDM
MN
MIP FA
MIP HA
NSF
ANI
E-AAA
HMM
ITS
ISC
DHCP
6802
6804
6806
6808
6810
6812
6814
6816
6818
6820
Registration Request
Registration Request
Binding Update
Registration Reply
Binding Acknowledge
Add Tunnel Exit
Binding Acknowledge
Add Tunnel Exit Ack
Registration Reply

FIG. 68

INTERNET PROTOCOL MOBILITY ARCHITECTURE FRAMEWORK

CLAIM OF PRIORITY

This application claims priority from U.S. Provisional Patent Application No. 60/152,916 entitled "IP MOBILITY ARCHITECTURE FRAMEWORK" filed on behalf of Haseeb Akhtar, et al, on Sep. 8, 1999

This application also claims priority from U.S. Provisional Patent Application No. 60/157,449 entitled "KEY EXCHANGE FOR NETWORK ARCHITECTURE (KENA)" filed on behalf of Mohamed Khalil, et al, on Oct. 4, 1999.

This application also claims priority from U.S. Provisional Patent Application No. 60/156,669 entitled "ROUTING MECHANISM FOR AAA PROTOCOL" filed on behalf of Haseeb Akhtar, et al, on Sep. 29, 1999.

This application also claims priority from U.S. Provisional Patent Application No. 60/157,289 entitled "NETWORK ACCESS ARBITRATOR" filed on behalf of Donald Wurch, et al, on Oct. 1, 1999.

This application also claims priority from U.S. Provisional Patent Application No. 60/192,411 entitled "USER SUPPORT FOR MULTIPLE DEVICES" filed on behalf of Khalil, et al, on Mar. 27, 2000.

TECHNICAL FIELD

The invention relates generally to communications and, more particularly, to a communications architecture that provides for mobile communications based on an Internet Protocol.

BACKGROUND

The advent of lightweight portable computers and handheld devices, the spread of wireless networks and services, and the popularity of the Internet combine to make mobile computing a key requirement for future networks. However, the heterogeneous nature of today's wireline networks (e.g., dial-up, xDSL, cable), wireless networks (e.g., GSM, CDMA, TDMA), and enterprise networks (e.g., LAN, WAN) significantly limits the scope of mobility between these heterogeneous networks.

What is needed is a mobility architecture framework by which the various types of networks and access thereto may converge into a unified homogeneous network that will carry multiple types of traffic and permit access to the network irrespective of the MN's location and the type of access media used to access the network.

SUMMARY

The present invention, accordingly, provides a communications architecture for enabling IP-based mobile communications. The architecture includes at least one Local Service Function (LSF) component configured to serve as an IP-based serving area network for a set of x-Access Networks (xAN), and at least one Network Service Function (NSF) component configured to serve as an IP-based home network by managing an MN's subscription and associated profile so that the MN is authorized to use the resources of the LSF. At least one xAN is interconnected to the LSF and NSF for providing heterogeneous Layer 2 access for MNs irrespective of access technology.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

FIG. **1** is a schematic drawing which depicts a representative high-level view of a network embodying features of the present invention;

FIG. **2** depicts a distributed and an integrated local service function (LSF) and network service function (NSF) embodying features of the present invention;

FIG. **3** shows a home network view and a visited network view of a network embodying features of the present invention;

FIGS. **4**A and **4**B depict the architectural components of LSFs and NSFs embodying features of the present invention;

FIGS. **4**C and **4**D show the components of HCDM and SCDM functions, respectively;

FIGS. **4**E and **4**F show the component functions of NSF and LSF AAA functions, respectively;

FIG. **5** show DDNS and DHCP functions embodying features of the present invention;

FIG. **5**A is a flow which depicts the operation of the DDNS;

FIGS. **5**B, **5**C and **5**D are flows which depicts the alternate embodiments of storing MN's COA in the DNS;

FIG. **6** shows directory services embodying features of the present invention;

FIG. **6**A is a schema relationship diagram which specifies a preferred relationship between object classes utilized by UDS and LDS subsystems;

FIGS. **6**B and **6**C depict class inheritance trees which specify a preferred hierarchy of object classes shown in FIG. **6**A;

FIG. **6**D depicts a preferred Directory Information Tree (DIT) which shows how sub-directories are organized in the UDS and LDS for storing the object classes shown in FIGS. **6**A. **6**B, and **6**C;

FIGS. **6**E, **6**F, **6**G, **6**H, **6**I, **6**J, **6**K, and **6**L are tables which exemplify attributes preferably associated with the object classes shown in FIGS. **6**A, **6**B, **6**C, and **6**D;

FIG. **6**M is a schematic diagram exemplifying a UDS database and its interfaces with other components;

FIG. **7** shows routing areas within an LSF embodying features of the present invention;

FIG. **8** shows a security framework embodying features of the present invention;

FIG. **9** shows security associations (SAs) between LSFs and NSFs embodying features of the present invention;

FIG. **10** shows Mobile Node (MN) and Correspondent Node Security embodying features of the present invention;

FIG. **11** shows an AAA framework embodying features of the present invention;

FIG. **12** shows AAA function locations in a network embodying features of the present invention;

FIG. **13** shows security for AAA functions embodying features of the present invention;

FIG. **14** shows interfaces embodying features of the present invention;

FIGS. **14**A and **14**B depicts the embodying features of the interface between an xAN and an LSF;

FIG. **15** shows a mobility Security Association (SA) between LSF and Home NSF AAA functions embodying features of the present invention;

FIG. **16** shows mobility SA between NSFs embodying features of the present invention;

FIG. **17** shows a single IP router in an LSF embodying features of the present invention;

FIG. **18** shows multiple IP routers in an LSF embodying features of the present invention;

FIG. **19** shows a hierarchical mobility router embodying features of the present invention;

FIG. **20** shows MN Components embodying features of the present invention;

FIG. **20**A shows origination and destination points of IPM messages;

FIG. **20**B shows a general format for an IPM message;

FIG. **20**C shows a preferred general format for a general MIP extension;

FIG. **20**D shows the message format of an Authentication Information Extension;

FIG. **20**E shows the message format of a Call Information Extension;

FIG. **20**F shows the message format of a CN List Extension;

FIG. **20**G shows the message format of an LSF NAI Extension;

FIG. **20**H shows the message format of an MN's L2 address extension;

FIG. **20**I shows an NAI extension;

FIG. **20**J shows an IPM Routing Area Extension;

FIG. **20**K shows a Terminal Information Extension;

FIG. **20**L shows the message format of a Registration Request message;

FIG. **20**M shows the message format for a Registration Reply message;

FIG. **20**N shows the message format for a Prepare for System Change message;

FIG. **20**O shows the message format for a System Change message;

FIG. **20**P shows a preferred general format for an IPM message;

FIG. **20**Q shows the message format for an Activate Packet Service message;

FIG. **20**R shows the message format for an Activate Packet Service Ack message;

FIG. **20**S shows a message format for an Add L2 IP Association message;

FIG. **20**T shows the format for a Buffer Data message;

FIG. **20**U shows the format for a Buffer Data Ack message;

FIG. **20**V shows the format for a Cleanup message;

FIG. **20**X shows the format for a Correspondent Node List message;

FIG. **20**Y shows the format for a Correspondent Node List Ack message;

FIG. **20**Z shows the format for a Forward Data message;

FIG. **20**AA shows the format for a Forward Data Ack;

FIG. **20**AB shows the format for a Handoff Required message;

FIG. **20**AC shows the format for a Handoff Required Ack;

FIG. **20**AD shows the format for an Access Request extension;

FIG. **20**AE shows the format for an Access Accept/Reject extension;

FIG. **20**AF shows the format for a Simple IPM Registration Request message;

FIG. **20**AG shows the format for a Simple IP Registration Reply message;

FIG. **21** is an event sequence diagram showing the flow of events for an Initial Registration, wherein a MN has a publicly routable IP Address;

FIG. **22** is an event sequence diagram showing the flow of events for a Initial Registration, wherein an MN has a publicly non-Routable IP Address;

FIG. **23** is an event sequence diagram showing the flow of events for a Initial Registration, wherein an MN has no IP address;

FIG. **24** is an event sequence diagram showing the flow of events for an Initial Registration using hierarchical routers;

FIG. **25** is an event sequence diagram showing the flow of events for an MN moving to new LSF

FIG. **26** is an event sequence diagram showing the flow of events for an MN moving to a new RA, new xAN, same LSF;

FIG. **27** is an event sequence diagram showing the flow of events for an MN moving to a new RA, same xAN/LSF, new COA;

FIG. **28** is an event sequence diagram showing the flow of events for an MN moving to a new RA, same xAN/LSF, same COA;

FIG. **29** is an event sequence diagram showing the flow of events for an MN moving to a Home Network;

FIG. **30** is an event sequence diagram showing the flow of events for an MN moving to a new RA, new LSF, no movement indication;

FIG. **31** is an event sequence diagram showing the flow of events for a De-registration packet data session;

FIG. **32** is an event sequence diagram showing the flow of events for an inter system handoff;

FIG. **33** is an event sequence diagram showing the flow of events for an inter xAN handoff, Same LSF;

FIG. **34** is an event sequence diagram showing the flow of events for an inter xAN handoff, same LSF, hierarchical routers; and

FIGS. **35** is an event sequence diagram showing the flow of events when an IPM MN registers from an IPM LSF;

FIG. **36** is an event sequence diagram showing the flow of events when an IPM MN registers from an IPM NSF;

FIG. **37** is an event sequence diagram showing the flow of events when an IPM MN registers from a Mobile IP (MIP) FA;

FIG. **38** is an event sequence diagram showing the flow of events when an MIP MN registers from an IPM LSF;

FIG. **39** is an event sequence diagram showing the flow of events for an IPM MN disconnect detection;

FIG. **40** is an event sequence diagram showing the flow of events when an IPM MN re-registers from an IPM LSF;

FIG. **41** is an event sequence diagram showing the flow of events when an IPM MN re-registers from an IPM NSF;

FIG. **42** is an event sequence diagram showing the flow of events when an IPM MN re-registers from an MIP FA;

FIG. **43** is an event sequence diagram showing the flow of events when an IPM MN re-registers from an IPM LSF;

FIG. **44** is an event sequence diagram showing the flow of events when an IPM MN de-registers from an IPM LSF;

FIG. **45** is an event sequence diagram showing the flow of events when an IPM MN de-registers from an IPM NSF;

FIG. **46** is an event sequence diagram showing the flow of events when an IPM MN de-registers from an MIP FA;

FIG. **47** is an event sequence diagram showing the flow of events when an IPM MN handoffs from ANI to ANI in the same SMM but different ITS;

FIG. **48** is an event sequence diagram showing the flow of events when an IPM MN handoffs from ANI to ANI in the same SMM and same ITS;

FIG. **49** is an event sequence diagram showing the flow of events when as IPM MN handoffs from SMM to SMM;

FIG. **50** is an event sequence diagram showing the flow of events when an IPM MN handoffs from LSF to NSF;

FIG. **51** is an event sequence diagram showing the flow of events when an IPM MN handoffs from NSF to LSF;

FIG. **52** is an event sequence diagram showing the flow of events of an IPM MN handoff from an IPM ANI to FA, wherein the FA does not support smooth handoffs;

FIG. **53** is an event sequence diagram showing the flow of events of an IPM MN handoff from an FA to an IPM ANI, wherein the FA does not support smooth handoffs;

FIG. **54** is an event sequence diagram showing the flow of events of an IPM MN handoff from an IPM ANI to FA, wherein the FA does support smooth handoffs;

FIG. **55** is an event sequence diagram showing the flow of events of an MIP MN handoff from an IPM ANI to an FA, wherein the FA does not support smooth handoffs;

FIG. **56** is an event sequence diagram showing the flow of events of an IPM MN handoff from an FA to an IPM ANI, wherein the FA supports smooth handoffs;

FIG. **57** is an event sequence diagram showing the flow of events of an MIP MN handoff from an FA to an IPM ANI, wherein the FA does not support smooth handoffs;

FIG. **58** is an event sequence diagram showing the flow of events of an MIP MN handoff from an IPM ANI to an FA, wherein the FA supports smooth handoffs;

FIG. **59** is an event sequence diagram showing the flow of events of an MIP MN handoff from an NSF to an FA, wherein the FA does not support smooth handoffs;

FIG. **60** is an event sequence diagram showing the flow of events of an MIP MN handoff from an FA to an IPM ANI, wherein the FA supports smooth handoffs;

FIG. **61** is an event sequence diagram showing the flow of events of an MIP MN handoff from an FA to an NSF, wherein the FA does not support smooth handoffs;

FIG. **62** is an event sequence diagram showing the flow of events of an MIP MN handoff from an NSF to an FA, wherein the FA supports smooth handoffs; and

FIG. **63** is an event sequence diagram showing the flow of events of an MIP MN handoff from an FA to an NSF, wherein the FA supports smooth handoffs.

FIG. **64** is a message flow event sequence diagram showing the flow of messages for MIP MN handoffs from IPM ANI to FA, no smooth handoff;

FIG. **65** is a message flow event sequence diagram showing the flow of messages for MIP MN handoffs from NSF to FA, no smooth handoff;

FIG. **66** is a message flow event sequence diagram showing the flow of messages for MIP MN handoffs from NSF to FA, smooth handoff;

FIG. **67** is a message flow event sequence diagram showing the flow of messages for MIP MN handoffs from FA to NSF, no smooth handoff; and

FIG. **68** is a message flow event sequence diagram showing the flow of messages for MIP MN handoffs from FA to NSF, smooth handoff.

DETAILED DESCRIPTION

In the following discussion, numerous specific details are set forth to provide a thorough understanding of the present invention. However, it will be obvious to those skilled in the art that the present invention may be practiced without such specific details. In other instances, well-known elements have been illustrated in schematic or block diagram form in order not to obscure the present invention in unnecessary detail. Additionally, for the most part, details concerning telecommunication networks, the InterWorking of networks with legacy networks such as the PSTN, and the like, have been omitted in as much as such details are not necessary to obtain a complete understanding of the present invention and are within the skills of persons of ordinary skill in the relevant art.

It is noted that RFC documents referenced herein are available from the IETF, including the IETF Internet web page located at http://www.ietf.org. All references to Layer 2 (L2) and Layer 3 (L3) are made in accordance with the Open System Interconnetion (OSI) Reference Model defined by the Internation Stantdard Organization (ISO) and as commonly known by the persons of orninary skills in the relevant art.

It is further noted that, unless indicated otherwise, all functions described herein are performed by a processor such as computer or electronic data processor in accordance with code such as computer program code or software or Integrated Circuits that are coded to perform certain functions.

1. Acronyms, Definitions, and Parameters

1.1 Acronyms

In the interest of conciseness, various components are referred to herein by the following acronyms:

AAA Authentication, Authorization, and Accounting
ANI Access Network Interface
BCCH Broadcast Control Channel
CA Certificate Authority
C/GOS Class/Grade of Service
CN Correspondent Node
COA Care Of Address (RFC 2002)
COPS Common Open Policy Service
DAP Directory Access Protocol
DHCP Dynamic Host Configuration Protocol
DHCS Dynamic Host Configuration Services
DDNS Dynamic Domain Name Services
DNS Domain Name Server
ESP Encapsulating Security Payload
FA Foreign Agent
GSM Global System for Mobile Communications
HCDM Home Control and Data Manager
HLR Home Location Register
HMM Home Mobility Manager
IETF Internet Engineering Task Force
IP Internet Protocol
IPM IP Mobility
IPSec IP Security
ISAKMP Internet Security Associations and Key Management Protocol
ISC IPM Security Center
ITS IPM Tunnel Service
ITU International Telecommunications Union
LAN Local Area Network
L2 Layer 2
L2TP Layer 2 Tunneling Protocol
LDAP Lightweight Directory Access Protocol
LSF Local Service Function
MIP Mobile IP
MN Mobile Node (also referred to as a mobile station or a mobile user)
NAC North American Cellular
NAI Network Access Identifier
NAT Network Address Translator
NG Next Generation
NSF Network Service Function

PSTN Public Switched Telephone Network
QoS Quality of Service
RAN Radio Access Network
SA Security Association
SCDM Serving Control and Data Manager
SLA Service Level Agreement
SMG Security Messaging Gateway
SMM Serving Mobility Manager
SOHO Small Office Home Office
TCP Transmission Control Protocol
UDS Unified Directory Service
VLR Visitor Location Register
WAN Wide Area Network
xAN x(any type) of Access Network

1.2 Definitions

In the interest of conciseness, various components are referred to herein by the following defined terms:

An "Access Network Interface" (ANI) is the logical entity that indicates the existence of an SMM to the mobile user. ANI preferably also implements mechanisms to implement the response to a solicitation and supports handoffs between itself and another ANI within the context of the same SMM. The deployment options for the ANI are very flexible. The ANI may reside in the context of the same LSF or reside outside the LSF in an access network.

A "Home Mobility Manager" "HMM" is the logical entity that manages and tracks a users state in the NSF by implementing the IPM protocol state machine. The HMM updates the user's current point of attachment into the UDS and interface with the ISC to validate a user's security requirements. The HMM interfaces with the ANI and ITS at the home domain such that a subscriber may be service at home. The HMM supports both IPM clients as well MIP (per RFC2002) clients.

A "home network" for a user is defined herein as a network, such as an LSF, an NSF, or a combination thereof, owned by a common administrative domain, with which a user has subscribed his services. A home network thus owns the user's subscription, and is responsible for authenticating and registering its users.

"Devices" include a mobile node, a mobile station, a cell phone, a Personal Digital Assistant (PDA), a personal computer (including a laptop computer), and the like. Devices are preferably addressed by IPv4/IPv6 addresses. Local device addresses (e.g. IEEE MAC, MIN, IMSI) preferably are specific to an access network, and are transparent to IPM. Devices may support their own L2 access protocols.

"IPM Tunnel Service" (ITS) provides basic IP-in-IP tunneling and de-tunnel functions that are required to support mobility, as discussed in RFC 2003. It also provides gratuitous ARP and proxy ARP functions as needed by the SMM and HMM for mobility management so that IP packets may be routed to an appropriate COA of the MN.

"Location updating" tracks the location of a device, and of a user also when the user is using the device. Location updating also updates the network databases as a user moves with the device so that the network is able to route information to the user. The location updates may be done automatically based on policies defined by a service provider (such as America Online, AOL), e.g. on initial registration, and the like.

"Mobile Node" (MN) and refers to a mobile station, a cell phone, a device, a personal digital assistant (PDA), a personal computer (including a laptop computer), and the like. The MN preferably includes an IP mobility client with dual mode behavior which interpret IP Mobility as well as IETF Mobile IP messaging (as per RFC 2002). The MN preferably supports signaling and dataflow arbitration between multiple access interfaces and implements an IPM state machine. The MN preferably maintains Security Associations (SA) with a home network as identified by the user's NAI or permanent IP address (if in a Mobile IP serving domain). In the case of a user's NAI, the IPM client may support dynamic allocation of IP address either at the home network or at the visited network. An MN node may also support handoffs between LSFs. MNs are also provided with IP stacks and all service application are data oriented to accommodate end-to-end IP packet data.

"Mobility" refers to user location tracking, handoff, and routing management functions to deliver data to the user, and generally includes personal mobility, device mobility, and service mobility.

"Mobility enabled IP centric networks" refers to networks that use IP addressing and routing protocols in concert with a mobility protocol to deliver multimedia traffic to roaming users. The term "users" includes "subscribers".

"Registration" binds a user (or a user's persona) to one or more devices.

"Routing management" refers to the ability to deliver datagrams from a host on a network to a roaming user's MN.

A "Secure Messaging Gateway" (SMG) supports IETF AAA requirements and routes all IPM messages between an LSF and NSF. The SMG also provides a secure tunnel for signaling messages between an NSF and LSF.

A "Serving Mobility Manager" (SMM) preferably tracks the user state and protocol state of a user in an LSF. From a signaling perspective, the SMM supports user authentication security, and billing functions. The SMM directs enforcement of the tunnel endpoints and provides support for dynamic configuration mechanisms. The SMM support both IPM clients as well as pure MIP (per RFC 2002) clients.

An "xAN" denotes any type access network, including both wireless (e.g., RAN and GSM), wireline access networks, (e.g., PSTN, IP Network, and DSL) and IEEE 802 LANs such as IEEE 802.3 Ethernet LAN and 802.11 Wireless LAN.

2. IPM Architecture Framework

The IPM Architecture of the present invention is discussed below in terms of functional components, interfaces, and messaging required to provide mobility.

2.1 Mobility Enabled Network Reference Model(s)

Referring to FIG. **1** of the drawings, the reference numeral **100** generally designates an IPM Architecture embodying features of the present invention. The IPM Architecture **100** includes a single network **102** shown in dashed outline, which is owned and administered by a single service provider. The single network **102** includes a Network Service Function (NSF) **104** and at least one Local Service Function (LSF) **106**, interconnected together using conventional means, such as wires or wireless Radio Frequency (RF) interfaces or the like. One or more x-Access Networks (xAN) **110** are connected to respective LSFs **106**, and one or more Mobile Nodes (MNs) **112** are connected to respective xANs **110**. Also shown are a user **114** interfacing with an MN **112**, and a Correspondent Node (CN, discussed further below) **116** connected to the IP network, though the CN **116** may alternatively be connected to other points in the IPM Architecture **100**, such as at an xAN **110**.

Each LSF **106** constitutes a serving area network for a group of xANs **110**, and is owned by the network operator and is delimited by geographical parameters. Each LSF **106** may also support multiple xANs **110** where each xAN **110**

is associated with a different technology, e.g. one xAN may be associated with an NAC wireless access network, another xAN may be associated with a GSM wireless access network, and yet another xAN may be associated with an Ethernet enterprise network. Each LSF **106** is configured for receiving messages from an MN **112** via a respective xAN **110** and forwarding such message to a suitable NSF **104** or the IP Network **108**. The LSF **106** also provides a mobility manager (discussed further below) for user mobility across the xANs **110** that it serves. Each LSF **106** also routes data to the MN **112** via the IP address that the MN **112** is currently using. Each LSF **106** also supports access to multiple NSFs **104** from the same MN **112**.

The NSF **104** constitutes a home network that owns the subscription associated with the MN **112**. The NSF **104** is a user subscription "defined" entity. In the context of the IPM Architecture **100**, the NSF **104** is the home network and "owns" the MN user's subscription and associated profile. The NSF **104** also supports a "unified" directory (discussed below) for user profiles and policies independent of the type of xAN **110**. The NSF **104** also provides mobility to users **114** on a larger scale. The user can roam into any LSF **106** and the handling of the mobility is achieved by the NSF **104**. A Home Mobility Manager entity (HMM, discussed below) in the NSF **104** is responsible for maintaining the current location of the MN **112** of the user **114**. The NSF **104** also provides routing information to anyone requesting establishment of communications with the MN **112**. The NSF **104** may also provide the Authentication and Authorization functions (discussed below) for MNs **112** that consider the NSF **104** to be their home network.

The xAN **110** denotes any type of access (e.g., wireless or wireline) technology. In the context of the IPM Architecture **100**, the xAN **110** preferably provides access network resource management, physical connectivity to the MN **112**, and local MN mobility within the xAN **110**.

The IP Network **108** provides a routing backbone for delivering packets between network elements. The IP network **108** may be the public Internet or a closed network that can access the public Internet.

A service provider's network may logically be composed of a single NSF **104** with multiple LSFs **106** to which it provides home network functionality. Such LSFs **106** may be physically (i.e., geographically) located anywhere. MNs **112** that are homed in the NSF **104** can roam in any of the LSFs **106** that are associated with this NSF and be considered to be in their home network.

FIG. **2** illustrates a network **200** similar to the IPM Architecture **100** described above with respect to FIG. **1**, comprising the single network **102** interconnected with the IP network **108**, and further comprising an integrated network **202** interconnected via the IP network **108** to the single network **102**. The integrated network **202** performs the functions of both the NSF and the LSF, thereby providing both access and home network functions to a group of MNs **110**.

2.1.1 Home Networks and Visited Networks

As defined above, and from a user's perspective, a Home Network is the network, e.g., an ISP, that owns a user's subscription. The home network is, furthermore, responsible for authenticating and registering a user.

When a user roams into and accesses a network that is not part of his/her home network, the user is said to be roaming into a visited network.

The network that the user is currently using is referred to herein as a serving network. The serving network may be either the home network or a visited network.

FIG. **3** depicts a IPM Architecture **300** similar to the IPM Architecture **100** (FIG. **1**) which more clearly distinguishes the foregoing differences between a home network and a visited network. Accordingly, in the network **300**, the NSF **104**A and an NSF **104**B constitute a home network **302**, one or more LSFs **106** constitute a visited network **304**, and the IP network **108** interconnecting the NSFs **104**A and **104**B to the LSFs **106** constitutes a backbone network **306**. The user **114**'s home NSF is the NSF **104**B, and a service level agreement (SLA) is established between the NSFs **104**A and **104**B, thereby permitting the user **112** with his/her MN **112** to roam in the network of NSF **104**A. When roaming in the NSF **104**A, via an xAN **110** and an LSF **106**, the NSF **104**A is considered in FIG. **3** to be a visited network since the user **114** is not homed in NSF **104**A. The NSF **104**A in FIG. **3** is also referred to as a "serving network" since it provides network access to the roaming user.

2.1.2 NSF and LSF Components

FIGS. **4**A and **4**B depict a high-level overview of the architectural mobility components, discussed below, preferably included within an NSF, LSF, and xAN, represented herein by the NSF **104**, the LSF **106**, and the xAN **110**, respectively, in accordance with the present invention. A number of such mobility components are used to support at least two types of xAN applications, namely, LAN and WAN applications, for each NSF **104**, LSF **106**, and xAN **110**.

As shown in FIGS. **4**A and **4**B, the NSF **104** includes a bus **400** for interconnecting LAN and WAN mobility components that constitute the NSF **104**. LAN components interconnected to the bus **400** within the NSF **104** include a billing component **402** and a policy component **404**. WAN components interconnected to the bus **400** within the NSF **104** include a server farm **406**, a service management component **408**, and a desktop management component **410**. The components **402**, **404**, **406**, **408**, **410** are considered to be well-known in the art and will, therefore, not be discussed in further detail herein, except insofar as necessary to describe the present invention. The NSF **104** further includes a Secure Messaging Gateway (SMG) **454**, discussed further below, through which the NSF **104** is connected to the IP Network **108** and, through the IP Network **108**, to an Accounting Service Bureau **470** and to a Service Agreement Broker **472**. The bureau **470** and broker **472** are considered to be well-known in the art and, therefore, will not be discussed in further detail herein, except insofar as relevant to the description of the present invention.

As further shown in FIGS. **4**A and **4**B, the LSF **106** includes a bus **411** for interconnecting LAN and WAN mobility components that constitute the LSF **106**. LAN components interconnected to the bus **411** within the LSF **106** include a policy component **412**, a server farm **414**, a VPN Proxy firewall **416**, an OA&M component **418**, an SS7/PTI gateway **420**, and a voice gateway **422**. WAN components interconnected to the bus **411** within the LSF **106** include a local services component **424**, a DDNS **426**, a router switch **428**, a billing component **432**, a gateway call manager **433**, and a call manager proxy **434** for providing. The components **412**, **414**, **416**, **418**, **420**, **422**, **424**, **426**, **428**, **432**, **433**, and **434** are considered to be well-known in the art and will, therefore, not be discussed in further detail herein, except insofar as necessary to describe the present invention. The LSF **104** further includes an SMG **466**, discussed further below, through which the LSF **106** is

connected to the bus **400** of the NSF **104** and to the IP Network **108** and, through the IP Network **108**, to the Accounting Service Bureau **470** and to the Service Agreement Broker **472**. The LSF **106** is further connected via the SS7/PRI Gateway **420** and the Voice Gateway **422** to the Public Switched Telephone Network (PSTN) **474**.

As still further shown in FIGS. **4**A and **4**B, the xAN **110** includes a bus **435** for interconnecting LAN and WAN mobility components that constitute the xAN **110**. LAN components interconnected to the bus **435** within the xAN **110** include an RF Management component **436**, a Location Tracking component **438**, an ARP component **440**, a router switch **442**, an Access Control component **444**, and a Connect Control component **446**. WAN components interconnected to the bus **435** within the xAN **110** include a one or more Cellsite Interfaces **448** which interface with cellsites **449**, such as MNs **112**. The components **436**, **438**, **440**, **442**, **444**, **446**, and **448** are considered to be well-known in the art and will, therefore, not be discussed in further detail herein, except insofar as necessary to describe the present invention. The xAN **110** is connected to the LSF **106** via Router Switches **428** and **442**.

2.1.2.1 NSF Components

As shown in FIG. **4**B, the NSF **104** also includes an AAA function **450** configured for distributing requests for authentication, authorization, and the like, for MNs **112** that are homed in their network using suitable servers dedicated to those tasks. Specifically, with reference to FIG. **4**E, the AAA function **450** includes an AAA routing function **450***a*, an authentication function **450***b*, an authorization function **450***c*, an accounting function **450***d*, and a security function **450***e* interconnected via a bus **450***f*, which is connected to the bus **400**. The AAA function **450** and the functions contained therein are considered to be well-known in the art and, therefore, will not be discussed in further detail herein, except insofar as necessary to describe the present invention.

The NSF **104** further includes a Home Mobility Manager (HMM) function **452** which constitutes the mobility component in the NSF. As shown in FIG. **4**C, the HMM function **452** includes an Access Network Interface (ANI) **452***a*, an HMM **452***b*, and an IPM Tunneling Service (ITS) **452***c* interconnected via a bus **452***d*, which is connected to the bus **400**. The HMM function **452** interfaces to the AAA function **450** in the NSF **104**. The AAA function **450** preferably includes mobility extensions that are used to exchange mobility related control messages with the LSFs **106**. Communications between an LSF **106** Serving Mobility Manager (SMM, discussed further below) and the HMM function **452** are effected by configuring multiple AAA functions **450** to serve as peer-to-peer components. The HMM function **452** is preferably configured for maintaining current location information regarding the movement of MNs **112** within different LSFs **106**, assigning an IP address to a user's MN **112**, forwarding datagrams to MNs **112** if policies are suitably set, binding users to MN's (e.g., devices), binding MNs to IP COAs, and sending COA updates to Correspondent Nodes (CNs) that the user is currently communicating with. CNs include any user nodes, whether mobile or fixed, that are connected to the IPM Architecture.

A Secure Messaging Gateway (SMG) **454** is provided for protecting the NSF **104** from the public IP network **108**. Policies are defined for the SMG **454** to filter incoming and outgoing traffic.

As discussed further below, the NSF **104** also utilizes a DNS **456** (including a dynamic DNS function), a DHCP **458**, and a Unified Directory Service (UDS) subsystem **460** for providing IP address management, mobility management, and policy management. Services are provided to users by application servers, such as the Server Farm **406**, the Server Management component **408**, and the Desktop Management component **410** on the NSF **104**, and the Server Farm **414** and Local Services **424** on the LSF **106**.

2.1.2.2 LSF Components

As discussed above, the LSF **106** provides access to the NSF **104** for a group of xANs **110**. The LSF **106** preferably also provides local mobility management, i.e. management of the mobility of MNs **112** within the xAN **110**, and across xANs and LSF boundaries that it serves, as discussed further below.

As depicted in FIG. **4**B, the LSF **106** preferably includes a local AAA function **462** that supports Authentication, Authorization, Accounting (AAA), and mobility functions by routing messages to appropriate AAA function **450** that resides on the NSF **104**. Specifically, with reference to FIG. **4**F, the AAA function **462** includes an AAA routing function **462***a*, an authentication function **462***b*, an authorization function **462***c*, an accounting function **462***d*, and a security function **462***e* interconnected via a bus **462***d*, which is connected to the bus **411**. The AAA function **462** and the functions contained therein are considered to be well-known in the art and, therefore, will not be discussed in further detail herein, except insofar as necessary to describe the present invention.

When a user **114** accesses an LSF **106**, the local AAA function **462** contacts the user's home NSF AAA function **450**. An AAA routing function **450***a* (FIG. **4**E) within the home AAA function **450** forwards requests to an appropriate function, e.g., authentication requests are forwarded to an authentication function **450***b* (FIG. **4**E), and mobility requests are forwarded to the HMM function **452**. The LSF local AAA function **462** and the NSF AAA function **450** communicate over a secure link to transmit AAA data.

The LSF **106** includes a Serving Mobility Manager (SMM) function **464** that handles mobility management for MNs **112** as they roam between different xANs **110** that are served by the LSF **106**. As shown in FIG. **4**D, the SCDM **464** includes an Access Network Interface (ANI) **464***a*, an SMM **464***b*, and an IPM Tunneling Service (ITS) **464***c* interconnected via a bus **464***d*, which is connected to the bus **411**. The point of connection between the MNs **112** and the NSF **104** may remain the same from an NSF perspective. The LSF **106** may hide the actual access network point of attachment of the MN **112** from the NSF **104**. This is achieved using a set of ANIs between the LSF **106** and the xANs **110**, as described further below with respect to FIG. **14**. The LSF **106** also supports access to multiple different NSFs **104** from the same MN **112**. Each NSF **104** access is associated with a different Network Access Identifier (NAI, discussed below) since the subscriptions owned by a an NSF **104** are unique across NSFs.

The SCDM **464** interfaces with the xAN **110** from an access network perspective and to an HCDM **452**, discussed above, from a core network perspective. The SCDM **464** is preferably configured for registering users, managing handoffs between xANs and LSFs, providing care-of addresses (COA, defined in RFC 2002) for tunnel datagrams to the user's MN **112**, user location tracking, and providing an interface to networks that support Mobile IP.

The LSF **106** is protected and secured from the Internet by a Secure Messaging Gateway (SMG) **466**. All inbound and

outbound data must flow through the SMG **466**. Policies are defined in the LSF **106** that protect the LSF **106** resources from the MNs **112**.

The LSF **106** includes Dynamic Host Configuration Protocol (DHCP) **468** for providing MN **112** home addresses. Local directory servers, discussed below, may be used to store policies related to the LSF **106**, user MN location, and the like. These components may be available locally in the LSF or may be located centrally elsewhere in the network and serve a set of LSFs **106**. The LSF **106** may also include the DNS **426** with the Dynamic DNS function (discussed below).

It is noted that the NSF **104** and LSF **106** may be integrated together to form the integrated network **202** (FIG. **2**) and, when so integrated, only require one of each of the foregoing components to perform the appropriate roles based on their association with an MN **112**.

2.1.2.3 Dynamic Host Configuration Service (DHCS) and Dynamic Domain Name Services (DDNS)

FIG. **5** is a schematic diagram showing a portion of the IPM architecture framework **500** as providing DHCP servers **458** and **468** for allocating network resources. DHCS enables devices to automatically obtain configuration parameters they need to participate in Intranet and Internet communications. Because any CN requires a unique IP address and an appropriate subnet mask, a DHCP is used to effectively automate the task of coordinating and assigning IP address information. The DHCP server **458** interacts with the DNS servers **456** and **468** in coordination with the HMM **456** and SMM **464**, respectively, to update the current IP address assigned to an MN **112**.

While the DHCP servers **458** and **468** both use DHCP and reside in the NSF **104** and the LSF **106**, respectively, the DHCP servers have different functions. In the NSF **104**, the DHCP server **458** may be used to assign temporary IP addresses to roaming MNs **112** that do not have pre-configured IP addresses, or that request IP addresses. In the LSF **106**, the DHCP server **468** may be used to assign co-located COAs, in addition to MN **112** home address, to the MN **112** that accesses the serving network, such as LSF **106**.

The DHCP servers **458** and **468** may also use DHCP to configure the MN **112** with other parameters such as identification of the NTP server, the NNTP server, and the like.

FIG. **5** also shows a portion of the IPM Architecture **400** providing a DDNS function using the DNS components **456** and **426** which support the HCDM **452** and SCDM **464**, respectively. At the LSF **106** and at the NSF **104**, the DDNS is a protocol used to update the DNS **426** and **456** respectively with the MN's IP address allocated by DHCP **468** and **458**.

FIG. **5**A is a flow which depicts the operation of the DDNS. Accordingly, when an MN **112** registers with an LSF **106**, in step **502** the HMM/SMM send a message to the DHCP **458** or **468** (which DHCP is only accessible by the HMM/SMM) requesting the IP Address of an attached NAI. In step **504**, the DHCP allocates the IP address of the NAI and, in step **506**, transmits the IP address (which may be public or private IP address) to the DNS in accordance with DDNS protocol. In step **508**, the DHCP transmits the IP address to the requesting HMM/SMM and, in step **510**, the HMM/SMM receives the IP Address. In step **511**, the HMM/SMM thus proxies the address management on behalf of the MN and renews the lease time of the address of each IPM re-registration. At de-registration of the MN **112**, the IP Address is released, as described in step **511**.

In step **512**, the DNS stores the IP Address. In step **514**, a CN sends a message to the DNS requesting the IP address of the NAI. In step **516**, the DNS looks up the IP address and, in step **518**, transmits the IP address to the requesting IP Address to the requesting CN. In step **520**, the CN receives the IP Address.

If the user **112** of the MN **114** is roaming, then the DDNS protocol is used to update the DNS **426** and/or DNS **456** with the COA of the MN **114**. The HMM **452**B interacts with the DNS server **456** to keep the MN's COA current.

DNS servers **426** similar to the DNS server **456** may reside in the LSF **106** and SMM **464** will update the DNS server **456** with the COA of the MN **112** during the initial Registration of the user **114** with the MN **112**.

The DNS server **456** at the LSF **106** may also have a reference (in its look-up table against the user **114**'s NAI) to the DNS server **426** at the NSF **104**. In that case, any DNS query initiated against the user **114**'s NAI at the LSF **106** is redirected to the DNS server **426** at the NSF **104**. The DNS server **426** at the NSF **104** then provides the COA of the MN **112**.

The DNS server **426** at the NSF **104** may have a reference (in its look-up table against the user **114**'s NAI) to the DNS server **456** at the LSF **106**. In that case, any DNS query initiated against the user **114**'s NAI at the NSF **104** is redirected to the DNS server **456** at the LSF **106**. The DNS server **456** at the LSF **106** then provides the COA of the MN **112**.

FIG. **5**B is a flow that depicts an operation of the DNS that stores the COA of the MN. Accordingly, in step **530**, the HMM and/or SMM sends a message to DNS **456** and/or DNS **426** store the MN **112**'s COA against the user **114**'s NAI. In step **532**, the NSF DNS **456** and/or LSF DNS **426** stores the MN **112**'s COA against the user **114**'s NAI. In step **534**, the CN **116** sends a message with the user **114**'s NAI to the NSF DNS **456** and/or LSF DNS **426** requesting the COA of the MN **112**. In step **536**, the NSF DNS **456** and/or LSF DNS **426** look up the MN **112**'s COA. In step **538**, the NSF DNS **456** and/or LSF DNS **426** transmits the COA of the MN **112** to the CN **116**. And finally, in step **540**, the CN **116** receives the COA of the MN **112**.

FIG. **5**C is a flow that depicts an operation of the DNS **426** that stores the NAI of the user **114** against the reference of the DNS **456**. Accordingly, in step **550**, the HMM **452** sends a message to NSF DNS **456** to store the COA of the MN **112** against the NAI of the user **114**. In step **552**, the NSF DNS **456** stores the COA of MN **112** against the NAI of the user **114** in a look-up table. In step **553**, the HMM **452** sends a message to SMM **464** to initiate storing the reference of the DNS **456** aginst the NAI of the user **114**. In step **554**, the SMM **464** sends a message to LSF DNS **426** to store the reference of the NSF DNS **456** against the NAI of the user **114**. In step **556**, the LSF DNS **426** stores the reference of the NSF DNS **456** against the NAI of the user **114** in a look-up table. In step **558**, the CN **116** sends a message with the user **114**'s NAI to the LSF DNS **426** requesting the COA of the MN **112**. In step **560**, the LSF DNS **426** looks up the reference of the NSF DNS **456** and sends a message to NSF DNS **456** with the NAI of the user **114** requesting the COA of the MN **112**. In step **562**, the NSF DNS **456** transmits the COA of the MN **112** to the LSF DNS **426**. In step **564**, the LSF DNS **426** receives the COA of the MN **112** and then the LSF DNS **426** transmits the COA of the MN **112** to the CN **116**. In step **566**, the CN **116** receives the COA of the MN **112**.

FIG. **5**D is a flow that depicts an operation of the NSF DNS **456** that stores the NAI of the user **114** against the

reference of the LSF DNS **426**. Accordingly, in step **570**, the SMM **464** sends a message to LSF DNS **426** to store the COA of the MN **112** against the NAI of the user **114**. In step **572**, the NSF DNS **426** stores the COA of MN **112** against the NAI of the user **114** in a look-up table. In step **573**, the SMM **464** sends a message to HMM **452** to initiate storing the reference of the LSF DNS **426** aginst the NAI of the user **114**. In step **574**, the HMM **452** sends a message to NSF DNS **456** to store the reference of the LSF DNS **426** against the NAI of the user **114**. In step **576**, the NSF DNS **456** stores the reference of the LSF DNS **426** against the NAI of the user **114** in a look-up table. In step **578**, the CN **116** sends a message with the user **114**'s NAI to the NSF DNS **456** requesting the COA of the MN **112**. In step **580**, the NSF DNS **456** looks up the reference of the LSF DNS **426** and sends a message to LSF DNS **426** with the NAI of the user **114** requesting the COA of the MN **112**. In step **582**, the LSF DNS **426** transmits the COA of the MN **112** to the NSF DNS **456**. In step **584**, the NSF DNS **456** receives the COA of the MN **112** and then the NSF DNS **456** transmits the COA of the MN **112** to the CN **116**. In step **586**, the CN **116** receives the COA of the MN **112**.

2.1.2.4 Unified and Local Directory Services

Each NSF **104** and each integrated LSF/NSF **202** includes a Unified Directory Service (UDS) subsystem, and each LSF includes a Local Directory Service (LDS) subsystem. Referring to FIGS. **4**A and **4**B, each UDS subsystem is based on a Client-Server architecture and comprises a UDS server **460**, a UDS database **461**, and a number of UDS clients, such as the mobility manager **452**, the billing component **402**, the policy server **404**, the server farm **406**, the service manager **408**, the desktop manager **410**, and the AAA function **450** interconnected via the bus **400**. Each LDS subsystem is also based on a Client-Server architecture and comprises an LDS server **430**, an LDS database **431**, and a number of LDS clients, such as the policy server **412**, the AAA function **462**, the mobility manager **464**, the server farm and local services **414**, the OA&M component **418**, and the billing component **431** interconnected via the bus **435**.

The UDS subsystem and the LDS subsystem serve similar functions, though at different levels of breadth. For example, a UDS subsystem for a particular network service provider (e.g., ATT™, GTE™, AOL™) represented by the NSF **104** or a integrated LSF/NSF **202**, maintains information in databases (discussed below) for all users **112** of mobile and fixed nodes and for all networks who subscribe to services provided by, or who provide services to, the particular network service provider. Each respective LDS subsystem maintains information in databases (discussed below) only for users **112** of mobile and fixed nodes and for networks who are connected via RANs or xANs **110** to a respective LSF **106**. As discussed further below, the information maintained in the UDS and LDS databases **431** and **461** includes, for example, user profiles ("unified" in the sense that they are independent of the xAN **110** serving the user **112**), user policies, network usage, network policies, security policies, and information related to availability of services and their location.

Because the functionality of the UDS subsystem and the LDS subsystem are substantially similar, that functionality will be described representatively herein with respect primarily to the UDS subsystem, and more specifically, with respect to the UDS subsystem of the integrated LSF/NSF **202**, as representative of the NSF **104** and LSF **106** as well. Accordingly, FIG. **6** depicts an integrated LSF/NSF **202** as comprising a UDS subsystem having a UDS server **460**, and two UDS databases **461** connected to the UDS server **460**. It is understood that, while only two databases **461** are shown, one or more such databases may be connected to the UDS server **460**.

UDS client software is installed in each LSF/NSF **202** component, and each LSF/NSF Server or Manager interfaces with the UDS server **460** through the UDS client. Details of the operation of the UDS server are thereby hidden from the respective NSF/LSF Server or Manager hosting the UDS Client. For example, an LSF/NSF component may utilize a Lightweight Directory Access Protocol (LDAP) Client which would hide the details of Client/Server protocol from the UDS Client.

The UDS Server **460** is associated with the LSF/NSF **202** for enforcing a common information model for NSF components that access the UDS subsystem **460**. The common information model is a schema for each Directory Information Tree (DIT), discussed further below with respect to FIG. **6**D. The schema identifies object classes, such as "ipmUser", and attributes that may comprise a directory entry into the UDS database **461**. The schema also lists attributes that an entry with an object class of "ipmuser" must have (e.g., a common name) and those attributes that an entry of object class "ipmuser" may, but is not required to, have (e.g. naiUser). The attributes are discussed in greater detail below with respect to FIGS. **6**E–**6**L. The UDS Server **460** incorporates UDS clients that interface to UDS databases **461** where data is physically stored.

The one or more UDS Databases **461** are utilized to physically store information. The interface between the UDS Server **460** and a given UDS database **461** may be proprietary or standards-based. The physical organization of the data is hidden from the NSF **104** components that interface with the UDS subsystem.

The term "schema" is used herein to describe a type of data that may be included in the UDS subsystem. The schema includes object classes and attributes that may be used to meet most UDS server **461** requirements. An object class defines a collection of attributes that may be used to define an entry, and provides a convenient way for a UDS client to retrieve a subset of data entries during a search operation to provide for a particular service. Object classes generally define a set of required and optional attributes. Attributes contain information about a specific descriptive aspect of an entry, and each attribute consists of an attribute type and value, as are discussed in greater detail below with respect to FIGS. **6**E–**6**L.

FIG. **6**A is a schema relationship diagram which specifies a preferred relationship between object classes utilized by the UDS subsystem (as well as the LDS subsystem) in accordance with the present invention. As shown, the UDS subsystem includes eight object classes, namely, an ipmUser object class **620**, an ipmUserDevice object class **622**, an ipmUserProfile object class **624**, an ipmClassOfService object class **626**, an ipmLsfDomain object class **628**, an ipnLsfSubnet object class **630**, an ipmNsfSubnet object class **632**, and an ipmLsfSubnet object class **634**, described in further detail below.

The schema relationship diagram of FIG. **6**A is depicted utilizing conventional database drawing techniques that are considered to be well-known in the art. Accordingly, the number "1" indicates one object class, "1 . . . *", indicates one or more object classes, and "0 . . . *" indicates zero or more object classes. For example, the ipmUser object class **620** may be related to zero or one or more ipmUserDevice object classes **622**, and the ipmUserDevice object classes

622 must be related to one or more ipmUser object classes 620. The attributes of each object class are described below.

FIG. 6B depicts a class inheritance tree which specifies a preferred hierarchy of the object classes 620, 622, 624, and 626 described above with respect to FIG. 6A, and identifies preferred attributes associated with each object class. Notably, the ipmUser object class 620 is an auxiliary object class, indicating that it is common to all sub-trees. Also depicted are a group 640 of four object classes well-known in the prior art, namely, a top object class 642, a person object class 644, an organizationperson class 646, and an inetOrgPerson object class 648. Because the object classes 642, 64, 646, and 648 contained within the group 640 are considered to be well-known they will not be discussed in further detail herein. The object class 620 may inherit, either singly or in any combination, from any of the prior art classes 642, 644, 646, or 648.

FIG. 6C depicts a class inheritance tree which specifies a preferred hierarchy of the object classes 628, 630, 632, and 634 described above with respect to FIG. 6A, and identifies preferred attributes associated with each object class. Notably, the object classes 628, 630, 632, and 634 are auxiliary object classes, indicating that they are common to all sub-trees. Also depicted are a group 650 of two object classes well-known in the prior art, namely, a top object class 652 and an organizationUnit object class 654. Because the object classes 652 and 654 contained within the group 650 are considered to be well-known, they will not be discussed in further detail herein. The object classes 628, 630, 632, and 634 may be inherit, either singly or any in any combination thereof, from either of the prior art classes 652 and 654.

FIG. 6D depicts a preferred Directory Information Tree (DIT) which shows how sub-directories are organized in the UDS and LDS for storing the object classes 620, 622, 624, 626, 628, 630, 632, 634, and 636 discussed above with respect to FIGS. 6A, 6B, and 6C. Accordingly, all object classes 620, 622, 624, 626, 628, 630, 632, 634, and 636 for all users 114 are organized under suitable sub-directories organized under a main IPM management organizational directory 660*a*. Specifically, the object classes 634 (IPM NSF Domain) and 628 (IPM LSF Domain) for all users 114 are stored under respective sub-directories 634*a* and 628*a*, which are organized under the directory 660*a*. The object classes 632 (IPM NSF Subnet), 620 (IPM User), 622 (IPM User Device), 624 (IPM User Profile), and 626 (IPM Class of Service) for all users 114 are stored under respective sub-directories 632*a*, 620*a*, 622*a*, 624*a*, and 626*a*, which are organized under the sub-directory 634*a*. The object class 630 (IPM LSF Subnet) for all users 114 is stored under a sub-directory 630*a*, which is organized under the sub-directory 634*a*.

FIGS. 6E, 6F, 6G, 6H, 6I, 6J, 6K, and 6L are tables which exemplify attributes preferably associated with each of the object classes 620, 622, 624, 626, 628, 630, 632, 634, and 636, respectively, discussed above with respect to FIGS. 6A, 6B, 6C, and 6D. Each attribute is defined in the schema as having a given "syntax" (e.g., DirectoryString) and, as indicating whether a respective attribute may only have a single value, or rather may be multi-valued (e.g., an "ipmUser" may have a "userEmail" attribute that has several values for multiple e-mail addresses). Matching Rules are associated with the attribute so that the directory understands how to establish such relationships as "equality" when comparing the values of the attribute from different entries. For example, the matching rule "caseIgnoreString" ignores the case of the characters when comparing strings.

The information stored in the UDS database 461 thus includes objects in a network infrastructure, which objects preferably comprise unified user profiles, server locations, applications, hubs, routers, network usage policies, security policies, and information related to availability of services and their location, and the like. The UDS subsystem thus provides structure to complex and heterogeneous networks by enabling access to, and management of, networks, such as home networks 302, visited networks 304, backbone networks 306, xANs 110, and the like. It is noted that the UDS subsystem 602 is preferably based on X.500, an International Telecommunications Union (ITU) standard for directories used in telecommunications.

The UDS subsystem also provides an interface to the UDS databases 461. Clients of the UDS subsystem preferably access the information contained in the UDS databases 461 via a standard access protocol such as Directory Access Protocol (DAP) or Lightweight DAP (LDAP).

The UDS database 461 schema, the type of UDS database 461, and storage techniques used by the UDS database 461 are preferably transparent to clients of the UDS database 461. The UDS subsystem receives information requests from clients, and retrieves the requested information from the UDS databases 461. The interface between the UDS server 460 and the databases 461 may be proprietary or based on standards. The UDS server 460 formats information retrieved from the UDS databases 461, and then sends the formatted information back to the UDS client in an appropriate response message, discussed further below.

FIG. 6M is a schematic diagram exemplifying how the UDS database 461 may interface with other components. The UDS database 461 includes a memory 461*a* configured for storing attributes 461*b* defining the behavior of a user 114, and for storing services 461*c* that the user 114 subscribes to. A single interface 461*d*, preferably an LDAP interface, is provided for provisioning the attributes 461*b* and services 461*c* into the UDS database memory 461*a*. The UDS database 461 further includes one or more interface 461*e*, preferably LDAP interfaces, configured for enabling the UDS database 461 to interface with other components of a local NSF 104. The UDS database 461 additionally includes one or more interfaces 461*e*, preferably LDAP exemplified as GSM, an IP Network, and DSL, of other network service providers.

As discussed in further detail below, the UDS database 461 is operable for providing to the local NSF 104 or other service providers via the interfaces 461*e* and 461*f* and the xANs 110 user profile information selectively drawn from the attributes 461*b* for services 461*c* to which a user subscribes.

By the use of the UDS subsystem 602 described herein, a common schema is provided between any number of services, thereby enabling common subscriber management and portability of applicable service data across data types. For example, User Authentication, DNS entries, and QoS may be made common across DSL and UMTS data environments.

2.1.2.5 Secure Messaging Gateway

The Secure Messaging Gateways (SMGs) 454 and 466 (FIG. 4B) serve both as routers and as firewalls that protect a network by monitoring and filtering incoming and outgoing traffic based on policies defined by administrators of a network, such as the home network 302, the visited network 304, the backbone network 306, the xANs 110, or the like. The SMGs 454 and 466 are located at the edge of the network and protect, for example, an internal network (e.g.,

the Intranet) from a public network (e.g., the Internet). The SMGs **454** and **466** preferably implement IPSec to provide secure (e.g., encrypted) communication links between networks.

The term "firewall" customarily refers to a collection of hardware, software, and policy that is placed between a private network (e.g., LSF/NSF), and an external network (e.g., the Internet). Packet filters and application gateways, either individually or in combination, normally constitute a firewall. Various firewall configurations may be set up based on the degree of security required and policies defined.

2.1.3 Network Types

The IPM Architecture, such as designated by the reference numeral **100** in FIG. **1**, will, in accordance with the present invention, support a number of different types of networks. For example, the IPM Architecture **100** will support a Private Network also referred to as an Intranet, which is defined as a network that is protected from a public network, such as the Internet **108** (FIG. **1**), by an SMG **454** and **466**, or the like, that enforces access restrictions via a predefined set of policies.

A private network may use IP addresses, sometimes referred to as public addresses or public IP addresses, which are routable on the public Internet **108**. Therefore hosts on the public Internet **108** are able to "directly" address hosts on a private network. An example of this type of network may be a Small Office or Home Office (SOHO).

Alternatively, a private network may use IP addresses, sometimes referred to as private addresses or private IP addresses, which are not routable on the public Internet. Hosts on the Internet may not then be able to "directly" address hosts on a private network. The private network can support some type of predefined access setup, e.g. SOCKS (RFC 1928) and tunneling, e.g., Layer 2 Tunneling Protocol (L2TP), IP tunneling, or the like, for sending data into the private network. The private networks may also use Network Address Translators (NATs) so their hosts may establish connections to hosts on the public Internet.

The IPM Architecture of the present invention is preferably configured to also support LSF control plane messaging to a private network's NSF.

The IPM Architecture of the present invention is preferably configured to also support Non-Private Networks, defined to be a network that does not restrict access into its network. Hence, all hosts in such a network have routable public Internet IP addresses.

The IPM Architecture of the present invention is preferably configured to also support LSF control plane messaging to the non-private network's NSF.

The IPM Architecture of the present invention is preferably configured to also support LSFs and NSFs that are non-private networks. Even though an LSF/NSF does not restrict access into the LSF/NSF, they provide a mechanism to allow encrypted data between itself and other networks.

The IPM Architecture of the present invention is preferably configured to also support LSFs and NSFs that are private networks with routable IP addresses. The LSF/NSF provides a mechanism to allow encrypted data between itself and other networks. The LSF/NSF also supports connectivity to enterprises, such as a SOHO, that do not support encrypted data services.

The IPM Architecture of the present invention is preferably configured to also support NSFs that are private networks and have private addresses that are not routable by the general Internet. The most common scenario for this is when a roaming user wants to perform a service at his home private network. Before a user's service can be established, the user's application must transverse the home network's security messaging gateway.

Given the flexibility of the types of networks supported by the mobility architecture framework of the present invention, users roaming within the LSFs are able to connect to a number of different types of home NSF types, such as, for example, private network ISPs that support L2TP, private network ISPs that support IP tunneling, non-private network ISPs, a company's private (or non-private) network, and the like.

The IPM Architecture of the present invention is preferably configured to also support Layer 3 tunneling mechanisms between LSFs and NSFs.

2.2 Frameworks

The present invention defines a number of different frameworks for handling various aspects of the IPM Architecture, which frameworks are responsible either directly or indirectly for providing mobility in the core network. The frameworks, discussed below in greater detail, include (1) a User Identity and Network Route Addressing Framework, (2) a Security Framework, (3) an Authentication, Authorization, and Accounting (AAA) Framework, (4) a Mobility Manager Framework, and (5) a Service Mobility Framework.

2.2.1 User Identity and Network Route Addressing Framework

In accordance with the IPM Architecture of the present invention, the linkage between the users **114** and their devices, such as MN **112**, is separated by assigning a unique identity to each user, and by assigning a unique identity to each device. This unique identity of these devices owned by the user **114** is linked to the NAI of the user **114** so that the identity of any of these devices can be linked to the user **114**. Furthermore, the unique identity of the device is of the form of NAI which includes attritbutes of both the device and the user. Some examples these unique identities based on NAI are, johndoe.mobilephone@anyserviceprovider.com and johndoe.pager@anyserviceprovider.com.

2.2.1.1 User Identity

A number of standardization methods for uniquely identifying users have been proposed, each with its own advantages and disadvantages. All proposals, though, require that the globally unique user identity must be resident in a "home database" that is accessible by all.

Because the network of the present invention is an IP-based network modeled on the Internet, the user name space must be consistent with what already exists within the Internet. Current Internet naming is based on domain names.

Accordingly, the IPM Architecture of the present invention supports unique identifiers as specified in the Internet RFC 2486, entitled "The Network Access Identifier" by B. Aboba; July 1998. The network access identifier (NAI) defined in this document is based on Internet domain names. The format of the identifiers is "user@realm" and may be, for example, "John.Doe@ISPxyz". The NAI may be used to identify users and to identify devices, such as routers. The NAI is not an e-mail address; however, in the most limited sense, an NAI may be a user's actual e-mail address.

When a user **112** accesses an LSF **106**, the MN **114** sends the user's NAI in the system access message. The NAI is used to access the user's profile in a UDS database **461** or LDS database **431** and to help perform other functions of the LSF **106**.

There are a number of ways a user **114**/MN **112** is able to supply an NAI. The NAI may be on the user's User Identity Module (SIM) card (similar to the SIM card used in GSM), configured in the MN **112**, or may have to be input by users **114** when they want to access the LSF **106**.

2.2.1.2 Network Route Addressing

Since the IPM Architecture is designed to support IP-based networks, network addressing is based on the Internet Protocol (IP). The IPM Architecture described herein is configured to support both IP version 4 (IPv4) and IP version 6 (IPv6) and is, generally, independent of the IP version. For the sake of illustration, however, routing within the IPM Architecture of the present invention will be described with respect to IPv4.

An MN **112** used by a user **114** will terminate (i.e., receive) IP datagrams destined to the user's application that is executing at a CN. To do this, the MN **112** must have an IP address. The IPM Architecture, such as depicted by the reference numeral **100** in FIG. **1**, supports two mechanisms for MNs **112** to acquire an IP address. First, an MN **112** may acquire a permanent IP address that is configured at or on the MN **112**. Alternatively, an MN **112** may acquire an IP address that the IPM Architecture allocates dynamically. It should be noted that, the expression "MN allocated IP address" is used herein to refer to an MN IP address independent of how the MN actually acquired the IP address.

In accordance with the present invention, at least five IP address allocation scenarios may be used either to allocate a permanent IP address that is configured at or on the MN **112**, or to dynamically allocate an IP address by the IPM Architecture. In a first scenario, an MN **112** owned by a user **114** is provided with a permanent IP address associated with the user's home network **104**B, depicted in FIG. **3**. In a second scenario, a user desires to use an MN **112** which is not his/her own MN **112**, and which MN **112** has a permanent IP address that is associated with a current point of attachment (associated with a visited LSF **106**). In a third scenario, the user **114** desires to use an MN **112** which is not his/her MN **112**, and which MN **112** has a permanent IP address that is not associated with his/her home network or the current point of attachment (associated with the visited LSF **106**). In a fourth scenario, the MN **112** owned by the user **114** does not have a permanent IP address and, hence, when the user roams with his/her MN **112**, the IPM Architecture will dynamically allocate an IP address. In a fifth scenario, similar to the fourth scenario, the device the user desires to use is an MN **112** which is not his/her MN **112** and which MN **112** does not have a permanent IP address, thereby resulting in a dynamic allocation of an IP address by a network as the user **114** roams with the MN **112** through the network, as discussed above with respect to FIG. **5**.

The IPM Architecture of the present invention enables an MN **112** to use either direct routing or a phenomena known as "triangle routing." Triangle routing is defined to have a data path that always passes through an anchor point between the MN and a host (e.g., a CN) somewhere in the IPM Architecture. The anchor point stays fixed throughout the entire data session irrespective of the MN's movement.

In the network of the present invention, the anchor point for the triangle route may be established at either a user's home NSF **104** or at a visited LSF **106**, depending on how the user's roaming address is allocated.

If the visited LSF **106** is configured to allocate an MN IP Address, the anchor point will be in the visited LSF **106**, referred to herein as an anchor LSF **106**. This would result from MN allocated IP address of the LSF **106** being updated in the user's home DDNS **456**. An advantage of the anchor LSF **106** allocating the IP address is that, as discussed below, a CN may send datagrams directly to the MN **112** via an MN allocated IP address that is topologically correct with the anchor LSF **106**. However, there are several issues that must be addressed before a CN may send datagrams directly to the MN **112** via an LSF topologically correct MN allocated IP address.

First, as the user **114** roams and registers in new LSFs, each LSF's MN allocated IP address will replace a previous MN allocated IP address in the user's home DDNS **456**. This may result in a window through which the CN may acquire a wrong IP address.

Second, since a CN's local DDNS **426** may cache the previous IP address, the CN applications will not be able to communicate with the user's application **414** or **424**. This may be overcome by setting the Time To Live (TTL) contained within the record of the home DDNS **456** to zero, indicating that the CN's DDNS should not cache the IP address. When this is done, consideration must be given to the additional capacity/performance that is incurred on the network and the home's DDNS **456** since other DDNSs **456**/**426** of other NSF and/or LSF networks will not be caching the additional records.

Third, when a user **114** initiates a TCP/IP application with a CN on the Internet, the TCP/IP application of the node on the Internet is given the current IP address of the MN **112**, which is the IP address allocated by the anchor LSF **106**. When the user **114** roams with the MN **112** from the anchor LSF **106** to one or more other LSFs, the Internet node's application data will still be routed to the anchor LSF which will then forward the datagrams through as many LSFs as the user has transversed, incurring more routing hops that datagrams must transverse.

Fourth, the preceding issue of incurring additional routing hops is resolved when the user **114**'s session datagrams are finally terminated, at which time the anchor LSF and any other LSFs in the routing determine when they may "clean up," e.g., return the MN's IP address to the DHCP **468**, remove routing information from the memory, and de-allocate all the resources used by the previous session.

If the visited MN's home NSF **104**, rather than the visited LSF **106**, is responsible for allocating the MN IP Address, the anchor point will be in the home NSF **104**. The advantages of the NSF **104** allocating the IP address are that CNs will always have a correct MN IP. The disadvantage is that a triangle route is created with the user's home NSF **104** serving as the anchor. To alleviate this issue, the IPM Architecture of the present invention provides a mechanism to inform CNs of the LSF's/MN's COA so it can send (tunnel) datagrams directly to the MN **112** of the user **114** and avoid a triangle route. This is discussed in further detail below with respect to the Mobility Manager Framework.

If a CN does not have software to support tunneling of datagrams, the IPM Architecture of the present invention supports policies defined at the user's home NSF **106** that allow for defining where the MN IP Address is allocated. For example, such a policy may provide for the home NSF **104** to permit an LSF **106** to allocate MN IP Addresses or, if the home NSF **104** wants to "hide" the location of the roaming user **114**, then the home NSF may allocate the MN's IP address. However, the home NSF **104** would preferably allocate the MN's IP address.

The IPM Architecture of the present invention also supports a policy at the NSF **104** that permits triangle routing. Such policy may be set when the NSF wants to hide the location of a user **114** from CNs.

2.2.1.3 Routing Area (RA)

FIG. **7** shows Routing Areas (RAs) **702** within the same LSF **704** served by a single SMM **706**. The RA **702** is the sub-network point of attachment at the edge of the xAN **708**. The format of an RA is a Network Access Identifier (NAI) as defined in RFC 2486. Each xAN **708** is configured to map the NAI to a set of partitions provisioned for the NAI. There may be more than one RA served by a single SMM **706**.

2.2.2 Security Framework

Security is applicable to the control plane, data plane, and management plane of the IPM Architecture. Within the architecture, security is preferably provided to control plane messages, including registration messages, authentication messages, location update messages, and the like. Depending on the application and the policies defined, security is preferably provided at different levels in the data plane.

There are a number of security alternatives that are used within conventional wireless and wireline networks. The IPM Architecture of the present invention defines a security framework that consolidates all the alternatives into one framework, as discussed further below. The Internet Engineering Task Force (IETF) security work group has defined a security architecture referred to as IPSec, discussed in further detail in an Internet Draft entitled "Security Architecture for the Internet Protocol", by Steve Kent and Randall Atkinson, July 1998, and has defined the associated protocols and cryptographic algorithms to support it.

IPSec affords at least five services. First, a security service referred to as Access Control prevents unauthorized use of a resource. A second service, referred to as Connectionless Integrity, detects modification of an individual datagram, without regard to the ordering of the datagram in a stream of traffic. Third, a security service referred to as Data Origin Authentication, verifies the identity of a claimed source of data. Fourth, a security service referred to as Replay Protection prevents data from being intercepted and/or for intercepted data to be used at a subsequent time to gain access. Fifth, a security service, referred to as Confidentiality, protects data from unauthorized disclosure. The foregoing five services are considered to be well-known in the art and, therefore, will not be described in further detail herein, except insofar as necessary to describe the present invention.

Two protocols have been specified to provide the foregoing five IPSec services. First, a preferred protocol is referred to as Authentication Header (AH) described by R. Atkinson, in an article entitled "IP Authentication Header", RFC 1826, August 1995. Second, an alternative protocol is Encapsulated Security Payload (ESP) described in an article entitled "IP Encapsulating Security Payload" by R. Atkinson, RFC 1827, August 1995. In the architecture framework of the present invention, IPSec is the preferred security architecture because IPSec provides interoperable, high quality, cryptographically based security for IPV4 and IPV6 at the IP layer. Furthermore, IPSec may be used in a many ways to implement VPNs, tunneling, security, and firewall transversals. IPSec is preferably used within the control plane and data plane of the security framework.

2.2.2.1 Network Security Associations

FIG. **8** depicts network security associations within an IPM Architecture **800** of the present invention, comprising an LSF network **106**, an NSF network **104**, and security messaging gateways (SMGs) **806**, and wherein a user is roaming with an MN **114** in a visited LSF **106**. As discussed below, at least five Security Associations (SA) may exist in the context of the IPM Architecture **800**.

First, an SA may exist as an IPSec SA between SMGs of (1) LSFs and (2) LSFs and NSFs, as exemplified in FIG. **8** by an IPSec SA**1**. For example, an IPSec SA**1** is shown connected between the SMGs **806** and protects all data that flows between the networks **104** and **106**. An SA between SMGs is always in tunnel mode and uses ESP (RFC 2406). As shown in FIG. **8**, the LSF network **106** is the network a user MN **112** is currently visiting. The NSF network **104** is the home network for the user **114**. The IPSec SA**1** between the SMGs **806** of the two networks **104** and **106** is preferably set up on a permanent basis, as per a roaming agreement established between the two networks. While FIG. **8** only shows the IPSec SA**1** as between the LSF **106** and the NSF **104**, the IPSec SA**1** may also exist between multiple LSFs **106**.

Second, an SA may exist between AAA function functions of two networks. Even though there is security between the LSF **106** and the NSF **104** via the SMGs **806**, the respective AAA functions **462** and **450** have their own SAs, depicted in FIG. **2** as IPSec SA**2**. The IPSec SA**2** is setup for end-to-end AH authentication to allow for verifying the networks **106** and **104**. However, IPSec SA**2** may also employ ESP to provide for data integrity. The IPSec SA**2** is preferably set up on a permanent basis, as per a roaming agreement established between the two networks **104** and **106**.

Third, an IPSec SA**3** may be established between the MN **114** and the SMM **464** in the LSF **106**. The IPSec SA**3** allows for encrypting data via ESP. The IPSec SA**3** is preferred if the access to the network LSF **106** is unsecured (e.g., wireless without encryption or cable modem).

Fourth, depending on security policies defined, an IPSec SA**4** may be established between the MN **112** and a CN **116**, preferably in the data plane. The IPSec SA**4** between the MN **112** and the CN **116** that the MN is communicating with protects the traffic between the two entities. It should be noted, though, that the existence or non-existence of the IPSec SA**4** is transparent to the IPM Architecture.

Fifth, depending on the security environment at the LSF **106**, the MN **112** may establish an IPSec SA**5** with an edge router **816** of the visited LSF network **106** for securing its data path. The IPSec SA**5** will ensure secure data transfer between the MN **112** and the edge of the LSF network **106** being accessed.

The NSFs **106** preferably have service roaming agreements between one another and hence have security associations established between the SMGs of their respective NSFs and LSFs. For example, in FIG. **9**, where IPSec SAs are designated schematically by dashed lines with arrows, the NSF **104** may have an SA with the LSFs of the integrated LSF/NSF **202**, and the LSF/NSF **202** may have SAs with LSFs **106** of the NSF **104**. The SAs are preferably initially pre-configured when the SLA is established or, alternatively, the SAs may be initially dynamically established via Internet Security Associations and Key Management Protocol (ISAKMP). SAs may also be established between LSFs **106** in order to manage inter-system handoffs in a secure fashion.

SAs of the type described herein are more fully disclosed and discussed in co-pending U.S. patent application Ser. No. 09/595,551, entitled "SECURITY FRAMEWORK FOR IP MOBILITY SYSTEMS USING VARIABLE BASED SECURITY ASSOCIATIONS AND BROKER REDIRECTION", filed Jun. 16, 2000 on behalf of Basavaraj B. Patil, et al, which is hereby incorporated in its entirety by reference.

2.2.2.2 Security Between a Network's LSF(S) and NSF

A home network **102** may comprise a number of LSFs **106** associated with an NSF **104**. Each LSF **106** and NSF **104** may be treated as a private subnet that is protected by an SMG. The LSFs **106** have an SA in place between their SMGs and the NSF's SMG. In FIG. **9**, this is shown by the SAs **902** between NSF **104** and the LSFs **106** shown in dashed outline **102**. The NSF **104** combined with the LSFs **106** shown in dashed outline **102** may constitute a home network, or a virtual private network (VPN).

An integrated network **202** also has LSF and NSF functions combined, i.e., the components are physically located together. In such a scenario, the LSF/NSF network **202** has an SMG **904** that protects its network from the IP Network **108**.

An NSF, such as the NSF **906**, may not control any LSFs **106**. In such case, users **114** of the NSF **906** will always be in other systems when it roams.

2.2.2.3 Security in the Data Plane

FIG. **10** shows IPM architecture **1000**, having a user **114** roaming in an LSF **106***b* and homed in a private network **102** NSF **104***a*. The user **114** wishes to establish a session with a Correspondent Node (CN) **116** within his/her home NSF **104***a*. To establish the session, the user **114** establishes an IPSec SA **1008**, designated schematically by dashed lines with arrows, with the home NSF **104***a* to which an SMG **1010** has access. Such IPSec SA **1008** permits the SMG **1010** to validate IPSec AH datagrams sent by the user **114** MN **112** to the home network **102**. The SA **1008** is preferably pre-configured at the MN **112** and the home NSF **104***a* to allow the user **114** to roam. If a roaming user **114** wants to contact CNs **1004** in other private networks, each of the private networks must have an SA established with the user **114** to permit the user to traverse the network's SMG.

If end-to-end security (e.g., encryption) between the MN user **114** and another user (not shown) were mandated based on decisions established by the home networks **102** of respective users **114**, then the MN user **114** would establish an IPSec SA **1012** with the CN **116**. Such an IPSec SA **1012** may be dynamically established at the time of session connection via ISAKMP, or the SA may be pre-configured. It should be noted, however, that the existence or non-existence of such IPSec SA **1012** is transparent to the IPM architecture framework **1000**.

2.2.2.3.1 Protection of MN Location

Security policies associated with an MN **112** may warrant a home NSF **104** to not disclose the MN's current network point of attachment to CNs. In such cases, CNs may send datagrams destined to the MN **112** through the user's home network **102**. The home network **102** is responsible for tunneling the datagrams to the LSF **106** currently serving the MN **112**.

2.2.3 Authentication, Authorization, and Accounting (AAA) Framework

FIG. **11** illustrates an IPM Architecture framework **1100** that utilizes an AAA protocol for performing authentication, authorization, and accounting operations. An AAA protocol provides a common messaging scheme, defined by standards, used between networks. The IPM architecture framework **1100** includes a visited network **304** and a home network **302**, and is based on requirements established by the AAA Business Operations Framework (BOF) that exists within the Internet Engineering Task Force (IETF). The AAA protocol is extensible so that it may define other functions and provide solutions to different problem domains. In the architecture framework **1100** of the present invention, a Diameter-based AAA with extensions for IP mobility is preferred, though another AAA protocol such as Radius may also be used. Both Diameter and Radius are considered to be well-known in the art and, therefore, will not be discussed in further detail herein, except insofar as necessary to describe the present invention.

AAA services are accessed through AAA functions **450** and **462** which, while not providing the function of Authentication, Authorization or Accounting, do provide an interface to the appropriate servers that implement AAA functions. The AAA functions **450** and **462** provide a standard means for addressing AAA messages sent between NSFs and LSFs, respectively, and, to that end, are located at the NSF **104** and LSF **106** shown in FIG. **11**.

The AAA function **462** at the LSF **106**, using the Network Access Identifier (NAI) received from an MN, is responsible for determining the NSF **104** that is home to a user **114** and for forwarding AAA messages to that user's home NSF **104**.

The AAA function **450** at the NSF **104** presents an integrated AAA interface (through a single IP address) to the rest of the IP Network **108** and is configured for forwarding AAA messages to the appropriate function within the NSF **104** (FIGS. **4**A, **4**B, **4**E, and **4**F) responsible for a particular function. This allows an operator-specific internal architecture of an NSF **104** to be hidden from other NSFs and LSFs and provides a homogeneous interface for the IPM Architecture.

A mobility extension to the AAA protocol enables mobility manager components, e.g., the SMM **464** in the LSF **106** and the HMM **452** in the NSF **104**, to communicate with each other. The AAA functions **450** and **462** provide a secure means of exchanging mobility related control messages. The SMM **464** and HMM **452** interface to respective AAA functions **462** and **450** via the mobility extension for their communication. Security between AAA functions **450** and **462** is based on IPSec.

2.2.3.1 Authentication

Authentication in the context of the present invention exemplified in the IPM Architecture AAA framework **1100** refers to authentication of an MN **112** and its user **114** by the authentication functions **450***b* and **462***b* (FIGS. **4**E and **4**F). Authentication of a user **114** is a process of validating the identity of the user **114**, and includes a combination of certificate authority (CA) **1116**, a key management system, and digital signature verification services. The authentication functions **450***b* and **462***b* interface with respective AAA functions **450** and **462** and validate authentication requests by MN users **114** as they access a network from either the home network **302** or the foreign (visiting) network **304**.

Conventional networks support two types of authentication methods, namely, strong authentication and weak authentication. Strong authentication is preferred in the present invention for use by the authentication functions **450***b* and **462***b*, and makes use of symmetric and asymmetric public key cryptography techniques. Examples of strong authentication include the use of digital signatures, public key cryptography using x.509 certificates, and the like. Weak authentication includes systems that use password-based protection mechanisms. The core network **101** (FIG. **1**) preferably supports multiple types of authentication mechanisms.

The AAA authentication functions **450***a* and **462***a* are front-ends or relays that securely carry authentication parameters of a user **114** from the LSF **106** of the visited network **304** to the home network **302** where the user **114**

may be authenticated. The authentication function **450***b* supports existing authentication protocols, such as PAP, CHAP, EAP, and the like. These functions may be provided by a RADIUS server, by an x.509 based CA, by an Authentication function in a wireless network, or the like. If the Authentication function **450***b* uses x.509 certificates, then a Certificate Authority (CA) **1114** may be a third party CA **1116**. The NSF **104** may also have it's own CA **1114** in order to authenticate certificates.

As a result of advances made in cryptography, as well as for security reasons, digital signatures and x.509 certificates for authentication are preferred in the present invention.

2.2.3.2 Authorization

Authorization is a process performed by the authorization functions **450***c* and **462***c* for determining which services and resources a user **114** is allowed to use. It is based on policies defined for the user and for the requested resource or service. Authorization may occur during authentication, or as a separate process. An authorization function **450***c* or **462***c* may consult the policy server **404** or **412**, respectively, that contains a user **114**'s profile, including services that the user has subscribed to.

2.2.3.3 Accounting

The accounting aspect of AAA is performed by the accounting functions **450***d* and **462***d* to transport accounting records generated for the user **114** in a visited system, such as the visited network **304**. An accounting entity in the xAN **110**/LSF **106** generates records that contain such information for each MN **112** user **114** served by a network **302** or **304**. The AAA function **450***d* or **462***d* is used as a front-end or relay to securely carry the accounting records from the visited network **304** to the accounting function **450***d* in the user's NSF **104** or, alternatively, to an accounting function in the accounting service bureau **470** (FIG. **4**B), if the bureau **470** supports an AAA accounting protocol.

The accounting functions **450***d* and **462***d* are back-end servers that store the network usage records of MN users **114**. The AAA function **450** in the NSF **104** interfaces with the accounting function **450***d* to transfer accounting records generated by the LSFs **106** and/or the NSF **104**. The accounting messages defined for AAA may carry the actual records or may provide a means to initiate the transfer of records in bulk. Since accounting records are the source of revenue to service providers (i.e., owners of an NSF **104** and/or LSF **106**), security must be provided between the links that are involved in the transfer of accounting records.

An Accounting function (not shown) may also be located on the Internet, and be hosted by the Accounting Service Bureau **470** (FIG. **4**B). In such a scenario the AAA Accounting function **450***d* in the NSF **104** would interface with the Accounting function in the service bureau **470**. A security association (SA) may be established between such entities to protect data.

The Accounting functions **450***d* and **462***d* may in turn interface with billing servers **402** or **432**, respectively, in an hierarchical manner.

2.2.3.4 Mobility

The mobility manager components SMM **464** and the HMM **452** of the IPM Architecture framework **1100** use the AAA protocol for its control plane messaging. The AAA protocol preferably includes support for mobility control messages. The mobility manager components SMM **464** and HMM **452** of the respective LSF **106** and NSF **104** interface to the AAA functions **462** and **450** in their respective domains.

2.2.3.5 AAA Function Locations in the Network

FIG. **12** shows various configurations of AAA functions in an IPM Architecture framework **1200** embodying features of the present invention. The framework **1200** includes the IP Network **108** through which are connected NSFs **104**A and **104**B, and respective LSFs **106**A and **106**B, the integrated LSF/NSF **202**, the Accounting Service Bureau **470**, the Security Agreement Broker **472**, and the CA **1116**. The NSFs **104**A and **104**B include respective AAA functions **450**A and **450**B, and the LSFs **106**A and **106**B include respective AAA functions **462**A and **462**B. The NSF **104**A and LSFs **106**A constitute a network **102**A, and the NSF **104**B and LSF **106**B constitute a network **102**B. The Accounting Service Bureau **470**, and the Security Agreement Broker **472** include respective AAA functions **470***a* and **472***a*. A number of xANs **110** are shown connected to an LSF **110**, and may be similarly connected to any of the LSFs **106**A or **106**B, or to the integrated LSF/NSF **202**.

When an entity of the LSF **106**A, **106**B or **202**, such as the AAA function **462** or the mobility manager SMM **464**, performs an AAA function, that entity generates an AAA message and sends it to a "local" AAA function. The "local" AAA function is defined with respect to FIG. **12** as the AAA function **462**A, **462**B, or **450**C located at the LSF **106**A, **106**B, or **202**, respectively, of the visited network **304**, or the AAA function **450**A or **450**B located at the NSF **104**A or **104**B, respectively, of the home network **302**, to which an MN **112** interfaces. The local AAA function is responsible for routing the AAA message to the MN user **114**'s home AAA function, such as the AAA function **450**A or **450**B, or, alternatively, for accounting, it may be routed to the AAA function **470***a* in the accounting service bureau **470**. The type of routing of AAA messages described herein is more fully disclosed and discussed in co-pending U.S. patent application Ser. No. 09/551,811, entitled "Apparatus and Method for Routing AAA Messages Between Domains of a Network", filed on behalf of Haseeb Akhtar, et al, on Apr, 18, 2000 which is hereby incorporated in its entirety by reference.

The "local" AAA function thus determines where to send an AAA message. The "local" AAA function uses the domain portion of the user's NAI to identify the home network **302** of the user **114**. If a service agreement (SA) is established between a respective NSF **102**A or NSF **102**B of the home network **302** and a respective LSF **106**A or **106**B or the LSF/NSF **202** of the visited network **304**, the AAA message is forwarded to the home AAA function **104**A or **104**B of the user **114**. If there is no roaming agreement (i.e., no SA) between the networks, the visited network **304** may, depending on its policy **412**, forward the AAA message to the AAA function **470***a* of the service bureau **470**.

The accounting service bureau **470** is an organization that has established service level agreements (SLAs) with other network service providers (i.e., owners of NSFs) and/or other service bureaus (such as **472**). The SLAs permit MNs **112** to roam between NSF and LSF networks that have not directly entered into SLAs with each other. In a global roaming scenario it may not be possible for an NSF **104** to enter into SLAs with every other NSF in the world. Therefore, having entered into an SLA with a Service Agreement Broker **472** may increase the scope of roaming that a user **112** of an MN **114** may enjoy through its NSF **104**.

It may be desirable to locate the "local" AAA function, that would otherwise be located at a respective LSF, at a visited system's NSF **104**A or **104**B when the service provider of the respective NSF owns a number of LSFs to avoid incurring the cost of an AAA function **462** in every

LSF. However, depending on where the NSF **104** is located, e.g., if the location of the NSF traverse a public IP-based network such as the Internet, the service provider will need to determine whether to provide secure links, such as an IPSec link, between the AAA function **462** located at the NSF **104**, and LSF **106** components, such as the SMM **464**. Alternatively, security between an LSF and NSF may be provided by an AAA protocol configured to only forward AAA messages to the NSF **104**A or **104**B, which then performs a domain lookup to forward the AAA messages to the user's home NSF **104**A or **104**B. In still another alternative, a service provider of an LSF **106**A or **106**B may use the AAA function **472***a* of the Broker **472** as its "local" AAA function.

2.2.3.6 Security in the AAA Framework

FIG. **13** exemplifies security associations (SAs) that may be provided on a one-to-one basis between AAA functions in an IPM Architecture framework **1300** embodying feature of the present invention. SAs are represented in FIG. **13** as dashed lines with arrows on each end of the line. For example, FIG. **13** depicts an SA **1302** between an AAA function **450**C of an NSF **202** and an AAA function **450**B in an NSF **104**B. SAs are setup for end-to-end authentication using IPSec's AH to allow for verifying a network's authenticity. However, an SA may also employ ESP to enhance data integrity. An SA is preferably set up on a permanent basis, in accordance with a roaming agreement, e.g., an SLA, established between the two networks.

In FIG. **13**, a number of different types of NSFs are depicted: an NSF **104**A having separate LSFs **106**A, an NSF **202** having an integrated LSF, and an NSF **104**B having no access networks.

The SA **1302** between the NSF **202** AAA function **450**C and the NSF **104**B AAA function **450**B enables users of the NSF **104**B to roam into the NSF **202** network. When users of the NSF **104**B roam into LSF **106**A, however, the NSF **104**A is not able to identify the user's domain (i.e., home NSF) because the NSF **104**A does not have an SLA established with the NSF **104**B. However, an SLA and an IPSec SA **1304** are established between the NSF **104**A and the Service Agreement Broker **472**, thereby creating a trust relationship therebetween. Hence, the NSF **104**A may relay AAA messages to the AAA function **472***a* of the Broker **472**.

An SLA and an SA **1306** are also established between the Broker **472** and the NSF **104**B. Therefore, the broker **472** is able to forward the AAA message received from the NSF **104**A to the NSF **104**B. Because of the SLAs between the NSFs **104**A and **104**B and the broker **472**, the broker **472** is able to forward all requests between the NSF **104**A and the NSF **104**B.

The broker **472** may remove itself from being the "middle man" for forwarding requests, by using ISAKMP to negotiate the creation of an SA (not shown) between the AAA function **450**A of the NSF **104***a* and the AAA function **450**B of the NSF **104**B. Once the SA is established, the NSF **104**A and the NSF **104**B may communicate directly to each other.

Also shown in FIG. **13** are an SA **1310** between the LSF **106**A and the NSF **104**A, an SA **1312** between the SMGs **806**A and **806**B, and an SA **1314** between the AAA function **450**C and the AAA function **472***a*.

2.2.4 Mobility Manager Framework

As mentioned above, the IPM Architecture of the present invention also includes a mobility manager framework. The mobility manager framework supports nomadic roaming users and roaming MN users who roam into wireline networks and wireless networks.

The term "nomadic users" is used herein to refer to users who, when they move from a first location to a second location, physically disconnect from a first point-of-attachment at the first location, and then physically re-connect at a second point-of-attachment at the second location. Nomadic users normally connect to wireline access networks, e.g., LAN connections and dialup connections.

In contrast to the term "nomadic users", the term "MN users" is used herein to refer to users who do not need to disconnect from a point-of-attachment when they roam. MN users normally connect to wireless access networks, e.g., NAC, GSM, and the like.

Conventionally, wireline networks and wireless networks each have their own unique infrastructures to achieve their respective user mobility. According to C. Perkins, editor of "IP Mobility Support", RFC 2002, October 1996, wireline networks use mobile IP to support user mobility, and the wireless networks use either NAC or GSM/UMTS standards. In contrast to conventional networks, the mobility manager framework of the present invention insures that there is seamless user mobility between wireline networks and wireless networks.

As discussed in further detail below, the mobility manager framework (including for example the SMM **464** and HMM **452**) supports a number of functions, including, such as, for example, protocol interfaces between network components (e.g., as shown in FIGS. **4**A and **4**B), unique identification of users, user security, network security, user location tracking, user packet data service activation to one or more service providers from the same device, user packet data service deactivation, user/MN context management, inter system (inter LSF) handoffs, intra system (intra LSF) handoffs between two xRANs, unified directory service that contains user profiles, roaming MN address resolution, IP router configurations, and mobility interface to the wireline networks.

2.2.4.1 Protocol Interfaces Between Network Components

As users **114** roam between heterogeneous access LSF and NSF networks, the access media used by the user **114** is very specific to the access type, e.g., GSM has air interface characteristics, dialup connections have wireline dialup characteristics, and the like. As a consequence of the different characteristics, each of the access networks has its own access protocol. However, to seamlessly integrate different access networks, the protocols needed between several interfaces are defined so that user mobility may be supported throughout the network. FIG. **14** depicts an IPM Architecture network **1400** having four of these interfaces between which protocols are defined.

First, in accordance with the present invention, a protocol is defined for a interface between the MN **112** and an LSF **106**B, depicted in FIG. **14** as an MN/LSF interface **1402**. The protocol that defines the interface **1402** is a Layer 3 protocol that enables users **114** to request access to the network **1400** through the LSF **106**A and to obtain IPM services. With respect to the interface **1402**, the network **1400** uses a mobile IP protocol as a base protocol with a number of enhancements to support functionality of the IPM, as discussed in further detail below with respect to FIGS. **21**–**63**.

Second, in accordance with the present invention, a protocol is defined for a interface between the xAN and LSF, depicted in FIG. **14** as an xAN/LSF interface **1404**. The protocol that defines the xAN/LSF interface **1404** is a Layer 3 protocol that translates xAN-LSF messages into MN-LSF messages so that an MN may communicate with an LSF

using IPM messages, and a user **114** may thereby roam within a LSF and between LSFs. The xAN/LSF interface **1404** is described in further detail below with respect to FIGS. **20**A–**63**

Third, in accordance with the present invention, a protocol is defined for an interface between LSFs and NSFs, depicted in FIG. **14** as an LSF/NSF Interface **1406**. The protocol that defines the interface **1406** provides information for user location tracking and for providing user profile information between the SMMs **464**A and **464**B and the user's HMM **452**.

Fourth, in accordance with the present invention, a protocol is defined for an interface between LSFs **106**A and **106**B, depicted in FIG. **14** as an LSF/LSF Interface **1408**. The protocol that defines this interface provides information for coordinating seamless mobility between two LSFs. The LSF/LSF Interface **1406** is described in further detail below with respect to FIGS. **21**–**63**.

It is noted that a conventional interface is defined between the MN **112** and an xAN **110**, depicted in FIG. **14** as an MN/xAN interface **1410**. The interface **1410** is defined by a Layer 2 protocol and uses any interface, such as, for example, NAC, GSM, DSL, IEEE 802.3, IEEE 802.11, and the like.

In light of the foregoing, the present invention enables an MN **112** to communicate with an LSF **106** at the Layer 2 level via the MN/xAN interface **1410** and the xAN/LSF interface **1404**, and at the Layer 3 level via the MN/LSF interface **1402**.

Two alternatives exist for defining the protocols for the LSF/NSF interface **1406** and the LSF/LSF **1408** interfaces described above. A preferred alternative is to extend the AAA protocol to support the required mobility functions SMM **464** and HMM **452**. A second alternative is to define a protocol that is independent of the AAA protocol.

The mobility framework of the present invention extends the AAA protocol to include an SMM **464** and an HMM **452**, for at least two reasons: first, the AAA protocol (preferably based on Diameter) is an extensible protocol that already includes many basic AAA functions and, second, the SMM **464** and an HMM **452** may take advantage of the AAA function's security associations.

2.2.4.2 User and Network Mobility Security

FIG. **15** shows a network **1500** having an LSF **106** being accessed by a roaming user **114**. Prior to being accessed, the LSF **106** must determine whether the user **114** is a valid user. To make such a determination, two levels of security must preferably be established. First, the user **114** and a home NSF **104**A should establish an IPSec SA **1502** that is used to authenticate the user **114**. Second, the LSF **106** and the NSF **104**A must have an IPSec SA **1502** that is used to validate whether the LSF **106** and NSF **104**A have a service level agreement (SLA) established between them.

The SA **1502** established between the user **114** and the home NSF **104**A may support one of a number of different types of authentication algorithms: preferably, digital certificates or, alternatively, symmetric keys, asymmetric keys, or the like. Hence, when a user accesses an LSF **106**, the MN **112** will need to send the user's digital signature and the NAI to the xAN. The LSF sends this information to the home NSF so that the home NSF can authenticate the user. The home NSF uses the NAI to access the user's profile in a directory service and initiate the user's authentication.

Alternatively, the LSF **106** may determine whether the user **114** is a valid user by requesting that the home NSF **104**A of the user **114** send to the LSF **106** authentication information, such as, for example, the user's private key, so that the LSF **106** may authenticate the user **114**. In still another alternative, the integrated LSF/NSF **202** may support the concept of a unique authentication challenge (similar to the CHAP unique challenge).

The SA **1502** between the LSF **106** and the NSF **104**A is established when the LSF and NSF execute their SLAs. The SA **1502** is based on IPSec. FIG. **15** thus depicts an option for a mobility SA between a serving LSF **106** and the MN User's home NSF **104**A when the LSF **106** has an AAA function **462**.

FIG. **16** is similar to FIG. **15**, but for the addition of an NSF **104**B which is designated as the home NSF of the user **114**, and an IPSec SA **1602** established between the AAA function **450**A and the AAA function **450**B. The AAA function **450**B is then utilized by an LSF **106** to authenticate the user **114**.

If the user **114** is accessing his/her home LSF **106** in an integrated LSF/NSF, such as the LSF/NSF **202** described above with respect to FIG. **2**, there may be no need to establish an SA between the LSF **106** and NSF **104**. However, the service provider of the respective integrated LSF/NSF may desire security within its own "closed" network. This may be achieved by establishing SAs between the multiple AAA functions within the closed network.

2.2.4.3 User Location Tracking

The expression "user location tracking" as used herein refers to the functions and data required to reliably discern where an MN is physically located at any time. There are two basic functions involved in user location tracking. First, a user's MN **112** must determine that a user **114** has moved to a different subnet (e.g., an IP network) and inform the network of such. Second, MNs **112** that are executing one or more applications must be tracked as they move (i.e., handoff) between different subnets.

As a user **114** roams within an access network (xAN **110**), his/her MN **112** determines whether it has changed its subnet point-of-attachment (as defined in RFC 2002). If the MN's subnet point-of-attachment has changed, then the MN **112** informs the network.

When a user **114** first accesses a system (e.g., an LSF) via an xAN **110**, the user's MN **112** sends a Registration message to the LSF's SMM **464** via the MN/LSF interface. The SMM has several functions it must perform, such as, for example, it must allocate a Care Of Address (COA, discussed further below with respect to MN Addresses), maintain local information pertaining to the MN, and the like.

The SMM **464** will use the LSF/NSF Interface, such as the LSF/NSF interface **1406** (FIG. **14**), which is based on the AAA protocol, to authenticate and register the user **114** with its home NSF **104**. The home NSF **104** uses information in the Registration message to update the user's location in the UDS **460**.

The LSF **106** supports the ability to restrict user **114** access within certain IP subnets. With the advent of global deployment of networks, there may be reasons for restricting users (or particular network domains) from accessing certain IP administrative domains. The ability to restrict user **114** access within certain IP subnets is a user authorization function that is configured and enforced at the LSFs by policy.

Finally, the LSF SMM **464** supports mobility between serving LSFs **106** via an LSF/LSF Interface. One of the functions the SMM **464** insures is that there is no loss of data during a transition (i.e., a handoff). LSFs **106** may also chare

the same security associations between the MN and the LSF (e.g., SA3 and SA5 as depicted in FIG. 8).

2.2.4.4 Registration Establishes A Packet Data Session

The term "architecture" as used herein supports the concept of a user **114** establishing a packet data session (i.e., an IP packet data session) with multiple home networks (NSFs **104**) from the user's current device, which is the same concept as found in GPRS and IMT2000. However, since each home network is a unique network, the user **114** will need to send a unique and separate registration request to each network, and each request will contain a unique NAI associated with the network to which the user desires to establish the packet data session.

In accordance with the IPM Architecture of the present invention, a packet data session is preferably established when an MN **112** sends a Registration Request. The Registration Request may be sent in two scenarios: first, when the user initially powers on the MN and, second, when a user wants to establish another packet data session with another home network (service provider, e.g., a second or third home network).

The user **114** may have one provider for access (e.g. ATT, AOL, or the like). This necessitates that the user have two "subscriptions," one to use (and be authenticated on) the access system, and another to use (and be authenticated on) the data services.

In accordance with the architecture of the present invention, it is not necessary for a user **114** to have a subscription with an access provider if the access provider is not providing the user's services. The actual service provider (i.e., the user's home network) only needs to perform the user's authentication, because the access provider (e.g., an LSF and/or an NSF) will preferably have established an SLA with the user's home NSF **104**, which provides the necessary trust relationship between the networks. If a user is not paying his bills, the home NSF is responsible for refusing access for the user.

2.2.4.5 De-Registration of a Packet Data Session

Occasionally, a user will need to explicitly terminate a packet data session. This may be achieved conventionally by hanging up a phone to a dial-up ISP, or by terminating a wireless data call. It may not always be so simple in future networks. For example, where a user has multiple packet data sessions, he/she may want to terminate only one of them. Also, there may be some shared fixed device that several users may use. For example, a first user may "slide" a User Identity Module (SIM) card in the device and "perform" his data session to some ISP. When that user is done, the packet data session is terminated so another user may use the device. The IPM Architecture of the present invention supports de-registration by sending a Registration Request with an indication that the user wants to terminate his/her packet data session.

2.2.4.6 Mobile Node Addresses

To route datagrams to a roaming user's MN **112**, an IP address must be allocated to the MN **112** that the user is currently using to send and receive datagrams. This address is stored in the home DDNS server **456** where it is available to anyone, such as a correspondent node (CN) that wishes to establish an application session with the user **114**.

There are at least two alternative methods for assigning an IP address to an MN **112**, henceforth referred to as the MN's allocated IP address. First, the MN's allocated IP address may be assigned when the MN is configured, wherein the allocated IP address is permanent and the MN always has the same IP address. Second, if the MN does not have a configured IP address, an IP address may be dynamically allocated (i.e., auto-configuration is executed) to the MN when the MN accesses an LSF **106** for the first time. In this scenario there are two options for dynamically allocating the IP address: (1) allocation by the visited LSF, and (2) allocation by the user's home NSF. In accordance with the present invention, it is preferable that IP address be assigned by the user's home NSF so that the IP address is topologically associated with the user's home NSF.

When a CN (anywhere on the Internet) wants to establish an application session with a roaming user, the CN will acquire the user's allocated IP address via a DDNS request to the user's home NSF. Since the allocated IP address is associated with the user's home NSF, the Internet will route the data to the home NSF. For the home NSF to send the datagrams to the user, the serving LSF allocates an IP address, called a care-of address (COA), which may be used to tunnel datagrams from the user's home NSF to the LSF router associated with the COA. The LSF router de-tunnels the packet and forwards it to the user. This creates the infamous "triangle routing," which is not an optimal path for data to transverse.

To help alleviate "triangle routing," the user's MN COA is given to the CN. In accordance with the present invention, there are at least two scenarios for giving the user's MN COA to the CN. First, when the home NSF receives data destined for a roaming user, the home NSF sends a message to the CN to update the CN with the user's COA. The NSF supports a policy that indicates that the NSF should hide or not hide the MN user's network location from the CN. If the policy is set for "do not hide," the NSF will send the COA to the CN; otherwise, the NSF will not send the MN's COA to the CN.

Second, the CN is given the COA in a DDNS response when the CN application requested the user's allocated IP address. This mechanism provides a more expeditious session setup between the CN and the MN user, and alleviates triangle routing. A policy at the NSF may dictate the need for sending the COA to the CN. However, prior to selecting this second option, there are number of issues that should be considered, which issues are exactly the same issues as discussed above with respect to Network Route Addressing for the case where the LSF allocates the MN's IP address.

With the addressing foundation established, the techniques will be applied to the five address allocation scenarios described above with respect to Network Route Addressing.

First, the device (e.g., MN **112**) owned by the user **114** has a permanent IP address associated with his home network NSF. The MN will use the permanent IP address to terminate MN datagrams. And the LSF's COA is used to tunnel datagrams to the LSF.

Second, the device the user is about to use is not his/her device and the device has a permanent IP address that is associated with the current point of attachment (associated with the visited LSF). The NSF will then allocate an IP address for the MN to be used by the MN to terminate datagrams, and the LSF COA is used to tunnel datagrams to the LSF.

Third, the device the user is about to use is not his/her device and the device has a permanent IP address that is not associated with his/her home network or the current point of attachment (associated with the visited LSF). The NSF will allocate an IP address for the MN to be used by the MN to terminate datagrams and the LSF COA is used to tunnel datagrams to the LSF.

Fourth, the device owned by the user does not have a permanent IP address, hence, when the user roams with this device, the network will dynamically allocate an IP address. The NSF will allocate an IP address for the MN to be used by the MN to terminate datagrams and the LSF COA is used to tunnel datagrams to the LSF.

Fifth, the device the user is about to use is not his/her device, and the device does not have a permanent IP address, hence, when the user roams with this device, the network will dynamically allocate an IP address. The NSF will allocate an IP address for the MN to be used by the MN to terminate datagrams, and the LSF COA is used to tunnel datagrams to the LSF.

In each of the above address allocation scenarios, if the user's home network is a private network that supports non-routable IP addresses, the LSF must allocate a co-located COA (as defined in RFC 2002) for the MN. This allows the home network to tunnel datagrams directly to the MN instead of tunneling datagrams to the LSF. Allocating a co-located COA to the MN is necessary since there may be another user who is roaming in the same network that has an MN with the same allocated IP address from a network that supports routable IP addresses. Allocating a co-located COA to the MN eliminates two MNs having the same IP address.

2.2.4.7 Updating Correspondent Nodes with COA'S

To alleviate triangle routing at the user's home network, the COA that represents the MN's current point of attachment is sent to the CN. When the home NSF receives data destined for a roaming user, the home NSF sends a message to the CN to update the CN with the user's COA. Alternatively, when an MN re-registers, the registration will include a CN IP address for each application with which the user is currently in session. In an alternative to the home NSF updating the CN, if the MN is given the COA (during registration), it may send the COA update directly to the CNs. However, this latter method may require increased airwave bandwidth.

When the CN receives the COA update, the CN must update its routing table to trigger the appropriate tunneling.

For the CN to insure that the COA it receives is valid, the user's NSF (or MN) should have a security association (SA) established with the CN or the CN's network to insure the validity of the COA updates.

The list of CNs included in the registration message may be prioritized based on some criteria, e.g., application Quality of Service (QoS).

2.2.4.8 IP Router Configurations

There are a number of IP router configurations that may be supported by an LSF of the present invention, several of which configurations are described in greater detail below. Router configurations should preferably support a single COA tunnel point into the LSF, i.e., a single router at the "top" of a hierarchy that provides the COA and tunneling. This minimizes the updating of a COA to a user's home network and the CNs the user is in correspondence with.

2.2.4.8.1 Single IP Router in LSF

Since a CN and/or home NSF requires a COA to deliver datagrams to a roaming user, it is preferable to have an LSF assign a single COA to a MN as a user roams within the LSF. In accordance with the present invention, and as depicted in FIG. **17**, this is achieved by configuring a single router **1702** in an LSF **106** that has a COA **1704** for all MNs **112** roaming in an LSF **106** between, for example, two routers **1706**A and **1706**B which interface via Radio Access Networks (RANs) with the MN **112**. It is noted that all routers shown in FIGS. **17-19** may include the ANI and/or the ITS functions.

2.2.4.8.2 Multiple IP Routers in the LSF

In some LSFs, it may be necessary to equip an LSF with more than one router to, for example, increase router capacity. As exemplified in FIG. **18**, each xAN **110**A and **110**B preferably has a router **1706**A and **1706**B, respectively, that is considered to be at the edge of the xAN **110** and LSF **106**.

In the configuration exemplified in FIG. **18**, the LSF **106** supports two COAs **1704**A and **1704**B, one for each router **1702**A and **1702**B, respectively, for serving the xAN **110**A and xAN **110**B, respectively. It should be noted with respect to the configuration shown that the CN **116** and/or home NSF **104** must be updated with the respective MN's new COA **1704**A and **1704**B when the MN **112** moves between xANs **110**A and **110**B attached to different routers **1706**A and **1706**B.

2.2.4.8.3 Hierarchical Mobility Router

To alleviate the burden of supporting more than one COA at an LSF, the LSF may support a hierarchical router configuration. FIG. **19** exemplifies such an hierarchical router configuration, wherein the MNs **112** may all be associated with a single COA **1704**, which is the COA of a single router **1902** connected to the two routers **1702**A and **1702**B in the LSF **106**.

2.2.4.9 Implementation Scenarios

The IPM Architecture framework of the present invention provides flexibility in deploying an SMM **464** within an LSF **106**. When deploying SMMs, however, there are a number of issues to consider. For example, in general, an ITS function may be implemented in the router since it on the data plane. An ANI/SMM may be deployed in the router or in different computing machines depending on the size and capacity of the LSF. An SMM **464** may be deployed on a standalone server, without other IPM components. The SMM **464** may also be deployed on a server, with other IPM components, such as the AAA function **462**. The SMM **464** may also be deployed on a router. Additionally, there may be more than one SMM **464** in an LSF **106**.

The choice of deployment turns on the type of IP router configuration being used and the LSF performance desired. For example, in a single IP router configured in an LSF, such as depicted in FIG. **17**, it may be preferable for the SMM **464** to be positioned on the router **1702**, instead of on a standalone server. This type of deployment looks similar to the IWF/PDSN data model in 2^{nd} and 2.5^{nd} generation cellular system. As the network grows and there is a need for more routers at the xAN/LSF interface, this could evolve into the Hierarchical Mobility Router configuration depicted in FIG. **19**.

The xAN and LSF may be configured such that there are multiple routers at the LSF and xAN, and the SMM **464** is on a server in the LSF **106**, as depicted in FIGS. **18** and **19**. A service provider may desire to assign a unique COA to each of these routers, as in FIG. **18** relating to multiple IP routers in an LSF. The MN is informed of which COA to use via the xAN/LSF interface. This information is then relayed to the SMM through a Registration Request message between the MN and the SMM. This scenario also allows the service provider to balance the IP datagram load across these routers, e.g., they may assign different routing areas to each router (if the xAN supports this functionality).

2.2.4.10 Mobile Node Components

To support seamless roaming between heterogeneous networks, the MN **112** must support an architecture that is

different from architectures conventionally used in diverse data technologies. FIG. **20** provides an overview of components needed by the MN **112** to support seamless roaming. As discussed further below, the components include Layer 2 access cards **2002**, a Layer 2 access arbitrator **2004**, and a registration control **2006**. Components needed by the MN **112** to support seamless roaming of the type described herein are still more fully disclosed and discussed in co-pending U.S. patent application Ser. NO. 09/631,251, entitled "Method and System for Switching Between Two Network Access Technologies Without Interrupting Interactive Network Applications", filed on behalf of Donald Wurch et al, on Aug. 2, 2000 which is hereby incorporated in its entirety by reference.

2.2.4.10.1 Layer 2 Access Cards

Each Layer 2 (L2) access card **2002** supports a specific wireless access protocol, e.g., L2 access card **1** may support CDMA+, L2 access card **2** may support TDMA+, and L2 access card N may be an Ethernet card. The "+" sign appended to CDMA and TDMA indicates that those wireless access protocols need to develop further to work in the IPM Architecture.

The wireless access cards **2002** perform functions similar to those performed in 2G and 3G systems. For example, the wireless access cards **2002** may be used to monitor the Broadcast Channel (BCCH) associated with its access protocol. The wireless access cards **2002** may also be used in handoffs with a Radio Access Network (RAN), discussed further below.

The wireless access cards **2002** may also perform Layer 2 access requests, similar to a conventional registration, but the cards **2002** are not user-oriented and does not go beyond the access network (xAN **110**). Layer 2 access informs the access network that the MN **112** is on its system. In a channelized RAN this would, logically, put the MN **112** in a standby/dormant mode.

In accordance with the present invention, the L2 access cards **2002** may also pass information to the Layer 2 Arbitrator **2004** via a standardized interface. This information may be LSF system information obtained in the BCCH and/or information generated by the Layer 2 access card, e.g., Received Signal Strength Indication (RSSI) values.

2.2.4.10.2 Layer 2 Arbitrator and Registration Control

There are a number of functions performed by the Layer 2 (L2) Arbitrator **2004**. For example, the L2 Arbitrator **2004** may be used to obtain information from each L2 Access Card **2002** that will allow the Arbitrator to determine which access is the best. When the L2 Arbitrator **2004** selects a new L2 Access Card **2002**, the Arbitrator may be used to update a routing table with the appropriate L2 interface driver. The L2 Arbitrator **2004** may be used to coordinate L2 Access Card **2002** changes with the Registration Control Object **2006**. The L2 Arbitrator **2004** may also be used to obtain information from current L2 access, and to inform the Registration Control Object **2006** that it is still on the same subnet point-of-attachment (i.e., it basically generates an agent advertisement or its equivalent).

Use of the L2 Arbitrator **2004** is exemplified as follows. The L2 Arbitrator **2004** receives information from each of the L2 Access Cards **2002** through a standardized API. With the information, the Arbitrator **2004** decides which access is best. When the Arbitrator **2004** decides that a new Access Card **2002** should be used, the Arbitrator **2004** informs the Registration Control Object **2006** so it may perform the appropriate functions, e.g., send the old LSF **106** a Registration that indicates movement. After the Registration Control Object **2006** performs its functions, the Arbitrator **2004** updates the routing table with the new L2 access driver. The Arbitrator **2004** will next receive information from the new Access Card **2002** indicating the current point of attachment which it would pass on to the Registration Control Object **2006**.

2.2.4.11 Any(X) Access Networks

The any(x) Access Network (xAN), also referred to herein as xAN **110**, is configured for providing Layer 2 access for devices used by MN users. From a mobility perspective, the functions of the xAN include providing LSF system access parameters to the M via a BCCH, e.g., SMM IP address, an LSF NAI, and the like. Further functions of the xAN include micro mobility (i.e., MN handoffs within the xAN). Still further functions of the xAN include providing the LSF with a handoff indication when the MN is handed off to a different system (e.g., a different LSF or xAN).

The IPM architecture framework of the present invention supports traditional channelized xANs, e.g., RAN, TDMA and CDMA, where a dedicated radio resource is used to generate BCCH messages. The MN's Layer 2 Access Card relays the information that is provided in the BCCH to help other components in the MN provide user mobility.

It is anticipated that future xANs will not be channelized. They will be designed to be a broadband access medium similar to 802.11 wireless LANs. It is also expected that there will still be some type of BCCH, similar to the 802.11 beacon which may be used to facilitate handoffs between xANs. Such developments are supported by the IPM architecture framework of the present invention.

It should be noted that Ethernet Layer 2 is a broadband access medium that does not have a BCCH. Since the Ethernet Layer 2 architecture is based on Mobile IP (MIP), MNs attached to an Ethernet access use an agent advertisement to acquire system information. This provides an alternative to the future broadband (non-channelized) xANs. It is not necessary that they have system information in their BCCHs. They can rely on agent advertisements (or whatever agent advertisements may evolve to).

The following specifies a preferred messaging interface between the xAN, also referred to herein as the xAN **110**, and the LSF **106** components as defined above with respect to the IPM Architecture Framework of the present invention.

2.2.4.11.1 IP Mobility Messages

IPM Messages consist of existing Mobile IP (MIP) messages, as defined in RFC 2002, MIP messages with changes, and completely new messages. In addition, the IPM Architecture of the present invention makes use of existing MIP extension(s) and defines new extensions. All of the extensions may be used with any IPM message. IPM messages uses the same port (number **434**) as Mobile IP. IPM Messages are built to insure interoperability and compatibility with existing implementations of MIP.

MIP-based IPM messages are relevant to the xAN-LSF interface include, for example, Registration Request messages, Registration Reply messages, Prepare for System Change messages, and System Change messages.

New IPM messages that are relevant to the xAN-LSF interface include, for example, Activate Packet Service messages, Activate Packet Service Ack messages, Add L2 IP Association messages, Buffer Data messages, Buffer Data Ack messages, Cleanup messages, Cleanup Ack messages, Correspondent Node List messages, Correspondent Node List Ack messages, Forward Data messages, Forward Data Ack messages, Handoff Required messages, and Handoff Required Ack messages.

FIGS. **14**A and **14**B depict an interface between a xAN **110** and a LSF **106** embodying features of the present invention. Accordingly, in step **1420**, a MN **112** of a user **114** initiates a L2 session to a xAN **110**. In step **1422**, the xAN **110** terminates the L2 session that was initiated by the MN **112**. In step **1424**, the xAN **110** sends a notification of L2 termination to the MN **112**. In step **1426**, the MN **112** receives the notification of termination of L2 session from the xAN **110**. In step **1428**, the MN **112** initiates an IPM L3 session with the LSF **106**. In step **1430**, the LSF **106** establishes an IPM L3 session and sends IPM messages to NSF **104**. In step **1431**, the NSF **104** receives IPM messages from the LSF **106**. In step **1432**, the NSF **104** sends IPM response messages to MN **112** via LSF **106**. In step **1434**, LSF **106** receives IPM messages from NSF that are destined for the MN **112**.

In step **1436**, the LSF **106** initiates resource management request to xAN **110**. This resource management task includes a function for mapping between L2 and L3, a function for allocating routing resources for buffering and forwarding data packets, a function for initiating a inter-LSF or intra-LSF handoff of data sessions and a function for reclaiming any unused routing resources. These functions are described in further detail below.

In step **1438**, the xAN **110** receives a resource management request from LSF **106**. In step **1440**, the xAN **110** manage its resources as requested by the LSF **106**. In step **1442**, the xAN **110** notifies the LSF **106** that it has completed the task of resource management. In step **1444**, the LSF **106** receives a notification that the xAN **110** has managed the resources requested by LSF **106**. In step **1446**, the LSF **106** sends the IPM messages to the MN **112**. In step **1448**, the MN **112** receives the IPM messages from the LSF **106**.

FIG. **20**A shows origination and destination points of the IPM messages. As shown, the MN **112** originates a message exchange by sending to the LSF **106** at least one of a Registration Request message, a Prepare for System Change message, a System Change message, and a Correspondent Node List. In response, the LSF **106** may send one of a Registration Reply message, and a Correspondent Node List Ack message.

The LSF **106** may also send to the xAN, **110** at least one of an Add L2 IP Association message, an Activate Packet Service message, a Buffer Data message, a Forward Data message, and a Cleanup message. In response to a message from the LSF **106**, the xAN **110** may send a suitable one of an Activate Packet Service message, a Buffer Data Ack message, a Forward Data Ack message, and a Cleanup Ack message.

The xAN **110** may also send a Handoff Required message to the LSF **106**, in response to which the LSF may respond with a Handoff Required Ack message.

FIG. **20**B shows a general format for an IPM message **20**B**02**. As discussed further below, the message **20**B**02** includes an IP Header field **20**B**04**, a UDP field **20**B**06**, a message field **20**B**08** for carrying an existing MIP message or a new IPM message, and an IPM extension(s) field **20**B**08**.

As discussed in further detail below, the IPM extension(s) field **20**B**08** may comprise a base MIP extension such as an NAI extension, or may comprise a new IPM extension in accordance with the present invention, such as an Authentication extension, a Call Information extension, a CN List extension, a LSF NAI extension, a Routing Area extension, an MN Layer 2 extension, or a Terminal Information extension.

FIG. **20**C shows a preferred general format for general MIP extensions, such as described below with respect to FIGS. **20**D–**20**K. The MIP extension depicted by FIG. **20**C comprises a type field, a length field, and a data field. The type field defines the extension type. The length field represents the length of data in bytes, which may range from 0 to 255 bytes. The data field contains the data of the extension.

FIG. **20**D shows the message format of an Authentication Information Extension, which is used to pass a user's Digital Signature.

FIG. **20**E shows the message format of a Call Information Extension, which is used to pass a user's call related information.

FIG. **20**F shows the message format of a CN List Extension, which is used to distribute Correspondent Nodes associated with the MN.

FIG. **20**G shows the message format of an LSF NAI Extension, which is used during handoff scenarios.

FIG. **20**H shows the message format of an MN's L2 address extension, which identifies the inherent Layer 2 (L2) address, such as IMSI, MAC, and the like, of the mobile device's technology. The L2 Address is required to identify an MN that does not have any IP address assigned to it. It is expected that in such cases the xAN would keep a mapping between the L2 and IP addresses of the MN.

FIG. **20**I shows the NAI extension, which identifies the user and home domain of the user. It is of type user@realm as defined in RFC 2486.

FIG. **20**J shows an IPM Routing Area Extension, which identifies the Routing Area (RA) that the MN is being served in. The format of a routing area is an NAI as defined in RFC 2486.

FIG. **20**K shows a Terminal Information Extension, which is used to identify terminal (e.g., the MN **112**) capabilities, such as whether the terminal is SIP capable, H.323 capable, and the like).

FIG. **20**L shows the message format of a Registration Request message, which is based upon the MIP message as specified in RFC 2002. Notably, the Registration Request message includes a number of mandatory IPM extensions, such as NAI extensions, an Authentication extension, a Routing Area extension, and an MN Layer 2 extension. The Registration Request message may optionally also include a Terminal Information extension.

FIG. **20**M shows the message format for a Registration Reply message, which is based upon the MIP message as specified in RFC 2002. Notably, the Registration Request Reply message includes at least two mandatory IPM extensions, including NAI extensions and an MN Layer 2 extension.

FIG. **20**N shows the message format for a Prepare for System Change message, which is based on the MIP Registration Request message as specified in RFC 2002. Notably, the Prepare for System Change message includes a number of mandatory IPM extensions, such as NAI extensions, a Routing Area extension, and an LSF NAI extension. The Prepare for System Change message may optionally also include an Authentication extension and a Terminal Information extension.

FIG. **20**O shows the message format for a System Change message, which is based on the MIP Registration Request message as specified in RFC 2002. Notably, the System Change message includes a number of mandatory IPM extensions, such as NAI extensions, a Routing Area extension, and an LSF NAI extension, an Authentication exten-

sion, and an MN Layer 2 extension. The System Change message may optionally also include a Terminal Information extension.

FIG. **20**P shows a preferred general format for IPM messages, such as described below with resect to FIGS. **20**Q–**20**AC. The IPM message depicted by FIG. **20**P comprises a type field, a length field, and a data field. The type field defines the extension type. The length field represents the length of data in bytes, which may range from 0 to 255 bytes. The data field contains the data of the extension.

FIG. **20**Q shows the message format for an Activate Packet Service message, which is used to prepare the target xAN for allocating resources. Notably, the Activate Packet Service message includes at least two mandatory IPM extensions, including a Call Information extension and an MN Layer 2 extension.

FIG. **20**R shows the message format for an Activate Packet Service Ack message, which is a reply to Activate Packet Service message. Notably, the Activate Packet Service Ack message includes at least one mandatory IPM extensions, namely, an MN Layer 2 extension.

FIG. **20**S shows a message format for an Add L2 IP Association message, which is used to notify the xAN of the User's IP Address and the MN's Layer 2 address. It is sent to the edge router at the xAN (as indicated by the RA). Notably, the Add L2 IP Association message includes at least two mandatory IPM extensions, including NAI extensions and an MN Layer 2 extension.

FIG. **20**T shows the format for a Buffer Data message, which is used to request that the xAN buffer data that is destined to a particular user.

FIG. **20**U shows the format for a Buffer Data Ack message, which is used reply to Buffer Data message. Notably, the Result Code may be set either to one to indicate that a buffer is not allocated, or to zero to indicate that the buffer is allocated to buffer data packets during handoffs.

FIG. **20**V shows the format for a Cleanup message, which is sent to the xAN at de-registration for freeing up resources.

FIG. **20**W shows the format for a Cleanup Ack, which is sent in reply to the Cleanup message.

FIG. **20**X shows the format for a Correspondent Node List message, which contains a list of CNs that are contemporaneously in session with the user. Notably, the Correspondent Node List message includes at least two mandatory IPM extensions, including NAI extensions and a CN List extension.

FIG. **20**Y shows the format for a Correspondent Node List Ack message, which is sent in reply to a Correspondent Node List message.

FIG. **20**Z shows the format for a Forward Data message, which is used to start forwarding buffered data from an old (previous) LSF to a new COA.

FIG. **20**AA shows the format for a Forward Data Ack, which is sent in reply to a Forward Data message.

FIG. **20**AB shows the format for a Handoff Required message, which is used to notify an old (previous) LSF about handoff requirement. Notably, the Handoff Required message includes at least one mandatory IPM extension, namely, an MN Layer 2 extension.

FIG. **20**AC shows the format for a Handoff Required Ack, which is sent in reply to a Handoff message. Notably, the Handoff Required Ack message includes at least one mandatory IPM extension, namely, an MN Layer 2 extension.

2.2.4.11.2 QOS and Policy Enforcement

The local directory server (LDS) **430** and database **431** at the LSF **106** is the repository for mobile user's home policy rules.

The QoS and Policy Server **412** that have an LDAP interface can retrieve an MN user's home policy rules from the LDS **430** and database **431**. The enforcement of these policies is part of xAN implementation.

One way of implementing an LDAP client-server interface is specified in RFC 1823 and in "Unified Directory Service MLD Phase II" by Mark O'Brien of Nortel Networks.

2.2.4.11.3 Simple IP Support

A driving factor for Simple IP (i.e., wireline IP) is the requirement that MNs that do not support MIP may be able to access LSFs and the IP network for Internet service and/or for private network service.

Application nodes, i.e., CNs without MIP, accessing the serving system in the Simple IP mode are assigned addresses dynamically by an LSF **106**, which plays the role of an access manager.

The xAN/LSF interface as defined below retains IPM messaging between the xAN and LSF and encapsulates Access Request/Reject/Accept messaging.

IPM includes at least two new extensions to be defined for Simple IP, namely, an Access Request extension and an Access Accept/Reject extension, discussed further below with respect to FIGS. **20**AD and **20**AE.

FIG. **20**AD shows the format for an Access Request extension for encapsulating Access Request messages as specified in RFC 2138.

FIG. **20**AE shows the format for an Access Accept/Reject extension for encapsulating an Access Accept/Reject message as specified in RFC 2138.

IPM also defines two new message types for Simple IP. One is a new type for IPM registration message and the second is a new type of registration reply, as discussed further below with respect to FIGS. **20**AF and **20**AG.

FIG. **20**AF shows the format for a Simple IPM Registration Request message, which is based upon the MIP message as specified in RFC 2002. Notably, the Simple IPM Registration Request message includes a number of mandatory IPM extensions, such as NAI extensions, a Routing Area extension, a CN (without MIP) Layer 2 extension, and an Access Request extension. The Simple IPM Registration Request message may optionally also include an Authentication extension and a Terminal Information extension.

FIG. **20**AG shows the format for a Simple IP Registration Reply message, which is based upon the MIP message as specified in RFC 2002. Notably, the Simple IPM Registration Request message includes a number of mandatory IPM extensions, such as NAI extensions, an MN Layer 2 extension, and an Access Accept/Reject extension.

3. Interfaces Between Framework Modules

There are a number of different scenarios by which the components of the IPM architecture framework of the present invention may interface with each other and by which messages may flow between components. These scenarios are enumerated as follows:

1. MN and xAN
2. MN and LSF
3. xAN and the LSF
4. Mobility manager functions between the LSF and NSF
5. Mobility manager functions between LSFs
6. Mobility manager function and DDNS
7. Mobility manager function and DHCP

8. Mobility manager function and policy server
9. AAA function and the mobility manager servers
10. AAA function and the Authentication servers
11. AAA function and the policy server
12. AAA function and the accounting function
13. Accounting functions and billing systems
14. DDNS and DHCS
15. NSF and MNs
16. Directory Service Interface
17. Security messaging gateways and policy servers

This document has described, to varying levels of detail, the functionality of each of these interfaces. The remainder of this chapter will provide a consolidated list of interface requirements for several of the items on the above list and a set of message flows for registration, routing area update, and inter system handoff scenarios.

The interface requirements and message flows depict how user mobility is achieved in the "final" vision of the architecture, where the basic fundamental requirements are:

- All service providers will provide data services for their users. Therefore, it is not necessary for the user to have a subscription with a specific wireless network provider just to gain access to the wireless networks.
- A user's home network must create SLAs with all networks, LSFs and Service Brokers, it wants it users to roam in.
- IPSec AH and/or ESP are used for all security associations
- The AAA protocol is used for all LSF to LSF and LSF to NSF mobility functions.
- For private network access, all tunneling is layer 3 tunneling (IP tunneling). There will be no layer 2 tunneling, e.g., L2TP.
- There is no triangle routing unless there is a NSF "hide the user" policy. Therefore, an LSF will maintain COAs for its network.

3.1 Roaming Message Flows

In operation, the present invention is adaptable to message flows for a number of different mobility scenarios, which scenarios may be categorized into at least three groups. A first group includes user registrations. A second group includes users roaming to new routing areas where there are no applications running (i.e., where no data is being transferred). A third group includes users roaming to new routing areas where there are applications running (e.g., handoffs).

The message flows for each scenario makes a number of different assumptions. For example, it is assumed that there is at least one router at the edge of an xAN/LSF interface, and that an IP router is considered to be part of the xAN.

It is further assumed that all messages sent between system components include fields (i.e., parameters). However, the number of fields that may be included in a message are not limited by the fields described herein, and there may be a greater number of fields.

It is still further assumed that an AAA function located in an LSF has full functionality, i.e., it has knowledge of SLAs in place between itself and the NSFs, and it provides a mechanism for determining where a user's home AAA function is. It is also assumed that SAs have all been pre-established.

It is still further assumed that the xAN's BCCHs are broadcasting the IP address of an SMM, unless otherwise indicated.

It is still further assumed that xANs are channelized xANs, such as TDMA, unless otherwise indicated.

It is still further assumed that, in handoff scenarios for channelized xANs, the xAN is responsible for buffering datagrams that are destined for the MN. In unchannelized xANs, the router at the xAN/LSF will be responsible for buffering.

3.1.1 Initial Registration, MN Configured with a Routable IP Address

FIG. **21** is a message flow event sequence diagram which represents a user MN **112** establishing a packet data session (i.e., logging in) with his/her home network **104**. The MN **112** is configured with a permanent IP address that is associated with the user's home network **104**. The home network **104** is configured with routable IP addresses.

The message flow sequence shown in FIG. **21** is applicable to at least two scenarios: first, when the MN **112** is initially powered-on and, second, when a user **114** wants to connect the MN **112** to another service provider, e.g., a second or third service provider.

The concept of "always on, always ready to receive/send data" is used herein to refer to an MN **112** configured to establish a connection with its home network service provider **104** when the MN **112** is powered-on.

When the user wants to connect to another service provider, e.g., a second or third service provider, the user will initiate the connection by accessing a user interface (not shown), by pushing a pre-configured button (not shown) on the MN **112**, or the like, to thereby cause the MN **112** to send a Registration Request to the user's home network **104**. Completion of the registration process results in a packet data session being established between the user, via the LSF **106**, and the user's home NSF **104**.

Referring to FIG. **21**, in an event **2102**, after the user **114** powers-on the MN **112** (or initiates another service provider connection request), the MN **112** sends a Registration message to the xAN **110** of the user's home network **104**. The Registration message is sent to the IP address (i.e., the IP address of the SMM **464**B) that was contained in the BCCH. The Registration message includes a number of parameters (i.e., fields) **2102***a*–**2102***g*. An NAI **2102***a* indicates the user who wants to establish the data session. An IP Addr parameter **2102***b* is the configured permanent IP address of the MN **112**, if the MN has a configured IP address. An Auth parameter **2102***c* is the user's authentication parameter, i.e., the user's digital signature. A Profile Type parameter **2102***d* indicates the profile that the user wants to use. The profile may indicate the type of services the user has, the type of access into the network, and the like. A Terminal Info parameter **2102***e* contains information about capabilities of the terminal, such as whether support is provided for L2 addresses, SIP, H.323, and the like. A RegType parameter **2102***f* indicates the type of registration being performed. An RA parameter indicates the name (NAI) of the current subnet point of attachment.

In event **2104**, the SMM **464**B creates an AAA Authentication Request, comprising the NAI parameter **2102***a* and Auth parameter **2102***c*, and forwards the Authentication Request to the LSF **106** local AAA function **462**.

In event **2106**, the local AAA function **462** uses the domain portion of the user's NAI to determine the home NSF **104** of the user **114**. A lookup is performed to determine the IP address of the user's home AAA function **450** and the type of security association (SA) established between the LSF **106** and the NSF **104**. IPSec authentication (AH) is preferably used for security. The local AAA function **462** will then send the Authentication Request to the user's home

AAA function **450**. Before the packet is sent, an IPSec authentication (AH) is preferably performed on the message.

In event **2108**, the user's home AAA function **450** receives the Authentication Request. The AAA function will first validate the IPSec AH, and then perform a lookup to determine which server it should forward the message to. The user's home AAA function **450** then forwards the Authentication Request to the authentication server **450***b*.

In event **2110**, the authentication server **450***b* authenticates the user **114**. The authentication server **450***b* may perform a number of functions, all depending on the type of authentication. Digital signatures are preferably used, so that the authentication server **450***b* would have received the user's digital signature. In the present case, the authentication server **450***b* would acquire the user's public key in a directory, which it would use to authenticate the user. In this case, the user **114** has been authenticated. The authentication server **450***b* then generates an Authentication Response message that includes the user's NAI and a Flag **2110***a* that indicates the authentication passed. The authentication server **450***b* then sends the Authentication Response to its home AAA function **462**.

NOTE: It may be possible for the authentication server **450***b* to send information to the LSF **106** that will permit the LSF **106** to authenticate the user **114** while the user roams in the LSF. However, the LSF **106** must be able to support the authentication mechanism required by the user **114**.

In event **2112**, the home AAA function **462** will generate an IPSec AH and send the IPSec AH to the local AAA function **462** serving the user **114**.

In event **2114**, the local AAA function **462** validates the IPSec AH and passes it to the SMM **464**B. The events **2104**–**2114** constitute the Authentication Procedure of FIG. **21**.

In event **2116**, the SMM **464**B establishes a packet data session with the user's home NSF **104**. This is achieved by sending the home NSF **104** a registration request. At least two parameters **2116***a* and **2116***b*, not included in the Registration Request of the event **2102**, are added to the Request. First, an LSF Info parameter **2116***a* is added which will contain information about the LSF **106** and user mobility. Second, a COA parameter **2116***b* is added which includes an IP address that is used by the home NSF **104** router and correspondent nodes to tunnel datagrams to the MN **112** and LSF **106**. The LSF Info parameter **2116***a* also includes an indication of the type of COA, i.e., whether the COA is a router COA or an MN co-located COA.

In event **2118**, the local AAA function **462** uses the domain portion of the user's NAI to determine the home system **106** of the user **114**. A lookup is performed to determine the IP address of the user's home AAA function **462** and the type of security association (SA) established between the LSF **106** and NSF **104**. The local AAA function **462** will then send the Registration Request message to the user's home AAA function **450**. Before the Registration Request message is sent, an IPSec authentication (AH) is preferably performed on the message.

In event **2120**, the user's home AAA function **450** receives the Registration Request message. The AAA function **450** first validates the IPSec AH, and then performs a lookup function to determine which server the message should be forwarded to. Since the message is a Registration Request, the home AAA function **450** forwards the message to the HMM **452**B.

In event **2122**, the HMM **452**B performs at least three functions. First, the HMM **452**B updates the local directory with the LSF **106** and mobility info. Second, the HMM **452**B sends a route update message to the local router so that it can update the MN's IP address and COA. Third, the HMM **452**B creates a Registration Reply message that includes the user's NAI and the user's profile. The profile will contain, at a minimum, the maximum bandwidth to be allocated to the user **114**. The HMM **452**B then sends the Registration Reply to its home AAA function **450**.

In event **2124**, the home AAA function **450** will create an IPSec AH message and send it to the local AAA function **462** serving the user **114**.

In event **2126**, the local AAA function **462** validates the IPSec AH message and passes it to the SMM **464**B. The events **2116**–**2126** constitute the Registration Procedure of FIG. **21**.

In event **2128**, the SMM **464**B informs the xAN **110** of the User's NAI, the User's IP address and the MN's layer 2 the address. The xAN **110** uses this information to route information to the MN **112**.

In event **2130**, the SMM **464**B updates its local directory with the appropriate info. It also updates the policy database with the user's maximum bandwidth allowed. The SMM **464**B may create an encryption key to be used by the user's MN **112** for over-the-air encryption. The SMM **464**B sends a Registration Reply to the xAN/LSF **106** router.

In event **2132**, the mobility agent at the xAN/LSF router must update the router's routing table to include the IP address of the MN **112**. The xAN **110** must be informed of the "binding" between the MN's IP Address and the MN's L2 Address. The xAN **110** then sends the registration reply to the MN **112**. In event **2126**, the local AAA function **462** validates the IPSec AH message and passes it to the SMM **464**B. The events **2128**–**2132** constitute the Registration Reply Procedure of FIG. **21**.

3.1.2 Initial Registration, MN Configured with a NON-Routable IP Address

FIG. **22** is an message flow event sequence diagram showing the flow of messages for a user connecting to his/her home network **104**, wherein the MN **112** and the user's home network **104** are configured with non-routable IP addresses. FIG. **22** is similar to FIG. **21** but for the MN **112** being provided with a co-located COA, i.e., an IP address that may be used with nodes on the Internet to tunnel datagrams directly to the MN **112**.

The message flow depicted by FIG. **22** is applicable to at least two scenarios: first, when the MN **112** is initially powered-on and, second, when a user **114** wants to connect to another service provider, such as a second or third service provider.

In event **2202**, the user has powered on the MN **112** (or initiated another service provider connection request). The MN **112** is configured to send a registration message to the user's home network. The registration message is sent to the IP address (which is the IP address of the SMM) that was contained in the BCCH. The parameters are the same as described above with respect to FIG. **21**.

Event **2204** represents an authentication procedure which similar to the authentication procedure described above with respect to events **2104**–**2114** of FIG. **21**, and will therefore not be described in further detail herein.

In event **2206**, the SMM now needs to establish the packet data session with the user's home network **104**. This is achieved by sending the home network **104** a Registration Request. Two additional parameters are added to the registration message, namely, an LSF Info parameter **2206***a* and a COA parameter **2206***b*. The LSF Info parameter **2206***a* includes information about the LSF and user mobility. The

COA parameter **2206***b* contains the IP address that is used by the home network router and correspondent nodes to tunnel datagrams to the MN **112** and LSF **106**. There is an indication of the type of COA (not co-located).

In event **2208**, the local AAA function uses the domain portion of the user's NAI to determine the home system of the user. A lookup is performed to determine the IP address of the user's home AAA function and the type of security association (SA) established between the LSF and NSF. The local AAA function will then send the message to the user's home AAA function. Before the packet is sent, an IPSec authentication (AH) is performed on the message.

In event **2210**, the user's home AAA function receives the message. The AAA function will first validate the IPSec AH. It then performs a lookup to see what server it should forward the message to. Since this is a registration request, it forwards the message to the HMM.

In event **2212**, the HMM **452**B performs at least two functions. First, the HMM **452**B updates the local directory server with the LSF **106** and mobility information. Second, the HMM **452**B realizes that the COA is not an MN co-located COA which is necessary for MN's that are associated with private networks with non-routable IP addresses. The HMM **452**B then creates a Registration Reply message that includes the user's NAI, the user's profile, and an indication that an MN co-located COA must be allocated. The HMM **452**B then sends the registration reply to its home AAA function **450** and a request for a co-located IP address. The HMM **452**B then sends the Registration Reply to its home AAA function **450**.

In event **2214**, the AAA function **450** generates an IPSec AH message and sends it to the local AAA function **462** serving the user **114**.

In event **2216**, the local AAA function **462** validates the IPSec AH and forwards the IPSec AH message to the SMM **464**B.

In event **2218**, the SMM **464**B updates its local directory with the appropriate information. The SMM **464**B also updates the policy database with the user's maximum bandwidth allowed. The SMM **464**B is configured to then allocate a co-located IP address for the MN **112**. A request is made to the DHCP server to allocate the address. The SMM **464**B creates an Address Update Request message with the MN co-located COA to send to the HMM **452**B. The Address Update Request message is then forwarded to the local AAA function **462**.

In event **2220**, the local AAA function **462** uses the domain portion of the user's NAI to determine the home NSF **104** of the user **114**. A lookup is performed to determine the IP address of the user's home AAA function **450** and the type of security association (SA) established between the LSF **106** and the NSF **104**. An IPSec authentication (AH) is then performed on the message. The local AAA function **462** then sends the Address Update Request message to the user's home AAA function **450**.

In event **2222**, the user's home AAA **450** server receives the Address Update Request message. The AAA function **450** will first validate the IPSec AH. It then performs a lookup to see what server it should forward the Address Update Request message to. Since the message is an Address Update Request, it forwards the message to the HMM **452**B.

In event **2224**, the HMM **452**B will perform at least two additional functions. Send a route update message to the local router so it can update the MN's IP address and MN **112** co-located COA. The HMM **452**B then creates an Address Update Response message that includes the user's NAI. The HMM function **452** then sends the Address Update Response message to its home AAA function **450**.

In event **2226**, the home AAA function **450** will create an IPSec AH and send the Address Update Response message to the local AAA function **462** serving the user **114**.

In event **2228**, the local AAA function **462** validates the IPSec AH and passes the message on to the SMM **464**B.

In event **2230**, the SMM **464**B will update its local directory with the appropriate information. The SMM **464**B may create an encryption key to be used by the user's MN **112**. The SMM **464**B will send a Registration Reply to a mobility agent on the xAN **110**/LSF **106** router.

In event **2232**, the mobility agent at the xAN **110**/LSF **106** router updates the router's routing table to include the MN's IP address. The xAN **110** is notified of the "binding" between the MN's IP Address and the MN's L2 Address. The mobility agent then sends the Registration Reply to the MN **112**.

3.1.3 Initial Registration in the Case where the MN does Not Have an IP Address

FIG. **23** is a message flow event sequence diagram showing the flow of messages for a user connecting to his/her home network, wherein the MN and the user's home network are configured with non-routable IP addresses. FIG. **21** is similar to FIG. **23** but for the MN is not configured with an IP address. The home network is, however, configured with routable IP addresses and will allocate a routable IP address to the MN.

This flow also applies to two scenarios: 1) when the MN is initially powered-on and, second, when a user wants to connect to another service provider, such as a second or third service provider.

In event **2302**, the user has powered on the MN (or initiated another service provider connection request). The MN is configured to send a registration message to the user's home network. The registration message is sent to the IP address (which is the IP address of the SMM) that was contained in the BCCH. The parameters are the same as defined in section 3.1.1. NOTE: the MN IP Address should be set to zero (0.0.0.0).

In event **2304**, the authentication procedure is performed. See section 3.1.1 for details.

In event **2306**, the SMM now needs to establish the packet data session with the user's home network. This is achieved by sending the home network a registration request. The registration message contains two additional parameters. First, the LSF Info will contain information about the LSF and user mobility. Second, the COA is the IP address that is used by the home network router and correspondent nodes to tunnel datagrams to the MN/LSF. There is also an indication of the type of COA (not co-located).

In event **2308**, he local AAA function uses the domain portion of the user's NAI to determine the home system of the user. A lookup is performed to determine the IP address of the user's home AAA function and the type of security association (SA) established between the LSF and NSF. The local AAA function will then send the message to the user's home AAA function. Before the packet is sent, an IPSec authentication (AH) is performed on the message.

In event **2310**, the user's home AAA function receives the message. The AAA function will first validate the IPSec AH. It then performs a lookup to see what server it should forward the message to. Since this is a registration request, it forwards the message to the HMM.

In event **2312**, the HMM updates the local directory with the LSF and mobility info. Additionally, since the MN does

not have a permanent IP address, the HMM will also allocate an IP address via DHCP for the MN. The MN IP address is dynamically updated in the home network's DDNS.

Furthermore, the HMM sends a route update message to the local router to update the MN's IP address and COA.

Moreover, the HMM creates a registration reply message that includes the user's NAI, the user's profile, and the newly created MN IP address.

After these functions are completed, the HMM sends the registration reply to its home AAA function.

In event **2314**, the AAA function will create an IPSec AH and send the message to the local AAA function serving the user.

In event **2316**, the local AAA function validates the IPSec AH and passes the message on to the SMM.

In event **2318**, the SMM updates its local directory with the appropriate information. It will also update the policy database with the user's maximum bandwidth allowed. The SMM realizes that the MN does not have an IP address. The SMM will send a registration reply to a mobility agent on the xAN/LSF router. The SMM will include the MN's layer 2 address in the reply. The xAN will use the layer 2 address to send the registration reply.

In event **2320**, the mobility agent at the xAN/LSF router must update the router's routing table to include the MN's IP address. The xAN must be told of the "binding" between the MN's IP Address and the MN's L2 Address. The mobility agent "updates" the datagram's destination address to be a broadcast address sends the registration reply to the xAN software and includes the MN's L2 address so the xAN can route it to the MN. NOTE: If the xAN is an Ethernet access point, the broadcast message will be sent to all MNs on the link.

3.1.4 Initial Registration, Hierarchical Routers

FIG. **24** is a message flow event sequence diagram showing the flow of messages for a user connecting to its home network where the home network is configured with routable IP addresses. FIG. **21** is similar to FIG. **24** but for the hierarchy of routers in the LSF/xAN. Particularly, the xAN has a router at edge of the xAN/LSF interface and there is another router, called the LSF router, which has a COA that is used to tunnel datagrams to.

In event **2402**, the user has powered on the MN (or initiated another service provider connection request). The MN is configured to send a registration message to the user's home network. The registration message is sent to the IP address (which is the IP address of the SMM) that was contained in the BCCH. The parameters are the same as defined in section 3.1.1.

In event **2404**, the authentication procedure is performed. See section 3.1.1 for details.

In event **2406**, the registration procedure is performed. See section 3.1.1 for details. NOTE: The COA sent in the registration message is the COA of the LSF router.

In event **2408**, the SMM will update its local directory with the appropriate information. The SMM will send a registration reply to a mobility agent on the xAN/LSF router.

In event **2410**, the mobility agent at the xAN/LSF router must update the router's routing table to include the MN's IP address. When this occurs, some routing protocol, such as RIP, will update the local network with routing information so datagrams can be delivered to the xAN router, such as when the LSF router will receive a route update and will know how to forward de-tunneled datagrams. The xAN must be told of the "binding" between the MN's IP Address and the MN's L2 Address. The mobility agent then sends the registration reply to the MN.

3.1.5 MN Moves to a New Routing Area, New LSF

When a user roams between LSFs, the user changes subnet points-of-attachments, therefore, the user changes Routing Areas. The LSF requires notification of the RA changes to re-authenticate the user to avoid fraudulent users. In an IP centric network, it is advisable to always have the LSF authenticate the user. Additionally, the user may have access restrictions within the new RA, or a different IP router may need to provide tunneling services, via a new COA, to the MN while it is in the new RA, both of which require notification of the LSF.

In this architecture, before the MN moves to the new LSF, it will send a registration request message to old LSF that indicates the MN is about to move to the new LSF. This triggers the old LSF to start queuing MN datagrams.

FIG. **25** is a message flow event sequence diagram showing the flow of messages for a user roaming between LSFs. This mechanism is used whenever the user is changing RAs.

This type of movement indication would be most beneficial in access networks that do not depend on paging the MN. In other types of access networks, the messaging overhead incurred by sending the LSF an indication of a user/MN moving may not be as beneficial because the number of MN's that will actually receive data during this process should be very small. Moreover, in RANs that are channelized, the LSF is still going to page the MN.

When the registration process is invoked, it may be necessary to perform registration for multiple users, all of who may be registered with their respective ISPs. The preferred method of registration occurs when the MN sends a registration message for each NAI that is in an active packet data session.

Registration may also occur when the MN sends a single registration message that includes all the NAIs and their associated parameters. A single registration message could result in a large message transmitted over the air, prone to transmission errors and, hence, requiring retransmissions of long messages.

Furthermore, the MN can register by sending a single registration message for only one of the NAIs e.g. the one associated with the first active data session. If the LSF has a policy to authenticate users, the LSF will request authentication for the single NAI. This may be a little risky since the authentication mechanism may be a weak authentication, such as a login ID and password, which is more prone to fraud (this is subject to the architecture supporting legacy authentication mechanisms).

Furthermore still, the MN can register by sending a single registration message that does not include any NAIs. The LSF could have a policy that initiates a unique challenge for each NAI associated with the MN (NAIs should be associated with the MN's L2 Addr). If it is assumed that the LSF will always want the MN's NAI authenticated, however, the unique challenge scenario applied to each NAI produces more messaging as compared to first registration procedure described above.

FIG. **35** is a message flow event sequence diagram showing the flow of messages for a MN moving from a first routing area on a first LSF to a second routing area on a second LSF.

The initial procedure involves the System Change Procedure, as indicated by events **2502**–**10**. The first event **2502**,

the MN detects it will move to a new system (new LSF) and informs the current system (old xAN/LSF) of the impending move by sending a registration message to the "old" system (LSF) with a registration type of "Prepare for System Change". The "old" system will have its router (xAN) start queuing datagrams for the MN. The parameters are the same as defined in section 3.1.1. The parameters in [brackets] are optional.

In event **2504**, the authentication procedure is performed, if necessary. See section 3.1.1 for details. The authentication procedure may not be necessary if the MN and the LSF have established keys to be used for over the air encryption.

In event **2506**, the SMM informs the mobility agent on the old router to start buffering datagrams destined to the user's MN.

To complete the System Change Procedure, acknowledgements are sent by the router, event **2508**, and the SMM, event **2510**.

In event **2512**, the MN has determined it has crossed over a LSF boundary (via a new system ID). The MN sends a registration message to the IP address (which is the IP address of the SMM) that is contained in the BCCH. The MN will send a registration request message for each active packet data session it has. In this scenario, there is only one active packet data session. The message includes the old LSF's system ID.

The SMM detects that the registration type is "System Change" and that the message includes the Old LSF ID. As a result, the SMM initiates the Contect Request Procedure, as indicated by events **2514**–**22**, to request MN information from the old LSF and have the old LSF start buffering datagrams destined to the MN. This is achieved by sending the old LSF a context request message via the local AAA function, event **2514**. The SMM will put the old LSF's NAI in the message so the local AAA function can route the message (to simplify this, the SMM may pass the IP address of the old LSF; this is an implementation detail.

If there is more than one active packet data session for the MN, the MN will send a registration request message for each active packet data session it has. This will incur multiple context requests being issued by the new LSF, but sending a single context request that includes the MN's L2 Addr to the old LSF can optimize it.

The context response includes MN information for all active packet data sessions. Hence, the new LSF will not have to send a context request message for each registration message.

The local AAA function uses the domain portion of the old LSF's NAI to determine the LSF's system. A lookup is performed to determine the IP address of LSF's AAA function and the type of security association (SA) established between the old LSF and new LSF. The local AAA function will then send the message to the LSF's AAA function. Before the packet is sent, an IPSec authentication (AH) is performed on the message.

In event **2516**, he old LSF's AAA function receives the message. The AAA function will first validate the IPSec AH. It then performs a lookup to determine to which server it should forward the message. Since this is a context request, it forwards the message to the SMM.

In event **2518**, the SMM informs the mobility agent on the old router to start buffering datagrams destined to the user's MN. The buffer data request can have multiple MN IP addresses. Additionally, if the SMM had previously initiated a buffer request, such as during the System Change Procedure, the SMM does not have to reissue the request here.

In event **2520**, the router mobility agent updates the local router to start queuing datagrams destined to the MN and then sends an ack message back to the SMM.

In event **2522**, the SMM creates a context response message with the MN's IP address(es) and sends it back to the new LSF SMM, in addition to performing normal AAA server functions. It is not necessary to send the user's profile since it will be retrieved during the registration procedure described below.

In event **2524**, the Authentication Procedure is performed. See section 3.1.1 for details.

In event **2526**, the Registration Procedure is performed. See section 3.1.1 for details.

In event **2528**, the Registration Reply Procedure is performed. See section 3.1.1 for details.

In the Binding Update Procedure, indicated by events **2530**–**36**, updates the MN's binding to include the new LSF before the binding to the old LSF is canceled.

In event **2530**, the new LSF's SMM creates a Binding Update request message that includes the user's NAI and the COA of the router that the MN's datagrams need to be tunneled to and sends it to the old LSF's SMM, in addition to performing all normal AAA server functions. This request will allow the old LSF to start forwarding the MN's datagrams.

In event **2532**, the old LSF's SMM sends a Forward Packets message to the mobility agent on the LSF/xAN router to request that the router start forwarding datagrams to the new router's COA.

In event **2534**, the mobility agent acknowledges the forward packets request.

In event **2536**, the SMM creates a Binding Update response message with the user's NAI and sends it to the new LSF's SMM, in addition to performing normal AAA server functions.

After the Binding Update Procedure is completed, the Registration Cancellation procedure, indicated by events **2538**–**44**, cancels the registration of the MN to the old LSF.

In event **2538**, after the user's home NSF performed the registration, it sends the old LSF a registration cancellation message, in addition to performing normal AAA server functions. The reason for sending the registration cancellation is that there is a window where the home NSF may have sent a CN a binding update that had the old LSF's COA. The home NSF must now update the CN with the new COA and then perform the registration cancellation procedure. This will insure that the old LSF will not stop forwarding datagrams to the MN prematurely. The registration procedure is being performed in parallel to the Binding Update procedure, which was initiated by the new LSF in event **2528**. Also, it is not necessary for the NSF to have a retry counter associated with the registration cancellation request.

In event **2540**, the old LSF's SMM initiates the cleanup after the Binding Update and the registration cancellation has completed. In event **2542**, the router's mobility agent acks the message, and the old LSF acks the registration cancellation reques in event. All the normal AAA server functions are performed.

3.1.6 MN Moves to a New RA, New XAN, Same LSF

FIG. **26** is a message flow event sequence diagram showing the flow of messages for a user roaming between xANs within the same LSF. The registration request message sent through the old xAN indicates movement to another system (xAN) and triggers the LSF to start queuing MN datagrams at the old xAN.

In event **2602**, the System Update procedure is performed. See section 3.1.1 for details.

In event **2604**, the MN determines a xAN boundary has been crossed via a new system ID. The MN sends a registration message to the IP address, which is the IP address of the SMM, contained in the BCCH or Agent Advertisement. The MN sends a registration request message for each active packet data session. In this scenario, there is only one active packet data session. The message includes the old LSF's system ID.

In event **2606**, the Authentication procedure is performed. See section 3.1.1 for details.

In event **2608**, the Address Update procedure is performed. See section 3.1.1 for details.

In event **2610**, the Registration Reply procedure is performed. See section 3.1.1 for details.

In event **2612**, the LSF's SMM sends a Forward Packets message to the mobility agent on the old xAN router to request that the router start forwarding datagrams to the new router's COA. These datagrams will be tunneled to the new router's COA.

In event **2614**, the mobility agent informs the xAN/router to start forwarding packets and acks the Forward Data request.

In event **2616**, the Registration Cancellation procedure is performed. See section 3.1.1 for details.

3.1.7 MN Moves to a New Routing Area, Same XAN/LSF, New COA

FIG. **27** is a message flow event sequence diagram showing the flow of messages for a user roaming between RAs within the same xAN/LSF. At the xAN/LSF boundary, however, there are multiple routers and, hence, multiple routing areas each having their own COA. When the user roams in a new RA, the associated COA must be updated at the user's home network.

Alternatively, instead of allocating a new COA and updating the COA at the user's home network, the original router may be updated with information on how to route MN datagrams to the new router(s). Since the present invention tries to avoid such configurations, it is preferred to update the COAs.

In event **2702**, the System Change Procedure is performed. See section 3.1.5 for details.

In event **2704**, the MN has determined it has crossed over a routing area boundary. The MN sends a registration message for each active packet data session. In this scenario, there is only one active packet data session. The parameters are the same as defined in section 3.1.1, brackets indicating optional parameters.

In event **2706**, the Authentication Procedure is performed. See section 3.1.1 for details.

In event **2708**, the SMM informs the mobility agent on the old router to start buffering datagrams destined to the user's MN. The SMM, however, will not issue the buffer data request if it was performed during the System Change Procedure.

In event **2710**, the router mobility agent acknowledges the message.

In event **2712**, the Address Update Procedure is performed. See section 3.1.2 for details.

In event **2714**, the Registration Reply Procedure is performed. See section 3.1.1 for details.

In event **2716**, the SMM informs the mobility agent on the old router to start forwarding datagrams destined to the user's MN. These datagrams will be tunneled to the new router's COA.

In event **2718**, the router mobility agent acknowledges the message.

In event **2720**, the SMM informs the mobility agent on the old router to have the xAN clean up its resources.

In event **2722**, the router mobility agent acknowledges the message.

3.1.8 MN Moves to a New Routing Area, Same XAN/LSF, Same COA

FIG. **28** is a message flow event sequence diagram showing the flow of messages for a user roaming to a new routing area where the MN's COA does not change. It should be noted that the MN does not know that the COA will not change. During the system change procedure, however, the SMM will know and will not have to buffer datagrams destined to the MN.

In event **2802**, the System Change Procedure is performed. See section 3.1.5 for details.

In event **2804**, the MN has determined it has moved to a new routing area. The MN sends a registration message for each active packet data session. In this scenario, there is only one active packet data session. The parameters are the same as defined in section 3.1.1. The parameters in [brackets] are optional.

In event **2806**, the Authentication Procedure is performed. See section 3.1.1 for details.

In event **2808**, if the user was authenticated, the SMM updates its local directory with the new RA and send a registration reply to the MN. Since a new COA was not allocated for the user, there are no other functions that the SMM needs to perform.

3.1.9 MN Moves Back to the User's Home Network, Combined LSF/NSF

FIG. **29** is a message flow event sequence diagram showing the flow of messages for a user roaming back into his/her home network, wherein the network is a combined LSF/NSF and the home subnet is accessed over some radio interface (RAN), not over an Ethernet connection. The combined LSF/NSF may be on the same subnet.

In event **2902**, the System Change Procedure is performed. See section 3.1.5 for details.

In event **2904**, the MN determines it has crossed over a LSF boundary via a new system ID. The MN sends a registration message to the IP address, which is the IP address of the SMM, contained in the BCCH. The MN will send a registration request message for each active packet data session. In this scenario, there is only one active packet data session. The message includes the old LSF's system ID.

In event **2906**, the Context Request Procedure is performed. See section 3.1.5 for details.

In event **2908**, the SMM creates an AAA Authentication Request and forwards it to the LSF's local AAA function. If the SMM and the Auth center are on the same subnet, or the same server, it is not necessary to have the Authentication Request go through the AAA function.

In event **2910**, the local AAA function uses the domain portion of the user's NAI to determine the home system of the user. A lookup is performed to determine the IP address of the user's home AAA function and the type of security association (SA) established between the LSF and NSF. The AAA function realizes it is its own network, so it forwards the message directly to the authentication server.

In event **2912**, the authentication server authenticates the user. The authentication server then sends an authentication response to its home AAA function.

In event **2914**, the AAA function realizes it is its own network, so it forwards the message directly to the SMM.

In event **2916**, the SMM creates a registration request message and forwards it to the LSF's local AAA function. If the SMM and the HMM are on the same subnet or the same server, it is not necessary to have the Authentication Request go through a AAA function

In event **2918**, the local AAA function uses the domain portion of the user's NAI to determine the home system of the user. A lookup is performed to determine the IP address of the user's home AAA function and the type of security association (SA) established between the LSF and NSF. The AAA function realizes it is its own network, so it forwards the message directly to the Authentication Server.

In event **2920**, the HMM updates the local directory with the LSF and mobility information. Additionally, the HMM sends a route update message to the local router to can update the MN's IP address, which is the MN's IP address in this scenario. Moreover, the HMM creates a registration reply message that includes the user's NAI and sends the registration reply to its AAA function.

In event **2922**, the AAA function realizes it is its own network, so it forwards the message directly to the SMM.

In event **2924**, the Registration Reply Procedure is performed. See section 3.1.1 for details.

In event **2926**, the Binding Update Procedure is performed. See section 3.1.5 for details.

In event **2928**, the Registration Cancellation Procedure is performed. See section 3.1.5 for details.

3.1.10 MN Moves to a New RA, New LSF, No Movement Indication

FIG. **30** is a message flow event sequence diagram showing the flow of messages for a user roaming between LSFs wherein the MN does not send a registration request message to the old LSF that indicates the MN is about to move. FIG. **30** is similar to FIG. **25** but for during the MN's transition to the new LSF, there is a window where the old LSF may lose datagrams destined to the MN while the MN was accessing the new LSF. This event sequence helps to minimize this window by having the new LSF request the old LSF to start queuing datagrams for the MN. The size of the window may vary since the old LSF may be in the process of paging the MN and, hence, already queuing the datagrams.

In event **3002**, the MN has determined it has crossed over a LSF boundary (via a new system ID). The MN will send a registration message for each active packet data session. In this scenario, there is only one active packet data session.

In event **3004**, the Context Request Procedure is performed. See section 3.1.5 for details.

In event **3006**, the Authentication Procedure is performed. See section 3.1.1 for details.

In event **3008**, the Registration Procedure is performed. See section 3.1.1 for details.

In event **3010**, the Registration Reply Procedure is performed. See section 3.1.1 for details.

In event **3012**, the Binding Update Procedure is performed. See section 3.1.5 for details.

In event **3014**, the Registration Cancellation Procedure is performed. See section 3.1.1 for details.

3.1.11 User Packet Data Session De-Registration

FIG. **31** is a message flow event sequence diagram showing the flow of messages for a user terminating a connection to their service provider.

In event **3102**, the user wants to disconnect (log off) from their service provider. Via some interface or configured button, the user selects the provider they want to disconnect from. The MN sends the de-registration message with the RegType field set to de-registration.

In event **3104**, the authentication procedure is performed. See section 3.1.1 for details.

In event **3106**, the SMM sends a registration request with the to the local AAA function.

In event **3108**, the local AAA function uses the domain portion of the user's NAI to determine the home system of the user. A lookup is performed to determine the IP address of the user's home AAA function and the type of security association (SA) established between the LSF and NSF. The local AAA function will then send the message to the user's home AAA function. Before the packet is sent, an IPSec authentication (AH) is performed on the message.

In event **3110**, the user's home AAA function receives the message. The AAA function will first validate the IPSec AH. It then performs a lookup to see what server it should forward the message to. It forwards the message to the HMM.

In event **3112**, the HMM sends a route update message to the local router to remove the MN's IP address and COA from the routing table. Additionally, the HMM updates the local directory and the user's entry in the DDNS. Furthermore, if the MN's IP address was allocated via DHCP, the HMM will release the IP address. The HMM then creates a deactivate response message that includes the user's NAI and sends it to its home AAA function.

In event **3114**, the AAA function will create an IPSec AH and send the message to the local AAA function serving the user.

In event **3116**, the local AAA function validates the IPSec AH and passes the message on to the SMM.

In event **3118**, the SMM will cleanup and send the registration reply to the mobility agent at the xAN/LSF router.

In event **3118**, the mobility agent will remove the MN's IP address from the router's route table and forward the registration reply to the MN.

3.1.12 Inter System (Inter LSF) Handoff

FIG. **32** is a message flow event sequence diagram showing the flow of messages for a handoff between two LSFs.

In this sequence of events, the old LSF recieves a handoff indication from the xAN to insure that the MN's datagrams are queued. The xAN must send the handoff required message in the event that the MN's registration request, with RegType set to "Prepare for System Change", is not received by the old LSF's SMM.

In order to prevent loss of data, datagrams destined to the MN are buffered.

In event **3202**, the System Update Procedure is performed. See section 3.1.5 for details.

In event **3204**, the xAN via the mobility agent sends the SMM a handoff required message, which indicates the target LSF for the handoff.

The Handoff Procedure, as illustrated by events **3206–12**, allocates the required resources to facilitate the communication with the new LSF.

In event **3206**, the SMM forwards the handoff required message to the new LSF SMM. All normal AAA functions are performed. The Call Info field includes the current active data session for the MN. The LSF domain is sent to identify the old LSF to the SMM in the new LSF. The LSF domain can be used by the new LSF's SMM for routing.

The LSF does not have to get involved with the actual handoff. The Handoff Procedure can be performed by the

xANs themselves. If the xANs do perform the procedure, they are responsible for queuing the MN's datagrams.

In event **3208**, the handoff required message indicates the target for the handoff. The SMM sends an activate packet service request to the xAN to allocate the appropriate resources. An activate packet service request is sent for every active session that is listed in the Call Info field.

In event **3210**, the xAN allocates the appropriate resources and sends an activate packet service response back to the SMM.

In event **3212**, the new SMM sends a handoff required acknowledgement to the old SMM. Normal AAA functions are performed.

In event **3214**, the SMM sends a Handoff required acknowledgement message to the mobility agent on the xAN router to indicate that the handoff initialized. The handoff required message also triggers the queing of datagrams.

In event **3216**, the MN retunes to the appropriate frequency. The MN realizes it has crossed over a LSF boundary via a new system ID. It also realizes that there are active application sessions, and, hence, it will set the RegType to be "SystemHO". The MN sends a registration request message for each active packet data session. In this scenario, there is only one active packet data session. The message includes the old LSF's system ID.

In event **3218**, the Context Request Procedure is performed. See section 3.1.5 for details. If the LSF is responsible for performing the Handoff Procedure, this step does not have to be performed.

In event **3220**, the Authentication Procedure is performed. See section 3.1.1 for details. While authentication does not need to be performed at this step, it is preferred. Alternatively, a unique challenge to authenticate the user may be performed upon handoff completion.

In event **3222**, the Registration Procedure is performed. See section 3.1.1 for details.

In event **3224**, the Registration Reply Procedure is performed. See section 3.1.1 for details.

In event **3226**, the Binding Update Procedure is performed. See section 3.1.5 for details.

The Update CN Procedure, events **3228**–**38**, updates the correspondence nodes with which it is MN is in communication.

In event **3228**, the MN realizes that it is in a new system and has active application session; hence, it sends the SMM a list of correspondent nodes with which it is in communications. Alternatively, the home network can request the CN list from the MN after the home network was updated with the new COA.

In event **3230**, the SMM forwards the message to the HMM at the MN's NSF. Normal AAA functions are performed.

In event **3232**, the HMM acknowledges the correspondent node list. Normal AAA functions are performed.

In event **3232**, the SMM forwards the message to the MN.

In event **3234**, the HMM receives the CN list and sends binding updates that include the MN's new COA to the CNs.

In event **3236**, the CNs acknowledge the binding update.

In event **3238**, the Registration Cancellation Procedure is performed. See section 3.1.5 for details.

3.1.13 Inter XAN Handoff, Same LSF

FIG. **33** is a message flow event sequence diagram showing the flow of messages for a handoff between two xANs on the same LSF.

In event **3302**, the System Change Procedure is performed. See section 3.1.5 for details.

In event **3304**, the xAN via the mobility agent sends the SMM a handoff required message, which indicates the target LSF for the handoff.

In event **3306**, the Handoff Procedure is performed. See section 3.1.12 for details.

In event **3308**, the SMM sends a Handoff required acknowledgement message to the mobility agent on the xAN router to inform the xAN that handoff is initialized. The handoff requided acknowledgement also triggers the queuing of datagrams for the MN.

In event **3310**, the MN retunes to the appropriate frequency. The MN realizes it has crossed over a LSF boundary via a new system ID. Additionally, the MN realizes that there are active application sessions and sets the RegType to be "SystemHO". The MN sends a registration request message for each active packet data session. In this scenario, there is only one active packet data session. The message includes the old LSF's system ID.

In event **3312**, the Authentication Procedure is performed. See section 3.1.1 for details.

In event **3314**, the Registration Procedure is performed. See section 3.1.1 for details.

In event **3316**, the Registration Reply Procedure is performed. See section 3.1.1 for details.

In event **3318**, the old LSF's SMM sends a Forward Packets message to the mobility agent on the LSF/xAN router to request the router start forwarding datagrams to the new router's COA. These datagrams will be tunneled to the new router's COA.

In event **3320**, the mobility agent informs the xAN/router to start forwarding packets.

In event **3322**, the MN realizes that it is in a new system and has active application sessions; hence, it sends its home network a list of correspondent nodes with which it is in communication. Alternative the home network may request the CN list from the MN after the home network was updated with the new COA.

In event **3324**, the HMM acks the correspondent node list.

In event **3326**, after the HMM receives the CN list and the new COA, it will send binding updates, which include the new COA to the CNs.

In event **3328**, the CNs will acknowledge the binding update.

In event **3330**, the Registration Cancellation Procedure is performed. See section 3.1.5 for details.

3.1.14 Inter XAN Handoff, Same LSF, Hierarchical Routers

FIG. **34** is a message flow event sequence diagram showing the flow of messages for a handoff between two xANs on the same LSF. FIG. **34** is similar to FIG. **33** but for the FIG. **34** includes a hierarchy of routers in the LSF/xAN.

In event **3402**, the System Change Procedure is performed. See section 3.1.5 for details.

In event **3404**, the xAN via the mobility agent on the xAN router sends the SMM a handoff required message which indicates the target LSF for the handoff.

In event **3406**, the Handoff Procedure is performed. See section 3.1.12 for details.

In event **3408**, the SMM sends a Handoff required acknowledgement message to the mobility agent on the xAN router to indicate that handoff is initilized. Additionally, the handoff required acknowledgement triggers datagram queuing for the MN.

In event **3410**, the MN retunes to the appropriate frequency. The MN realizes it has crossed over a LSF boundary via a new system ID. It also realizes that there are active application sessions, hence it will set the RegType to be

"SystemHO". The MN will send a registration request message for each active packet data session. In this scenario, there is only one active packet data session. The message includes the old LSF's system ID.

In event **3412**, the Authentication Procedure is performed. See section 3.1.1 for details.

In event **3414**, the Registration Procedure is performed. See section 3.1.1 for details.

In event **3416**, the SMM updates its local directory with the appropriate information. The SMM will send a registration reply to a mobility agent on the xAN/LSF router.

In event **3418**, the mobility agent at the xAN/LSF router must update the router's routing table to include the MN's IP address. When this occurs, some routing protocol, e.g., RIP, updates the local network with routing information so datagrams can be delivered to the xAN router, i.e., the LSF router will receive a route update and will know how to forward de-tunneled datagrams. The xAN must be told of the "binding" between the MN's IP Address and the MN's L2 Address. The mobility agent then sends the registration reply to the MN.

In event **3420**, the old LSF's SMM sends a Forward Packets message to the mobility agent on the LSF/xAN router to request that the router start forwarding datagrams to the new router's COA. These datagrams will be tunneled to the new router's COA.

In event **3422**, the mobility agent informs the xAN/router to start forwarding packets.

In event **3424**, the Update CN Procedure is performed. See section 3.1.12 for details.

In event **3426**, the Registration Cancellation Procedure is performed. See section 3.1.5 for details

4. Base Protocol Specifications

4.1 Introduction

4.2 IPM Message Flows

4.2.1 IPM MN Registers from the IPM LSF

Referring to FIG. **35**, Agent Discovery, events **3502**–**3504**, is the method by which a Mobile Node (MN) determines whether it is currently connected to its home network or to a foreign network, and by which a MN can detect when it has moved from one network to another. Home agents and foreign agents may advertise their availability on each link for which they provide service. A newly arrived MN can send a solicitation on the link to learn if any prospective agents are present. The Agent Discovery Process is primarily handled through Agent Solicitation and Agent Advertisement.

Agent Solicitation, event **3502**, is the broadcast/multicast message sent by the IPM MN to detect a Service Provider in the event that the IPM MN has not received an Advertising Agent message. The Agent Solicitation message contains, as the source address, the Mobile IP address belonging to the interface from which this message is sent, or 0. The destination address is the configured solicitation address. In addition to a checksum value, a type value of 10 and a code value of 0 is contained in the message.

In event **3504**, Agent Advertisement messages are sent periodically, either as a broadcast or multicast for the visiting IPM MN to recognize the availability of service and to keep track of their point of attachment. The message contains: a source address of the IP address belonging to the interface from which this message is sent; a destination address of the configured Advertisement Address or the IP address of a neighboring host; a type field of 9; a code field of 0; a checksum value, the number of router addresses advertised in this message; the number of 32-bit words of information per each router address (2, in the version of the protocol described here); the maximum number of seconds that the router addresses may be considered valid; the sending router's IP address(es) on the interface from which this message is sent; and the preferability of each router address as a default router address, relative to other router addresses on the same subnet. Additionally, the Agent Advertisement message contains the Mobility Agent Advertisement and ANI-NAI Extensions.

The purpose of the Registration Process, events **3506**–**3540**, is for the IPM MN to inform the HMM of the NSF (Network Serving Function) of its current location to which data packets can be forwarded to the IPM MN. The Registration process also includes the authenticating and authorizing of the IPM MN to have access to the visited network or LSF (Local Serving Function).

In event **3506**–**3508**, the Registration Request message is sent by the IPM MN to the SMM to register for the service. The Registration Request contains: the source IP address of the MN; the destination address of the COA within the ANI component; a type field of 0; the flags as in RFC2002; the lifetime requested by MN from the HMM or Home; the home IP address of the MN; the Home Agent's address of the MN; the Care-of-Address of the MN; and the identification, to provide replay protection. Additionally, the User-NAI Extension, L2-Address Extension (Optional), MN-Home Authentication Extension, Registration-Type Extension, Previous-SMM-NAI Extension (Optional), ANI-NAI Extension (Optional), MN-SMM Authentication Extension (Optional), ANI-SMM Authentication Extension (Optional), and ANI-HMM Authentication (Optional) are used in the Registration Request. The extensions are described further in section 4.4.

In events **3510**–**14**, the AAA-Registration-Request message is used to carry out various kinds of registrations; these registrations are encapsulated in the IPM-Registration-Type AVP. This message is used by SMM to authenticate and authorize the user.

The AAA-Registration-Request message is of the format of DIAMETER. The SMM sends the message to HMM with at least the mandatory fields of Command Code AVP of 335; User-Name AVP; Host-Name AVP; IPM-Registration-Request AVP; IPM-Registration-Request AVP; IPM-Care-of-Address AVP; and the IPM-Routing-Area-NAI AVP. The IPM-Registration-Request AVP is the AVP which carries the message received from the MN, which is encapsulated in the AVP format for the Home domain to authenticate the user. The HMM processes this message based on the Registration-Type AVP, which carries the type of registration requested.

The AVPs that can optionally be used in the Registration Request message include, and are further explained in section 4.5, Destination-NAI AVP, IPM-Client-Address AVP, Home-Agent-Address AVP, IPM-SMM-NAI AVP, IPM-Terminal-Type AVP, IPM-Profile-Type AVP, Proxy-State AVP, Timestamp AVP, Nonce AVP, and Integrity-Check-Value AVP.

In event **3516**, the Service Request message is sent from the HMM to the ISC (IPM Security Center) to authenticate a user or message, generate, renew, or delete session secret keys. It also can be sent from the PPS Manager to the ISC to generate or construct the IPMC.

The Service Request message contains: a type of USER_SERVICE_REQUEST_MSG; a sub-type of 0; the length of the message payload including all the extensions; a 64-bit number used for matching User Service Request

messages with User Service Reply messages, and for protecting against replay attacks of User Service Request messages; and, in phase I, this extension has the user NAI and in the future will have an index which will be used to index the user data in the UDS.

The Service Request message uses the extensions, which are explained in further detail in section 4.4, User Authentication Information Extension, Control Message Authentication Extension, Session Key Allocation Extension 0 . . . N, Session Key Lifetime Renewal Extension 0 . . . N, and Session Key Delete Extension 0 . . . N.

In event **3518**, the Service Reply message is sent from the ISC (IPM Security Center) to the HMM in response to a Service Request message.

The message exchanged between the ISC and the HMM contains: a type of USER_SERVICE_REPLY_MSG; a subtype of 0; the length of the message payload including all the extensions; a code; a 64-bit number used for matching User Service Request messages with User Service Reply messages, and for protecting against replay attacks of User Service Request messages; and a User NAI, which in phase I has the user NAI and in the future will have an index which will be used to index the user data in the UDS. The code value is defined as the following hexadecimal values:

00000001 User Authenticated successfully.

00000002 All required keys have been allocated.

00000003 Some keys have been allocated.

00000004 User Authentication failed.

00000005 Key Lifetime Renewal is completely honoured.

00000006 Key Lifetime Renewal is partially honoured.

00000007 User Account is created successfully.

00000008 User is deleted successfully.

Additionally, the following Extensions, which are described in greater detail in section 4.4, are used in the Service Response message: Control Message Authentication Extension; Session Key Allocation Extension 0 . . . N; Session Key Lifetime Renewal Extension 0 . . . N; and Session Key Delete Extension 0 . . . N.

In event **3524**, the Add Tunnel Entry message is sent by the HMM to instruct the ITS to set up a tunnel entry point. The message exchanged between the HMM and the ITS contains: a code of 1; the length of the message including the header fields; and an identification used in matching requests and acknowledgements. The sender must ensure the identifier in a message is locally unique at any given time.

Additionally, the following extensions, which are explained in further detail in section 4.4, are used in the Add Tunnel Entry message: Host NAI Extension, Flag Extension, Lifetime Extension, Mobile Node IP Address Extension, User NAI Extension (Optional), and Tunnel Entry IP Address Extension.

In event **3526**, the Add Tunnel Entry Acknowledgement message is sent by the ITS to acknowledge the Add Tunnel Entry message. The message exchanged between the ITS and the HMM contains: a code of 2; the length of the message including the header fields; and an identification used in matching requests and acknowledgements. The sender must ensure the identifier in a message is locally unique at any given time.

Additionally, the following extensions, which are explained in further detail in section 4.4, are used in the Add Tunnel Entry message: Host NAI Extension, Result Code Extension, Mobile Node IP Address Extension (Optional), and User NAI Extension (Optional).

In events **3528–32**, the AAA Registration Reply message is the response message sent by the HMM to the SMM to indicate the result of the AAA-Registration Request message.

The AAA-Registration Reply message is of the format of DIAMETER, and contains a DIAMETER Header, a Command-Code AVP of 336, a Destination-NAI AVP, Host-Name AVP, User-Name AVP, IPM-Registration-Response-Code AVP, IPM-Client-Address AVP, and IPM-Registration-Reply AVP. The HMM sends a message to the SMM with at least the mandatory fields in response to AAA-Registration Request message. The IPM-Registration Response Code AVP indicates the success or failure of the request. The IPM Registration Reply message AVP contains the reply message built by HMM with authentication. The SMM has to use this AVP to send a reply to ANI/MN.

Additionally, the Registration Reply message can optionally use the following AVPs, which are discussed in further detail in section 4.5: IPM-Profile AVP, IPM-SMM-MN-Key AVP, IPM-HMM-NAI AVP, Proxy-State AVP, Time AVP, Nonce AVP, and Integrity-Check-Value AVP.

In event **3534**, the Add Tunnel Exit message is sent by the SMM to instruct the ITS to set up a tunnel exit point. The message exchanged between the SMM and the ITS contains: a code of 3; the length of the message including the header fields; and an identification used in matching requests and acknowledgements. The sender must ensure the identifier in a message is locally unique at any given time.

Additionally, the Extensions, which are explained further in section 4.4, used in the Add Tunnel Exit message are: Host NAI Extension, Lifetime Extension, Mobile Node IP Address Extension, User NAI Extension (Optional), and Tunnel Exit IP Address Extension.

In event **3536**, the Add Tunnel Exit Acknowledgement message is sent by the ITS to acknowledge the Add Tunnel Exit message. The message exchanged between the ITS and the SMM contains: a code of 4; the length of the message including the header fields; and an identification used in matching requests and acknowledgements. The sender must ensure the identifier in a message is locally unique at any given time.

Additionally, the Extensions, which are explained further in the section 4.5, used in the Add Tunnel Exit Acknowledgement message are: Host NAI Extension, Result Code Extension, Mobile Node IP Address Extension (Optional), User NAI Extension (Optional), and Tunnel Forwarding IP Address Extension.

In events **3538–40**, the Registration Reply message is sent by the SMM to the IPM MN to indicate the result of the Registration Request message sent. The message exchanged between the SMM and the IPM MN contains: a type of 3; a code for all the existing MIP Response codes, this field is being extended to include IPM specific items; the Home lifetime for the registration; the IP address of the MN; the Home Agent's address of the MN; and the identification, to provide replay protection.

Additionally, the Extensions, which are explained further in section 4.4, used in the Registration Reply message are: User-NAI Extension, SMM-Key Extension (Optional), MN-Home Authentication Extension, Local Registration Lifetime Extension (Optional), SMM-NAI Extension (Optional), MN-SMM Authentication Extension (Optional), and ANI-SMM Authentication Extension (Optional).

4.2.2 IPM MN Registers From IPM NSF

FIG. **36** is a message flow event sequence diagram showing the flow of messages for IPM MN register from IPM NSF.

In events **3602**–**3604**, the Agent Discovery Process is performed. See section 4.2.1 for details.

In event **3606**–**3608**, the Registration Request message is sent by the IPM MN to the HMM to register for the service. See section 4.2.1 for the message exchanged between the IPM MN and the HMM.

In event **3610**, the Service Request message is sent. See section 4.2.1 for details.

In event **3612**, the Service Response message is sent. See section 4.2.1 for details.

In event **3614**–**16**, the Registration Reply message is sent by the HMM to the IPM MN to indicate the result of the Registration Request message sent. See section 4.2.1 for details.

4.2.3 IPM MN Disconnect Detection

FIG. **37** is a message flow event sequence diagram showing the flow of messages for IPM MN disconnect detection.

In event **3702**, the Registration Request message is sent by the IPM MN to the ANI when a disconnect is detected. See section 4.2.1 for details but for MN-Home Authentication Extension (Optional).

In event **3704**, the Registration Reply message is sent by the ANI to the IPM MN to indicate the result of the Registration Request message sent. See section 4.2.1 for details but for the MN-Home Authentication Extension (Optional).

4.2.4 IPM MN Re-Registers from IPM LSF

FIG. **38** is a message flow event sequence diagram showing the flow of messages for IPM MN re-registers from IPM LSF.

In event **3802**–**3804**, the Registration Request message is sent. See section 4.2.1 for details.

In event **3806**–**10**, the AAA-Registration Request message is sent. See section 4.2.1 for details.

In event **3812**, the Service Request message is sent. See section 4.2.1 for details.

In event **3814**, the Service Reply message is sent. See section 4.2.1 for details.

In event **3816**–**20**, the AAA-Registration Reply message is sent. See section 4.2.1 for details.

In event **3822**–**24**, the Registration Reply message is sent. See section 4.2.1 for details.

4.2.5 IPM MN Re-Registers from IPM NSF

FIG. **39** is a message flow event sequence diagram showing the flow of messages for IPM MN re-registers from IPM NSF.

In events **3902**–**3904**, the Registration Request message is sent. See section 4.2.1 for details.

In event **3906**, the Service Request message is sent. See section 4.2.1 for details.

In event **3908**, the Service Reply message is sent. See section 4.2.1 for details.

In events **3910**–**3912**, the Registration Reply message is sent. See section 4.2.1 for details.

4.2.6 IPM MN De-Registers from IPM LSF

FIG. **40** is a message flow event sequence diagram showing the flow of messages for IPM MN de-registers from IPM LSF.

In events **4002**–**4004**, the Registration Request message is sent. See section 4.2.1 for details.

In events **4006**–**4010**, the AAA-Registration Request message is sent. See section 4.2.1 for details.

In event **4012**, the Service Request message is sent. See section 4.2.1 for details.

In event **4014**, the Service Reply message is sent. See section 4.2.1 for details.

In event **4016**, the Delete Tunnel Entry message is sent by the HMM to instruct the ITS to delete a tunnel entry point. The message exchanged between the HMM and the ITS contains: a code of 7; a length of the message including the header fields; an identification used in matching requests and acknowledgements. The sender must ensure the identifier in a message is locally unique at any given time. Additionally, extensions, which are discussed further in section 4.4, used in the Delete Tunnel Entry message are: Host NAI Extension; Mobile Node IP Address Extension; and User NAI Extension (Optional).

In event **4018**, the Delete Tunnel Entry Acknowledgement message is sent by the ITS to acknowledge the Delete Tunnel Entry message. The identification field should be used for matching with the Delete Tunnel Entry message. The message exchanged between the ITS and the HMM contains: a code of 8; a length of the message including the header fields; and an identification used in matching requests and acknowledgements. The sender must ensure the identifier in a message is locally unique at any given time. Additionally, extensions, which are discussed further in section 4.4, used in the Delete Tunnel Entry Acknowledgement message are: Host NAI Extension; Result Code Extension; Mobile Node IP Address Extension (Optional); andUser NAI Extension (Optional).

In events **4020**–**4024**, the AAA-Registration Reply message is sent. See section 4.2.1 for details.

In event **4026**, the Delete Tunnel Exit message is sent by the SMM to instruct the ITS to delete a tunnel exit point. The message exchanged between the SMM and the ITS contains: a code of 9; a length of the message including the header fields; and an identification used in matching requests and acknowledgements. The sender must ensure the identifier in a message is locally unique at any given time. Additionally, extensions, which are discussed further in section 4.4, used in the Delete Tunnel Exit message are: Host NAI Extension; Mobile Node IP Address Extension (Optional); User NAI Extension (Optional); and Tunnel Exit IP Address Extension.

In event **4028**, the Delete Tunnel Exit Acknowledgement message is sent by the ITS to acknowledge the Delete Tunnel Exit message. The identification field should be used for matching with the Delete Tunnel Exit message. The message exchanged between the ITS and the SMM contains: a code of 10; the length of the message including the header fields; and an identification used in matching requests and acknowledgements. The sender must ensure the identifier in a message is locally unique at any given time. Additionally, extensions, which are discussed further in section 4.4, used in the Delete Tunnel Exit Acknowledgement message are: Host NAI Extension; Result Code Extension; Mobile Node IP Address Extension (Optional); and User NAI Extension (Optional).

In events **4030**–**32**, the Registration Reply message is sent. See section 4.2.1 for details.

4.2.7 IPM MN De-Registers from IPM NSF

FIG. **41** is a message flow event sequence diagram showing the flow of messages for IPM MN De-registers from IPM NSF.

In events **4102**–**4104**, the Registration Request message is sent. See section 4.2.1 for details.

In event **4106**, the Service Request message is sent. See section 4.2.1 for details.

In events **4108**, the Service Reply message is sent. See section 4.2.1 for details.

In events **4110**–**4112**, the Registration Reply message is sent. See section 4.2.1 for details.

4.2.8 IPM MN Handoffs from ANI to ANI in the Same SMM (Different ITS)

FIG. **42** is a message flow event sequence diagram showing the flow of messages for IPM MN handoffs from ANI to ANI in the same SMM, different ITS.

In events **4202**–**4204**, the Registration Request message is sent. See section 4.2.1 for details.

In events **4206**, **4212**, and **4218**, the AAA-Registration Request message is sent. See section 4.2.1 for details.

In event **4208**, the Add Tunnel Exit message is sent. See section 4.2.1 for details.

In event **4210**, the Tunnel Forwarding message is sent by the SMM to instruct the ITSO to set up tunnel forwarding. The message exchanged between the SMM and the ITSO contains: a code of 5; a length of the message including the header fields; and an identification used in matching requests and acknowledgements. The sender must ensure the identifier in a message is locally unique at any given time. Additionally, extensions, which are discussed further in section 4.4, used in the Tunnel Forwarding message are: Host NAI Extension; Mobile Node IP Address Extension; User NAI Extension (Optional); Lifetime Extension; and Tunnel Exit IP Address Extension.

In event **4214**, the Add Tunnel Exit Acknowledgement message is sent. See section 4.2.1 for details.

In event **4216**, the Tunnel Forwarding Acknowledgement message is sent by the ITSO to acknowledge the Tunnel Forwarding message. The identification field should be used for matching with the Tunnel Forwarding message. The message exchanged between the ITSO and the SMM contains: a code of 6; a length of the message including the header fields; and an identification used in matching requests and acknowledgements. The sender must ensure the identifier in a message is locally unique at any given time. Additionally, extensions, which are discussed further in section 4.4, used in the Tunnel Forwarding Acknowledgement message are: Host NAI Extension; Mobile Node IP Address Extension; User NAI Extension (Optional); and Result Code Extension.

In event **4220**, the Add Tunnel Entry message is sent. See section 4.2.1 for details.

In event **4222**, the Add Tunnel Entry Acknowledgement message is sent. See section 4.2.1 for details.

In event **4224**–**4228**, the AAA-Registration Reply message is sent. See section 4.2.1 for details.

In event **4230**, the Delete Tunnel Exit message is sent. See section 4.2.6 for details.

In event **4232**, the Delete Tunnel Exit Acknowledgement message is sent. See section 4.2.6 for details.

In event **4234**–**36**, the Registration Reply message is sent. See section 4.2.1 for details.

4.2.9 IPM MN Handoffs from ANI to ANI in the Same SMM (Same ITS)

FIG. **43** is a message flow event sequence diagram showing the flow of messages for IPM MN handoffs from ANI to ANI in the same SMM, same ITS.

In event **4302**–**4304**, the Registration Request message is sent. See section 4.2.1 for details.

In event **4310**–**4314**, the AAA-Registration Request message is sent. See section 4.2.1 for details.

In event **4316**–**4320**, the AAA-Registration Reply message is sent. See section 4.2.1 for details.

In event **4322**–**4324**, the Registration Reply message is sent. See section 4.2.1 for details.

4.2.10 IPM MN Handoffs from SMM to SMM

FIG. **44** is a message flow event sequence diagram showing the flow of messages for IPM MN handoffs from SMM to SMM message is sent. See section 4.2.1 for details.

In events **4402**–**4404**, the Registration Request message is sent. See section 4.2.1 for details.

In events **4406**, **4408**, and **4410**, the AAA-Registration Request message is sent. See section 4.2.1 for details.

In events **4407**, **4409**, and **4411**, the AAA-Context-Request message is sent by the current SMM of the User to the previous SMM to request the Context-Data of the User's session.

The AAA-Context-Request message is of the format of DIAMETER. The current SMM of the MN sends this message to previous SMM, to request for the context of the user's data and also to request to forward the data to the current COA. The current SMM sends the IPM-Registration-Request AVP that encapsulates the incoming IPM-Registration-Request message for the previous SMM to authenticate before forwarding the data. The IPM-Context-Request-Type AVP informs the previous SMM what kind of action is requested. Additionally, AVPs, which are discussed further in section 4.5, optionally used in the AAA-Context-Request message are: IPM-Registration-Request AVP; IPM-SMM-NAI AVP; Proxy-State AVP; Time AVP; Nonce AVP; and Integrity-Check-Value AVP.

In events **4413**, **4415**, and **4419**, the AAA-Context-Response message is sent by previous SMM of the User to the current SMM in response to the AAA-Context-Request message. The AAA-Context-Response message is of the format of DIAMETER. The previous SMM of the MN sends this message to current SMM, to response to the AAA-Context-Request message. The successful message must have IPM-Context-Data AVP in the message. Additionally, AVPs, which are discussed further in section 4.5, optionally used in the AAA-Context-Request message are: IPM-Context-Data AVP; Proxy-State AVP; Time AVP; Nonce AVP; and Integrity-Check-Value AVP.

In event **4414**, the Service Response message is sent. See section 4.2.1 for details.

In event **4416**, the Add Tunnel Entry message is sent. See section 4.2.1 for details.

In event **4418**, the Add Tunnel Entry Acknowledgement message is sent. See section 4.2.1 for details.

In events **4420**, **4422**, and **4424**, the AAA-Registration Reply message is sent. See section 4.2.1 for details.

In events **4426**, the Registration Reply message is sent. See section 4.2.1 for details.

In events **4427** and **4428**, the AAA-Binding-Update Request message is sent by the current SMM of the User to the previous SMM to complete the hand-off of the User's session. The AAA-Binding-Update Request message is of the format of DIAMETER. The current SMM of the MN sends this message to the previous SMM, to complete the hand-off of the User's session and clean up of the resources that are allocated for the user. The message contains: a Command-Code of 341; Destination-NAI AVP; Host-Name AVP; User-Name AVP; IPM-Client-Address AVP; and IPM-Care-of-Address AVP. Additionally, AVPs, which are discussed further in section 4.5, optionally used in the AAA-

Binding-Update Request message are: IPM-SMM-NAI AVP; Proxy-State AVP; Time AVP; Nonce AVP; and Integrity-Check-Value AVP.

In events **4430** and **4432**, the AAA-Binding-Update Response message is sent by the previous SMM of the User to the current SMM in response to the AAA-Binding-Update Request message. The AAA-Binding-Update Response message is of the format of DIAMETER. The previous SMM of the MN sends this message to the current SMM, in response to the AAA-Binding-Update Request message. The successful message completes the hand-off of the MN from SMM to SMM. The AAA-Binding-Update Response message contains: Command-Code of 342; Destination-NAI AVP; Host-Name AVP; User-Name AVP; and Result-Code AVP. Additionally, AVPs, which are discussed further in section 4.5, optionally used in the AAA-Binding-Update Request message are: Proxy-State AVP; Time AVP; Nonce AVP; and Integrity-Check-Value AVP.

4.2.11 IPM MN Handoffs LSF to NSF (Home ANI)

FIG. **45** is a message flow event sequence diagram showing the flow of messages for IPM MN handoffs LSF to NSF, home ANI.

In events **4502**–**4504**, the Registration Request message is sent. See section 4.2.1 for details.

In event **4506**, the Service Request message is sent. See section 4.2.1 for details.

In event **4508**, the Service Reply message is sent. See section 4.2.1 for details.

In event **4510**, the Delete Tunnel Entry message is sent. See section 4.2.6 for details.

In event **4512**, the Delete Tunnel Entry Acknowledgement message is sent. See section 4.2.6 for details.

In events **4514** and **4516**, the Registration Reply message is sent. See section 4.2.1 for details.

In events **4515**, **4517**, and **4518**, the AAA-Registration Cancellation message is sent by the HMM to the SMM to cancel the existing User's registration at the visiting system. The AAA-Registration Cancellation message is of the format of DIAMETER. The HMM sends the message to the SMM with at least the mandatory fields to cancel the registration of the user. The IPM-Registration-Cancellation-Reason AVP indicates the reason for the cancellation of the registration. The AAA-Registration Cancellation message contains: Command-Code of 337; Destination-NAI AVP; Host-Name AVP; User-Name AVP; and IPM-Registration-Cancellation-Reason AVP. Additionally, AVPs, which are discussed further in section 4.5, optionally used in the AAA-Binding-Update Request message are: IPM-Client-Address AVP; Proxy-State AVP; Time AVP; Nonce AVP; and Integrity-Check-Value AVP.

In events **4520**–**24**, the AAA-Registration Cancellation Acknowledgement message is sent by the SMM to acknowledge the AAA-Registration Cancellation message. The AAA-Registration Cancellation Acknowledgement message is of the format of DIAMETER. The SMM sends the message to the HMM with at least the mandatory fields. The Response-Code AVP indicates the failure or success of the AAA-Registration Cancellation message. The AAA-Registration Cancellation Acknowledgement message contains: Command-Code of 338; Destination-NAI AVP; Host-Name AVP; User-Name AVP; and Result-Code AVP. Additionally, AVPs, which are discussed further in section 4.5, optionally used in the AAA-Binding-Update Request message are: Proxy-State AVP; Time AVP; Nonce AVP; and Integrity-Check-Value AVP.

4.2.12 IPM MN Handoffs NSF (Home ANI) to LSF

FIG. **46** is a message flow event sequence diagram showing the flow of messages for IPM MN handoffs NSF, home ANI, to LSF.

In events **4602**–**4604**, the Registration Request message is sent. See section 4.2.1 for details.

In events **4606**–**4610**, the AAA-Registration Request message is sent. See section 4.2.1 for details.

In event **4612**, the Service Request message is sent. See section 4.2.1 for details.

In event **4614**, the Service Reply message is sent. See section 4.2.1 for details.

In event **4616**, the Add Tunnel Entry message is sent. See section 4.2.1 for details.

In event **4618**, the Add Tunnel Entry Acknowledgement message is sent. See section 4.2.1 for details.

In events **4620**–**24**, the AAA-Registration Reply message is sent. See section 4.2.1 for details.

In event **4626**, the Add Tunnel Exit message is sent. See section 4.2.1 for details.

In event **4628**, the Add Tunnel Exit Acknowledgement message is sent. See section 4.2.1 for details.

In events **4630**–**32**, the Registration Reply message is sent. See section 4.2.1 for details.

4.2.13 IPM MN Handoffs from LSF to NSF (Foreign ANI)

FIG. **47** is a message flow event sequence diagram showing the flow of messages for IPM MN handoffs from LSF to NSF, foreign ANI.

In events **4702**–**4704**, the Registration Request message is sent. See section 4.2.1 for details.

In event **4706**, the Service Request message is sent. See section 4.2.1 for details.

In event **4708**, the Service Reply message is sent. See section 4.2.1 for details.

In event **4710**, the Add Tunnel Exit message is sent. See section 4.2.1 for details.

In event **4711**, the Add Tunnel Entry message is sent. See section 4.2.1 for details.

In event **4712**, the Add Tunnel Exit Acknowledgement message is sent. See section 4.2.1 for details.

In events **4713**, the Add Tunnel Entry Acknowledgement message is sent. See section 4.2.1 for details.

In events **4714** and **4716**, the Registration Reply message is sent. See section 4.2.1 for details.

In events **4715**, **4717**, and **4718**, the AAA Registration Cancellation message is sent. See section 4.2.11 for details.

In events **4720**–**24**, the AAA Registration Cancellation Acknowledgement message is sent. See section 4.2.11 for details.

4.2.14 IPM MN Handoffs from NSF (Foreign ANI) to LSF

FIG. **48** is a message flow event sequence diagram showing the flow of messages for IPM MN handoffs from NSF, foreign ANI, to LSF.

In events **4802**–**4804**, the Registration Request message is sent. See section 4.2.1 for details.

In events **4806**–**4810**, the AAA Registration Request message is sent. See section 4.2.1 for details.

In event **4812**, the Service Request message is sent. See section 4.2.1 for details.

In event **4814**, the Service Reply message is sent. See section 4.2.1 for details.

In event **4816**, the Add Tunnel Entry message is sent. See section 4.2.1 for details.

In event **4817**, the Delete Tunnel Exit message is sent. See section 4.2.6 for details.

In event **4818**, the Add Tunnel Entry Acknowledgement message is sent. See section 4.2.1 for details.

In event **4819**, the Delete Tunnel Exit Acknowledgement message is sent. See section 4.2.6 for details.

In events **4820**–**24**, the AAA Registration Reply message is sent. See section 4.2.1 for details.

In event **4826**, the Add Tunnel Exit message is sent. See section 4.2.1 for details.

In event **4828**, the Add Tunnel Exit Acknowledgement message is sent. See section 4.2.1 for details.

In events **4830**–**32**, the Registration Reply message is sent. See section 4.2.1 for details.

4.2.15 IPM MN Handoffs from Foreign ANI to Foreign ANI in the Same NSF

FIG. **49** is a message flow event sequence diagram showing the flow of messages for IPM MN handoffs from foreign ANI to foreign ANI in the same NSF.

In events **4902**–**4904**, the Registration Request message is sent. See section 4.2.1 for details.

In event **4906**, the Add Tunnel Exit message is sent. See section 4.2.1 for details.

In event **4908**, the Tunnel Forwarding message is sent. See section 4.2.1 for details.

In event **4910**, the Service Request message is sent. See section 4.2.1 for details.

In event **4912**, the Add Tunnel Exit Acknowledgement message is sent. See section 4.2.1 for details.

In event **4914**, the Tunnel Forwarding Acknowledgement message is sent. See section 4.2.1 for details.

In event **4916**, the Service Reply message is sent. See section 4.2.1 for details.

In event **4918**, the Add Tunnel Entry message is sent. See section 4.2.1 for details.

In event **4920**, the Add Tunnel Entry Acknowledgement message is sent. See section 4.2.1 for details.

In events **4922** and **4926**, the Registration Reply message is sent. See section 4.2.1 for details.

In event **4924**, the Delete Tunnel Exit message is sent. See section 4.2.1 for details.

In event **4928**, the Delete Tunnel Exit Acknowledgement message is sent. See section 4.2.1 for details.

4.2.16 IPM MN Handoffs from Home ANI to Foreign ANI in the Same NSF

FIG. **50** is a message flow event sequence diagram showing the flow of messages for IPM MN handoffs from foreign ANI to foreign ANI in the same NSF.

In events **5002**–**5004**, the Registration Request message is sent. See section 4.2.1 for details.

In event **5006**, the Service Request message is sent. See section 4.2.1 for details.

In event **5008**, the Service Reply message is sent. See section 4.2.1 for details.

In event **5010**, the Add Tunnel Entry message is sent. See section 4.2.1 for details.

In event **5012**, the Add Tunnel Exit message is sent. See section 4.2.1 for details.

In event **5014**, the Add Tunnel Entry Acknowledgement message is sent. See section 4.2.1 for details.

In event **5016**, the Add Tunnel Exit Acknowledgement message is sent. See section 4.2.1 for details.

In events **5018**–**5020**, the Registration Reply message is sent. See section 4.2.1 for details.

4.2.17 IPM MN Handoffs from Foreign ANI to Home ANI in the Same NSF

FIG. **51** is a message flow event sequence diagram showing the flow of messages for IPM MN handoffs from foreign ANI to home ANI in the same NSF.

In events **5102**–**5104**, the Registration Request message is sent. See section 4.2.1 for details.

In event **5106**, the Service Request message is sent. See section 4.2.1 for details.

In event **5108**, the Service Reply message is sent. See section 4.2.1 for details.

In event **5110**, the Delete Tunnel Entry message is sent. See section 4.2.6 for details.

In event **5112**, the Delete Tunnel Exit message is sent. See section 4.2.6 for details.

In event **5114**, the Delete Tunnel Entry Acknowledgement message is sent. See section 4.2.6 for details.

In event **5116**, the Delete Tunnel Exit Acknowledgement message is sent. See section 4.2.6 for details.

In events **5118**–**20**, the Registration Reply message is sent. See section 4.2.1 for details.

4.3 Interworking Message Flow IPM-MIP

4.3.1 IPM MN Registers from MIP FA

FIG. **52** is a message flow event sequence diagram showing the flow of messages for IPM MN registers from MIP FA.

Agent Discovery, events **5202**–**5204**, is the method by which a Mobile Node (MN) determines whether it is currently connected to its home network or to a foreign network, and by which a MN can detect when it has moved from one network to another. Home agents and foreign agents may advertise their availability on each link for which they provide service. A newly arrived MN can send a solicitation on the link to learn if any prospective agents are present. The Agent Discovery Process is primarily handled through Agent Solicitation and Agent Advertisement.

In event **5202**, the Agent Solicitation is the broadcast/multicast message sent by the IPM MN to detect a Service Provider in the event that the IPM MN has not received an Advertising Agent message. The message exchanged between the IPM MN and the MIP FA contains: a Mobile IP address belonging to the interface from which this message is sent, or 0; the configured solicitation address as the destination address; a type of 10; a code of 0; and a checksum value.

In step **5204**, the Agent Advertisement are messages sent periodically, either as a broadcast or multicast for the visiting IPM MN to recognize the availability of service and to keep track of their point of attachment. The message exchanged between the MIP FA and the IPM MN contains: an IP address belonging to the interface from which this message is sent; the configured Advertisement Address or the IP address of a neighboring host as a destination address; a type of 9; a code of 0; a checksum value; the number of router addresses advertised in this message; the number of 32-bit words of information per each router address (2, in the version of the protocol described here); the maximum number of seconds that the router addresses may be considered valid; the sending router's IP address(es) on the interface from which this message is sent; and the preferability of each router address [i] as a default router address, relative to other router addresses on the same subnet.

Additionally, the following extensions, which are explained in further detail in section 4.4, are used in the Agent Advertisement message: Mobility Agent Advertise-

ment Extension; Prefix-Lengths Extension (Optional); and One-Byte Padding Extension (Optional).

In events **5206**–**5208**, Registration Request message is sent by the IPM MN to the HMM to register for the service. The Registration process also includes the authenticating and authorizing of the IPM MN to have access to the visited network or FA.

The purpose of registration is for the IPM MN to inform the HMM of the NSF (Network Serving Function) of its current location to which data packets can be forwarded to the IPM MN. The Registration process also includes the authenticating and authorizing of the MIP MN to have access to the visited network or LSF (Local Serving Function).

The message exchanged between the IPM MN and the HMM contains: an IP address of the MN; the COA within the ANI component as the destination address; a type of 0; the flags as filed with RFC2002; the lifetime requested by MN from the HMM or Home; the IP address of the MN; the Home Agent's address of the MN; the Care-of-Address of the MN; and the identification, to provide replay protection.

Additionally, the following extensions, which are explained in further detail in section 4.4, are used in the Registration Request message: Mobile-Home Authentication Extension; Mobile-Foreign Authentication Extension (Optional); and Foreign-Home Authentication Extension (Optional).

In event **5210**, the Service Request message is sent from the HMM to the ISC (IPM Security Center) to authenticate a user or message, generate, renew, or delete session secret keys. It also can be sent from the PPS Manager to the ISC to generate or construct the IPMC. The message exchanged between the HMM and the ISC contains: a type of USER_SERVICE_REQUEST_MSG; a sub-type of 0; a length of the message payload including all the extensions; an identification number used for matching User Service Request messages with User Service Reply messages, and for protecting against replay attacks of User Service Request messages; and a User NAI.

Additionally, the following extensions, which are explained in further detail in section 4.4, are used in the Service Request message: User Authentication Information Extension; Control Message Authentication Extension; Session Key Allocation Extension 0 . . . N; Session Key Lifetime Renewal Extension 0 . . . N; and Session Key Delete Extension 0 . . . N.

In event **5212**, the Service Reply message is sent from the ISC (IPM Security Center) to the HMM in response to a Service Request message. The message exchanged between the ISC and the HMM contains: a type of USER_SERVICE-_REPLY_MSG; a sub-type of 0; the length of the message payload including all the extensions; a code; an identification number used for matching User Service Request messages with User Service Reply messages, and for protecting against replay attacks of User Service Request messages; and a User NAI. The value of the code is defined as the following hexadecimal value:

00000001 User Authenticated successfully.
00000002 All required keys have been allocated.
00000003 Some keys have been allocated.
00000004 User Authentication failed.
00000005 Key Lifetime Renewal is completely honoured.
00000006 Key Lifetime Renewal is partially honoured.
00000007 User Account is created successfully.
00000008 User is deleted successfully.

Additionally, the following extensions, which are explained in further detail in section 4.4, are used in the Service Reply message: Control Message Authentication Extension; Session Key Allocation Extension 0 . . . N; Session Key Lifetime Renewal Extension 0 . . . N; and Session Key Delete Extension 0 . . . N.

In event **5214**, the Add Tunnel Entry message is sent by the HMM to instruct the ITS to set up a tunnel entry point. The message exchanged between the HMM and the ITS contains: a code of 1; the length of the message including the header fields; and an identification used in matching requests and acknowledgements. The sender must ensure the identifier in a message is locally unique at any given time.

Additionally, the following extensions, which are explained in further detail in section 4.4, are used in the Add Tunnel Entry message: Host NAI Extension; Flag Extension; Lifetime Extension; Mobile Node IP Address Extension; User NAI Extension (Optional); and Tunnel Entry IP Address Extension.

In event **5216**, the Add Tunnel Entry Acknowledgement message is sent by the ITS to acknowledge the Add Tunnel Entry message. The message exchanged between the ITS and the HMM contains: a code of 2; a length of the message including the header fields; and an identification used in matching requests and acknowledgements. The sender must ensure the identifier in a message is locally unique at any given time.

Additionally, the following extensions, which are explained in further detail in section 4.4, are used in the Add Tunnel Entry Acknowledgement message: Host NAI Extension; Result Code Extension; Mobile Node IP Address Extension (Optional); and User NAI Extension (Optional).

In events **5218**–**22**, the Registration Reply message is sent by the HMM to the IPM MN to indicate the result of the Registration Request message sent. The message exchanged between the HMM and the IPM MN contains: a type of 3; the MIP Response codes; the Home lifetime for the registration; the IP address of the MN; the Home Agent's address of the MN; and the identification, to provide replay protection.

Additionally, the following extensions, which are explained in further detail in section 4.4, are used in the Registration Reply message: Mobile-Home Authentication Extension; Foreign-Home Authentication Extension (Optional); and Mobile-Foreign Authentication Extension (Optional).

4.3.2 IPM MN Re-Registers From MIP FA

FIG. **53** is a message flow event sequence diagram showing the flow of messages for IPM MN re-registers from MIP FA.

In events **5302**–**5304**, the Registration Request message is sent. See section 4.3.1 for details.

In event **5306**, the Service Request message is sent. See section 4.3.1 for details.

In event **5308**, the Service Reply message is sent. See section 4.3.1 for details.

In events **5310**–**14**, the Registration Reply message is sent. See section 4.3.1 for details.

4.3.3 IPM MN De-Registers from MIP FA

FIG. **54** is a message flow event sequence diagram showing the flow of messages for IPM MN de-registers from MIP FA.

In events **5402**–**5404**, the Registration Request message is sent. See section 4.3.1 for details.

In event **5406**, the Service Request message is sent. See section 4.3.1 for details.

In event **5408**, the Service Reply message is sent. See section 4.3.1 for details.

In event **5410**, the Delete Tunnel Entry message is sent by the HMM to instruct the ITS to delete a tunnel entry point. The message exchanged between the HMM and the ITS contains: a code of 7; the length of the message including the header fields; and an identification used in matching requests and acknowledgements. The sender must ensure the identifier in a message is locally unique at any given time.

Additionally, the following extensions, which are explained in further detail in section 4.4, are used in the Delete Tunnel Entry message: Host NAI Extension; Mobile Node IP Address Extension; and User NAI Extension (Optional).

In event **5412**, the Delete Tunnel Entry Acknowledgement message is sent by the ITS to acknowledge the Delete Tunnel Entry message. The identification field should be used for matching with the Delete Tunnel Entry message. The message exchanged between the ITS and the HMM contains: a code of 8; the length of the message including the header fields; and an identification used in matching requests and acknowledgements. The sender must ensure the identifier in a message is locally unique at any given time.

Additionally, the following extensions, which are explained in further detail in section 4.4, are used in the Delete Tunnel Entry Acknowledgement message: Host NAI Extension; Result Code Extension; Mobile Node IP Address Extension (Optional); and User NAI Extension (Optional).

In events **5414**–**18**, the Registration Reply message is sent. See section 4.3.1 for details.

4.3.4 IPM MN Handoffs from IPM ANI to FA (No Smooth Handoff)

FIG. **55** is a message flow event sequence diagram showing the flow of messages for IPM MN de-registers from MIP FA.

In events **5502**–**5504**, the Registration Request message is sent. See section 4.3.1 for details.

In event **5506**, the Service Request message is sent. See section 4.3.1 for details.

In event **5508**, the Service Reply message is sent. See section 4.3.1 for details.

In event **5510**, the Add Tunnel Entry message is sent. See section 4.3.1 for details.

In event **5512**, the Add Tunnel Entry Acknowledgement message is sent. See section 4.3.1 for details.

In events **5514** and **5418**, the Registration Reply message is sent. See section 4.3.1 for details.

In events **5516**, **5520**, and **5522**, the AAA-Registration Cancellation message is sent by the HMM to the SMM to cancel the existing User's registration at the visiting system.

The AAA-Registration Cancellation message is of the format of DIAMETER. The HMM sends the message to the SMM with at least the mandatory fields to cancel the registration of the user. The IPM-Registration-Cancellation-Reason AVP indicates the reason for the cancellation of the registration. The AAA-Registration Cancellation message contains: Command-Code AVP of 337, Destination-NAI AVP; Host-Name AVP; User-Name AVP; and IPM-Registration-Cancellation-Reason AVP.

Additionally, the AAA-Registration Cancellation message can optionally use the following AVPs, which are discussed in further detail in section 4.5: IPM-Client-Address AVP; Proxy-State AVP; Time AVP; Nonce AVP; and Integrity-Check-Value AVP.

In event **5524**, the Delete Tunnel Exit message is sent by the SMM to instruct the ITS to delete a tunnel exit point. The message exchanged between the SMM and the ITS contains: a code of 9; the length of the message including the header fields; and an identification used in matching requests and acknowledgements. The sender must ensure the identifier in a message is locally unique at any given time.

Additionally, the following extensions, which are explained in further detail in section 4.4, are used in the Delete Tunnel Exit message: Host NAI Extension; Mobile Node IP Address Extension (Optional); and Tunnel Exit IP Address Extension.

In event **5526**, the Delete Tunnel Exit Acknowledgement message is sent by the ITS to acknowledge the Delete Tunnel Exit message. The identification field should be used for matching with the Delete Tunnel Exit message. The message exchanged between the ITS and the SMM contains: a code of 10; the length of the message including the header fields; and an identification used in matching requests and acknowledgements. The sender must ensure the identifier in a message is locally unique at any given time.

Additionally, the following extensions, which are explained in further detail in section 4.4, are used in the Delete Tunnel Exit message: Host NAI Extension; Result Code Extension; Mobile Node IP Address Extension (Optional); and User NAI Extension (Optional).

In events **5528**–**32**, the AAA-Registration Cancellation Acknowledgement message is sent by the SMM to the HMM in response to the AAA-Registration Cancellation message. The AAA-Registration Cancellation Acknowledgement message is of the format of DIAMETER. The SMM sends the message to the HMM with at least the mandatory fields. The Response-Code AVP indicates the failure or success of the AAA-Registration Cancellation message. The message exchanged between the SMM and the HMM contains: Command-Code AVP of 338, Destination-NAI AVP; Host-Name AVP; User-Name AVP; and Result-Code AVP.

Additionally, the AAA-Registration Cancellation Acknowledgement message can optionally use the following AVPs, which are discussed in further detail in section 4.5: Proxy-State AVP; Time AVP; Nonce AVP; and Integrity-Check-Value AVP.

4.3.5 IPM MN Handoffs from IPM ANI to FA (Smooth Handoff)

FIG. **56** is a message flow event sequence diagram showing the flow of messages for IPM MN handoffs from IPM ANI to FA, smooth handoff.

In events **5602**–**5604**, the Registration Request message is sent. See section 4.3.1 for details.

In events **5606** and **5609**, the Binding Update message is used for notification of a MN's current mobility binding. It should be sent by the MN's home agent in response to a Binding Request message, a Binding Warning message, or the reception of a Binding Warning extension to a Registration Request message. It should also be sent by a MN, or by the foreign agent with which the MN is registering, when notifying the MN's previous foreign agent that the MN has moved. The message exchanged between the MIP FA and the SMM contains: a type of 18; the 'A' (acknowledge) bit is set by the node sending the Binding Update message to request a Binding Acknowledge message be returned; the 'I' (identification present) bit is set by the node sending the Binding Update message if the identification field is present in the message; if the 'M' (minimal encapsulation) bit is set, datagrams MAY be tunneled to the MN using the minimal encapsulation protocol; if the 'G' (Generic Record Encapsulation, or GRE) bit is set, datagrams MAY be tunneled to the MN using GRE; the number of seconds remaining before the binding cache entry must be considered expired; the

home address of the MN to which the Binding Update message refers; the current care-of-address of the MN (when set equal to the home address of the MN, the Binding Update message instead indicates that no binding cache entry for the MN should be created, and any existing binding cache entry and visitor list entry, in the case of a MN's previous foreign agent for the MN should be deleted); and an identification used to assist in matching requests with replies, and in protection against replay attacks.

In event **5608**, the Service Request message is sent. See section 4.3.1 for details.

In event **5610**, the Service Reply message is sent. See section 4.3.1 for details.

In event **5612**, the Tunnel Forwarding message is sent by the SMM to instruct the ITS to set up a tunnel forwarding. The message exchanged between the SMM and the ITS contains: a code of 5; the length of the message including the header fields; and an identification used in matching requests and acknowledgements. The sender must ensure the identifier in a message is locally unique at any given time.

Additionally, the following extensions, which are explained in further detail in section 4.4, are used in the Tunnel Forwarding message: Host NAI Extension; Mobile Node IP Address Extension; User NAI Extension (Optional); Lifetime Extension; and Tunnel Exit IP Address Extension.

In event **5614**, the Add Tunnel Entry message is sent. See section 4.3.1 for details.

In event **5616**, the Tunnel Forwarding Acknowledgement message is sent by the ITS to acknowledge the Tunnel Forwarding message. The identification field should be used for matching with the Tunnel Forwarding message. The message exchanged between the ITS and the SMM contains: a code of 6; the length of the message including the header fields; and an identification used in matching requests and acknowledgements. The sender must ensure the identifier in a message is locally unique at any given time.

Additionally, the following extensions, which are explained in further detail in section 4.4, are used in the Tunnel Forwarding Acknowledgement message: Host NAI Extension; Mobile Node IP Address Extension; User NAI Extension (Optional); and Result Code Extension.

In event **5618**, the Add Tunnel Entry Acknowledgement message is sent. See section 4.3.1 for details.

In events **5620**,**5626**, and **5632**, the Binding Acknowledge message is used to acknowledge receipt of a Binding Update message. It SHOULD be sent by a node receiving a Binding Update message if the acknowledge (A) bit is set in the Binding Update message. The message exchanged between the SMM and the MN contains: a type of 19; the status (if the Status is nonzero, this acknowledgement is negative); a Mobile Node Home Address copied from the Binding Update message being acknowledged; and an identification.

In events **5622** and **5628**, the Registration Reply message is sent. See section 4.3.1 for details.

In events **5624**, **5630**, and **5634**, the AAA-Registration Cancellation message is sent. See section 4.3.1 for details.

In event **5636**, the Delete Tunnel Exit message is sent. See section 4.3.1 for details.

In event **5638**, the Delete Tunnel Exit Acknowledgement message is sent. See section 4.3.1 for details.

In events **5640**–**44**, the AA-Registration Cancellation Acknowledgement message is sent. See section 4.3.1 for details.

4.3.6 IPM MN Handoffs from FA to IPM ANI (No Smooth Handoff)

FIG. **57** is a message flow event sequence diagram showing the flow of messages for IPM MN handoffs from FA to IPM ANI, no smooth handoff.

In events **5702**–**5704**, the Registration Request message is sent. See section 4.3.1 for details.

In events **5706**–**10**, the AAA-Registration-Request message is used to carry out various kinds of registrations; these registrations are encapsulated in the IPM-Registration-Type AVP. This message is used by SMM to authenticate and authorize the user. The AAA-Registration-Request message is of the format of DIAMETER. The SMM sends the message to HMM with at least these mandatory fields. The IPM-Registration-Request AVP is the AVP which carries the message received from the MN, which is encapsulated in the AVP format for the Home domain to authenticate the user. The HMM processes this message based on the Registration-Type AVP, which carries the type of registration requested. The message exchanged between the SMM and the HMM contains: Command-Code AVP of 335; User-Name AVP; Host-Name AVP; IPM-Registration-Type AVP; IPM-Registration-Request AVP; IPM-Care-of-Address AVP; and IPM-Routing-Area-NAI AVP.

Additionally, the AAA-Registration Cancellation Acknowledgement message can optionally use the following AVPs, which are discussed in further detail in section 4.5: Destination-NAI AVP; IPM-Client-Address AVP; Home-Agent-Address AVP; IPM-SMM-NAI AVP; IPM-Terminal-Type AVP; IPM-Profile-Type AVP; Proxy-State AVP; Timestamp AVP; Nonce AVP; and Integrity-Check-Value AVP.

In event **5712**, the Service Request message is sent. See section 4.3.1 for details.

In event **5714**, the Service Reply message is sent. See section 4.3.1 for details.

In event **5716**, the Add Tunnel Entry message is sent. See section 4.3.1 for details.

In event **5718**, the Add Tunnel Entry Acknowledgement message is sent. See section 4.3.1 for details.

In events **5720**–**24**, the AAA Registration Reply message is sent by the HMM to the SMM to indicate the result of the AAA-Registration Request message.

The AAA-Registration Reply message is of the format of DIAMETER. The HMM sends a message to the SMM with at least the mandatory fields in response to AAA-Registration Request message. The IPM-Registration Response Code AVP indicates the success or failure of the request. The IPM Registration Reply message AVP contains the reply message built by HMM with authentication. The SMM has to use this AVP to send a reply to ANI/MN. The message exchanged between the HMM and the SMM contains: Command-Code AVP of 336; Destination-NAI AVP; Host-Name AVP; User-Name AVP; IPM-Registration-Response-Code AVP; IPM-Client-Address AVP; and IPM-Registration-Reply AVP.

Additionally, the Registration Reply message can optionally use the following AVPs, which are discussed in further detail in section 4.5: IPM-Profile AVP; IPM-SMM-MN-Key AVP; IPM-HMM-NAI AVP; Proxy-State AVP; Time AVP; Nonce AVP; and Integrity-Check-Value AVP.

In events **5726** and **5732**, the Registration Reply message is sent. See section 4.3.1 for details.

In event **5728**, the Add Tunnel Exit message is sent by the SMM to instruct the ITS to set up a tunnel exit point. The message exchanged between the SMM and the ITS contains: a code of 3, the length of the message including the header

fields; and an indication used in matching requests and acknowledgements. The sender must ensure the identifier in a message is locally unique at any given time.

Additionally, the following extensions, which are explained in further detail in section 4.4, are used in the Add Tunnel Exit message: Host NAI Extension; Lifetime Extension; Mobile Node IP Address Extension; User NAI Extension (Optional); and Tunnel Exit IP Address Extension.

In event **5730**, the Tunnel Exit Acknowledgement message is sent by the ITS to acknowledge the Add Tunnel Exit message. The message exchanged between the ITS and the SMM contains: a code of 4; the length of the message including the header fields; and an indication used in matching requests and acknowledgements. The sender must ensure the identifier in a message is locally unique at any given time.

Additionally, the following extensions, which are explained in further detail in section 4.4, are used in the Add Tunnel Exit Acknowledgement message: Host NAI Extension; Result Code Extension; Mobile Node IP Address Extension (Optional); User NAI Extension (Optional); and Tunnel Forwarding IP Address Extension.

4.3.7 IPM MN Handoffs from FA to IPM ANI (Smooth Handoff)

FIG. **58** is a message flow event sequence diagram showing the flow of messages for IPM MN handoffs from FA to IPM ANI, smooth handoff.

In events **5802**–**5804**, the Registration Request message is sent. See section 4.3.1 for details.

In events **5806**, **5812**, and **5818**, the AAA-Registration Request message is sent. See section 4.3.6 for details.

In events **5808** and **5814**, the Binding Update message is used for notification of a MN's current mobility binding. It should be sent by the MN's home agent in response to a Binding Request message, a Binding Warning message, or the reception of a Binding Warning extension to a Registration Request message. It should also be sent by a MN, or by the foreign agent with which the MN is registering, when notifying the MN's previous foreign agent that the MN has moved

See section 4.3.5 for details.

In event **5810**, the Add Tunnel Exit message is sent. See section 4.3.6 for details.

In event **5816**, the Add Tunnel Exit Acknowledgement message is sent. See section 4.3.6 for details.

In event **5820**, the Service Request message is sent. See section 4.3.1 for details.

In event **5822**, the Binding Acknowledge message is sent. See section 4.3.5 for details.

In event **5824**, the Service Reply message is sent. See section 4.3.1 for details.

In event **5828**, the Add Tunnel Entry message is sent. See section 4.3.1 for details.

In event **5830**, the Add Tunnel Entry Acknowledgement message is sent. See section 4.3.1 for details.

In events **5832**–**36**, the AAA-Registration Reply message is sent. See section 4.3.6 for details.

In events **5838**–**40**, the Registration Reply message is sent. See section 4.3.1 for details.

4.3.8 MIP MN Registers from IPM LSF

FIG. **59** is a message flow event sequence diagram showing the flow of messages for MIP MN registers from IPM LSF.

In event **5902**, the Agent Solicitation message is sent. See section 4.3.1 for details.

In event **5904**, the Agent Advertisement message is sent. See section 4.3.1 for details.

In events **5906**–**10**, the Registration Request message is sent. See section 4.3.1 for details.

In events **5912** and **5918**–**20**, the Registration Reply message is sent. See section 4.3.1 for details.

In event **5914**, the Add Tunnel Exit message is sent. See section 4.3.6 for details.

In events **5916**, the Add Tunnel Exit Acknowledgement message is sent. See section 4.3.6 for details.

4.3.9 MIP MN Re-Registers from IPM LSF

FIG. **60** is a message flow event sequence diagram showing the flow of messages for MIP MN re-registers from IPM LSF.

In event **6002**, the Agent Solicitation message is sent. See section 4.3.1 for details.

In event **6004**, the Agent Advertisement message is sent. See section 4.3.1 for details.

In events **6006**–**10**, the Registration Request message is sent. See section 4.3.1 for details.

In events **6012**–**16**, the Registration Reply message is sent. See section 4.3.1 for details.

4.3.10 MIP MN Handoffs from IPM ANI to FA (No Smooth Handoff)

FIG. **61** is a message flow event sequence diagram showing the flow of messages for MIP MN handoffs from IPM ANI to FA, no smooth handoff.

In events **6102**–**6104**, the Registration Request message is sent. See section 4.3.1 for details.

In events **6106**–**6108**, the Registration Reply message is sent. See section 4.3.1 for details.

In event **6110**, the Delete Tunnel Exit message is sent. See section 4.3.4 for details.

In event **6112**, the Delete Tunnel Exit Acknowledgement message is sent. See section 4.3.4 for details.

4.3.11 MIP MN Handoffs from IPM ANI to FA (Smooth Handoff)

FIG. **62** is a message flow event sequence diagram showing the flow of messages for MIP MN handoffs from IPM ANI to FA, smooth handoff.

In events **6202**–**6204**, the Registration Request message is sent. See section 4.3.1 for details.

In event **6206**, the Binding Update message is sent. See section 4.3.5 for details.

In events **6208** and **6212**, the Registration Reply message is sent. See section 4.3.1 for details.

In event **6214**, the Tunnel Forwarding message is sent. See section 4.3.5 for details.

In event **6216**, the Tunnel Forwarding Acknowledgement message is sent. See section 4.3.5 for details.

In events **6218**–**22**, the Binding Acknowledge message is sent. See section 4.3.5 for details.

In event **6224**, the Delete Tunnel Exit message is sent. See section 4.3.4 for details.

In event **6226**, the Delete Tunnel Exit Acknowledgement message is sent. See section 4.3.4 for details.

4.3.12 MIP MN Handoffs from FA to IPM ANI (No Smooth Handoff)

FIG. **63** is a message flow event sequence diagram showing the flow of messages for MIP MN handoffs from IPM ANI to FA, no smooth handoff.

In events **6302**–**6306**, the Registration Request message is sent. See section 4.3.1 for details.

In events **6308** and **6314**–**16**, the Registration Reply message is sent. See section 4.3.1 for details.

In event **6310**, the Add Tunnel Exit message is sent. See section 4.3.6 for details.

In event **6312**, the Add Tunnel Exit Acknowledgement message is sent. See section 4.3.6 for details.

4.3.13 MIP MN Handoffs from FA to IPM ANI (Smooth Handoff)

FIG. **64** is a message flow event sequence diagram showing the flow of messages for MIP MN handoffs from IPM ANI to FA, no smooth handoff.

In events **6402**–**6406**, the Registration Request message is sent. See section 4.3.1 for details.

In events **6408** and **6414**, the Binding Update message is sent. See section 4.3.5 for details.

In event **6410**, the Add Tunnel Exit message is sent. See section 4.3.6 for details.

In events **6412**, **6418**, and **6422**, the Registration Reply message is sent. See section 4.3.1 for details.

In event **6416**, the Add Tunnel Exit Acknowledgement message is sent. See section 4.3.6 for details.

In events **6420** and **6424**, the Binding Acknowledge message is sent. See section 4.3.5 for details.

4.3.14 MIP MN Handoffs from NSF to FA (No Smooth Handoff)

FIG. **65** is a message flow event sequence diagram showing the flow of messages for MIP MN handoffs from NSF to FA, no smooth handoff.

In events **6502**–**6504**, the Registration Request message is sent. See section 4.3.1 for details.

In events **6506**–**6508**, the Registration Reply message is sent. See section 4.3.1 for details.

In event **6510**, the Delete Tunnel Exit message is sent. See section 4.3.4 for details.

In event **6512**, the Delete Tunnel Exit Acknowledgement message is sent. See section 4.3.4 for details.

4.3.15 MIP MN Handoffs from NSF to FA (Smooth Handoff)

FIG. **66** is a message flow event sequence diagram showing the flow of messages for MIP MN handoffs from NSF to FA, smooth handoff.

In events **6602**–**6604**, the Registration Request message is sent. See section 4.3.1 for details.

In events **6606** and **6610**, the Binding Update message is sent. See section 4.3.5 for details.

In events **6608** and **6612**, the Registration Reply message is sent. See section 4.3.1 for details.

In event **6614**, the Tunnel Forwarding message is sent. See section 4.3.5 for details.

In event **6616**, the Tunnel Forwarding Acknowledgement message is sent. See section 4.3.5 for details.

In events **6618**–**6622**, the Binding Acknowledge message is sent. See section 4.3.5 for details.

In event **6624**, the Delete Tunnel Exit message is sent. See section 4.3.4 for details.

In event **6626**, the Delete Tunnel Exit Acknowledgement message is sent. See section 4.3.1 for details.

4.3.16 MIP MN Handoffs from FA to NSF (No Smooth Handoff)

FIG. **67** is a message flow event sequence diagram showing the flow of messages for MIP MN handoffs from FA to NSF, no smooth handoff.

In events **6702**–**6706**, the Registration Request message is sent. See section 4.3.1 for details.

In events **6708** and **6714**–**16**, the Registration Reply message is sent. See section 4.3.1 for details.

In event **6710**, the Add Tunnel Exit message is sent. See section 4.3.6 for details.

In event **6712**, the Add Tunnel Exit Acknowledgement message is sent. See section 4.3.6 for details.

4.3.17 MIP MN Handoffs from FA to NSF (Smooth Handoff)

FIG. **68** is a message flow event sequence diagram showing the flow of messages for MIP MN handoffs from FA to NSF, smooth handoff.

In events **6802**–**6806**, the Registration Request message is sent. See section 4.3.1 for details.

In events **6808**, the Binding Update message is sent. See section 4.3.5 for details.

In events **6810** and **6820**, the Registration Reply message is sent. See section 4.3.1 for details.

In events **6812** and **6816**, the Binding Acknowledge message is sent. See section 4.3.5 for details.

In event **6814**, the Add Tunnel Exit message is sent. See section 4.3.6 for details.

In event **6818**, the Add Tunnel Exit Acknowledgement message is sent. See section 4.3.6 for details.

4.4 Extensions

4.4.1 Agent Discovery Extensions

4.4.1.1 ANI-NAI Extension

The ANI-NAI Extension is used to carry the ANI information, such as ANI's NAI (Network Access Identifier). This extension contains: a type of IPM-VENDOR-SPECIFIC-EXTENSION or 255; a length field; a sub-type of 0; and the NAI string of the ANI.

4.4.1.2 Mobility Agent Advertisement Extension

The Mobility Agent Advertisement Extension is added to the ICMP Router Advertisement message to indicate to MNs that this is an Agent Advertisement message (not an Router Advertisement message) with the specified Care-of Addresses. This extension contains: a type of 16; a length of the message including the Care-of-Addresses; the count of Agent Advertisement messages sent since the agent was initialized; the longest lifetime (measured in seconds) that this agent is willing to accept in any Registration Request message; advertised foreign agent Care-of-Addres(es) provided by this foreign agent; and indicator bits for Registration Required, Busy, Home Agent, Foreign Agent, Minimal Encapsulation, GRE Encapsulation, and Van Jackson header compression. An Agent Advertisement message MUST include at least one Care-of Address if the Foreign Agent bit is set. The length field in the extension determines the number of Care-of-Address(es) present.

4.4.1.3 One-Byte Padding Extension

Some IP protocol implementations insist upon padding ICMP messages to an even number of bytes. If the ICMP length of an Agent Advertisement message is odd, this extension may be included in order to make the ICMP length even. This extension is not intended to be a general purpose extension to be included in order to word or long align the various fields of the Agent Advertisement message. An Agent Advertisement message should not include more than one One-byte Padding Extension, and if present, this extension should be the last extension in the Agent Advertisement message.

Note that unlike other extensions used in Mobile IP, the One-byte Padding Extension is encoded as a single byte, with no "Length" or "Data" field present, with a value of zero.

4.4.1.4 Prefix-Lengths Extension

The Prefix-Lengths Extension MAY follow the Mobility Agent Advertisement Extension. It is used to indicate the number of bits of network prefix that applies to each Router Address listed in the ICMP Router Advertisement portion of the Agent Advertisement message. Note that the prefix lengths given do not apply to care-of address(es) listed in the Mobility Agent Advertisement Extension.

This extension contains: a type of 19; the value (possibly zero) of the NUM Addrs field in the ICMP Router Advertisement portion of the Agent Advertisement message; and the number of leading bits that define the network number of the corresponding Router Address listed in the ICMP Router Advertisement portion of the message. The prefix length for each Router Address is encoded as a separate byte, in the order that the Router Addresses are listed in the ICMP Router Advertisement portion of the message.

4.4.2 ITS Control Extensions

All of the extensions for ITS Messages contain a code, an extension length, and data fields.

4.4.2.1 Authentication Extension

The Authentication Extension is used by the ITS to authenticate the requesting message before performing the requested action. The code value is 10 and the extension length and data fields are user dependent.

4.4.2.2 Flag Extension

The Flag Extension is used only if the message type is Add Tunnel Entry. If this Extension is missing, the application should assume that all flags are zero. The code value is 3, the extension length is 6 bytes, and the data field is a 16-bit value with the lower byte contains the flags as defined in RFC 2002 for Registration Request message.

4.4.2.3 Host NAI Extension

The Host NAI Extension is used to let the IPM Tunnel Service (ITS) server know which node a request message comes from. The ITS can maintain the request information per each requesting node so that it can clean up resources for that requesting node when necessary. (Ex. Requesting node is down abnormally). The code value is 1, the extension length is variable, and the data field contains a Host NAI string.

4.4.2.4 Lifetime Extension

The Lifetime Extension is required for Add Tunnel Entry, Add Tunnel Exit, and Tunnel Forwarding. It is required for ITS to implement the session timeout. The code value is 4, the extension length is 8 bytes and the data field is a 32-bit value.

4.4.2.5 Mobile Node IP Address Extension

The Mobile Node IP Address Extension is required for all messages except Delete all . . . messages. The code value is 5, the extension length is 8 bytes for Ipv4 and 20 bytes for Ipv6, and the data field contains the IP address of the MN.

4.4.2.6 Result Code Extension

The Result Code Extension is required for all acknowledgement messages. The code value is 9, the extension length is 6 bytes, and the data field contains the result code of the previous request message.

4.4.2.7 Tunnel Entry IP Address Extension

The Tunnel Entry IP Address Extension is required only for Add Tunnel Entry and Delete Tunnel Entry. The code value is 6, the extension length is 8 bytes for Ipv4 and 20 bytes for Ipv6, and the data field contains the IP address of the Tunnel Entry IP Address.

4.4.2.8 Tunnel Exit IP Address Extension

The Tunnel Exit IP Address Extension is required only for Add Tunnel Exit, Tunnel Forwarding, and Delete Tunnel Exit. The code value is 7, the extension length is 8 bytes for Ipv4 and 20 bytes for Ipv6, and the data field contains the IP address of the Tunnel Exit IP Address.

4.4.2.9 Tunnel Forwarding IP Address Extension

The Tunnel Forwarding IP Address Extension is only required for Tunnel Forwarding. The code value is 8, the extension length is 8 bytes for Ipv4 and 20 bytes for Ipv6, and the data field contains Contains the IP address of the Tunnel Forwarding IP Address.

4.4.2.10 User-NAI Extension

The User-NAI Extension contains the User NAI string. The code value is 2, the extension length is variable, and the data field contains the User-NAI string.

4.4.3 IPM Registration Extensions

4.4.3.1 ANI-HMM Authentication Extension

The ANI-HMM Authentication Extension is used in the Registration messages to carry the Authentication Extension between ANI and HMM. This extension contains: a type of IPM_VENDOR_SPECIFIC_EXTENSION (255); the length of the extension; a sub-type of 6; and the authenticator calculated over the entire message up to the extension header.

4.4.3.2 ANI-SMM Authentication Extension

The ANI-SMM Authentication Extension is used in the Registration essages to carry the Authentication Extension between ANI and SMM. This extension contains: a type of IPM-VENDOR-SPECIFIC-EXTENSION (255); the length of the extension; a sub-type of 5; and the authenticator calculated over the entire message up to the extension header.

4.4.3.3 L2-Address Extension

The L2-Address Extension is used in the Registration Request message to carry the MN's L2 Address. This extension contains: a type of IPM-VENDOR-SPECIFIC-EXTENSION (255); the length of the address plus the header; a sub-type of 9; the Address-Type of the MN; and the layer 2 address of the MN. The Address-Type may be 802.3 Address, 802.11 Address, IMSI, or MIN

4.4.3.4 Local Registration Lifetime Extension

The Local Registration Lifetime Extension is used to carry the lifetime of local registration. This extension contains: a type of IMP_VENDOR_SPECIFIC_EXTENSION (255); a length of 6 bytes; a sub-type of 10; and the lifetime allowed by SMM for local re-registration in seconds.

4.4.3.5 MN-Home Authentication Extension

The MN-Home Authentication Extension is used in the Registration messages to carry the Authentication Extension between the MN and Home. This extension contains: a type of IPM-VENDOR-SPECIFIC-EXTENSION (255); the length of the authenticator plus the header; a sub-type of 3; and the authenticator calculated over the entire message up to the extension header.

4.4.3.6 MN-SMM Authentication Extension

The MN-SMM Authentication Extension is used in the Registration message to carry the Authentication Extension between MN and SMM. This extension contains: a type of IPM-VENDOR-SPECIFIC-EXTENSION (255); a length of

Authenticator plus the header; a sub-type of 4; and the authenticator calculated over the entire message up to the extension header.

4.4.3.7 Foreign-Home Authentication Extension

The Foreign-Home Authentication Extension MAY be included in Registration Requests and Reply messages in cases in which a mobility security association exists between the foreign agent and the home agent. This extension contains: a type of 34; a length of authenticator plus the header; the Security Parameter Index; and a variable length Authenticator.

4.4.3.8 Mobile-Foreign Authentication Extension

The Mobile-Foreign Authentication Extension MAY be included in Registration Requests and Reply message in cases in which a mobility security association exists between the mobile node and the foreign agent. This extension contains: a type of 33; a length of the Authenticator plus the header; the Security Parameter Index; and a variable length Authenticator.

4.4.3.9 Mobile-Home Authentication Extension

Exactly one Mobile-Home Authentication Extension MUST be present in all Registration Requests and Registration Reply messages, and is intended to eliminate problems, which can result from the uncontrolled propagation of remote redirects in the Internet. The location of the extension marks the end of the authenticated data. This extension contains: a type of 32; a length of the Authenticator plus the header; the Security Parameter Index; and a variable length Authenticator.

4.4.3.10 Previous-SMM-NAI Extension

The Previous-SMM-NAI Extension is used in the Registration Request message to carry the previous SMM's NAI. This extension is not applicable with Registration type of "Initial Registration". This extension contains: a type of IPM-VENDOR-SPECIFIC-EXTENSION (255); the length of the SMM-NAI string plus the header; a sub-type of 8; and the NAI string of the SMM.

4.4.3.11 4Registration-Type Extension

The Registration-Type Extension is used in the Registration Request message to indicate what type of registration is requested. This extension contains: a type of IPM-VENDOR-SPECIFIC-EXTENSION (255); a length of 6 bytes; a sub-type of 2; and the Registration type. The Registration types include, among others, Initial Registration (0), De-Registration (1), System-Change (2), ANI-Change (3), Local Re-Registration (4), Re-Registration (5), and Clean-up (6).

4.4.3.12 SMM Key Extension

The SMM Key Extension is used to carry the shared secret key that is to be used between the SMM and MN. This extension contains: a type of IMP_VENDOR_SPECIFIC_EXTENSION (255); a length of the SMM-Key plus the header; a sub-type of 7; and the SMM-Key, which is encrypted using the MN-Home shared secret key.

4.4.3.13 SMM-NAI Extension

The SMM-NAI Extension carries the SMM-NAI in the IPM messages. This extension contains: a type of IMP_VENDOR_SPECIFIC_EXTENSION (255); the length of the SMM-NAI string plus the header; a sub-type of 0; and the NAI string of the SMM.

4.4.3.14 User-NAI Extension

The User-NAI Extension contains the User NAI string. This extension contains: a type of 131; the length of User-NAI; and the User-NAI string.

4.4.4 IPM Security Extensions

4.4.4.1 Control Message Authentication Request Extension

This extension contains: a type of IPM_EXT; a sub-type of CNTL_MSG_AUTH_EXT; the length of all the attributes values; and the attribute values. If the Sub-Type is: 0, then there is no Attribute; 1 then the Data Authentication Request Attribute applies; and 2 then the Data Authentication Reply Attribute applies. The attributes are explained in further detail in section 4.6.

4.4.4.2 Control Message Authentication Reply Extension

This extension contains: a type of IPM_EXT; a sub-type of CNTRL_MSG_AUTH_EXT; the length of all the attributes values; and the attribute values. If the Sub-Type is: 0 then there is no Attribute; 1 then the Data Authentication Request Attribute applies; and 2 then the Data Authentication Reply Attribute applies. The attributes are explained in further detail in section 4.6.

4.4.4.3 Session Key Allocation Extension

The Session Key Allocation Extension is used when allocation of a secret or a public session key is required. The sub-type field value of this extension determines if it is used in the Request or Reply message. This extension contains: a type of KEY_ALLOCATION_EXT; a sub-type; the length of all the attributes values; and the Attribute values. The Sub-Type is: 1 for the Session Key Allocation Request Extension; 2 for the Session Key Allocation Reply Extension, single key allocated; and 3 for the Session Key Allocation Reply Extension, duplicate key allocated. If the Sub-Type is: 1, the Secret Key Request Data Attribute applies; 2, the Single Secret Key Reply Data Attribute applies; and 3, the Duplicate Secret Key Reply Data Attribute applies. The attributes are explained in further detail in section 4.6.

4.4.4.4 Session Key Delete Extension

The Session Key Delete Extension is used when the delete of a secret or public session key is required. This extension contains: a type of IPM_EXTENSIONS; a sub-type of SESSION_KEY_DELETE_REQUEST_EXT; a length of the extension including the Key IDs; and the Key ID assigned by the User Authentication Server.

4.4.4.5 Session Key Lifetime Renewal Extension

The Session Key Lifetime Renewal Extension is used when the renewal of a secret or public session key lifetime is required. Also, it is added to the User Service Reply message if the request is honored by the User Authentication Server. This extension contains: a type of IPM_EXTENSIONS; a sub-type of SESSION_KEY_LIFETIME_RENEWAL_EXT, a length of the extension including the Key IDs; the required new lifetime for the key; and the ID for the key to extend his lifetime.

4.4.4.6 User Authentication Information Extension

The User Authentication Information Extension can only be sent in the User Service Request message. It contains all the needed data attributes, which contain the required information about the user for the process of verification and authentication (e.g. SSN, Account Number, etc.). This extension contains: a type of USER_AUTH_INFO_EXT; a sub-type of 0; the length of all the attributes values. The Attributes used in the User Authentication Information Extension are: Account Number Data Attribute; SSN Data

Attribute (Optional); User Name Data Attribute (Recommended); User Birthday Data Attribute (Recommended); User Password Data Attribute (Optional); User Address Data Attribute (Optional); User Home Phone Number Data Attribute (Optional); User Work Phone Number Data Attribute (Optional); User NAI Data Attribute (Recommended); User PIN Number Data Attribute (Optional); and Digital Signature Data Attribute (Recommended). The Attributes are discussed further in section 4.6.

4.5 AVPS

AVPs is a method of encapsulating information relevant to the DIAMETER message.

DIAMETER AVPs carry specific authentication, accounting and authorization information, security information as well as configuration details for the request and reply messages.

The AVP format is shown below and must be sent in network byte order. The AVPs contain: an AVP Code that identifies the attribute uniquely; the AVP length of this attribute including the AVP Code, AVP Length, AVP Flags, Reserved, The Tag and Vendor ID fields if present and the AVP data; AVP flags that inform the DIAMETER host how each attribute must be handled; a Vendor ID field; a Tag field to provide a means of grouping attributes in the same message which refer to the same set; and a Data field, which contains information specific to the attribute.

The AVP Flags include, among others: Reserved Bits; a mandatory bit, indicates whether support of the AVP is required; a Vendor-Specific bit, indicates whether the optional Vendor ID field is present in the AVP header; and a Tag bit, is used to group sets of AVPs together.

The Data Field may be one of several types, among others. First, the data may contain a variable length of arbitrary data. Unless otherwise noted, the AVP Length field MUST be set to at least 9. Second, the data may contain a non-NULL terminated variable length string using the UTF-8 character set. Unless otherwise noted, the AVP Length field MUST be set to at least 9. Third, it may be an address as a 32 bit (Ipv4) or 128 bit (Ipv6) address, most significant octet first. The format of the address (Ipv4 or Ipv6) is determined by the length. If the attribute value is an Ipv4 address, the AVP Length field MUST be 12, otherwise the AVP Length field MUST be set to 24 for Ipv6 addresses. Fourth, it may be a 32-bit value, in network byte order. The AVP Length field MUST be set to 12. Fifth, it may be a 64-bit value, in network byte order. The AVP Length field MUST be set to 16. Sixth, it may be indicate a time as a 32-bit unsigned value, in network byte order, and contains the seconds since 00:00:00 GMT, Jan. 1, 1900. The AVP Length field MUST be set to 12. Finally, it may be a complex data type is reserved for AVPs that includes multiple information fields, and therefore do not fit within any of the AVP types defined above. Complex AVPs must provide the data format, and the expected length of the AVP.

4.5.1 Command-Code AVP

The Command-Code AVP must be the first AVP following the DIAMETER header. A DIAMETER message must have at most one Command-Code AVP, and it is used in order to communicate the command associated with the message. The code value is 256 and the type is Integer32.

4.5.2 Destination-NAI AVP

This AVP is used to carry the NAI of the destination. The code value is 269 and the type is String.

4.5.3 Home-Agent-Address AVP

This AVP contains the MN's Home Agent Address. The code value is 334 and the type is Address.

4.5.4 Host-Name AVP

The Host-Name AVP is used to inform a DIAMETER peer of the sender's identity. All DIAMETER messages MUST include the Host-Name AVP, which contains the host name of the originator of the DIAMETER message that MUST follow the NAI naming conventions. The code value is 32 and the type is String.

4.5.5 IPM-Care-of-Address AVP

This AVP is used to carry the MN's Care-of-Address. The code value is 362 and the type is Address.

4.5.6 IPM-Client-Address AVP

This AVP is used to carry the MN's IP Address, either Static or Dynamic. The code value is 360 and the type is Address.

4.5.7 IPM-Context-Data AVP

This AVP carries the Context Data of the User at previous SMM. The complex data could contain AVP format data. The Context-Data could potentially carry the QOS information that MN was receiving at previous SMM. The code value is 373 and the type is Data.

4.5.8 IPM-Context-Request-Type AVP

This AVP carries the Context requested by the SMM. The code value is 372 and the type is Integer32. The Context-Request is: 0; 1 with IP-Forwarding; and 2 with IP-Buffering.

4.5.9 IPM-HMM-NAI AVP

This AVP is used to carry the HMM's NAI. The code value is 364 and the type is String.

4.5.10 IPM-L2-Address AVP

This AVP carries the L2-Address of IPM Client connection. The AVP carries both the types of Address and Data. The code value is 374 and the type is Data. The types of Addresses include, among others, 802.3 Address (0), 802.11 Address (1), IMSI (2), and MIN (3).

4.5.11 IPM-Profile AVP

This AVP carries the Profile of the User, who is registering. The complex data could contain AVP format data. The code value is 371 and the type is Data.

4.5.12 IPM-Profile-Type AVP

This AVP carries the user Profile requested by SMM with the IRR message. The code value is 370 and the type is Integer32. The Profile types include, among others: Partial (0)—Minimal Profile required; and Full (1)—Complete Profile of the user.

4.5.13 IPM-Registration-Cancellation-Reason AVP

This AVP carries the reason for the Registration Cancellation message being sent by MNN to SMM. The code value is 375 and the type is Integer32.

4.5.14 IPM-Registration-Reply AVP

This AVP carries IPM Registration-Reply message received from the HMM to SMM. The code value is 367 and the type is Data.

4.5.15 IPM-Registration-Request AVP

This AVP carries either complete or partial IPM-Registration Request message received from the MN. The code value is 366 and the type is Data.

4.5.16 IPM-Registration-Response-Code AVP

This AVP carries the Registration-Response-Code. The code value is 368 and the type is Integer32.

4.5.17 IPM-Registration-Type AVP

This AVP is used to carry the type of Registration. The code value is 361 and the type is Integer32. The types of Registration include, among others: Initial Registration (0); De-Registration (1); System-Change (2); ANI-Change (3); Local Re-Registration (4); Re-Registration (5); Clean-Up (6); Location-Update (7); and Admin-Initiated-Clean-Up (8).

4.5.18 IPM-Routing-Area-NAI AVP

This AVP carries the ANI's NAI, where the MN is currently registered. The code value is 365 and the type is String.

4.5.19 IPM-SMM-MN-Key AVP

This AVP carries the shared secret key between SMM and MN. This key is only valid for the session. The code value is 376 and the type is Data.

4.5.20 IPM-SMM-NAI AVP

This AVP carries the SMM's NAI. The code value is 363 and the type is String.

4.5.21 IPM-Terminal-Type AVP

This AVP carries the Terminal Type of MN. The code value is 369 and the type is Integer32. The Terminal-Types include, among others: 802.3 Type Terminal (1); 802.11 Type Terminal (1); IS91 Type Terminal (2); IS36 Type Terminal (3); IS96 Type Terminal (4); Modem (5); and Unknown Terminal (#ffffffff).

4.5.22 Integrity-Check-Value AVP

The Integrity-Check-Value AVP is used for hop-by-hop message authentication and integrity. The code value is 259 and the type is Complex.

4.5.23 Nonce AVP

The Nonce AVP MUST be present prior to the Integrity-Check-Value AVPs within a message and is used to ensure randomness within a message. The code value is 261 and the type is Data.

4.5.24 Proxy-State AVP

The Proxy-State AVP is used by proxy servers when forwarding requests and contains opaque data that is used by the proxy to further process the response. The code value is 33 and the type is Address.

4.5.25 Result-Code AVP

The Result-Code AVP indicates whether a particular request was completed successfully or whether an error occurred. The code value is 268 and the type is Complex.

4.5.26 Timestamp AVP

The Timestamp AVP is used to add replay protection to the DIAMETER protocol. This AVP MSUT appear prior to the Integrity-Check-Value AVP or any other message integrity AVP defined in separate extensions. The code value is 262 and the type is Time.

4.5.27 User-Name AVP

The User-Name AVP contains the User-Name in a format consistent with the NAI specification. All DIAMETER systems SHOULD support usernames of at least 72 octets in length. The code value is 1 and the type is String.

4.6 Attributes

Data Attribute is a payload for extensions. The format of the Data Attributes provides the flexibility for representation of many different types of information. There can be multiple Data Attributes within any extension payload. The length of Data Attributes will either be 2 octets or defined by the payload length field. Data Attributes contain: an Attr Type (AT), a unique identifier for each type of attribute; a Sub-Type, which defines the attribute sub-type; an Attribute Format (AF) that format indicates whether the data attribute follows the type Type/Value (TV) format (AF=1) or follows the Type/Length/Value (TLV) format (AF=0); the length of the attribute value; and a variable length attribute value.

4.6.1 Account Number Data Attribute

The Account Number Data Attribute defines the User's account number assigned by the ISP. The AF is 0, the AT is 1, the length is 4, and the attribute value is the Account Number Value. The sub-type values are: 0, for the default value; 1 for secret key encryption using the shared secret key between the user and its home domain; 2 for public key encryption using the user's private key; and 3 for public key encryption using the home domain public key.

4.6.2 Data Authentication Reply Attribute

The Data Authentication Reply Attribute carries the authenticator, which is the result of running the hash function on the authentication data provided in the Data Authentication Request Attribute. The AF is 0, the AT is 24, the length is variable, and the attribute value is the Authenticator Data. The sub-type values are: 0 for the default sub-type; 1 for secret key encryption using the shared secret key between the user and its home domain; 2 for public key encryption using the user's private key; and 3 for public key encryption using the home domain public key.

4.6.3 Data Authentication Request Attribute

The Data Authentication Request Attribute is used to carry the data, which needs to be authenticated by the IPM Security Center by running the hash function on this data. The AF is 0, the AT is 23, the length is variable, and the attribute value is the Authentication Data.

The Authentication Data is is the control message data, which needs to be authenticated by the IPM Security Center by running the hash function on this data.

The sub-type values are: 0 for the default sub-type; 1 for secret key encryption using the shared secret key between the user and its home domain; 2 for public key encryption using the user's private key; and 3 for public key encryption using the home domain public key.

4.6.4 Digital Signature Data Attribute

The Digital Signature Data Attribute defines the User's Digital Signature, which is created by running a hash function H (e.g. MD5) over a message fragment. This Attribute should be encrypted using the full secret key between the MN and its home domain or the private key for the MN. The AF is 0, the AT is 11, the length is variable, and the attribute value is the Digital Signature Value.

The Digital Signature Value is a sequence of bytes generated from running a hash function over all the attribute's payload for the User Authentication Information Extension.

The sub-type values are: 0 for the default sub-type; 1 for secret key encryption using the shared secret key between the user and its home domain; 2 for public key encryption using the user's private key; and 3 for public key encryption using the home domain public key.

4.6.5 Duplicate Secret Key Reply Data Attribute

The Duplicate Secret Key Reply Data Attribute carries the session key information, which is allocated by IPM Security Center. Another encrypted copy is generated and sent in

conjunction with the original one. This attribute can be included in the Session Key Allocation Extension when the extension sub-type field value is 3. The AF is 0, the AT is 22, the length is variable, and the attribute value is the Key ID (the key unique identifier issued by the IPM Security Center), Key Data (the secret key generated by the IPM Security Center), and the Encrypted Duplicate Key Data (a copy from the key data encrypted by the method defined by the sub-type field).

The sub-type values are: 0 for the default sub-type; 1 for secret key encryption using the shared secret key between the user and its home domain; and 2 for public key encryption using the user's private key.

4.6.6 SSN Data Attribute

The SSN Data Attribute defines the User's SSN. The AF is 0, the AT is 2, the length is 4, and the attribute value is the SSN Value.

The Digital Signature Value is a sequence of bytes generated from running a hash function over all the attribute's payload for the User Authentication Information Extension.

The sub-type values are: 0 for the default sub-type; 1 for secret key encryption using the shared secret key between the user and its home domain; 2 for public key encryption using the user's private key; and 3 for public key encryption using the home domain public key.

4.6.7 Secret Key Request Data Attribute

The Secret Key Request Data Attribute is used to request a dynamically allocated session secret key with a specific length from the IPM Security Center. The Session Key Allocation Request Extension may have multiple Secret Key Request Data Attributes. The AF is 1, the AT is 20, the length is variable, and the attribute value is the Encryption Type, Key length, and a request number.

The sub-type values are: 0 for a single key to be allocated and encrypted using the Encryption type; and 1 for a single key to be allocated and duplicated, the duplicate will be encrypted by the encryption method defined by the Encryption Type field

The Encryption Type values are: 0 for the default sub-type; 1 for secret key encryption using the shared secret key between the user and its home domain; and 2 for public key encryption using the user's private key.

The request number is a number that distinguishes between the different key allocation requests issued to the IPM Security Center. The issuer of the request will use the request number to match the key allocation request with the Key Allocation Reply.

4.6.8 Single Secret Key Reply Data Attribute

The Single Secret Key Reply Data Attribute carries the session key information, which is allocated by the IPM Security Center. This attribute is carried by the Session Key Allocation Extension when the extension Sub-Type value is 2. The AF is 0, the AT is 21, the length is variable, and the attribute value is the key lifetime, a Security Parameter Index, a Key ID, and the Key Data The sub-type values are: 0 for the default sub-type; 1 for secret key encryption using the shared secret key between the user and its home domain; and 2 for public key encryption using the user's private key.

The Security Parameter Index in conjunction with the generated key will be used to define a security association between two entities (e.g. MN and HMM, MN and SMM).

4.6.9 User Address Data Attribute

The User Address Data Attribute defines the User's current address. The AF is 0, the AT is 6, the length is variable, and the attribute value is the User Address Value.

The sub-type values are: 0 for the default sub-type; 1 for secret key encryption using the shared secret key between the user and its home domain; 2 for public key encryption using the user's private key; and 3 for public key encryption using the home domain public key.

The User Address Value contains the country, state, city, street, and apartment number.

4.6.10 User Birthday Data Attribute

The User Birthday Data Attribute defines the User's birthday. The AF is 0, the AT is 4, the length is variable, and the attribute value is the User Birthday Value.

The sub-type values are: 0 for the default sub-type; 1 for secret key encryption using the shared secret key between the user and its home domain; 2 for public key encryption using the user's private key; and 3 for public key encryption using the home domain public key.

The User Birthday contains the month, day, and year.

4.6.11 User Home Phone Number Data Attribute

The User Home Phone Number Data Attribute defines the User's home phone number. The AF is 0, the AT is 7, the length is variable, and the attribute value is the User Home Phone Number Value.

The sub-type values are: 0 for the default sub-type; 1 for secret key encryption using the shared secret key between the user and its home domain; 2 for public key encryption using the user's private key; and 3 for public key encryption using the home domain public key.

4.6.12 User NAI Data Attribute

The User NAI Data Attribute defines the User Network Access Identifier. The AF is 0, the AT is 9, the length is variable, and the attribute value is the User NAI Data.

The sub-type values are: 0 for the default sub-type; 1 for secret key encryption using the shared secret key between the user and its home domain; 2 for public key encryption using the user's private key; and 3 for public key encryption using the home domain public key.

The User NAI contains a string representing the User Network Access Identifier.

4.6.13 User Name Data Attribute

The User Name Data Attribute defines the User's full name. The AF is 0, the AT is 3, the length is variable, and the attribute value is the User Name Data.

The sub-type values are: 0 for the default sub-type; 1 for secret key encryption using the shared secret key between the user and its home domain; 2 for public key encryption using the user's private key; and 3 for public key encryption using the home domain public key.

The User Name Value contains the user's first, middle, and last name.

4.6.14 User Password Data Attribute

The User Password Data Attribute defines the User's password. The AF is 0, the AT is 5, the length is variable, and the attribute value is the User Password Data.

The sub-type values are: 0 for the default sub-type; 1 for secret key encryption using the shared secret key between the user and its home domain; 2 for public key encryption using the user's private key; and 3 for public key encryption using the home domain public key.

The User Password Data is a string representing the user's password.

4.6.15 User Pin Number Data Attribute

It is an integer value selected by the user to secure access to his account This Attribute may be included with User

Authentication Information Extension. The AF is 0, the AT is 10, the length is variable, and the attribute value is the User PIN Number Data.

The sub-type values are: 0 for the default sub-type; 1 for secret key encryption using the shared secret key between the user and its home domain; 2 for public key encryption using the user's private key; and 3 for public key encryption using the home domain public key.

4.6.16 User Work Phone Number Data Attribute

The User Work Phone Number Data Attribute defines the User's work phone number. One or more of these Attributes may be included with the User Authentication Information Extension. The AF is 0, the AT is 8, the length is variable, and the attribute value is the User Work Phone Number Data.

The sub-type values are: 0 for the default sub-type; 1 for secret key encryption using the shared secret key between the user and its home domain; 2 for public key encryption using the user's private key; and 3 for public key encryption using the home domain public key.

The use of the present invention results in a flexible and scalable architecture that supports user mobility across heterogeneous access networks in a totally IP centric network. Furthermore, the present invention achieves these results and provides a Mobility Enabled Network using many existing and/or proposed IP technologies and philosophies (defined, e.g., by the IETF or ITU) to achieve the foregoing results. Such a network may be used for a number for purposes. For example, the network may be used to evolve existing Cellular Networks and/or become the Next Generation (NG) Network base reference; the network may be used to provide an enhanced Intranet for enterprise, that is, an Intranet that supports seamless mobility for users between subnets, access technologies, and has an integrated voice and data network; the network may be used as a product offering for Mobility Internet Service Provider (ISP) services offering; and/or the network may be used to provide "Always-On" loop access.

It is understood that the present invention may take many forms and embodiments. Accordingly, several variations may be made in the foregoing without departing from the spirit or the scope of the invention. For example, while the Internet may constitute a public domain network, the present invention may comprise an IP based network that is not necessarily part of the public Internet.

Having thus described the present invention by reference to certain of its preferred embodiments, it is noted that the embodiments disclosed are illustrative rather than limiting in nature and that a wide range of variations, modifications, changes, and substitutions are contemplated in the foregoing disclosure and, in some instances, some features of the present invention may be employed without a corresponding use of the other features. Many such variations and modifications may be considered obvious and desirable by those skilled in the art based upon a review of the foregoing description of preferred embodiments. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the scope of the invention.

The invention claimed is:

1. A Unified Directory Service (UDS) schema for a database configured to store information about a user of an IP-based mobile communications architecture, the schema comprising:

a) an ipmUser object class for storing information about the user, which information is required for services to which a user is subscribed;

b) one or more ipmUserProfile object classes related in the database to the ipmUser object class for storing information selected from the ipmUser object class which is associated for each service to which a user is subscribed;

c) zero or more ipmUserDevice object classes related in the database to the ipmUser object class and to the ipmUserProfile object class for storing information about each device through which a user is authorized to communicate with a network;

d) one or more ipmClassOfService object classes related in the database to the ipmUserProfile object class for storing information about the class of service a user is entitled to receive for one or more services to which the user is subscribed;

e) one or more ipmLsfDomain object classes related in the database to the ipmClassOfService object class for storing information about a serving network through which a user is contemporaneiously accessing;

f) one or more ipmLsfSubnet object classes related in the database to the ipmLsfDomain object class for storing the IP address of a subnetwork that a user is contemporaneously accessing;

g) one or more ipmNsfSubnet object classes related in the database to the ipmUser object class for storing at a home network, information about an IP subnetwork; and

h) an ipmNsfDomain object class related in the database to the ipmNsfSubnet object class for storing information about a home network of a user.

2. The UDS schema of claim **1** wherein the ipmUser object class comprises an ipmUserProfile object class, an ipmUserDevice object class, and an ipmNsfSubnet object class.

3. The UDS schema of claim **1** wherein the IPM user profile comprises a plurality of object classes including an ipmUser object class, an ipmUserProfile object class, an ipmUserDevice object class, and an ipmClassOfService object class.

4. The UDS schema of claim **1** wherein the IPM user profile comprises a user name, a mobile node address, a class of service, an account number, and a care of address.

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