(54) Title: COVERAGE ENHANCEMENT RESTRICTION FOR CIOT DEVICES
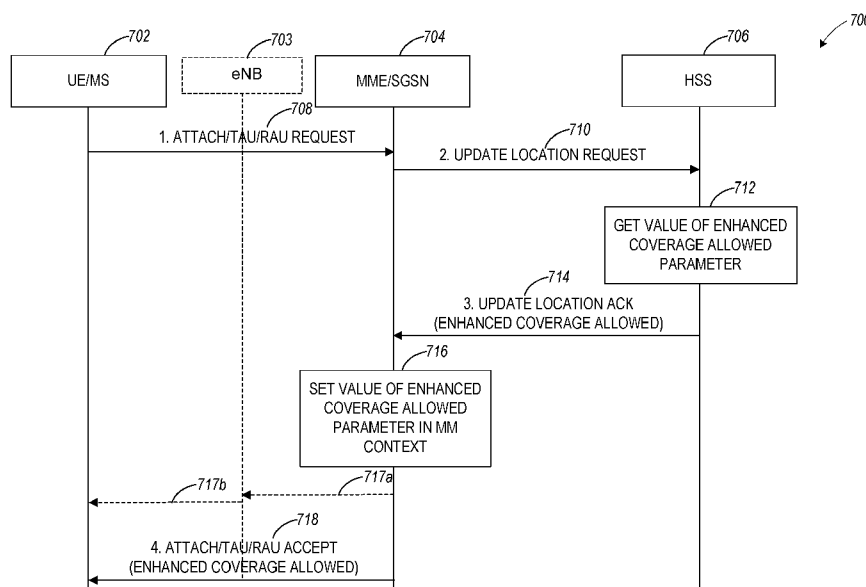
FIG. 7

(57) Abstract: An apparatus of a Cellular-Internet-of-Things (CIoT) capable user equipment (UE) is configured for Evolved Packet System (EPS) communications in a Public Land Mobile Network (PLMN). The apparatus includes processing circuitry configured to encode an Attach Request message for transmission to a Mobility Management Entity (MME) in the EPS, the Attach Request message including a UE Network Capability Information Element (IE) indicating whether the UE supports restriction on using enhanced coverage. The processing circuitry can decode an Attach Accept message confirming attachment to the MME, the Attach Accept message including an EPS Network Feature Support IE indicating whether use of enhanced coverage is restricted for the UE. The processing circuitry can refrain from using enhanced coverage in the PLMN when the UE supports restriction on using enhanced coverage and the EPS Network Feature Support IE indicates enhanced coverage is restricted for the UE.

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COVERAGE ENHANCEMENT RESTRICTION FOR CIOT DEVICES

PRIORITY CLAIM

[0001] This application claims the benefit of priority to United States Provisional Patent Application Serial No. 62/444,200, filed January 9, 2017, and entitled "RESTRICTIONS FOR COVERAGE ENHANCEMENTS FOR CIOT DEVICES," which provisional application is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] Aspects pertain to wireless communications. Some aspects relate to wireless networks including 3GPP (Third Generation Partnership Project) networks, 3GPP LTE (Long Term Evolution) networks, 3GPP LTE-A (LTE Advanced) networks, and fifth-generation (5G) networks including new radio (NR) networks. Other aspects are directed to coverage enhancement (CE) restriction for Cellular Internet-of-Things (CIoT) devices.

BACKGROUND

[0003] Mobile communications have evolved significantly from early voice systems to today's highly sophisticated integrated communication platform. With the increase in different types of devices communicating with various network devices, usage of 3GPP LTE systems has increased. The penetration of mobile devices (user equipment or UEs) in modern society has continued to drive demand for a wide variety of networked devices in a number of disparate environments.

[0004] LTE and LTE-Advanced are standards for wireless communications of high-speed data for user equipment (UE) such as mobile telephones. In LTE-Advanced and various wireless systems, carrier aggregation is a technology according to which multiple carrier signals operating on different frequencies may be used to carry communications for

a single UE, thus increasing the bandwidth available to a single device. In some aspects, carrier aggregation may be used where one or more component carriers operate on unlicensed frequencies.

[0005]   The use of networked UEs using 3GPP LTE systems has increased in areas of home and work life. Fifth generation (5G) wireless systems are forthcoming, and are expected to enable even greater speed, connectivity, and usability. Next generation 5G networks are expected to increase throughput, coverage, and robustness. As current cellular network frequency is saturated, high frequencies, such as millimeter wave (mmWave) frequency, can be beneficial due to their high bandwidth.

[0006]   The explosive wireless traffic growth leads to a need of rate improvement. With mature physical layer techniques, further improvement in the spectral efficiency may be marginal. On the other hand, the scarcity of licensed spectrum in low frequency bands results in a deficit in the data rate boost. Thus, there are emerging interests in the operation of LTE systems in the unlicensed spectrum. As a result, an important enhancement for LTE in 3GPP Release 13 has been to enable its operation in the unlicensed spectrum via Licensed-Assisted Access (LAA), which expands the system bandwidth by utilizing the flexible carrier aggregation (CA) framework introduced by the LTE-Advanced system. Rel-13 LAA system focuses on the design of downlink operation on unlicensed spectrum via CA, while Rel-14 enhanced LAA (eLAA) system focuses on the design of uplink operation on unlicensed spectrum via CA.

[0007]   Potential LTE operation in the unlicensed spectrum includes (and is not limited to) the LTE operation in the unlicensed spectrum via dual connectivity (DC), or DC-based LAA, and the standalone LTE system in the unlicensed spectrum, according to which LTE-based technology solely operates in unlicensed spectrum without requiring an "anchor" in the licensed spectrum, called MulteFire. MulteFire, combines the performance benefits of LTE technology with the simplicity of Wi-Fi-like deployments. Further enhanced operation of LTE systems in the licensed as well as unlicensed spectrum is expected in future releases and 5G systems.

[0008]   Machine-to-Machine (M2M) communications represents a significant growth opportunity for 3GPP ecosystems. With proliferation of the wireless networks, there is an accelerated push towards connected, smart physical objects, such as wireless sensors, smart meters, dedicated microprocessors, etc., that span different ecosystems with diverse business models.

BRIEF DESCRIPTION OF THE FIGURES

[0009]   In the figures, which are not necessarily drawn to scale, like numerals may describe similar components in different views. Like numerals having different letter suffixes may represent different instances of similar components. The figures illustrate generally, by way of example, but not by way of limitation, various aspects discussed in the present document.

[0010]   FIG. 1A illustrates an architecture of a network in accordance with some aspects.

[0011]   FIG. 1B is a simplified diagram of an overall next generation (NG) system architecture in accordance with some aspects.

[0012]   FIG. 1C illustrates a functional split between NG – RAN and the 5G Core (5GC) in accordance with some aspects.

[0013]   FIG. 1D and FIG. 1E illustrate a non-roaming 5G system architecture in accordance with some aspects.

[0014]   FIG. 1F illustrates an example CIoT network architecture in accordance with some aspects.

[0015]   FIG. 2 illustrates example components of a device 200 in accordance with some aspects.

[0016]   FIG. 3 illustrates example interfaces of baseband circuitry in accordance with some aspects.

[0017]   FIG. 4 is an illustration of a control plane protocol stack in accordance with some aspects.

[0018]   FIG. 5 is an illustration of a user plane protocol stack in accordance with some aspects.

[0019]   FIG. 6 is a block diagram illustrating components, according to some example aspects, able to read instructions from a machine-readable or computer-readable medium (e.g., a non-transitory machine-readable storage medium) and perform any one or more of the methodologies discussed herein.

[0020]   FIG. 7 illustrates an example communication sequence in a CIoT environment in accordance with some aspects.

[0021]   FIG. 8 illustrates an example UE Network Capability information element in accordance with some aspects.

[0022]   FIG. 9 illustrates an example EPS Network Feature Support information element in accordance with some aspects.

[0023]   FIG. 10 illustrates an example MS Network Capability information element in accordance with some aspects.

[0024]   FIG. 11 illustrates an example Additional Network Feature Support information element in accordance with some aspects.

[0025]   FIG. 12 illustrates generally a flowchart of an example method of operating a UE supporting restriction on using enhanced coverage, in accordance with some aspects.

[0026]   FIG. 13 illustrates a block diagram of a communication device such as an evolved Node-B (eNB), a new generation Node-B (gNB), an access point (AP), a wireless station (STA), a mobile station (MS), or a user equipment (UE), in accordance with some aspects.

DETAILED DESCRIPTION

[0027]   The following description and the drawings sufficiently illustrate aspects to enable those skilled in the art to practice them. Other aspects may incorporate structural, logical, electrical, process, and other changes. Portions and features of some aspects may be included in, or substituted for, those of other aspects. Aspects set forth in the claims encompass all available equivalents of those claims.

[0028]   Any of the radio links described herein may operate according to any one or more of the following exemplary radio

communication technologies and/or standards including but not limited
to: a Global System for Mobile Communications (GSM) radio
communication technology, a General Packet Radio Service (GPRS) radio
communication technology, an Enhanced Data Rates for GSM Evolution
(EDGE) radio communication technology, and/or a Third Generation
Partnership Project (3GPP) radio communication technology, for example
Universal Mobile Telecommunications System (UMTS), Freedom of
Multimedia Access (FOMA), 3GPP Long Term Evolution (LTE), 3GPP
Long Term Evolution Advanced (LTE Advanced), Code division multiple
access 2000 (CDMA2000), Cellular Digital Packet Data (CDPD), Mobitex,
Third Generation (3G), Circuit Switched Data (CSD), High-Speed Circuit-
Switched Data (HSCSD), Universal Mobile Telecommunications System
(Third Generation) (UMTS (3G)), Wideband Code Division Multiple
Access (Universal Mobile Telecommunications System) (W-CDMA
(UMTS)), High Speed Packet Access (HSPA), High-Speed Downlink
Packet Access (HSDPA), High-Speed Uplink Packet Access (HSUPA),
High Speed Packet Access Plus (HSPA+), Universal Mobile
Telecommunications System-Time-Division Duplex (UMTS-TDD), Time
Division-Code Division Multiple Access (TD-CDMA), Time Division-
Synchronous Code Division Multiple Access (TD-CDMA), 3rd Generation
Partnership Project Release 8 (Pre-4th Generation) (3GPP Rel. 8 (Pre-4G)),
3GPP Rel. 9 (3rd Generation Partnership Project Release 9), 3GPP Rel. 10
(3rd Generation Partnership Project Release 10), 3GPP Rel. 11 (3rd
Generation Partnership Project Release 11), 3GPP Rel. 12 (3rd Generation
Partnership Project Release 12), 3GPP Rel. 13 (3rd Generation Partnership
Project Release 13), 3GPP Rel. 14 (3rd Generation Partnership Project
Release 14), 3GPP Rel. 15 (3rd Generation Partnership Project Release 15),
3GPP Rel. 16 (3rd Generation Partnership Project Release 16), 3GPP Rel.
17 (3rd Generation Partnership Project Release 17), 3GPP Rel. 18 (3rd
Generation Partnership Project Release 18), 3GPP 5G, 3GPP LTE Extra,
LTE-Advanced Pro, LTE Licensed-Assisted Access (LAA), MuLTEfire,
UMTS Terrestrial Radio Access (UTRA), Evolved UMTS Terrestrial
Radio Access (E-UTRA), Long Term Evolution Advanced (4th
Generation) (LTE Advanced (4G)), cdmaOne (2G), Code division multiple

access 2000 (Third generation) (CDMA2000 (3G)), Evolution-Data

Optimized or Evolution-Data Only (EV-DO), Advanced Mobile Phone

System (1st Generation) (AMPS (1G)), Total Access Communication

System/Extended Total Access Communication System (TACS/ETACS),

Digital AMPS (2nd Generation) (D-AMPS (2G)), Push-to-talk (PTT),

Mobile Telephone System (MTS), Improved Mobile Telephone System

(IMTS), Advanced Mobile Telephone System (AMTS), OLT (Norwegian

for Offentlig Landmobil Telefoni, Public Land Mobile Telephony), MTD

(Swedish abbreviation for Mobiltelefonisystem D, or Mobile telephony

system D), Public Automated Land Mobile (Autotel/PALM), ARP (Finnish

for Autoradiopuhelin, "car radio phone"), NMT (Nordic Mobile

Telephony), High capacity version of NTT (Nippon Telegraph and

Telephone) (Hicap), Cellular Digital Packet Data (CDPD), Mobitex,

DataTAC, Integrated Digital Enhanced Network (iDEN), Personal Digital

Cellular (PDC), Circuit Switched Data (CSD), Personal Handy-phone

System (PHS), Wideband Integrated Digital Enhanced Network (WiDEN),

iBurst, Unlicensed Mobile Access (UMA), also referred to as also referred

to as 3GPP Generic Access Network, or GAN standard), Zigbee,

Bluetooth(r), Wireless Gigabit Alliance (WiGig) standard, mmWave

standards in general (wireless systems operating at 10-300 GHz and above

such as WiGig, IEEE 802.11ad, IEEE 802.11ay, and the like), technologies

operating above 300 GHz and THz bands, (3GPP/LTE based or IEEE

802.11p and other) Vehicle-to-Vehicle (V2V) and Vehicle-to-X (V2X) and

Vehicle-to-Infrastructure (V2I) and Infrastructure-to-Vehicle (I2V)

communication technologies, 3GPP cellular V2X, DSRC (Dedicated Short

Range Communications) communication systems such as Intelligent-

Transport-Systems and others.

[0029]   Aspects described herein can be used in the context of any

spectrum management scheme including, for example, dedicated licensed

spectrum, unlicensed spectrum, (licensed) shared spectrum (such as

Licensed Shared Access (LSA) in 2.3-2.4 GHz, 3.4-3.6 GHz, 3.6-3.8 GHz

and further frequencies and Spectrum Access System (SAS) in 3.55-3.7

GHz and further frequencies). Applicable exemplary spectrum bands

include IMT (International Mobile Telecommunications) spectrum
(including 450 - 470 MHz, 790 - 960 MHz, 1710 - 2025 MHz, 2110 - 2200
MHz, 2300 - 2400 MHz, 2500 - 2690 MHz, 698-790 MHz, 610 - 790 MHz,
3400 - 3600 MHz, to name a few), IMT-advanced spectrum, IMT-2020

5 spectrum (expected to include 3600-3800 MHz, 3.5 GHz bands, 700 MHz
bands, bands within the 24.25-86 GHz range, for example), spectrum made
available under the Federal Communications Commission's "Spectrum
Frontier" 5G initiative (including 27.5 - 28.35 GHz, 29.1 - 29.25 GHz, 31 -
31.3 GHz, 37 - 38.6 GHz, 38.6 - 40 GHz, 42 - 42.5 GHz, 57 - 64 GHz, 71 -

10 76 GHz, 81 - 86 GHz and 92 - 94 GHz, etc), the ITS (Intelligent Transport
Systems) band of 5.9 GHz (typically 5.85-5.925 GHz) and 63-64 GHz,
bands currently allocated to WiGig such as WiGig Band 1 (57.24-59.40
GHz), WiGig Band 2 (59.40-61.56 GHz) and WiGig Band 3 (61.56-63.72
GHz) and WiGig Band 4 (63.72-65.88 GHz), the 70.2 GHz - 71 GHz band,

15 any band between 65.88 GHz and 71 GHz, bands currently allocated to
automotive radar applications such as 76-81 GHz, and future bands
including 94-300 GHz and above. Furthermore, the scheme can be used on
a secondary basis on bands such as the TV White Space bands (typically
below 790 MHz) where in particular the 400 MHz and 700 MHz bands can

20 be employed. Besides cellular applications, specific applications for
vertical markets may be addressed, such as PMSE (Program Making and
Special Events), medical, health, surgery, automotive, low-latency, drones,
and the like.

[0030]   Aspects described herein can also be applied to different

25 Single Carrier or OFDM flavors (CP-OFDM, SC-FDMA, SC-OFDM, filter
bank-based multicarrier (FBMC), OFDMA, etc.) and in particular 3GPP
NR (New Radio) by allocating the OFDM carrier data bit vectors to the
corresponding symbol resources.

[0031]   FIG. 1A illustrates an architecture of a network in

30 accordance with some aspects. The network 140A is shown to include a
user equipment (UE) 101 and a UE 102. The UEs 101 and 102 are
illustrated as smartphones (e.g., handheld touchscreen mobile computing
devices connectable to one or more cellular networks), but may also

comprise any mobile or non-mobile computing device, such as Personal Data Assistants (PDAs), pagers, laptop computers, desktop computers, wireless handsets, drones, or any other computing device including a wired and/or wireless communications interface.

[0032]   In some aspects, any of the UEs 101 and 102 can comprise an Internet of Things (IoT) UE, which can comprise a network access layer designed for low-power IoT applications utilizing short-lived UE connections. An IoT UE can utilize technologies such as machine-to-machine (M2M) or machine-type communications (MTC) for exchanging data with an MTC server or device via a public land mobile network (PLMN), Proximity-Based Service (ProSe) or device-to-device (D2D) communication, sensor networks, or IoT networks. The M2M or MTC exchange of data may be a machine-initiated exchange of data. An IoT network describes interconnecting IoT UEs, which may include uniquely identifiable embedded computing devices (within the Internet infrastructure), with short-lived connections. The IoT UEs may execute background applications (e.g., keep-alive messages, status updates, etc.) to facilitate the connections of the IoT network.

[0033]   The UEs 101 and 102 may be configured to connect, e.g., communicatively couple, with a radio access network (RAN) 110 - the RAN 110 may be, for example, an Evolved Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (E-UTRAN), a NextGen RAN (NG RAN), or some other type of RAN. The UEs 101 and 102 utilize connections 103 and 104, respectively, each of which comprises a physical communications interface or layer (discussed in further detail below); in this example, the connections 103 and 104 are illustrated as an air interface to enable communicative coupling, and can be consistent with cellular communications protocols, such as a Global System for Mobile Communications (GSM) protocol, a code-division multiple access (CDMA) network protocol, a Push-to-Talk (PTT) protocol, a PTT over Cellular (POC) protocol, a Universal Mobile Telecommunications System (UMTS) protocol, a 3GPP Long Term

Evolution (LTE) protocol, a fifth generation (5G) protocol, a New Radio (NR) protocol, and the like.

[0034]   In some aspects, RAN 110 can include NG RAN or NG Core RAN. The NG RAN 110 can include various functions, such as, for example, an access and mobility management function (AMF), a session management function (SMF), a user plane function (UPF), a policy control function (PCF), a unified data management (UDM) function, and a network function (NF) repository function (NRF). The AMF can be used to manage access control and mobility, and can also include network slice selection functionality. The SMF can be configured to set up and manage various sessions according to a network policy. The UPF can be deployed in one or more configurations according to a desired service type. The PCF can be configured to provide a policy framework using network slicing, mobility management, and roaming (similar to PCRF in a 4G communication system). The UDM can be configured to store subscriber profiles and data (similar to an HSS in a 4G communication system). Various aspects of NG RAN and NG Core are discussed herein in reference to FIG. 1B, FIG. 1C, FIG. 1D, and FIG. 1E.

[0035]   In an aspect, the UEs 101 and 102 may further directly exchange communication data via a ProSe interface 105. The ProSe interface 105 may alternatively be referred to as a sidelink interface comprising one or more logical channels, including but not limited to a Physical Sidelink Control Channel (PSCCH), a Physical Sidelink Shared Channel (PSSCH), a Physical Sidelink Discovery Channel (PSDCH), and a Physical Sidelink Broadcast Channel (PSBCH).

[0036]   The UE 102 is shown to be configured to access an access point (AP) 106 via connection 107. The connection 107 can comprise a local wireless connection, such as, for example, a connection consistent with any IEEE 802.11 protocol, according to which the AP 106 can comprise a wireless fidelity (WiFi®) router. In this example, the AP 106 is shown to be connected to the Internet without connecting to the core network of the wireless system (described in further detail below).

[0037]   The RAN 110 can include one or more access nodes that enable the connections 103 and 104. These access nodes (ANs) can be referred to as base stations (BSs), NodeBs, evolved NodeBs (eNBs), next Generation NodeBs (gNBs), RAN nodes, and the like, and can comprise ground stations (e.g., terrestrial access points) or satellite stations providing coverage within a geographic area (e.g., a cell). In some aspects, the communication nodes 111 and 112 can be transmission/reception points (TRPs). In instances when the communication nodes 111 and 112 are NodeBs (e.g., eNBs or gNBs), one or more TRPs can function within the communication cell of the NodeBs. The RAN 110 may include one or more RAN nodes for providing macrocells, e.g., macro RAN node 111, and one or more RAN nodes for providing femtocells or picocells (e.g., cells having smaller coverage areas, smaller user capacity, or higher bandwidth compared to macrocells), e.g., low power (LP) RAN node 112.

[0038]   Any of the RAN nodes 111 and 112 can terminate the air interface protocol and can be the first point of contact for the UEs 101 and 102. In some aspects, any of the RAN nodes 111 and 112 can fulfill various logical functions for the RAN 110 including, but not limited to, radio network controller (RNC) functions such as radio bearer management, uplink and downlink dynamic radio resource management and data packet scheduling, and mobility management. In an example, any of the nodes 111 and/or 112 can be a new generation node-B (gNB), an evolved node-B (eNB) or another type of RAN node.

[0039]   In accordance with some aspects, the UEs 101 and 102 can be configured to communicate using Orthogonal Frequency-Division Multiplexing (OFDM) communication signals with each other or with any of the RAN nodes 111 and 112 over a multicarrier communication channel in accordance various communication techniques, such as, but not limited to, an Orthogonal Frequency-Division Multiple Access (OFDMA) communication technique (e.g., for downlink communications) or a Single Carrier Frequency Division Multiple Access (SC-FDMA) communication technique (e.g., for uplink and ProSe or sidelink communications), although

such aspects are not required. The OFDM signals can comprise a plurality of orthogonal subcarriers.

[0040]   In some aspects, a downlink resource grid can be used for downlink transmissions from any of the RAN nodes 111 and 112 to the UEs 101 and 102, while uplink transmissions can utilize similar techniques. The grid can be a time-frequency grid, called a resource grid or time-frequency resource grid, which is the physical resource in the downlink in each slot. Such a time-frequency plane representation may be used for OFDM systems, which makes it applicable for radio resource allocation. Each column and each row of the resource grid may correspond to one OFDM symbol and one OFDM subcarrier, respectively. The duration of the resource grid in the time domain may correspond to one slot in a radio frame. The smallest time-frequency unit in a resource grid may be denoted as a resource element. Each resource grid may comprise a number of resource blocks, which describe mapping of certain physical channels to resource elements. Each resource block may comprise a collection of resource elements; in the frequency domain, this may, in some aspects, represent the smallest quantity of resources that currently can be allocated. There may be several different physical downlink channels that are conveyed using such resource blocks.

[0041]   The physical downlink shared channel (PDSCH) may carry user data and higher-layer signaling to the UEs 101 and 102. The physical downlink control channel (PDCCH) may carry information about the transport format and resource allocations related to the PDSCH channel, among other things. It may also inform the UEs 101 and 102 about the transport format, resource allocation, and H-ARQ (Hybrid Automatic Repeat Request) information related to the uplink shared channel. Typically, downlink scheduling (assigning control and shared channel resource blocks to the UE 102 within a cell) may be performed at any of the RAN nodes 111 and 112 based on channel quality information fed back from any of the UEs 101 and 102. The downlink resource assignment information may be sent on the PDCCH used for (e.g., assigned to) each of the UEs 101 and 102.

[0042]   The PDCCH may use control channel elements (CCEs) to convey the control information. Before being mapped to resource elements, the PDCCH complex-valued symbols may first be organized into quadruplets, which may then be permuted using a sub-block interleaver for rate matching. Each PDCCH may be transmitted using one or more of these CCEs, where each CCE may correspond to nine sets of four physical resource elements known as resource element groups (REGs). Four Quadrature Phase Shift Keying (QPSK) symbols may be mapped to each REG. The PDCCH can be transmitted using one or more CCEs, depending on the size of the downlink control information (DCI) and the channel condition. There can be four or more different PDCCH formats defined in LTE with different numbers of CCEs (e.g., aggregation level, L=1, 2, 4, or 8).

[0043]   Some aspects may use concepts for resource allocation for control channel information that are an extension of the above-described concepts. For example, some aspects may utilize an enhanced physical downlink control channel (EPDCCH) that uses PDSCH resources for control information transmission. The EPDCCH may be transmitted using one or more enhanced control channel elements (ECCEs). Similar to above, each ECCE may correspond to nine sets of four physical resource elements known as an enhanced resource element groups (EREGs). An ECCE may have other numbers of EREGs according to some arrangements.

[0044]   The RAN 110 is shown to be communicatively coupled to a core network (CN) 120 via an S1 interface 113. In aspects, the CN 120 may be an evolved packet core (EPC) network, a NextGen Packet Core (NPC) network, or some other type of CN (e.g., as illustrated in reference to FIGS. 1B-1E). In this aspect, the S1 interface 113 is split into two parts: the S1-U interface 114, which carries traffic data between the RAN nodes 111 and 112 and the serving gateway (S-GW) 122, and the S1-mobility management entity (MME) interface 115, which is a signaling interface between the RAN nodes 111 and 112 and MMEs 121.

[0045]   In this aspect, the CN 120 comprises the MMEs 121, the S-GW 122, the Packet Data Network (PDN) Gateway (P-GW) 123, and a home subscriber server (HSS) 124. The MMEs 121 may be similar in function to the control plane of legacy Serving General Packet Radio Service (GPRS) Support Nodes (SGSN). The MMEs 121 may manage mobility aspects in access such as gateway selection and tracking area list management. The HSS 124 may comprise a database for network users, including subscription-related information to support the network entities' handling of communication sessions. The CN 120 may comprise one or several HSSs 124, depending on the number of mobile subscribers, on the capacity of the equipment, on the organization of the network, etc. For example, the HSS 124 can provide support for routing/roaming, authentication, authorization, naming/addressing resolution, location dependencies, etc.

[0046]   The S-GW 122 may terminate the S1 interface 113 towards the RAN 110, and routes data packets between the RAN 110 and the CN 120. In addition, the S-GW 122 may be a local mobility anchor point for inter-RAN node handovers and also may provide an anchor for inter-3GPP mobility. Other responsibilities of the S-GW 122 may include lawful intercept, charging, and some policy enforcement.

[0047]   The P-GW 123 may terminate a SGi interface toward a PDN. The P-GW 123 may route data packets between the EPC network 123 and external networks such as a network including the application server 130 (alternatively referred to as application function (AF)) via an Internet Protocol (IP) interface 125. Generally, the application server 130 may be an element offering applications that use IP bearer resources with the core network (e.g., UMTS Packet Services (PS) domain, LTE PS data services, etc.). In this aspect, the P-GW 123 is shown to be communicatively coupled to an application server 130 via an IP communications interface 125. The application server 130 can also be configured to support one or more communication services (e.g., Voice-over-Internet Protocol (VoIP) sessions, PTT sessions, group

communication sessions, social networking services, etc.) for the UEs 101 and 102 via the CN 120.

[0048]   The P-GW 123 may further be a node for policy enforcement and charging data collection. Policy and Charging Enforcement Function (PCRF) 126 is the policy and charging control element of the CN 120. In a non-roaming scenario, in some aspects, there may be a single PCRF in the Home Public Land Mobile Network (HPLMN) associated with a UE's Internet Protocol Connectivity Access Network (IP-CAN) session. In a roaming scenario with local breakout of traffic, there may be two PCRFs associated with a UE's IP-CAN session: a Home PCRF (H-PCRF) within a HPLMN and a Visited PCRF (V-PCRF) within a Visited Public Land Mobile Network (VPLMN). The PCRF 126 may be communicatively coupled to the application server 130 via the P-GW 123. The application server 130 may signal the PCRF 126 to indicate a new service flow and select the appropriate Quality of Service (QoS) and charging parameters. The PCRF 126 may provision this rule into a Policy and Charging Enforcement Function (PCEF) (not shown) with the appropriate traffic flow template (TFT) and QoS class of identifier (QCI), which commences the QoS and charging as specified by the application server 130.

[0049]   In an example, any of the nodes 111 or 112 can be configured to communicate to the UEs 101/102 (e.g., dynamically) an antenna panel selection and a receive (Rx) beam selection that can be used by the UE for data reception on a physical downlink shared channel (PDSCH) as well as for channel state information reference signal (CSI-RS) measurements and channel state information (CSI) calculation.

[0050]   In an example, any of the nodes 111 or 112 can be configured to communicate to the UEs 101/102 (e.g., dynamically) an antenna panel selection and a transmit (Tx) beam selection that can be used by the UE for data transmission on a physical uplink shared channel (PUSCH) as well as for sounding reference signal (SRS) transmission.

[0051]   In some aspects, LTE-based communications can use a fixed transmission time interval (TTI) length of 1 ms with 12-14 symbols, or a

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smaller TTI can also be used (e.g., in NR-based communications). The transmission of a request, grant, or data can be achieved by using one or more subframes with a TTI. In this regard, the TTI length can impact both the time for transmitting over the air as well as the processing time at

5   transmitters and receivers.

[0052]   FIG. 1B is a simplified diagram of a next generation (NG) system architecture in accordance with some aspects. Referring to FIG. 1B, the NG system architecture 140B includes NG-RAN 110 and a 5G network core (5GC) 120. The NG-RAN 110 can include a plurality of

10   nodes, such as gNBs 128 and ng-eNBs 130. The gNBs 128 and the ng-eNBs 130 can be communicatively coupled to the UE 102 via, e.g., an N1 interface.

[0053]   The 5GC 120 includes an access and mobility management function (AMF) 132 and/or a user plane function (UPF) 134. The AMF

15   132 and the UPF 134 can be communicatively coupled to the gNBs 128 and the ng-eNBs 130 via NG interfaces. More specifically, in some aspects, the gNBs 128 and the ng-eNBs 130 can be connected to the AMF 132 by NG-C interfaces, and to the UPF 134 by NG-U interfaces. The gNBs 128 and the ng-eNBs 130 can be coupled to each other via Xn interfaces.

20   [0054]   In some aspects, a gNB 128 can include a node providing new radio (NR) user plane and control plane protocol termination towards the UE, and is connected via the NG interface to the 5GC 120. In some aspects, an ng-eNB 130 can include a node providing evolved universal terrestrial radio access (E-UTRA) user plane and control plane protocol

25   terminations towards the UE, and is connected via the NG interface to the 5GC 120.

[0055]   In some aspects, each of the gNBs 128 and the ng-eNBs 130 can be implemented as a base station, a mobile edge server, a small cell, a home eNB, and so forth.

30   [0056]   FIG. 1C illustrates a functional split between NG – RAN and the 5G Core (5GC) in accordance with some aspects. Referring to FIG. 1C, there is illustrated a more detailed diagram of the functionalities that can be performed by the gNBs 128 and the ng-eNBs 130 within the NG-

RAN 110, as well as the AMF 132, the UPF 134, and the SMF 136 within the 5GC 120. In some aspects, the 5GC 120 can provide access to the Internet 138 to one or more devices via the NG-RAN 110.

[0057]   In some aspects, the gNBs 128 and the ng-eNBs 130 can be configured to host the following functions: functions for Radio Resource Management (e.g., inter-cell radio resource management 129A, radio bearer control 129B, radio admission control 129D, connection mobility control 129C, dynamic allocation of resources to UEs in both uplink and downlink (scheduling) 129F); IP header compression, encryption and integrity protection of data; selection of an AMF at UE attachment when no routing to an AMF can be determined from the information provided by the UE; routing of User Plane data towards UPF(s); routing of Control Plane information towards AMF; connection setup and release; scheduling and transmission of paging messages (originated from the AMF); scheduling and transmission of system broadcast information (originated from the AMF or Operation and Maintenance); measurement and measurement reporting configuration for mobility and scheduling 129E; transport level packet marking in the uplink; session management; support of network slicing; QoS flow management and mapping to data radio bearers; support of UEs in RRC_INACTIVE state; distribution function for non-access stratus (NAS) messages; radio access network sharing; dual connectivity; and tight interworking between NR and E-UTRA, to name a few.

[0058]   In some aspects, the AMF 132 can be configured to host the following functions, for example: NAS signaling termination; NAS signaling security 133A; access stratus (AS) security control; inter core network (CN) node signaling for mobility between 3GPP access networks; idle mode mobility handling 133B, including mobile device, such as a UE, reachability (e.g., control and execution of paging retransmission); registration area management; support of intra-system and inter-system mobility; access authentication; access authorization including check of roaming rights; mobility management control (subscription and policies); support of network slicing; and/or SMF selection, among other functions.

[0059]   The UPF 134 can be configured to host the following functions, for example: mobility anchoring 135A (e.g., anchor point for Intra-/Inter-RAT mobility); packet data unit (PDU) handling 135B (e.g., external PDU session point of interconnect to data network); packet routing and forwarding; packet inspection and user plane part of policy rule enforcement; traffic usage reporting; uplink classifier to support routing traffic flows to a data network; branching point to support multi-homed PDU session; QoS handling for user plane, e.g. packet filtering, gating, UL/DL rate enforcement; uplink traffic verification (SDF to QoS flow mapping); and/or downlink packet buffering and downlink data notification triggering, among other functions.

[0060]   The Session Management function (SMF) 136 can be configured to hosts the following functions, for example: session management; UE IP address allocation and management 137A; selection and control of UP function; PDU session control 137B, including configuring traffic steering at UPF to route traffic to proper destination; control part of policy enforcement and QoS; and/or downlink data notification, among other functions.

[0061]   FIG. 1D and FIG. 1E illustrate a non-roaming 5G system architecture in accordance with some aspects. Referring to FIG. 1D, there is illustrated a 5G system architecture 140D in a reference point representation. More specifically, UE 102 can be in communication with RAN 110 as well as one or more other 5GC network entities. The 5GC of system architecture 140D includes a plurality of network functions (NFs), such as access and mobility management function (AMF) 132, session management function (SMF) 136, policy control function (PCF) 148, application function (AF) 150, user plane function (UPF) 134, network slice selection function (NSSF) 142, authentication server function (AUSF) 144, and unified data management (UDM) 146. The UPF 134 can provide a connection to a data network (DN) 152, which can include, for example, operator services, Internet access, or third-party services.

[0062]   Referring to FIG. 1E, there is illustrated a 5G system architecture 140E and a service-based representation. System architecture

140E can be substantially similar to (or the same as) system architecture 140D. In addition to the network entities illustrated in FIG. 1D, system architecture 140E can also include a network exposure function (NEF) 154 and a network repository function (NRF) 156.

[0063]   In some aspects, the 5G system architectures can be service-based and interaction between network functions can be represented by corresponding point-to-point reference points Ni (as illustrated in FIG. 1D) or as service-based interfaces (as illustrated in FIG. 1E).

[0064]   A reference point representation shows that an interaction can exist between corresponding NF services. For example, FIG. 1D illustrates the following reference points: N1 (between the UE and the AMF), N2 (between the RAN and the AMF), N3 (between the RAN and the UPF), N4 (between the SMF and the UPF), N5 (between the PCF and the AF), N6 (between the UPF and the DN), N7 (between the SMF and the PCF), N8 (between the UDM and the AMF), N9 (between two UPFs), N10 (between the UDM and the SMF), N11 (between the AMF and the SMF), N12 (between the AUSF and the AMF), N13 (between the AUSF and the UDM), N14 (between two AMFs), N15 (between the PCF and the AMF in case of a non-roaming scenario, or between the PCF and a visited network and AMF in case of a roaming scenario), N16 (between two SMFs; not illustrated in FIG. 1D), and N22 (between AMF and NSSF). Other reference point representations not shown in FIG. 1D can also be used.

[0065]   In some aspects, as illustrated in FIG. 1E, service-based representations can be used to represent network functions within the control plane that enable other authorized network functions to access their services. In this regard, 5G system architecture 140E can include the following service-based interfaces: Namf 158H (a service-based interface exhibited by the AMF 132), Nsmf 158I (a service-based interface exhibited by the SMF 136), Nnef 158B (a service-based interface exhibited by the NEF 154), Npcf 158D (a service-based interface exhibited by the PCF 148), a Nudm 158E (a service-based interface exhibited by the UDM 146), Naf 158F (a service-based interface exhibited by the AF 150), Nnrf 158C (a service-based interface exhibited by the NRF 156), Nnssf 158A (a service-

based interface exhibited by the NSSF 142), Nausf 158G (a service-based interface exhibited by the AUSF 144). Other service-based interfaces (e.g., Nudr, N5g-eir, and Nudsf) not shown in FIG. 1E can also be used.

[0066]   FIG. 1F illustrates an example CIoT network architecture in accordance with some aspects. Referring to FIG. 1F, the CIoT architecture 140F can include the UE 102 and the RAN 110 coupled to a plurality of core network entities. In some aspects, the UE 102 can be machine type communication (MTC) UE. The CIoT network architecture 140F can further include a mobile services switching center (MSC) 160, MME 121, a serving GPRS support note (SGSN) 162, a S-GW 122, an IP-Short-Message-Gateway (IP-SM-GW) 164, a Short Message Service Service Center (SMS-SC)/gateway mobile service center (GMSC)/Interworking MSC (IWMSC) 166, MTC interworking function (MTC-IWF) 170, a Service Capability Exposure Function (SCEF) 172, a gateway GPRS support node (GGSN)/Patent-GW 174, a charging data function (CDF)/charging gateway function (CGF) 176, a home subscriber server (HSS)/a home location register (HLR) 177, short message entities (SME) 168, MTC authorization, authentication, and accounting (MTC AAA) server 178, a service capability server (SCS) 180, and application servers (AS) 182 and 184.

[0067]   In some aspects, the SCEF 172 can be configured to securely expose services and capabilities provided by various 3GPP network interfaces. The SCEF 172 can also provide means for the discovery of the exposed services and capabilities, as well as access to network capabilities through various network application programming interfaces (e.g., API interfaces to the SCS 180).

[0068]   FIG. 1F further illustrates various reference points between different servers, functions, or communication nodes of the CIoT architecture 140F. Some example reference points related to MTC – IWF 170 and SCEF 172 include the following: Tsms (a reference point used by an entity outside the 3GPP network to communicate with UEs used for MTC via SMS), Tsp (a reference point used by a SCS to communicate with the MTC-IWF related control plane signaling), T4 (a reference point used

between MTC-IWF 170 and the SMS-SC 166 in the HPLMN), T6a (a reference point used between SCEF 172 and serving MME 121), T6b (a reference point used between SCEF 172 and serving SGSN 162), T8 (a reference point used between the SCEF 172 and the SCS/AS 180/182),

5   S6m (a reference point used by MTC-IWF 170 to interrogate HSS/HLR 177), S6n (a reference point used by MTC-AAA 178 to interrogate HSS/HLR 177), and S6t (a reference point used between SCEF 172 and HSS 177).

[0069]   In some aspects, the CIoT UE 102 can be configured to

10   communicate with one or more entities within the CIoT architecture 140F via the RAN 110 according to a Non-Access Stratum (NAS) protocol, and using one or more reference points, such as a narrowband air interface, for example, based on one or more communication technologies, such as Orthogonal Frequency-Division Multiplexing (OFDM) technology. As

15   used herein, the term "CIoT UE" refers to a UE capable of CIoT optimizations, as part of a CIoT communications architecture.

[0070]   In some aspects, the NAS protocol can support a set of NAS messages for communication between the CIoT UE 102 and an Evolved Packet System (EPS) Mobile Management Entity (MME) 121 and SGSN

20   162.

[0071]   In some aspects, the CIoT network architecture 140F can include a packet data network, an operator network, or a cloud service network, having, for example, among other things, a Service Capability Server (SCS) 180, an Application Server (AS) 182, or one or more other

25   external servers or network components.

[0072]   The RAN 110 can be coupled to the HSS/AAA servers 177178 using one or more reference points including, for example, an air interface based on an S6a reference point, and configured to authenticate/authorize CIoT UE 102 access the CIoT network. The RAN

30   110 can be coupled to the network 140F using one or more other reference points including, for example, an air interface corresponding to an SGi/Gi interface for 3GPP accesses. The RAN 110 can be coupled to the SCEF 172 using, for example, an air interface based on a T6a/T6b reference point,

for service capability exposure. In some aspects, the SCEF 172 may act as an API GW towards a 3rd party application server such as AS 182. The SCEF 172 can be coupled to the HSS/AAA servers using an S6t reference point, and can further expose an Application Programming Interface to network capabilities.

[0073]   In certain examples, one or more of the CIoT devices disclosed herein, such as the CIoT UE 102, the CIoT RAN 110, etc., can include one or more other non-CIoT devices, or non-CIoT devices acting as CIoT devices, or having functions of a CIoT device. For example, the CIoT UE 102 can include a smart phone, a tablet computer, or one or more other electronic device acting as a CIoT device for a specific function, while having other additional functionality.

[0074]   In some aspects, the RAN 110 can include a CIoT enhanced Node B (CIoT eNB) 111 communicatively coupled to the CIoT Access Network Gateway (CIoT GW) 190. In certain examples, the RAN 110 can include multiple base stations (e.g., CIoT eNBs) connected to the CIoT GW 190, which can include MSC 160, MME 121, SGSN 162, and/or S – GW 122. In certain examples, internal architecture of RAN 110 and CIoT GW 190 may be left to the implementation and need not be standardized.

[0075]   As used herein, the term circuitry may refer to, be part of, or include an Application Specific Integrated Circuit (ASIC) or other special purpose circuit, an electronic circuit, a processor (shared, dedicated, or group), or memory (shared, dedicated, or group) executing one or more software or firmware programs, a combinational logic circuit, or other suitable hardware components that provide the described functionality. In some aspects, the circuitry may be implemented in, or functions associated with the circuitry may be implemented by, one or more software or firmware modules. In some aspects, circuitry may include logic, at least partially operable in hardware. In some aspects, circuitry as well as modules disclosed herein may be implemented in combinations of hardware, software and/or firmware. In some aspects, functionality associated with a circuitry can be distributed across more than one piece of hardware or software/firmware module. In some aspects, modules (as

disclosed herein) may include logic, at least partially operable in hardware. Aspects described herein may be implemented into a system using any suitably configured hardware or software.

[0076]   FIG. 2 illustrates example components of a device 200 in accordance with some aspects. In some aspects, the device 200 may include application circuitry 202, baseband circuitry 204, Radio Frequency (RF) circuitry 206, front-end module (FEM) circuitry 208, one or more antennas 210, and power management circuitry (PMC) 212 coupled together at least as shown. The components of the illustrated device 200 may be included in a UE or a RAN node. In some aspects, the device 200 may include fewer elements (e.g., a RAN node may not utilize application circuitry 202, and instead include a processor/controller to process IP data received from an EPC). In some aspects, the device 200 may include additional elements such as, for example, memory/storage, display, camera, sensor, and/or input/output (I/O) interface elements. In other aspects, the components described below may be included in more than one device (e.g., said circuitries may be separately included in more than one device for Cloud-RAN (C-RAN) implementations).

[0077]   The application circuitry 202 may include one or more application processors. For example, the application circuitry 202 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) may include any combination of general-purpose processors, special-purpose processors, and dedicated processors (e.g., graphics processors, application processors, etc.). The processors may be coupled with, and/or may include, memory/storage and may be configured to execute instructions stored in the memory/storage to enable various applications or operating systems to run on the device 200. In some aspects, processors of application circuitry 202 may process IP data packets received from an EPC.

[0078]   The baseband circuitry 204 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 204 may include one or more baseband processors or control logic to process baseband signals received from a receive signal

path of the RF circuitry 206 and to generate baseband signals for a transmit signal path of the RF circuitry 206. Baseband processing circuity 204 may interface with the application circuitry 202 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 206.

5 For example, in some aspects, the baseband circuitry 204 may include a third generation (3G) baseband processor 204A, a fourth generation (4G) baseband processor 204B, a fifth generation (5G) baseband processor 204C, or other baseband processor(s) 204D for other existing generations, generations in development or to be developed in the future (e.g., second

10 generation (2G), sixth generation (6G), etc.). The baseband circuitry 204 (e.g., one or more of baseband processors 204A-D) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 206. In other aspects, some or all of the functionality of baseband processors 204A-D may be included in modules

15 stored in the memory 204G and executed via a Central Processing Unit (CPU) 204E. The radio control functions may include, but are not limited to, signal modulation/demodulation, encoding/decoding, radio frequency shifting, etc. In some aspects, modulation/demodulation circuitry of the baseband circuitry 204 may include Fast-Fourier Transform (FFT),

20 precoding, or constellation mapping/demapping functionality. In some aspects, encoding/decoding circuitry of the baseband circuitry 204 may include convolution, tail-biting convolution, turbo, Viterbi, or Low Density Parity Check (LDPC) encoder/decoder functionality. Aspects of modulation/demodulation and encoder/decoder functionality are not limited

25 to these examples and may include other suitable functionality in other aspects.

[0079] In some aspects, the baseband circuitry 204 may include one or more audio digital signal processor(s) (DSP) 204F. The audio DSP(s) 204F may be include elements for compression/decompression and echo

30 cancellation and may include other suitable processing elements in other aspects. Components of the baseband circuitry may be suitably combined in a single chip, a single chipset, or disposed on a same circuit board in some aspects. In some aspects, some or all of the constituent components

of the baseband circuitry 204 and the application circuitry 202 may be implemented together such as, for example, on a system on a chip (SOC).

[0080] In some aspects, the baseband circuitry 204 may provide for communication compatible with one or more radio technologies. For example, in some aspects, the baseband circuitry 204 may support communication with an evolved universal terrestrial radio access network (EUTRAN) or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), and/or a wireless personal area network (WPAN). Baseband circuitry 204 configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry, in some aspects.

[0081] RF circuitry 206 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various aspects, the RF circuitry 206 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 206 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 208 and provide baseband signals to the baseband circuitry 204. RF circuitry 206 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 204 and provide RF output signals to the FEM circuitry 208 for transmission.

[0082] In some aspects, the receive signal path of the RF circuitry 206 may include a mixer 206A, an amplifier 206B, and a filter 206C. In some aspects, the transmit signal path of the RF circuitry 206 may include a filter 206C and a mixer 206A. RF circuitry 206 may also include a synthesizer 206D for synthesizing a frequency for use by the mixer 206A of the receive signal path and the transmit signal path. In some aspects, the mixer 206A of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 208 based on the synthesized frequency provided by synthesizer 206D. The amplifier 206B may be configured to amplify the down-converted signals and the filter 206C may be a low-pass filter (LPF) or band-pass filter (BPF) configured to remove

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unwanted signals from the down-converted signals to generate output baseband signals. Output baseband signals may be provided to the baseband circuitry 204 for further processing. In some aspects, the output baseband signals may optionally be zero-frequency baseband signals. In some aspects, mixer 206A of the receive signal path may comprise passive mixers.

[0083]　　　　In some aspects, the mixer 206A of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer 206D to generate RF output signals for the FEM circuitry 208. The baseband signals may be provided by the baseband circuitry 204 and may be filtered by filter 206C.

[0084]　　　　In some aspects, the mixer 206A of the receive signal path and the mixer 206A of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and upconversion, respectively. In some aspects, the mixer 206A of the receive signal path and the mixer 206A of the transmit signal path may include two or more mixers and may be arranged for image rejection (e.g., Hartley image rejection). In some aspects, the mixer 206A of the receive signal path and the mixer 206A may be arranged for direct downconversion and direct upconversion, respectively. In some aspects, the mixer 206A of the receive signal path and the mixer 206A of the transmit signal path may be configured for super-heterodyne operation.

[0085]　　　　In some aspects, the output baseband signals and the input baseband signals may optionally be analog baseband signals. According to some alternate aspects, the output baseband signals and the input baseband signals may be digital baseband signals. In these alternate aspects, the RF circuitry 206 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 204 may include a digital baseband interface to communicate with the RF circuitry 206.

[0086]　　　　In some dual-mode aspects, a separate radio IC circuitry may optionally be provided for processing signals for each spectrum.

[0087]   In some aspects, the synthesizer 206D may optionally be a fractional-N synthesizer or a fractional N/N+1 synthesizer, although other types of frequency synthesizers may be suitable. For example, the synthesizer 206D may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[0088]   The synthesizer 206D may be configured to synthesize an output frequency for use by the mixer circuitry 206A of the RF circuitry 206 based on a frequency input and a divider control input. In some aspects, the synthesizer 206D may be a fractional N/N+1 synthesizer.

[0089]   In some aspects, frequency input may be provided by a voltage controlled oscillator (VCO), although that is not a requirement. Divider control input may be provided, for example, by either the baseband circuitry 204 or the applications processor 202 depending on the desired output frequency. In some aspects, a divider control input (e.g., N) may be determined from a look-up table based on a channel indicated by the applications processor 202.

[0090]   Synthesizer circuitry 206D of the RF circuitry 206 may include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some aspects, the divider may be a dual modulus divider (DMD) and the phase accumulator may be a digital phase accumulator (DPA). In some aspects, the DMD may be configured to divide the input signal by either N or N+1 (e.g., based on a carry out) to provide a fractional division ratio. In some example aspects, the DLL may include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-flop. In these aspects, the delay elements may be configured to break a VCO period up into Nd equal packets of phase, where Nd is the number of delay elements in the delay line. In this way, the DLL provides negative feedback to assist in keeping the total delay through the delay line to one VCO cycle.

[0091]   In some aspects, synthesizer circuitry 206D may be configured to generate a carrier frequency as the output frequency, while in other aspects, the output frequency may be a multiple of the carrier frequency (e.g., twice the carrier frequency, or four times the carrier

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frequency) and may be used in conjunction with quadrature generator and divider circuitry to generate multiple signals at the carrier frequency with multiple different phases with respect to each other. In some aspects, the output frequency may be a LO frequency (fLO). In some aspects, the RF

5   circuitry 206 may include an IQ/polar converter.

[0092]   FEM circuitry 208 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 210, and/or to amplify the received signals and provide the amplified versions of the received signals to the RF circuitry

10   206 for further processing. FEM circuitry 208 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 206 for transmission by one or more of the one or more antennas 210. In various aspects, the amplification through the transmit signal paths or the receive signal paths may be done in

15   part or solely in the RF circuitry 206, in part or solely in the FEM 208, or in both the RF circuitry 206 and the FEM 208.

[0093]   In some aspects, the FEM circuitry 208 may include a TX/RX switch to switch between transmit mode and receive mode operation. The FEM circuitry may include a receive signal path and a

20   transmit signal path. The receive signal path of the FEM circuitry may include an LNA to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 206). The transmit signal path of the FEM circuitry 208 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry

25   206), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 210).

[0094]   In some aspects, the PMC 212 may manage power provided to the baseband circuitry 204. The PMC 212 may control power-source selection, voltage scaling, battery charging, and/or DC-to-DC conversion.

30   The PMC 212 may, in some aspects, be included when the device 200 is capable of being powered by a battery, for example, when the device is included in a UE. The PMC 212 may increase the power conversion

efficiency while providing beneficial implementation size and heat dissipation characteristics.

[0095]   FIG. 2 shows the PMC 212 coupled with the baseband circuitry 204. In other aspects, the PMC 212 may be additionally or alternatively coupled with, and perform similar power management operations for, other components such as, but not limited to, application circuitry 202, RF circuitry 206, or FEM 208.

[0096]   In some aspects, the PMC 212 may control, or otherwise be part of, various power saving mechanisms of the device 200. For example, if the device 200 is in an RRC_Connected state, in which it is still connected to the RAN node as it expects to receive traffic shortly, then it may enter a state known as Discontinuous Reception Mode (DRX) after a period of inactivity. During this state, the device 200 may power down for brief intervals of time and thus save power.

[0097]   According to some aspects, if there is no data traffic activity for an extended period of time, then the device 200 may transition off to an RRC_Idle state, in which it disconnects from the network and does not perform operations such as channel quality feedback, handover, etc. The device 200 goes into a very low power state and it performs paging during which it periodically wakes up to listen to the network and then powers down again. The device 200 may transition back to RRC_Connected state to receive data.

[0098]   An additional power saving mode may allow a device to be unavailable to the network for periods longer than a paging interval (ranging from seconds to a few hours). During this time, the device 200 in some aspects may be unreachable to the network and may power down. Any data sent during this time incurs a delay, which may be large, and it is assumed the delay is acceptable.

[0099]   Processors of the application circuitry 202 and processors of the baseband circuitry 204 may be used to execute elements of one or more instances of a protocol stack. For example, processors of the baseband circuitry 204, alone or in combination, may be used execute Layer 3, Layer 2, or Layer 1 functionality, while processors of the application circuitry 204

may utilize data (e.g., packet data) received from these layers and further execute Layer 4 functionality (e.g., transmission communication protocol (TCP) and user datagram protocol (UDP) layers). As referred to herein, Layer 3 may comprise a radio resource control (RRC) layer, described in further detail below. As referred to herein, Layer 2 may comprise a medium access control (MAC) layer, a radio link control (RLC) layer, and a packet data convergence protocol (PDCP) layer, described in further detail below. As referred to herein, Layer 1 may comprise a physical (PHY) layer of a UE/RAN node, described in further detail below.

[00100]   FIG. 3 illustrates example interfaces of baseband circuitry in accordance with some aspects. As discussed above, the baseband circuitry 204 of FIG. 2 may comprise processors 204A-204E and a memory 204G utilized by said processors. Each of the processors 204A-204E may include a memory interface, 304A-304E, respectively, to send/receive data to/from the memory 204G.

[00101]   The baseband circuitry 204 may further include one or more interfaces to communicatively couple to other circuitries/devices, such as a memory interface 312 (e.g., an interface to send/receive data to/from memory external to the baseband circuitry 204), an application circuitry interface 314 (e.g., an interface to send/receive data to/from the application circuitry 202 of FIG. 2), an RF circuitry interface 316 (e.g., an interface to send/receive data to/from RF circuitry 206 of FIG. 2), a wireless hardware connectivity interface 318 (e.g., an interface to send/receive data to/from Near Field Communication (NFC) components, Bluetooth® components (e.g., Bluetooth® Low Energy), Wi-Fi® components, and other communication components), and a power management interface 320 (e.g., an interface to send/receive power or control signals to/from the PMC 212).

[00102]   FIG. 4 is an illustration of a control plane protocol stack in accordance with some aspects. In one aspect, a control plane 400 is shown as a communications protocol stack between the UE 101 (or alternatively, the UE 102), the RAN node 111 (or alternatively, the RAN node 112), and the MME 121.

[00103]   The PHY layer 401 may in some aspects transmit or receive information used by the MAC layer 402 over one or more air interfaces. The PHY layer 401 may further perform link adaptation or adaptive modulation and coding (AMC), power control, cell search (e.g., for initial synchronization and handover purposes), and other measurements used by higher layers, such as the RRC layer 405. The PHY layer 401 may in some aspects still further perform error detection on the transport channels, forward error correction (FEC) coding/decoding of the transport channels, modulation/demodulation of physical channels, interleaving, rate matching, mapping onto physical channels, and Multiple Input Multiple Output (MIMO) antenna processing.

[00104]   The MAC layer 402 may in some aspects perform mapping between logical channels and transport channels, multiplexing of MAC service data units (SDUs) from one or more logical channels onto transport blocks (TB) to be delivered to PHY via transport channels, de-multiplexing MAC SDUs to one or more logical channels from transport blocks (TB) delivered from the PHY via transport channels, multiplexing MAC SDUs onto TBs, scheduling information reporting, error correction through hybrid automatic repeat request (HARQ), and logical channel prioritization.

[00105]   The RLC layer 403 may in some aspects operate in a plurality of modes of operation, including: Transparent Mode (TM), Unacknowledged Mode (UM), and Acknowledged Mode (AM). The RLC layer 403 may execute transfer of upper layer protocol data units (PDUs), error correction through automatic repeat request (ARQ) for AM data transfers, and concatenation, segmentation and reassembly of RLC SDUs for UM and AM data transfers. The RLC layer 403 may also in some aspects execute re-segmentation of RLC data PDUs for AM data transfers, reorder RLC data PDUs for UM and AM data transfers, detect duplicate data for UM and AM data transfers, discard RLC SDUs for UM and AM data transfers, detect protocol errors for AM data transfers, and perform RLC re-establishment.

[00106]   The PDCP layer 404 may in some aspects execute header compression and decompression of IP data, maintain PDCP Sequence

Numbers (SNs), perform in-sequence delivery of upper layer PDUs at re-establishment of lower layers, eliminate duplicates of lower layer SDUs at re-establishment of lower layers for radio bearers mapped on RLC AM, cipher and decipher control plane data, perform integrity protection and

5   integrity verification of control plane data, control timer-based discard of data, and perform security operations (e.g., ciphering, deciphering, integrity protection, integrity verification, etc.).

[00107]   In some aspects, primary services and functions of the RRC layer 405 may include broadcast of system information (e.g., included in

10   Master Information Blocks (MIBs) or System Information Blocks (SIBs) related to the non-access stratum (NAS)), broadcast of system information related to the access stratum (AS), paging, establishment, maintenance and release of an RRC connection between the UE and E-UTRAN (e.g., RRC connection paging, RRC connection establishment, RRC connection

15   modification, and RRC connection release), establishment, configuration, maintenance and release of point to point Radio Bearers, security functions including key management, inter radio access technology (RAT) mobility, and measurement configuration for UE measurement reporting. Said MIBs and SIBs may comprise one or more information elements (IEs), which

20   may each comprise individual data fields or data structures.

[00108]   The UE 101 and the RAN node 111 may utilize a Uu interface (e.g., an LTE-Uu interface) to exchange control plane data via a protocol stack comprising the PHY layer 401, the MAC layer 402, the RLC layer 403, the PDCP layer 404, and the RRC layer 405.

25   [00109]   The non-access stratum (NAS) protocols 406 form the highest stratum of the control plane between the UE 101 and the MME 121 as illustrated in FIG. 4. In aspects, the NAS protocols 406 support the mobility of the UE 101 and the session management procedures to establish and maintain IP connectivity between the UE 101 and the P-GW 123.

30   [00110]   The S1 Application Protocol (S1-AP) layer 415 may support the functions of the S1 interface and comprise Elementary Procedures (EPs). An EP is a unit of interaction between the RAN node 111 and the CN 120. In certain aspects, the S1-AP layer services may comprise two

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groups: UE-associated services and non UE-associated services. These services perform functions including, but not limited to: E-UTRAN Radio Access Bearer (E-RAB) management, UE capability indication, mobility, NAS signaling transport, RAN Information Management (RIM), and configuration transfer.

[00111]   The Stream Control Transmission Protocol (SCTP) layer (which may alternatively be referred to as the SCTP/IP layer) 414 may ensure reliable delivery of signaling messages between the RAN node 111 and the MME 121 based, in part, on the IP protocol, supported by the IP layer 413. The L2 layer 412 and the L1 layer 411 may refer to communication links (e.g., wired or wireless) used by the RAN node and the MME to exchange information.

[00112]   The RAN node 111 and the MME 121 may utilize an S1-MME interface to exchange control plane data via a protocol stack comprising the L1 layer 411, the L2 layer 412, the IP layer 413, the SCTP layer 414, and the S1-AP layer 415.

[00113]   FIG. 5 is an illustration of a user plane protocol stack in accordance with some aspects. In this aspect, a user plane 500 is shown as a communications protocol stack between the UE 101 (or alternatively, the UE 102), the RAN node 111 (or alternatively, the RAN node 112), the S-GW 122, and the P-GW 123. The user plane 500 may utilize at least some of the same protocol layers as the control plane 400. For example, the UE 101 and the RAN node 111 may utilize a Uu interface (e.g., an LTE-Uu interface) to exchange user plane data via a protocol stack comprising the PHY layer 401, the MAC layer 402, the RLC layer 403, and the PDCP layer 404.

[00114]   The General Packet Radio Service (GPRS) Tunneling Protocol for the user plane (GTP-U) layer 504 may be used for carrying user data within the GPRS core network and between the radio access network and the core network. The user data transported can be packets in IPv4, IPv6, or PPP formats, for example. The UDP and IP security (UDP/IP) layer 503 may provide checksums for data integrity, port numbers for addressing different functions at the source and destination,

and encryption and authentication on the selected data flows. The RAN node 111 and the S-GW 122 may utilize an S1-U interface to exchange user plane data via a protocol stack comprising the L1 layer 411, the L2 layer 412, the UDP/IP layer 503, and the GTP-U layer 504. The S-GW 122 and the P-GW 123 may utilize an S5/S8a interface to exchange user plane data via a protocol stack comprising the L1 layer 411, the L2 layer 412, the UDP/IP layer 503, and the GTP-U layer 504. As discussed above with respect to FIG. 4, NAS protocols support the mobility of the UE 101 and the session management procedures to establish and maintain IP connectivity between the UE 101 and the P-GW 123.

[00115]   FIG. 6 is a block diagram illustrating components, according to some example aspects, able to read instructions from a machine-readable or computer-readable medium (e.g., a non-transitory machine-readable storage medium) and perform any one or more of the methodologies discussed herein. Specifically, FIG. 6 shows a diagrammatic representation of hardware resources 600 including one or more processors (or processor cores) 610, one or more memory/storage devices 620, and one or more communication resources 630, each of which may be communicatively coupled via a bus 640. For aspects in which node virtualization (e.g., NFV) is utilized, a hypervisor 602 may be executed to provide an execution environment for one or more network slices and/or sub-slices to utilize the hardware resources 600

[00116]   The processors 610 (e.g., a central processing unit (CPU), a reduced instruction set computing (RISC) processor, a complex instruction set computing (CISC) processor, a graphics processing unit (GPU), a digital signal processor (DSP) such as a baseband processor, an application specific integrated circuit (ASIC), a radio-frequency integrated circuit (RFIC), another processor, or any suitable combination thereof) may include, for example, a processor 612 and a processor 614.

[00117]   The memory/storage devices 620 may include main memory, disk storage, or any suitable combination thereof. The memory/storage devices 620 may include, but are not limited to any type of volatile or non-volatile memory such as dynamic random access memory

(DRAM), static random-access memory (SRAM), erasable programmable read-only memory (EPROM), electrically erasable programmable read-only memory (EEPROM), Flash memory, solid-state storage, etc.

[00118]   The communication resources 630 may include interconnection or network interface components or other suitable devices to communicate with one or more peripheral devices 604 or one or more databases 606 via a network 608. For example, the communication resources 630 may include wired communication components (e.g., for coupling via a Universal Serial Bus (USB)), cellular communication components, NFC components, Bluetooth® components (e.g., Bluetooth® Low Energy), Wi-Fi® components, and other communication components.

[00119]   Instructions 650 may comprise software, a program, an application, an applet, an app, or other executable code for causing at least any of the processors 610 to perform any one or more of the methodologies discussed herein. The instructions 650 may reside, completely or partially, within at least one of the processors 610 (e.g., within the processor's cache memory), the memory/storage devices 620, or any suitable combination thereof. Furthermore, any portion of the instructions 650 may be transferred to the hardware resources 600 from any combination of the peripheral devices 604 or the databases 606. Accordingly, the memory of processors 610, the memory/storage devices 620, the peripheral devices 604, and the databases 606 are examples of computer-readable and machine-readable media.

[00120]   In some aspects and in reference to the CIoT network architecture 140F in FIG. 1F, coverage enhancement (CE) functionality can be used to ensure that specific subscribers (e.g., those subscribed to use the CE service) are able to benefit from the CE-related features. In some aspects, in order to address use of extensive resources from the network, specific subscribers can be prevented from using enhanced coverage functionalities. In some aspects, a new subscription parameter (e.g., Enhanced Coverage Allowed parameter) can be introduced and may be kept in the HSS 177. In some aspects, the Enhanced Coverage Allowed parameter can be configured to specify on a per public land mobile network

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(PLMN) basis whether enhanced coverage functionality is allowed or not for a given UE. In some aspects, third party service providers can query the status of, or request MNO to enable/disable Enhanced Coverage via the SCEF 172. This solution can include updating NAS procedures (e.g.,

5   ATTACH ACCEPT, tracking area update (TAU)/routing area update (RAU) ACCEPT messages) to receive the Enhanced Coverage Allowed parameter, store this parameter per PLMN in the UE and then based on value of this parameter use the enhanced coverage capability. In some aspects, the HSS 177 can be configured to update the subscription

10   information to determine whether or not a UE is allowed to use CE functionality, and then provide this information to the MME 121 where it can be stored as part of a mobility management (MM) context and EPS bearer context. In some aspects, the SCEF 172 can be configured to query the HSS 177 to determine the status of enhanced coverage and, if required,

15   enable or disable it. For example, in instances when the UE does not subscribe to CE functionalities, enhanced coverage can be restricted for the UE.

[00121]   In some aspects, the UE may indicate its support for restriction of enhanced coverage feature in the ATTACH REQUEST and

20   TRACKING AREA UPDATE REQUST message, and if the UE supports this feature, the MME can be configured to indicate whether enhanced coverage is restricted or not in the ATTACH ACCEPT and TRACKING AREA UPDATE ACCEPT message. In instances when enhanced coverage is restricted for a particular PLMN, then the UE shall not access

25   enhanced coverage capabilities in that PLMN.

[00122]   FIG. 7 illustrates an example communication sequence in a CIoT environment in accordance with some aspects. Referring to FIG. 7, the communication sequence 700 can take place between UE 702, MME/SGSN 704, and HSS 706.

30   [00123]   In one aspect, the CIoT architecture 140F can be associated with an evolved packet system (EPS). In this case, at 708, the UE can send an Attach request to the MME 704. In one aspect, the Attach request can include a UE Network Capability information element (IE) 800, as

illustrated in FIG. 8. The UE network capability IE 800 can include a RestrictEC bit 802, which can be used to indicate whether or not the UE supports restriction of enhanced coverage. For example, when the RestrictEC bit 802 is set, the UE network capability IE 800 indicates that

5   restriction of use of enhanced coverage is supported by the UE. Conversely, when the RestrictEC bit 802 is not set, the UE network capability IE 800 indicates that restriction of use of enhanced coverage is not supported by the UE. In some aspects, the RestrictEC bit 802 can be located in bit number 3 of octet 9 of the UE network capability IE 800.

10   **[00124]**   Referring to FIG. 7, at 710, an update location request can be communicated from the MME 704 to the HSS 706. The HSS 706 can, at 712, obtain a value of the Enhanced Coverage Allowed parameter for the particular UE 702. At 714, the HSS 706 can communicate an update location acknowledgment, which can include the Enhanced Coverage

15   Allowed parameter (or another type of indication such as subscription information on whether or not the UE 702 subscribes to enhanced coverage functionalities or restriction of enhanced coverage functionalities). At 716, the MME 704 can set the value of Enhanced Coverage Allowed parameter in the MM context for the UE 702 based on the parameter value received

20   from the HSS 706.

      [00125]   At 718, the MME 704 can send an Attach Accept message, which can include an indication of whether or not enhanced coverage is restricted for the UE. More specifically, the MME 704 can send an EPS network feature support IE, which can include a bit indicating whether use

25   of enhanced coverage is restricted or not restricted for the UE 702. FIG. 9 illustrates an example EPS Network Feature Support information element in accordance with some aspects. Referring to FIG. 9, the EPS network feature support IE 900 can include a RestrictEC bit 902, which can be used to indicate whether or not the enhanced coverage is restricted for the UE.

30   For example, when the RestrictEC bit 902 is set, enhanced coverage is restricted for the UE. Conversely, when the RestrictEC bit 902 is not set, use of enhanced coverage is not restricted for the UE. In some aspects, the

RestrictEC bit 802 can be located in bit number 5 of octet 4 of the EPS
Network Feature Support IE 900.

[00126]   In some aspects, the UE may indicate its support for
restriction of enhanced coverage feature in a tracking area update (TAU)
Request message, which can be communicated at 708. In this case, the
MME 704 can indicate whether enhanced coverage is restricted or not for
the UE 702 in a tracking area update (TAU) Accept message, as
communicated at 718. More specifically, the UE network capability IE 800
(with the RestrictEC bit indication of whether restriction of use of enhanced
coverage is supported or not supported by the UE) is communicated in the
TAU Request message sent at 708, and the EPS Network Feature Support
IE 900 (with the RestrictEC bit indication of whether use of enhanced
coverage is restricted or not restricted for the UE) is communicated in the
TAU Accept message sent at 718.

[00127]   In some aspects, the CIoT architecture 140F can be
associated with a General Packet Radio Service (GPRS). In this case, the
UE 702 (which can be referred to as mobile station, or MS) can
communicate with the SGSN 704 in place of the MME, and different
information elements can be used to convey indication of whether the MS
supports restriction of use of enhanced coverage and whether or not
enhanced coverage is restricted for the MS.

[00128]   For example and referring to FIG. 7, at 708, the MS 702 can
send an Attach request to the SGSN 704. In one aspect, the Attach request
can include a MS Network Capability IE 1000, as illustrated in FIG. 10.
The MS Network Capability IE 1000 can include a bit 1002, which can be
used to indicate whether or not the MS supports restriction of use of
enhanced coverage. For example, when the bit 1002 is set, the MS
Network Capability IE 1000 indicates that restriction of use of enhanced
coverage is supported by the MS. Conversely, when the bit 1002 is not set,
the MS Network Capability IE 1000 indicates that restriction of use of
enhanced coverage is not supported by the MS.

[00129]   At 710, an update location request can be communicated
from the SGSN 704 to the HSS 706. The HSS 706 can, at 712, obtain a

value of the Enhanced Coverage Allowed parameter for the particular MS
702. At 714, the HSS 706 can communicate an update location
acknowledgment, which can include the Enhanced Coverage Allowed
parameter (or another type of indication such as subscription information

5   on whether or not the MS 702 subscribes to enhanced coverage
functionalities or restriction of enhanced coverage functionalities). At 716,
the SGSN 704 can set the value of Enhanced Coverage Allowed parameter
in the MM context for the MS 702 based on the parameter value received
from the HSS 706.

10   **[00130]**   At 718, the SGSN 704 can send an Attach Accept message,
which can include an indication of whether or not enhanced coverage is
restricted for the MS. More specifically, the SGSN 704 can send an
Additional Network Feature support IE, which can include a bit indicating
whether use of enhanced coverage is restricted or not restricted for the MS

15   702. FIG. 11 illustrates an example Additional Network Feature Support
information element in accordance with some aspects. Referring to FIG.
11, the Additional Network Feature support IE 900 can include a
RestrictEC bit 1102, which can be used to indicate whether or not the
enhanced coverage is restricted for the MS 702. For example, when the

20   RestrictEC bit 1102 is set, enhanced coverage is restricted for the MS.
Conversely, when the RestrictEC bit 1102 is not set, use of enhanced
coverage is not restricted for the MS. In some aspects, the RestrictEC bit
1102 can be located in bit number 2 of octet 3 of the Additional Network
Feature Support IE 1100.

25   **[00131]**   In some aspects, the MS may indicate its support for
restriction of enhanced coverage feature in a routing area update (RAU)
Request message, which can be communicated at 708. In this case, the
SGSN 704 can indicate whether enhanced coverage is restricted or not for
the MS 702 in a routing area update (RAU) Accept message, as

30   communicated at 718. More specifically, the MS Network Capability IE
1000 (with the bit 1002 indicating whether restriction of use of enhanced
coverage is supported or not supported by the MS) is communicated in the
TAU Request message sent at 708, and the Additional Network Feature

Support IE 1100 (with the RestrictEC bit indication of whether use of enhanced coverage is restricted or not restricted for the MS) is communicated in the TAU Accept message sent at 718.

[00132] In some aspects, the MME 704 can communicate the Attach Accept or TAU Accept messages at 718 as NAS messages that are communicated at 717A to the eNB 703, and then forwarded by the eNB 703 to the UE 702 at the communication 717B. in some aspects, the MME 704 can send one or more additional messages to the eNB 703 at communication 717A, which messages can include the Enhanced Coverage Restricted parameter (e.g., indicating whether the UE is restricted for use of coverage enhancement). In some aspects, the messages communicated from the MME 704 to the eNB 703 at 717A can include one or more of an Initial Context Setup Request message, a Handover Request message, and a Downlink NAS Transport message.

[00133] FIG. 12 illustrates generally a flowchart of an example method of operating a UE supporting restriction on using enhanced coverage, in accordance with some aspects. Referring to FIG. 12, the example method 1200 can be performed by a CIoT UE (e.g., 102) configured for Evolved Packet System (EPS) communications in a Public Land Mobile Network (PLMN). At operation 1202, processing circuitry of the UE can be configured to encode an Attach Request message for transmission to a Mobility Management Entity (MME) in the EPS (e.g., as communicated at 708 in FIG. 7). The Attach Request message can include a UE Network Capability Information Element (IE) (e.g. 800) indicating whether the UE supports restriction on using enhanced coverage. At operation 1204, the processing circuitry of the UE can be configured to decode an Attach Accept message confirming attachment to the MME (e.g., as communicated at operation 718 in FIG. 7). The Attach Accept message can include an EPS Network Feature Support IE (e.g., 900) indicating whether use of enhanced coverage is restricted for the UE. At operation 1206, the processing circuitry of the UE can be configured to refrain from using enhanced coverage in the PLMN when the UE supports restriction on

using enhanced coverage and the EPS Network Feature Support IE indicates enhanced coverage is restricted for the UE.

[00134]   FIG. 13 illustrates a block diagram of a communication device such as an evolved Node-B (eNB), a new generation Node-B (gNB), an access point (AP), a wireless station (STA), or a user equipment (UE), in accordance with some aspects. In alternative aspects, the communication device 1300 may operate as a standalone device or may be connected (e.g., networked) to other communication devices.

[00135]   Circuitry (e.g., processing circuitry) is a collection of circuits implemented in tangible entities of the device 1300 that include hardware (e.g., simple circuits, gates, logic, etc.). Circuitry membership may be flexible over time. Circuitries include members that may, alone or in combination, perform specified operations when operating. In an example, hardware of the circuitry may be immutably designed to carry out a specific operation (e.g., hardwired). In an example, the hardware of the circuitry may include variably connected physical components (e.g., execution units, transistors, simple circuits, etc.) including a machine readable medium physically modified (e.g., magnetically, electrically, moveable placement of invariant massed particles, etc.) to encode instructions of the specific operation.

[00136]   In connecting the physical components, the underlying electrical properties of a hardware constituent are changed, for example, from an insulator to a conductor or vice versa. The instructions enable embedded hardware (e.g., the execution units or a loading mechanism) to create members of the circuitry in hardware via the variable connections to carry out portions of the specific operation when in operation. Accordingly, in an example, the machine readable medium elements are part of the circuitry or are communicatively coupled to the other components of the circuitry when the device is operating. In an example, any of the physical components may be used in more than one member of more than one circuitry. For example, under operation, execution units may be used in a first circuit of a first circuitry at one point in time and reused by a second circuit in the first circuitry, or by a third circuit in a

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second circuitry at a different time. Additional examples of these components with respect to the device 1300 follow.

[00137]   In some aspects, the device 1300 may operate as a standalone device or may be connected (e.g., networked) to other devices. In a networked deployment, the communication device 1300 may operate in the capacity of a server communication device, a client communication device, or both in server-client network environments. In an example, the communication device 1300 may act as a peer communication device in peer-to-peer (P2P) (or other distributed) network environment. The communication device 1300 may be a UE, eNB, PC, a tablet PC, a STB, a PDA, a mobile telephone, a smart phone, a web appliance, a network router, switch or bridge, or any communication device capable of executing instructions (sequential or otherwise) that specify actions to be taken by that communication device. Further, while only a single communication device is illustrated, the term "communication device" shall also be taken to include any collection of communication devices that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein, such as cloud computing, software as a service (SaaS), other computer cluster configurations.

[00138]   Examples, as described herein, may include, or may operate on, logic or a number of components, modules, or mechanisms. Modules are tangible entities (e.g., hardware) capable of performing specified operations and may be configured or arranged in a certain manner. In an example, circuits may be arranged (e.g., internally or with respect to external entities such as other circuits) in a specified manner as a module. In an example, the whole or part of one or more computer systems (e.g., a standalone, client or server computer system) or one or more hardware processors may be configured by firmware or software (e.g., instructions, an application portion, or an application) as a module that operates to perform specified operations. In an example, the software may reside on a communication device-readable medium. In an example, the software, when executed by the underlying hardware of the module, causes the hardware to perform the specified operations.

[00139]   Accordingly, the term "module" is understood to encompass a tangible entity, be that an entity that is physically constructed, specifically configured (e.g., hardwired), or temporarily (e.g., transitorily) configured (e.g., programmed) to operate in a specified manner or to perform part or all of any operation described herein. Considering examples in which modules are temporarily configured, each of the modules need not be instantiated at any one moment in time. For example, where the modules comprise a general-purpose hardware processor configured using software, the general-purpose hardware processor may be configured as respective different modules at different times. Software may accordingly configure a hardware processor, for example, to constitute a particular module at one instance of time and to constitute a different module at a different instance of time.

[00140]   Communication device (e.g., UE) 1300 may include a hardware processor 1302 (e.g., a central processing unit (CPU), a graphics processing unit (GPU), a hardware processor core, or any combination thereof), a main memory 1304, a static memory 1306, and mass storage 1316 (e.g., hard drive, tape drive, flash storage, or other block or storage devices), some or all of which may communicate with each other via an interlink (e.g., bus) 1308.

[00141]   The communication device 1300 may further include a display unit 1310, an alphanumeric input device 1312 (e.g., a keyboard), and a user interface (UI) navigation device 1314 (e.g., a mouse). In an example, the display unit 1310, input device 1312 and UI navigation device 1314 may be a touch screen display. The communication device 1300 may additionally include a signal generation device 1318 (e.g., a speaker), a network interface device 1320, and one or more sensors 1321, such as a global positioning system (GPS) sensor, compass, accelerometer, or other sensor. The communication device 1300 may include an output controller 1328, such as a serial (e.g., universal serial bus (USB), parallel, or other wired or wireless (e.g., infrared (IR), near field communication (NFC), etc.) connection to communicate or control one or more peripheral devices (e.g., a printer, card reader, etc.).

[00142] The storage device 1316 may include a communication device-readable medium 1322, on which is stored one or more sets of data structures or instructions 1324 (e.g., software) embodying or utilized by any one or more of the techniques or functions described herein. In some aspects, registers of the processor 1302, the main memory 1304, the static memory 1306, and/or the mass storage 1316 may be, or include (completely or at least partially), the device-readable medium 1322, on which is stored the one or more sets of data structures or instructions 1324, embodying or utilized by any one or more of the techniques or functions described herein. In an example, one or any combination of the hardware processor 1302, the main memory 1304, the static memory 1306, or the mass storage 1316 may constitute the device-readable medium 1322.

[00143] As used herein, the term "device-readable medium" is interchangeable with "computer-readable medium" or "machine-readable medium". While the communication device-readable medium 1322 is illustrated as a single medium, the term "communication device-readable medium" may include a single medium or multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) configured to store the one or more instructions 1324.

[00144] The term "communication device-readable medium" may include any medium that is capable of storing, encoding, or carrying instructions for execution by the communication device 1300 and that cause the communication device 1300 to perform any one or more of the techniques of the present disclosure, or that is capable of storing, encoding or carrying data structures used by or associated with such instructions. Non-limiting communication device-readable medium examples may include solid-state memories, and optical and magnetic media. Specific examples of communication device-readable media may include: non-volatile memory, such as semiconductor memory devices (e.g., Electrically Programmable Read-Only Memory (EPROM), Electrically Erasable Programmable Read-Only Memory (EEPROM)) and flash memory devices; magnetic disks, such as internal hard disks and removable disks; magneto-optical disks; Random Access Memory (RAM); and CD-ROM

and DVD-ROM disks. In some examples, communication device-readable media may include non-transitory communication device-readable media. In some examples, communication device-readable media may include communication device-readable media that is not a transitory propagating

5   signal.

[00145]   The instructions 1324 may further be transmitted or received over a communications network 1326 using a transmission medium via the network interface device 1320 utilizing any one of a number of transfer protocols (e.g., frame relay, internet protocol (IP), transmission control

10   protocol (TCP), user datagram protocol (UDP), hypertext transfer protocol (HTTP), etc.). Example communication networks may include a local area network (LAN), a wide area network (WAN), a packet data network (e.g., the Internet), mobile telephone networks (e.g., cellular networks), Plain Old Telephone (POTS) networks, and wireless data networks (e.g., Institute of

15   Electrical and Electronics Engineers (IEEE) 802.11 family of standards known as Wi-Fi®, IEEE 802.16 family of standards known as WiMax®), IEEE 802.15.4 family of standards, a Long Term Evolution (LTE) family of standards, a Universal Mobile Telecommunications System (UMTS) family of standards, peer-to-peer (P2P) networks, among others. In an

20   example, the network interface device 1320 may include one or more physical jacks (e.g., Ethernet, coaxial, or phone jacks) or one or more antennas to connect to the communications network 1326. In an example, the network interface device 1320 may include a plurality of antennas to wirelessly communicate using at least one of single-input multiple-output

25   (SIMO), MIMO, or multiple-input single-output (MISO) techniques. In some examples, the network interface device 1320 may wirelessly communicate using Multiple User MIMO techniques.

[00146]   The term "transmission medium" shall be taken to include any intangible medium that is capable of storing, encoding or carrying

30   instructions for execution by the communication device 1300, and includes digital or analog communications signals or other intangible medium to facilitate communication of such software. In this regard, a transmission medium in the context of this disclosure is a device-readable medium.

[00147]   Additional notes and examples:

[00148]   Example 1 is an apparatus of a Cellular-Internet-of-Things
(CIoT) capable user equipment (UE), the apparatus configured for Evolved
Packet System (EPS) communications in a Public Land Mobile Network
(PLMN), the apparatus comprising: processing circuitry, the processing
circuitry configured to: encode an Attach Request message for transmission
to a Mobility Management Entity (MME) in the EPS, the Attach Request
message including a UE Network Capability Information Element (IE)
indicating whether the UE supports restriction on using enhanced coverage;
decode an Attach Accept message confirming attachment to the MME, the
Attach Accept message including an EPS Network Feature Support IE
indicating whether use of enhanced coverage is restricted for the UE; and
refrain from using enhanced coverage in the PLMN when the UE supports
restriction on using enhanced coverage and the EPS Network Feature
Support IE indicates enhanced coverage is restricted for the UE; and
memory coupled to the processing circuitry, the memory configured to
store the EPS Network Feature Support IE.

[00149]   In Example 2, the subject matter of Example 1 includes,
wherein to refrain from using enhanced coverage, the processing circuitry
is further configured to: disable one or more enhanced coverage
functionalities in the PLMN when the UE supports restriction on using
enhanced coverage and the EPS Network Feature Support IE indicates
enhanced coverage is restricted for the UE.

[00150]   In Example 3, the subject matter of Examples 1–2 includes,
wherein the memory stores a list of equivalent PLMNs, and the processing
circuitry is further configured to: refrain from using enhanced coverage in
any PLMN in the list of equivalent PLMNs, when the UE supports
restriction on using enhanced coverage and the EPS Network Feature
Support IE indicates enhanced coverage is restricted for the UE.

[00151]   In Example 4, the subject matter of Examples 1–3 includes,
wherein the UE Network Capability IE includes a bit indicating restriction
of use of enhanced coverage is supported by the UE when the bit is set, and

restriction of use of enhanced coverage is not supported by the UE when the bit is not set.

[00152]   In Example 5, the subject matter of Example 4 includes, wherein the bit is a Restrict Enhanced Coverage (RestrictEC) bit located in octet 9 of the UE Network Capability IE.

[00153]   In Example 6, the subject matter of Examples 1–5 includes, wherein the processing circuitry is configured to: permit using enhanced coverage in the PLMN when the EPS Network Feature Support IE indicates enhanced coverage is not restricted for the UE.

[00154]   In Example 7, the subject matter of Examples 1–6 includes, wherein the EPS Network Support IE includes a bit indicating the use of enhanced coverage is restricted for the UE when the bit is set, and the use of enhanced coverage is not restricted for the UE when the bit is not set.

[00155]   In Example 8, the subject matter of Example 7 includes, wherein the bit is a Restrict Enhanced Coverage (RestrictEC) bit located in octet 4 of the EPS Network Feature Support IE.

[00156]   In Example 9, the subject matter of Examples 1–8 includes, wherein the processing circuitry is further configured to: encode a Tracking Area Update Request message for transmission to the MME in the EPS, the Tracking Area Update Request message including the UE Network Capability IE indicating whether the UE supports the restriction on using enhanced coverage.

[00157]   In Example 10, the subject matter of Example 9 includes, wherein the processing circuitry is further configured to: decode a Tracking Area Update Accept message confirming a UE location update, the Tracking Area Update Accept message further including the EPS Network Feature Support IE indicating whether the use of enhanced coverage is restricted for the UE.

[00158]   In Example 11, the subject matter of Examples 1–10 includes, transceiver circuitry coupled to the processing circuitry; and, one or more antennas coupled to the transceiver circuitry.

[00159]   Example 12 is a non-transitory computer-readable storage medium that stores instructions for execution by one or more processors of a Cellular-Internet-of-Things (CIoT) capable mobile station (MS), the

apparatus configured for General Packet Radio Service (GPRS) communications in a Public Land Mobile Network (PLMN), the instructions to configure the one or more processors to cause the MS to: encode an Attach Request message for transmission to a Serving GPRS Support Node (SGSN), the Attach Request message including an MS Network Capability Information Element (IE) indicating whether the MS supports restriction on using enhanced coverage; decode an Attach Accept message confirming attachment to the SGSN, the Attach Accept message including an Additional Network Feature Support IE indicating whether use of enhanced coverage is restricted for the MS; and refrain from using enhanced coverage in the PLMN when the MS supports restriction on using enhanced coverage and the Additional Network Feature Support IE indicates enhanced coverage is restricted for the MS.

[00160]   In Example 13, the subject matter of Example 12 includes, wherein the one or more processors further cause the MS to: refrain from using enhanced coverage in any PLMN in a list of equivalent PLMNs, when the MS supports restriction on using enhanced coverage and the Additional Network Feature Support IE indicates enhanced coverage is restricted for the MS.

[00161]   In Example 14, the subject matter of Examples 12–13 includes, wherein the MS Network Capability IE includes a bit indicating restriction of use of enhanced coverage is supported by the MS when the bit is set, and restriction of use of enhanced coverage is not supported by the MS when the bit is not set.

[00162]   In Example 15, the subject matter of Examples 12–14 includes, wherein the one or more processors further cause the MS to: permit using enhanced coverage in the PLMN when the Additional Network Feature Support IE indicates enhanced coverage is not restricted for the MS.

[00163]   In Example 16, the subject matter of Examples 12–15 includes, wherein the Additional Network Support IE includes a bit indicating the use of enhanced coverage is restricted for the MS when the bit is set, and the use of enhanced coverage is not restricted for the MS when the bit is not set.

[00164]   In Example 17, the subject matter of Examples 12–16 includes, wherein the bit is a Restrict Enhanced Coverage (RestrictEC) bit located in an octet of the Additional Network Feature Support IE.

[00165]   In Example 18, the subject matter of Example 17 includes, wherein the RestrictEC bit is located in octet 3 of the Additional Network Feature Support IE.

[00166]   In Example 19, the subject matter of Examples 12–18 includes, wherein the one or more processors further cause the MS to: encode a Routing Area Update (RAU) Request message for transmission to the SGSN in the GPRS, the RAU Request message including the MS Network Capability IE indicating whether the MS supports the restriction on using enhanced coverage.

[00167]   In Example 20, the subject matter of Example 19 includes, wherein the one or more processors further cause the MS to: decode a Routing Area Update Accept message confirming a MS location update, the RAU Accept message further including the Additional Network Feature Support IE indicating whether the use of enhanced coverage is restricted for the MS.

[00168]   Example 21 is an apparatus of a Node-B (NB), the apparatus comprising: processing circuitry, configured to: decode a configuration message from a Mobility Management Entity (MME), the configuration message including an Enhanced Coverage Restricted information element (IE) indicating whether use of enhanced coverage is restricted for a user equipment (UE); create a context for the UE based on the configuration message; and forward a downlink Network Access Stratum (NAS) Accept message for transmission to the UE based on the UE context, the NAS Accept message including an EPS Network Feature Support IE indicating whether use of enhanced coverage is restricted for the UE; and memory coupled to the processing circuitry, the memory configured to store the Enhanced Coverage Restricted IE.

[00169]   In Example 22, the subject matter of Example 21 includes, wherein the configuration message is an Initial Context Setup Request message.

[00170]   In Example 23, the subject matter of Examples 21–22 includes, wherein the configuration message is a Handover Request message.

[00171]   In Example 24, the subject matter of Examples 21–23 includes, wherein the configuration message is a Downlink NAS Transport message.

[00172]   In Example 25, the subject matter of Examples 21–24 includes, wherein the processing circuitry is further configured to: encode an uplink non-access stratum (NAS) message for transmission to the MME, the NAS message including a UE Network Capability Information Element (IE) indicating whether the UE supports restriction on using enhanced coverage.

[00173]   In Example 26, the subject matter of Examples 21–25 includes, transceiver circuitry coupled to the processing circuitry; and, one or more antennas coupled to the transceiver circuitry.

[00174]   Example 27 is at least one machine-readable medium including instructions that, when executed by processing circuitry, cause the processing circuitry to perform operations to implement of any of Examples 1–26.

[00175]   Example 28 is an apparatus comprising means to implement of any of Examples 1–26.

[00176]   Example 29 is a system to implement of any of Examples 1–26.

[00177]   Example 30 is a method to implement of any of Examples 1–26.

[00178]   Although an aspect has been described with reference to specific example aspects, it will be evident that various modifications and changes may be made to these aspects without departing from the broader scope of the present disclosure. Accordingly, the specification and drawings are to be regarded in an illustrative rather than a restrictive sense. The accompanying drawings that form a part hereof show, by way of illustration, and not of limitation, specific aspects in which the subject matter may be practiced. The aspects illustrated are described in sufficient detail to enable those skilled in the art to practice the teachings disclosed

herein. Other aspects may be utilized and derived therefrom, such that structural and logical substitutions and changes may be made without departing from the scope of this disclosure. This Detailed Description, therefore, is not to be taken in a limiting sense, and the scope of various aspects is defined only by the appended claims, along with the full range of equivalents to which such claims are entitled.

[00179] Such aspects of the inventive subject matter may be referred to herein, individually and/or collectively, merely for convenience and without intending to voluntarily limit the scope of this application to any single aspect or inventive concept if more than one is in fact disclosed. Thus, although specific aspects have been illustrated and described herein, it should be appreciated that any arrangement calculated to achieve the same purpose may be substituted for the specific aspects shown. This disclosure is intended to cover any and all adaptations or variations of various aspects. Combinations of the above aspects, and other aspects not specifically described herein, will be apparent to those of skill in the art upon reviewing the above description.

[00180] The Abstract of the Disclosure is provided to allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. In addition, in the foregoing Detailed Description, it can be seen that various features are grouped together in a single aspect for the purpose of streamlining the disclosure. This method of disclosure is not to be interpreted as reflecting an intention that the claimed aspects require more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive subject matter lies in less than all features of a single disclosed aspect. Thus the following claims are hereby incorporated into the Detailed Description, with each claim standing on its own as a separate aspect.

CLAIMS

What is claimed is:

1.   An apparatus of a Cellular-Internet-of-Things (CIoT) capable user
equipment (UE), the apparatus configured for Evolved Packet System
(EPS) communications in a Public Land Mobile Network (PLMN), the
apparatus comprising:

        processing circuitry, the processing circuitry configured to:

        encode an Attach Request message for transmission to a
Mobility Management Entity (MME) in the EPS, the Attach
Request message including a UE Network Capability Information
Element (IE) indicating whether the UE supports restriction on
using enhanced coverage;

        decode an Attach Accept message confirming attachment to
the MME, the Attach Accept message including an EPS Network
Feature Support IE indicating whether use of enhanced coverage is
restricted for the UE; and

        refrain from using enhanced coverage in the PLMN when
the UE supports restriction on using enhanced coverage and the
EPS Network Feature Support IE indicates enhanced coverage is
restricted for the UE; and

        memory coupled to the processing circuitry, the memory configured
to store the EPS Network Feature Support IE.

2.   The apparatus of claim 1, wherein to refrain from using enhanced
coverage, the processing circuitry is further configured to:

        disable one or more enhanced coverage functionalities in the PLMN
when the UE supports restriction on using enhanced coverage and the EPS
Network Feature Support IE indicates enhanced coverage is restricted for
the UE.

3.   The apparatus of any of claims 1–2, wherein the memory stores a list of equivalent PLMNs, and the processing circuitry is further configured to:

5   refrain from using enhanced coverage in any PLMN in the list of equivalent PLMNs, when the UE supports restriction on using enhanced coverage and the EPS Network Feature Support IE indicates enhanced coverage is restricted for the UE.

10   4.   The apparatus of any of claims 1–2, wherein the UE Network Capability IE includes a bit indicating restriction of use of enhanced coverage is supported by the UE when the bit is set, and restriction of use of enhanced coverage is not supported by the UE when the bit is not set.

15   5.   The apparatus of claim 4, wherein the bit is a Restrict Enhanced Coverage (RestrictEC) bit located in octet 9 of the UE Network Capability IE.

6.   The apparatus of any of claims 1–2, wherein the processing
20   circuitry is configured to:

permit using enhanced coverage in the PLMN when the EPS Network Feature Support IE indicates enhanced coverage is not restricted for the UE.

25   7.   The apparatus of any of claims 1–2, wherein the EPS Network Support IE includes a bit indicating the use of enhanced coverage is restricted for the UE when the bit is set, and the use of enhanced coverage is not restricted for the UE when the bit is not set.

8.   The apparatus of claim 7, wherein the bit is a Restrict Enhanced Coverage (RestrictEC) bit located in octet 4 of the EPS Network Feature Support IE.

5   9.   The apparatus of any of claims 1–2, wherein the processing circuitry is further configured to:

encode a Tracking Area Update Request message for transmission to the MME in the EPS, the Tracking Area Update Request message including the UE Network Capability IE indicating whether the UE
10 supports the restriction on using enhanced coverage.

10.   The apparatus of claim 9, wherein the processing circuitry is further configured to:

decode a Tracking Area Update Accept message confirming a UE
15 location update, the Tracking Area Update Accept message further including the EPS Network Feature Support IE indicating whether the use of enhanced coverage is restricted for the UE.

11.   The apparatus of any of claims 1–2, further comprising transceiver
20 circuitry coupled to the processing circuitry; and, one or more antennas coupled to the transceiver circuitry.

12.   A computer-readable storage medium that stores instructions for execution by one or more processors of a Cellular-Internet-of-Things (CIoT) capable mobile station (MS), the apparatus configured for General Packet Radio Service (GPRS) communications in a Public Land Mobile
5   Network (PLMN), the instructions to configure the one or more processors to cause the MS to:

encode an Attach Request message for transmission to a Serving GPRS Support Node (SGSN), the Attach Request message including an MS Network Capability Information Element (IE) indicating whether the
10   MS supports restriction on using enhanced coverage;

decode an Attach Accept message confirming attachment to the SGSN, the Attach Accept message including an Additional Network Feature Support IE indicating whether use of enhanced coverage is restricted for the MS; and

15   refrain from using enhanced coverage in the PLMN when the MS supports restriction on using enhanced coverage and the Additional Network Feature Support IE indicates enhanced coverage is restricted for the MS.

20   13.   The computer-readable storage medium of claim 12, wherein the one or more processors further cause the MS to:

refrain from using enhanced coverage in any PLMN in a list of equivalent PLMNs, when the MS supports restriction on using enhanced coverage and the Additional Network Feature Support IE indicates
25   enhanced coverage is restricted for the MS.

14.   The computer-readable storage medium of any of claims 12–13, wherein the MS Network Capability IE includes a bit indicating restriction of use of enhanced coverage is supported by the MS when the bit is set, and
30   restriction of use of enhanced coverage is not supported by the MS when the bit is not set.

15.   The computer-readable storage medium of any of claims 12–13, wherein the one or more processors further cause the MS to:

permit using enhanced coverage in the PLMN when the Additional Network Feature Support IE indicates enhanced coverage is not restricted for the MS.

16.   The computer-readable storage medium of any of claims 12–13, wherein the Additional Network Support IE includes a bit indicating the use of enhanced coverage is restricted for the MS when the bit is set, and the use of enhanced coverage is not restricted for the MS when the bit is not set.

17.   The computer-readable storage medium of any of claims 12–13, wherein the bit is a Restrict Enhanced Coverage (RestrictEC) bit located in an octet of the Additional Network Feature Support IE.

18.   The computer-readable storage medium of claim 17, wherein the RestrictEC bit is located in octet 3 of the Additional Network Feature Support IE.

19.   The computer-readable storage medium of any of claims 12–13, wherein the one or more processors further cause the MS to:

encode a Routing Area Update (RAU) Request message for transmission to the SGSN in the GPRS, the RAU Request message including the MS Network Capability IE indicating whether the MS supports the restriction on using enhanced coverage.

20. The computer-readable storage medium of claim 19, wherein the one or more processors further cause the MS to:

decode a Routing Area Update Accept message confirming a MS location update, the RAU Accept message further including the Additional

5   Network Feature Support IE indicating whether the use of enhanced coverage is restricted for the MS.

21. An apparatus of a Node-B (NB), the apparatus comprising:

processing circuitry, configured to:

10   decode a configuration message from a Mobility Management Entity (MME), the configuration message including an Enhanced Coverage Restricted information element (IE) indicating whether use of enhanced coverage is restricted for a user equipment (UE);

15   create a context for the UE based on the configuration message; and

forward a downlink Network Access Stratum (NAS) Accept message for transmission to the UE based on the UE context, the NAS Accept message including an EPS Network Feature Support

20   IE indicating whether use of enhanced coverage is restricted for the UE; and

memory coupled to the processing circuitry, the memory configured to store the Enhanced Coverage Restricted IE.

25   22. The apparatus of claim 21, wherein the configuration message is an Initial Context Setup Request message.

23. The apparatus of any of claims 21–22, wherein the configuration message is a Handover Request message.

30

24.   The apparatus of any of claims 21–22, wherein the configuration message is a Downlink NAS Transport message.

25.   The apparatus of any of claims 21–22, wherein the processing circuitry is further configured to:

encode an uplink non-access stratum (NAS) message for transmission to the MME, the NAS message including a UE Network Capability Information Element (IE) indicating whether the UE supports restriction on using enhanced coverage.
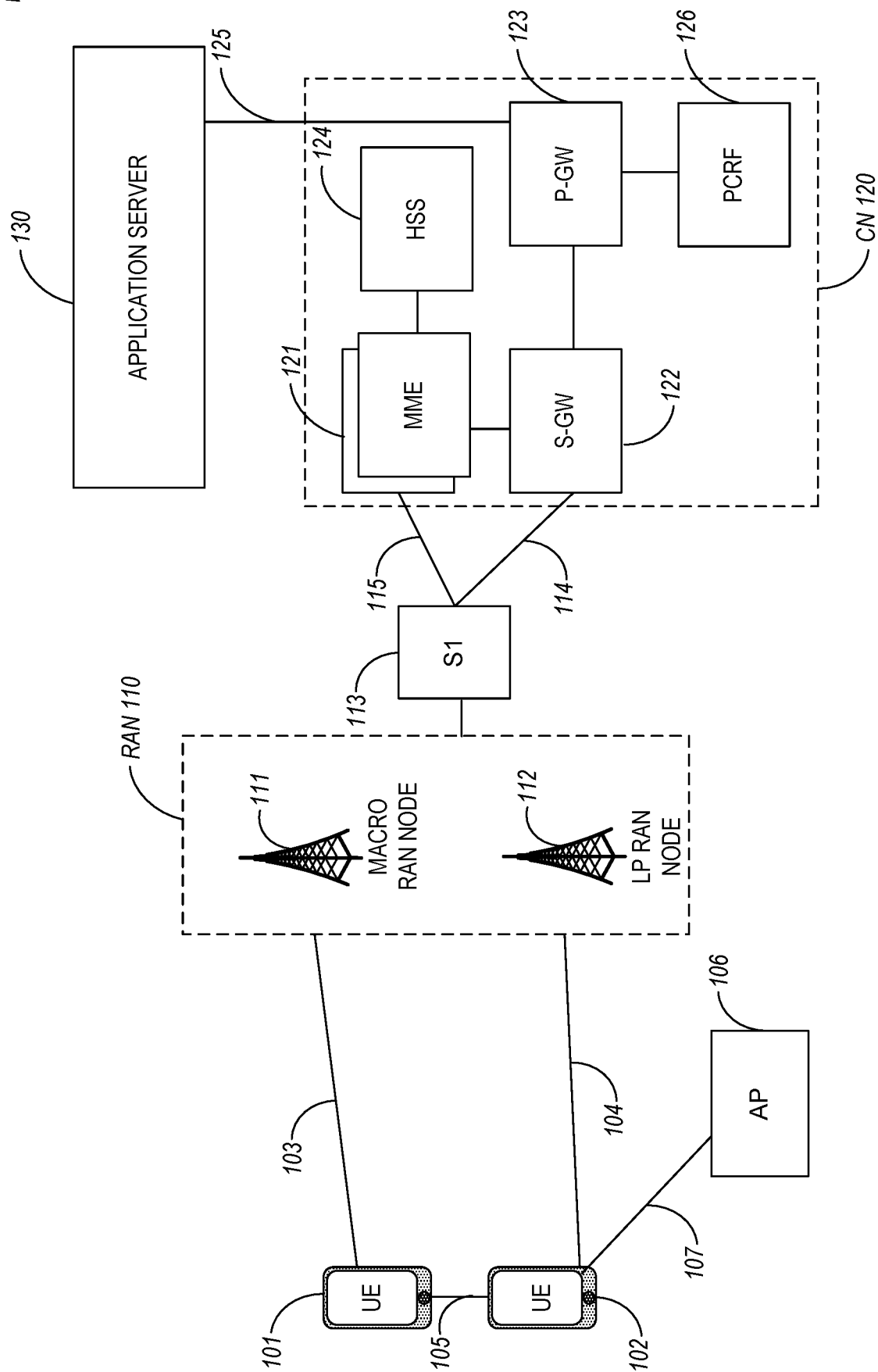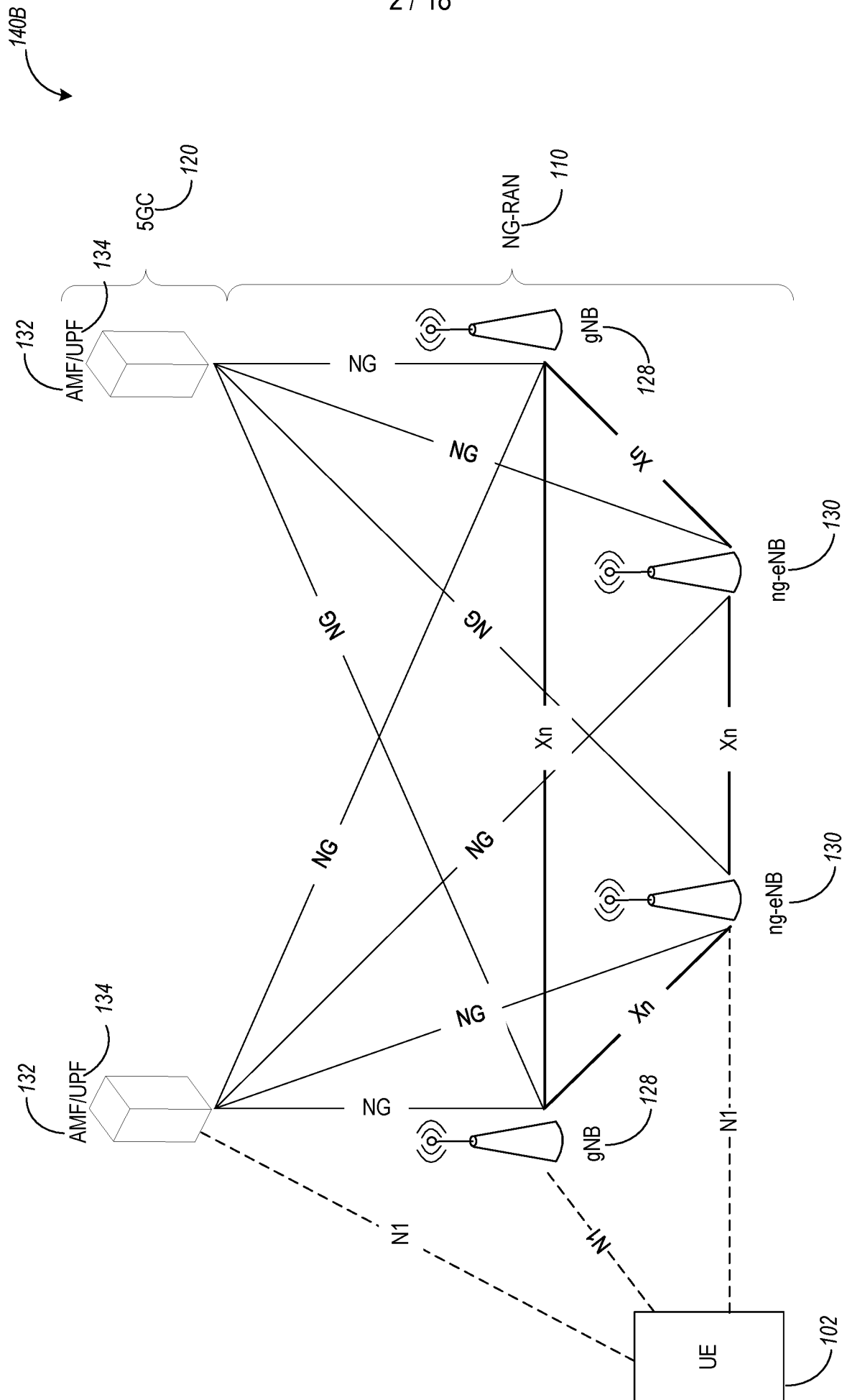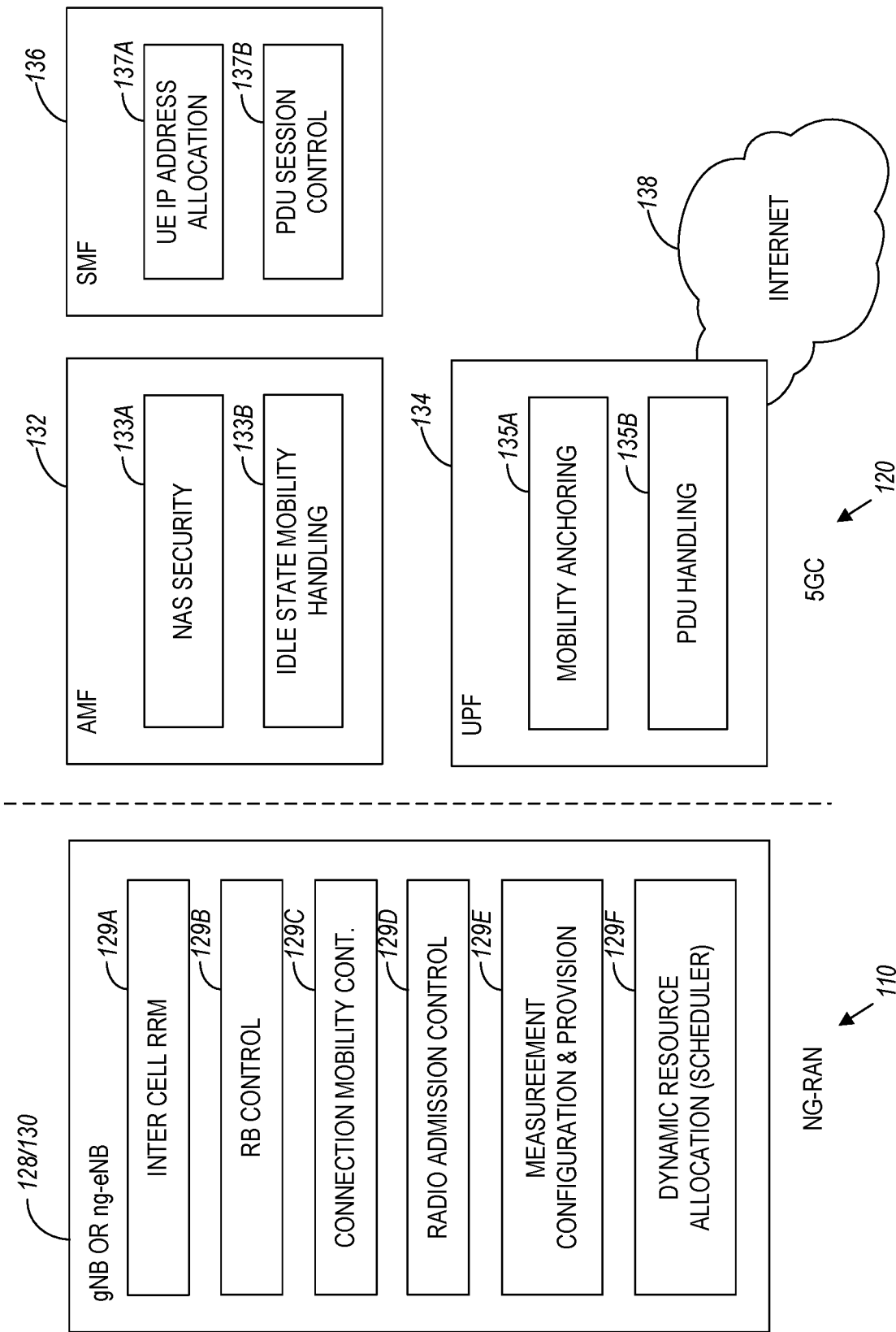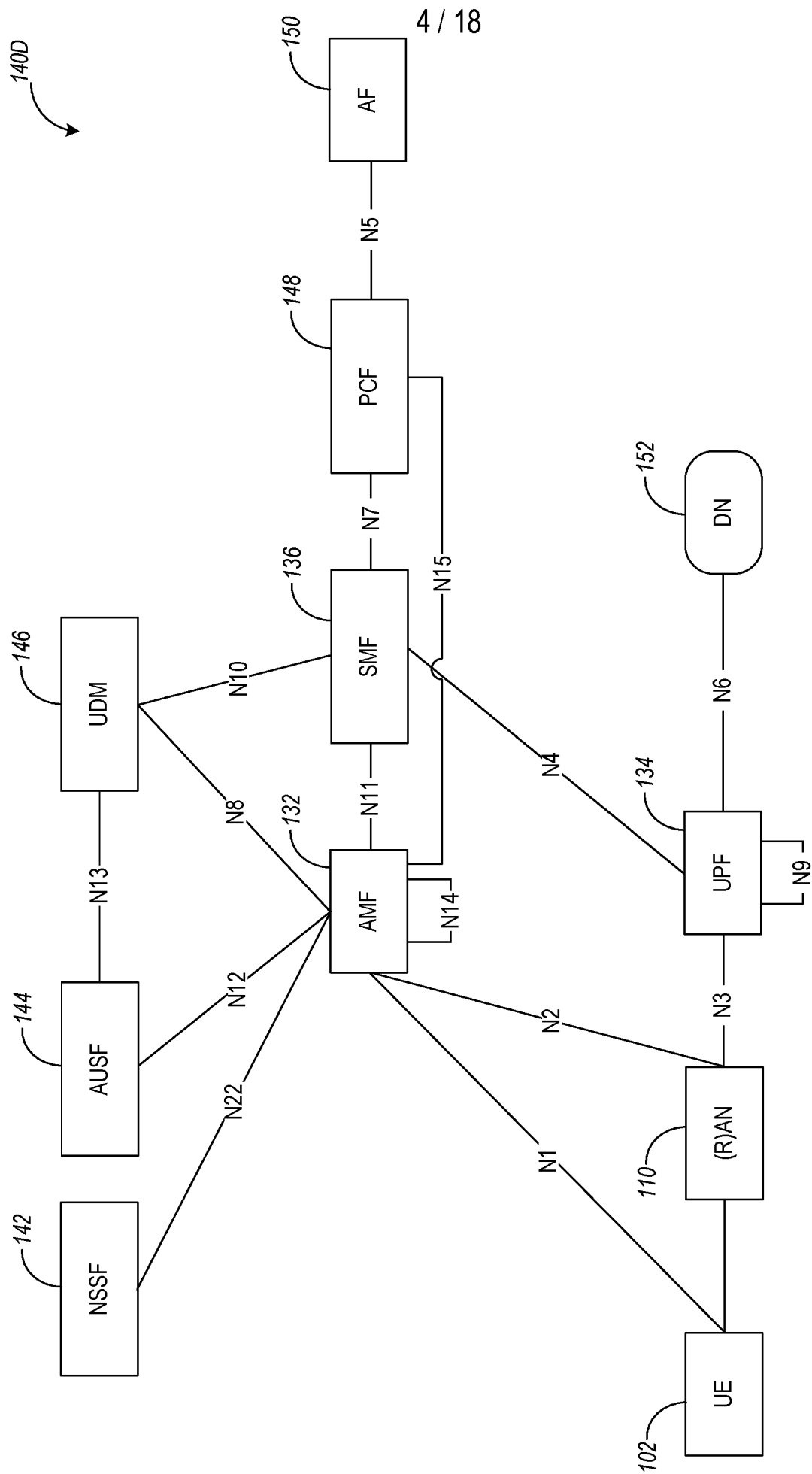
FIG. 1A

FIG. 1B

FIG. 1C

FIG. 1D

FIG. 1E

FIG. 1F

7 / 18

FIG. 2

FIG. 3

400

121

NAS	406
S1-AP	415
SCTP	414
IP	413
L2	412
L1	411

MME

111/112

RRC	405	S1-AP	415
PDCP	404	SCTP	414
RLC	403	IP	413
MAC	402	L2	412
PHY	401	L1	411

RAN NODE

101/102

NAS	406
RRC	405
PDCP	404
RLC	403
MAC	402
PHY	401

UE
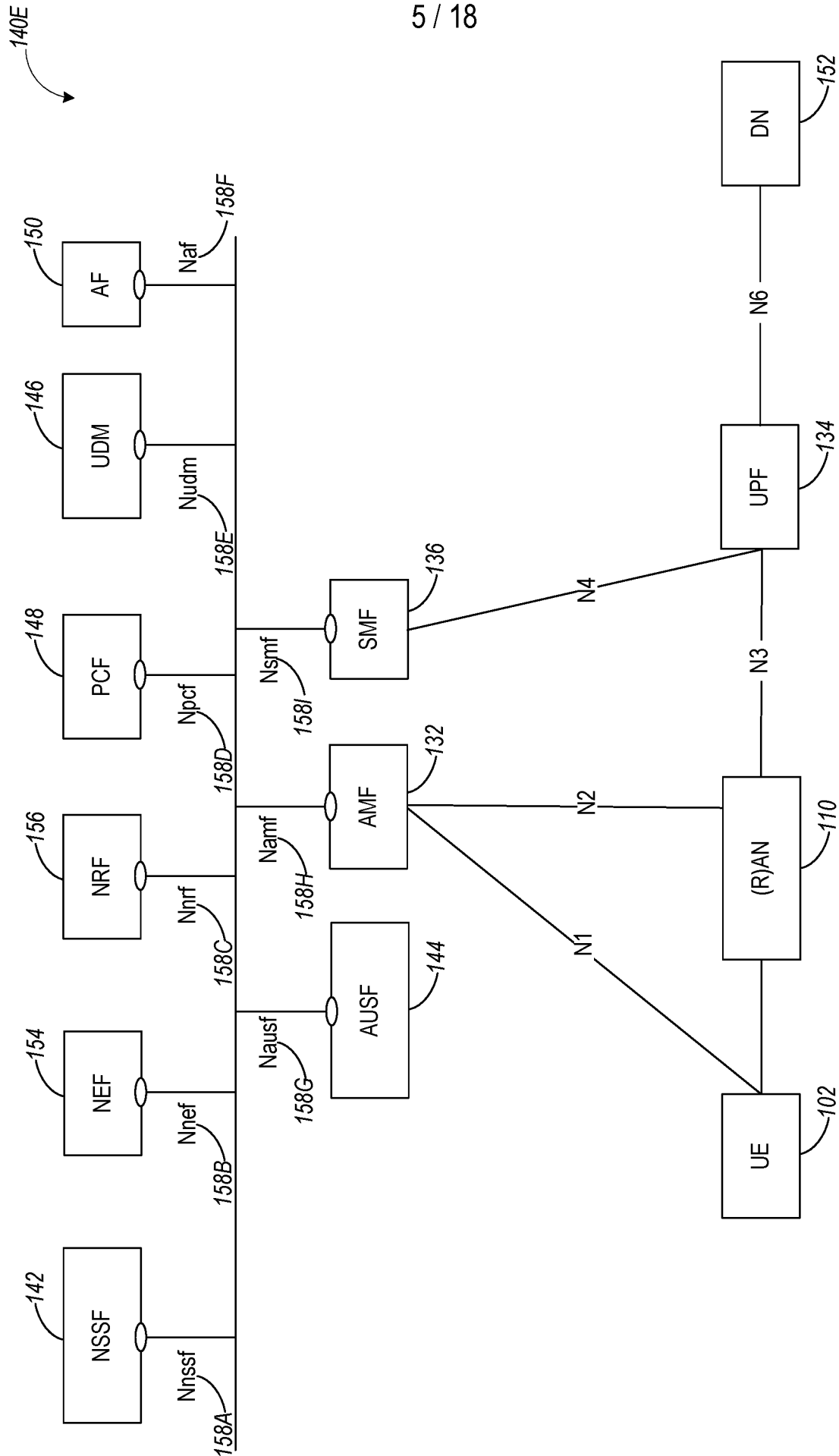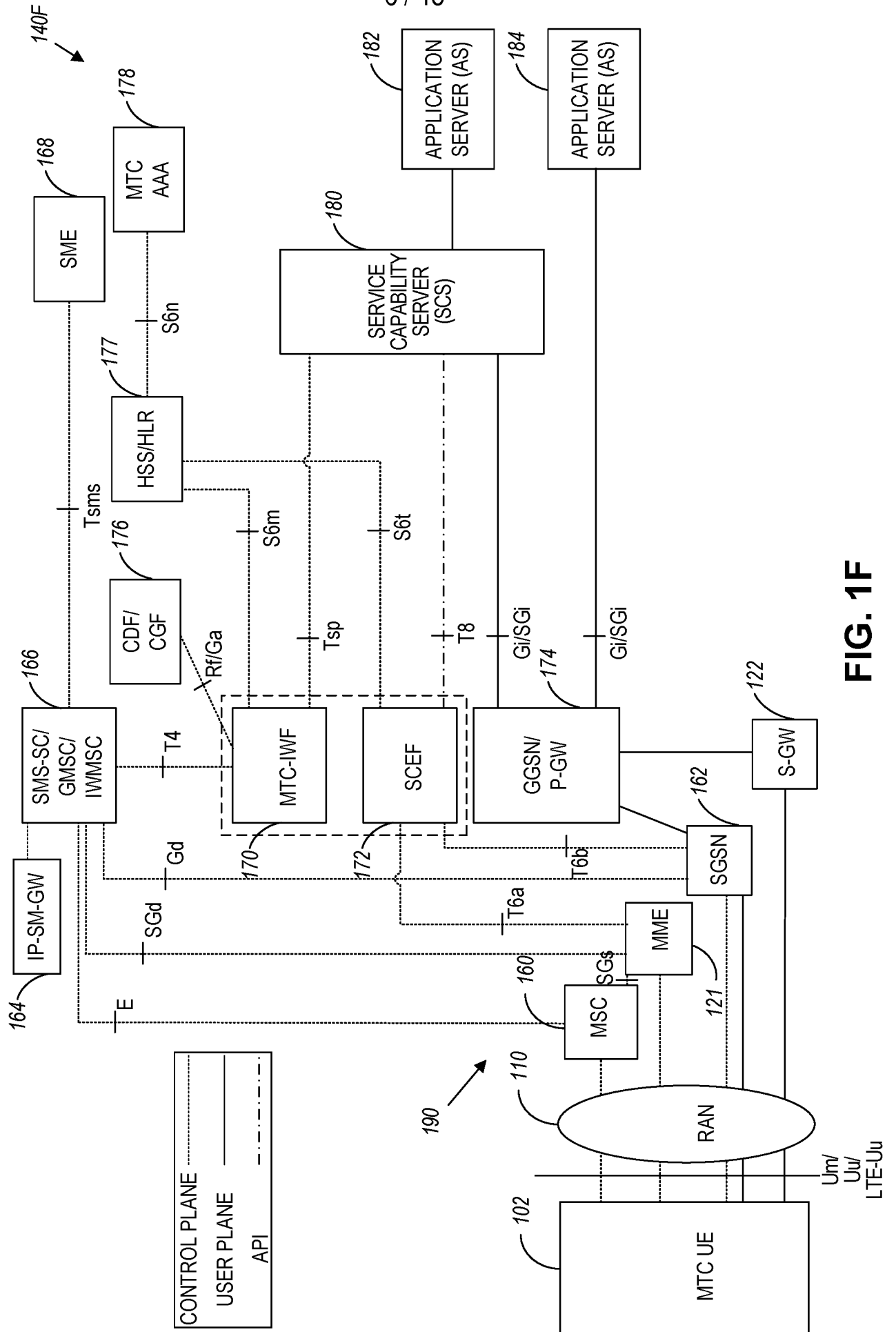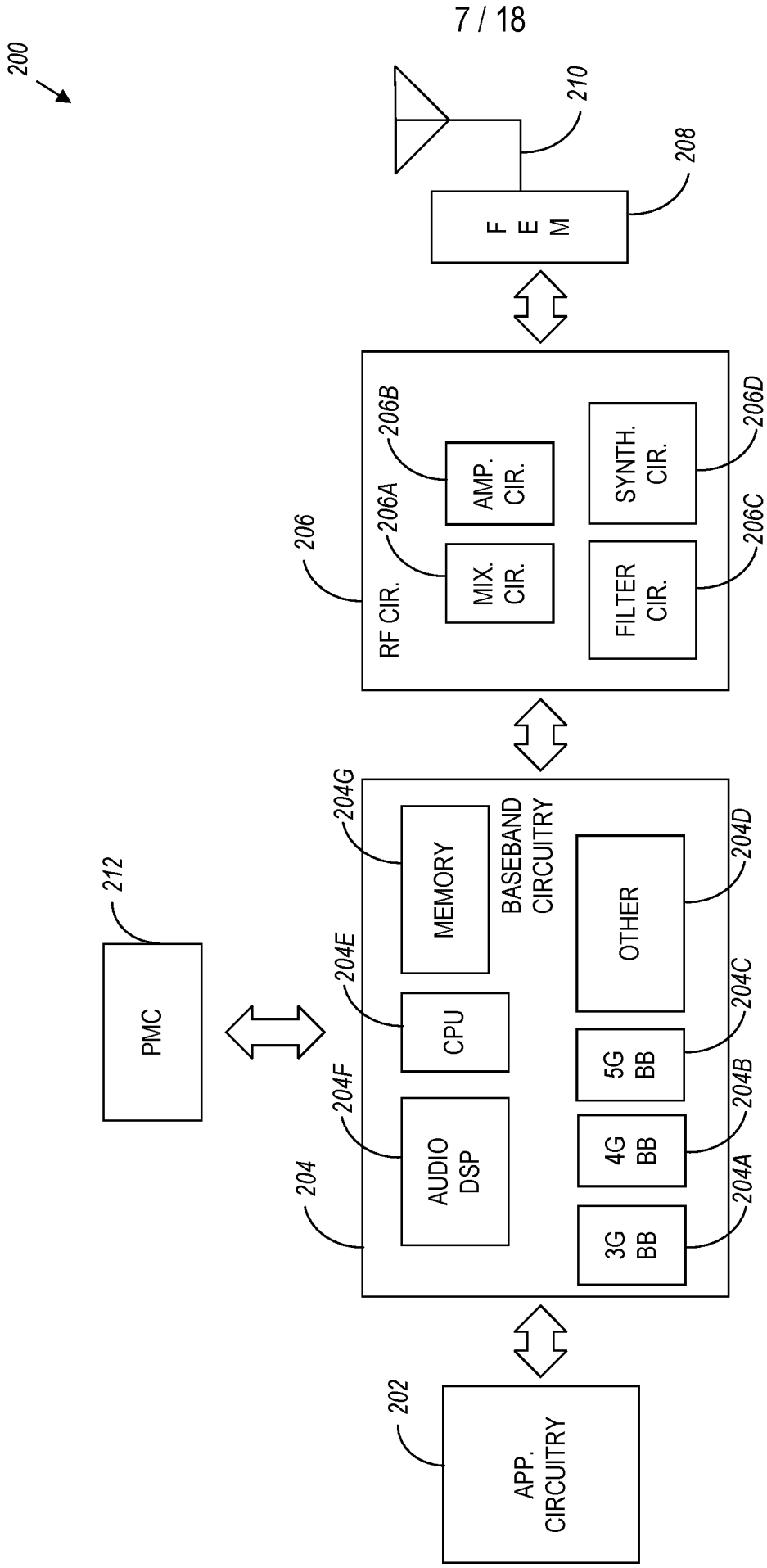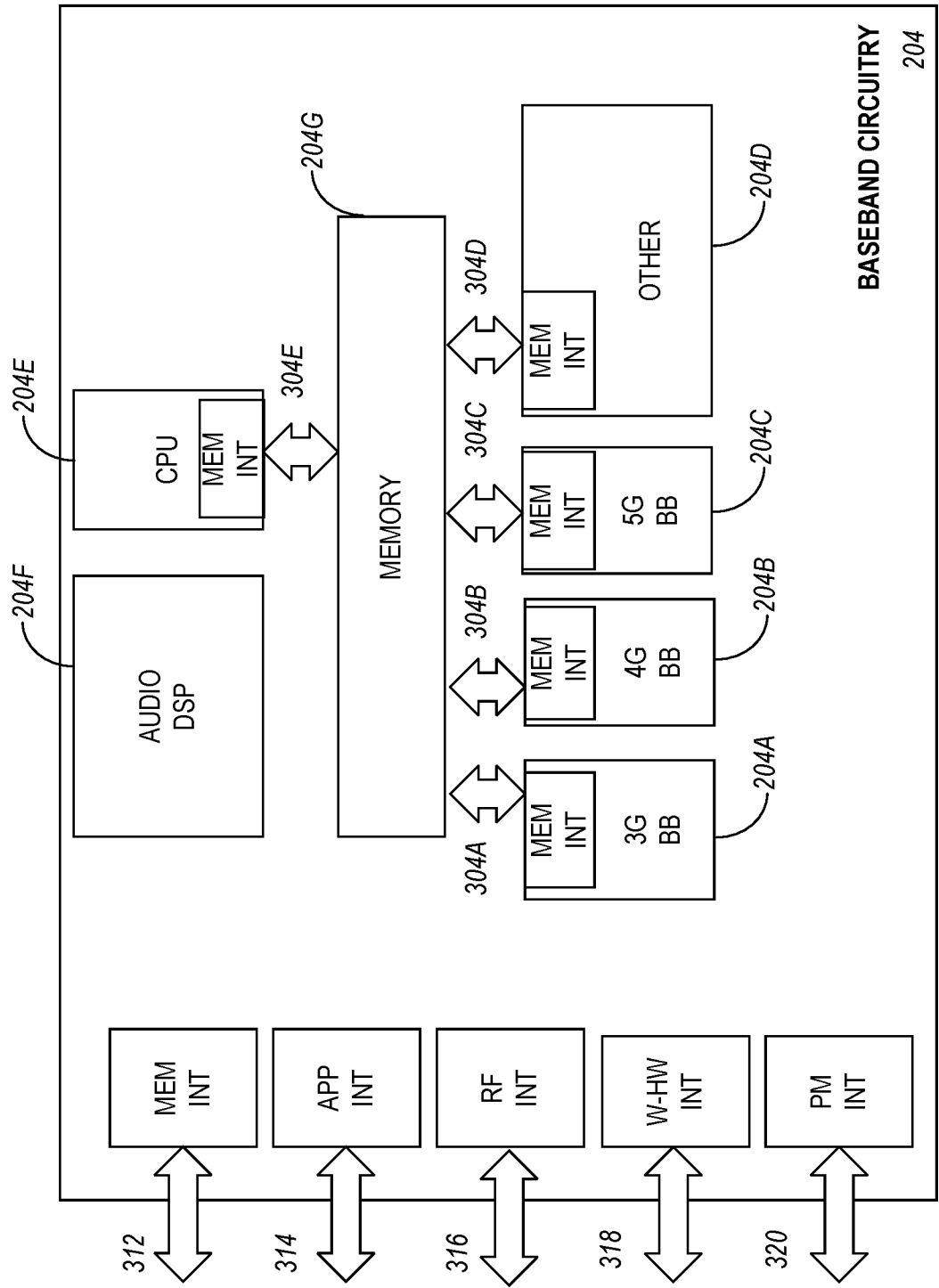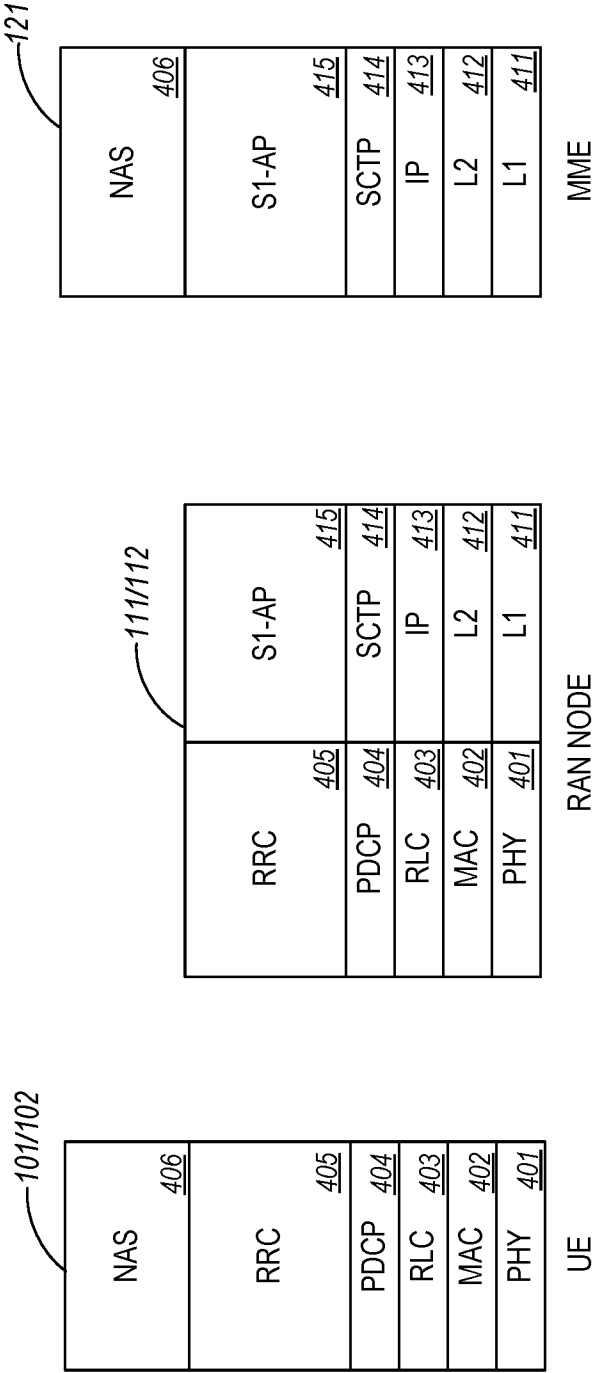
FIG. 4
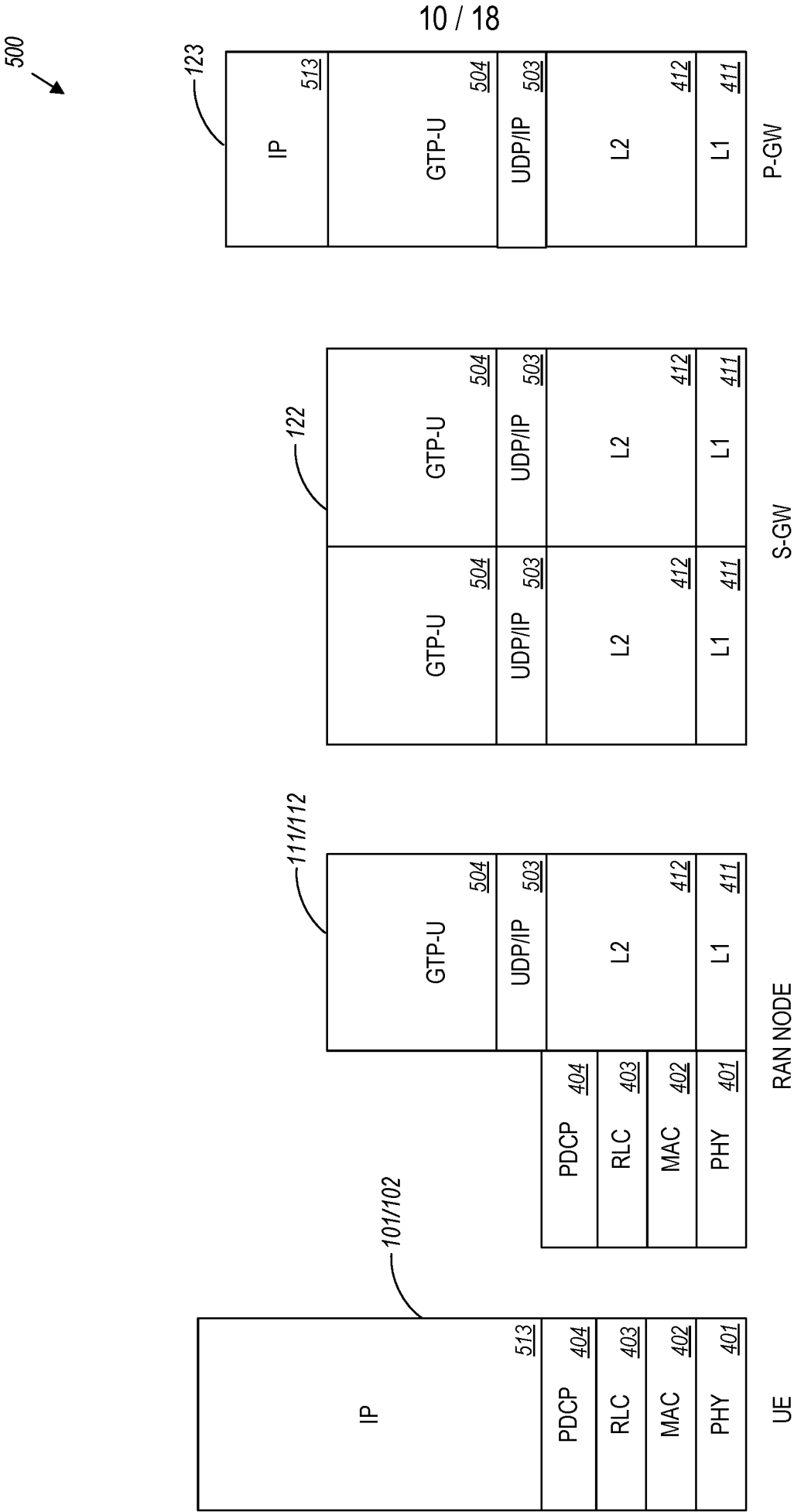
FIG. 5

FIG. 6

FIG. 7

800

802
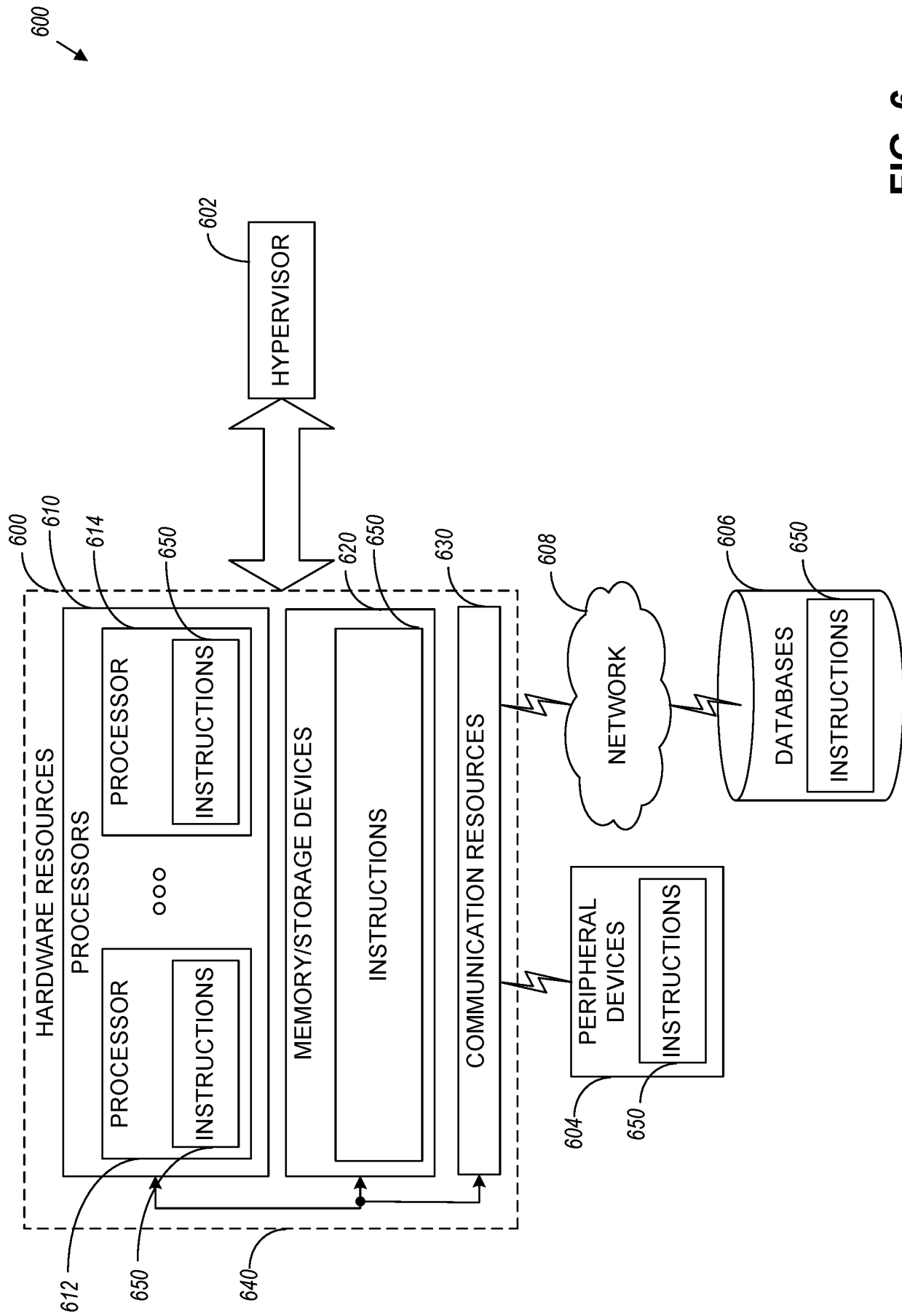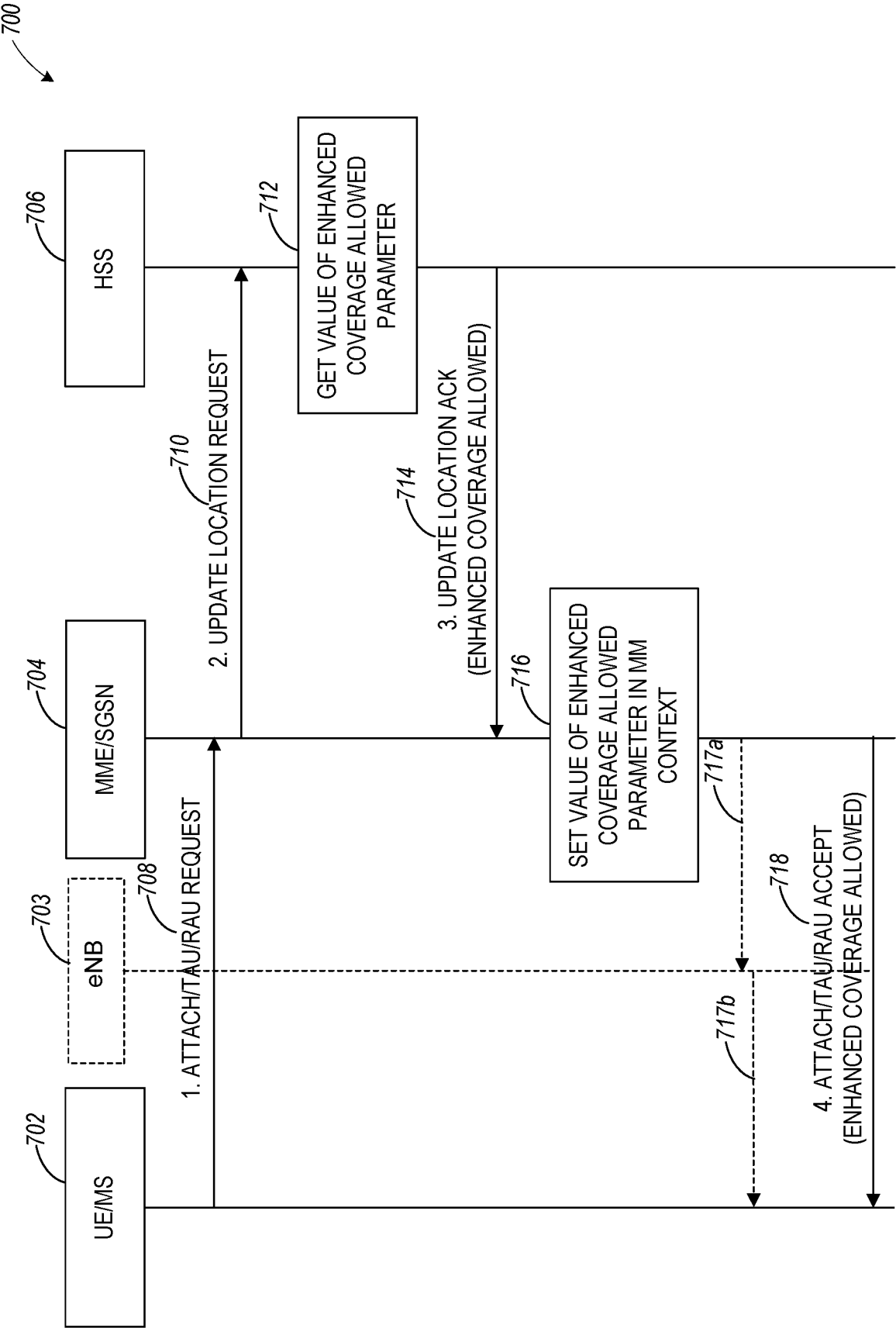
8	7	6	5	4	3	2	1	
UE NETWORK CAPABILITY IEI								OCTET 1
LENGTH OF UE NETWORK CAPABILITY CONTENTS								OCTET 2
EEA0	128-EEA1	128-EEA2	128-EEA3	EEA4	EEA5	EEA6	EEA7	OCTET 3
EIA0	128-EIA1	128-EIA2	128-EIA3	EIA4	EIA5	EIA6	EIA7	OCTET 4
UEA0	UEA1	UEA2	UEA3	UEA4	UEA5	UEA6	UEA7	OCTET 5*
UCS2	UIA1	UIA2	UIA3	UIA4	UIA5	UIA6	UIA7	OCTET 6*
ProSe-dd	ProSe	H.245-ASH	ACC-CSFB	LPP	LCS	1xSRVCC	NF	OCTET 7*
ePCO	HC-CP CIoT	Erw/o PDN	S1-U data	UP CIoT	CP CIoT	Prose relay	ProSe-dc	OCTET 8*
0 Spare	0 Spare	0 Spare	DCNR	CP backoff	RestrictEC	V2X PC5	multipleDRB	OCTET 9*
0	0	0	0	0	0	0	0	OCTET 10* - 15*
SPARE								

UE NETWORK CAPABILITY INFORMATION ELEMENT

FIG. 8

900

8	7	6	5	4	3	2	1	
EPS NETWORK FEATURE SUPPORT IEI									OCTET 1
LENGTH OF EPS NETWORK FEATURE SUPPORT CONTENTS									OCTET 2
CP CIoT	ERw/o PDN	ESR PS	CS-LCS		EPC-LCS	EMC-BS	IMS VoPS	OCTET 3
0 Spare	0 Spare	RestrictDCNR	RestrictEC	ePCO	HC-CP CIoT	S1-U data	UP CIoT	OCTET 4

902

EPS NETWORK FEATURE SUPPORT INFORMATION ELEMENT

FIG. 9

_1000_

```
<MS network capability value part> ::=

    <GEA1 bits>
    <SM capabilities via dedicated channels: bit>
    <SM capabilities via GPRS channels: bit>
    <UCS2 support: bit>
    <SS Screening Indicator: bit string(2)>
    <SoLSA Capability : bit>
    <Revision level indicator: bit>
    <PFC feature mode: bit>
    <Extended GEA bits>
    <LCS VA capability: bit>
    <PS inter-RAT HO from GERAN to UTRAN Iu mode capability: bit>
    <PS inter-RAT HO from GERAN to E-UTRAN S1 mode capability: bit>
    <EMM Combined procedures Capability: bit>
    <ISR support: bit>
    <SRVCC to GERAN/UTRAN capability: bit>
    <EPC capability: bit>

    <NF capability: bit>
    <GERAN network sharing capability: bit>
    <User plane integrity protection support: bit>
    <GIA/4: bit>
    <GIA/5: bit>
    <GIA/6: bit>
    <GIA/7: bit>
    <ePCO IE indicator: bit>
    <Restriction on use of enhanced coverage capability: bit>    ── 1002
    <Dual connectivity of E-UTRA with NR capability: bit>
    <Spare bits>;

<GEA1 bits> ::= < GEA/1 bit>;

<Extended GEA bits> ::= <GEA/2 bit><GEA/3 bit>< GEA/4 bit >< GEA/5 bit >< GEA/6 bit ><GEA/7 bit>;

<Spare bits> ::= null | {<spare bit> < Spare bits >};
```

FIG. 10

1100

8	7	6	5	4	3	2	1	
ADDITIONAL NETWORK FEATURE SUPPORT IE								OCTET 1
LENGTH OF ADDITIONAL NETWORK FEATURE SUPPORT CONTENTS								OCTET 2
0 Spare	0 Spare	0 Spare	0 Spare	0 Spare	ePCO	RestrictEC	GPRS-SMS	OCTET 3

1102

FIG. 11

1200

ENCODE AN ATTACH REQUEST MESSAGE FOR
TRANSMISSION TO A MOBILITY MANAGEMENT ENTITY
(MME) IN AN EPS, THE ATTACH REQUEST MESSAGE
INCLUDING A UE NETWORK CAPABILITY INFORMATION
ELEMENT (IE) INDICATING WHETHER A UE SUPPORTS
RESTRICTION ON USING ENHANCED COVERAGE
— 1202

DECODE AN ATTACH ACCEPT MESSAGE CONFIRMING
ATTACHMENT TO THE MME, THE ATTACH ACCEPT
MESSAGE INCLUDING AN EPS NETWORK FEATURE
SUPPORT IE INDICATING WHETHER USE OF ENHANCED
COVERAGE IS RESTRICTED FOR THE UE
— 1204

REFRAIN FROM USING ENHANCED COVERAGE IN THE
PLMN WHEN THE UE SUPPORTS RESTRICTION ON USING
ENHANCED COVERAGE AND THE EPS NETWORK
FEATURE SUPPORT IE INDICATES ENHANCED COVERAGE
IS RESTRICTED FOR THE UE
— 1206

FIG. 12

FIG. 13

A.	**CLASSIFICATION OF SUBJECT MATTER**

H04W 8/16(2009.01)i, H04W 60/00(2009.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B.	**FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
H04W 8/16; H04L 5/00; H04B 1/713; H04W 68/00; H04W 68/02; H04W 52/02; H04W 60/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: attach request, enhanced coverage, restriction, UE Network
Capability Information Element (IE), EPS Network Feature Support IE, refrain, Network Access Stratum (NAS)

C.	**DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	3GPP TS 23.401 V14.2.0, `3GPP; TSG SA; General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access(Release 14)`, 16 December 2016 (https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=849) See sections 4.3.28, 4.3.5.2, 5.3.2.1, 5.3.3.0, L.1; and figure L.2-1.	1-25
A	3GPP TS 23.682 V14.2.0, `3GPP; TSG SA; Architecture enhancements to facilitate communications with packet data networks and applications (Release 14)`, 16 December 2016 (https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=862) See sections 4.5.17, 4.5.19.	1-25
A	EP 2836029 A1 (ALCATEL LUCENT) 11 February 2015 See paragraphs [0045]-[0054]; and figure 2.	1-25
A	US 2016-0100380 A1 (SATISH CHANDRA JHA et al.) 07 April 2016 See paragraphs [0040]-[0048]; and figure 4.	1-25
A	US 2016-0226639 A1 (GANG XIONG et al.) 04 August 2016 See paragraphs [0049]-[0056]; and claim 1.	1-25

☐ Further documents are listed in the continuation of Box C.	☒ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance		
"E"	earlier application or patent but published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 April 2018 (24.04.2018)	**24 April 2018 (24.04.2018)**

Name and mailing address of the ISA/KR	Authorized officer
International Application Division Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea	YANG, Jeong Rok
Facsimile No. +82-42-481-8578	Telephone No. +82-42-481-5709

Form PCT/ISA/210 (second sheet) (January 2015)

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2836029 A1	11/02/2015	EP 2836032 A1	11/02/2015
		TW 201521503 A	01/06/2015
		TW I555429 B	21/10/2016
		WO 2015-018482 A1	12/02/2015
		WO 2015-018498 A1	12/02/2015
US 2016-0100380 A1	07/04/2016	US 9769788 B2	19/09/2017
		WO 2016-057137 A1	14/04/2016
US 2016-0226639 A1	04/08/2016	EP 3251265 A1	06/12/2017
		WO 2016-122782 A1	04/08/2016