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(54) Title: ACCESSING LEGACY TECHNOLOGIES BY A USER EQUIPMENT

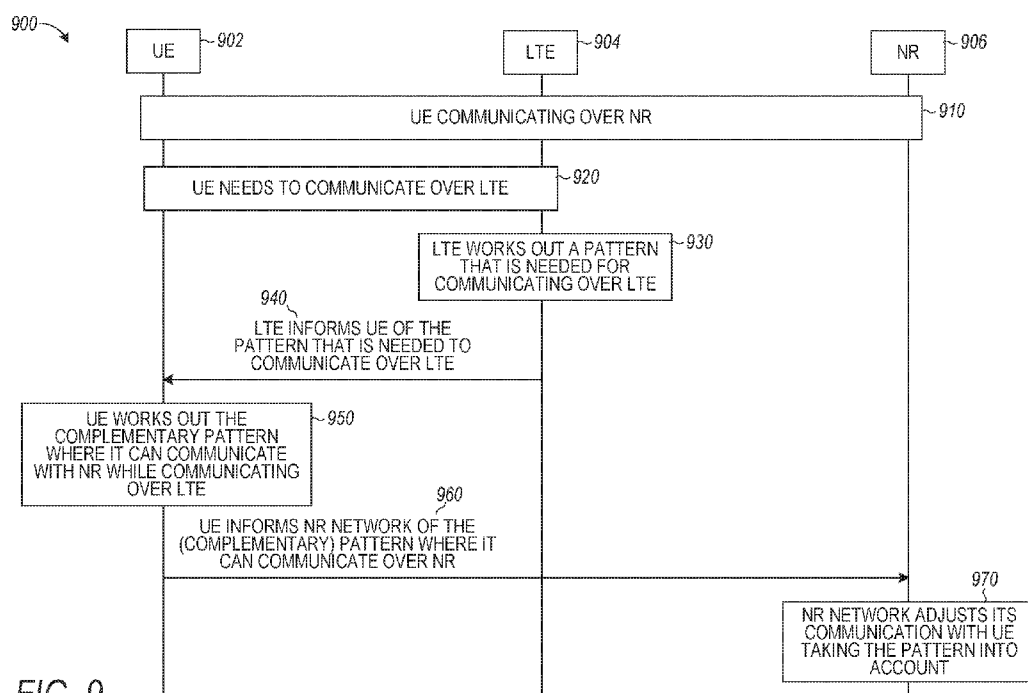


FIG. 9

(57) Abstract: In some embodiments, a user equipment (UE) determines, during a communication session with a first node in accordance with a first networking protocol, to communicate with a second node in accordance with a second networking protocol while continuing the communication session, the communication session being for providing a first service, and the second networking protocol being used for providing a second service. The UE determines a pattern for communicating in accordance with the second networking protocol. The UE determines a complimentary pattern for communicating in accordance with the first networking protocol while communicating in accordance with the second networking protocol using the pattern. The UE encodes, for transmission to the first node in accordance with the first networking protocol, an indication of the complimentary pattern. The UE communicates in accordance with the first networking protocol using the complimentary pattern and in accordance with the second networking protocol using the pattern.

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ACCESSING LEGACY TECHNOLOGIES BY A USER EQUIPMENT

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PRIORITY CLAIM

[0001] This application claims priority under 35 U.S.C. § 89 to United States Provisional Patent Application Serial No. 62/374,617, filed August 12, 2016, and titled, “SIMULTANEOUS ACCESS OF LEGACY TECHNOLOGIES WHILE USER EQUIPMENT IS IN NEW RADIO ACCESS TECHNOLOGY,” which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

15 [0002] Embodiments pertain to wireless communications. Some embodiments pertain to accessing legacy technologies by a UE (user equipment). Some embodiments relate to systems and methods for simultaneous access of legacy technologies while a UE is in NR (new radio).

20

BACKGROUND

[0003] It may be desirable for a UE (user equipment) in NR (new radio) to access legacy technologies, such as LTE (long term evolution) or UMTS (universal mobile telecommunications service). For example, while browsing the web in NR, a UE may receive a voice call using a legacy technology.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] FIG. 1 illustrates an architecture of a system of a network in accordance with some embodiments.

[0005] FIG. 2 illustrates example components of a device in accordance with some embodiments.

[0006] FIG. 3 illustrates example interfaces of baseband circuitry in accordance with some embodiments.

[0007] FIG. 4 is an illustration of a control plane protocol stack in accordance with some embodiments.

5 [0008] FIG. 5 is an illustration of a user plane protocol stack in accordance with some embodiments.

[0009] FIG. 6 illustrates components of a core network in accordance with some embodiments.

[0010] FIG. 7 is a block diagram illustrating components, according to some example embodiments, of a system to support NFV (Network Functions Virtualization).

[0011] FIG. 8 is a block diagram illustrating components, according to some example embodiments, able to read instructions from a machine-readable or computer-readable medium and perform any one or more of the
15 methodologies discussed herein.

[0012] FIG. 9 is a data flow diagram illustrating a NR (new radio) UE (user equipment) accessing LTE (long term evolution) in accordance with some embodiments.

[0013] FIG. 10 is a data flow diagram illustrating a NR UE accessing
20 UMTS (universal mobile telecommunications service) in accordance with some embodiments.

[0014] FIG. 11 is a flow chart illustrating a method for accessing legacy technologies by a UE in accordance with some embodiments.

25 DETAILED DESCRIPTION

[0015] The following description and the drawings sufficiently illustrate specific embodiments to enable those skilled in the art to practice them. Other embodiments may incorporate structural, logical, electrical, process, and other
30 changes. Portions and features of some embodiments may be included in, or substituted for, those of other embodiments. Embodiments set forth in the claims encompass all available equivalents of those claims.

[0016] FIG. 1 illustrates an architecture of a system 100 of a network in accordance with some embodiments. The system 100 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, or any computing device including a wireless communications interface.

[0017] In some embodiments, 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.

[0018] 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.

[0019] In this embodiment, the UEs 101 and 102 may further directly
5 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
10 Channel (PSBCH).

[0020] 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 a connection consistent with any IEEE 802.11 protocol, wherein the AP 106 would comprise a wireless fidelity (WiFi®) router. In this
15 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).

[0021] 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 (gNB), RAN nodes, and so forth, and can comprise ground stations (e.g.,
20 terrestrial access points) or satellite stations providing coverage within a geographic area (e.g., a cell). 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
25 coverage areas, smaller user capacity, or higher bandwidth compared to macrocells), e.g., low power (LP) RAN node 112.

[0022] 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 embodiments, any of the RAN nodes 111 and 112 can fulfill various
30 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.

[0023] In accordance with some embodiments, 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 the scope of the embodiments is not limited in this respect. The OFDM signals can comprise a plurality of orthogonal subcarriers.

[0024] In some embodiments, 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 is a common practice for OFDM systems, which makes it intuitive for radio resource allocation. Each column and each row of the resource grid corresponds to one OFDM symbol and one OFDM subcarrier, respectively. The duration of the resource grid in the time domain corresponds to one slot in a radio frame. The smallest time-frequency unit in a resource grid is denoted as a resource element. Each resource grid comprises a number of resource blocks, which describe the mapping of certain physical channels to resource elements. Each resource block comprises a collection of resource elements; in the frequency domain, this may represent the smallest quantity of resources that currently can be allocated. There are several different physical downlink channels that are conveyed using such resource blocks.

[0025] 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
5 information may be sent on the PDCCH used for (e.g., assigned to) each of the UEs 101 and 102.

[0026] 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
10 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
15 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).

[0027] Some embodiments may use concepts for resource allocation for control channel information that are an extension of the above-described
20 concepts. For example, some embodiments 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 the control channel elements (ECCEs). Similar to above, each ECCE may correspond to nine sets of four physical resource elements known as an
25 enhanced resource element groups (EREGs). An ECCE may have other numbers of EREGs in some situations.

[0028] The RAN 110 is shown to be communicatively coupled to a core network (CN) 120 —via an S1 interface 113. In embodiments, the CN 120 may be an evolved packet core (EPC) network, a NextGen Packet Core (NPC)
30 network, or some other type of CN. In this embodiment 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.

[0029] In this embodiment, 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.

[0030] 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 may include lawful intercept, charging, and some policy enforcement.

[0031] The P-GW 123 may terminate an 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 embodiment, 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.

[0032] 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, 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.

[0033] FIG. 2 illustrates example components of a device 200 in accordance with some embodiments. In some embodiments, 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 embodiments, the device 200 may include less 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 embodiments, the device 200 may include additional elements such as, for example, memory/storage, display, camera, sensor, or input/output (I/O) interface. In other embodiments, 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).

[0034] 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 and dedicated processors (e.g., graphics processors, application processors, etc.). The processors may be coupled with 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 embodiments, processors of application circuitry 202 may process IP data packets received from an EPC.

[0035] 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 circuitry 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. For example, in some embodiments, 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 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 embodiments, some or all of the functionality of baseband processors 204A-D may be included in modules 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 embodiments, modulation/demodulation circuitry of the baseband circuitry 204 may include Fast-Fourier Transform (FFT), precoding, or constellation mapping/demapping functionality. In some embodiments,

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. Embodiments of modulation/demodulation and encoder/decoder functionality are not limited to these examples and may include other suitable functionality in other embodiments.

[0036] In some embodiments, the baseband circuitry 204 may include one or more audio digital signal processor(s) (DSP) 204F. The audio DSP(s) 204F may include elements for compression/decompression and echo cancellation and may include other suitable processing elements in other embodiments. 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 embodiments. In some embodiments, 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).

[0037] In some embodiments, the baseband circuitry 204 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, 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), a wireless personal area network (WPAN). Embodiments in which the baseband circuitry 204 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

[0038] RF circuitry 206 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, 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.

[0039] In some embodiments, the receive signal path of the RF circuitry 206 may include mixer circuitry 206A, amplifier circuitry 206B and filter circuitry 206C. In some embodiments, the transmit signal path of the RF circuitry 206 may include filter circuitry 206C and mixer circuitry 206A. RF circuitry 206 may also include synthesizer circuitry 206D for synthesizing a frequency for use by the mixer circuitry 206A of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 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 circuitry 206D. The amplifier circuitry 206B may be configured to amplify the down-converted signals and the filter circuitry 206C may be a low-pass filter (LPF) or band-pass filter (BPF) configured to remove 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 embodiments, the output baseband signals may be zero-frequency baseband signals, although this is not a requirement. In some embodiments, mixer circuitry 206A of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[0040] In some embodiments, the mixer circuitry 206A of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 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 circuitry 206C.

[0041] In some embodiments, the mixer circuitry 206A of the receive signal path and the mixer circuitry 206A of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and upconversion, respectively. In some embodiments, the mixer circuitry 206A of the receive signal path and the mixer circuitry 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 embodiments, the mixer circuitry 206A of the

receive signal path and the mixer circuitry 206A may be arranged for direct downconversion and direct upconversion, respectively. In some embodiments, the mixer circuitry 206A of the receive signal path and the mixer circuitry 206A of the transmit signal path may be configured for super-heterodyne operation.

5 [0042] In some embodiments, the output baseband signals and the input baseband signals may be analog baseband signals, although the scope of the embodiments is not limited in this respect. In some alternate embodiments, the output baseband signals and the input baseband signals may be digital baseband signals. In these alternate embodiments, the RF circuitry 206 may include
10 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.

[0043] In some dual-mode embodiments, a separate radio IC circuitry may be provided for processing signals for each spectrum, although the scope of
15 the embodiments is not limited in this respect.

[0044] In some embodiments, the synthesizer circuitry 206D may be a fractional-N synthesizer or a fractional $N/N+1$ synthesizer, although the scope of the embodiments is not limited in this respect as other types of frequency synthesizers may be suitable. For example, synthesizer circuitry 206D may be a
20 delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[0045] The synthesizer circuitry 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 embodiments,
25 the synthesizer circuitry 206D may be a fractional $N/N+1$ synthesizer.

[0046] In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although that is not a requirement. Divider control input may be provided by either the baseband circuitry 204 or the applications processor 202 depending on the desired output frequency. In some
30 embodiments, 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.

[0047] 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 embodiments, the divider may be a dual modulus divider (DMD) and the phase accumulator may be a digital phase accumulator (DPA). In some embodiments, 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
5 example embodiments, 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 embodiments, 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 help ensure that
10 the total delay through the delay line is one VCO cycle.

[0048] In some embodiments, synthesizer circuitry 206D may be configured to generate a carrier frequency as the output frequency, while in other embodiments, the output frequency may be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency) and used in
15 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 embodiments, the output frequency may be a LO frequency (fLO). In some embodiments, the RF circuitry 206 may include an IQ/polar converter.

20 [0049] 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, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 206 for further processing. FEM circuitry 208 may also include a transmit signal path which may include circuitry
25 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 embodiments, the amplification through the transmit or receive signal paths may be done solely in the RF circuitry 206, solely in the FEM 208, or in both the RF circuitry 206 and the FEM 208.

30 [0050] In some embodiments, 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 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 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).

[0051] In some embodiments, the PMC 212 may manage power provided to the baseband circuitry 204. In particular, the PMC 212 may control power-source selection, voltage scaling, battery charging, or DC-to-DC conversion. The PMC 212 may often 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 desirable implementation size and heat dissipation characteristics.

[0052] While FIG. 2 shows the PMC 212 coupled only with the baseband circuitry 204. However, in other embodiments, 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.

[0053] In some embodiments, 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 (Radio Resource Control Connected) state, where 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.

[0054] 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, where 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 where again it periodically wakes up to listen to the network and then powers down again. The device 200 may not receive data in this state, in order to receive data, it must transition back to RRC_Connected state.

[0055] 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 is totally unreachable to the network and may power down completely. Any data sent during this time incurs a large delay and it is assumed the delay is acceptable.

[0056] 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.

[0057] FIG. 3 illustrates example interfaces of baseband circuitry in accordance with some embodiments. 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.

[0058] 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).

[0059] FIG. 4 is an illustration of a control plane protocol stack in accordance with some embodiments. In this embodiment, 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.

[0060] The PHY layer 401 may 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 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.

[0061] The MAC layer 402 may 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.

[0062] The RLC layer 403 may 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 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.

[0063] The PDCP layer 404 may execute header compression and decompression of IP data, maintain PDCP Sequence Numbers (SNs), perform
5 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 integrity verification of control plane data, control timer-based discard of data, and perform security operations (e.g.,
10 ciphering, deciphering, integrity protection, integrity verification, etc.).

[0064] The main services and functions of the RRC layer 405 may include broadcast of system information (e.g., included in 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
15 (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 modification, and RRC connection release), establishment, configuration, maintenance and release of point to point Radio Bearers, security functions including key management, inter radio access
20 technology (RAT) mobility, and measurement configuration for UE measurement reporting. Said MIBs and SIBs may comprise one or more information elements (IEs), which may each comprise individual data fields or data structures.

[0065] The UE 101 and the RAN node 111 may utilize a Uu interface
25 (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.

[0066] The non-access stratum (NAS) protocols 406 form the highest stratum of the control plane between the UE 101 and the MME 121. The NAS
30 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.

[0067] 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. The S1-AP layer services may comprise two 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.

[0068] The Stream Control Transmission Protocol (SCTP) layer (alternatively 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.

[0069] 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.

[0070] FIG. 5 is an illustration of a user plane protocol stack in accordance with some embodiments. In this embodiment, 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, the PDCP layer 404.

[0071] 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 any of 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.

[0072] FIG. 6 illustrates components of a core network in accordance with some embodiments. The components of the CN 120 may be implemented in one physical node or separate physical nodes including components to read and execute instructions from a machine-readable or computer-readable medium (e.g., a non-transitory machine-readable storage medium). In some embodiments, Network Functions Virtualization (NFV) is utilized to virtualize any or all of the above described network node functions via executable instructions stored in one or more computer readable storage mediums (described in further detail below). A logical instantiation of the CN 120 may be referred to as a network slice 601. A logical instantiation of a portion of the CN 120 may be referred to as a network sub-slice 602 (e.g., the network sub-slice 602 is shown to include the PGW 123 and the PCRF 126).

[0073] NFV architectures and infrastructures may be used to virtualize one or more network functions, alternatively performed by proprietary hardware, onto physical resources comprising a combination of industry-standard server hardware, storage hardware, or switches. In other words, NFV systems can be used to execute virtual or reconfigurable implementations of one or more EPC components/functions.

[0074] FIG. 7 is a block diagram illustrating components, according to some example embodiments, of a system 700 to support NFV. The system 700 is illustrated as including a virtualized infrastructure manager (VIM) 702, a network function virtualization infrastructure (NFVI) 704, a VNF manager (VNFM) 706, virtualized network functions (VNFs) 708, an element manager

(EM) 710, an NFV Orchestrator (NFVO) 712, and a network manager (NM) 714.

[0075] The VIM 702 manages the resources of the NFVI 704. The NFVI 704 can include physical or virtual resources and applications (including
5 hypervisors) used to execute the system 700. The VIM 702 may manage the life cycle of virtual resources with the NFVI 704 (e.g., creation, maintenance, and tear down of virtual machines (VMs) associated with one or more physical resources), track VM instances, track performance, fault and security of VM instances and associated physical resources, and expose VM instances and
10 associated physical resources to other management systems.

[0076] The VNFM 706 may manage the VNFs 708. The VNFs 708 may be used to execute EPC components/functions. The VNFM 706 may manage the life cycle of the VNFs 708 and track performance, fault and security of the virtual aspects of VNFs 708. The EM 710 may track the performance, fault and
15 security of the functional aspects of VNFs 708. The tracking data from the VNFM 706 and the EM 710 may comprise, for example, performance measurement (PM) data used by the VIM 702 or the NFVI 704. Both the VNFM 706 and the EM 710 can scale up/down the quantity of VNFs of the system 700.

[0077] The NFVO 712 may coordinate, authorize, release and engage
20 resources of the NFVI 704 in order to provide the requested service (e.g., to execute an EPC function, component, or slice). The NM 714 may provide a package of end-user functions with the responsibility for the management of a network, which may include network elements with VNFs, non-virtualized network functions, or both (management of the VNFs may occur via the EM
25 710).

[0078] FIG. 8 is a block diagram illustrating components, according to some example embodiments, 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.
30 Specifically, FIG. 8 shows a diagrammatic representation of hardware resources 800 including one or more processors (or processor cores) 810, one or more memory/storage devices 820, and one or more communication resources 830, each of which may be communicatively coupled via a bus 840. For embodiments

where node virtualization (e.g., NFV) is utilized, a hypervisor 802 may be executed to provide an execution environment for one or more network slices/sub-slices to utilize the hardware resources 800

[0079] The processors 810 (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 812 and a processor 814.

[0080] The memory/storage devices 820 may include main memory, disk storage, or any suitable combination thereof. The memory/storage devices 820 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.

[0081] The communication resources 830 may include interconnection or network interface components or other suitable devices to communicate with one or more peripheral devices 804 or one or more databases 806 via a network 808. For example, the communication resources 830 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.

[0082] Instructions 850 may comprise software, a program, an application, an applet, an app, or other executable code for causing at least any of the processors 810 to perform any one or more of the methodologies discussed herein. The instructions 850 may reside, completely or partially, within at least one of the processors 810 (e.g., within the processor's cache memory), the memory/storage devices 820, or any suitable combination thereof. Furthermore, any portion of the instructions 850 may be transferred to the hardware resources 800 from any combination of the peripheral devices 804 or

the databases 806. Accordingly, the memory of processors 810, the memory/storage devices 820, the peripheral devices 804, and the databases 806 are examples of computer-readable and machine-readable media.

[0083] NR (new radio) may be implemented with a broad range of use cases, including enhanced mobile broadband, massive MTC (machine-type communication), critical MTC, and additional requirements defined during the RAN (radio access network) requirements study.

[0084] In certain scenarios, a UE might simultaneously have to access another technology and be communicating over NR, without much coordination between the networks. These scenarios could occur for example, when a UE attaches over another technology while already communicating over NR for an inter-system change. In another example, the UE simultaneously does voice communication over one technology and data communication over another. In some schemes, the UE may support two radios with simultaneous transmission (TX) on both. This is expensive and often may not be possible to due to RF (radio frequency) limitations.

[0085] One solution may include having interactions between network nodes, for example, with LTE (long term evolution) and NR tight inter-working. This may include extensive specification work especially for other legacy technologies (e.g., GSM (global system for mobile communications) and UMTS (universal mobile telecommunications service)) where the specification and implementations are quite frozen and changes are not typically considered by vendors or network operators.

[0086] Some aspects of the subject technology provide a mechanism where the UE provides information to the network to allow the NR network to adjust itself while allowing the UE to access another network. This information may include an IDC (in-device coexistence) like time pattern information provided by the UE to NR and/or LTE. NR and LTE base stations may respect the pattern when they communicate with the UE (that is, each network does or does not transmit or receive data according to the pattern provided to it). The pattern in LTE and NR is complementary in that it allows UE to communicate over one technology or the other technology at any time. The pattern can be derived by the UE for LTE and NR such that it allows time shared

communication over LTE for the service required (e.g., voice, attach, etc.) while still maintaining the communication over NR.

[0087] Another class of solution implements a LAA (licensed-assisted access) kind of solution. In LAA, a UE may have to turn off LTE/ NR due to
5 LBT (listen-before-talk) restrictions while some other device is communicating. The network has to adjust its communication with the UE based on the restrictions. A similar solution may be adopted for LTE and NR communication. The UE inform the network that it is communicating over legacy technologies. The UE then does autonomous prioritization of legacy systems (e.g., UMTS) as
10 appropriate. The NR network is aware of this and adjusts itself accordingly. Knowing the technology over which the UE is communicating allows the network to better adjust to the disruption by communicating in available instances. Alternatively, if even that is not possible, the NR network may keep the UE context active so communication can continue with minimal further
15 disruption when the UE comes back.

[0088] Given the shorter TTI (transmission time interval) and numerology of NR, NR may allow sufficient time for the UE to indicate to the network on a subframe (or set of subframes) basis that needs to prioritize the other technology over NR. This may occur before the UE has to send packets
20 over the other technology. According to another class of solutions, the UE adjusts (in NR) its capabilities to indicate what it can and cannot do over NR while communicating over the other technology. For example, if the UE is communicating over the other technology in certain RF bands, the UE may withdraw support for certain NR bands that can cause interference with those RF
25 bands.

[0089] According to some schemes, solutions that provide access to legacy technologies by a UE in NR include a full dual radio solution. However, the full dual radio solution is expensive to implement, uses excessive battery, and may have SAR (specific absorption rate) problems. In another scheme, the
30 UE autonomously “leaves” one technology to service another. This can cause a lot of problems with the network algorithms since the network may try to adjust or compensate, based on an assumption that the UE might temporarily be in a radio shadow. This can then lead to many other problems with the UE-network

connection. Yet another scheme provides full interwork coordination. This may include extensive specification work for other legacy technologies (such as GSM and UMTS) where the specification and implementations are relatively frozen and changes are not typically considered by vendors or network operators.

5 **[0090]** IDC was defined in LTE to solve in-device coexistence issues between LTE and Bluetooth® or between LTE and WiFi®. This is based on the UE providing a time pattern to the network indicating the time opportunities (sub-frames) that the UE can use to communicate over LTE. Use of those time opportunities does not reduce the quality of the in-device coexistence. NR may support this feature. This feature can be exploited to support simultaneous access of NR and LTE.

10 **[0091]** Depending on the type of service required over LTE (e.g., voice), the UE (or LTE network) may compute out a pattern where UE communicates over LTE sufficient for the service. The UE can then provide a complementary pattern to NR. The complimentary pattern indicates the opportunities the UE has to communicate over NR.

15 **[0092]** FIG. 9 is a data flow diagram of a method 900 for a NR UE 902 to access LTE in accordance with some embodiments. As shown in FIG. 9, a UE 902 communicates with an LTE node 904 (e.g., an eNB) and a NR node 906 (e.g., a 5G Node B (gNB)). At operation 910, the UE 902 is communicating over NR. At operation 920, the UE 902 determines that it needs to communicate over LTE. At operation 930, the LTE node 904 works out a pattern that is needed for communicating over LTE. At operation 940, the LTE node 904 informs the UE 902 of the pattern that is needed to communicate over LTE. At operation 950, the UE 902 works out the complimentary pattern, using which the UE 902 can communicate with NR while communicating over LTE. At operation 960, the UE 902 informs the NR node 906 of the complimentary pattern for the UE 902 to communicate over NR. At operation 970, the NR node 906 adjusts its communication with the UE 902 based on the complimentary pattern.

25 **[0093]** The method 900 may be used in conjunction with dual radio (e.g., dual receiver (Rx)) solutions. The UE 902 can monitor the LTE paging channel for paging messages without disrupting the LTE or NR networks. A similar

method may be used for communication over a UMTS network, as shown in FIG. 10.

[0094] FIG. 10 is a data flow diagram illustrating a method 1000 for a NR UE 1002 to access UMTS in accordance with some embodiments. As shown, the method 1000 is implemented with the UE 1002, a UMTS node 1004, and a NR node (e.g., a gNB) 1006. At operation 1010, the UE 1002 is communicating over NR. At operation 1020, the UE 1002 determines that it needs to communicate over UMTS. At operation 1030, the UE 1002 works out a pattern that is needed for communicating over UMTS. At operation 1040, the UE 1002 works out the complimentary pattern using which the UE 1002 can communicate over NR while communicating over UMTS. At operation 1050, the UE 1002 informs the NR node 1006 of the complimentary pattern, using which the UE 1002 can communicate over NR. At operation 1060, the NR node 1006 adjusts its communication with the UE based on the complimentary pattern.

[0095] Another solution is to extend LAA (Licensed Assist Access) solutions. LTE in LAA mode is used in unlicensed bands. In unlicensed bands, the UE has to monitor other technologies (such as WiFi) using listen before talk (LBT). When the UE determine that the UE cannot communicate over LTE due to ongoing activity in another technology, the UE uses DTX (discontinuous Transmission) – that is, not TX (transmission) over LTE. The network is aware of the DTX, since the network is using an unlicensed operation and acts according to its scheduling algorithms. This can be extended to apply to NR while the UE communicates over LTE or other legacy technologies. One difference may be that LBT is performed on the same or overlapped frequency carriers in LAA, while other technologies may use the same or different frequency carriers. The UE can indicate to the network the need to communicate over the other technology, and the network can adjust for that as it does for LAA operation. Based on the indication from the UE to the network, the operation can be limited to the period where the UE needs to communicate over the other technology. The granularity and the frequency of this indication may vary depending on the UE, NR, and other technology. For example, if the communication over the other technology is based on UL grants, where the UE

has 4 milliseconds (ms) to send data after it receives the UL grant, the UE may send an indication in those 4 ms to NR that the UE is to switch to LTE and the time of the switch. The NR node can take this into account in its algorithms. For example, the NR node may not schedule the UE at the time when the UE cannot receive or transmit in NR. The NR node may consider the fact that the UE may not be receiving or transmitting, instead of assuming that the UE is in a radio shadow and try to compensate. In some cases, it may be possible for the NR node to detect the UE's absence in a technology by using its own detection mechanism (such as an absence of reference symbols) to identify that the UE is away. In these cases, the UE might not indicate its absence explicitly.

[0096] Another solution is for the UE to adjust its capability when it needs to communicate over another technology. One challenge with this approach is that at least one version of the LTE specification does not allow any dynamic change of UE capabilities. However, a dynamic signal may be introduced for the UE to update its capability. For example, if the UE is using certain frequency bands for communicating over legacy technologies, it may not be possible to communicate in NR using those frequency bands. The UE can indicate this by updating its capability to remove those frequency bands or band combinations from the UE's NR capability. It is also possible to signal these changes using separate signaling, which is independent of the UE's capability signaling. Apart from frequency bands, other aspects, like UL (uplink) TX (transmit) power, processing capability, and the like, can also be updated based on the needs of the other technology. The signaling of dynamic capability could be through an update of the UE capability using RRC signaling or through layer 1 or layer 2 signaling, such as power head room reporting. In this solution, if the UE indicates that the updated UE capability is temporary changed, the eNB may not deliver this UE capability information to the MME. Thus, the MME still stores the original UE capability information.

[0097] In the above cases, the UE can take into account its capabilities. For example if the UE has two RX chains, it can use the two RX chains to receive data from both technologies simultaneously. The UE can take this information into account when providing capability indications to the network. If

the UE can receive over LTE, it only needs to indicate when it has to stop TX over NR due to TX over LTE, and not when it needs to receive over LTE.

[0098] In some cases, if such short term switching between two technologies is not possible based on the UE capabilities, the network capabilities or the bands or features in use at that time, the UE may stop communicating over NR for a period of time while it is communicating over other technologies. One use case where this might happen is when the UE is communicating over UMTS with non-HSPA (High Speed Packet Access) channels that require continuous transmission and reception, thereby preventing short and quick switching back and forth between the two technologies. This can also be communicated to the NR network, and taken into account by the NR network. In some cases, the NR network completely stops communicating with the UE while keeping the context alive.

[0099] When the UE comes back to the NR network, the UE can indicate this to the network in whatever channel is available. The UE may have to use common channels if no dedicated channels are available. For example, if all channels of communication have been shut down while the UE was away, the UE can perform a RACH (Random Access Channel) and resumption procedure to bring its context back to life. This resumption procedure can be done in another cell, if the UE has moved cells while it was away from NR and communicating over other technologies.

[00100] There may several reasons why UE may need or want to communicate over other technologies while in NR. For example, the UE may want to perform some short communication such as signaling exchange for attach in another technology for inter-RAT (Radio Access Technology) mobility. Other use case could be send some amount of data, for example, MTC data, over the legacy technology while dual attached to both systems. Another use case could be when the UE needs to be communicating over other technology over a longer period of time, such as communicating over UMTS for voice. Other use cases could include the UE is communicating simultaneously over both technologies to reach multiple network operators, to access different services, or to increase throughput.

[00101] FIG. 11 is a flow chart illustrating a method 1100 for accessing legacy technologies by a UE in accordance with some embodiments.

[00102] At operation 1110, the UE determines, during a communication session with a first node in accordance with a first networking protocol and
5 based on a request from a higher layer, to communicate with a second node in accordance with a second networking protocol while continuing the communication session. The communication session is for providing a first service, and the second networking protocol is used for providing a second service.

10 [00103] At operation 1120, the UE determines a pattern for communicating in accordance with the second networking protocol.

[00104] At operation 1130, the UE determines a complimentary pattern for communicating in accordance with the first networking protocol while communicating in accordance with the second networking protocol using the
15 pattern. The pattern and the complimentary pattern are determined to allow time-shared communicating via the first networking protocol for the first service and via the second networking protocol for the second service.

[00105] At operation 1140, the UE encodes, for transmission to the first node in accordance with the first networking protocol, an indication of the
20 complimentary pattern.

[00106] At operation 1150, the UE configures its own transceiver circuitry to communicate in accordance with the first networking protocol using the complimentary pattern and in accordance with the second networking protocol using the pattern. The communication in accordance with the first networking
25 protocol and in accordance with the second networking protocol are conducted using the same transceiver circuitry. Each of the first networking protocol and the second networking protocol is a cellular communication protocol.

[00107] The subject technology is described below in conjunction with various examples.

30 [00108] Example 1 is an apparatus of a UE (user equipment), the apparatus comprising: processing circuitry and memory; the processing circuitry to: determine, during a communication session with a first node in accordance with a first networking protocol and based on a request from a higher layer, to

- communicate with a second node in accordance with a second networking protocol while continuing the communication session, the communication session being for providing a first service, and the second networking protocol being used for providing a second service; determine a pattern for
- 5 communicating in accordance with the second networking protocol; determine a complimentary pattern for communicating in accordance with the first networking protocol while communicating in accordance with the second networking protocol using the pattern, wherein the pattern and the complimentary pattern are determined to allow time-shared communicating via
- 10 the first networking protocol for the first service and via the second networking protocol for the second service; encode, for transmission to the first node in accordance with the first networking protocol, an indication of the complimentary pattern; and configure transceiver circuitry to communicate in accordance with the first networking protocol using the complimentary pattern
- 15 and in accordance with the second networking protocol using the pattern, the communication in accordance with the first networking protocol and in accordance with the second networking protocol being conducted using the same transceiver circuitry, each of the first networking protocol and the second networking protocol being a cellular communication protocol.
- 20 **[00109]** Example 2 is the apparatus of Example 1, wherein the first networking protocol is NR (new radio), wherein the second networking protocol is LTE (long term evolution), wherein the first service is data, and wherein the second service is voice.
- [00110]** Example 3 is the apparatus of Example 1, wherein the first
- 25 networking protocol is NR (new radio), wherein the second networking protocol is UMTS (universal mobile telecommunications service), wherein the first service is data, and wherein the second service is voice.
- [00111]** Example 4 is the apparatus of any of Examples 1-3, wherein the processing circuitry is to: encode, for transmission to the first node in
- 30 accordance with the first networking protocol, the indication of the complimentary pattern to cause the first node to adjust communication with the UE based on the complimentary pattern.

[00112] Example 5 is the apparatus of any of Examples 1-3, wherein the pattern is received in accordance with the second networking protocol.

[00113] Example 6 is the apparatus of any of Examples 1-3, wherein the processing circuitry is further to: determine the pattern for communicating in
5 accordance with the second networking protocol.

[00114] Example 7 is the apparatus of any of Examples 1-3, wherein the processing circuitry is to: store, in the memory, the pattern and the complimentary pattern.

[00115] Example 8 is the apparatus of any of Examples 1-3, wherein the
10 complimentary pattern comprises an IDC (in-device coexistence) time pattern.

[00116] Example 9 is the apparatus of any of Examples 1-3, wherein the complimentary pattern comprises a TDM (time division multiplexing) pattern.

[00117] Example 10 is the apparatus of any of Examples 1-3, wherein the processing circuitry comprises a baseband processor.

15 [00118] Example 11 is the apparatus of any of Examples 1-3, further comprising the transceiver circuitry to: transmit the indication of the complimentary pattern in accordance with the first networking protocol.

[00119] Example 12 is the apparatus of Example 9, further comprising an antenna coupled with the transceiver circuitry.

20 [00120] Example 13 is an apparatus of a UE (user equipment), the apparatus comprising: processing circuitry and memory; the processing circuitry to: encode information for communication with a first node in accordance with a first networking protocol using a first capability set; determine, based on a request from a higher layer, to communicate with a second node in accordance
25 with a second networking protocol; determine a capability requirement for communicating in accordance with the second networking protocol; encode information for communication with the second node in accordance with the second networking protocol using the capability requirement; and encode information for communication with the first node in accordance with the first
30 networking protocol using a subset of the first capability set, the subset excluding the capability requirement.

[00121] Example 14 is the apparatus of Example 13, wherein the first networking protocol is NR (new radio), and wherein the second networking protocol is LTE (long term evolution).

5 [00122] Example 15 is the apparatus of Example 13, wherein the first networking protocol is NR (new radio), and wherein the second networking protocol is UMTS (universal mobile telecommunications service).

[00123] Example 16 is the apparatus of Example 13, wherein the first capability set includes a first band and a second band, wherein the capability requirement includes the first band, and wherein the subset includes the second
10 band.

[00124] Example 17 is the apparatus of Example 13, wherein the first capability set comprises an uplink transmission power or a processing capability.

[00125] Example 18 is the apparatus of Example 13, wherein the processing circuitry is to: encode, using RRC (radio resource control) signaling,
15 for communication with the second node in accordance with the second networking protocol using the capability requirement; and encode, using RRC signaling, for communication with the first node in accordance with the first networking protocol using the subset.

[00126] Example 19 is the apparatus of Example 13, wherein the processing circuitry is to: encode, using layer 1 signaling or layer 2 signaling, for
20 communication with the second node in accordance with the second networking protocol using the capability requirement; and encode, using layer 1 signaling or layer 2 signaling, for communication with the first node in accordance with the first networking protocol using the subset.

25 [00127] Example 20 is a machine-readable medium comprising instructions which, when executed by processing circuitry of a UE (user equipment), cause the processing circuitry to: encode information for communication with a first node in accordance with a first networking protocol; determine, based on a request from a higher layer, to communicate with a second
30 node in accordance with a second networking protocol; encode, for transmission to the first node in accordance with the first networking protocol, an indication that the UE is communicating in accordance with the second networking protocol; and encode for communication over both the first networking protocol

and the second networking protocol while prioritizing communications in accordance with the second networking protocol.

[00128] Example 21 is the machine-readable medium of Example 20, wherein the instructions further cause the processing circuitry to: encode, for
5 transmission to the first node in accordance with the first networking protocol, an indication of a time when the UE is to communicate in accordance with the second networking protocol and be unavailable for communication in accordance with the first networking protocol.

[00129] Example 22 is a machine-readable medium comprising
10 instructions which, when executed by processing circuitry of a UE (user equipment), cause the processing circuitry to: determine, during a communication session with a first node in accordance with a first networking protocol and based on a request from a higher layer, to communicate with a second node in accordance with a second networking protocol while continuing
15 the communication session, the communication session being for providing a first service, and the second networking protocol being used for providing a second service; determine a pattern for communicating in accordance with the second networking protocol; determine a complimentary pattern for communicating in accordance with the first networking protocol while
20 communicating in accordance with the second networking protocol using the pattern, wherein the pattern and the complimentary pattern are determined to allow time-shared communicating via the first networking protocol for the first service and via the second networking protocol for the second service; encode, for transmission to the first node in accordance with the first networking
25 protocol, an indication of the complimentary pattern; and configure transceiver circuitry to communicate in accordance with the first networking protocol using the complimentary pattern and in accordance with the second networking protocol using the pattern, the communication in accordance with the first networking protocol and in accordance with the second networking protocol
30 being conducted using the same transceiver circuitry, each of the first networking protocol and the second networking protocol being a cellular communication protocol.

[00130] Example 23 is the machine-readable medium of Example 22, wherein the first networking protocol is NR (new radio), and wherein the second networking protocol is LTE (long term evolution).

5 [00131] Example 24 is the machine-readable medium of Example 22, wherein the first networking protocol is NR (new radio), and wherein the second networking protocol is UMTS (universal mobile telecommunications service).

[00132] Example 25 is the machine-readable medium of Example 22, wherein the processing circuitry is to: encode, for transmission to the first node in accordance with the first networking protocol, the indication of the
10 complimentary pattern to cause the first node to adjust communication with the UE based on the complimentary pattern.

[00133] Although an embodiment has been described with reference to specific example embodiments, it will be evident that various modifications and changes may be made to these embodiments. Accordingly, the specification and
15 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 embodiments in which the subject matter may be practiced. The embodiments illustrated are described in sufficient detail to enable those skilled in the art to practice the teachings disclosed herein. Other
20 embodiments 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 embodiments is defined only by the appended claims, along with the full range of equivalents to which such claims
25 are entitled.

[00134] Such embodiments of the inventive subject matter may be referred to herein, individually and/or collectively, by the term “invention” merely for convenience and without intending to voluntarily limit the scope of this application to any single invention or inventive concept if more than one is
30 in fact disclosed. Thus, although specific embodiments 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 embodiments shown. This disclosure is intended to cover any and all adaptations or variations

of various embodiments. Combinations of the above embodiments, and other embodiments not specifically described herein, will be apparent to those of skill in the art upon reviewing the above description.

[00135] In this document, the terms "a" or "an" are used, as is common in patent documents, to include one or more than one, independent of any other instances or usages of "at least one" or "one or more." In this document, the term "or" is used to refer to a nonexclusive or, such that "A or B" includes "A but not B," "B but not A," and "A and B," unless otherwise indicated. In this document, the terms "including" and "in which" are used as the plain-English equivalents of the respective terms "comprising" and "wherein." Also, in the following claims, the terms "including" and "comprising" are open-ended, that is, a system, UE, article, composition, formulation, or process that includes elements in addition to those listed after such a term in a claim are still deemed to fall within the scope of that claim. Moreover, in the following claims, the terms "first," "second," and "third," etc. are used merely as labels, and are not intended to impose numerical requirements on their objects.

[00136] The Abstract is provided to allow the reader to ascertain the nature and gist of the technical disclosure. It is submitted with the understanding that it will not be used to limit or interpret the scope or meaning of the claims. The following claims are hereby incorporated into the detailed description, with each claim standing on its own as a separate embodiment.

CLAIMS

What is claimed is:

1. An apparatus of a UE (user equipment), the apparatus
5 comprising:
processing circuitry and memory; the processing circuitry to:
determine, during a communication session with a first node in
accordance with a first networking protocol and based on a request from a higher
layer, to communicate with a second node in accordance with a second
10 networking protocol while continuing the communication session, the
communication session being for providing a first service, and the second
networking protocol being used for providing a second service;
determine a pattern for communicating in accordance with the second
networking protocol;
15 determine a complimentary pattern for communicating in accordance
with the first networking protocol while communicating in accordance with the
second networking protocol using the pattern, wherein the pattern and the
complimentary pattern are determined to allow time-shared communicating via
the first networking protocol for the first service and via the second networking
20 protocol for the second service;
encode, for transmission to the first node in accordance with the first
networking protocol, an indication of the complimentary pattern; and
configure transceiver circuitry to communicate in accordance with the
first networking protocol using the complimentary pattern and in accordance
25 with the second networking protocol using the pattern, the communication in
accordance with the first networking protocol and in accordance with the second
networking protocol being conducted using the same transceiver circuitry, each
of the first networking protocol and the second networking protocol being a
cellular communication protocol.

30

2. The apparatus of claim 1, wherein the first networking protocol is NR (new radio), wherein the second networking protocol is LTE (long term evolution), wherein the first service is data, and wherein the second service is voice.

5

3. The apparatus of claim 1, wherein the first networking protocol is NR (new radio), wherein the second networking protocol is UMTS (universal mobile telecommunications service), wherein the first service is data, and wherein the second service is voice.

10

4. The apparatus of any of claims 1-3, wherein the processing circuitry is to:

encode, for transmission to the first node in accordance with the first networking protocol, the indication of the complimentary pattern to cause the first node to adjust communication with the UE based on the complimentary pattern.

15

5. The apparatus of any of claims 1-3, wherein the pattern is received in accordance with the second networking protocol.

20

6. The apparatus of any of claims 1-3, wherein the processing circuitry is further to:

determine the pattern for communicating in accordance with the second networking protocol.

25

7. The apparatus of any of claims 1-3, wherein the processing circuitry is to:

store, in the memory, the pattern and the complimentary pattern.

30

8. The apparatus of any of claims 1-3, wherein the complimentary pattern comprises an IDC (in-device coexistence) time pattern.

9. The apparatus of any of claims 1-3, wherein the complimentary pattern comprises a TDM (time division multiplexing) pattern.

10. The apparatus of any of claims 1-3, wherein the processing
5 circuitry comprises a baseband processor.

11. The apparatus of any of claims 1-3, further comprising the transceiver circuitry to:

10 transmit the indication of the complimentary pattern in accordance with the first networking protocol.

12. The apparatus of claim 9, further comprising an antenna coupled with the transceiver circuitry.

13. An apparatus of a UE (user equipment), the apparatus
15 comprising:

processing circuitry and memory; the processing circuitry to:

20 encode information for communication with a first node in accordance with a first networking protocol using a first capability set;

determine, based on a request from a higher layer, to communicate with a second node in accordance with a second networking protocol;

determine a capability requirement for communicating in accordance with the second networking protocol;

25 encode information for communication with the second node in accordance with the second networking protocol using the capability requirement; and

encode information for communication with the first node in accordance with the first networking protocol using a subset of the first capability set, the subset excluding the capability requirement.

30

14. The apparatus of claim 13, wherein the first networking protocol is NR (new radio), and wherein the second networking protocol is LTE (long term evolution).

15. The apparatus of claim 13, wherein the first networking protocol is NR (new radio), and wherein the second networking protocol is UMTS (universal mobile telecommunications service).

5

16. The apparatus of claim 13, wherein the first capability set includes a first band and a second band, wherein the capability requirement includes the first band, and wherein the subset includes the second band.

10

17. The apparatus of claim 13, wherein the first capability set comprises an uplink transmission power or a processing capability.

18. The apparatus of claim 13, wherein the processing circuitry is to:
encode, using RRC (radio resource control) signaling, for communication
15 with the second node in accordance with the second networking protocol using the capability requirement; and
encode, using RRC signaling, for communication with the first node in accordance with the first networking protocol using the subset.

20

19. The apparatus of claim 13, wherein the processing circuitry is to:
encode, using layer 1 signaling or layer 2 signaling, for communication
with the second node in accordance with the second networking protocol using the capability requirement; and

encode, using layer 1 signaling or layer 2 signaling, for communication
25 with the first node in accordance with the first networking protocol using the subset.

20. A machine-readable medium comprising instructions which, when executed by processing circuitry of a UE (user equipment), cause the processing circuitry to:

- 5 encode information for communication with a first node in accordance with a first networking protocol;
- determine, based on a request from a higher layer, to communicate with a second node in accordance with a second networking protocol;
- encode, for transmission to the first node in accordance with the first networking protocol, an indication that the UE is communicating in accordance with the second networking protocol; and
- 10 encode for communication over both the first networking protocol and the second networking protocol while prioritizing communications in accordance with the second networking protocol.

15 21. The machine-readable medium of claim 20, wherein the instructions further cause the processing circuitry to:

- encode, for transmission to the first node in accordance with the first networking protocol, an indication of a time when the UE is to communicate in accordance with the second networking protocol and be unavailable for
- 20 communication in accordance with the first networking protocol.

22. A machine-readable medium comprising instructions which, when executed by processing circuitry of a UE (user equipment), cause the processing circuitry to:

- 25 determine, during a communication session with a first node in accordance with a first networking protocol and based on a request from a higher layer, to communicate with a second node in accordance with a second networking protocol while continuing the communication session, the communication session being for providing a first service, and the second networking protocol being used for providing a second service;
- 30 determine a pattern for communicating in accordance with the second networking protocol;

determine a complimentary pattern for communicating in accordance with the first networking protocol while communicating in accordance with the second networking protocol using the pattern, wherein the pattern and the complimentary pattern are determined to allow time-shared communicating via
5 the first networking protocol for the first service and via the second networking protocol for the second service;

encode, for transmission to the first node in accordance with the first networking protocol, an indication of the complimentary pattern; and

configure transceiver circuitry to communicate in accordance with the
10 first networking protocol using the complimentary pattern and in accordance with the second networking protocol using the pattern, the communication in accordance with the first networking protocol and in accordance with the second networking protocol being conducted using the same transceiver circuitry, each of the first networking protocol and the second networking protocol being a
15 cellular communication protocol.

23. The machine-readable medium of claim 22, wherein the first networking protocol is NR (new radio), and wherein the second networking protocol is LTE (long term evolution).
20

24. The machine-readable medium of claim 22, wherein the first networking protocol is NR (new radio), and wherein the second networking protocol is UMTS (universal mobile telecommunications service).

25. The machine-readable medium of claim 22, wherein the processing circuitry is to:

encode, for transmission to the first node in accordance with the first networking protocol, the indication of the complimentary pattern to cause the first node to adjust communication with the UE based on the complimentary
30 pattern.

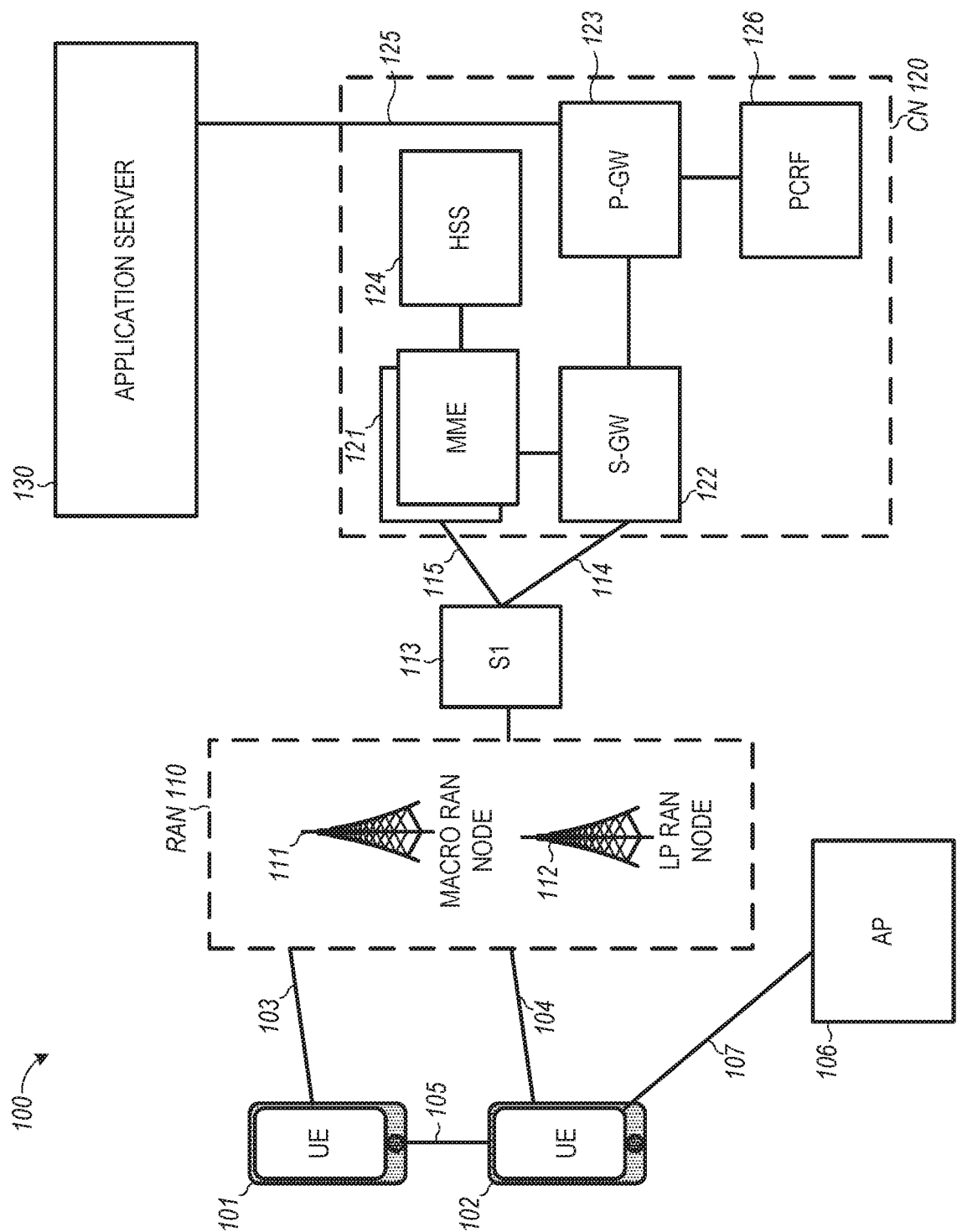


FIG. 1

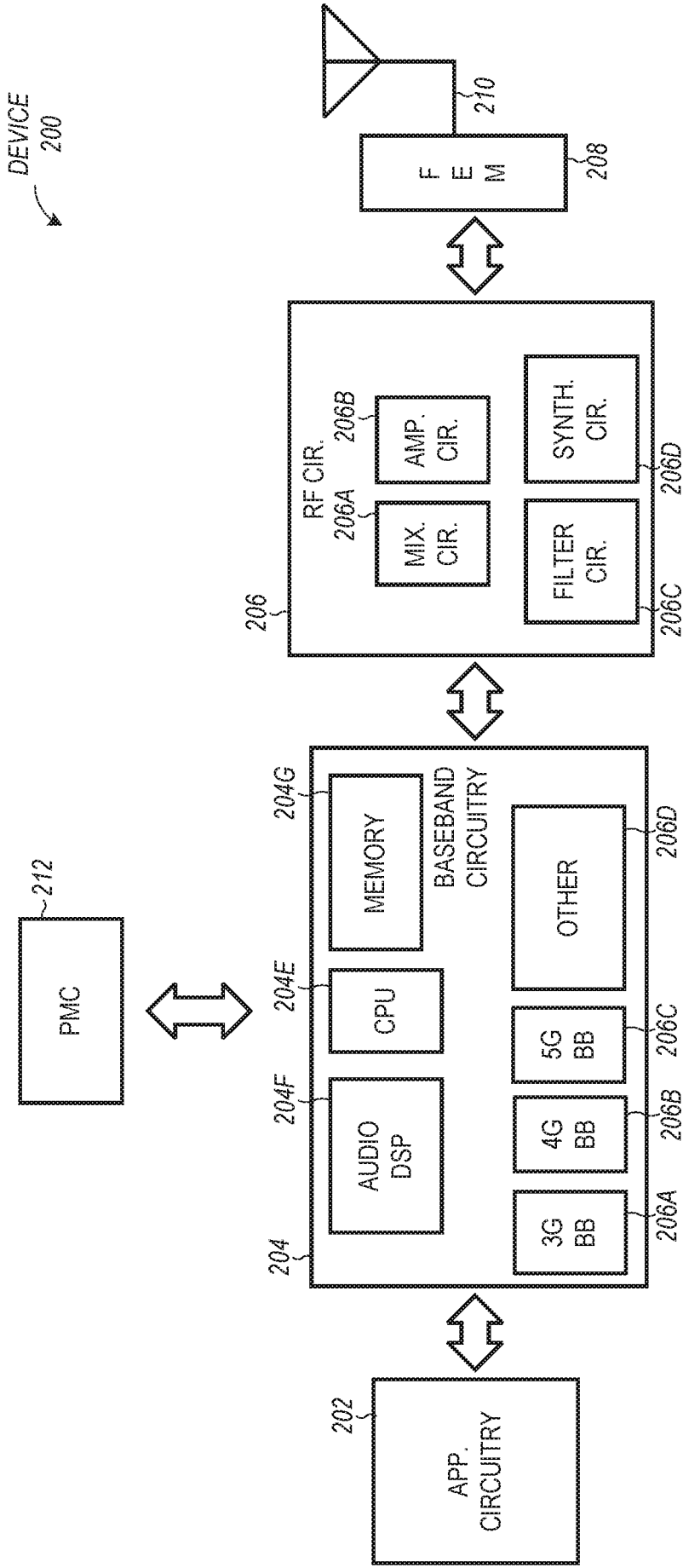


FIG. 2

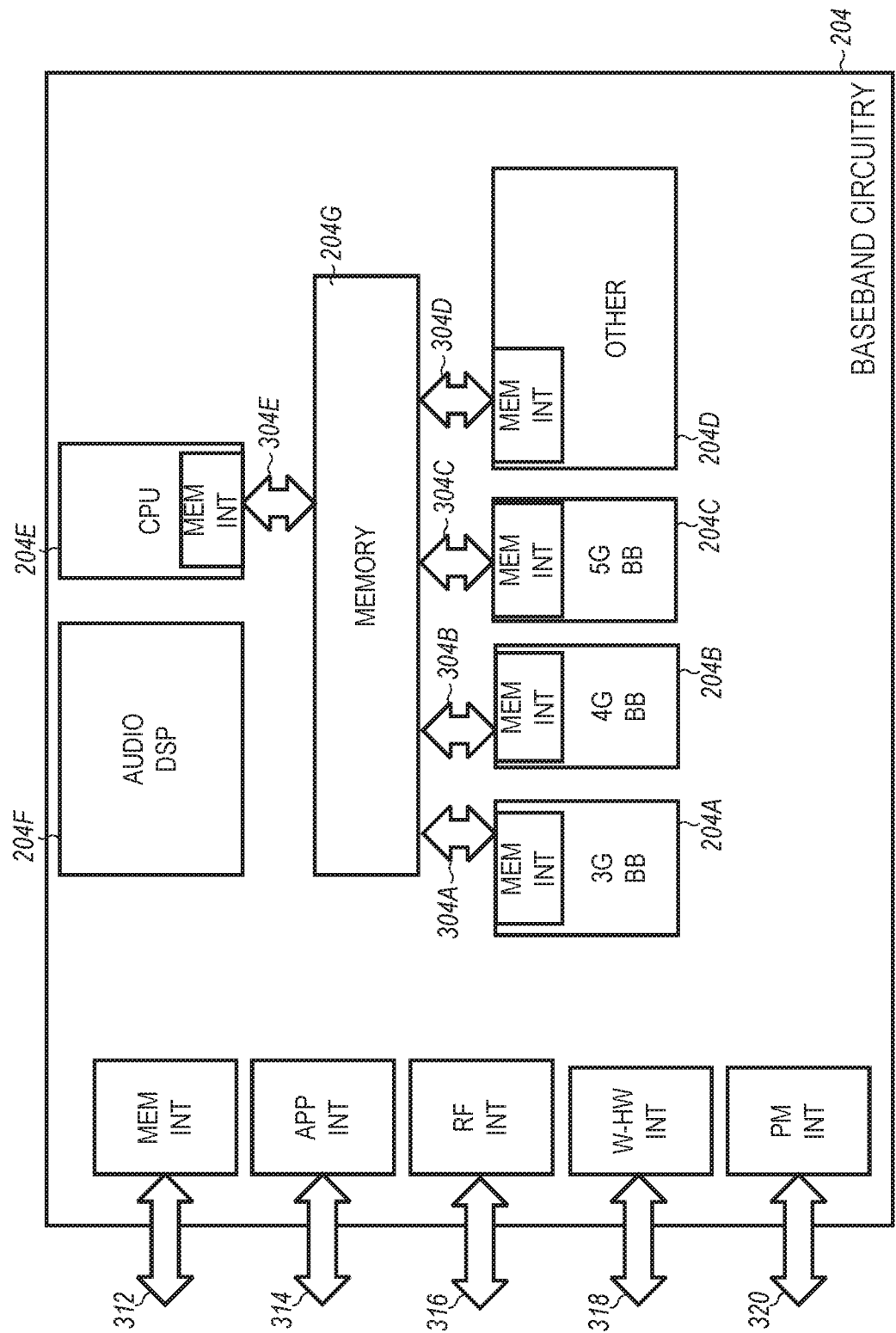


FIG. 3

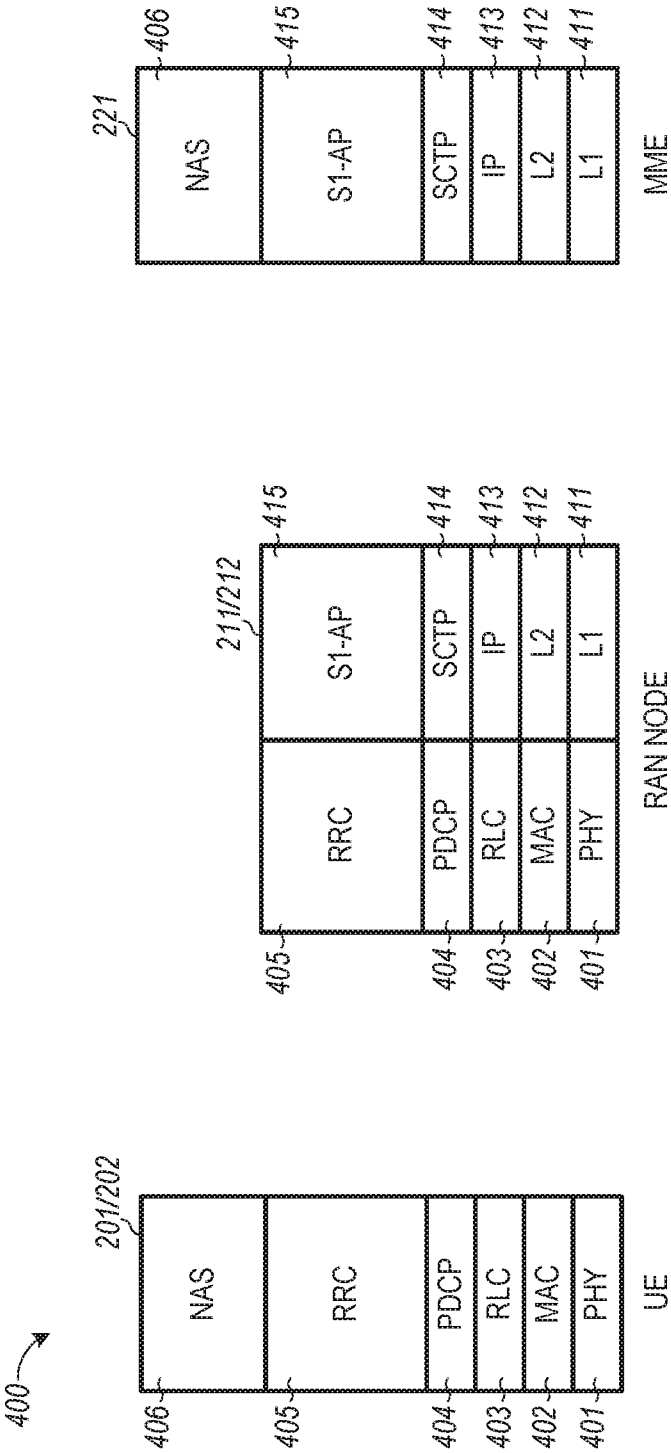


FIG. 4

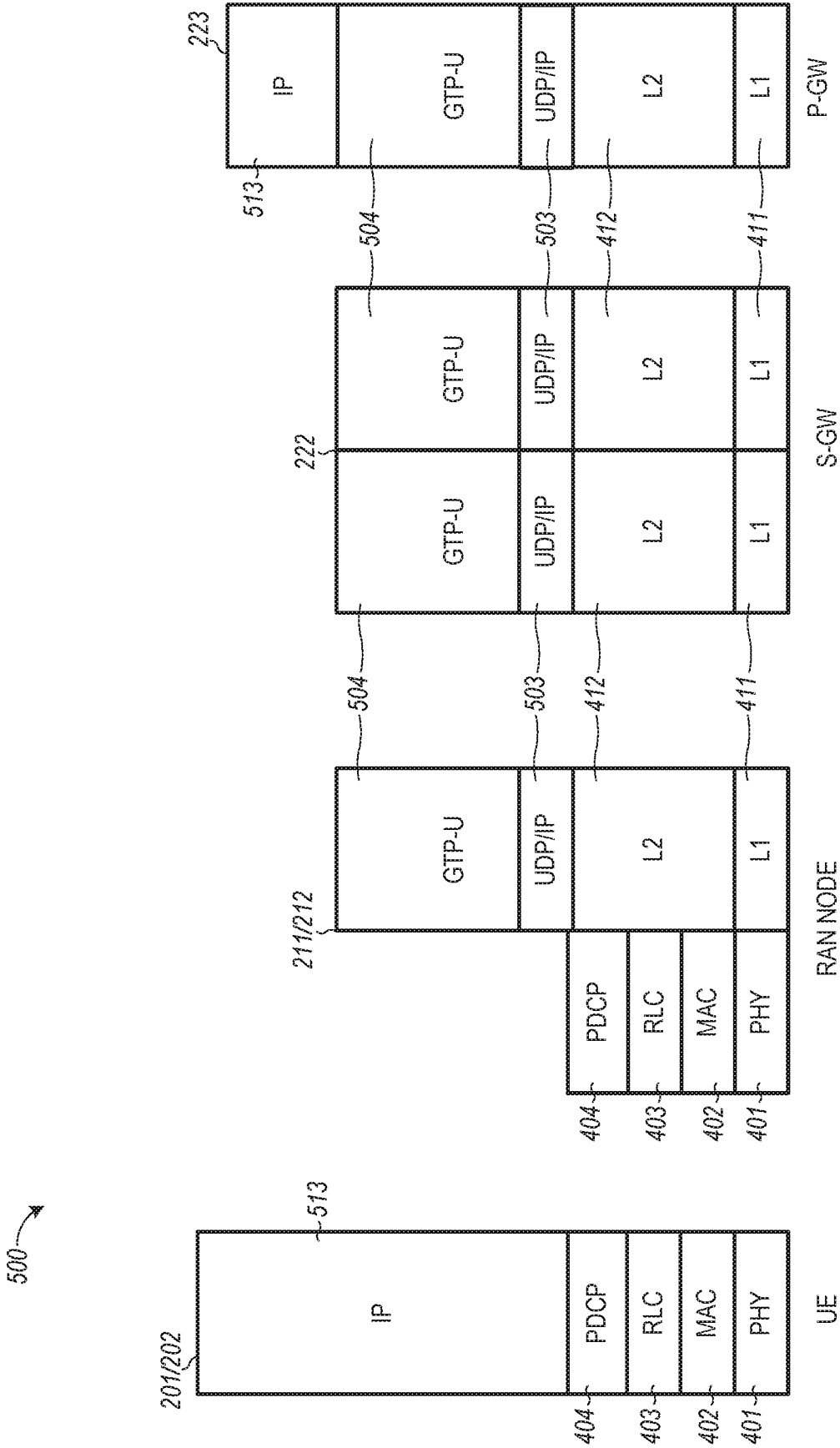


FIG. 5

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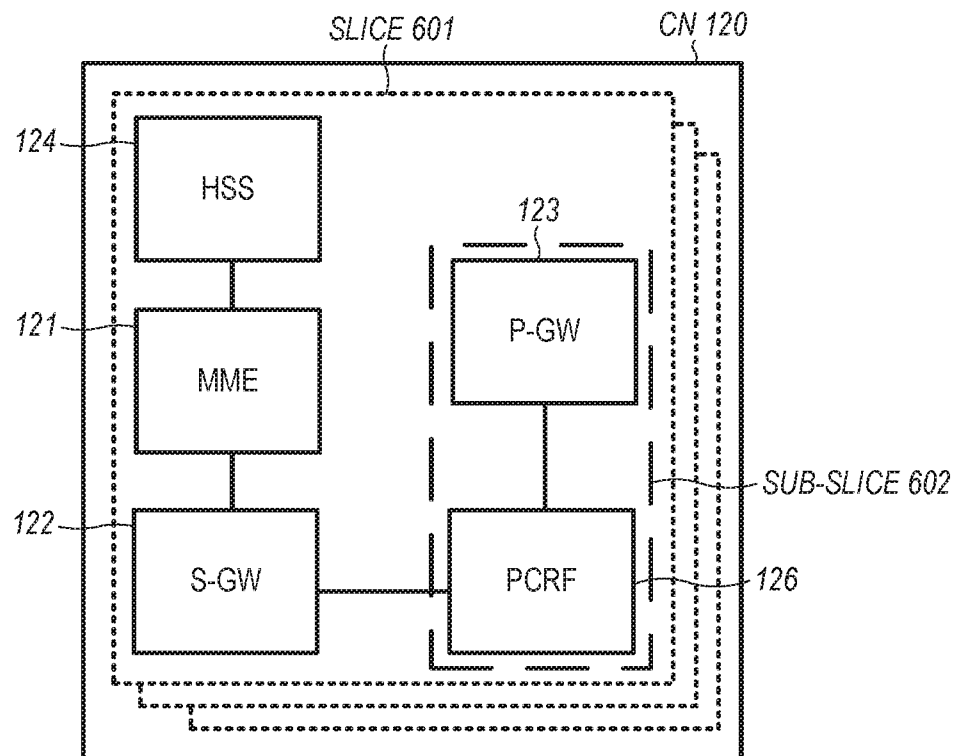


FIG. 6

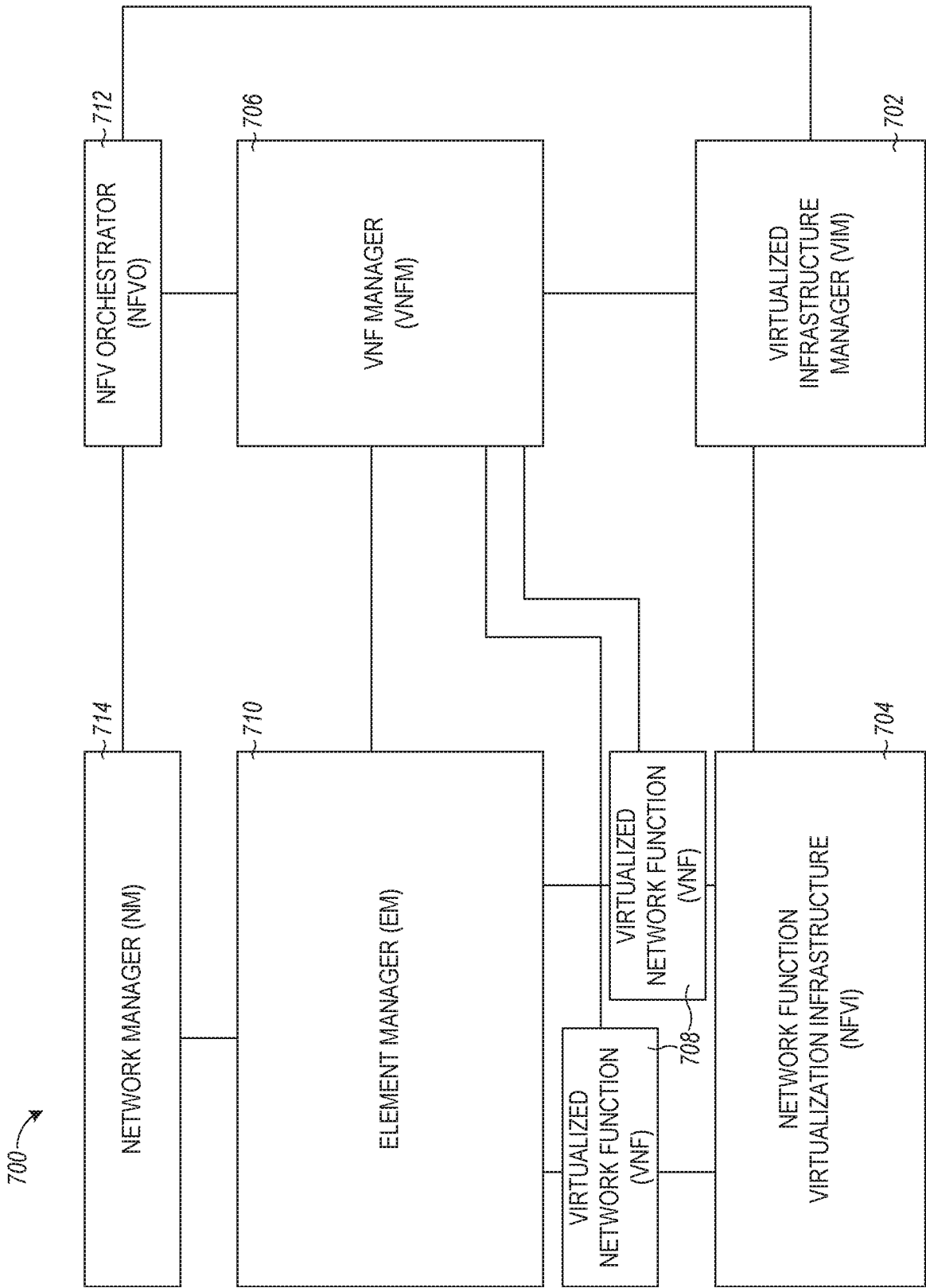


FIG. 7

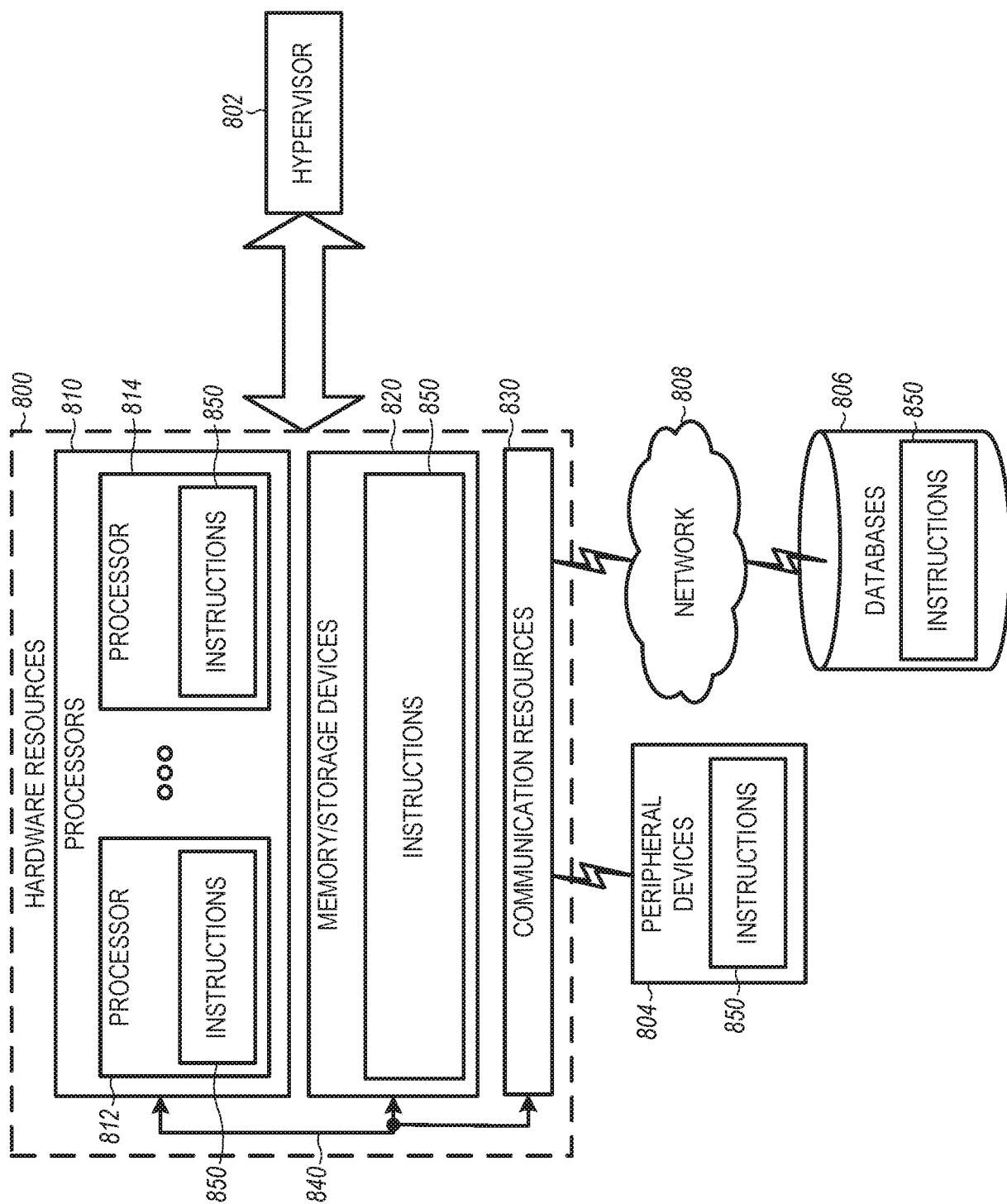


FIG. 8

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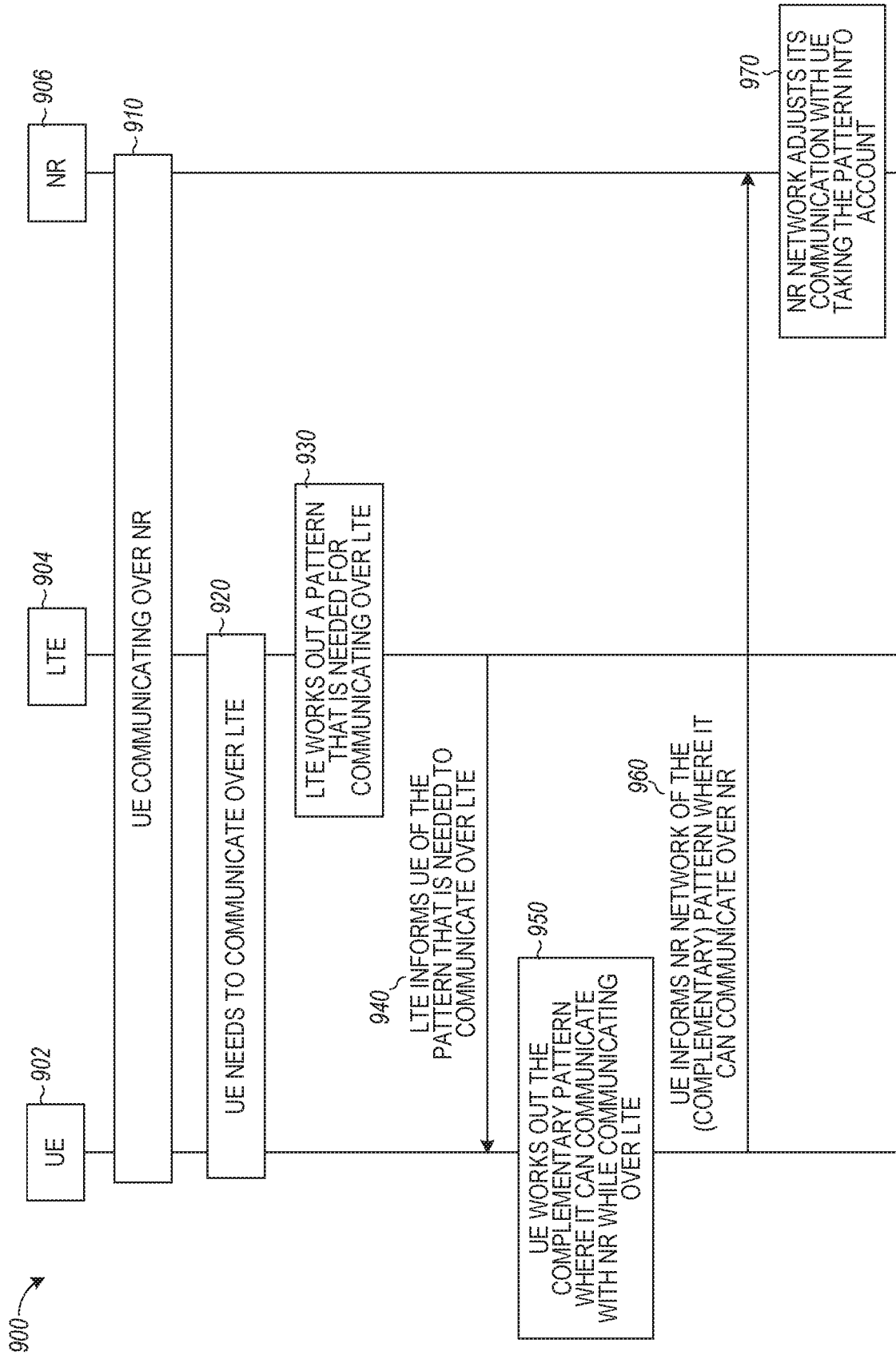


FIG. 9

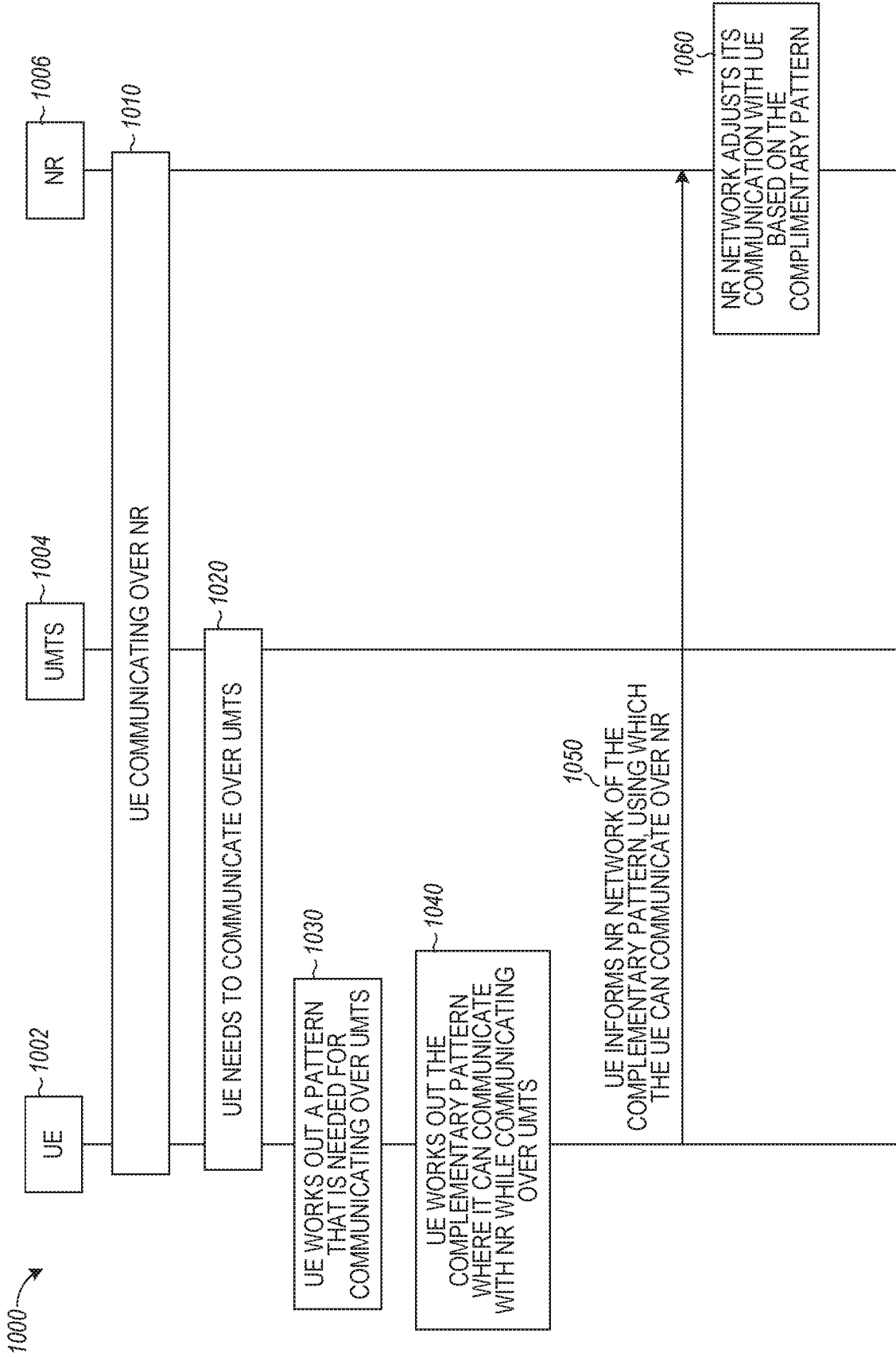


FIG. 10

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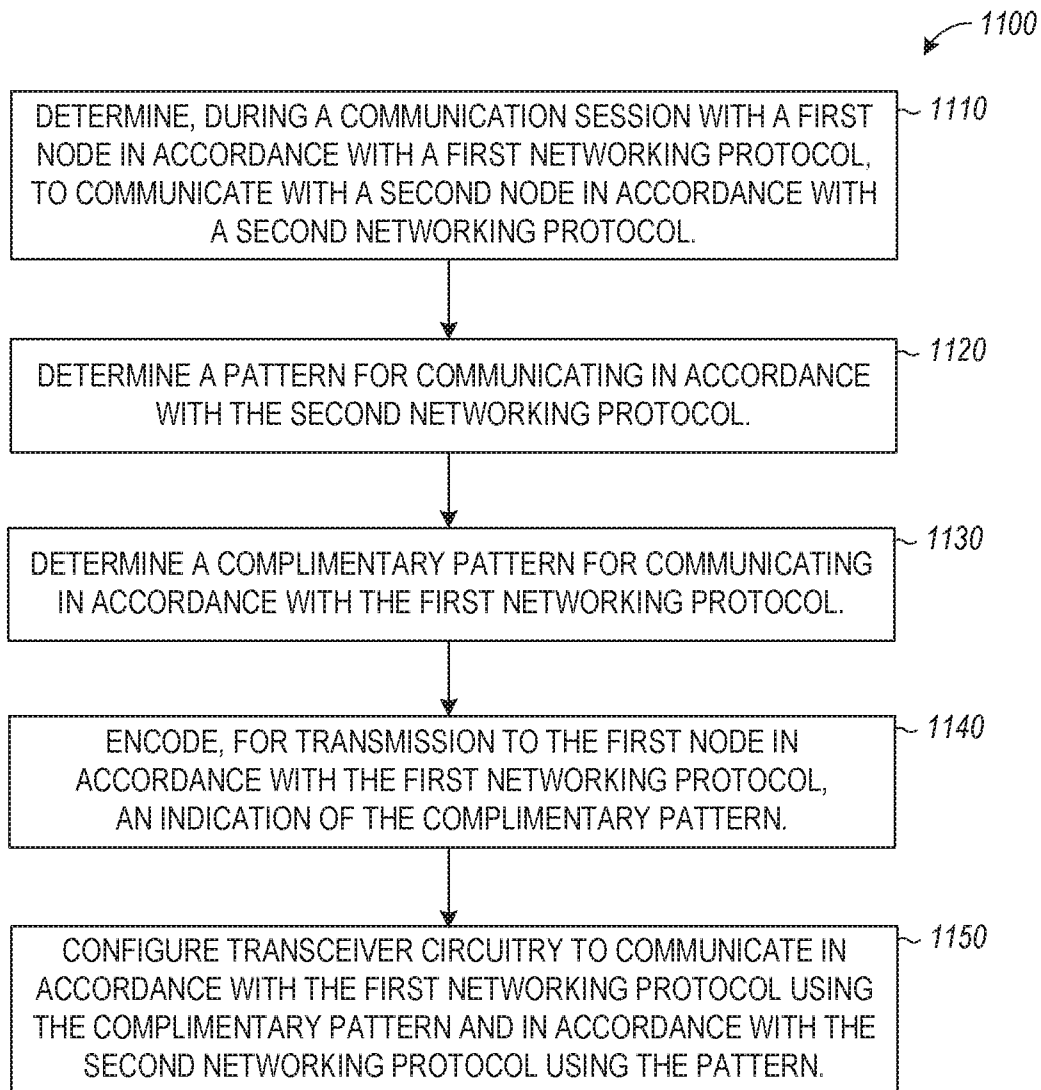


FIG. 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/046088**A. CLASSIFICATION OF SUBJECT MATTER****H04W 72/12(2009.01)i, H04W 76/02(2009.01)i, H04W 88/06(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 72/12; H04W 88/02; H04W 8/02; H04L 29/06; H04W 88/06; H04B 1/3816; H04W 16/14; H04L 29/12; H04W 76/02

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: NR(new radio), LTE, data, voice, pattern, capability, band, prioritizing

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2016-0029222 A1 (APPLE INC.) 28 January 2016 See paragraphs [0069]–[0096]; claims 1–5; and figures 5A–6.	1–25
A	US 2015-0063346 A1 (MAVENIR SYSTEMS, INC.) 05 March 2015 See paragraphs [0068]–[0075]; and figures 9–11.	1–25
A	US 2012-0275350 A1 (SAI C. KWOK) 01 November 2012 See paragraphs [0056]–[0066]; and figures 5–7.	1–25
A	US 2014-0362778 A1 (BROADCOM CORPORATION) 11 December 2014 See paragraphs [0019]–[0051]; and figures 1–3.	1–25
A	KR 10-2015-0102505 A (SAMSUNG ELECTRONICS CO., LTD.) 07 September 2015 See paragraphs [0093]–[0118]; and figures 11–13.	1–25



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

20 November 2017 (20.11.2017)

Date of mailing of the international search report

22 November 2017 (22.11.2017)

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2017/046088

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