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(54) Title: EVOLVED NODE-B (ENB), USER EQUIPMENT (UE) AND METHODS FOR TRAFFIC REPORTING ON OFF-LOADED PACKET DATA NETWORK (PDN) CONNECTIONS

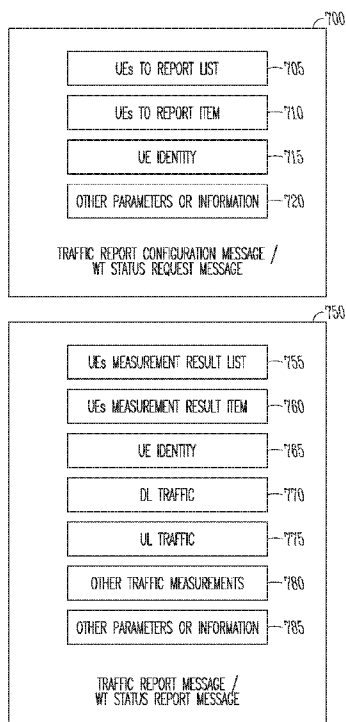


FIG. 7

(57) Abstract: Embodiments of an Evolved Node-B (eNB), User Equipment (UE) and methods for offloading of packet data network (PDN) connections are generally described herein. The eNB may transmit a traffic offload message to the UE to indicate that one or more PDN connections are to be offloaded from a cellular network to a wireless local area network (WLAN). The eNB may send a traffic report configuration message to the WLAN to indicate that the WLAN is to send traffic measurements for traffic exchanged between the UE and the WLAN on the offloaded PDN connections. The eNB may determine whether the UE is to be transitioned to a radio resource control (RRC) idle mode based at least partly on the traffic measurements. Example traffic measurements may include a data rate, a number of packets or other measurements.



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EVOLVED NODE-B (ENB), USER EQUIPMENT (UE) AND METHODS
FOR TRAFFIC REPORTING ON OFFLOADED PACKET DATA NETWORK
(PDN) CONNECTIONS

5

PRIORITY CLAIM

[0001] This application claims priority to United States Provisional
10 Patent Application Serial No. 62/289,007, filed January 29, 2016, which is
incorporated herein by reference in its entirety.

TECHNICAL FIELD

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[0002] Embodiments pertain to wireless communications. Some
embodiments relate to wireless networks including 3GPP (Third Generation
Partnership Project) networks, 3GPP LTE (Long Term Evolution) networks,
3GPP LTE-A (LTE Advanced) networks, and wireless local area networks
20 (WLANs), although the scope of the embodiments is not limited in this respect.
Some embodiments relate to radio access network (RAN) controlled LTE-
WLAN interworking (RCLWI) arrangements. Some embodiments relate to
packet data network (PDN) connections.

25

BACKGROUND

[0003] A mobile network may support communication with mobile
devices. In some cases, an increased data rate and/or demand for services may
30 provide various challenges. As an example, an increased number of mobile
devices may need to be supported by a base station. As another example, an
increased system throughput for the mobile devices may approach or exceed a

capacity of the base station. Accordingly, there is a general need for methods and systems in these and other scenarios.

5 BRIEF DESCRIPTION OF THE DRAWINGS

[0004] FIG. 1 is a functional diagram of a 3GPP network in accordance with some embodiments;

10 [0005] FIG. 2 illustrates a block diagram of an example machine in accordance with some embodiments;

[0006] FIG. 3 is a block diagram of an Evolved Node-B (eNB) in accordance with some embodiments;

[0007] FIG. 4 is a block diagram of a User Equipment (UE) in accordance with some embodiments;

15 [0008] FIG. 5 illustrates an example of connectivity between a UE, an eNB and an access point (AP) in accordance with some embodiments;

[0009] FIG. 6 illustrates the operation of a method of communication in accordance with some embodiments;

20 [0010] FIG. 7 illustrates examples of messages that may be used in accordance with some embodiments;

[0011] FIG. 8 illustrates the operation of another method of communication in accordance with some embodiments;

[0012] FIG. 9 illustrates additional examples of messages that may be used in accordance with some embodiments;

25 [0013] FIG. 10 illustrates the operation of another method of communication in accordance with some embodiments; and

[0014] FIG. 11 illustrates the operation of another method of communication in accordance with some embodiments.

30

DETAILED DESCRIPTION

[0015] The following description and the drawings sufficiently illustrate specific embodiments to enable those skilled in the art to practice them. Other
5 embodiments may incorporate structural, logical, electrical, process, and other 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 is a functional diagram of a 3GPP network in accordance
10 with some embodiments. It should be noted that embodiments are not limited to the example 3GPP network shown in FIG. 1, as other cellular networks and/or other networks may be used in some embodiments. As an example, a Fifth Generation (5G) network may be used in some cases. As another example, a wireless local area network (WLAN) may be used in some cases. Embodiments
15 are not limited to these example networks, however, as other networks may be used in some embodiments. In addition, in some embodiments, one or more networks, including these example networks and/or other networks, may be used in combination. As an example, the UE 102 may be configured to communicate with a 3GPP network and with a WLAN in some cases. As another example, the
20 UE 102 may be configured to communicate with a cellular network and with a WLAN in some cases. Such networks may include one or more of the components shown in FIG. 1, and may include additional components and/or alternative components in some cases.

[0017] The network shown in FIG. 1 may comprise a radio access
25 network (RAN) (e.g., as depicted, the E-UTRAN or evolved universal terrestrial radio access network) 100 and the core network 120 (e.g., shown as an evolved packet core (EPC)) coupled together through an S1 interface 115. For convenience and brevity sake, only a portion of the core network 120, as well as the RAN 100, is shown.

30 [0018] The core network 120 includes a mobility management entity (MME) 122, a serving gateway (serving GW) 124, and packet data network gateway (PDN GW) 126. The RAN 100 includes Evolved Node-B's (eNBs) 104

(which may operate as base stations) for communicating with User Equipment (UE) 102. The eNBs 104 may include macro eNBs and low power (LP) eNBs.

[0019] In some embodiments, the eNB 104 may transmit a traffic offload message to the UE 102 to indicate that one or more PDN connections between the eNB 104 and the UE 102 are to be offloaded to a wireless local area network (WLAN). These embodiments will be described in more detail below.

[0020] The MME 122 is similar in function to the control plane of legacy Serving GPRS Support Nodes (SGSN). The MME 122 manages mobility aspects in access such as gateway selection and tracking area list management.

10 The serving GW 124 terminates the interface toward the RAN 100, and routes data packets between the RAN 100 and the core network 120. In addition, it may be a local mobility anchor point for inter-eNB handovers and also may provide an anchor for inter-3GPP mobility. Other responsibilities may include lawful intercept, charging, and some policy enforcement. The serving GW 124 and the MME 122 may be implemented in one physical node or separate physical nodes. The PDN GW 126 terminates an SGI interface toward the packet data network (PDN). The PDN GW 126 routes data packets between the EPC 120 and the external PDN, and may be a key node for policy enforcement and charging data collection. It may also provide an anchor point for mobility with non-LTE
20 accesses. The external PDN can be any kind of IP network, as well as an IP Multimedia Subsystem (IMS) domain. The PDN GW 126 and the serving GW 124 may be implemented in one physical node or separated physical nodes. It should be noted that in some embodiments, the PDN GW 126 may not necessarily be connected directly to the eNB 104. In some embodiments, the PDN GW 126 may be configured to operate as a local gateway (LGW) and may be directly connected to the eNB 104, in some cases.

[0021] The eNBs 104 (macro and micro) terminate the air interface protocol and may be the first point of contact for a UE 102. In some embodiments, an eNB 104 may fulfill various logical functions for the RAN 100
30 including but not limited to RNC (radio network controller functions) such as radio bearer management, uplink and downlink dynamic radio resource management and data packet scheduling, and mobility management. In accordance with embodiments, UEs 102 may be configured to communicate

Orthogonal Frequency Division Multiplexing (OFDM) communication signals with an eNB 104 over a multicarrier communication channel in accordance with an Orthogonal Frequency Division Multiple Access (OFDMA) communication technique. The OFDM signals may comprise a plurality of orthogonal subcarriers.

[0022] The S1 interface 115 is the interface that separates the RAN 100 and the EPC 120. It is split into two parts: the S1-U, which carries traffic data between the eNBs 104 and the serving GW 124, and the S1-MME, which is a signaling interface between the eNBs 104 and the MME 122. The X2 interface is the interface between eNBs 104. The X2 interface comprises two parts, the X2-C and X2-U. The X2-C is the control plane interface between the eNBs 104, while the X2-U is the user plane interface between the eNBs 104.

[0023] With cellular networks, LP cells are typically used to extend coverage to indoor areas where outdoor signals do not reach well, or to add network capacity in areas with very dense phone usage, such as train stations. As used herein, the term low power (LP) eNB refers to any suitable relatively low power eNB for implementing a narrower cell (narrower than a macro cell) such as a femtocell, a picocell, or a micro cell. Femtocell eNBs are typically provided by a mobile network operator to its residential or enterprise customers. A femtocell is typically the size of a residential gateway or smaller and generally connects to the user's broadband line. Once plugged in, the femtocell connects to the mobile operator's mobile network and provides extra coverage in a range of typically 30 to 50 meters for residential femtocells. Thus, a LP eNB might be a femtocell eNB since it is coupled through the PDN GW 126. Similarly, a picocell is a wireless communication system typically covering a small area, such as in-building (offices, shopping malls, train stations, etc.), or more recently in-aircraft. A picocell eNB can generally connect through the X2 link to another eNB such as a macro eNB through its base station controller (BSC) functionality. Thus, LP eNB may be implemented with a picocell eNB since it is coupled to a macro eNB via an X2 interface. Picocell eNBs or other LP eNBs may incorporate some or all functionality of a macro eNB. In some cases, this may be referred to as an access point base station or enterprise femtocell.

- [0024] In some embodiments, a downlink resource grid may be used for downlink transmissions from an eNB 104 to a UE 102, while uplink transmission from the UE 102 to the eNB 104 may utilize similar techniques. The grid may 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 correspond 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 (RE). Each resource grid comprises a number of resource blocks (RBs), which describe the mapping of certain physical channels to resource elements. Each resource block comprises a collection of resource elements in the frequency domain and may represent the smallest quanta of resources that currently can be allocated. There are several different physical downlink channels that are conveyed using such resource blocks. With particular relevance to this disclosure, two of these physical downlink channels are the physical downlink shared channel and the physical down link control channel.
- [0025] The physical downlink shared channel (PDSCH) carries user data and higher-layer signaling to a UE 102 (FIG. 1). The physical downlink control channel (PDCCH) carries information about the transport format and resource allocations related to the PDSCH channel, among other things. It also informs the UE 102 about the transport format, resource allocation, and hybrid automatic repeat request (HARQ) information related to the uplink shared channel. Typically, downlink scheduling (e.g., assigning control and shared channel resource blocks to UEs 102 within a cell) may be performed at the eNB 104 based on channel quality information fed back from the UEs 102 to the eNB 104, and then the downlink resource assignment information may be sent to a UE 102 on the control channel (PDCCH) used for (assigned to) the UE 102.
- [0026] The PDCCH uses CCEs (control channel elements) to convey the control information. Before being mapped to resource elements, the PDCCH complex-valued symbols are first organized into quadruplets, which are then

permuted using a sub-block inter-leaver for rate matching. Each PDCCH is transmitted using one or more of these control channel elements (CCEs), where each CCE corresponds to nine sets of four physical resource elements known as resource element groups (REGs). Four QPSK symbols are mapped to each REG.

- 5 The PDCCH can be transmitted using one or more CCEs, depending on the size of DCI and the channel condition. There may 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] As used herein, the term "circuitry" may refer to, be part of, or
10 include an Application Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group), and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit, and/or other suitable hardware components that provide the described functionality. In some embodiments, the circuitry may be
15 implemented in, or functions associated with the circuitry may be implemented by, one or more software or firmware modules. In some embodiments, circuitry may include logic, at least partially operable in hardware. Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software.

20 [0028] FIG. 2 illustrates a block diagram of an example machine in accordance with some embodiments. The machine 200 is an example machine upon which any one or more of the techniques and/or methodologies discussed herein may be performed. In alternative embodiments, the machine 200 may operate as a standalone device or may be connected (e.g., networked) to other
25 machines. In a networked deployment, the machine 200 may operate in the capacity of a server machine, a client machine, or both in server-client network environments. In an example, the machine 200 may act as a peer machine in peer-to-peer (P2P) (or other distributed) network environment. The machine 200 may be a UE 102, eNB 104, access point (AP), station (STA), mobile device,
30 base station, personal computer (PC), a tablet PC, a set-top box (STB), a personal digital assistant (PDA), a mobile telephone, a smart phone, a web appliance, a network router, switch or bridge, or any machine capable of executing instructions (sequential or otherwise) that specify actions to be taken

by that machine. Further, while only a single machine is illustrated, the term “machine” shall also be taken to include any collection of machines that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein, such as cloud

5 computing, software as a service (SaaS), other computer cluster configurations.

[0029] Examples as described herein, may include, or may operate on, logic or a number of components, modules, or mechanisms. Modules are tangible entities (e.g., hardware) capable of performing specified operations and may be configured or arranged in a certain manner. In an example, circuits may
10 be arranged (e.g., internally or with respect to external entities such as other circuits) in a specified manner as a module. In an example, the whole or part of one or more computer systems (e.g., a standalone, client or server computer system) or one or more hardware processors may be configured by firmware or software (e.g., instructions, an application portion, or an application) as a module
15 that operates to perform specified operations. In an example, the software may reside on a machine readable medium. In an example, the software, when executed by the underlying hardware of the module, causes the hardware to perform the specified operations.

[0030] Accordingly, the term “module” is understood to encompass a
20 tangible entity, be that an entity that is physically constructed, specifically configured (e.g., hardwired), or temporarily (e.g., transitorily) configured (e.g., programmed) to operate in a specified manner or to perform part or all of any operation described herein. Considering examples in which modules are temporarily configured, each of the modules need not be instantiated at any one
25 moment in time. For example, where the modules comprise a general-purpose hardware processor configured using software, the general-purpose hardware processor may be configured as respective different modules at different times. Software may accordingly configure a hardware processor, for example, to constitute a particular module at one instance of time and to constitute a different
30 module at a different instance of time.

[0031] The machine (e.g., computer system) 200 may include a hardware processor 202 (e.g., a central processing unit (CPU), a graphics processing unit (GPU), a hardware processor core, or any combination thereof), a main memory

204 and a static memory 206, some or all of which may communicate with each other via an interlink (e.g., bus) 208. The machine 200 may further include a display unit 210, an alphanumeric input device 212 (e.g., a keyboard), and a user interface (UI) navigation device 214 (e.g., a mouse). In an example, the display
5 unit 210, input device 212 and UI navigation device 214 may be a touch screen display. The machine 200 may additionally include a storage device (e.g., drive unit) 216, a signal generation device 218 (e.g., a speaker), a network interface device 220, and one or more sensors 221, such as a global positioning system (GPS) sensor, compass, accelerometer, or other sensor. The machine 200 may
10 include an output controller 228, such as a serial (e.g., universal serial bus (USB), parallel, or other wired or wireless (e.g., infrared (IR), near field communication (NFC), etc.) connection to communicate or control one or more peripheral devices (e.g., a printer, card reader, etc.).

[0032] The storage device 216 may include a machine readable medium
15 222 on which is stored one or more sets of data structures or instructions 224 (e.g., software) embodying or utilized by any one or more of the techniques or functions described herein. The instructions 224 may also reside, completely or at least partially, within the main memory 204, within static memory 206, or within the hardware processor 202 during execution thereof by the machine
20 200. In an example, one or any combination of the hardware processor 202, the main memory 204, the static memory 206, or the storage device 216 may constitute machine readable media. In some embodiments, the machine readable medium may be or may include a non-transitory computer-readable storage medium.

25 [0033] While the machine readable medium 222 is illustrated as a single medium, the term "machine readable medium" may include a single medium or multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) configured to store the one or more instructions 224. The term "machine readable medium" may include any medium that is capable of
30 storing, encoding, or carrying instructions for execution by the machine 200 and that cause the machine 200 to perform any one or more of the techniques of the present disclosure, or that is capable of storing, encoding or carrying data structures used by or associated with such instructions. Non-limiting machine

readable medium examples may include solid-state memories, and optical and magnetic media. Specific examples of machine readable media may include: non-volatile memory, such as semiconductor memory devices (e.g., Electrically Programmable Read-Only Memory (EPROM), Electrically Erasable Programmable Read-Only Memory (EEPROM)) and flash memory devices; magnetic disks, such as internal hard disks and removable disks; magneto-optical disks; Random Access Memory (RAM); and CD-ROM and DVD-ROM disks. In some examples, machine readable media may include non-transitory machine readable media. In some examples, machine readable media may include machine readable media that is not a transitory propagating signal.

[0034] The instructions 224 may further be transmitted or received over a communications network 226 using a transmission medium via the network interface device 220 utilizing any one of a number of transfer protocols (e.g., frame relay, internet protocol (IP), transmission control protocol (TCP), user datagram protocol (UDP), hypertext transfer protocol (HTTP), etc.). Example communication networks may include a local area network (LAN), a wide area network (WAN), a packet data network (e.g., the Internet), mobile telephone networks (e.g., cellular networks), Plain Old Telephone (POTS) networks, and wireless data networks (e.g., Institute of Electrical and Electronics Engineers (IEEE) 802.11 family of standards known as Wi-Fi®, IEEE 802.16 family of standards known as WiMax®, IEEE 802.11 family of standards known as WiGig®, IEEE 802.15.4 family of standards, a Long Term Evolution (LTE) family of standards, a Universal Mobile Telecommunications System (UMTS) family of standards, peer-to-peer (P2P) networks, among others. In an example, the network interface device 220 may include one or more physical jacks (e.g., Ethernet, coaxial, or phone jacks) or one or more antennas to connect to the communications network 226. In an example, the network interface device 220 may include a plurality of antennas to wirelessly communicate using at least one of single-input multiple-output (SIMO), multiple-input multiple-output (MIMO), or multiple-input single-output (MISO) techniques. In some examples, the network interface device 220 may wirelessly communicate using Multiple User MIMO techniques. The term “transmission medium” shall be taken to include any intangible medium that is capable of storing, encoding or carrying

instructions for execution by the machine 200, and includes digital or analog communications signals or other intangible medium to facilitate communication of such software.

[0035] FIG. 3 is a block diagram of an Evolved Node-B (eNB) in accordance with some embodiments. It should be noted that in some embodiments, the eNB 300 may be a stationary non-mobile device. The eNB 300 may be suitable for use as an eNB 104 as depicted in FIG. 1, in some embodiments. The eNB 300 may include physical layer circuitry 302 and a transceiver 305, one or both of which may enable transmission and reception of signals to and from the UE 200, other eNBs, other UEs or other devices using one or more antennas 301. As an example, the physical layer circuitry 302 may perform various encoding and decoding functions that may include formation of baseband signals for transmission and decoding of received signals. As another example, the transceiver 305 may perform various transmission and reception functions such as conversion of signals between a baseband range and a Radio Frequency (RF) range. Accordingly, the physical layer circuitry 302 and the transceiver 305 may be separate components or may be part of a combined component. In addition, some of the described functionality related to transmission and reception of signals may be performed by a combination that may include one, any or all of the physical layer circuitry 302, the transceiver 305, and other components or layers. The eNB 300 may also include medium access control layer (MAC) circuitry 304 for controlling access to the wireless medium. The eNB 300 may also include processing circuitry 306 and memory 308 arranged to perform the operations described herein. The eNB 300 may also include one or more interfaces 310, which may enable communication with other components, including other eNBs 104 (FIG. 1), components in the EPC 120 (FIG. 1) or other network components. In addition, the interfaces 310 may enable communication with other components that may not be shown in FIG. 1, including components external to the network. As an example, the interfaces 310 may enable communication between the eNB 300 and an access point (AP) and/or other component of a WLAN. The interfaces 310 may be wired or wireless or a combination thereof. It should be noted that in some embodiments,

an eNB or other base station may include some or all of the components shown in either FIG. 2 or FIG. 3 or both.

[0036] FIG. 4 is a block diagram of a User Equipment (UE) in accordance with some embodiments. The UE 400 may be suitable for use as a
5 UE 102 as depicted in FIG. 1. In some embodiments, the UE 400 may include application circuitry 402, baseband circuitry 404, Radio Frequency (RF) circuitry 406, front-end module (FEM) circuitry 408 and one or more antennas 410, coupled together at least as shown. In some embodiments, other circuitry or arrangements may include one or more elements and/or components of the
10 application circuitry 402, the baseband circuitry 404, the RF circuitry 406 and/or the FEM circuitry 408, and may also include other elements and/or components in some cases. As an example, “processing circuitry” may include one or more elements and/or components, some or all of which may be included in the application circuitry 402 and/or the baseband circuitry 404. As another example,
15 a “transceiver” or “transceiver circuitry” may include one or more elements and/or components, some or all of which may be included in the RF circuitry 406 and/or the FEM circuitry 408. These examples are not limiting, however, as the processing circuitry, the transceiver and/or the transceiver circuitry may also include other elements and/or components in some cases. It should be noted that
20 in some embodiments, a UE or other mobile device may include some or all of the components shown in either FIG. 2 or FIG. 4 or both.

[0037] The application circuitry 402 may include one or more application processors. For example, the application circuitry 402 may include circuitry such as, but not limited to, one or more single-core or multi-core
25 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 and/or may include memory/storage and may be configured to execute instructions stored in the memory/storage to enable various applications and/or operating systems to
30 run on the system.

[0038] The baseband circuitry 404 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 404 may include one or more baseband processors and/or control logic

to process baseband signals received from a receive signal path of the RF circuitry 406 and to generate baseband signals for a transmit signal path of the RF circuitry 406. Baseband processing circuitry 404 may interface with the application circuitry 402 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 406. For example, in some embodiments, the baseband circuitry 404 may include a second generation (2G) baseband processor 404a, third generation (3G) baseband processor 404b, fourth generation (4G) baseband processor 404c, and/or other baseband processor(s) 404d for other existing generations, generations in development or to be developed in the future (e.g., fifth generation (5G), 6G, etc.). The baseband circuitry 404 (e.g., one or more of baseband processors 404a-d) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 406. 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 404 may include Fast-Fourier Transform (FFT), precoding, and/or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 404 may include convolution, tail-biting convolution, turbo, Viterbi, and/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.

[0039] In some embodiments, the baseband circuitry 404 may include elements of a protocol stack such as, for example, elements of an evolved universal terrestrial radio access network (EUTRAN) protocol including, for example, physical (PHY), media access control (MAC), radio link control (RLC), packet data convergence protocol (PDCP), and/or radio resource control (RRC) elements. A central processing unit (CPU) 404e of the baseband circuitry 404 may be configured to run elements of the protocol stack for signaling of the PHY, MAC, RLC, PDCP and/or RRC layers. In some embodiments, the baseband circuitry may include one or more audio digital signal processor(s) (DSP) 404f. The audio DSP(s) 404f 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 404 and the application circuitry 402 may be implemented together such as, for example, on a system on a chip (SOC).

[0040] In some embodiments, the baseband circuitry 404 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 404 may support communication with an evolved universal terrestrial radio access network (EUTRAN) and/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 404 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

[0041] RF circuitry 406 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 406 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 406 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 408 and provide baseband signals to the baseband circuitry 404. RF circuitry 406 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 404 and provide RF output signals to the FEM circuitry 408 for transmission.

[0042] In some embodiments, the RF circuitry 406 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 406 may include mixer circuitry 406a, amplifier circuitry 406b and filter circuitry 406c. The transmit signal path of the RF circuitry 406 may include filter circuitry 406c and mixer circuitry 406a. RF circuitry 406 may also include synthesizer circuitry 406d for synthesizing a frequency for use by the mixer circuitry 406a of the receive signal path and the transmit signal path. In some

embodiments, the mixer circuitry 406a of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 408 based on the synthesized frequency provided by synthesizer circuitry 406d. The amplifier circuitry 406b may be configured to amplify the down-converted signals and the filter circuitry 406c 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 404 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 406a of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect. In some embodiments, the mixer circuitry 406a of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 406d to generate RF output signals for the FEM circuitry 408. The baseband signals may be provided by the baseband circuitry 404 and may be filtered by filter circuitry 406c. The filter circuitry 406c may include a low-pass filter (LPF), although the scope of the embodiments is not limited in this respect.

[0043] In some embodiments, the mixer circuitry 406a of the receive signal path and the mixer circuitry 406a of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and/or upconversion respectively. In some embodiments, the mixer circuitry 406a of the receive signal path and the mixer circuitry 406a 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 406a of the receive signal path and the mixer circuitry 406a may be arranged for direct downconversion and/or direct upconversion, respectively. In some embodiments, the mixer circuitry 406a of the receive signal path and the mixer circuitry 406a of the transmit signal path may be configured for super-heterodyne operation.

[0044] 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 406 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 404 may include a digital baseband interface to communicate with the RF circuitry 406. In some dual-mode embodiments, a separate radio IC circuitry may be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect.

[0045] In some embodiments, the synthesizer circuitry 406d 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 406d may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider. The synthesizer circuitry 406d may be configured to synthesize an output frequency for use by the mixer circuitry 406a of the RF circuitry 406 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 406d may be a fractional $N/N+1$ synthesizer. 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 404 or the applications processor 402 depending on the desired output frequency. In some 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 402.

[0046] Synthesizer circuitry 406d of the RF circuitry 406 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 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 N_d equal packets of phase, where N_d is the number of delay elements in the

delay line. In this way, the DLL provides negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

[0047] In some embodiments, synthesizer circuitry 406d may be configured to generate a carrier frequency as the output frequency, while in other
5 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 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
10 (f_{LO}). In some embodiments, the RF circuitry 406 may include an IQ/polar converter.

[0048] FEM circuitry 408 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 410, amplify the received signals and provide the amplified versions of
15 the received signals to the RF circuitry 406 for further processing. FEM circuitry 408 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 406 for transmission by one or more of the one or more antennas 410.

[0049] In some embodiments, the FEM circuitry 408 may include a
20 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 a low-noise amplifier (LNA) to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 406). The transmit signal path of
25 the FEM circuitry 408 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 406), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 410). In some embodiments, the UE 400 may include additional elements such as, for example, memory/storage, display, camera, sensor, and/or
30 input/output (I/O) interface.

[0050] The antennas 230, 301, 410 may comprise one or more directional or omnidirectional antennas, including, for example, dipole antennas, monopole antennas, patch antennas, loop antennas, microstrip antennas or other

types of antennas suitable for transmission of RF signals. In some multiple-input multiple-output (MIMO) embodiments, the antennas 230, 301, 410 may be effectively separated to take advantage of spatial diversity and the different channel characteristics that may result.

- 5 **[0051]** In some embodiments, the UE 400 and/or the eNB 300 may be a mobile device and may be a portable wireless communication device, such as a personal digital assistant (PDA), a laptop or portable computer with wireless communication capability, a web tablet, a wireless telephone, a smartphone, a wireless headset, a pager, an instant messaging device, a digital camera, an
- 10 access point, a television, a wearable device such as a medical device (e.g., a heart rate monitor, a blood pressure monitor, etc.), or other device that may receive and/or transmit information wirelessly. In some embodiments, the UE 400 or eNB 300 may be configured to operate in accordance with 3GPP standards, although the scope of the embodiments is not limited in this respect.
- 15 Mobile devices or other devices in some embodiments may be configured to operate according to other protocols or standards, including IEEE 802.11 or other IEEE standards. In some embodiments, the UE 400, eNB 300 or other device may include one or more of a keyboard, a display, a non-volatile memory port, multiple antennas, a graphics processor, an application processor, speakers,
- 20 and other mobile device elements. The display may be an LCD screen including a touch screen.

- [0052]** Although the UE 400 and the eNB 300 are each illustrated as having several separate functional elements, one or more of the functional elements may be combined and may be implemented by combinations of
- 25 software-configured elements, such as processing elements including digital signal processors (DSPs), and/or other hardware elements. For example, some elements may comprise one or more microprocessors, DSPs, field-programmable gate arrays (FPGAs), application specific integrated circuits (ASICs), radio-frequency integrated circuits (RFICs) and combinations of
- 30 various hardware and logic circuitry for performing at least the functions described herein. In some embodiments, the functional elements may refer to one or more processes operating on one or more processing elements.

[0053] Embodiments may be implemented in one or a combination of hardware, firmware and software. Embodiments may also be implemented as instructions stored on a computer-readable storage device, which may be read and executed by at least one processor to perform the operations described
5 herein. A computer-readable storage device may include any non-transitory mechanism for storing information in a form readable by a machine (e.g., a computer). For example, a computer-readable storage device may include read-only memory (ROM), random-access memory (RAM), magnetic disk storage media, optical storage media, flash-memory devices, and other storage devices
10 and media. Some embodiments may include one or more processors and may be configured with instructions stored on a computer-readable storage device.

[0054] It should be noted that in some embodiments, an apparatus for a UE may include various components of the UE 400 and/or the machine 200 as shown in FIGs. 2 and 4. Accordingly, techniques and operations described
15 herein that refer to the UE 400 (or 102) may be applicable to an apparatus for a UE, in some embodiments. In addition, an apparatus for an eNB may include various components of the eNB 300 and/or the machine 200 as shown in FIGs. 3 and 4. Accordingly, techniques and operations described herein that refer to the eNB 300 (or 104) may be applicable to an apparatus for an eNB, in some
20 embodiments.

[0055] In accordance with some embodiments, the eNB 104 may transmit a traffic offload message to the UE 102 to indicate that one or more PDN connections are to be offloaded from a cellular network to a wireless local area network (WLAN). The eNB 104 may send a traffic report configuration
25 message to the WLAN to indicate that the WLAN is to send traffic measurements for traffic exchanged between the UE 102 and the WLAN on the offloaded PDN connections. The eNB 104 may determine whether the UE 102 is to be transitioned to a radio resource control (RRC) idle mode based at least partly on the traffic measurements. Example traffic measurements may include
30 a data rate, a number of packets or other measurements. These embodiments are described in more detail below.

[0056] FIG. 5 illustrates an example of connectivity between a UE, an eNB and an access point (AP) in accordance with some embodiments. It should

be noted that embodiments are not limited by the example scenario 500 in terms of number, type or arrangement of components, interfaces or networks. In some embodiments, the cellular network 510 may be or may include a 3GPP LTE network, although the scope of embodiments is not limited in this respect.

5 Accordingly, references may be made herein to a 3GPP LTE network 510, but such references are not limiting. For instance, some operations, techniques and/or methods may be described herein in terms of embodiments that include a 3GPP LTE network 510, but some or all of those operations, techniques and/or methods may be applicable to embodiments that include a different type of
10 cellular network 510 and/or other network.

[0057] It should also be noted that in some embodiments, one or more components from FIG. 1 and/or FIG. 5 may be used. As an example, the 3GPP LTE network 510 may include one or more components shown in FIG. 1, in some embodiments. As another example, the UE 102 may be arranged to
15 communicate with the WLAN 520 and to communicate with one or more components from the 3GPP network shown in FIG. 1, in some embodiments. Accordingly, references herein to usage of a 3GPP network and/or 3GPP LTE network may include usage of the 3GPP network shown in FIG. 1, the 3GPP LTE network shown in FIG. 5, other 3GPP networks and/or a combination
20 thereof, in some embodiments.

[0058] In some embodiments, the UE 102 may be arranged to operate in accordance with one or more protocols. The UE 102 may be configured to communicate with multiple networks and/or multiple components in accordance with one or more such protocols, in some cases. Referring to FIG. 5, the UE 102
25 may communicate with the eNB 104 of the 3GPP LTE network 510 over the wireless link 512. The UE 102 may communicate with the AP 525 of the WLAN 520 over the wireless link 522. In some embodiments, the UE 102 may communicate with the AP 525 in accordance with a WLAN protocol and may communicate with the eNB 104 in accordance with a 3GPP LTE protocol. The
30 AP 525 and the eNB 104 may communicate with each other over an interface 530, which may be a wired interface in some cases. The interface 530 may be or may include an Xw interface in some embodiments. However, the scope of embodiments is not limited in this respect, as other interfaces (which may or

may not be part of a standard) may be used for communication between the eNB 104 and the AP 525. In some embodiments, the eNB 104 and the AP 525 may communicate using wireless techniques or a combination of wired and wireless techniques.

5 [0059] In some embodiments, the WLAN 520 may be or may include a Wi-Fi network. Components of the WLAN 520 may communicate with each other and/or other components in accordance with Wi-Fi operation, protocols and/or standards, in some cases. Embodiments are not limited to Wi-Fi networks, however, as the WLAN 520 may be or may include a Wi-Gig
10 network, in some embodiments. Components of the WLAN 520 may communicate with each other and/or other components in accordance with Wi-Gig operation, protocols and/or standards, in some cases. In addition, the WLAN 520 may be arranged to support Wi-Fi operation and/or Wi-Gig operation, in some embodiments. Accordingly, the UE 102 may communicate
15 with the AP 525 of the WLAN 520 in accordance with Wi-Fi operation and/or Wi-Gig operation, in some embodiments.

[0060] FIG. 6 illustrates the operation of a method of communication in accordance with some embodiments. It is important to note that embodiments of the method 600 may include additional or even fewer operations or processes in
20 comparison to what is illustrated in FIG. 6. In addition, embodiments of the method 600 are not necessarily limited to the chronological order that is shown in FIG. 6. In describing the method 600, reference may be made to FIGs. 1-5 and 7-11, although it is understood that the method 600 may be practiced with any other suitable systems, interfaces and components.

25 [0061] In addition, while the method 600 and other methods described herein may refer to eNBs 104 or UEs 102 operating in accordance with 3GPP standards, 5G standards and/or other standards, embodiments of those methods are not limited to just those eNBs 104 or UEs 102 and may also be practiced on other devices, such as a Wi-Fi access point (AP) or user station (STA). For
30 instance, APs and/or STAs may be arranged to operate in accordance with standards and/or protocols such as Wi-Fi, WiGig and/or others, in some embodiments. In some embodiments, the UE 102 and/or other device may be arranged to operate in accordance with multiple protocols, such as a 3GPP

protocol and a WLAN protocol. In addition, the method 600 and other methods described herein may be practiced by wireless devices configured to operate in other suitable types of wireless communication systems, including systems configured to operate according to various IEEE standards such as IEEE 802.11.

- 5 The method 600 may also refer to an apparatus for a UE 102 and/or eNB 104 and/or other device described above.

[0062] It should be noted that the method 600 and other methods described herein may be practiced by a wireless device that may be arranged to operate in accordance with one or more standards, such as 3GPP LTE standards,
10 WLAN standards and/or other standards, in some embodiments. Accordingly, although reference may be made to a UE 102 in the description of the method 600, it is understood that any suitable wireless device, such as a STA 102 and/or other device, may be used in some embodiments. In some embodiments, a UE 102 may be configured to communicate with a 3GPP LTE network and a
15 WLAN, in some embodiments. As a non-limiting example, the UE 102 may communicate with the 3GPP LTE network 510 and with the WLAN 520 to exchange signals, messages, data and/or other elements. Accordingly, references may be made to the 3GPP LTE network 510 and the WLAN 520 as part of descriptions of the methods 600, 800, 1000, 1100 and/or other descriptions
20 herein, but such references are not limiting, as other networks may be used in some embodiments.

[0063] It should also be noted that embodiments are not limited by references herein (such as in descriptions of the methods 600, 800, 1000 and 1100 and/or other descriptions herein) to transmission, reception and/or
25 exchanging of elements such as frames, messages, requests, indicators, signals or other elements. In some embodiments, such an element may be generated, encoded or otherwise processed by processing circuitry (such as by a baseband processor included in the processing circuitry) for transmission. The transmission may be performed by a transceiver or other component, in some
30 cases. In some embodiments, such an element may be decoded, detected or otherwise processed by the processing circuitry (such as by the baseband processor). The element may be received by a transceiver or other component, in some cases. In some embodiments, the processing circuitry and the

transceiver may be included in a same apparatus. The scope of embodiments is not limited in this respect, however, as the transceiver may be separate from the apparatus that comprises the processing circuitry, in some embodiments.

[0064] At operation 605 of the method 600, the eNB 104 may determine
5 one or more traffic measurements based on traffic exchanged between the eNB 104 and a UE 102. In some embodiments, the traffic may be exchanged on one or more PDN connections of a 3GPP LTE network 510. As an example, the eNB 104 may determine an average, maximum and/or minimum data rate of the UE 102. As another example, the eNB 104 may determine a data rate requested
10 by the UE 102 and/or a data rate of services requested by the UE 102. As another example, the eNB 104 may compare such data rates to an available system data rate. These examples are not limiting, as other suitable traffic measurements may be determined, in some cases.

[0065] At operation 610, the eNB 104 may determine a traffic loading of
15 the eNB 104. In some embodiments, the traffic loading may be related to traffic exchanged between the eNB 104 and one or more UEs 102, a system data rate, a requested data rate, an expected data rate, a number of UEs 102 and/or other devices requesting service and/or any suitable factors. In some cases, the traffic loading may indicate a capability of the eNB 104 to provide services and/or data
20 rates requested by UEs 102.

[0066] At operation 615, the eNB 104 may determine whether one or more PDN connections of the UE 102 are to be offloaded from the 3GPP LTE network to a WLAN 520. In some embodiments, the determination may be based on one or any combination of factors such as the traffic measurements
25 determined at operation 605, the traffic loading determined at operation 610 and/or other factors. It should be noted that the other factors may or may not be related to data rates and/or number of users. For instance, one or more factors related to LTE and WLAN signal strengths, a number of available WLANs 520, and/or others may also be used, in addition to or instead of factors related to data
30 rates and/or number of users, in some cases.

[0067] As an example, the eNB 104 may determine that a data rate of the UE 102 is too high in comparison to an available system data rate, and may decide to offload one or more PDN connections of the UE 102 to the WLAN

520. As another example, the eNB 104 may determine that a number of UEs 102 being served and/or requesting service from the 3GPP LTE network 510 is too high, and may decide to offload one or more PDN connections of the UE 102 to the WLAN 520. It should be noted that the eNB 104 may offload one or more PDN connections from multiple UEs 102, in some cases. In addition, the eNB 104 may also decide to offload, for a group of one or more UEs 102, a portion of PDN connections used by each of the UEs 102 in the group. For instance, the UE 102 may communicate with the 3GPP LTE network 510 over multiple PDN connections, and the eNB 104 may decide to offload a first portion of the PDN connections to the WLAN 520 and to maintain a second portion of the PDN connections with the 3GPP LTE network 510.

[0068] It should also be noted that some embodiments may be extended to include more than two networks, in some cases. As an example, the 3GPP LTE network 510 may determine that a first portion of PDN connections of the UE 102 is to be offloaded to a first WLAN 520 and that a second portion of the PDN connections is to be offloaded to another network (including but not limited to a second WLAN).

[0069] At operation 620, the eNB 104 may transmit a traffic offload message to the UE 102. In some embodiments, the traffic offload message may indicate that one or more PDN connections are to be offloaded to the WLAN 520. In some embodiments, a steering message and/or steering command may be used. Accordingly, references to the traffic offload message as part of descriptions of techniques, methods and/or operations are not limiting. Some or all such techniques, methods and/or operations may be applicable to embodiments that include usage of a steering message and/or steering command, in some cases.

[0070] The eNB 104 may transmit the traffic offload message when it is determined that one or more PDN connections of the UE 102 are to be offloaded, in some cases. In some embodiments, the PDN connections may be offloaded from the 3GPP LTE network 510 to the WLAN 520 in accordance with a radio access network (RAN) controlled LTE-WLAN interworking (RCLWI) arrangement between the 3GPP network 510 and the WLAN 520, although the scope of embodiments is not limited in this respect. In some embodiments, the

traffic offload message may be, may include or may be included in a radio resource control (RRC) message. Embodiments are not limited to usage of these or other messages, however, as the indication that the PDN connections are to be offloaded and/or related information may be communicated using other

5 techniques. For instance, other messages that may not necessarily be related to offloading of PDN connections may be used, in some embodiments.

[0071] At operation 625, the eNB 104 may send, to the WLAN 520, a traffic report configuration message that may indicate a request to receive offloaded traffic measurements for traffic between the WLAN 520 and the UE 102 on the offloaded PDN connections. Accordingly, the eNB 104 may request that the WLAN 520 keep the eNB 104 updated on traffic exchanged between the UE 102 and the WLAN 520 on PDN connections that are offloaded to the WLAN 520. A non-limiting example of a traffic report configuration message will be described below. In some embodiments, the traffic report configuration message may be sent to the WLAN 520 (and/or to the AP 525 or other component of the WLAN 520) over an Xw interface between the eNB 104 and the WLAN 520. These embodiments are not limiting, however, as other interfaces may be used for exchanging of messages between the eNB 104 and the WLAN 520. Such interfaces may be wired, wireless or a combination thereof.

[0072] FIG. 7 illustrates examples of messages that may be used in accordance with some embodiments. FIG. 9 illustrates additional examples of messages that may be used in accordance with some embodiments. It should be noted that embodiments are not limited to the arrangement and/or elements shown in the messages 700, 750, 900, 950. For instance, all parameters and/or information shown in FIGs. 7 or 9 for the example messages 700, 750, 900, 950 may not necessarily be included in some embodiments. In some embodiments, a message may include one or more parameters that may be similar to and/or related to those shown in the example messages 700, 750, 900, 950. In addition, the organization of the parameters and/or information shown in the example messages 700, 750, 900, 950 is not limiting.

[0073] Referring to FIG. 7, in some embodiments, the eNB 104 may send the traffic report configuration message 700 to the AP 525. The AP 525

may send the traffic report message 750 to the eNB 104, in some embodiments. As indicated by FIG. 7, the traffic report configuration message 700 may be or may include a WT status request message in some embodiments. In addition, the traffic report message 750 may be or may include a WT status report message, in some embodiments. In some cases, the WT status request and WT status report messages may be included in one or more standards or protocols, including but not limited to 3GPP, WLAN and/or RCLWI. It should be noted that embodiments are not limited to usage of the WT status report message or WT status request message, however. Other suitable messages, which may or may not be included in a standard, may be used in some embodiments.

[0074] In addition, a WT status request message that includes information related to traffic reporting, such as an extended WT status request message, may be used in some embodiments. A WT status response message that includes information related to traffic reporting, such as an extended WT status response message, may be used in some embodiments.

[0075] The example traffic report configuration message 700 may include a "UEs to report list" parameter 705, which may include a list of UEs 102 for which measurements (such as measurements related to traffic exchanged between the UE 102 and the WLAN) are requested and/or needed by the eNB 104. The traffic report configuration message 700 may include a "UEs to report item" parameter 710, which may include information such as a maximum number of UEs 102 per WT. For instance, a value such as 65,536 may be used, in some cases, although embodiments are not limited to this particular value. The traffic report configuration message 700 may include one or more "UE identity" parameters 715, which may include identify information for the UEs 102 that are to report measurements. For instance, WLAN Medium Access Control (MAC) addresses of the UEs 102 may be used, in some cases.

[0076] The traffic report configuration message 700 may also include any number (including zero) of other parameters or information 720. As an example, the traffic report configuration message 700 may include parameters or information that may be included in a message of a standard or protocol, such as a WT status request message and/or other message. For instance, one or more of a message type, an eNB measurement ID, a WT measurement ID, a registration

request, report characteristic, a list of BSS to report, a BSS to report item, BSSIDs, a reporting periodicity, a partial success indicator and/or other parameters may be included in some embodiments. As another example, control information for the traffic report configuration message 700 may be included.

- 5 These examples are not limiting, however, as other suitable parameters or information may be included in the traffic report configuration message 700, in some embodiments.

[0077] Returning to the method 600, at operation 630, the eNB 104 may refrain from transmission of traffic to the UE 102 on offloaded PDN connections. For instance, while the PDN connections are offloaded to the WLAN 520, the eNB 104 may refrain from transmission to the UE 102 on the offloaded PDN connections. At operation 635, the eNB 104 may transmit traffic to the UE 102 on a second group of one or more PDN connections that are not offloaded to the WLAN 520. For instance, the eNB 104 may determine that a first group of PDN connections is to be offloaded to the WLAN 520. The eNB 104 may also determine that a second group of PDN connections is not to be offloaded to the WLAN 520 and is to be maintained in the 3GPP LTE network 510. Accordingly, the eNB 104 may refrain from transmission to the UE 102 on the PDN connections that are offloaded but may continue to transmit to the UE 102 on the PDN connections that are not offloaded, in some cases.

[0078] At operation 640, the eNB 104 may maintain the UE 102 in an RRC connected mode for at least a time period after the PDN connections are offloaded. At operation 645, the eNB 104 may receive, from the WLAN 520, traffic measurements for traffic exchanged between the UE 102 and the WLAN 520 on one or more PDN connections offloaded to the WLAN 520. Non-limiting examples of traffic measurements will be described below.

[0079] At operation 650, the eNB 104 may determine, based at least partly on the traffic measurements received from the WLAN 520, whether the UE 102 is to transition from an RRC connected mode to an RRC idle mode. As an example, when it is determined that a data rate, amount of data exchanged and/or other traffic level on the offloaded PDN connections is zero (or below a threshold in some cases), the eNB 104 may decide that the UE 102 is to transition to the RRC idle mode. It should be pointed out that in some cases, a

first group of PDN connections may be offloaded to the WLAN 520 and a second group of PDN connections may be maintained by the 3GPP LTE network 510. In such cases, the determination of whether the UE 102 is to transition to the RRC idle mode may be further based at least partly on traffic measurements of the second group of PDN connections maintained by the 3GPP LTE network 510, in some cases. For instance, the eNB 104 may determine that the transition of the UE 102 to the RRC idle mode is to occur when traffic levels become zero on the offloaded PDN connections and on the PDN connections not offloaded.

[0080] In some embodiments, the eNB 104 may maintain the UE 102 in the RRC connected mode during a time period between the offloading of the PDN connections to the WLAN 520 and a determination that the UE 102 is to be transitioned out of the RRC connected mode (such as to the RRC idle mode).

[0081] In some embodiments, one or more traffic measurements may be received at the eNB 104 from the WLAN 520. In some cases, the traffic measurements may be included in a traffic report message, an example of which will be described below. As a non-limiting example, the traffic report message may be or may include a WT status report message, in some cases. The WT status report message may be included in one or more standards, but embodiments are not limited to usage of messages that are included in standards.

In some embodiments, the traffic measurements and/or traffic report message may be sent by the WLAN 520 and received at the eNB 104 over an Xw interface. Embodiments are not limited as such, however, as other suitable interfaces may be used in some cases.

[0082] Referring to FIG. 7, the example traffic report message 750 may include a “UEs measurement result list” parameter 755, which may include a list of UEs 102 for which measurements (such as measurements related to traffic exchanged between the UE 102 and the WLAN) are reported by the message 750, requested by the eNB 104 and/or needed by the eNB 104. The traffic report message 750 may include a “UEs measurement result item” parameter 760, which may include information such as a maximum number of UEs 102 per WT. For instance, a value such as 65,536 may be used, in some cases. The traffic report message 750 may include one or more “UE identity” parameters 765, which may include identify information for the UEs 102 for which

measurements are reported or for which measurements are requested. For instance, WLAN Medium Access Control (MAC) addresses of the UEs 102 may be used, in some cases.

[0083] The example traffic report message 750 may include a downlink (DL) traffic parameter 770, which may be based on DL traffic for the UE 102 from the WLAN on PDN connections offloaded to the WLAN. The example traffic report message 750 may also include an uplink (UL) traffic parameter 775, which may be based on UL traffic for the UE 102 from the WLAN on PDN connections offloaded to the WLAN. As an example, a DL data rate and/or UL data rate may be included. Any suitable values may be used to indicate the data rates, including measurements in terms of bits/sec, Mbits/sec or other unit. The measurements may be based on average, minimum, maximum and/or other measurements. The measurements may be related to one or more time periods, in some cases. For instance, a data rate measurement for a time period between transmissions of traffic report messages 750 may be used. In addition, the traffic report message 750 may also include other traffic measurements 780, in addition to or instead of the DL traffic parameter 770 and/or UL traffic parameter 775, in some embodiments. It should be noted that embodiments may not necessarily include all parameters shown in the example messages 700, 750. Accordingly, the traffic report message 750 may include one or more of the DL traffic parameter 770, UL traffic parameter 775, and other traffic measurements, in some cases.

[0084] The traffic report message 750 may also include any number (including zero) of other parameters or information 785. As an example, the traffic report message 750 may include parameters or information that may be included in a message of a standard or protocol, such as a WT status report message and/or other message. For instance, one or more of a message type, an eNB measurement ID, a WT measurement ID, a BSS measurement result list, a BSS measurement result item, a BSSID, a BSS load, WAN metrics and/or other parameters may be included in some embodiments. As another example, control information for the traffic report message 750 may be included. These examples are not limiting, however, as other suitable parameters or information may be included in the traffic report message 750, in some embodiments.

- [0085] Returning to the method 600, at operation 655, the UE 102 may transmit, to the UE 102, an RRC control message that indicates that the UE 102 is to be transitioned to the RRC idle mode. Accordingly, the RRC control message may be transmitted when it is determined, such as in operation 650 or
5 otherwise, that the UE 102 is to be transitioned to the RRC idle mode, in some cases. It should be noted that embodiments are not limited to transitions between these RRC modes or to any RRC modes. In some embodiments, other modes may be used, including modes such as active, idle, dormant or other, which may or may not be part of a standard.
- 10 [0086] It should be noted that in some embodiments, a PDN connection may include one or more internet protocol (IP) flows. Usage of the IP flows and/or PDN connections may be performed in accordance with a 3GPP standard and/or other standard, in some embodiments. Accordingly, one or more operations described herein for PDN connections (such as those in any of the
15 methods 600, 800, 1000, 1100 and/or others) may be applicable to IP flows, in some cases, such as measurement of traffic on PDNs, reporting of WLAN traffic for PDNs, offloading of PDNs, transitioning of the UE 102 to the RRC idle mode based on reported WLAN traffic on offloaded PDNs and/or other operations. As an example, one or more IP flows of a PDN connection may be
20 offloaded to the WLAN from the 3GPP LTE network based on traffic on those IP flows on the 3GPP LTE network. As another example, WLAN traffic for offloaded IP flows may be measured and/or reported to the 3GPP LTE network by the WLAN. As another example, the eNB 104 may determine whether the UE 102 is to be transitioned to the RRC idle mode based on WLAN traffic
25 measurements for the offloaded IP flows reported by the WLAN.
- [0087] FIG. 8 illustrates the operation of another method of communication in accordance with some embodiments. FIG. 10 illustrates the operation of another method of communication in accordance with some
30 embodiments. FIG. 11 illustrates the operation of another method of communication in accordance with some embodiments. As mentioned previously regarding the method 600, embodiments of the methods 800, 1000 and/or 1100 may include additional or even fewer operations or processes in comparison to what is illustrated in FIGs. 8, 10 and 11. Embodiments of the

methods 800, 1000 and/or 1100 are not necessarily limited to the chronological order that is shown in FIGs. 8, 10 and 11. In describing the methods 800, 1000 and/or 1100, reference may be made to any of FIGs. 1-11, although it is understood that the methods 800, 1000 and/or 1100 may be practiced with any other suitable systems, interfaces and components. In addition, embodiments of the method 800, 1000 and/or 1100 may be applicable to UEs 102, eNBs 104, STAs, APs and/or other wireless or mobile devices. The methods 800, 1000 and/or 1100 may be applicable to an apparatus for a UE 102, eNB 104, STA, AP and/or other wireless or mobile device, in some embodiments.

10 [0088] In some embodiments, the methods 600, 1000 and 1100 may be practiced by an eNB 104 or other base station and the method 800 may be practiced by a UE 102 or other mobile device. It should be noted that one or more operations of the methods 600, 800, 1000 and/or 1100 may be reciprocal to, similar to and/or related to one or more operations included in one of the other methods. As an example, an operation of the method 600 may include transmission of a message by the eNB 104, and an operation of the method 800 may include reception of the same message or similar message by the UE 102. As an example, an operation of the method 1000 may include transmission of a message by the eNB 104, and an operation of the method 800 may include reception of the same message or similar message by the UE 102. As another example, methods 600, 800, 1000 and/or 1100 may include one or more operations that may be similar to each other, in some cases. In addition, previous discussion of various techniques and concepts may be applicable to the methods 800, 1000 and/or 1100 in some cases, including traffic measurements, PDN connections, offloading of PDN connections to other networks, usage of multiple networks, usage of a 3GPP LTE network and a WLAN, traffic offload messages, traffic report configuration messages, traffic report messages, RRC modes, RRC messages and/or others. In addition, some or all aspects of the examples shown in FIGs. 1-11 may be applicable in some cases.

30 [0089] It should also be noted that in some embodiments, operations of the methods 800, 1000, 1100 and/or other methods described herein may be performed in accordance with a cellular network such as the 3GPP network shown in FIG. 1, the 3GPP LTE network 510 shown in FIG. 5, the WLAN 520

shown in FIG. 5 and/or a combination of these and other networks. In addition, such operations may also be performed, in some embodiments, in accordance with one or more networks that may include components from one or more of the figures herein, including but not limited to FIGs. 1 and 5. In some
5 embodiments, the networks may include additional components, some of which may not necessarily be shown in those figures.

[0090] At operation 805 of the method 800, the UE 102 may receive first data traffic from an eNB 104 on one or more PDN connections of a 3GPP LTE network 510. At operation 810, the UE 102 may receive a traffic offload
10 message from the eNB 104. In some embodiments, the traffic offload message may indicate that one or more of the PDN connections are to be offloaded to a WLAN 520. As a non-limiting example, the traffic offload message may be or may include a Report Config Inter Radio Access Technology (RAT) message that may be included in a 3GPP LTE standard and/or other standard. An
15 example traffic offload message will be presented below.

[0091] Referring to FIG. 9, in some embodiments, the eNB 104 may transmit the traffic offload message 900 to the UE 102. The UE 102 may send the traffic report message 950 to the eNB 104, in some embodiments. As a non-limiting example, the traffic offload message 900 may be or may include a
20 Report Config Inter RAT message. As another non-limiting example, the traffic report message 950 may be or may include a WLAN Connection Status Report message. In some cases, the Report Config Inter RAT message and/or the WLAN Connection Status Report message may be included in one or more standards or protocols, including but not limited to 3GPP, WLAN and/or
25 RCLWI. It should be noted that embodiments are not limited to usage of the Report Config Inter RAT message or the WLAN Connection Status Report message, however. Other suitable messages, which may or may not be included in a standard, may be used in some embodiments.

[0092] The example traffic offload message 900 may include a Report
30 Config Inter RAT information element (IE) 902, which may include any suitable parameters. As an example, a WLAN DL traffic threshold 905 and/or a WLAN UL traffic threshold 910 may be included in the IE 902. For instance, the eNB 104 may indicate to the UE 102 that the UE 102 is to compare a DL data rate

and/or other DL traffic measurement with the DL traffic threshold 905 to determine if an event has occurred. Such an event may be or may include a W4 event included in a 3GPP standard and/or other standard, in some cases.

Similarly, the eNB 104 may indicate to the UE 102 that the UE 102 is to

- 5 compare a UL data rate and/or other UL traffic measurement with the UL traffic threshold 910 to determine if another event has occurred. Such an event may be or may include a W5 event included in a 3GPP standard and/or other standard, in some cases. Accordingly, the UE 102 may send a traffic report message to the eNB 104 when an event (such as the W4 event, W5 event and/or other event)
10 occurs.

[0093] It should be noted that other events may be configured by the network, and messages such as the Report Config Inter RAT message 900 may include parameters related to events, like thresholds or other parameters.

- Examples of such events may include, but are not limited to a B1 event, in which
15 a measurement of a neighbor becomes better than a threshold; a B2 event, in which a measurement of a PCell becomes worse than a first threshold and a measurement of a neighbor becomes better than a second threshold; a W1 event, in which a measurement of a WLAN becomes better than a threshold; a W2 event, in which measurements of a WLAN mobility set become worse than a
20 first threshold and measurements of a WLAN outside mobility set become better than a second threshold; a W3 event, in which measurements of WLAN inside mobility sets become worse than a threshold; and/or other events. Such events may be included in a 3GPP standard and/or other standard, in some cases, but embodiments are not limited to usage of events that are included in standards. It
25 should be noted that one or more of those events may be configured in addition to a W4 event and/or W5 event, in some cases.

- [0094] In some cases, parameters of other events may be included in the Report Config Inter RAT IE 902. The IE 902 may also include any suitable number (including zero) of other parameters or information 915. It should be
30 noted that embodiments are not limited to usage of the IE 902 or other IEs. Accordingly, parameters such as 905, 910, event parameters and/or other parameters included in the traffic offload message 900 may not necessarily be included in an IE, in some embodiments. The traffic offload message 900 may

also include other traffic measurement parameters 920, including but not limited to one or more types of measurement that the UE 102 is to perform, one or more parameters for such measurements and/or other information.

[0095] The traffic offload message 900 may also include any suitable number (including zero) of other parameters or information 925. As an example, the traffic offload message 900 may include parameters or information that may be included in a message of a standard or protocol, such as a Report Config Inter RAT message and/or other message. For instance, one or more of a bN-ThresholdM parameter, event ID, max report cells parameter, purpose parameter, report amount parameter, report quantity UTRA-FDD parameter, SI request for HO parameter, GERAN threshold, UTRA threshold, WLAN threshold, time to trigger parameter and/or other parameters may be included in some embodiments. As another example, control information for the traffic offload message 900 may be included. These examples are not limiting, however, as other suitable parameters or information may be included in the traffic offload message 900, in some embodiments.

[0096] At operation 815, the UE 102 may receive second data traffic on the one or more PDN connections offloaded to the WLAN 520 from an AP 525 of the WLAN 520. It should be noted that, as part of the offloading of the PDN connections to the WLAN 520, one or more setup messages and/or control messages may be exchanged between the UE 102, eNB 104, AP 525 and/or WLAN 520, in some cases. At operation 817, the UE 102 may receive third data traffic from the eNB 104 on another PDN connection that is maintained by the 3GPP LTE network 510. For instance, a first portion of PDN connections between the eNB 104 and the UE 102 in the 3GPP LTE network 510 may be offloaded to the WLAN 520 and a second portion may be maintained by the 3GPP LTE network 510. The UE 102 may receive data traffic on PDN connections with both networks 510, 520, in some cases.

[0097] At operation 820, the UE 102 may determine one or more traffic measurements based at least partly on the second data traffic. In some cases, the traffic measurements may be performed in accordance with one or more traffic measurement parameters indicated by the traffic offload message. Non-limiting examples of traffic measurements that may be used include, but are not limited

to a DL data rate of the second data traffic, a UL data rate of the second data traffic, whether the second data traffic has stopped and/or whether the second data traffic has resumed after a stoppage. In some cases, other traffic measurements may be used, including previously described traffic measurements and/or other traffic measurements.

[0098] At operation 825, the UE 102 may transmit a traffic report message to the eNB 104 that indicates the one or more traffic measurements. It should be noted that in some cases, the UE 102 may transmit multiple traffic reports in a periodic manner. For instance, the traffic reports may be based on traffic measurements of the second data traffic during periodic intervals.

[0099] In some embodiments, the eNB 104 may configure a new WLAN measurement object (such as reportStrongestCells or other). Accordingly, the UE may report WLAN APs periodically. As an example, the UE 102 may report measurements on cells on which WLAN (Wi-Fi, WiGig and/or other WLAN) traffic is being received. The UE 102 may continue sending the periodic measurement reports while the WLAN traffic is being received and may stop sending the reports when the WLAN traffic finishes. As another example, the UE 102 may report measurements on cells that the UE 102 is not connected to. The UE 102 may refrain from sending the measurement reports while the WLAN traffic is being received. When the WLAN traffic finishes, the UE 102 may disconnect from the AP 525 and may begin sending measurement reports. As another example, the UE 102 may report measurements on cells on which no WLAN traffic is received. The UE 102 may refrain from sending the measurement reports while the WLAN traffic is being received. When the WLAN traffic finishes, the UE 102 may begin sending measurement reports. Accordingly, as indicated by these non-limiting examples, when WLAN traffic finishes (or there is no WLAN traffic for at least a particular time duration), the measurement report may be either triggered or stopped. The eNB 104 may use the information to bring the UE 102 back to LTE, in some cases.

[00100] In some embodiments, the traffic report may be transmitted when an event occurs. The traffic report may indicate that the event has occurred, information related to the event, information related to the traffic measurements and/or other information, in some cases. It should be noted that the events may

be configured by the eNB 104 using messages such as the traffic offload message.

[00101] As an example, a DL data rate of the second data traffic may be zero during a predetermined time period, and the traffic report message may indicate that the DL data rate is zero. As another example, a DL data rate of the second data traffic may be below a DL threshold during a predetermined time period, and the traffic report message may indicate that the DL data rate is below the DL threshold. As another example, a UL data rate of the second data traffic may be zero during a predetermined time period, and the traffic report message may indicate that the UL data rate is zero. As another example, a UL data rate of the second data traffic may be below a UL threshold during a predetermined time period, and the traffic report message may indicate that the UL data rate is below the UL threshold.

[00102] As another example, a stoppage of the second data traffic from the AP 525 may occur, and the traffic report message may indicate that the stoppage has occurred. As another example, the second data traffic from the AP 525 may restart / resume after the stoppage, and the traffic report message may indicate that the second data traffic has restarted / resumed. It should be noted that these examples of events are not limiting, as other suitable events may be used, including but not limited to events configured by the eNB 104 by the traffic offload message.

[00103] Referring to FIG. 9, in some embodiments, the UE 102 may transmit the traffic report message 950 to the eNB 104. In some embodiments, the traffic report message 950 may include a WLAN status IE 952, which may include any suitable parameters. It should be noted that in some embodiments, one or more parameters may not necessarily be included in the IE 952. In some cases, the message 950 may not necessarily include the IE 952. As an example, one or more WLAN status parameters 955 may be included in the IE 952 and/or message 950. In some cases, the WLAN status parameter(s) 955 may indicate WLAN connection status and/or causes of failures. As another example, one or more WLAN identifiers 960 may be included in the IE 952 and/or in the message 950. In some cases, the WLAN identifier(s) may be related to which WLANs are indicated by the WLAN status parameters 955.

[00104] The traffic report message 950 may also include other traffic measurements 970, such as a data rate, a number of data packets and/or other information, including but not limited to one or more measurements indicated by the traffic offload message 900. The traffic report message 950 may also include
5 any suitable number (including zero) of other parameters or information 975.

[00105] Returning to the method 800, at operation 830, the UE 102 may monitor for downlink RRC messages from the eNB 104 that may indicate that the UE 102 is to transition from an RRC connected mode to an RRC idle mode. In some cases, the UE 102 may monitor for the downlink RRC messages while
10 the PDN connection is offloaded to the WLAN 520. In some embodiments, operation of the UE 102 in the RRC idle mode may include restricted transmission and/or reception of signals. For instance, transmission of signals to the eNB 104 and reception of signals from the eNB 104 may be restricted. In some cases, the UE 102 may enter a mode of reduced operation, reduced power
15 consumption or other mode as part of operation in the RRC idle mode, although the scope of embodiments is not limited in this respect.

[00106] At operation 832, the UE 102 may determine whether one or more PDN connections are to be switched from the WLAN 520 to the 3GPP LTE network 510. The UE 102 may perform operation 832 while in the RRC
20 idle mode, in some cases. For instance, the UE 102 may transition to the RRC idle mode based on an RRC message received from the eNB 104. The determination of whether the PDN connections are to be switched to the 3GPP LTE network 510 may be based on one or more factors, including but not limited to a loading of the 3GPP LTE network 510, a loading of the WLAN 520, data
25 rates of the UE 102 on offloaded PDN connections, data rates of the UE 102 on PDN connections maintained by the 3GPP LTE network 510, requested data rates of the UE 102 and/or other factors. Accordingly, the UE 102 may decide that one or more PDN connections previously offloaded to the WLAN 520 may return to the 3GPP LTE network 510, in some cases. As an example, a portion
30 of the PDN connections previously offloaded to the WLAN 520 may return to the 3GPP LTE network 510. As another example, all PDN connections previously offloaded to the WLAN 520 may return to the 3GPP LTE network 510.

- [00107] At operation 835, the UE 102 may transmit additional traffic measurements to the eNB 104. For instance, additional traffic measurements related to traffic received from the WLAN 520 may be transmitted to the eNB 104 after the UE 102 has exited the RRC idle mode and returned to the RRC connected mode.
- [00108] Referring to the method 1000, which may be practiced at an eNB 104, it should be noted that one or more operations may be similar to or reciprocal to one or more operations of the method 600 and/or 800. Accordingly, it is understood that some or all of the descriptions of those methods and/or other descriptions herein may be applicable to the method 100, in some embodiments. In the method 1000, the eNB 104 may perform one or more of the following operations: determine that one or more PDN connections are to be offloaded to the WLAN, indicate traffic measurements that the UE 102 is to make for the offloaded PDN connections, receive such traffic measurements from the UE 102, decide whether or not to transition the UE 102 into an RRC idle mode based on traffic measurements received from the UE 102, decide whether or not one or more of the offloaded PDN connections are to be resumed by the 3GPP LTE network, decide to transition the UE 102 into an RRC idle mode based on traffic measurements received from the UE 102, exchange data with the UE 102 over PDN connections, send data to the WLAN for relay to the UE 102 on offloaded PDN connections and/or other operations.
- [00109] Referring to FIG. 11, at operation 1105, the eNB 104 may determine whether one or more PDN connections between the eNB 104 and a UE 102 are to be offloaded from a 3GPP LTE network 510 to a WLAN 520. The eNB 104 may transmit a traffic offload message to the UE 102 to indicate that one or more PDN connections are to be offloaded to the WLAN 520 at operation 1110. At operation 1115, the eNB 104 may refrain from transmission of traffic to the UE 102 on PDN connections that are offloaded to the WLAN 520.
- [00110] At operation 1120, the eNB 104 may set a first inactivity timer to a first value for the UE 102 for the offloaded PDN connections. At operation 1125, the eNB 104 may transmit, to the UE 102, an RRC control message that indicates that the UE 102 is to transition to the RRC idle mode when the

inactivity timer expires. At operation 1130, the eNB 104 may set a second inactivity timer to a second value. For instance, the second inactivity timer may be for a second PDN connection (with a second UE 102) that is not offloaded from the 3GPP LTE network 510.

5 [00111] In some embodiments, the first value may be greater than the second value, and may be significantly greater in some cases. For instance, the eNB 104 may set the first inactivity timer to a large value after PDN connections of the UE 102 have been offloaded from the 3GPP LTE network 510.

Accordingly, the eNB 104 may not necessarily receive any feedback from the
10 UE 102 about traffic exchanged between the UE 102 and the WLAN 525 on the offloaded PDN connections, but may still allow the offloaded PDN connections to operate for a finite time period. After the expiration of the inactivity timer, the eNB 104 may indicate that the UE 102 is to enter the RRC idle mode. The UE 102, even if not actually idle with the PDN connections to the WLAN 520,
15 may restart and/or refresh the PDN connection with the 3GPP LTE network 510.

[00112] Accordingly, the UE 102 may remain in the RRC connected mode for a period of time. When the inactivity timer expires, the eNB 104 may steer the UE 102 back to LTE, which may depend on whether the traffic of the UE may be supported by LTE in some cases. The eNB 104 may periodically
20 bring the UE 102 back to LTE to check for a status related to traffic of the UE 102.

[00113] In some embodiments, RAN based mechanisms for traffic reported for the UE 102 to the eNB 104 may be used. However, such information may also be available at components such as the P-GW 126 (FIG. 1), S-GW 124 (FIG. 1), MME 122 (FIG. 1) and/or other components, in some cases. Accordingly, traffic information of the UE 102 may be made available to the eNB 104 via the P-GW 126, S-GW 124, MME 122 and/or other component, in some cases. For instance, an interface between the WLAN 520 and cellular network 510 (such as the Xw interface 530) is unavailable, such techniques may
30 be used. In some cases, inactivity timers similar to those previously described may be used.

[00114] In Example 1, an apparatus for an Evolved Node-B (eNB) may comprise memory. The apparatus may further comprise processing circuitry.

The processing circuitry may be configured to encode, for transmission to a User Equipment (UE), a traffic offload message that indicates that a group of one or more packet data network (PDN) connections between the eNB and the UE are to be offloaded from a cellular network to a wireless local area network

- 5 (WLAN). The processing circuitry may be further configured to encode, for communication to the WLAN, a traffic report configuration message that indicates a request to receive an offloaded traffic measurement from the WLAN based on traffic exchanged between the UE and the WLAN on the group of PDN connections. The processing circuitry may be further configured to determine,
10 based at least partly on the offloaded traffic measurement, whether to transition the UE from a radio resource control (RRC) connected mode to an RRC idle mode for the group of PDN connections.

[00115] In Example 2, the subject matter of Example 1, wherein the offloaded traffic measurement may indicate a data rate of the traffic exchanged
15 between the UE and the WLAN on the group of PDN connections.

[00116] In Example 3, the subject matter of one or any combination of Examples 1-2, wherein when the offloaded traffic measurement indicates that a data rate of traffic exchanged between the UE and the WLAN on the group of PDN connections is zero during a measurement window, the eNB may transition
20 the UE to the RRC idle mode.

[00117] In Example 4, the subject matter of one or any combination of Examples 1-3, wherein when the offloaded traffic measurement indicates an inactivity of the traffic exchanged between the UE and the WLAN on the group of PDN connections, the eNB may transition the UE to the RRC idle mode.

25 [00118] In Example 5, the subject matter of one or any combination of Examples 1-4, wherein the processing circuitry may be further configured to maintain the UE in the RRC connected mode for at least a period of time between the offloading of the PDN connections to the WLAN and a reception of the offloaded traffic measurement.

30 [00119] In Example 6, the subject matter of one or any combination of Examples 1-5, wherein the processing circuitry may be further configured to, when it is determined that the eNB is to transition the UE to the RRC idle mode,

generate, for transmission to the UE, an RRC control message that indicates that the UE is to be transitioned to the RRC idle mode.

[00120] In Example 7, the subject matter of one or any combination of Examples 1-6, wherein the offloaded traffic measurement is a first traffic measurement and the group of PDN connections is a first group of PDN connections. The determination of whether to transition the UE to the RRC idle mode may be further based at least partly on a second traffic measurement based on traffic exchanged between the UE and the eNB on a second group of PDN connections of the cellular network that are not offloaded to the WLAN.

10 [00121] In Example 8, the subject matter of one or any combination of Examples 1-7, wherein the cellular network may include a Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) network. The PDN connections may be offloaded from the 3GPP LTE network to the WLAN in accordance with a radio access network (RAN) controlled LTE-WLAN interworking (RCLWI) arrangement between the 3GPP LTE network and the WLAN.

[00122] In Example 9, the subject matter of one or any combination of Examples 1-8, wherein the processing circuitry may be further configured to refrain from transmission of traffic to the UE on the offloaded PDN connections.

20 [00123] In Example 10, the subject matter of one or any combination of Examples 1-9, wherein the cellular network may include a Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) network. The traffic report configuration message may include a WLAN termination (WT) status request message that includes a list of UEs that are to report traffic measurements to the eNB.

[00124] In Example 11, the subject matter of one or any combination of Examples 1-10, wherein the offloaded traffic measurement may be included in a WT status report message that indicates a data rate for the UE on the offloaded PDN connections.

30 [00125] In Example 12, the subject matter of one or any combination of Examples 1-11, wherein the group of PDN connections is a first group of PDN connections. The processing circuitry may be further configured to transmit traffic to the UE on a second group of PDN connections maintained in the

cellular network while the first group of PDN connections is offloaded to the WLAN.

[00126] In Example 13, the subject matter of one or any combination of Examples 1-12, wherein the apparatus may further include a transceiver to
5 transmit the traffic offload message to the UE.

[00127] In Example 14, the subject matter of one or any combination of Examples 1-13, wherein the processing circuitry may include a baseband processor to determine whether to transition the UE from the RRC connected mode to the RRC idle mode.

10 [00128] In Example 15, the subject matter of one or any combination of Examples 1-14, wherein the apparatus may further include interface circuitry to communicate, to the WLAN, the traffic report configuration message over an Xw interface between the eNB and the WLAN.

[00129] In Example 16, a computer-readable storage medium may store
15 instructions for execution by one or more processors to perform operations for communication by an Evolved Node-B (eNB). The operations may configure the one or more processors to determine a cellular traffic measurement based on a data rate of traffic exchanged between the eNB and a User Equipment (UE) on an internet protocol (IP) flow of a packet data network (PDN) connection of a
20 cellular network. The operations may further configure the one or more processors to determine, based at least partly on the cellular traffic measurement, whether the IP flow is to be offloaded to a wireless local area network (WLAN). The operations may further configure the one or more processors to, when it is determined that the IP flow is to be offloaded to the WLAN, determine whether
25 the UE is to be transitioned from a radio resource control (RRC) connected mode to an RRC idle mode based at least partly on a WLAN traffic measurement received from the WLAN. The WLAN traffic measurement may be based on a data rate of traffic exchanged between the WLAN and the UE on the IP flow.

[00130] In Example 17, the subject matter of Example 16, wherein the
30 cellular network may include a Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) network. The operations may further configure the one or more processors to encode, for communication to the WLAN, a WLAN termination (WT) status request message that indicates a request to receive the

traffic measurement from the WLAN. The WLAN traffic measurement may be included in a WT status report message from the WLAN based on the WT status request message. The WLAN traffic measurement may be received over an Xw interface between the eNB and the WLAN.

5 [00131] In Example 18, the subject matter of one or any combination of Examples 16-17, wherein the UE is a first UE. The determination of whether the IP flow is to be offloaded to the WLAN may be further based at least partly on a traffic loading of the eNB for a group of UEs that is supported by the eNB and includes the first UE. The traffic loading may be based on a number of UEs in
10 the group or one or more requested data rates of the UEs in the group.

[00132] In Example 19, the subject matter of one or any combination of Examples 16-18, wherein the IP flow is a first IP flow of the PDN connection. The PDN connection may be configurable to include one or more IP flows that includes the first IP flow. When the PDN connection includes a plurality of IP
15 flows and when multiple IP flows of the PDN connection are offloaded to the WLAN, the determination of whether the UE is to be transitioned from the RRC connected mode to the RRC idle mode may be based at least partly on multiple WLAN traffic measurements, received from the WLAN, for the offloaded IP flows.

20 [00133] In Example 20, an apparatus for a User Equipment (UE) may comprise memory. The apparatus may further comprise processing circuitry. The processing circuitry may be configured to decode first data traffic received from an Evolved Node-B (eNB) on a packet data network (PDN) connection of a cellular network. The processing circuitry may be further configured to decode a
25 traffic offload message received from the eNB that indicates that the PDN connection is to be offloaded to a wireless local area network (WLAN). The processing circuitry may be further configured to decode second data traffic received from an access point (AP) of the WLAN on the PDN connection. The processing circuitry may be further configured to encode, for transmission to the
30 eNB, a traffic report message that indicates a WLAN traffic measurement based at least partly on the second data traffic.

[00134] In Example 21, the subject matter of Example 20, wherein the WLAN traffic measurement may indicate a data rate of the second data traffic.

[00135] In Example 22, the subject matter of one or any combination of Examples 20-21, wherein the processing circuitry may be further configured to determine the WLAN traffic measurement in accordance with a WLAN traffic measurement parameter indicated by the traffic offload message.

- 5 [00136] In Example 23, the subject matter of one or any combination of Examples 20-22, wherein the processing circuitry may be configured to decode the second data traffic while the PDN connection is offloaded to the WLAN. The processing circuitry may be further configured to monitor, while the PDN connection is offloaded to the WLAN, for downlink radio resource control
10 (RRC) messages from the eNB that indicate that the UE is to transition from an RRC connected mode to an RRC idle mode.

- [00137] In Example 24, the subject matter of one or any combination of Examples 20-23, wherein the processing circuitry may be further configured to transition to the RRC idle mode based on a downlink RRC message. The
15 processing circuitry may be further configured to, while the UE operates in the RRC idle mode, determine whether the PDN connection is to be resumed on the cellular network based at least partly on the WLAN traffic measurement.

- [00138] In Example 25, the subject matter of one or any combination of Examples 20-24, wherein operation of the UE in the RRC idle mode may
20 include restricted reception of signals from the eNB.

- [00139] In Example 26, the subject matter of one or any combination of Examples 20-25, wherein the traffic report message may be encoded when a downlink data rate of the second data traffic is zero during a predetermined time period. The WLAN traffic measurement may indicate that the downlink data
25 rate of the second data traffic is zero.

- [00140] In Example 27, the subject matter of one or any combination of Examples 20-26, wherein the traffic report message may be encoded when a stoppage of the second data traffic from the AP occurs. The WLAN traffic measurement may indicate the stoppage of the second data traffic.

- 30 [00141] In Example 28, the subject matter of one or any combination of Examples 20-27, wherein the traffic report message is a first traffic report message. The processing circuitry may be further configured to encode, for transmission to the eNB when a restarting of the second data traffic from the AP

occurs, a second traffic report message that indicates the restarting of the second data traffic.

[00142] In Example 29, the subject matter of one or any combination of Examples 20-28, wherein the traffic report message may be encoded when a data rate event occurs. The data rate event may be in a group of candidate data rate events that includes a W4 event or a W5 event. The W4 event and W5 event may be included in a Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) protocol. The W4 event may occur when a downlink data rate of the second data traffic is less than or equal to a downlink threshold indicated by the traffic offload message. The W5 event may occur when an uplink data rate of data traffic from the UE to the AP is less than or equal to an uplink threshold indicated by the traffic offload message. The WLAN traffic measurement may indicate which data event has occurred.

[00143] In Example 30, the subject matter of one or any combination of Examples 20-29, wherein the WLAN traffic measurement is a first WLAN traffic measurement and the traffic report message is a first traffic report message. The first WLAN traffic measurement may be included in a group of WLAN traffic measurements based at least partly on the second data traffic from the AP during periodic intervals. The processing circuitry may be further configured to encode, for transmission to the eNB, a group of traffic report messages that includes the first traffic report message.

[00144] In Example 31, the subject matter of one or any combination of Examples 20-30, wherein the traffic report message may include a radio resource control (RRC) WLAN connection status report message included in a Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) standard. The traffic offload message may include a Report Config Inter Radio Access Technology (RAT) message included in a 3GPP LTE standard.

[00145] In Example 32, the subject matter of one or any combination of Examples 20-31, wherein the PDN connection is a first PDN connection. The processing circuitry may be further configured to decode third data traffic received from the eNB on a second PDN connection of the cellular network while the first PDN connection is offloaded to the WLAN.

[00146] In Example 33, the subject matter of one or any combination of Examples 20-32, wherein the apparatus may further include a transceiver to receive the first data traffic, the second data traffic, and the traffic offload configuration message and to transmit the traffic report message.

- 5 [00147] In Example 34, the subject matter of one or any combination of Examples 20-33, wherein the processing circuitry may include a baseband processor to decode the first data traffic, the second data traffic, and the traffic offload message and to encode the traffic report message.

- [00148] In Example 35, an apparatus for an Evolved Node-B (eNB) may
10 comprise means for encoding, for transmission to a User Equipment (UE), a traffic offload message that indicates that a group of one or more packet data network (PDN) connections between the eNB and the UE are to be offloaded from a cellular network to a wireless local area network (WLAN). The apparatus may further comprise means for encoding, for communication to the
15 WLAN, a traffic report configuration message that indicates a request to receive an offloaded traffic measurement from the WLAN based on traffic exchanged between the UE and the WLAN on the group of PDN connections. The apparatus may further comprise means for determining, based at least partly on the offloaded traffic measurement, whether to transition the UE from a radio
20 resource control (RRC) connected mode to an RRC idle mode for the group of PDN connections.

[00149] In Example 36, the subject matter of Example 35, wherein the offloaded traffic measurement indicates a data rate of the traffic exchanged between the UE and the WLAN on the group of PDN connections.

- 25 [00150] In Example 37, the subject matter of one or any combination of Examples 35-36, wherein when the offloaded traffic measurement indicates that a data rate of traffic exchanged between the UE and the WLAN on the group of PDN connections is zero during a measurement window, the eNB may transition the UE to the RRC idle mode.

- 30 [00151] In Example 38, an apparatus for a User Equipment (UE) may comprise means for decoding first data traffic received from an Evolved Node-B (eNB) on a packet data network (PDN) connection of a cellular network. The apparatus may further comprise means for decoding a traffic offload message

received from the eNB that indicates that the PDN connection is to be offloaded to a wireless local area network (WLAN). The apparatus may further comprise means for decoding second data traffic received from an access point (AP) of the WLAN on the PDN connection. The apparatus may further comprise means for
5 encoding, for transmission to the eNB, a traffic report message that indicates a WLAN traffic measurement based at least partly on the second data traffic.

[00152] In Example 39, the subject matter of Example 38, wherein the WLAN traffic measurement may indicate a data rate of the second data traffic.

[00153] In Example 40, the subject matter of one or any combination of
10 Examples 38-39, wherein the apparatus may further comprise means for determining the WLAN traffic measurement in accordance with a WLAN traffic measurement parameter indicated by the traffic offload message.

[00154] The Abstract is provided to comply with 37 C.F.R. Section 1.72(b) requiring an abstract that will allow the reader to ascertain the nature and
15 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:

- 5 1. An apparatus for an Evolved Node-B (eNB), the apparatus comprising:
memory; and processing circuitry, configured to:
 encode, for transmission to a User Equipment (UE), a traffic offload
message that indicates that a group of one or more packet data network (PDN)
connections between the eNB and the UE are to be offloaded from a cellular
10 network to a wireless local area network (WLAN);
 encode, for communication to the WLAN, a traffic report configuration
message that indicates a request to receive an offloaded traffic measurement
from the WLAN based on traffic exchanged between the UE and the WLAN on
the group of PDN connections; and
15 determine, based at least partly on the offloaded traffic measurement,
whether to transition the UE from a radio resource control (RRC) connected
mode to an RRC idle mode for the group of PDN connections.
- 20 2. The apparatus according to claim 1, wherein the offloaded traffic
measurement indicates a data rate of the traffic exchanged between the UE and
the WLAN on the group of PDN connections.
- 25 3. The apparatus according to claim 1, wherein when the offloaded traffic
measurement indicates that a data rate of traffic exchanged between the UE and
the WLAN on the group of PDN connections is zero during a measurement
window, the eNB is to transition the UE to the RRC idle mode.
- 30 4. The apparatus according to claim 1, wherein when the offloaded traffic
measurement indicates an inactivity of the traffic exchanged between the UE and
the WLAN on the group of PDN connections, the eNB is to transition the UE to
the RRC idle mode.

5. The apparatus according to claim 1, the processing circuitry further configured to maintain the UE in the RRC connected mode for at least a period of time between the offloading of the PDN connections to the WLAN and a reception of the offloaded traffic measurement.

5

6. The apparatus according to claim 1, the processing circuitry further configured to:

when it is determined that the eNB is to transition the UE to the RRC idle mode:

10 generate, for transmission to the UE, an RRC control message that indicates that the UE is to be transitioned to the RRC idle mode.

7. The apparatus according to claim 1, wherein:

15 the offloaded traffic measurement is a first traffic measurement and the group of PDN connections is a first group of PDN connections, and

the determination of whether to transition the UE to the RRC idle mode is further based at least partly on a second traffic measurement based on traffic exchanged between the UE and the eNB on a second group of PDN connections of the cellular network that are not offloaded to the WLAN.

20

8. The apparatus according to claim 1, wherein:

the cellular network includes a Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) network, and

25 the PDN connections are offloaded from the 3GPP LTE network to the WLAN in accordance with a radio access network (RAN) controlled LTE-WLAN interworking (RCLWI) arrangement between the 3GPP LTE network and the WLAN.

30 9. The apparatus according to any of claims 1-8, the processing circuitry further configured to refrain from transmission of traffic to the UE on the offloaded PDN connections.

10. The apparatus according to claim 1, wherein:
the cellular network includes a Third Generation Partnership Project
(3GPP) Long Term Evolution (LTE) network, and
the traffic report configuration message includes a WLAN termination
5 (WT) status request message that includes a list of UEs that are to report traffic
measurements to the eNB.
11. The apparatus according to claim 10, wherein the offloaded traffic
measurement is included in a WT status report message that indicates a data rate
10 for the UE on the offloaded PDN connections.
12. The apparatus according to any of claims 1-8, wherein:
the group of PDN connections is a first group of PDN connections, and
the processing circuitry is further configured to transmit traffic to the UE
15 on a second group of PDN connections maintained in the cellular network while
the first group of PDN connections is offloaded to the WLAN.
13. The apparatus according to any of claims 1-8, wherein the apparatus
further includes a transceiver to transmit the traffic offload message to the UE.
20
14. The apparatus according to any of claims 1-8, wherein the processing
circuitry includes a baseband processor to determine whether to transition the
UE from the RRC connected mode to the RRC idle mode.
- 25 15. The apparatus according to any of claims 1-8, wherein the apparatus
further includes interface circuitry to communicate, to the WLAN, the traffic
report configuration message over an Xw interface between the eNB and the
WLAN.
- 30 16. A computer-readable storage medium that stores instructions for
execution by one or more processors to perform operations for communication
by an Evolved Node-B (eNB), the operations to configure the one or more
processors to:

determine a cellular traffic measurement based on a data rate of traffic exchanged between the eNB and a User Equipment (UE) on an internet protocol (IP) flow of a packet data network (PDN) connection of a cellular network;

determine, based at least partly on the cellular traffic measurement,
5 whether the IP flow is to be offloaded to a wireless local area network (WLAN);
and

when it is determined that the IP flow is to be offloaded to the WLAN,
determine whether the UE is to be transitioned from a radio resource control (RRC) connected mode to an RRC idle mode based at least partly on a WLAN
10 traffic measurement received from the WLAN,

wherein the WLAN traffic measurement is based on a data rate of traffic exchanged between the WLAN and the UE on the IP flow.

15 17. The computer-readable storage medium according to claim 16,
wherein:

the cellular network includes a Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) network,

the operations are to further configure the one or more processors to
20 encode, for communication to the WLAN, a WLAN termination (WT) status
request message that indicates a request to receive the traffic measurement from
the WLAN, and

the WLAN traffic measurement is included in a WT status report
message from the WLAN based on the WT status request message, and

25 the WLAN traffic measurement is received over an Xw interface
between the eNB and the WLAN.

18. The computer-readable storage medium according to claim 16,
wherein:

30 the UE is a first UE,

the determination of whether the IP flow is to be offloaded to the WLAN
is further based at least partly on a traffic loading of the eNB for a group of UEs
that is supported by the eNB and includes the first UE, and

the traffic loading is based on a number of UEs in the group or one or more requested data rates of the UEs in the group.

19. The computer-readable storage medium according to claim 16,

5 wherein:

the IP flow is a first IP flow of the PDN connection,

the PDN connection is configurable to include one or more IP flows that includes the first IP flow, and

when the PDN connection includes a plurality of IP flows and when

10 multiple IP flows of the PDN connection are offloaded to the WLAN:

the determination of whether the UE is to be transitioned from the RRC connected mode to the RRC idle mode is based at least partly on multiple WLAN traffic measurements, received from the WLAN, for the offloaded IP flows.

15

20. An apparatus for a User Equipment (UE), the apparatus comprising: memory; and processing circuitry, configured to:

decode first data traffic received from an Evolved Node-B (eNB) on a packet data network (PDN) connection of a cellular network;

20 decode a traffic offload message received from the eNB that indicates that the PDN connection is to be offloaded to a wireless local area network (WLAN);

decode second data traffic received from an access point (AP) of the WLAN on the PDN connection; and

25 encode, for transmission to the eNB, a traffic report message that indicates a WLAN traffic measurement based at least partly on the second data traffic.

30

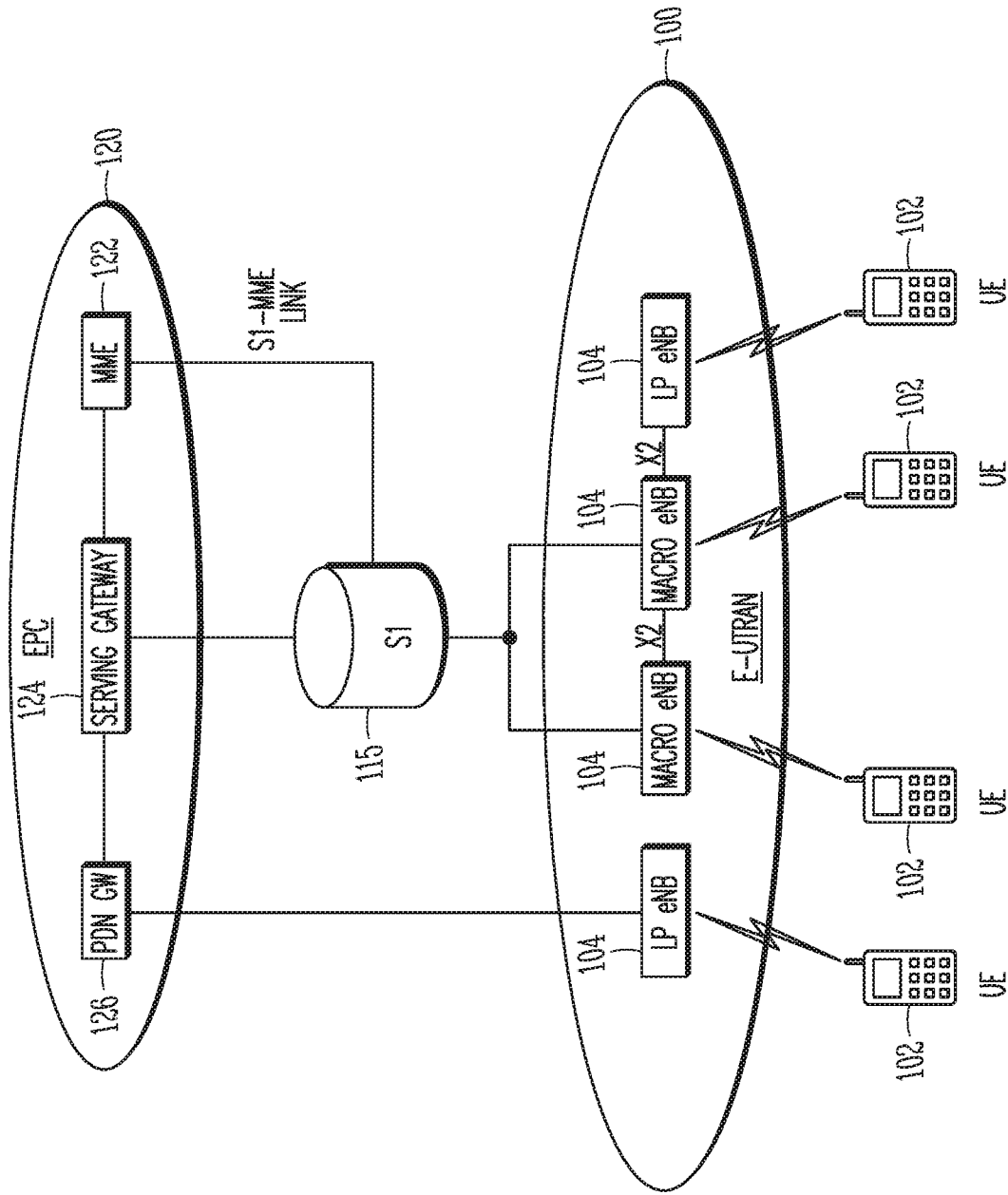


FIG. 1

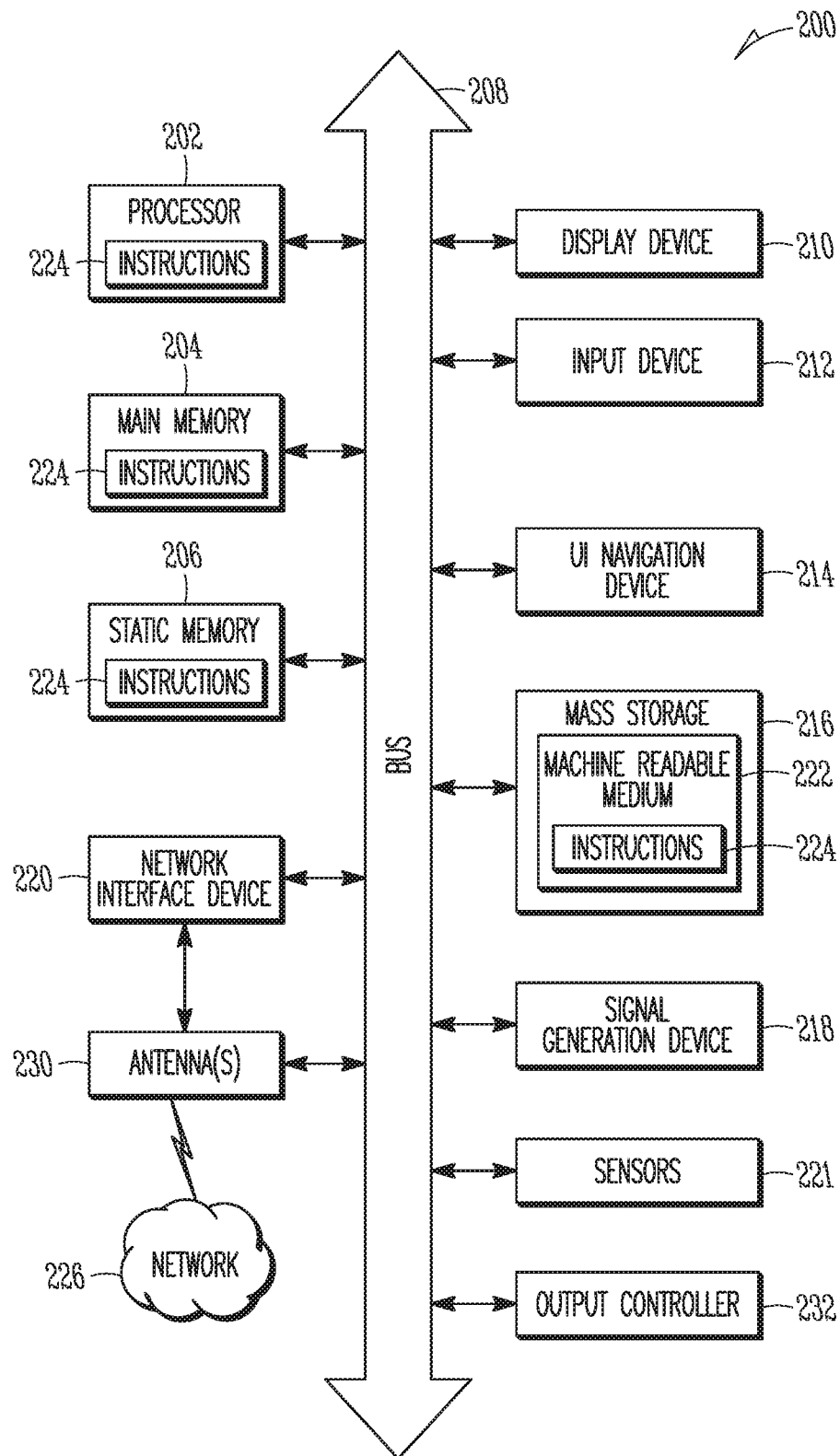
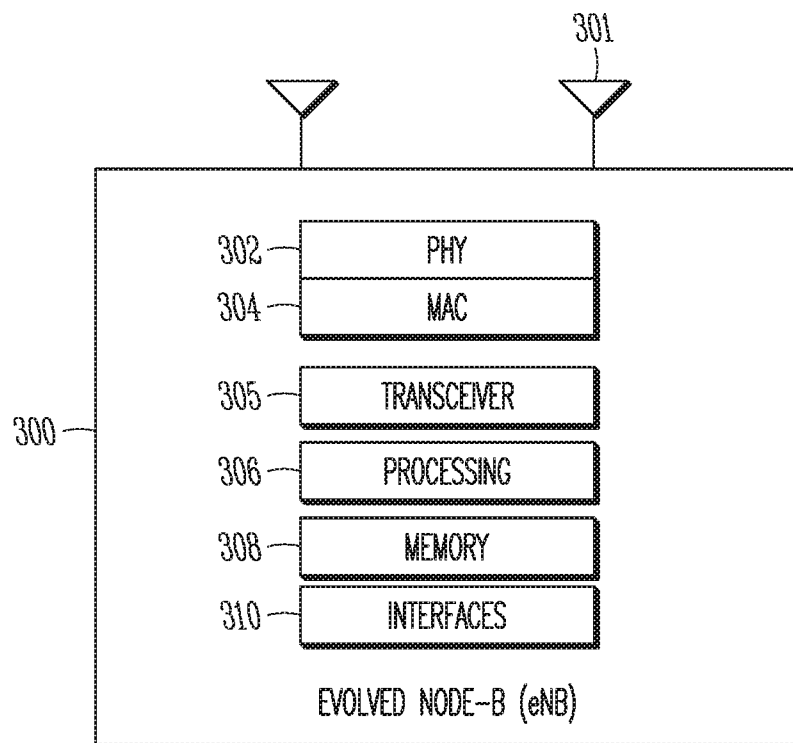
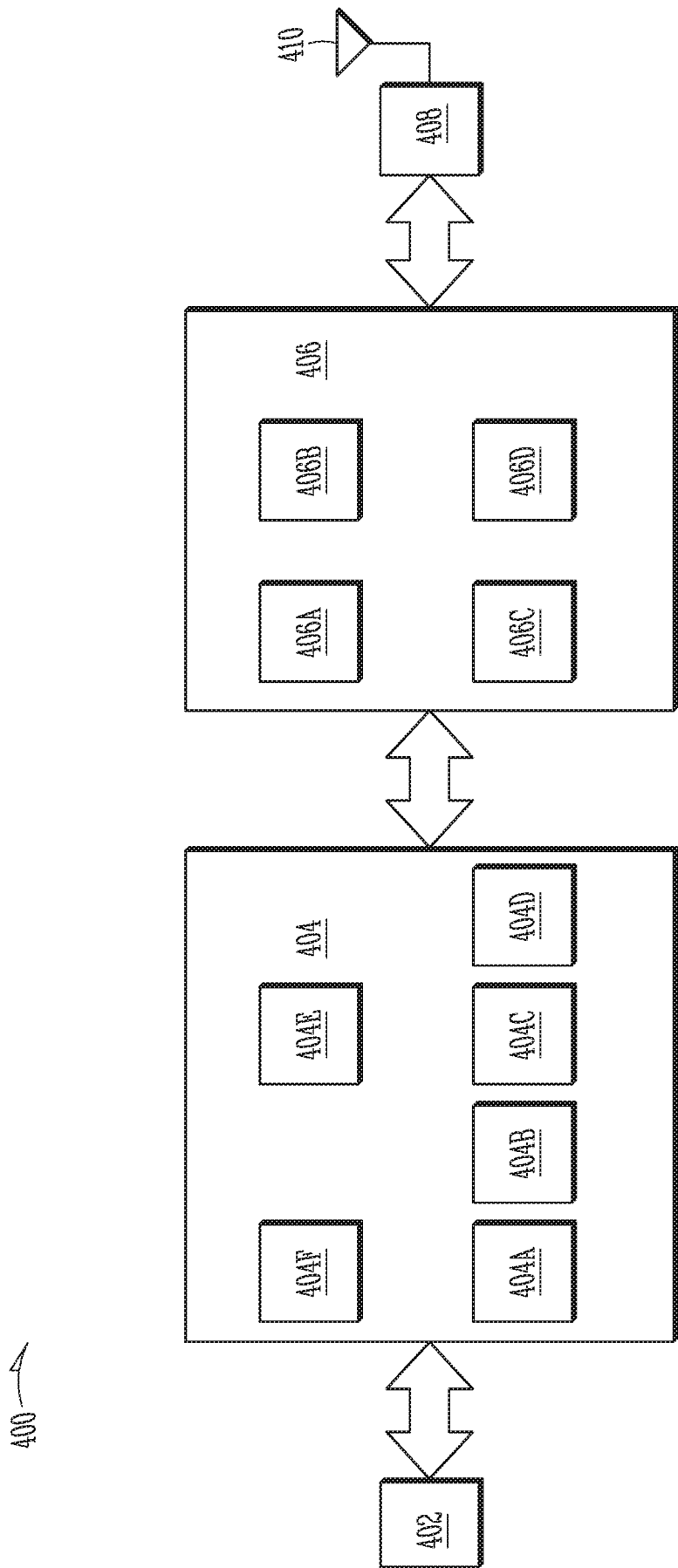


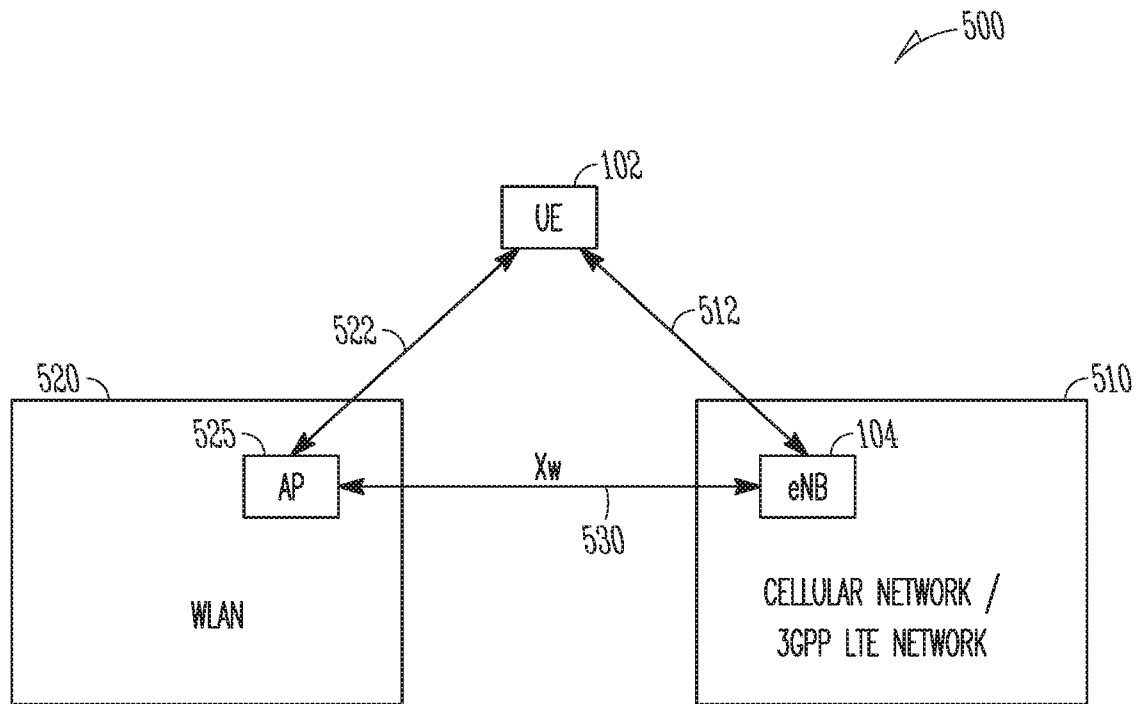
FIG. 2

**FIG. 3**



USER EQUIPMENT (UE)

FIG. 4

**FIG. 5**

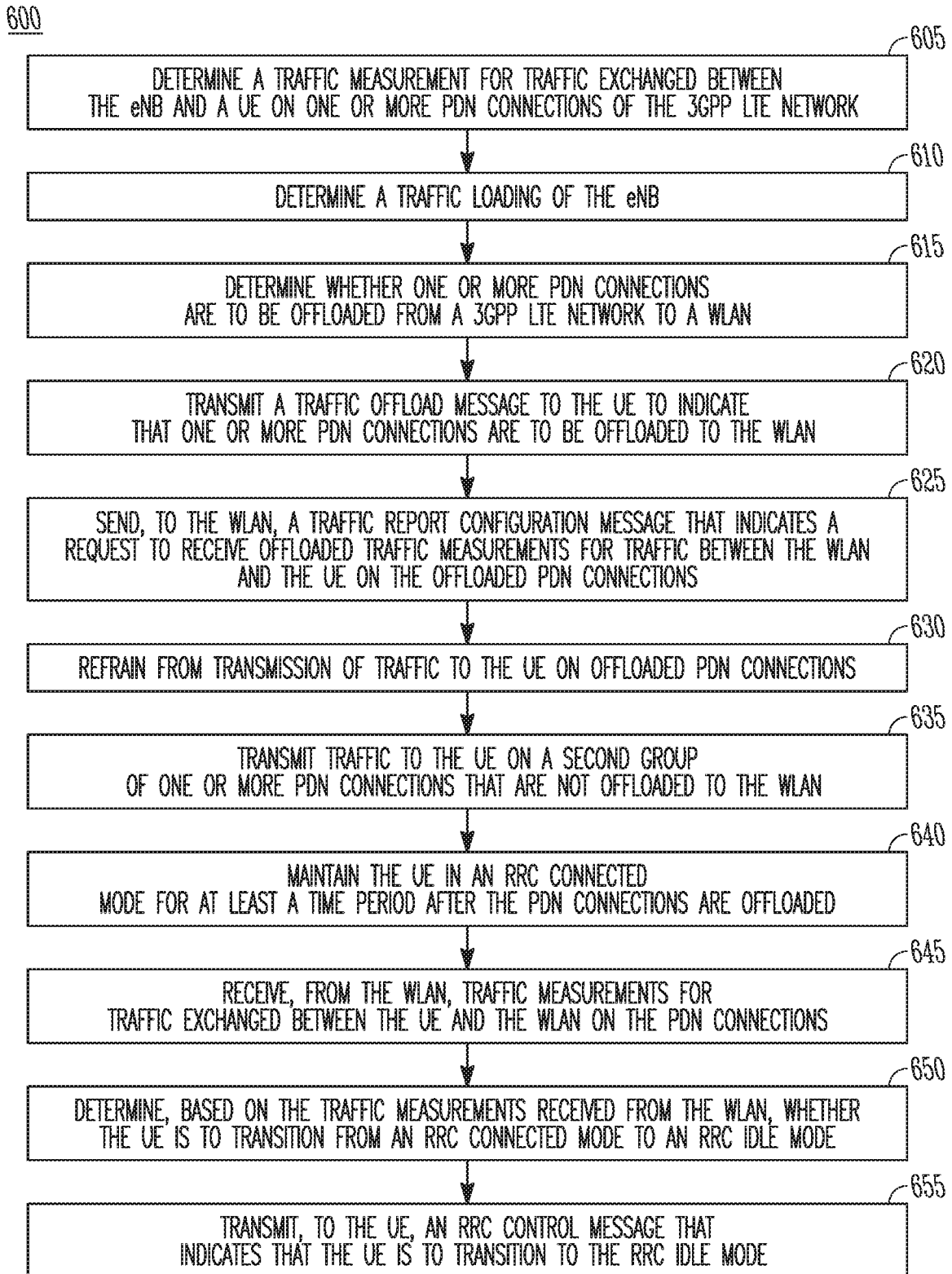
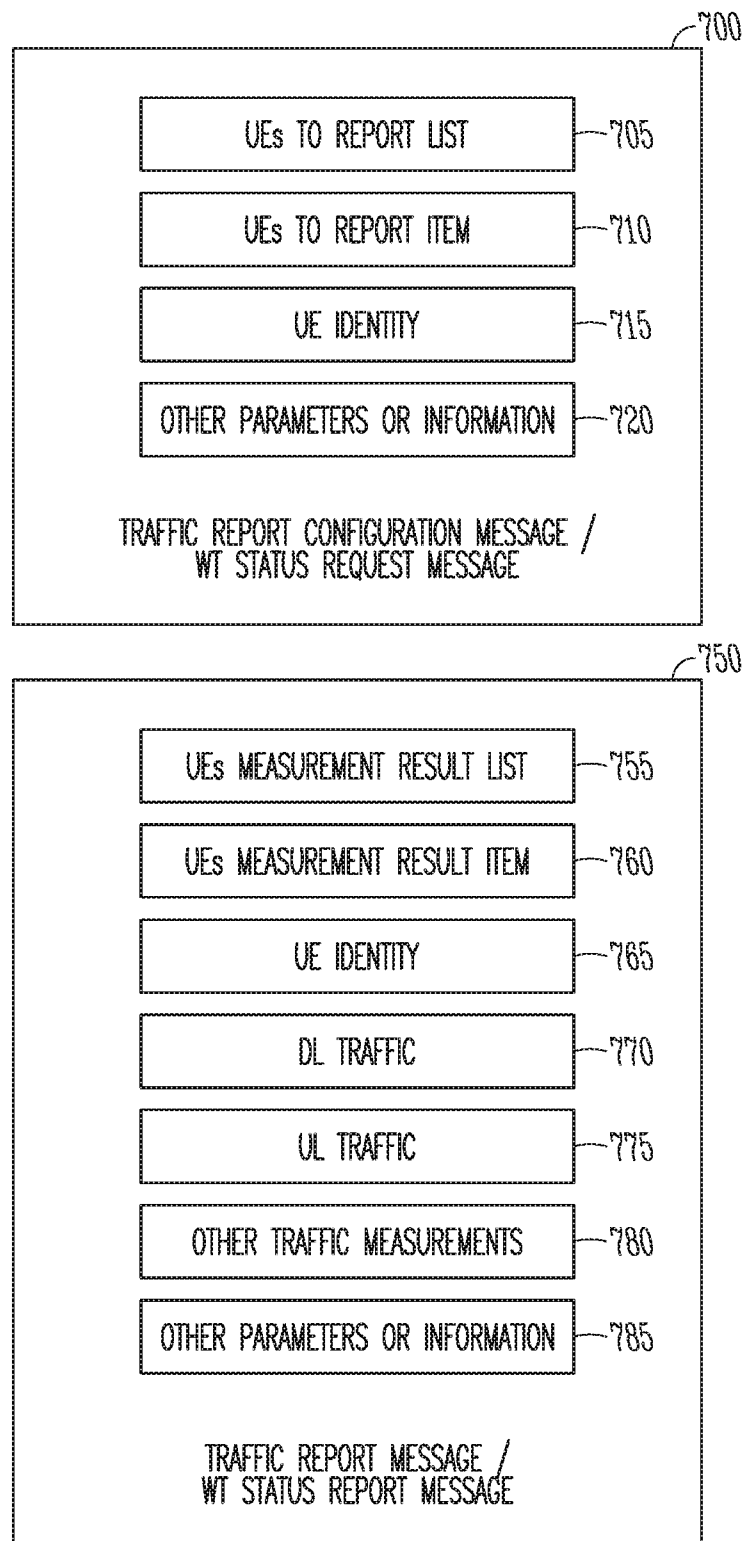


FIG. 6

**FIG. 7**

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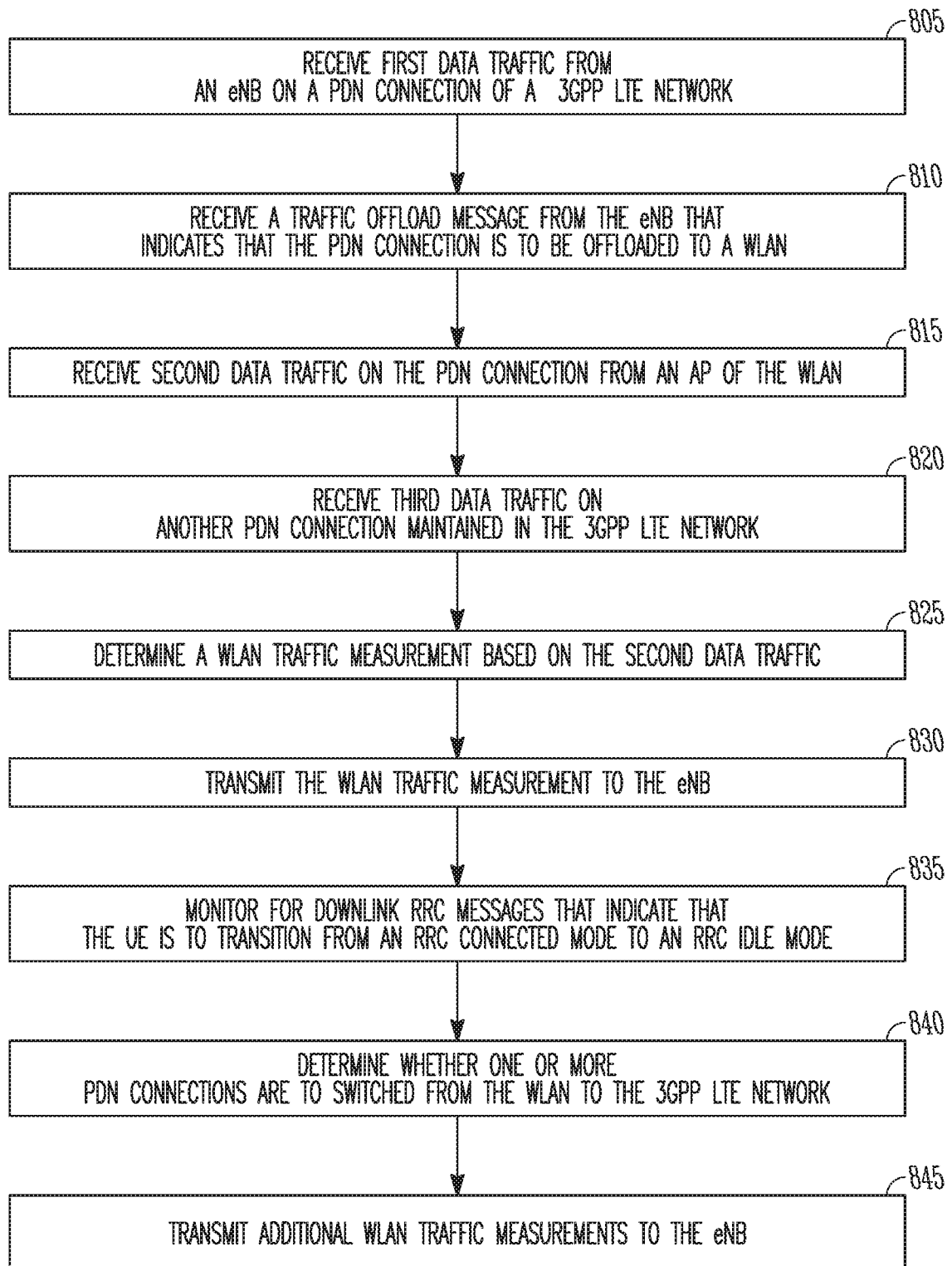
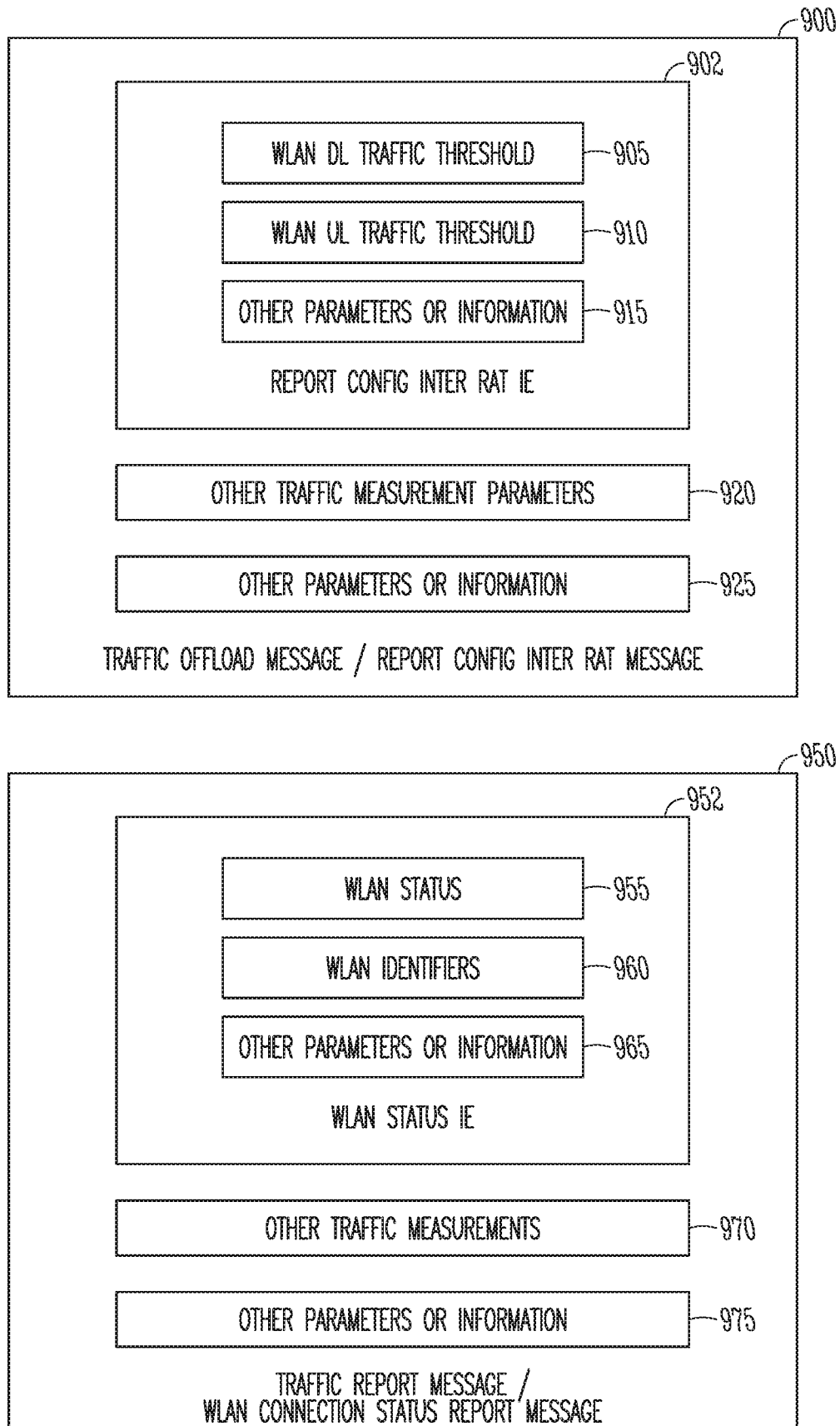
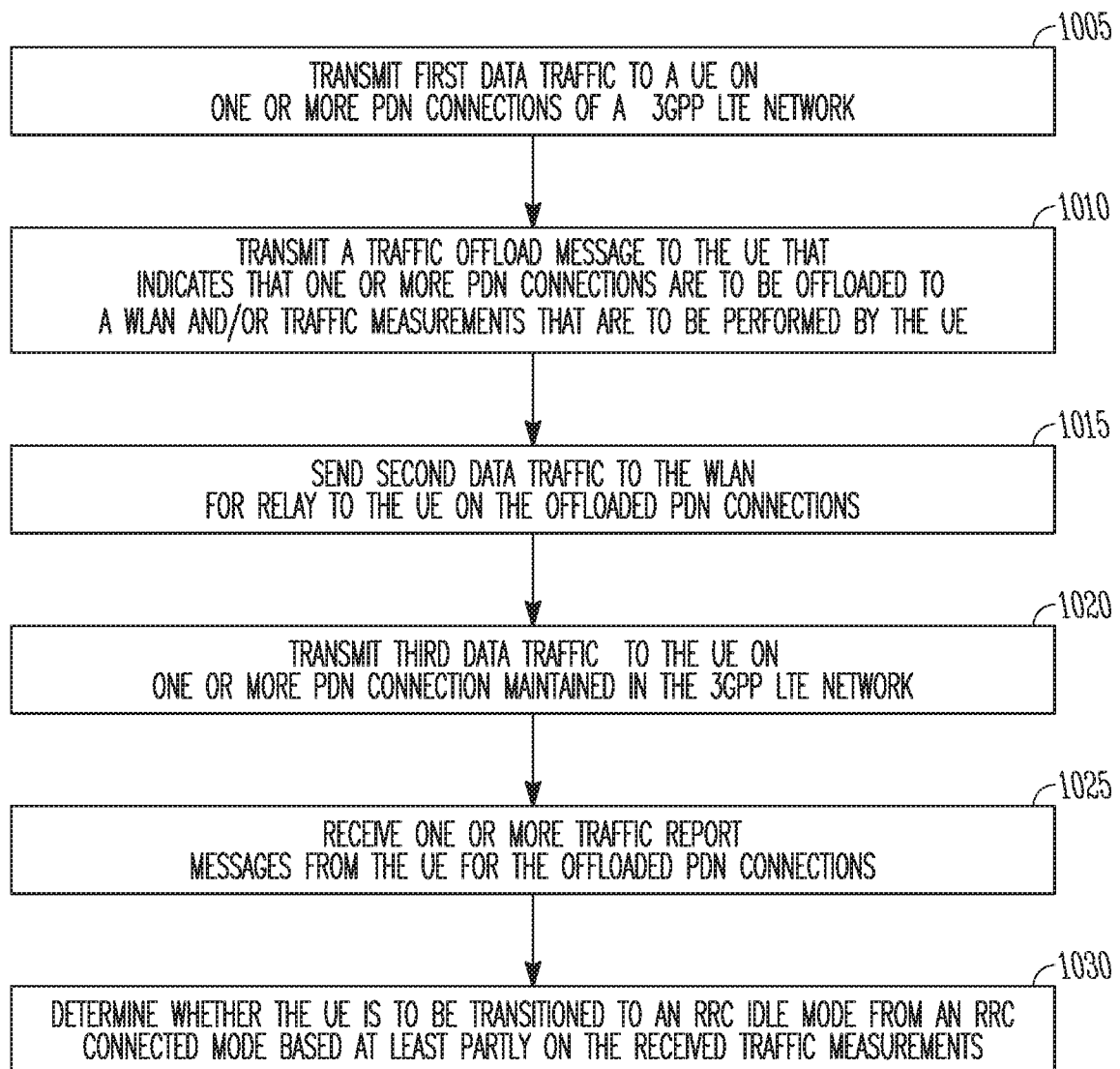
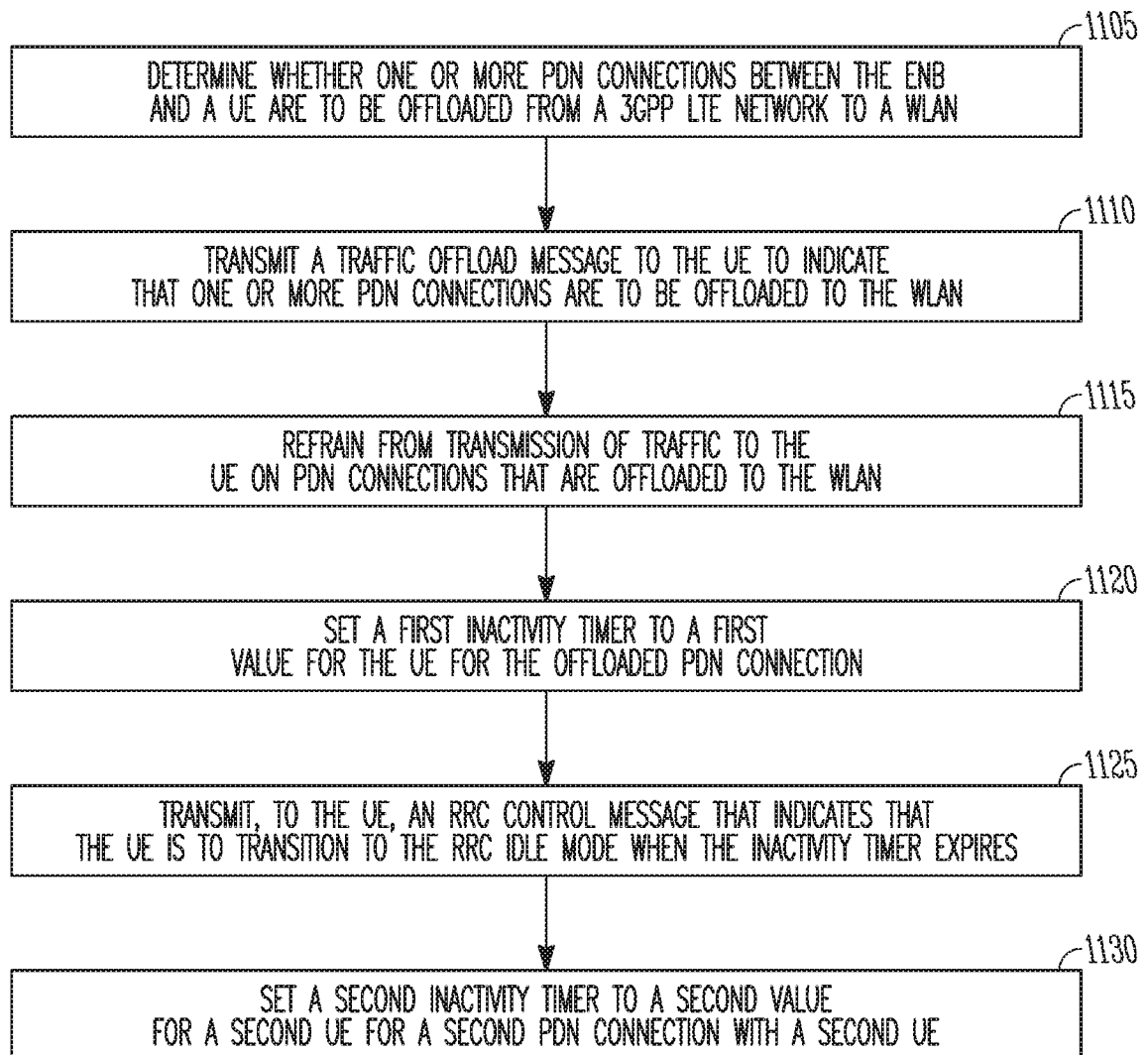


FIG. 8

**FIG. 9**

1000**FIG. 10**

1100**FIG. 11**

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/038711**A. CLASSIFICATION OF SUBJECT MATTER****H04W 24/10(2009.01)I, H04W 28/02(2009.01)I, H04W 76/04(2009.01)I, H04W 88/08(2009.01)I, H04W 88/06(2009.01)I, H04W 84/12(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 24/10; H04W 28/08; H04W 24/00; H04W 28/02; H04W 36/00; H04W 76/04; H04W 88/08; H04W 88/06; H04W 84/12

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: eNB, UE, cellular network, WLAN network, traffic offload message, traffic report configuration message, offloaded traffic measurement

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2014-165832 A1 (INTERDIGITAL PATENT HOLDINGS, INC.) 09 October 2014 See paragraphs [0074]–[0077], [0097]; and figures 1–2, 4.	1–20
A	WO 2014-157898 A1 (SAMSUNG ELECTRONICS CO., LTD.) 02 October 2014 See paragraphs [66]–[109]; and figure 4.	1–20
A	WO 2015-161817 A1 (MEDIATEK SINGAPORE PTE. LTD.) 29 October 2015 See paragraph [0063]; and figure 10.	1–20
A	US 2015-0029879 A1 (JOEY CHOU et al.) 29 January 2015 See paragraph [0042]; and figure 10.	1–20
A	WO 2014-119968 A1 (LG ELECTRONICS INC.) 07 August 2014 See paragraphs [0288]–[0320]; and figure 16.	1–20



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

12 September 2016 (12.09.2016)

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2016/038711

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2014-165832 A1	09/10/2014	AU 2014-247958 A1	12/11/2015
		CN 105103605 A	25/11/2015
		EP 2982168 A1	10/02/2016
		JP 2016-514930 A	23/05/2016
		KR 10-2015-0138367 A	09/12/2015
		TW 201507400 A	16/02/2015
		US 2016-0044567 A1	11/02/2016
WO 2014-157898 A1	02/10/2014	CN 105247920 A	13/01/2016
		EP 2981129 A1	03/02/2016
		KR 10-2014-0118650 A	08/10/2014
		US 2016-0050605 A1	18/02/2016
WO 2015-161817 A1	29/10/2015	EP 3014922 A1	04/05/2016
		US 2015-0312831 A1	29/10/2015
US 2015-0029879 A1	29/01/2015	CN 105325029 A	10/02/2016
		CN 105340203 A	17/02/2016
		CN 105340332 A	17/02/2016
		CN 105340339 A	17/02/2016
		CN 105359424 A	24/02/2016
		CN 105359429 A	24/02/2016
		CN 105359492 A	24/02/2016
		CN 105359561 A	24/02/2016
		CN 105379147 A	02/03/2016
		CN 105453635 A	30/03/2016
		EP 3025435 A1	01/06/2016
		EP 3025440 A1	01/06/2016
		EP 3025441 A1	01/06/2016
		EP 3025445 A1	01/06/2016
		EP 3025484 A1	01/06/2016
		EP 3025533 A1	01/06/2016
		EP 3025540 A1	01/06/2016
		EP 3025542 A1	01/06/2016
		EP 3025546 A1	01/06/2016
		EP 3025553 A1	01/06/2016
		EP 3025555 A1	01/06/2016
		KR 10-2016-0005109 A	13/01/2016
		KR 10-2016-0014003 A	05/02/2016
		TW 201517577 A	01/05/2015
		TW 201519668 A	16/05/2015
		TW 201521483 A	01/06/2015
		TW 201521495 A	01/06/2015
		TW I527475 B	21/03/2016
		US 2014-0226984 A1	14/08/2014
		US 2015-0029875 A1	29/01/2015
		US 2015-0029910 A1	29/01/2015
		US 2015-0029918 A1	29/01/2015
		US 2015-0029919 A1	29/01/2015

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2016/038711

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2014-119968 A1	07/08/2014	US 2015-0029936 A1	29/01/2015
		US 2015-0029955 A1	29/01/2015
		US 2015-0029956 A1	29/01/2015
		US 2015-0029957 A1	29/01/2015
		US 2015-0031308 A1	29/01/2015
		US 2016-0142961 A1	19/05/2016
		US 9265076 B2	16/02/2016
		US 9313812 B2	12/04/2016
		US 9391768 B2	12/07/2016
		US 9426836 B2	23/08/2016
		WO 2015-012900 A1	29/01/2015
		WO 2015-013038 A1	29/01/2015
		WO 2015-013189 A1	29/01/2015
		WO 2015-013190 A1	29/01/2015
		WO 2015-013192 A1	29/01/2015
		WO 2015-013193 A1	29/01/2015
		WO 2015-013194 A1	29/01/2015
		WO 2015-013563 A1	29/01/2015
		WO 2015-013567 A1	29/01/2015
		WO 2015-013580 A1	29/01/2015
		WO 2015-013650 A1	29/01/2015
		EP 2953397 A1	09/12/2015
		EP 2953398 A1	09/12/2015
		KR 10-2015-0115749 A	14/10/2015
		KR 10-2015-0117257 A	19/10/2015
		US 2016-0007268 A1	07/01/2016
		WO 2014-119966 A1	07/08/2014