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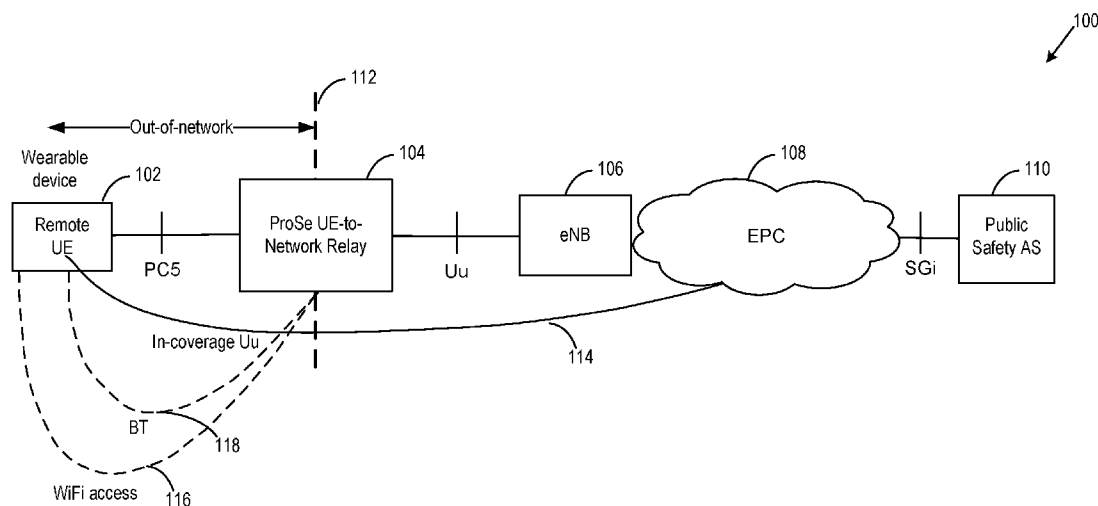


FIG. 1

Remote UE out of coverage from eNB with non-3GPP access via relay UE

(57) Abstract: Layer 2 relaying optimizations for a remote user equipment (UE) transmits data over a non-3GPP link (e.g., WLAN, Bluetooth (BT), etc.) to a relay UE (e.g., smartphone, etc.) when it is in-coverage or out-of-coverage. The relay UE forwards the data to a node in the network. This saves the battery of the device as it need not send or receive data over a direct Uu connection and instead uses a nearby, low-power device as its relay. The wearable device can be identified, authenticated, and addressed beforehand or through the relay link.



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METHODS FOR LAYER 2 RELAYING OPTIMIZATIONS

Related Applications

[0001] This application is a non-provisional of U.S. Provisional Patent Application No. 62/374,656, filed August 12, 2016 which is incorporated by reference herein in its entirety.

Technical Field

[0002] The present disclosure relates to cellular communications. In particular, the present disclosure relates to a layer 2 relay of data from a remote UE through a relay UE.

Background

[0003] Wireless mobile communication technology uses various standards and protocols to transmit data between a base station and a wireless mobile device. Wireless communication system standards and protocols can include the 3rd Generation Partnership Project (3GPP) long term evolution (LTE); the Institute of Electrical and Electronics Engineers (IEEE) 802.16 standard, which is commonly known to industry groups as worldwide interoperability for microwave access (WiMAX); and the IEEE 802.11 standard for wireless local area networks (WLAN), which is commonly known to industry groups as Wi-Fi. In 3GPP radio access networks (RANs) in LTE systems, the base station can include a RAN Node such as an Evolved Universal Terrestrial Radio Access Network (E-UTRAN) Node B (also commonly denoted as evolved Node B, enhanced Node B, eNodeB, or eNB) and/or Radio Network Controller (RNC) in an E-UTRAN, which communicate with a wireless communication device, known as user equipment (UE). In fifth generation (5G) wireless RANs, RAN Nodes can include a 5G Node (e.g., 5G eNB or gNB).

[0004] RANs use a radio access technology (RAT) to communicate between the RAN Node and UE. RANs can include global system for mobile communications (GSM), enhanced data rates for GSM evolution (EDGE) RAN (GERAN), Universal Terrestrial Radio Access Network (UTRAN), and/or E-UTRAN, which provide access to communication services through a core network. Each of the RANs operates according to a specific 3GPP RAT. For example, the GERAN 104 implements GSM and/or EDGE RAT, the UTRAN 106 implements universal mobile telecommunication system (UMTS) RAT or other 3GPP RAT, and the E-UTRAN 108 implements LTE RAT.

Brief Description of the Drawings

[0005] FIG. 1 is a diagram of a layer 2 information relay system for relaying non-3GPP data from a remote UE, according to one embodiment.

[0006] FIG. 2 is a communication diagram illustrating layer 2 relaying using network-aided discovery when a relay UE and remote UE are in connected mode, according to one embodiment.

[0007] FIG. 3 is a communication diagram illustrating layer 2 relaying using local discovery when the relay UE and remote UE are in connected mode, according to one embodiment.

[0008] FIG. 4 is a communication diagram illustrating layer 2 relaying using ProSe discovery when the relay UE and remote UE are in connected mode, according to one embodiment.

[0009] FIG. 5 is a block diagram of a remote UE out of coverage and connected through a relay UE to a network and using separate bearers for the remote UE and relay UE, according to one embodiment.

[0010] FIG. 6 is a block diagram of a remote UE out of coverage and connected through a relay UE to a network and using separate bearers for the remote UE and relay UE, according to one embodiment.

[0011] FIG. 7 is a block diagram illustrating a D2D relaying adaptation entity as part of a WLAN (e.g., WiFi®) protocol stack and cellular protocol stack (e.g., LTE) that is above the RLC layer and Uu MAC layer, according to one embodiment.

[0012] FIG. 8 is a communication diagram illustrating packet relay by an eNB to a network with one bearer per UE, according to one embodiment.

[0013] FIG. 9 is a communication diagram illustrating packet relay by an eNB to a network with multiplexing of packets on a single bearer, according to one embodiment.

[0014] FIG. 10 illustrates an architecture of a system 1000 of a network in accordance with some embodiments.

[0015] FIG. 11 illustrates example components of a device in accordance with some embodiments.

[0016] FIG. 12 illustrates example interfaces of baseband circuitry in accordance with some embodiments.

[0017] FIG. 13 is an illustration of a control plane protocol stack in accordance with some embodiments.

[0018] FIG. 14 is an illustration of a user plane protocol stack in accordance with some embodiments.

[0019] FIG. 15 is a block diagram illustrating components, according to some example embodiments, able to read instructions from a machine-readable or computer-readable medium (e.g., a non-transitory machine-readable storage medium) and perform any one or more of the methodologies discussed herein.

Detailed Description

[0020] A detailed description of systems and methods consistent with embodiments of the present disclosure is provided below. While several embodiments are described, it should be understood that the disclosure is not limited to any one embodiment, but instead encompasses numerous alternatives, modifications, and equivalents. In addition, while numerous specific details are set forth in the following description in order to provide a thorough understanding of the embodiments disclosed herein, some embodiments can be practiced without some or all of these details. Moreover, for the purpose of clarity, certain technical material that is known in the related art has not been described in detail in order to avoid unnecessarily obscuring the disclosure.

[0021] Techniques, apparatus and methods are disclosed that enable layer 2 relaying optimizations for a remote UE (e.g., a wearable device, etc.) to transmit data over a non-3GPP or short-range link (e.g., WLAN, Bluetooth (BT), etc.) to a relay (e.g., smartphone, etc.) when it is in-coverage or out-of-coverage and get the data forwarded to a node in the network. This saves battery of the device as it need not

send or receive data over direct Uu connection and instead uses a nearby low power device as its relay. At the same time, the wearable device has to be identified, authenticated, and addressed.

[0022] LTE technology can be used to connect and manage low power wearable devices. The diverse set of wearable devices and use cases (ranging from low data rate delay tolerant monitoring to high data rate delay sensitive virtual reality) uses different communication capabilities.

[0023] Support of layer 3 UE to network (UE to NW) relaying can make it feasible to apply LTE PC5 technology to support some wearable use cases. However, the Proximity Services (ProSe) framework targets long range and relatively low rate broadcast communication, robust to interference.

[0024] Wearables as a subset of MTC use cases can benefit from D2D technology, and use the enhancements to the cellular and sidelink air interface jointly with UE to NW relaying functionality in order to support a broader range of wearable use cases. Furthermore, when the wearable device supports non-3GPP capabilities such as WLAN (WiFi®) and Bluetooth® (BT), and uses these alternatives to communicate, solutions can have integration with existing Uu and relay UE to transfer the data to the network. This can enable smooth switching between direct Uu and non-3GPP access for the remote UE.

[0025] The solutions described address the problem by describing how relaying can be performed using L2 relaying primarily using non-3GPP access technologies for D2D communication and addressing some of the questions raised.

[0026] Layer 2 relaying optimizations are used for a wearable device to transmit data over WLAN or BT to a relay or smartphone when it is in-coverage or out-of-coverage and get the data forwarded to a node in the network. This saves battery of the wearable device as it need not send or receive data over direct Uu connection and instead uses a nearby low power device as its relay. At the same time, the wearable device has to be identified, authenticated, and addressed.

[0027] Device to device (D2D) discovery or D2D communication in wireless communication is being standardized. The D2D feature enables the direct discovery or the direct communication among UEs over the cellular radio spectrum. Examples disclosed herein include D2D discovery and D2D communication in E-UTRA (Evolved - Universal Terrestrial Radio Access)/LTE (Long Term Evolution) in 3GPP (3rd Generation Project Partnership) systems. However, the embodiments described

can be also applicable for other wireless systems. In Enhanced LTE Device to Device ProSe, UE-to-NW Relay or relay UE is a layer 3 relay (i.e., an IP router). In contrast, the embodiments described herein describe a relay at a layer 2 level, sometimes referred to as FeD2D.

[0028] FIG. 1 is a diagram of a L2 information relay system 100 for relaying non-3GPP data from a remote UE, according to one embodiment. The system includes a remote UE 102, a ProSe UE-to-Network Relay (or relay UE) 104, an eNB 106, an Evolved Packet Core (EPC) 108, and a Public Safety AS 110.

[0029] In the D2D embodiments described, unless otherwise stated, the remote UE 102 is using the relay UE 104 for communication via non-3GPP access and a relay UE is in coverage. The remote UE 102 includes a wearable or evolved remote UE or MTC device communicating using D2D communication. The relay UE 104 includes smartphone or evolved relay UE or master node or master sensor capable of relaying data through 3GPP/5G connection and through D2D with another UE such as the remote UE 102. D2D communication includes Bluetooth™, WLAN (e.g., WiFi), ProSe (e.g., LTE Rel 13 ProSe) or other near field communication. A PC5 interface is the interface using D2D communication that currently refers to the ProSe communication, but can refer to any D2D communication (e.g., WLAN or Bluetooth™) that can happen over that interface. This interface is treated more broadly to indicate D2D communication. A base station includes a radio access network node (e.g., eNB, gNB) in the context of LTE and includes a New RAT base station (gNB or g Node B or 5G eNB) in the context of 5G and beyond. A 3GPP connection includes the LTE or 5G Uu connection (i.e., a connection over the air between the UE and the base station which is used to communicate to the network).

[0030] The system 100 further includes a boundary 112, which represents the geographic extent of the coverage network of the 3GPP access as provided by the eNB 106. A WLAN channel 116 of the system 100 represents D2D WLAN communication established between the remote UE 102 and the ProSe UE-to-Network Relay 104. A BT channel 118 of the system 100 represents D2D BT communication established between the remote UE 102 and the ProSe UE-to-Network Relay 104. The system 100 also includes a virtual communications channel 114 between the remote UE 102 and the EPC 108.

[0031] In the embodiment of FIG. 1, the remote UE 102 is a wearable device. In one embodiment, the remote UE 102 is not able to communicate directly with the

eNB 106 to access the EPC 108 (and subsequently the Public Safety AS 110) because it is not in a 3GPP coverage range 112. However, the remote UE 102 has established a connection with the ProSe UE-to-Network Relay 104 over interface PC5 using the WLAN D2D communication channel 116 and/or the BT D2D communication channel 118. The remote UE 102 may send data over the PC5 interface to the ProSe UE-to-Network Relay 104. The ProSe UE-to-Network Relay 104 is configured to receive this data and forward it to the eNB 106 via the Uu interface using 3GPP access methods. Once at the eNB 106, the data may be transferred to the EPC 108 and subsequently to the Public Safety AS 110. The relayed communications between the remote UE 102 and the EPC 108 are considered to be transferred along the virtual communications channel 114.

[0032] In other embodiments, this relay of data may also occur while the remote UE 102 and the ProSe UE-to-Network Relay 104 are both within the boundary 112. Further, while the two D2D channels 116 and 118 are illustrated, the transfer of data may still occur using any number of available D2D channels. In contemplated variations of the embodiment, the eNB 106 may instead be a gNB or any other type of network node capable of providing 3GPP access to a UE. In some embodiments, the EPC 108 may be a 5G Core or any other appropriate network infrastructure. That data from the remote UE 102 may have been eventually bound for the Public Safety AS 110 and is not intended to be limiting. Once data arrives at the EPC 108, it may travel to any network destination reachable from the EPC 108.

[0033] Remote UE may be any device capable of communicating in a D2D fashion with another device over a PC5 interface. The ProSe UE-to-Network Relay 104 may be any device capable of receiving data from another device over a PC5 interface and forwarding that data over a 3GPP interface Uu.

[0034] FIGs. 2-4 show embodiments that describe how non-3GPP based access (e.g., WLAN based (Neighbor Aware Networking/WiFi Direct based), Bluetooth™, etc.) supports discovery of a remote UE of peer WiFi Direct UE. In some embodiments, the relay UE can forward data received over non-3GPP access from another UE (which has 3GPP credentials and is registered in the 3GPP network). The two UEs (one of them being the relay UE) can discover each other and begin 1:1 communication.

[0035] In the embodiments, before the data can be transferred by the remote UE, the remote UE determines that the relay UE can forward remote UE data to the

network before it performs WLAN discovery and communication related messages with the relay UE over the PC5 interface. In the embodiment, the remote UE is capable of 3GPP/5G connectivity with the base station and is connected while the remote UE is making a decision to perform data transfer via the relay UE due to internal UE implementation, e.g., to reduce power consumption.

[0036] It is assumed that the relay UE and remote UE are in RRC Connected mode throughout the document except with respect to FIG. 3. However, it may be also applicable for the relay UE and/or the remote UE to be in idle mode although it is not described in the embodiments. As the remote UE is in connected mode, its EPS bearer is still active at the network side. Therefore, the eNB could forward and receive data over the remote UE's own EPS (51) bearer to the UE or from the UE respectively through the relay UE as shown in FIG. 1 in the background section.

[0037] FIGs. 2-4 show the case when the remote UE is in-coverage and connected with the eNB. The embodiment associated with FIG. 3 describes the case when the remote UE is out-of-coverage. In some embodiments, relay UE and/or remote UE provide their own WLAN MAC address at attach or registration or connection establishment to the eNB/MME and it is stored as part of the UE context information. In many embodiments, non-3GPP access is used as the D2D communication mode between the remote UE and relay UE.

[0038] FIG. 2 is a communication diagram illustrating layer 2 relaying using network-aided discovery when a relay UE and remote UE are in connected mode. FIG. 2 includes a remote UE 202, a relay UE 204, an eNB 206, and an MME 208.

[0039] A relay UE which has a 3GPP connection and supports the necessary relaying capability (e.g., over WLAN/BT/non-3GPP access) will activate its relay operation and inform the base station/cell/core network entity (e.g., Mobility Management Entity (MME) or ProSe function) along with its relay UE ID information. The relay UE ID can be relay UE WLAN, Bluetooth™ or non-3GPP access related identifiers (e.g., MAC Address). When the remote UE performs an attach process, registration process or upon connection establishment over 3GPP/5G Uu, the remote UE can request available relay UEs in the cell information from the base station using an RRC message such as SidelinkUEInformation or other message. The request can include its location information also in order to help the base station or core network entity to list nearby relay UE information. The request can be sent to either a base-station or core network entity. In some embodiments, the request can

be inferred based on pre-configured information in UE capabilities or other Home Subscriber Server (HSS) information of the remote UE, or based on interest indication, the network provides a list of candidate relay UEs supported in this cell. The remote UE then can compare using the list of relay UE IDs (e.g., WLAN MAC Address) to determine whether a given relay UE matches and is available in its proximity supports relaying. (In ProSe D2D the relay service code can be sufficient, while in non-3GPP access it is either MAC Address or other ID such as IP Address.)

[0040] A method 200 of passing messages to configure data relaying from the remote UE 202 through the relay UE 204 to the eNB 206 when both the remote UE 202 and the relay UE 204 are in connected mode with the eNB 206 is shown in FIG. 2. Both the relay UE 204 and the remote UE 202 registered and attached with 3GPP through the eNB 206 and the MME 208, as shown by operations 210 and 212. As shown by the operation 212, the remote UE 202 has an active S1 connection through the eNB 206 and the MME 208. A UE capability inquiry message is passed from the eNB 206 to the relay UE 204. Another UE capability inquiry message is passed from the eNB 206 to the remote UE 202. The relay UE 204 then passes a UE capability info message to the eNB 206, and the remote UE 202 passes a UE capability info message to the eNB 206. During this exchange, UE MAC addresses are provided to the eNB.

[0041] A broadcast configuration for relay message then passes from the eNB 206 to the relay UE 204. At this point, the relay UE 204 determines to act as a relay for remote UEs on the network. At this point in the process, the remote UE 202 and the relay UE 204 are both in connected mode, as shown by states 218 and 216 respectively.

[0042] Operations 220 are then executed. The eNB 206 passes an RRC Connection Reconfiguration message to the remote UE 202; this message may also include a list of candidate relay UE IDs. In response to this message, the remote UE 202 sends an RRC Connection Reconfiguration Complete message to the eNB 206.

[0043] As illustrated by an operation 222, the remote UE 202 initiates the discovery of the relay UE 204. This discovery process may or may not be initiated by some trigger to the remote UE 202.

[0044] Discovery operations 224 are executed. Discovery can occur through the sending of a non-3GPP (e.g., WLAN) or ProSe discovery announcement message from the relay UE 204 to the remote UE 202. Alternatively, discovery may occur in a

two-step process when the remote UE 202 sends a solicitation request message to the relay UE 204. The relay UE 204 then responds with a solicitation response message.

[0045] One-to-one communication operations 226 are executed. One-to-one communication between the remote UE 202 and the relay UE 204 may be established as the remote UE 202 passes a direct communication request message to the relay UE 204. Further messages may then be passed to provide for mutual authentication between the remote UE 202 and the relay UE 204.

[0046] Once one-to-one communication between the remote UE 202 and the relay UE 204 has been established, a SidelinkUEInformation message is passed from the relay UE 204 to the eNB 206. This message includes ID information corresponding to the remote UE 202. This ID information can include a WLAN MAC address, a BT MAC address, a ProSe communication ID and/or code or token, or any other appropriate ID information corresponding to the remote UE 202. The eNB 206 then authorizes the remote UE 202 with the MME 208 as shown in an authorization 230.

[0047] In response, a SidelinkUEInformation response message is then passed from the eNB 206 to the relay UE 204. This message can include an authorization for the remote UE, a data radio bearer (DRB) ID, resource information in the case of ProSe communication, or any other piece of information that may be of aid in facilitating the relay of forthcoming data information from the remote UE 202 through the relay UE 204 and on to the eNB 206.

[0048] The remote UE 202 may then begin sending data messages to relay UE 204. Upon receipt, the relay UE 204 may relay those data messages to the eNB 206. The eNB 206 may then map this incoming data to the remote UE's own EPS bearer, as shown in step 232.

[0049] FIG. 3 is a communication diagram illustrating layer 2 relaying using local discovery when the relay UE and remote UE are in connected mode. FIG. 3 includes a remote UE 302, a relay UE 304, an eNB 306, and a MME 308.

[0050] In the embodiment shown, the remote UE informs the relay UE ID (e.g., MAC Address) obtained during non-3GPP access based discovery (e.g., WLAN beacon) to the eNB/base station as part of a new RRC message or existing SidelinkUEInformation message. The eNB responds with an acknowledgement on whether the given relay UE supports layer 2 relaying or layer 3 relaying or no

relaying over 3GPP/5G. Relay UE has already informed the eNB that relay UE can operate as relay UE in advance and the eNB keeps that information in the database. When the eNB responds with acknowledgement to the remote UE, the eNB can also inform the corresponding/informed relay UE of the acknowledgement (including the remote UE's 3GPP, WLAN, Bluetooth™ MAC ID and/or address information) of the remote UE so that it is aware of a remote UE. By this process, the eNB can be performing network control based policing or admission control as the data arriving over non-3GPP access cannot be controlled later on, once admitted.

[0051] Changes to non-3GPP access may not be able to be standardized. The relay UE may not have any other 3GPP based means of communication to release the PC5 connection (as ProSe may not be available on the remote UE and/or relay UE). However, in this scenario, the relay UE can inform the eNB and the eNB can perform some downlink configuration message to the remote UE (assuming the remote UE is in connected mode), to throttle its non-3GPP relay access. This may still require an interface or entity to communicate cross-layer between the non-3GPP and 3GPP layers.

[0052] The relay UE ID provided by the remote UE may be its Bluetooth, WLAN MAC address or any other network provided ID or a paired form of ID in case the remote UE and relay UE are paired (although in some embodiments, when pairing is defined, it is assumed that the relay UE supports 3GPP relaying).

[0053] A method 300 begins with both the relay UE 304 and the remote UE 302 registered and attached with 3GPP through the eNB 306 and the MME 308, as shown by operations 310 and 312, respectively. As shown by the operation 312, the remote UE 302 further has an active S1 connection through the eNB 306 and the MME 308. A UE capability inquiry message is passed from the eNB 306 to the relay UE 304. Another UE capability inquiry message is passed from the eNB 306 to the remote UE 302. The relay UE 304 passes a UE capability info message to the eNB 306, and the remote UE 302 passes a UE capability info message to the eNB 306. During this exchange, UE MAC addresses are provided to the eNB.

[0054] A broadcast configuration for relay message then passes from the eNB 306 to the relay UE 304. The relay UE 304 determines to act as a relay for remote UEs on the network. At this point in the process, the remote UE 302 and the relay UE 304 are both in connected mode, as shown by states 318 and 316 respectively.

[0055] Discovery operations 324 are executed. Discovery can occur through the sending of a non-3GPP or ProSe discovery announcement message from the relay UE 304 to the remote UE 302. Alternatively, discovery can occur in a two-step process when the remote UE 302 sends a solicitation request message to the relay UE 304. Relay UE then responds with a solicitation response message.

[0056] The remote UE 302 then passes a sidelink UE information message to the eNB 306; this message may also include a list of available relay UE IDs that were discovered by the remote UE 302 during discovery operations 324. In response to this message, the remote eNB 306 sends a sidelink UE information response message to the remote UE 302. This message may include a list of relays with 3GPP support.

[0057] One-to-one communication operations 326 is then executed. One-to-one communication between the remote UE 302 and the relay UE 304 may be established as the remote UE 302 passes a direct communication request message to the relay UE 304. Further messages may then be passed to provide for mutual confirmation between the remote UE 302 and the relay UE 304.

[0058] Once one-to-one communication between the remote UE 302 and the relay UE 304 has been established, a sidelink UE information message is passed from the relay UE 304 to the eNB 306. This message includes ID information corresponding to the remote UE 302. This ID information can be a WLAN MAC address, a Bluetooth™ MAC address, a ProSe communication ID or code or token, or any other appropriate ID information corresponding to the remote UE 302. The eNB 306 then authorizes the remote UE with the MME 308 as shown in an operation 330.

[0059] In response, a sidelink UE information response message is then passed from the eNB 306 to the relay UE 304. This message may include an authorization for the remote UE, a DRB ID, resource information in the case of ProSe communication, or any other piece of information that may be of aid in facilitating the relay of forthcoming data information from the remote UE 302 through the relay UE 304 and on to the eNB 306.

[0060] The remote UE 302 may then begin sending data messages to the relay UE 304. Upon receipt, the relay UE 304 may relay those data messages to the eNB 306. The eNB 306 may then map this incoming data to the remote UE's own EPS bearer, as shown in a step 332.

[0061] FIG. 4 is a communication diagram illustrating layer 2 relaying using ProSe discovery when the relay UE and remote UE are in connected mode. FIG. 4 includes a remote UE 402, a relay UE 404, an eNB 406, and a MME 408. During ProSe discovery, wherein the remote UE sends solicitation request and the relay UE responds with solicitation response, the relay UE can inform the remote UE that it is also capable of performing non-3GPP access (for both discovery and communication over WLAN or BT as it applies) and the remote UE could then obtain the relay UE's MAC Address through this process and use it for non-3GPP discovery or directly performs communication with security exchange depending on the restrictions imposed by the non-3GPP access methodology.

[0062] Alternatively, the relay UE can use ProSe association procedure instead of discovery procedure over PC5. For example, during ProSe association, the remote UE sends a Direct Communication request message and the relay UE responds with a response in which the relay UE informs the remote UE that it is also capable of performing non-3GPP access (for both discovery and communication over WLAN, BT, etc.) and provide its corresponding relay UE ID. The remote UE thus obtains the relay UE's MAC Address through this process and uses it for non-3GPP discovery or directly performs communication with security exchange depending on the restrictions imposed by the non-3GPP access methodology.

[0063] A method 400 begins with both the relay UE 404 and the remote UE 402 registered and attached with 3GPP through the eNB 406 and the MME 408, as shown by operations 410 and 412, respectively. As shown by the operation 412, the remote UE 402 further has an active S1 connection through the eNB 406 and the MME 408. A UE capability inquiry message is passed from the eNB 406 to the relay UE 404. Another UE capability inquiry message is passed from the eNB 406 to the remote UE 402. The relay UE 404 passes a UE capability info message to the eNB 406, and the remote UE 402 passes a UE capability info message to the eNB 406. During this exchange, UE MAC addresses are provided to the eNB.

[0064] A broadcast configuration for relay message then passes from the eNB 406 to the relay UE 404. The relay UE 404 determines to act as a relay for remote UEs on the network. At this point in the process, the remote UE 402 and the relay UE 404 are both in connected mode, as shown by states 418 and 416 respectively.

[0065] Discovery operations 424 are executed. Discovery can occur through the sending of a ProSe discovery announcement message (including that layer 2 relay is

supported and a relay UE ID) from the relay UE 404 to the remote UE 402.

Alternatively, discovery can occur in a two-step process when the remote UE 402 sends a solicitation request message to the relay UE 404. Relay UE then responds with a solicitation response message (including that layer 2 relay is supported and a relay UE ID).

[0066] One-to-one communication operations 426 is then executed. One-to-one communication between the remote UE 402 and the relay UE 404 may be established as the remote UE 402 passes a direct communication request message to the relay UE 404. In response, the relay UE 404 passes a direct communication response (including that layer 2 relay is supported and a relay UE ID). Further messages may then be passed to provide for mutual confirmation between the remote UE 402 and the relay UE 404.

[0067] Once one-to-one communication between the remote UE 402 and the relay UE 404 has been established, a sidelink UE information message is passed from the relay UE 404 to the eNB 406. This message includes ID information corresponding to the remote UE 402. This ID information can be a WLAN MAC address, a Bluetooth™ MAC address, a ProSe communication ID or code or token, or any other appropriate ID information corresponding to the remote UE 402. The eNB 406 then authorizes the remote UE with the MME 408 as shown in an operation 430.

[0068] In response, a sidelink UE information response message is then passed from the eNB 406 to the relay UE 404. This message may include an authorization for the remote UE, a DRB ID, resource information in the case of ProSe communication, or any other piece of information that may be of aid in facilitating the relay of forthcoming data information from the remote UE 402 through the relay UE 404 and on to the eNB 406.

[0069] The remote UE 402 may then begin sending data messages to the relay UE 404. Upon receipt, the relay UE 404 may relay those data messages to the eNB 406. The eNB 406 may then map this incoming data to the remote UE's own EPS bearer, as shown in a step 432.

[0070] FIGs. 5-6 show a block diagram of a remote UE out of coverage and connected through a relay UE to a network. FIG. 5 shows use of separate bearers for a remote UE 508, 608 and a relay UE 510, 610 used by the eNB, while FIG. 6 shows a shared relay UE 510, 610 bearer used by an eNB 502, 602. The remote

UE 508, 608 is connected to a relay UE 510, 610 through a non-3GPP D2D interface. The relay UE 510, 610 is connected to an eNB 502, 602 through a radio interface. The eNB 502, 602 is connected to a serving gateway (S-GW or SGW) and includes one or more S1 bearers related to the relay UE 510, 610 and/or the remote UE 508, 608. S-GW is connected to a serving gateway (S-GW or SGW) and includes one or more S1/S8 bearers related to the relay UE 510, 610 and/or the remote UE 508, 608.

[0071] In some embodiments, the remote UE 508, 608 goes out of coverage and/or into an RRC idle state. In the embodiments, the remote UE 508, 608 has established direct connection at attach with the same eNB 502, 602 (or cell). Then, either the remote UE 508, 608 enters idle or goes out of coverage.

[0072] In this situation, the remote UE 508, 608 uses a candidate relay UE list obtained while it was in connected mode (e.g., such as through one of the options discussed above) or it is considered pre-configured (e.g., associated to a specific relay). It is also possible to receive information over ProSe D2D discovery or association procedure; however, it may not be possible to modify non-3GPP communication to provide such information as to whether the relay UE supports backhaul to be able to relay.

[0073] Furthermore, the relay UE 510, 610 can carry control plane signaling or perform control plane signaling on behalf of the remote UE 508, 608 for downlink paging or service request procedure or similar procedure to activate or establish EPS bearer for the remote UE 508, 608 through the non-3GPP access data path. The signalling radio bearer (SRB) data can be encapsulated within WLAN MAC data for example. The eNB should be able to decipher the information and perform the corresponding procedure and respond accordingly. The scenario for an out of coverage (OOC) remote UE is shown in FIGs. 5-6.

[0074] FIG. 5 is a block diagram of a remote UE out of coverage and connected through a relay UE to a network and using separate bearers for the remote UE 508 and the relay UE 510. When the relay UE 510 prepares to act as a relay for the remote UE 508, a separate bearer is created for use with data provided by the remote UE 508.

[0075] FIG. 6 is a block diagram of a remote UE out of coverage and connected through a relay UE to a network and using separate bearers for the remote UE 608 and the relay UE 610. When the relay UE 610 prepares to act as a relay for the

remote UE 608, a bearer associated with the relay UE 610 is shared with data provided by the remote UE 608. In the embodiment shown, the S-GW splits the shared S1 bearer into two S1/S8 bearers, one each for the remote UE 608 and the relay UE 610.

[0076] In some embodiments, the relay can enter connected mode, if it is in idle mode at discovery. For a non-3GPP access case, when the remote UE establishes communication with the relay UE, if the relay UE is in RRC idle mode, multiple options can be used to trigger the UE to enter connected mode to forward the data. This forwarding can be in uplink from the remote UE to the network side or to trigger the network to deliver data to the remote UE through the relay UE in case that is the only option configured or preferred by the remote UE.

[0077] In some embodiments, there is an entity defined and implemented within the relay UE to support layer 2 relaying/data forwarding. When the entity receives incoming data (from the WLAN interface with the remote UE) in the buffer, the entity moves the data to the RLC buffer to trigger the UE to enter connected mode.

[0078] In other embodiments, the eNB can signal through paging message (example RAN-based paging) and wake up the relay UE. The eNB can include remote UE ID information to let the relay UE be informed about the intention of the paging. This option can be triggered by the remote UE's request over the Uu link providing relay UE's ID information (e.g., using dedicated RRC/control message such as SidelinkUEInformation message). This paging enables downlink data communication to the remote UE via a relay UE, which is in idle mode, to be made possible as soon as the network is aware of the remote UE and relay UE pairing even as it is through the non-3GPP access as discussed previously.

[0079] After discovering the relay UE ID through non-3GPP access, the remote UE can exchange messages with the eNB with the candidate relay UE ID (e.g., non-3GPP access based MAC addresses) to select a final relay to be used for relaying communication. When the remote UE is finalizing on the relay UE to be used for non-3GPP access over PC5, the eNB can let the remote UE know if the relay UE is authorized and can perform layer 2 relaying, supports a defined PDN connection, and is in idle or connected mode, and whether the eNB can page the relay UE if RAN based paging is supported.

[0080] In some embodiments, the relay UE forwards remote UE information to the eNB. The relay UE verifies the 3GPP credentials of the remote UE and provides the

remote UE's ID to the network for authentication and verification. The remote UE is registered and attached at the network either by itself or as a paired device with a given relay UE (the paired ID or information can be provided at attach accept by the network and stored as part of the UE context of both the remote UE and relay UE).

[0081] Depending on the embodiment, the pairing can be based on 3GPP or non-3GPP access. Once data is available at the relay UE to be forwarded to the network, the relay UE can provide paired information to the network.

[0082] In an embodiment, the eNB already has a remote UE ID of the non-3GPP access, when relay UE provides that ID (e.g., WLAN MAC address obtained from the first data packet), the authorization can be granted immediately as the remote UE is in connected mode and the eNB already has the remote UE's context information. The eNB can assign a DRB ID for the relay UE to use for relaying or acknowledge that the remote UE is authorized for access. The eNB can further check for authorization with other functions in the network (ProSe Function or MME, etc.).

[0083] In some embodiments, the relay UE identifies the non-3GPP access based data to be relayed and packages it into a DRB over the Uu. In uplink (from remote UE to network side), the remote UE's non-3GPP access data packet header has the destination ID or address that provides an indicator that can be used to infer that the data needs to be forwarded to the network, as the destination ID or address will not match the relay UE's ID.

[0084] In an embodiment, unless previously paired or known to the network, it is not probable to receive downlink data through a relay UE for a given remote UE. It can follow the same path once uplink has been initiated based on storage of the information at the network nodes.

[0085] FIG. 7 shows a D2D relaying an adaptation entity 702 as part of a WLAN (e.g., WiFi) protocol stack 704 and cellular protocol stack (e.g., LTE) that is above an RLC layer 706 and Uu MAC layer 708. In some embodiments, an entity (e.g., a D2D relaying adaptation entity) can be defined within the relay UE 701 that maps the data arriving from non-3GPP access to the DRB. The entity can obtain the remote UE WLAN MAC address or certain remote UE ID and provide it to the eNB. For non-3GPP access, this can be from the first data packet received itself or the remote UE provides a C-RNTI or other ID (WLAN/Bluetooth/D2D MAC address) or network-configured ID to the relay UE and the relay UE forwards this information to the eNB. For example, the eNB uses the remote UE ID (e.g., WLAN MAC address of the

remote UE) to keep track of the remote UE in the network and assign a given DRB ID to the relay UE (e.g., a DRB ID for the DRB to be used between relay and eNB). This DRB ID enables the eNB to identify relayed traffic when the relay UE uses this specific DRB ID. In some embodiments, a relay configuration can specify whether the DRB ID is for only one remote UE's traffic or supports multiplexing of multiple remote UEs' traffic.

[0086] In some embodiments, the entity adds a new header to the data packet including the EPS bearer ID. This can aid in case the remote UE has multiple bearers set up so that the eNB may later be able to map the data correspondingly into different EPS bearers in the link between the eNB and the network.

[0087] In some embodiments, the entity adds another information element (IE) such as remote UE ID within the packet header such that multiple remote UEs with multiple bearers may be mapped onto a single DRB ID over the relay UE to eNB link. This can aid with the support of multiple remote UEs by the relay UE and not be limited by the DRBs that the relay UE supports.

[0088] The entity may reside below the PDCP (above RLC) or at the MAC. It depends on the type of relaying being performed. The header can be modified at different layers, depending on the placement of the entity within the protocol stack. The relay protocol layer discussed in the IDF may potentially be combined to also act as the "D2D relaying adaptation entity" that is a generic entity that handles data from both ProSe and non-3GPP access.

[0089] FIGs. 8-9 show packet relay by an eNB to a network. FIG. 8 shows one bearer per UE and FIG. 9 shows multiplexing of packets on a single bearer. Over non-3GPP RAT (e.g., WLAN/Bluetooth) the relay UE may receive both the packet that needs to be relayed to the network and the packet that does not need to be relayed to the network. In order to distinguish two kinds of packets, a non-3GPP RAT header field can be used (e.g., some reserved value in a WLAN header field can be used to distinguish two kinds of packets). The relay UE will forward the packet to the network if it receives the packet having the WLAN header field value indicating it needs to be relayed.

[0090] FIG. 8 shows a packet relay by an eNB to a network with one bearer per UE. The system includes a remote UE 1 (802) and remote UE 2 (814) connected to a relay UE 804 using non-3GPP access and PC5 respectively. The relay UE 804 is wirelessly connected to an eNB 806 over an LTE-Uu wireless link. The eNB 806 is

connected to the core network including an MME 812 and S-GW 808. The S-GW 808 provides access to a P-GW 810. This embodiment shows that the data 816 and 820 from each remote UE 802 and 814 is mapped onto an individual bearer (826 and 828 respectively) at the relay UE 804. These data radio bearers (DRBs) 826 and 828 are associated with evolved packet system (EPS) bearers 734 and 738 that are identified with S1-U tunnel endpoint identifiers (TEID) used with GPRS tunneling protocol (GTP). After the S-GW 808, the S1-U tunnel endpoint identifiers are associated with S5 TEID due to the transition to the S5 link. The disadvantage of this mapping is that the relay UE 804 is limited by the number of parallel remote UE sessions that it can support by the maximum number of DRBs supported or allowed to be supported. Although it is possible that 5G may support further more DRBs, the LTE network has a limitation to support only 8-11 bearers. It should be noted that the relay UE 804 also has its own DRB 824, which is associated with an EPS bearer 730 having S1-U TEID and S5 TEID 732.

[0091] FIG. 9 shows a packet relay by an eNB to a network with multiplexing of packets on a single bearer. The system includes a remote UE 1 (902) and remote UE 2 (914) connected to a relay UE 904 using non-3GPP access and PC5 respectively. The relay UE 904 is wirelessly connected to an eNB 906 over an LTE-Uu wireless link. The eNB 906 is connected to the core network including an MME 912 and S-GW 908. The S-GW 908 provides access to a P-GW 910. This embodiment shows that the data 916 and 920 from each remote UE 902 and 914 is mapped onto a shared bearer 924 at the relay UE 904. This data radio bearer (DRB) 924 is split at the eNB 906 into associated evolved packet system (EPS) bearers 734 and 738 for each of the remote UEs that are identified with S1-U tunnel endpoint identifiers (TEID) used with GPRS tunneling protocol (GTP). After the S-GW 908, the S1-U tunnel endpoint identifiers are associated with S5 TEID due to the transition to the S5 link.

[0092] In the embodiment shown, multiple data from multiple remote UEs and relay UE data can be multiplexed onto one single relay UE DRB over LTE-Uu between relay UE and eNB. The different data packets are multiplexed and spread across two DRBs as shown in the figure (although a single DRB or more DRBs can also be used). In some embodiments, every protocol data unit (PDU) carries the remote UE ID in addition to the DRB ID onto which the eNB maps downlink data.

[0093] FIG. 10 illustrates an architecture of a system 1000 of a network in accordance with some embodiments. The system 1000 is shown to include a user equipment (UE) 1001 and a UE 1002. The UEs 1001 and 1002 are illustrated as smartphones (e.g., handheld touchscreen mobile computing devices connectable to one or more cellular networks), but may also comprise any mobile or non-mobile computing device, such as Personal Data Assistants (PDAs), pagers, laptop computers, desktop computers, wireless handsets, or any computing device including a wireless communications interface.

[0094] In some embodiments, any of the UEs 1001 and 1002 can comprise an Internet of Things (IoT) UE, which can comprise a network access layer designed for low-power IoT applications utilizing short-lived UE connections. An IoT UE can utilize technologies such as machine-to-machine (M2M) or machine-type communications (MTC) for exchanging data with an MTC server or device via a public land mobile network (PLMN), Proximity-Based Service (ProSe) or device-to-device (D2D) communication, sensor networks, or IoT networks. The M2M or MTC exchange of data may be a machine-initiated exchange of data. An IoT network describes interconnecting IoT UEs, which may include uniquely identifiable embedded computing devices (within the Internet infrastructure), with short-lived connections. The IoT UEs may execute background applications (e.g., keep-alive messages, status updates, etc.) to facilitate the connections of the IoT network.

[0095] The UEs 1001 and 1002 may be configured to connect, e.g., communicatively couple, with a radio access network (RAN) 1010. The RAN 1010 may be, for example, an Evolved Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (E-UTRAN), a NextGen RAN (NG RAN), or some other type of RAN. The UEs 1001 and 1002 utilize connections 1003 and 1004, respectively, each of which comprises a physical communications interface or layer (discussed in further detail below); in this example, the connections 1003 and 1004 are illustrated as an air interface to enable communicative coupling, and can be consistent with cellular communications protocols, such as a Global System for Mobile Communications (GSM) protocol, a code-division multiple access (CDMA) network protocol, a Push-to-Talk (PTT) protocol, a PTT over Cellular (POC) protocol, a Universal Mobile Telecommunications System (UMTS) protocol, a 3GPP Long Term Evolution (LTE) protocol, a fifth generation (5G) protocol, a New Radio (NR) protocol, and the like.

[0096] In this embodiment, the UEs 1001 and 1002 may further directly exchange communication data via a ProSe interface 1005. The ProSe interface 1005 may alternatively be referred to as a sidelink interface comprising one or more logical channels, including but not limited to a Physical Sidelink Control Channel (PSCCH), a Physical Sidelink Shared Channel (PSSCH), a Physical Sidelink Discovery Channel (PSDCH), and a Physical Sidelink Broadcast Channel (PSBCH).

[0097] The UE 1002 is shown to be configured to access an access point (AP) 1006 via connection 1007. The connection 1007 can comprise a local wireless connection, such as a connection consistent with any IEEE 802.11 protocol, wherein the AP 1006 would comprise a wireless fidelity (WiFi®) router. In this example, the AP 1006 is shown to be connected to the Internet without connecting to the core network of the wireless system (described in further detail below).

[0098] The RAN 1010 can include one or more access nodes that enable the connections 1003 and 1004. These access nodes (ANs) can be referred to as base stations (BSs), NodeBs, evolved NodeBs (eNBs), next Generation NodeBs (gNB), RAN nodes, and so forth, and can comprise ground stations (e.g., terrestrial access points) or satellite stations providing coverage within a geographic area (e.g., a cell). The RAN 1010 may include one or more RAN nodes for providing macrocells, e.g., macro RAN node 1011, and one or more RAN nodes for providing femtocells or picocells (e.g., cells having smaller coverage areas, smaller user capacity, or higher bandwidth compared to macrocells), e.g., low power (LP) RAN node 1012.

[0099] Any of the RAN nodes 1011 and 1012 can terminate the air interface protocol and can be the first point of contact for the UEs 1001 and 1002. In some embodiments, any of the RAN nodes 1011 and 1012 can fulfill various logical functions for the RAN 1010 including, but not limited to, radio network controller (RNC) functions such as radio bearer management, uplink and downlink dynamic radio resource management and data packet scheduling, and mobility management.

[0100] In accordance with some embodiments, the UEs 1001 and 1002 can be configured to communicate using Orthogonal Frequency-Division Multiplexing (OFDM) communication signals with each other or with any of the RAN nodes 1011 and 1012 over a multicarrier communication channel in accordance various communication techniques, such as, but not limited to, an Orthogonal Frequency-Division Multiple Access (OFDMA) communication technique (e.g., for downlink communications) or a Single Carrier Frequency Division Multiple Access (SC-FDMA)

communication technique (e.g., for uplink and ProSe or sidelink communications), although the scope of the embodiments is not limited in this respect. The OFDM signals can comprise a plurality of orthogonal subcarriers.

[0101] In some embodiments, a downlink resource grid can be used for downlink transmissions from any of the RAN nodes 1011 and 1012 to the UEs 1001 and 1002, while uplink transmissions can utilize similar techniques. The grid can be a time-frequency grid, called a resource grid or time-frequency resource grid, which is the physical resource in the downlink in each slot. Such a time-frequency plane representation is a common practice for OFDM systems, which makes it intuitive for radio resource allocation. Each column and each row of the resource grid corresponds to one OFDM symbol and one OFDM subcarrier, respectively. The duration of the resource grid in the time domain corresponds to one slot in a radio frame. The smallest time-frequency unit in a resource grid is denoted as a resource element. Each resource grid comprises a number of resource blocks, which describe the mapping of certain physical channels to resource elements. Each resource block comprises a collection of resource elements; in the frequency domain, this may represent the smallest quantity of resources that currently can be allocated. There are several different physical downlink channels that are conveyed using such resource blocks.

[0102] The physical downlink shared channel (PDSCH) may carry user data and higher-layer signaling to the UEs 1001 and 1002. The physical downlink control channel (PDCCH) may carry information about the transport format and resource allocations related to the PDSCH channel, among other things. It may also inform the UEs 1001 and 1002 about the transport format, resource allocation, and H-ARQ (Hybrid Automatic Repeat Request) information related to the uplink shared channel. Typically, downlink scheduling (assigning control and shared channel resource blocks to the UE 1002 within a cell) may be performed at any of the RAN nodes 1011 and 1012 based on channel quality information fed back from any of the UEs 1001 and 1002. The downlink resource assignment information may be sent on the PDCCH used for (e.g., assigned to) each of the UEs 1001 and 1002.

[0103] The PDCCH may use control channel elements (CCEs) to convey the control information. Before being mapped to resource elements, the PDCCH complex-valued symbols may first be organized into quadruplets, which may then be permuted using a sub-block interleaver for rate matching. Each PDCCH may be

transmitted using one or more of these CCEs, where each CCE may correspond to nine sets of four physical resource elements known as resource element groups (REGs). Four Quadrature Phase Shift Keying (QPSK) symbols may be mapped to each REG. The PDCCH can be transmitted using one or more CCEs, depending on the size of the downlink control information (DCI) and the channel condition. There can be four or more different PDCCH formats defined in LTE with different numbers of CCEs (e.g., aggregation level, $L=1, 2, 4$, or 8).

[0104] Some embodiments may use concepts for resource allocation for control channel information that are an extension of the above-described concepts. For example, some embodiments may utilize an enhanced physical downlink control channel (EPDCCH) that uses PDSCH resources for control information transmission. The EPDCCH may be transmitted using one or more enhanced the control channel elements (ECCEs). Similar to above, each ECCE may correspond to nine sets of four physical resource elements known as enhanced resource element groups (EREGs). An ECCE may have other numbers of EREGs in some situations.

[0105] The RAN 1010 is shown to be communicatively coupled to a core network (CN) 1020 —via an S1 interface 1013. In embodiments, the CN 1020 may be an evolved packet core (EPC) network, a NextGen Packet Core (NPC) network, or some other type of CN. In this embodiment the S1 interface 1013 is split into two parts: the S1-U interface 1014, which carries traffic data between the RAN nodes 1011 and 1012 and a serving gateway (S-GW) 1022, and an S1-mobility management entity (MME) interface 1015, which is a signaling interface between the RAN nodes 1011 and 1012 and MMEs 1021.

[0106] In this embodiment, the CN 1020 comprises the MMEs 1021, the S-GW 1022, a Packet Data Network (PDN) Gateway (P-GW) 1023, and a home subscriber server (HSS) 1024. The MMEs 1021 may be similar in function to the control plane of legacy Serving General Packet Radio Service (GPRS) Support Nodes (SGSN). The MMEs 1021 may manage mobility aspects in access such as gateway selection and tracking area list management. The HSS 1024 may comprise a database for network users, including subscription-related information to support the network entities' handling of communication sessions. The CN 1020 may comprise one or several HSSs 1024, depending on the number of mobile subscribers, on the capacity of the equipment, on the organization of the network, etc. For example, the HSS

1024 can provide support for routing/roaming, authentication, authorization, naming/addressing resolution, location dependencies, etc.

[0107] The S-GW 1022 may terminate the S1 interface 1013 towards the RAN 1010, and routes data packets between the RAN 1010 and the CN 1020. In addition, the S-GW 1022 may be a local mobility anchor point for inter-RAN node handovers and also may provide an anchor for inter-3GPP mobility. Other responsibilities may include lawful intercept, charging, and some policy enforcement.

[0108] The P-GW 1023 may terminate an SGi interface toward a PDN. The P-GW 1023 may route data packets between the CN 1020 (e.g., an EPC network) and external networks such as a network including the application server 1030 (alternatively referred to as application function (AF)) via an Internet Protocol (IP) interface 1025. Generally, an application server 1030 may be an element offering applications that use IP bearer resources with the core network (e.g., UMTS Packet Services (PS) domain, LTE PS data services, etc.). In this embodiment, the P-GW 1023 is shown to be communicatively coupled to an application server 1030 via an IP communications interface 1025. The application server 1030 can also be configured to support one or more communication services (e.g., Voice-over-Internet Protocol (VoIP) sessions, PTT sessions, group communication sessions, social networking services, etc.) for the UEs 1001 and 1002 via the CN 1020.

[0109] The P-GW 1023 may further be a node for policy enforcement and charging data collection. A Policy and Charging Enforcement Function (PCRF) 1026 is the policy and charging control element of the CN 1020. In a non-roaming scenario, there may be a single PCRF in the Home Public Land Mobile Network (HPLMN) associated with a UE's Internet Protocol Connectivity Access Network (IP-CAN) session. In a roaming scenario with local breakout of traffic, there may be two PCRFs associated with a UE's IP-CAN session: a Home PCRF (H-PCRF) within a HPLMN and a Visited PCRF (V-PCRF) within a Visited Public Land Mobile Network (VPLMN). The PCRF 1026 may be communicatively coupled to the application server 1030 via the P-GW 1023. The application server 1030 may signal the PCRF 1026 to indicate a new service flow and select the appropriate Quality of Service (QoS) and charging parameters. The PCRF 1026 may provision this rule into a Policy and Charging Enforcement Function (PCEF) (not shown) with the appropriate traffic flow template (TFT) and QoS class of identifier (QCI), which commences the QoS and charging as specified by the application server 1030.

[0110] FIG. 11 illustrates example components of a device 1100 in accordance with some embodiments. In some embodiments, the device 1100 may include application circuitry 1102, baseband circuitry 1104, Radio Frequency (RF) circuitry 1106, front-end module (FEM) circuitry 1108, one or more antennas 1110, and power management circuitry (PMC) 1112 coupled together at least as shown. The components of the illustrated device 1100 may be included in a UE or a RAN node. In some embodiments, the device 1100 may include fewer elements (e.g., a RAN node may not utilize application circuitry 1102, and instead include a processor/controller to process IP data received from an EPC). In some embodiments, the device 1100 may include additional elements such as, for example, memory/storage, display, camera, sensor, or input/output (I/O) interface. In other embodiments, the components described below may be included in more than one device (e.g., said circuitries may be separately included in more than one device for Cloud-RAN (C-RAN) implementations).

[0111] The application circuitry 1102 may include one or more application processors. For example, the application circuitry 1102 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) may include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors may be coupled with or may include memory/storage and may be configured to execute instructions stored in the memory/storage to enable various applications or operating systems to run on the device 1100. In some embodiments, processors of application circuitry 1102 may process IP data packets received from an EPC.

[0112] The baseband circuitry 1104 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 1104 may include one or more baseband processors or control logic to process baseband signals received from a receive signal path of the RF circuitry 1106 and to generate baseband signals for a transmit signal path of the RF circuitry 1106. Baseband processing circuitry 1104 may interface with the application circuitry 1102 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 1106. For example, in some embodiments, the baseband circuitry 1104 may include a third generation (3G) baseband processor 1104A, a fourth generation (4G) baseband processor 1104B, a fifth generation (5G) baseband

processor 1104C, or other baseband processor(s) 1104D for other existing generations, generations in development or to be developed in the future (e.g., second generation (2G), sixth generation (6G), etc.). The baseband circuitry 1104 (e.g., one or more of baseband processors 1104A-D) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 1106. In other embodiments, some or all of the functionality of baseband processors 1104A-D may be included in modules stored in the memory 1104G and executed via a Central Processing Unit (CPU) 1104E. 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 1104 may include Fast-Fourier Transform (FFT), precoding, or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 1104 may include convolution, tail-biting convolution, turbo, Viterbi, or Low Density Parity Check (LDPC) encoder/decoder functionality. Embodiments of modulation/demodulation and encoder/decoder functionality are not limited to these examples and may include other suitable functionality in other embodiments.

[0113] In some embodiments, the baseband circuitry 1104 may include one or more audio digital signal processor(s) (DSP) 1104F. The audio DSP(s) 1104F 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 1104 and the application circuitry 1102 may be implemented together such as, for example, on a system on a chip (SOC).

[0114] In some embodiments, the baseband circuitry 1104 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 1104 may support communication with an evolved universal terrestrial radio access network (EUTRAN) or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), or a wireless personal area network (WPAN). Embodiments in which the baseband circuitry 1104 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

[0115] RF circuitry 1106 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 1106 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. The RF circuitry 1106 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 1108 and provide baseband signals to the baseband circuitry 1104. RF circuitry 1106 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 1104 and provide RF output signals to the FEM circuitry 1108 for transmission.

[0116] In some embodiments, the receive signal path of the RF circuitry 1106 may include mixer circuitry 1106A, amplifier circuitry 1106B and filter circuitry 1106C. In some embodiments, the transmit signal path of the RF circuitry 1106 may include filter circuitry 1106C and mixer circuitry 1106A. RF circuitry 1106 may also include synthesizer circuitry 1106D for synthesizing a frequency for use by the mixer circuitry 1106A of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 1106A of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 1108 based on the synthesized frequency provided by synthesizer circuitry 1106D. The amplifier circuitry 1106B may be configured to amplify the down-converted signals and the filter circuitry 1106C 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 1104 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, the mixer circuitry 1106A of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[0117] In some embodiments, the mixer circuitry 1106A of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 1106D to generate RF output signals for the FEM circuitry 1108. The baseband signals may be provided by the baseband circuitry 1104 and may be filtered by the filter circuitry 1106C.

[0118] In some embodiments, the mixer circuitry 1106A of the receive signal path and the mixer circuitry 1106A of the transmit signal path may include two or more

mixers and may be arranged for quadrature downconversion and upconversion, respectively. In some embodiments, the mixer circuitry 1106A of the receive signal path and the mixer circuitry 1106A 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 1106A of the receive signal path and the mixer circuitry 1106A may be arranged for direct downconversion and direct upconversion, respectively. In some embodiments, the mixer circuitry 1106A of the receive signal path and the mixer circuitry 1106A of the transmit signal path may be configured for super-heterodyne operation.

[0119] 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 1106 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 1104 may include a digital baseband interface to communicate with the RF circuitry 1106.

[0120] 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.

[0121] In some embodiments, the synthesizer circuitry 1106D 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 1106D may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[0122] The synthesizer circuitry 1106D may be configured to synthesize an output frequency for use by the mixer circuitry 1106A of the RF circuitry 1106 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 1106D may be a fractional $N/N+1$ synthesizer.

[0123] 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 1104 or the application circuitry 1102 (such as an applications processor) 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 application circuitry 1102.

[0124] Synthesizer circuitry 1106D of the RF circuitry 1106 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.

[0125] In some embodiments, the synthesizer circuitry 1106D may be configured to generate a carrier frequency as the output frequency, while in other embodiments, the output frequency may be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency) and used in 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 (f_{LO}). In some embodiments, the RF circuitry 1106 may include an IQ/polar converter.

[0126] FEM circuitry 1108 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 1110, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 1106 for further processing. The FEM circuitry 1108 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 1106 for transmission by one or more of the one or more antennas 1110. In various embodiments, the amplification through the transmit or receive signal paths may be done solely in the RF circuitry 1106, solely in the FEM circuitry 1108, or in both the RF circuitry 1106 and the FEM circuitry 1108.

[0127] In some embodiments, the FEM circuitry 1108 may include a TX/RX switch to switch between transmit mode and receive mode operation. The FEM circuitry 1108 may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry 1108 may include an LNA to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 1106). The transmit signal path of the FEM circuitry 1108 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by the RF circuitry 1106), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 1110).

[0128] In some embodiments, the PMC 1112 may manage power provided to the baseband circuitry 1104. In particular, the PMC 1112 may control power-source selection, voltage scaling, battery charging, or DC-to-DC conversion. The PMC 1112 may often be included when the device 1100 is capable of being powered by a battery, for example, when the device 1100 is included in a UE. The PMC 1112 may increase the power conversion efficiency while providing desirable implementation size and heat dissipation characteristics.

[0129] FIG. 11 shows the PMC 1112 coupled only with the baseband circuitry 1104. However, in other embodiments, the PMC 1112 may be additionally or alternatively coupled with, and perform similar power management operations for, other components such as, but not limited to, the application circuitry 1102, the RF circuitry 1106, or the FEM circuitry 1108.

[0130] In some embodiments, the PMC 1112 may control, or otherwise be part of, various power saving mechanisms of the device 1100. For example, if the device 1100 is in an RRC_Connected state, where it is still connected to the RAN node as it expects to receive traffic shortly, then it may enter a state known as Discontinuous Reception Mode (DRX) after a period of inactivity. During this state, the device 1100 may power down for brief intervals of time and thus save power.

[0131] If there is no data traffic activity for an extended period of time, then the device 1100 may transition off to an RRC_Idle state, where it disconnects from the network and does not perform operations such as channel quality feedback, handover, etc. The device 1100 goes into a very low power state and it performs paging where again it periodically wakes up to listen to the network and then powers down again. The device 1100 may not receive data in this state, and in order to receive data, it transitions back to an RRC_Connected state.

[0132] An additional power saving mode may allow a device to be unavailable to the network for periods longer than a paging interval (ranging from seconds to a few hours). During this time, the device is totally unreachable to the network and may power down completely. Any data sent during this time incurs a large delay and it is assumed the delay is acceptable.

[0133] Processors of the application circuitry 1102 and processors of the baseband circuitry 1104 may be used to execute elements of one or more instances of a protocol stack. For example, processors of the baseband circuitry 1104, alone or in combination, may be used to execute layer 3, layer 2, or layer 1 functionality, while processors of the application circuitry 1102 may utilize data (e.g., packet data) received from these layers and further execute layer 4 functionality (e.g., transmission communication protocol (TCP) and user datagram protocol (UDP) layers). As referred to herein, layer 3 may comprise a radio resource control (RRC) layer, described in further detail below. As referred to herein, layer 2 may comprise a medium access control (MAC) layer, a radio link control (RLC) layer, and a packet data convergence protocol (PDCP) layer, described in further detail below. As referred to herein, layer 1 may comprise a physical (PHY) layer of a UE/RAN node, described in further detail below.

[0134] FIG. 12 illustrates example interfaces of baseband circuitry in accordance with some embodiments. As discussed above, the baseband circuitry 1104 of FIG. 11 may comprise processors 1104A-1104E and a memory 1104G utilized by said processors. Each of the processors 1104A-1104E may include a memory interface, 1204A-1204E, respectively, to send/receive data to/from the memory 1104G.

[0135] The baseband circuitry 1104 may further include one or more interfaces to communicatively couple to other circuitries/devices, such as a memory interface 1212 (e.g., an interface to send/receive data to/from memory external to the baseband circuitry 1104), an application circuitry interface 1214 (e.g., an interface to send/receive data to/from the application circuitry 1102 of FIG. 11), an RF circuitry interface 1216 (e.g., an interface to send/receive data to/from RF circuitry 1106 of FIG. 11), a wireless hardware connectivity interface 1218 (e.g., an interface to send/receive data to/from Near Field Communication (NFC) components, Bluetooth® components (e.g., Bluetooth® Low Energy), Wi-Fi® components, and other communication components), and a power management interface 1220 (e.g., an interface to send/receive power or control signals to/from the PMC 1112).

[0136] FIG. 13 is an illustration of a control plane protocol stack in accordance with some embodiments. In this embodiment, a control plane 1300 is shown as a communications protocol stack between the UE 1001 (or alternatively, the UE 1002), the RAN node 1011 (or alternatively, the RAN node 1012), and the MME 1021.

[0137] A PHY layer 1301 may transmit or receive information used by the MAC layer 1302 over one or more air interfaces. The PHY layer 1301 may further perform link adaptation or adaptive modulation and coding (AMC), power control, cell search (e.g., for initial synchronization and handover purposes), and other measurements used by higher layers, such as an RRC layer 1305. The PHY layer 1301 may still further perform error detection on the transport channels, forward error correction (FEC) coding/decoding of the transport channels, modulation/demodulation of physical channels, interleaving, rate matching, mapping onto physical channels, and Multiple Input Multiple Output (MIMO) antenna processing.

[0138] The MAC layer 1302 may perform mapping between logical channels and transport channels, multiplexing of MAC service data units (SDUs) from one or more logical channels onto transport blocks (TB) to be delivered to PHY via transport channels, de-multiplexing MAC SDUs to one or more logical channels from transport blocks (TB) delivered from the PHY via transport channels, multiplexing MAC SDUs onto TBs, scheduling information reporting, error correction through hybrid automatic repeat request (HARQ), and logical channel prioritization.

[0139] An RLC layer 1303 may operate in a plurality of modes of operation, including: Transparent Mode (TM), Unacknowledged Mode (UM), and Acknowledged Mode (AM). The RLC layer 1303 may execute transfer of upper layer protocol data units (PDUs), error correction through automatic repeat request (ARQ) for AM data transfers, and concatenation, segmentation and reassembly of RLC SDUs for UM and AM data transfers. The RLC layer 1303 may also execute re-segmentation of RLC data PDUs for AM data transfers, reorder RLC data PDUs for UM and AM data transfers, detect duplicate data for UM and AM data transfers, discard RLC SDUs for UM and AM data transfers, detect protocol errors for AM data transfers, and perform RLC re-establishment.

[0140] A PDCP layer 1304 may execute header compression and decompression of IP data, maintain PDCP Sequence Numbers (SNs), perform in-sequence delivery of upper layer PDUs at re-establishment of lower layers, eliminate duplicates of lower layer SDUs at re-establishment of lower layers for radio bearers mapped on

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

[0141] The main services and functions of the RRC layer 1305 may include broadcast of system information (e.g., included in Master Information Blocks (MIBs) or System Information Blocks (SIBs) related to the non-access stratum (NAS)), broadcast of system information related to the access stratum (AS), paging, establishment, maintenance and release of an RRC connection between the UE and E-UTRAN (e.g., RRC connection paging, RRC connection establishment, RRC connection modification, and RRC connection release), establishment, configuration, maintenance and release of point-to-point radio bearers, security functions including key management, inter radio access technology (RAT) mobility, and measurement configuration for UE measurement reporting. Said MIBs and SIBs may comprise one or more information elements (IEs), which may each comprise individual data fields or data structures.

[0142] The UE 1001 and the RAN node 1011 may utilize a Uu interface (e.g., an LTE-Uu interface) to exchange control plane data via a protocol stack comprising the PHY layer 1301, the MAC layer 1302, the RLC layer 1303, the PDCP layer 1304, and the RRC layer 1305.

[0143] In the embodiment shown, the non-access stratum (NAS) protocols 1306 form the highest stratum of the control plane between the UE 1001 and the MME 1021. The NAS protocols 1306 support the mobility of the UE 1001 and the session management procedures to establish and maintain IP connectivity between the UE 1001 and the P-GW 1023.

[0144] The S1 Application Protocol (S1-AP) layer 1315 may support the functions of the S1 interface and comprise Elementary Procedures (EPs). An EP is a unit of interaction between the RAN node 1011 and the CN 1020. The S1-AP layer services may comprise two groups: UE-associated services and non UE-associated services. These services perform functions including, but not limited to: E-UTRAN Radio Access Bearer (E-RAB) management, UE capability indication, mobility, NAS signaling transport, RAN Information Management (RIM), and configuration transfer.

[0145] The Stream Control Transmission Protocol (SCTP) layer (alternatively referred to as the stream control transmission protocol/internet protocol (SCTP/IP)

layer) 1314 may ensure reliable delivery of signaling messages between the RAN node 1011 and the MME 1021 based, in part, on the IP protocol, supported by an IP layer 1313. An L2 layer 1312 and an L1 layer 1311 may refer to communication links (e.g., wired or wireless) used by the RAN node and the MME to exchange information.

[0146] The RAN node 1011 and the MME 1021 may utilize an S1-MME interface to exchange control plane data via a protocol stack comprising the L1 layer 1311, the L2 layer 1312, the IP layer 1313, the SCTP layer 1314, and the S1-AP layer 1315.

[0147] FIG. 14 is an illustration of a user plane protocol stack in accordance with some embodiments. In this embodiment, a user plane 1400 is shown as a communications protocol stack between the UE 1001 (or alternatively, the UE 1002), the RAN node 1011 (or alternatively, the RAN node 1012), the S-GW 1022, and the P-GW 1023. The user plane 1400 may utilize at least some of the same protocol layers as the control plane 1300. For example, the UE 1001 and the RAN node 1011 may utilize a Uu interface (e.g., an LTE-Uu interface) to exchange user plane data via a protocol stack comprising the PHY layer 1301, the MAC layer 1302, the RLC layer 1303, the PDCP layer 1304.

[0148] The General Packet Radio Service (GPRS) Tunneling Protocol for the user plane (GTP-U) layer 1404 may be used for carrying user data within the GPRS core network and between the radio access network and the core network. The user data transported can be packets in any of IPv4, IPv6, or PPP formats, for example. The UDP and IP security (UDP/IP) layer 1403 may provide checksums for data integrity, port numbers for addressing different functions at the source and destination, and encryption and authentication on the selected data flows. The RAN node 1011 and the S-GW 1022 may utilize an S1-U interface to exchange user plane data via a protocol stack comprising the L1 layer 1311, the L2 layer 1312, the UDP/IP layer 1403, and the GTP-U layer 1404. The S-GW 1022 and the P-GW 1023 may utilize an S5/S8a interface to exchange user plane data via a protocol stack comprising the L1 layer 1311, the L2 layer 1312, the UDP/IP layer 1403, and the GTP-U layer 1404. As discussed above with respect to FIG. 13, NAS protocols support the mobility of the UE 1001 and the session management procedures to establish and maintain IP connectivity between the UE 1001 and the P-GW 1023.

[0149] FIG. 15 is a block diagram illustrating components, according to some example embodiments, able to read instructions from a machine-readable or

computer-readable medium (e.g., a non-transitory machine-readable storage medium) and perform any one or more of the methodologies discussed herein. Specifically, FIG. 15 shows a diagrammatic representation of hardware resources 1500 including one or more processors (or processor cores) 1510, one or more memory/storage devices 1520, and one or more communication resources 1530, each of which may be communicatively coupled via a bus 1540. For embodiments where node virtualization (e.g., NFV) is utilized, a hypervisor 1502 may be executed to provide an execution environment for one or more network slices/sub-slices to utilize the hardware resources 1500.

[0150] The processors 1510 (e.g., a central processing unit (CPU), a reduced instruction set computing (RISC) processor, a complex instruction set computing (CISC) processor, a graphics processing unit (GPU), a digital signal processor (DSP) such as a baseband processor, an application specific integrated circuit (ASIC), a radio-frequency integrated circuit (RFIC), another processor, or any suitable combination thereof) may include, for example, a processor 1512 and a processor 1514.

[0151] The memory/storage devices 1520 may include main memory, disk storage, or any suitable combination thereof. The memory/storage devices 1520 may include, but are not limited to any type of volatile or non-volatile memory such as dynamic random access memory (DRAM), static random-access memory (SRAM), erasable programmable read-only memory (EPROM), electrically erasable programmable read-only memory (EEPROM), Flash memory, solid-state storage, etc.

[0152] The communication resources 1530 may include interconnection or network interface components or other suitable devices to communicate with one or more peripheral devices 1504 or one or more databases 1506 via a network 1508. For example, the communication resources 1530 may include wired communication components (e.g., for coupling via a Universal Serial Bus (USB)), cellular communication components, NFC components, Bluetooth® components (e.g., Bluetooth® Low Energy), Wi-Fi® components, and other communication components.

[0153] Instructions 1550 may comprise software, a program, an application, an applet, an app, or other executable code for causing at least any of the processors 1510 to perform any one or more of the methodologies discussed herein. The

instructions 1550 may reside, completely or partially, within at least one of the processors 1510 (e.g., within the processor's cache memory), the memory/storage devices 1520, or any suitable combination thereof. Furthermore, any portion of the instructions 1550 may be transferred to the hardware resources 1500 from any combination of the peripheral devices 1504 or the databases 1506. Accordingly, the memory of processors 1510, the memory/storage devices 1520, the peripheral devices 1504, and the databases 1506 are examples of computer-readable and machine-readable media.

Example Embodiments

[0154] Example 1 is an apparatus for a user equipment (UE), comprising a memory interface and baseband processor circuitry. The memory interface to store or access a relay UE identifier (ID) in a memory. The baseband processor circuitry is configured to perform a UE discovery to identify a relay UE having the relay UE ID; generate a direct communication request for the relay UE utilizing the relay UE ID; perform mutual authentication with the relay UE, based on receiving approval from the relay UE for the direct communication request, to obtain an authorization from a radio access network (RAN) node to relay data to the RAN node; and generate a device-to-device (D2D) message to provide, via a D2D link, data to the relay UE to communicate with the RAN node in response to performing mutual authentication.

[0155] Example 2 is the apparatus of Example 1, wherein the one or more baseband processors configured to provide the data to the relay UE via the D2D interface are further configured to provide the data to the relay UE via a non-3rd Generation Partnership Project (3GPP) interface.

[0156] Example 3 is the apparatus of Example 1, wherein the one or more baseband processors configured to provide the data to the relay UE via the non-3GPP interface are further configured to provide the data to the relay UE via at least one of a WiFi interface or a Bluetooth interface.

[0157] Example 4 is the apparatus of Example 1, wherein the one or more baseband processors are further configured to process a first radio resource control (RRC) connection reconfiguration message received from the RAN node, the RRC connection reconfiguration message comprising a plurality of relay UE IDs.

[0158] Example 5 is the apparatus of Example 4, wherein the one or more baseband processors are further configured to generate a second RRC connection

reconfiguration message for the RAN node comprising the plurality of relay UE IDs and the relay UE ID.

[0159] Example 6 is the apparatus of Example 1, wherein the one or more baseband processors configured to perform the UE discovery are further configured to perform a layer 2 UE discovery through a proximity services (ProSe) D2D discovery procedure to obtain a plurality of relay UE IDs including the relay UE ID.

[0160] Example 7 is the apparatus of Example 6, wherein the one or more baseband processors configured to provide the data to the relay UE via the D2D interface to communicate with the RAN node are further configured to provide the data to the relay UE via the D2D interface to communicate with the RAN node when the UE enters an out-of-coverage area to communicate with the RAN.

[0161] Example 8 is an apparatus for a user equipment (UE), comprising a memory interface and baseband processor circuitry. The memory interface to store or access a remote UE identifier (ID) in a memory. The baseband processor circuitry configured to authenticate a remote UE having the remote UE ID; obtain an authorization from a radio access network (RAN) node to relay data to the RAN node; process the data received from the remote UE via a wireless local area network (WLAN) interface; based on the authorization, generate service data units (SDUs) comprising the data received from the remote UE; and encode an uplink message to communicate the SDUs to a RAN node utilizing a wide area network (WAN) interface.

[0162] Example 9 is the apparatus of Example 8, wherein the one or more baseband processors configured to encode the uplink message are further configured to encode the uplink message to communicate the SDUs to the RAN node utilizing a Uu interface with the RAN node.

[0163] Example 10 is the apparatus of Example 8, wherein the one or more baseband processors configured to authenticate the remote UE having the remote UE ID are further configured to access a media access control (MAC) address of the remote UE through an authentication procedure.

[0164] Example 11 is the apparatus of Example 10, wherein the one or more baseband processors are further configured to generate an uplink message for the RAN node comprising the MAC address to authorize the remote UE with a mobility management entity (MME) of the RAN.

[0165] Example 12 is the apparatus of Example 11, wherein the one or more baseband processors are further configured to: process a downlink message, received from the RAN node in response to generating the uplink message, comprising a data radio bearer (DRB) ID of a DRB corresponding to the remote UE; and generate a mapping between the remote UE and the DRB over a Uu interface using the DRB ID.

[0166] Example 13 is the apparatus of Example 12, wherein the one or more baseband processors configured to transmit the SDUs utilizing the Uu interface are further configured to transmit the SDUs utilizing the DRB having the DRB ID.

[0167] Example 14 is the apparatus of Example 12, wherein the one or more baseband processors configured to generate the mapping are further configured to configure an adaptation layer to link the MAC address or remote UE ID over a short-range interface to the DRB ID over the Uu interface.

[0168] Example 15 is the apparatus of Example 14, wherein the adaptation layer is part of a packet data convergence protocol (PDCP).

[0169] Example 16 is the apparatus of Example 14, wherein the adaptation layer resides between a radio link control (RLC) and PDCP.

[0170] Example 17 is the apparatus of Example 8, wherein the one or more baseband processors are further configured to perform a proximity services (ProSe) D2D discovery procedure by providing an access ID and capabilities to perform layer 2 relaying of the UE.

[0171] Example 18 is the apparatus of Example 8, wherein the one or more baseband processors are further configured to relay control plane information received from the RAN node via a Uu interface to the remote UE via the WLAN interface.

[0172] Example 19 is the apparatus of Example 8, wherein the one or more baseband processors are further configured to configure the UE to enter a connected mode based on processing the data for relaying purposes.

[0173] Example 20 is a computer-readable storage medium having stored thereon instructions that, when implemented by a radio access network (RAN) node, cause the RAN node to store a plurality of user equipment (UE) identifiers (IDs) corresponding to relay UEs; generate a first radio resource control (RRC) message to configure the relay UEs to relay data to a plurality of remote UEs; generate a second RRC message for a remote UE from the plurality of remote UEs to provide

the remote UE with the plurality of UE IDs of the relay UEs; decode sidelink information identifying a relay UE from the relay UEs and the remote UE; assign a data radio bearer (DRB) ID to a relay UE to map the remote UE's data received over a layer 2 relay to a DRB having the DRB ID; and generate a configuration message to configure the relay UE to forward data received via a wireless local area network (WLAN) access device-to-device (D2D) based layer 2 indirect connection utilizing the DRB.

[0174] Example 21 is the computer-readable storage medium of Example 20, wherein the DRB is a shared DRB, shared across multiple UEs.

[0175] Example 22 is the computer-readable storage medium of Example 20, wherein the DRB is a dedicated DRB that services a single UE.

[0176] Example 23 is a method of enabling a relay user equipment (UE) by a radio access network (RAN) node, the method comprising storing a plurality of UE identifiers (IDs) corresponding to relay UEs; generating a first radio resource control (RRC) message to configure the relay UEs to relay data to a plurality of remote UEs; generating a second RRC message for a remote UE from the plurality of remote UEs to provide the remote UE with the plurality of UE IDs of the relay UEs; decoding sidelink information identifying a relay UE from the relay UEs and the remote UE; assigning a data radio bearer (DRB) ID to a relay UE to map the remote UE's data received over a layer 2 relay to a DRB having the DRB ID; and generating a configuration message to configure the relay UE to forward data received via a wireless local area network (WLAN) access device-to-device (D2D) based layer 2 indirect connection utilizing the DRB.

[0177] Example 24 is the method of Example 20, wherein the DRB is a shared DRB, shared across multiple UEs.

[0178] Example 25 is the method of Example 20, wherein the DRB is a dedicated DRB that services a single UE.

[0179] Example 26 is an apparatus for a user equipment (UE), comprising a memory interface to store or access a remote UE identifier (ID) in a memory; and means for authenticating a remote UE having the remote UE ID. The apparatus also comprises means for obtaining an authorization from a radio access network (RAN) node to relay data to the RAN node; means for processing the data received from the remote UE via a wireless local area network (WLAN) interface; means for generating service data units (SDUs) comprising the data received from the remote

UE based on the authorization; and means for encoding an uplink message to communicate the SDUs to a RAN node utilizing a wide area network (WAN) interface.

Additional Embodiments

[0180] Regarding the remote UE:

[0181] Additional Example 1 is a user equipment or (UE) referred to as (evolved) remote UE that is WiFi-enabled (or Bluetooth-enabled) and/or ProSe D2D and capable to communicate to the network either through communication over LTE Uu interface or through an evolved UE-to-Network Relay over BT or WiFi interface.

[0182] Additional Example 2 is an example of Additional Example 1 capable of receiving a list of candidate eRelay UEs within the cell along with its MAC address information.

[0183] Additional Example 3 is an example of Additional Example 1 capable of discovering evolved relay UEs using non-3GPP access and providing the list or a selected one to the eNB along with its MAC address information.

[0184] Additional Example 4 is an example of Additional Example 1 capable of discovering layer 2 relays through ProSe D2D discovery or association procedure and obtaining the relay UE IDs.

[0185] Additional Example 5 is an example of Additional Example 1 using the relay UEs list and capable of finding a suitable relay UE and performing layer 2 relaying when the UE enters out-of-coverage to communicate to the network.

[0186] Regarding the relay UE:

[0187] Additional Example 6 is a user equipment (UE) that is Bluetooth-enabled (or WiFi-enabled) and ProSe D2D enabled and capable of communicating to an evolved remote UE over a non-3GPP interface such as WiFi or BT and capable of layer 2 relaying of forwarding the SDUs of the evolved remote UEs over to the Uu interface with eNB.

[0188] Additional Example 7 is an example of Additional Example 6 capable of providing remote UE ID information to the eNB wherein the ID could be a non-3GPP access based MAC address.

[0189] Additional Example 8 is an example of Additional Example 6 capable of receiving a specific DRB ID corresponding to an associated evolved remote UE from the eNB/network.

[0190] Additional Example 9 is an example of Additional Example 6 capable of advertising as part of ProSe discovery about its non-3GPP access ID such as a MAC address and its capability to perform layer 2 relaying.

[0191] Additional Example 10 is an example of Additional Example 6 capable of relaying control plane information of evolved remote UE via non-3GPP D2D link to the network (both ways).

[0192] Additional Example 11 is an example of Additional Example 6 capable of entering connected mode based on incoming data in the buffer for relaying purposes only.

[0193] Additional Example 12 is an example of Additional Example 6 capable of receiving downlink paging for evolved remote UE with which it has associated a non-3GPP D2D link and entering connected mode to relay the remote UE's information.

[0194] Additional Example 13 is an example of Additional Example 6 capable of distinguishing incoming remote UE's different data available over a non-3GPP D2D link and conveying it on its own (each remote UE) radio bearer and mapping to the assigned DRB ID from the network.

[0195] Additional Example 14 is an example of Additional Example 6 capable of multiplexing multiple remote UEs' data within the same radio bearer and adding header information to distinguish the remote UEs' non-3GPP access based data.

[0196] Regarding the eNB:

[0197] Additional Example 15 is an evolved Node B (eNB) or similar network node which can support D2D communication along with relay operation and configure certain UEs to act as evolved UE-to-Network relays (relay UEs) and send or receive communication from such relays.

[0198] Additional Example 16 is an example of Additional Example 15 capable of maintaining a list of evolved layer 2 relay UEs supporting non-3GPP access and providing this information to the evolved remote UE upon request.

[0199] Additional Example 17 is an example of Additional Example 15 capable of controlling the evolved remote UE over direct connection to move to a non-3GPP access D2D based layer 2 indirect connection.

[0200] Additional Example 18 is an example of Additional Example 15 capable of storing evolved remote UE and relay UE non-3GPP based MAC address information as part of their context.

[0201] Additional Example 19 is an example of Additional Example 15 capable of assigning a DRB ID to the evolved relay UE on behalf of specific non-3GPP access D2D based evolved remote UE.

[0202] Additional Example 20 is an example of Additional Example 15 capable of mapping remote UE's non-3GPP access D2D data received over layer 2 relay on to its own EPS bearer.

[0203] Various techniques, or certain aspects or portions thereof, may take the form of program code (i.e., instructions) embodied in tangible media, such as floppy diskettes, CD-ROMs, hard drives, a non-transitory computer-readable storage medium, or any other machine-readable storage medium wherein, when the program code is loaded into and executed by a machine, such as a computer, the machine becomes an apparatus for practicing the various techniques. In the case of program code execution on programmable computers, the computing device may include a processor, a storage medium readable by the processor (including volatile and non-volatile memory and/or storage elements), at least one input device, and at least one output device. The volatile and non-volatile memory and/or storage elements may be a RAM, an EPROM, a flash drive, an optical drive, a magnetic hard drive, or another medium for storing electronic data. The eNodeB (or other base station) and UE (or other mobile station) may also include a transceiver component, a counter component, a processing component, and/or a clock component or timer component. One or more programs that may implement or utilize the various techniques described herein may use an application programming interface (API), reusable controls, and the like. Such programs may be implemented in a high-level procedural or an object-oriented programming language to communicate with a computer system. However, the program(s) may be implemented in assembly or machine language, if desired. In any case, the language may be a compiled or an interpreted language, and combined with hardware implementations.

[0204] It should be understood that many of the functional units described in this specification may be implemented as one or more components, which is a term used to more particularly emphasize their implementation independence. For example, a component may be implemented as a hardware circuit comprising custom very large scale integration (VLSI) circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. A component may also be

implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices, or the like.

[0205] Components may also be implemented in software for execution by various types of processors. An identified component of executable code may, for instance, comprise one or more physical or logical blocks of computer instructions, which may, for instance, be organized as an object, a procedure, or a function. Nevertheless, the executables of an identified component need not be physically located together, but may comprise disparate instructions stored in different locations that, when joined logically together, comprise the component and achieve the stated purpose for the component.

[0206] Indeed, a component of executable code may be a single instruction, or many instructions, and may even be distributed over several different code segments, among different programs, and across several memory devices. Similarly, operational data may be identified and illustrated herein within components, and may be embodied in any suitable form and organized within any suitable type of data structure. The operational data may be collected as a single data set, or may be distributed over different locations including over different storage devices, and may exist, at least partially, merely as electronic signals on a system or network. The components may be passive or active, including agents operable to perform desired functions.

[0207] Reference throughout this specification to “an example” means that a particular feature, structure, or characteristic described in connection with the example is included in at least one embodiment. Thus, appearances of the phrase “in an example” in various places throughout this specification are not necessarily all referring to the same embodiment.

[0208] As used herein, a plurality of items, structural elements, compositional elements, and/or materials may be presented in a common list for convenience. However, these lists should be construed as though each member of the list is individually identified as a separate and unique member. Thus, no individual member of such list should be construed as a de facto equivalent of any other member of the same list solely based on its presentation in a common group without indications to the contrary. In addition, various embodiments and examples may be referred to herein along with alternatives for the various components thereof. It is understood that such embodiments, examples, and alternatives are not to be construed as de

facto equivalents of one another, but are to be considered as separate and autonomous representations of embodiments.

[0209] Although the foregoing has been described in some detail for purposes of clarity, it will be apparent that certain changes and modifications may be made without departing from the principles thereof. It should be noted that there are many alternative ways of implementing both the processes and apparatuses described herein. Accordingly, the present embodiments are to be considered illustrative and not restrictive, and the embodiments are not to be limited to the details given herein, but may be modified within the scope and equivalents of the appended claims.

CLAIMS

1. An apparatus for a user equipment (UE), comprising:
a memory interface to store or access a relay UE identifier (ID) in a memory;
and
baseband processor circuitry configured to:
perform a UE discovery to identify a relay UE having the relay UE ID;
generate a direct communication request for the relay UE utilizing the relay UE ID;
perform mutual authentication with the relay UE, based on receiving approval from the relay UE for the direct communication request, to obtain an authorization from a radio access network (RAN) node to relay data to the RAN node; and
generate a device-to-device (D2D) message to provide, via a D2D link, data to the relay UE to communicate with the RAN node in response to performing mutual authentication.
2. The apparatus of claim 1, wherein the one or more baseband processors configured to provide the data to the relay UE via the D2D interface are further configured to provide the data to the relay UE via a non-3rd Generation Partnership Project (3GPP) interface.
3. The apparatus of claim 1, wherein the one or more baseband processors configured to provide the data to the relay UE via the non-3GPP interface are further configured to provide the data to the relay UE via at least one of a WiFi interface or a Bluetooth interface.
4. The apparatus of claim 1, wherein the one or more baseband processors are further configured to process a first radio resource control (RRC) connection reconfiguration message received from the RAN node, the RRC connection reconfiguration message comprising a plurality of relay UE IDs.
5. The apparatus of claim 4, wherein the one or more baseband processors are further configured to generate a second RRC connection reconfiguration message for the RAN node comprising the plurality of relay UE IDs and the relay UE ID.
6. The apparatus of claim 1, wherein the one or more baseband processors configured to perform the UE discovery are further configured to perform a layer 2

UE discovery through a proximity services (ProSe) D2D discovery procedure to obtain a plurality of relay UE IDs including the relay UE ID.

7. The apparatus of claim 6, wherein the one or more baseband processors configured to provide the data to the relay UE via the D2D interface to communicate with the RAN node are further configured to provide the data to the relay UE via the D2D interface to communicate with the RAN node when the UE enters an out-of-coverage area to communicate with the RAN.

8. An apparatus for a user equipment (UE), comprising:

a memory interface to store or access a remote UE identifier (ID) in a memory; and

baseband processor circuitry configured to:

authenticate a remote UE having the remote UE ID;

obtain an authorization from a radio access network (RAN) node to relay data to the RAN node;

process the data received from the remote UE via a wireless local area network (WLAN) interface;

based on the authorization, generate service data units (SDUs) comprising the data received from the remote UE; and

encode an uplink message to communicate the SDUs to a RAN node utilizing a wide area network (WAN) interface.

9. The apparatus of claim 8, wherein the one or more baseband processors configured to encode the uplink message are further configured to encode the uplink message to communicate the SDUs to the RAN node utilizing a Uu interface with the RAN node.

10. The apparatus of claim 8, wherein the one or more baseband processors configured to authenticate the remote UE having the remote UE ID are further configured to access a media access control (MAC) address of the remote UE through an authentication procedure.

11. The apparatus of claim 10, wherein the one or more baseband processors are further configured to generate an uplink message for the RAN node comprising the MAC address to authorize the remote UE with a mobility management entity (MME) of the RAN.

12. The apparatus of claim 11, wherein the one or more baseband processors are further configured to:

process a downlink message, received from the RAN node in response to generating the uplink message, comprising a data radio bearer (DRB) ID of a DRB corresponding to the remote UE; and

generate a mapping between the remote UE and the DRB over a Uu interface using the DRB ID.

13. The apparatus of claim 12, wherein the one or more baseband processors configured to transmit the SDUs utilizing the Uu interface are further configured to transmit the SDUs utilizing the DRB having the DRB ID.

14. The apparatus of claim 12, wherein the one or more baseband processors configured to generate the mapping are further configured to configure an adaptation layer to link the MAC address or remote UE ID over a short-range interface to the DRB ID over the Uu interface.

15. The apparatus of claim 14, wherein the adaptation layer is part of a packet data convergence protocol (PDCP).

16. The apparatus of claim 14, wherein the adaptation layer resides between a radio link control (RLC) and PDCP.

17. The apparatus of claim 8, wherein the one or more baseband processors are further configured to perform a proximity services (ProSe) D2D discovery procedure by providing an access ID and capabilities to perform layer 2 relaying of the UE.

18. The apparatus of claim 8, wherein the one or more baseband processors are further configured to relay control plane information received from the RAN node via a Uu interface to the remote UE via the WLAN interface.

19. The apparatus of claim 8, wherein the one or more baseband processors are further configured to configure the UE to enter a connected mode based on processing the data for relaying purposes.

20. A computer-readable storage medium having stored thereon instructions that, when implemented by a radio access network (RAN) node, cause the RAN node to:
store a plurality of user equipment (UE) identifiers (IDs) corresponding to relay UEs;

generate a first radio resource control (RRC) message to configure the relay UEs to relay data to a plurality of remote UEs;

generate a second RRC message for a remote UE from the plurality of remote UEs to provide the remote UE with the plurality of UE IDs of the relay UEs;

decode sidelink information identifying a relay UE from the relay UEs and the remote UE;

assign a data radio bearer (DRB) ID to a relay UE to map the remote UE's data received over a layer 2 relay to a DRB having the DRB ID; and

generate a configuration message to configure the relay UE to forward data received via a wireless local area network (WLAN) access device-to-device (D2D) based layer 2 indirect connection utilizing the DRB.

21. The computer-readable storage medium of claim 20, wherein the DRB is a shared DRB, shared across multiple UEs.

22. The computer-readable storage medium of claim 20, wherein the DRB is a dedicated DRB that services a single UE.

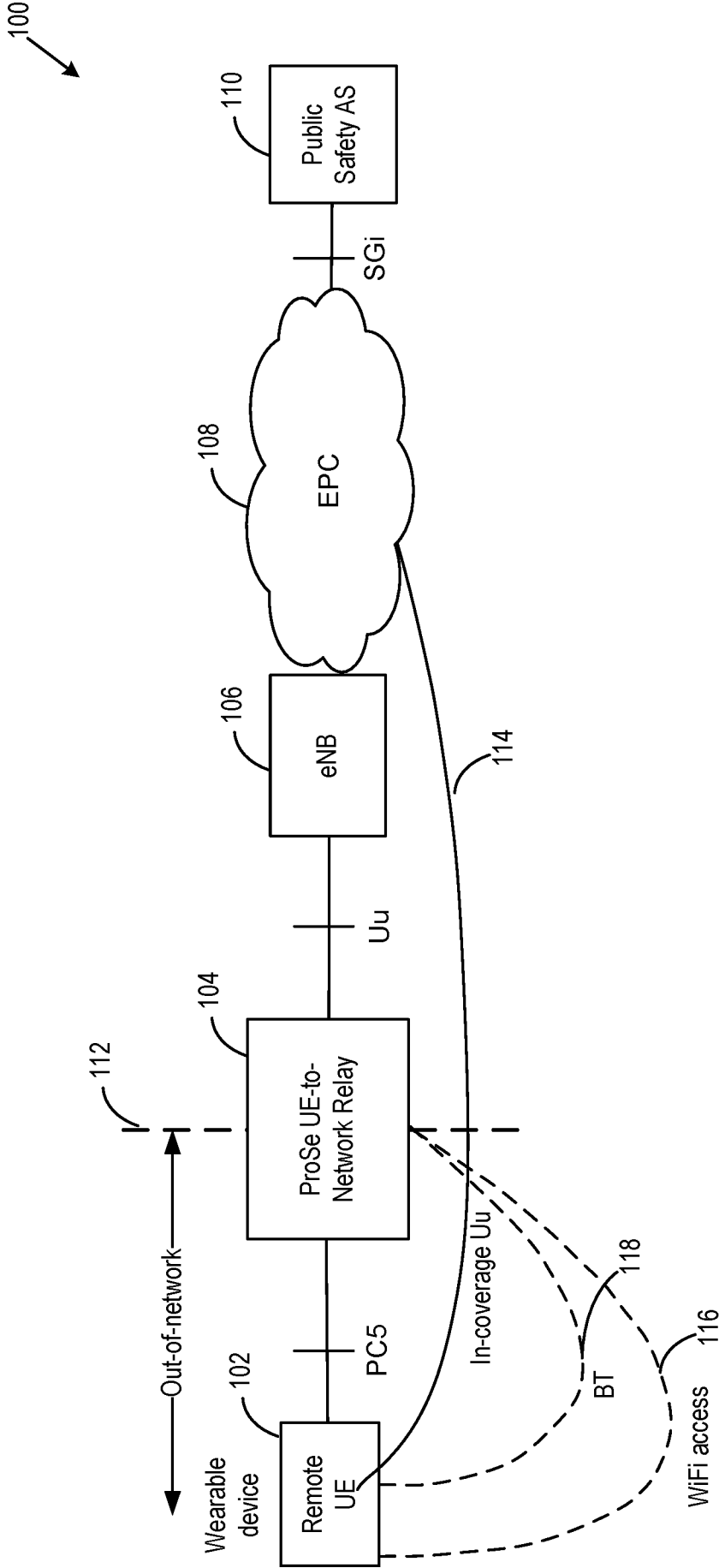


FIG. 1

Remote UE out of coverage from eNB with non-3GPP access via relay UE

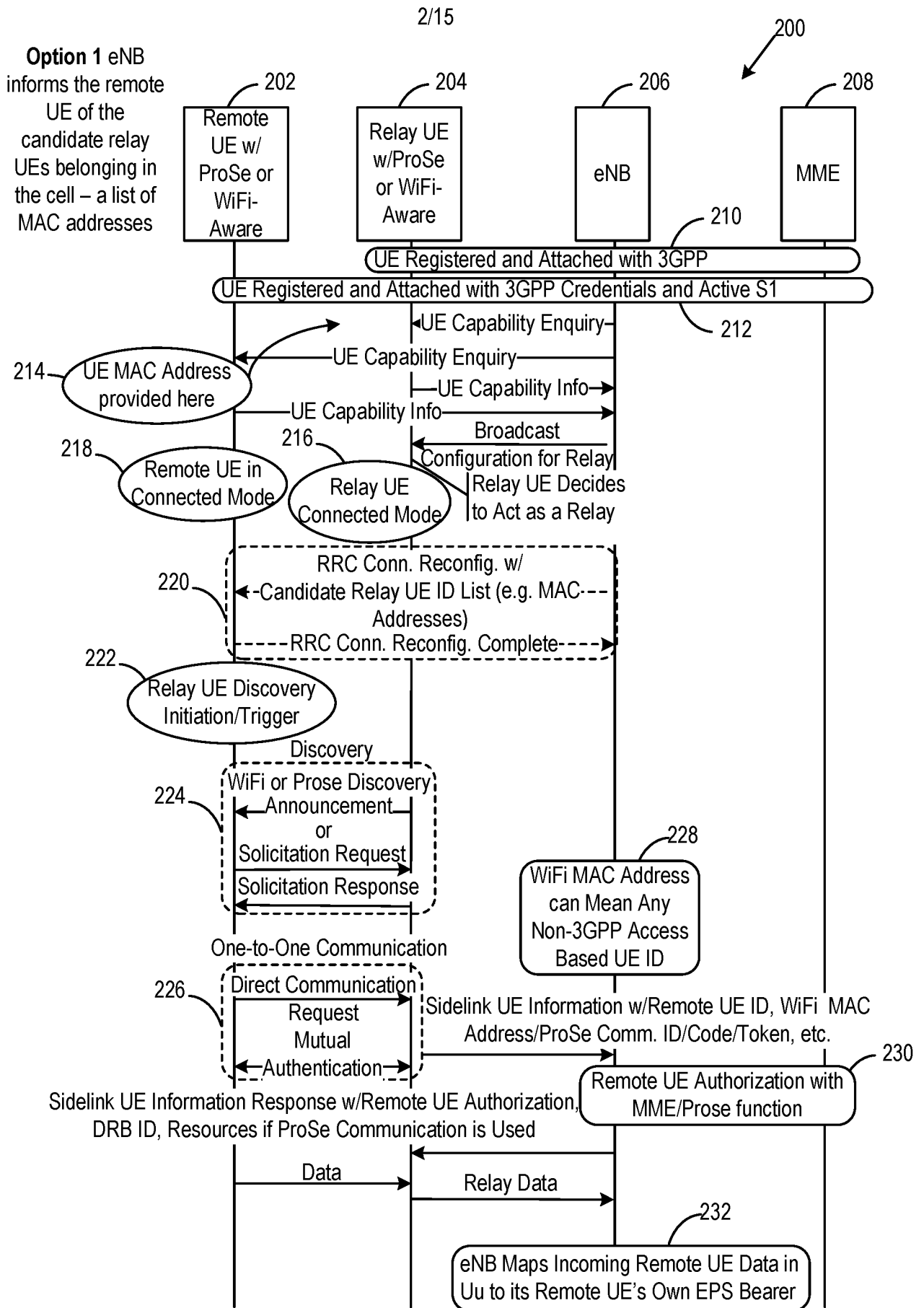


FIG. 2

Layer 2 relaying when relay UE and remote UE are in connected mode – option 1

Option 2 The remote UE provides the candidate relay UE MAC addresses that it finds to the eNB

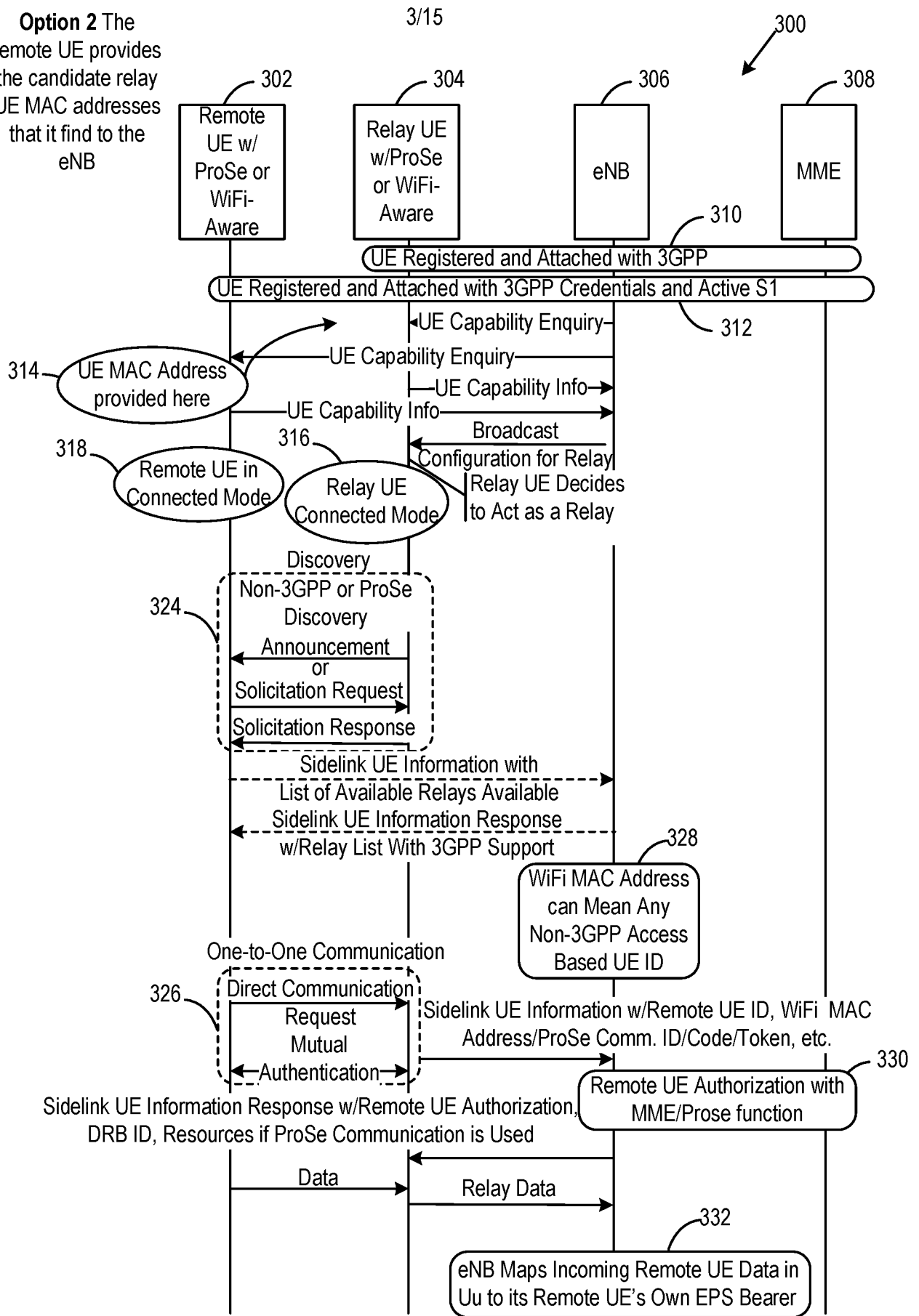


FIG. 3

Layer 2 relaying when relay UE and remote UE are in connected mode – option 2

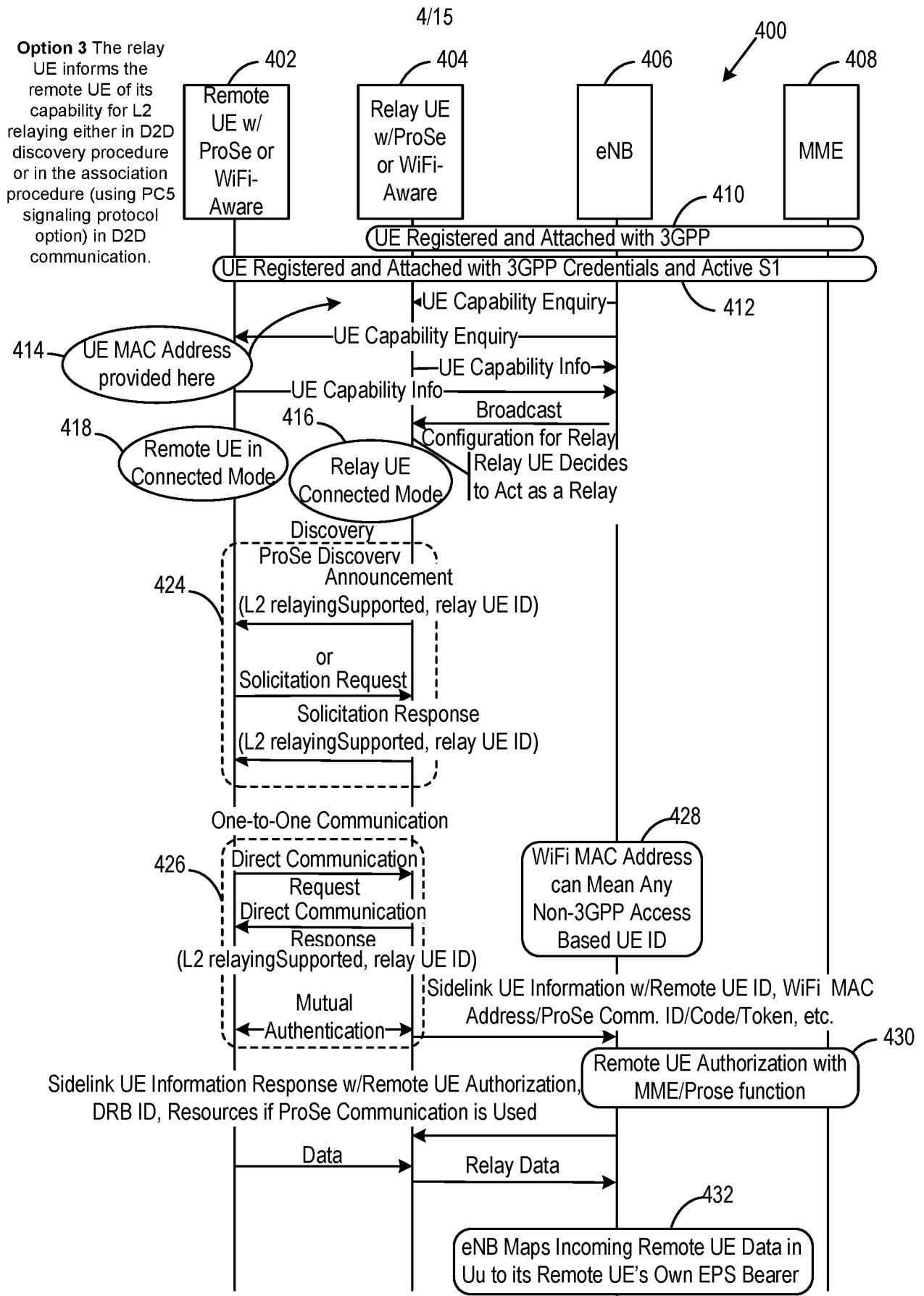


FIG. 4

Layer 2 relaying when relay UE and remote UE are in connected mode – option 3

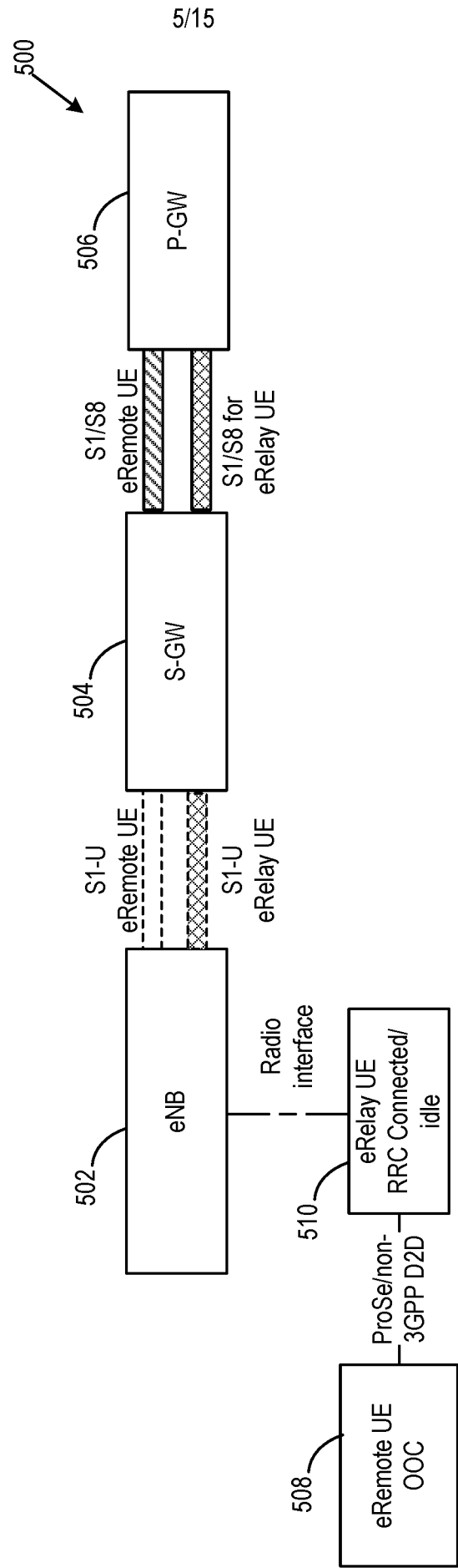


FIG. 5
Out-of-coverage scenario for eRemote UE

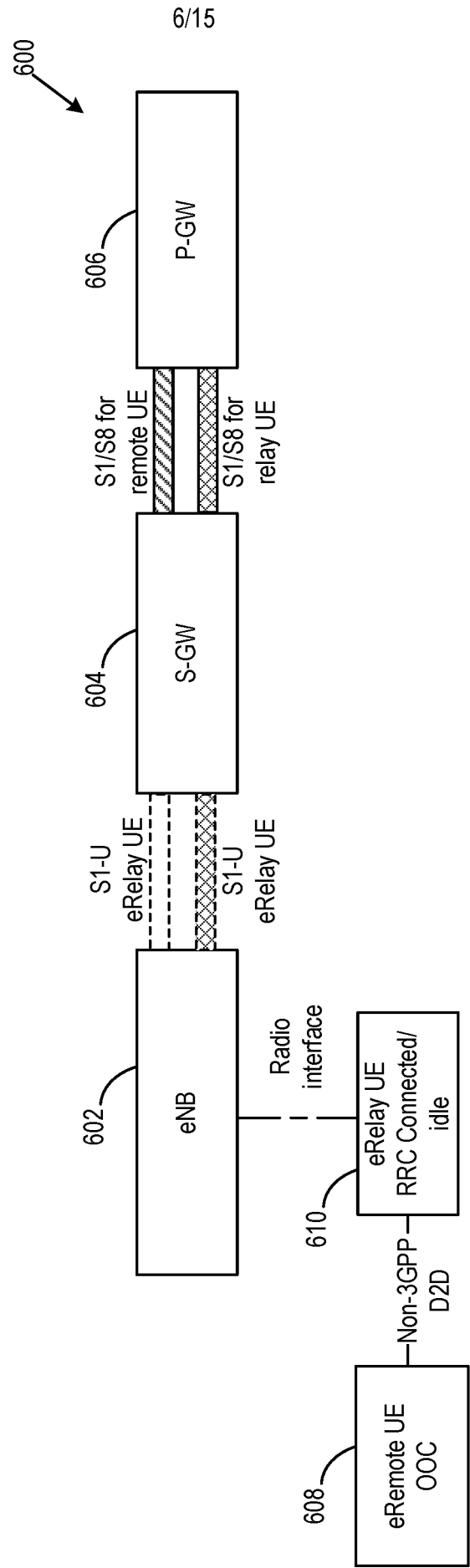


FIG. 6
Out-of-coverage scenario for eRemote UE

700 ↗

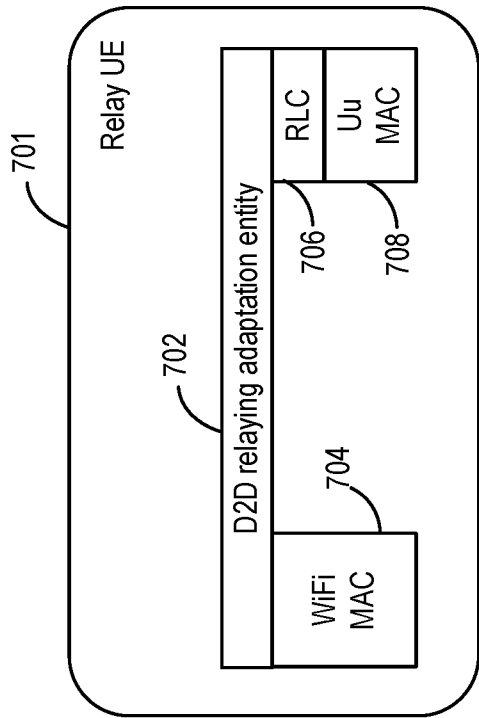


FIG. 7
D2D relaying adaptation entity example (adds DRB ID; remote UE ID as necessary)

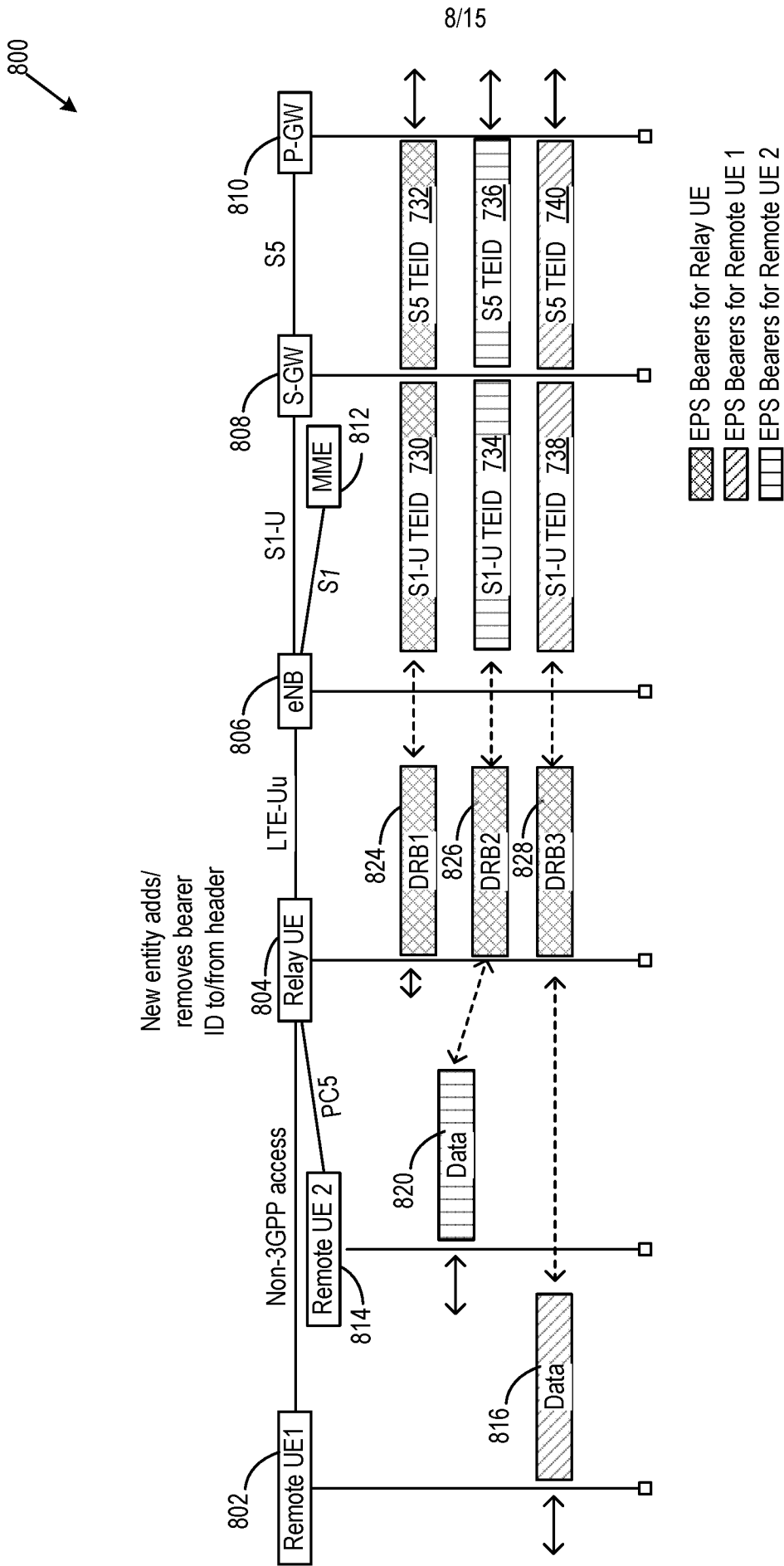


FIG. 8
1:1 DRB to UE mapping while relaying (one bearer per UE)

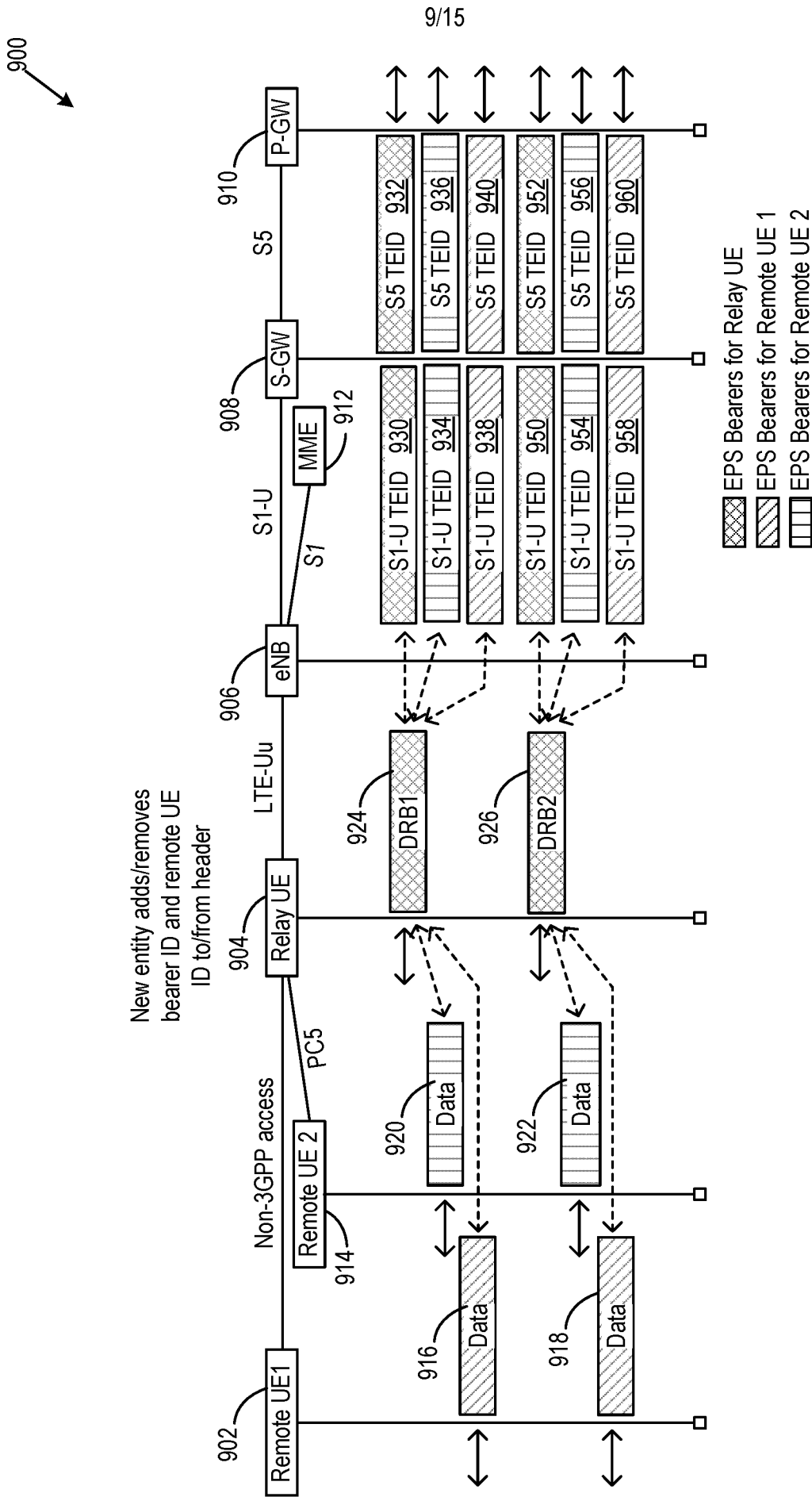


FIG. 9

1:m relay UE DRB to remote UE ID mapping with multiple UE EPS bearers multiplexed onto a single DRB at relay UE

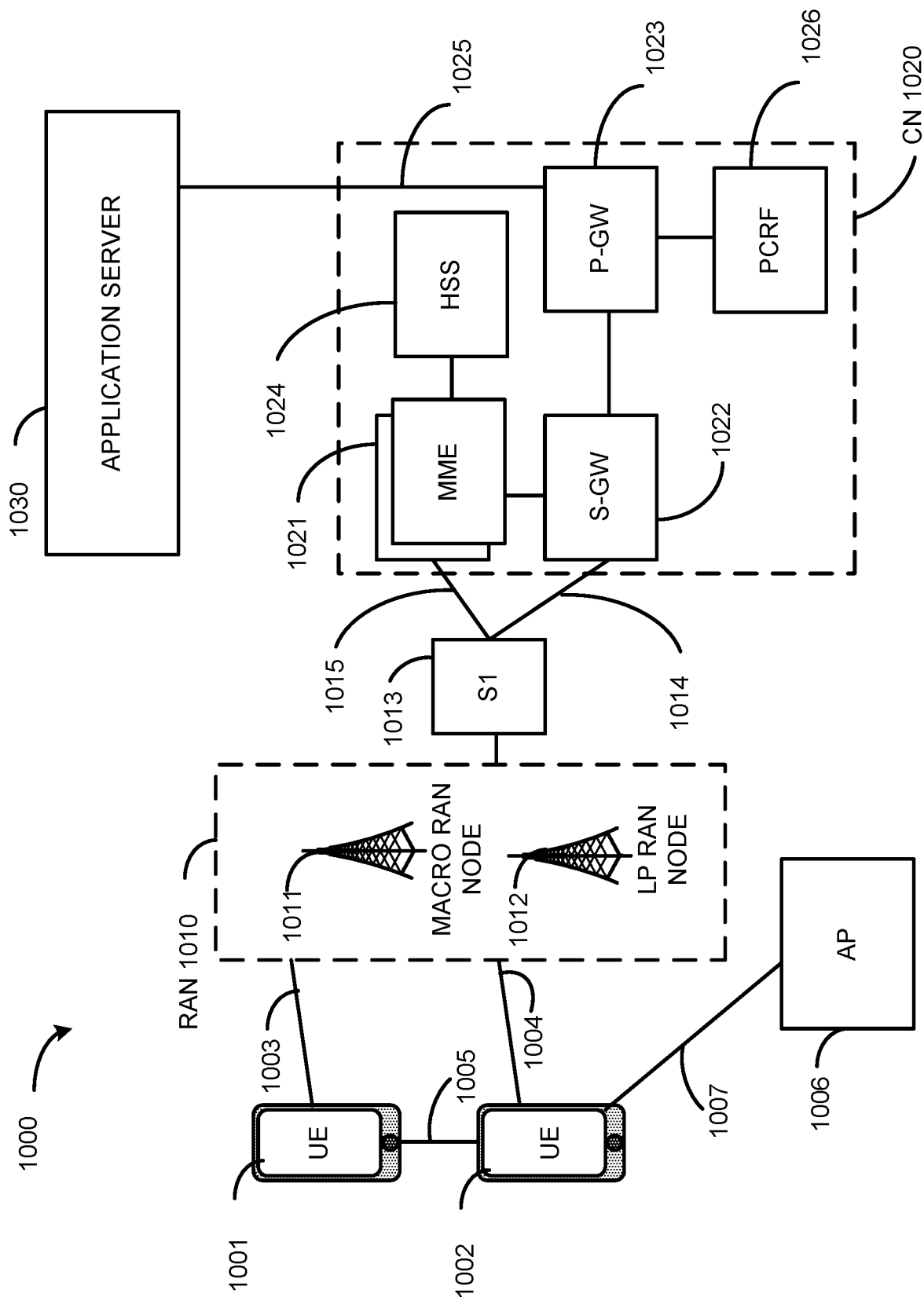


FIG. 10

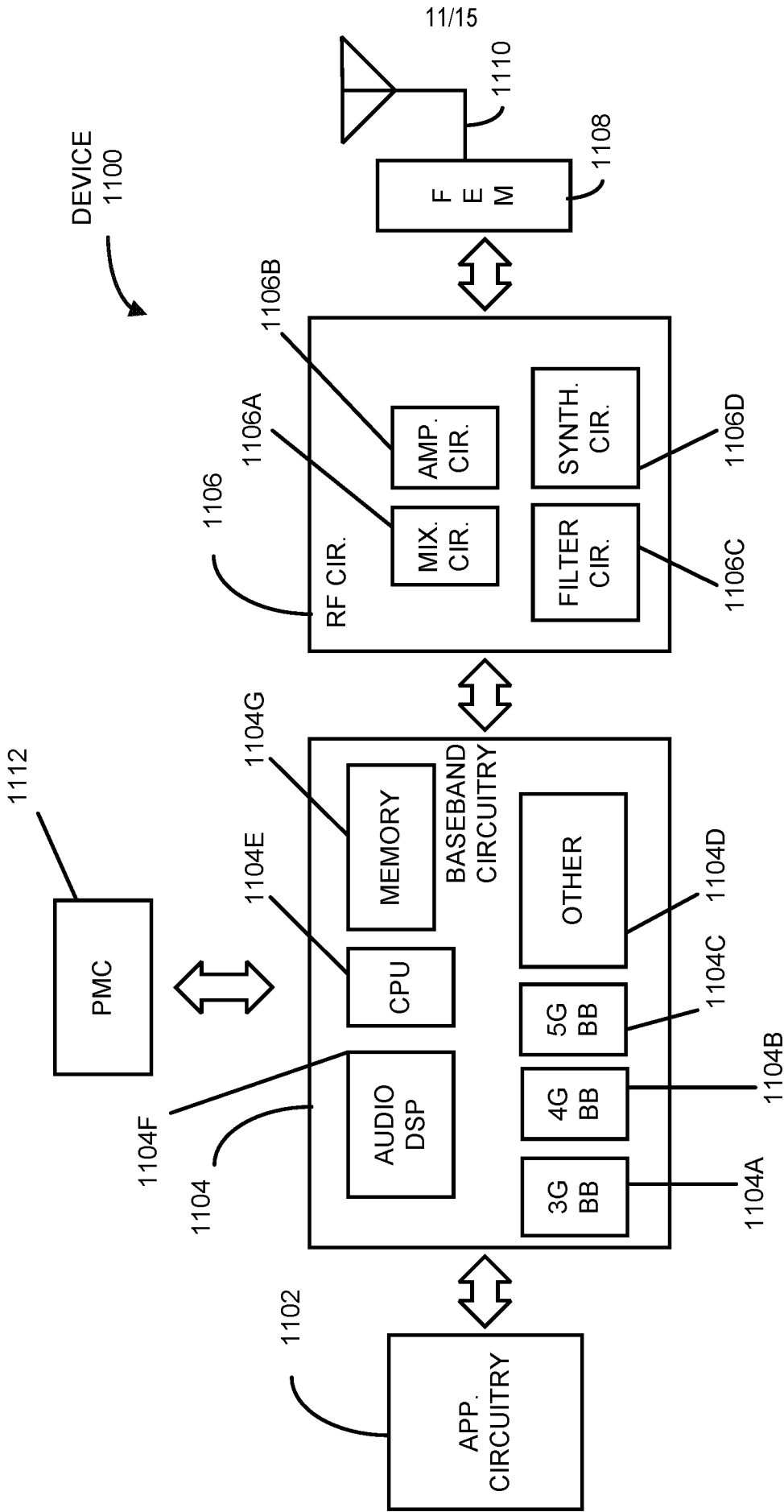


FIG. 11

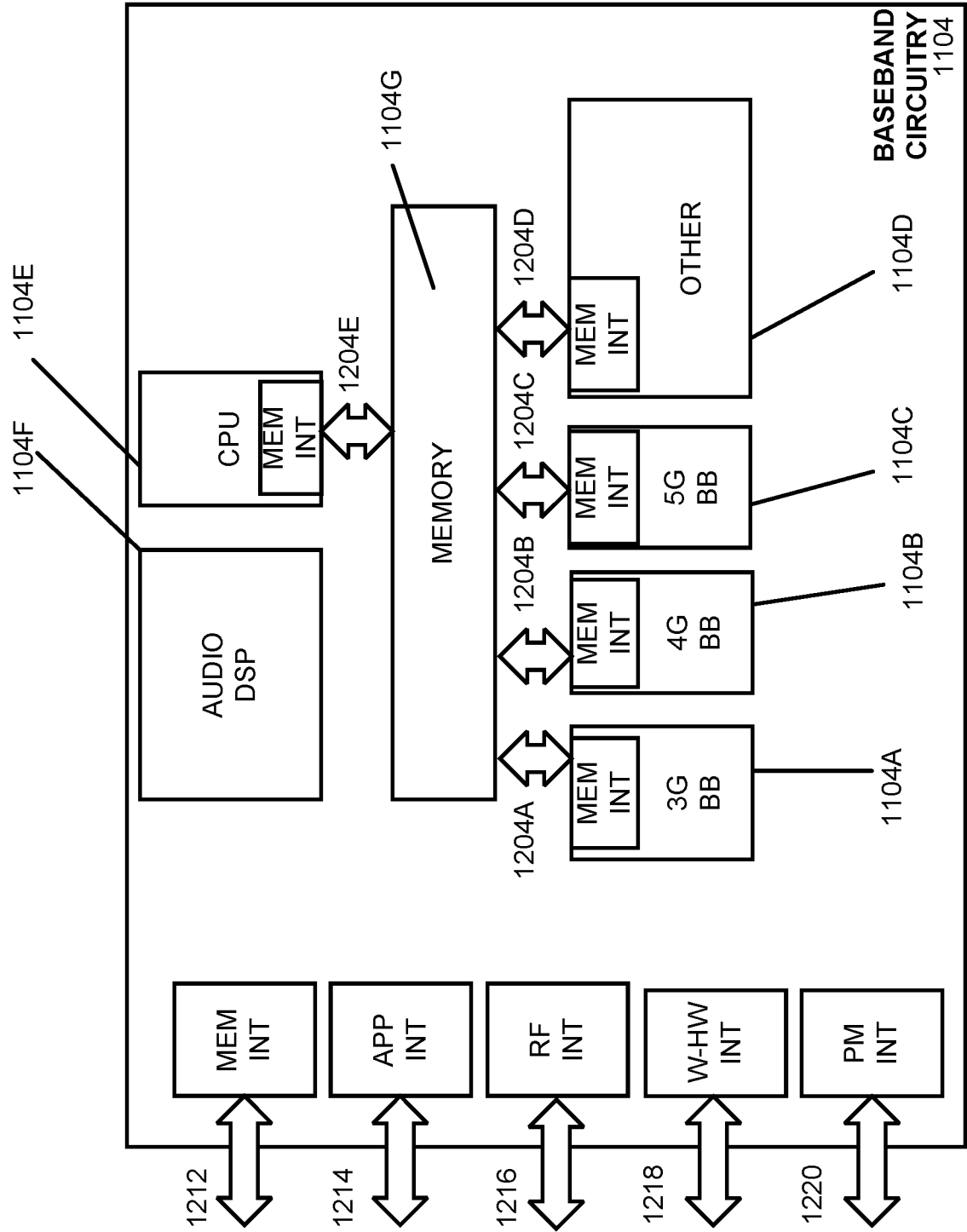


FIG. 12

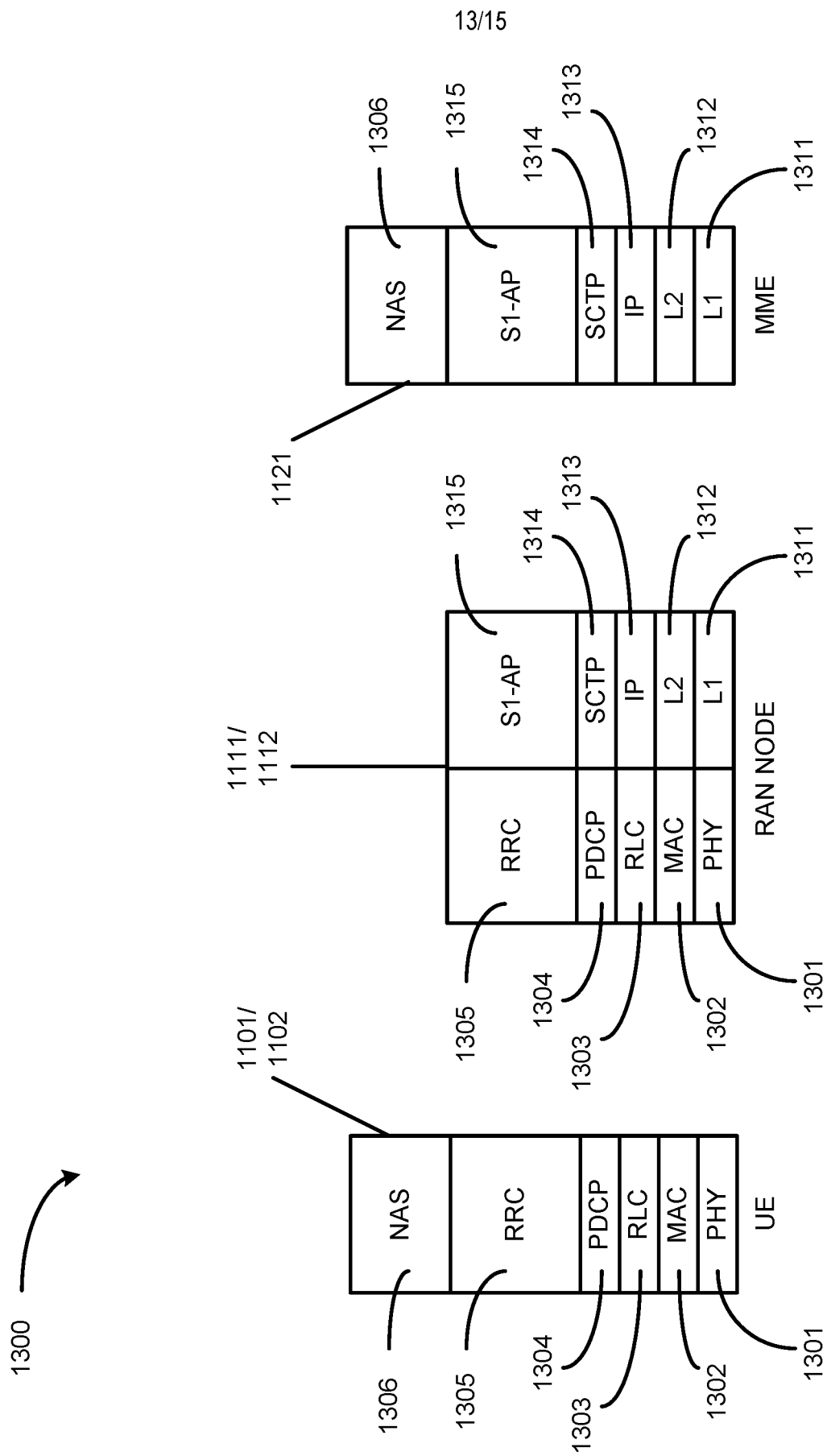


FIG. 13

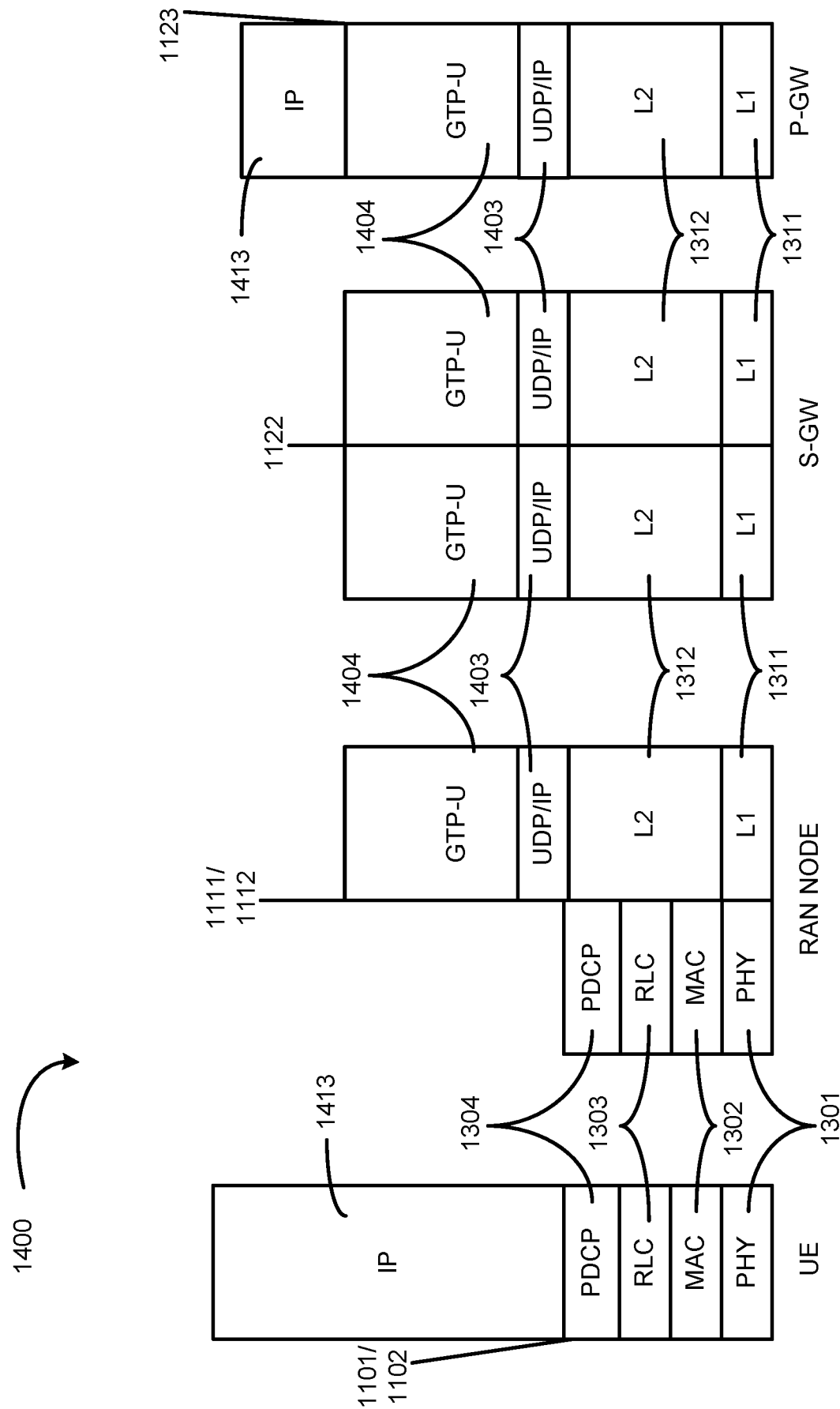


FIG. 14

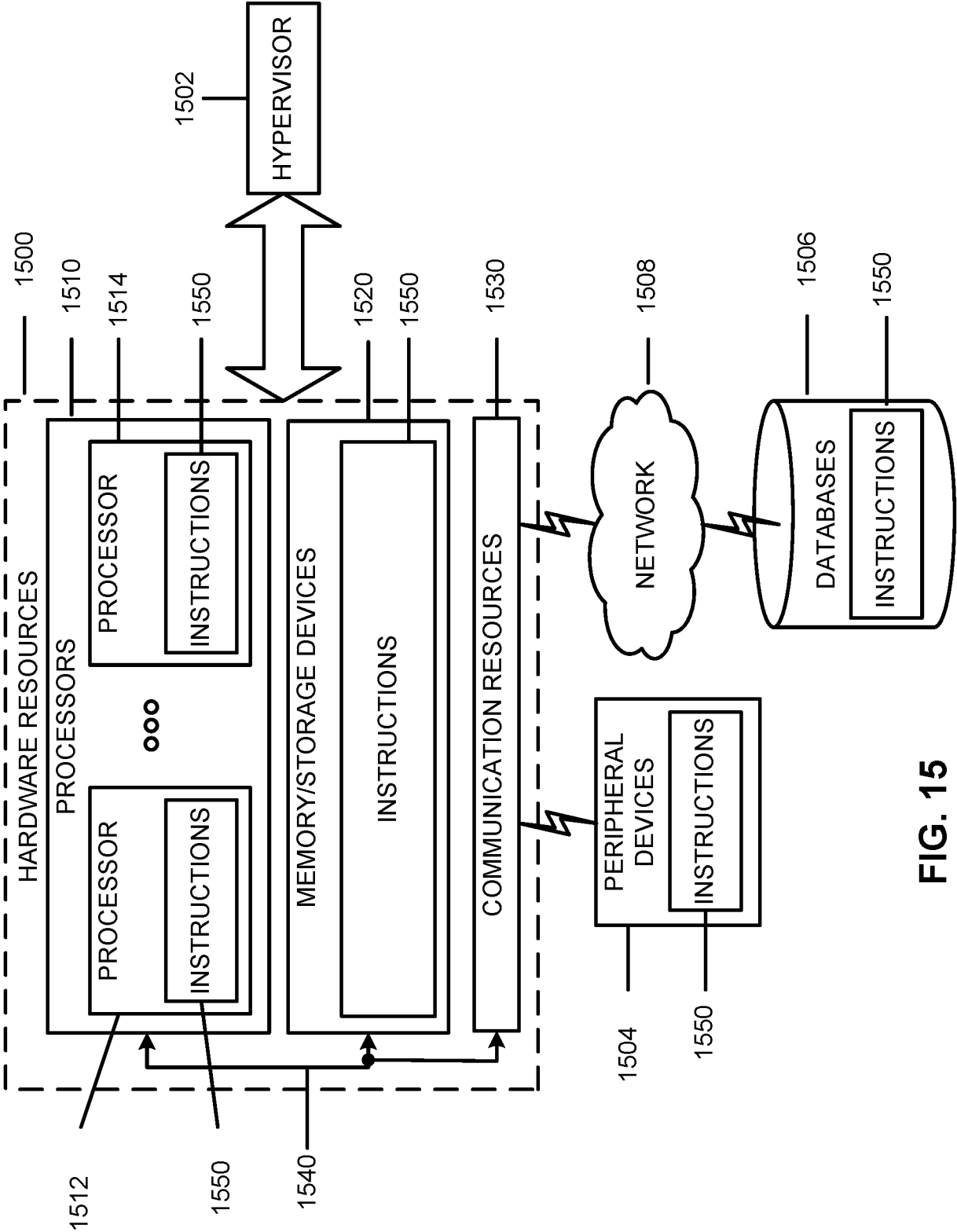


FIG. 15

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/045163

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W76/02

ADD. H04W12/06 H04W88/04

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	"3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Study on extended architecture support for proximity-based services (Release 13)", 3GPP STANDARD; 3GPP TR 23.713, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. SA WG2, no. V13.0.0, 15 September 2015 (2015-09-15), pages 1-80, XP051294298, page 37 page 41 - page 51 ----- -/-	1,4-7



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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

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

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

2 November 2017

Date of mailing of the international search report

16/01/2018

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
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Authorized officer

Lastoria, Gianluca

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/045163

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-7

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/045163

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2016/116128 A1 (ERICSSON TELEFON AB L M [SE]) 28 July 2016 (2016-07-28) page 1, line 30 - page 2, line 9; figures 1,2 page 17, line 30 - page 22, line 5; figure 10	1-5
A	----- HUAWEI ET AL: "L2 UE Relay technology consideration for wearable", 3GPP DRAFT; R2-162642 L2 RELAY TECHNOLOGY CONSIDERATION FOR WEARABLE, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; F , vol. RAN WG2, no. Dubrovnik, Croatia; 20160411 - 20160415 2 April 2016 (2016-04-02), XP051082482, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_93bis/Docs/ [retrieved on 2016-04-02] the whole document	1-7
A	----- ZTE: "Considerations on the UE-to-Network Relays", 3GPP DRAFT; R2-151169 - CONSIDERATIONS ON THE UE-TO-NETWORK RELAYS, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRA , vol. RAN WG2, no. Bratislava, Slovakia; 20150420 - 20150424 19 April 2015 (2015-04-19), XP050936143, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN2/Docs/ [retrieved on 2015-04-19] the whole document ----- -/--	1-6

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/045163

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	HUAWEI ET AL: "Procedures of the remote UE connection establishment with CN via a relay UE", 3GPP DRAFT; R2-165461, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG2, no. Gothenburg, Sweden; 20160822 - 20160826 13 August 2016 (2016-08-13), XP051142822, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_95/Docs/ [retrieved on 2016-08-13] the whole document -----	1-7

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2017/045163

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2016116128 A1	28-07-2016	EP 3248404 A1	29-11-2017
		US 2016345169 A1	24-11-2016
		US 2017311157 A1	26-10-2017
		WO 2016116128 A1	28-07-2016

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-7

User equipment [UE], comprising: (a1) a memory interface to store or access a relay UE identifier [ID] in a memory; and (b1) baseband processor circuitry configured to: (c1) perform a UE discovery to identify a relay UE having the relay UE ID; (d1) generate a direct communication request for the relay UE utilizing the relay UE ID; (e1) perform mutual authentication with the relay UE, (f1) based on receiving approval from the relay UE for the direct communication request, (g1) to obtain an authorization from a radio access network [RAN] node to relay data to the RAN node; and (h1) generate a device-to-device (D2D) message to provide, via a D2D link, (i1) data to the relay UE to communicate with the RAN node in response to performing mutual authentication.

2. claims: 8-19

User equipment [UE], comprising: (a2=a1) a memory interface to store or access a remote UE identifier [ID] in a memory; and (b2=b1) baseband processor circuitry configured to: (c2) authenticate a remote UE having the remote UE ID; (d2=f1) obtain an authorization from a radio access network [RAN] node to relay data to the RAN node; (e2) process the data received from the remote UE via a wireless local area network [WLAN] interface; (f2) based on the authorization, generate service data units [SDUs] comprising the data received from the remote UE; and (g2) encode an (h2) uplink message to communicate the SDUs to a RAN node utilizing a wide area network [WAN] interface.

3. claims: 20-22

Computer-readable storage medium having stored thereon instructions that, when implemented by a radio access network [RAN] node, cause the RAN node to: (a3=a1) store a plurality of user equipment [UE] identifiers [IDs] corresponding to relay UEs; (b3) generate a first radio resource control [RRC] message to configure the relay UEs to relay data to a plurality of remote UEs; (c3) generate a second RRC message for a remote UE from the plurality of remote UEs to provide the remote UE with the plurality of UE IDs of the relay UEs; (d3) decode sidelink information identifying a relay UE from the relay UEs and the remote UE; (e3) assign a data radio bearer [DRB] ID to a relay UE to map the remote UE's data received over a layer 2 relay to a DRB having the DRB ID; and (f3) generate a configuration message to configure the relay UE to forward data received via a wireless local area network [WLAN] access

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

device-to-device [D2D] based layer 2 indirect connection
utilizing the DRB.
