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(54) **QOS MAPPING FOR INTEGRATED ACCESS BACKHAUL SYSTEMS**

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(57) **ABSTRACT**

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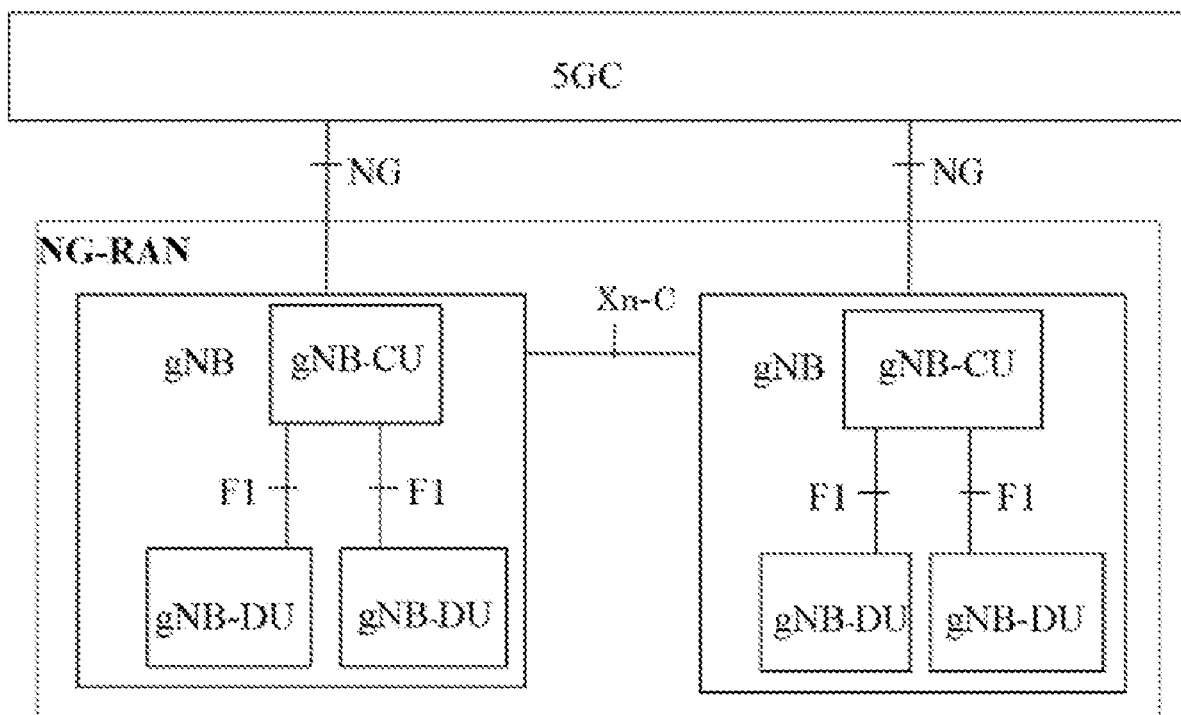
§ 371 (c)(1),

(2) Date: **Dec. 14, 2020**

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According to some embodiments of the invention, a number of hops from a donor node to an integrated access backhaul relay node, IAB node, is determined (3402). The number of hops is stored (3404) for subsequent use in mapping packets to a backhaul bearer between the donor node and the IAB node.



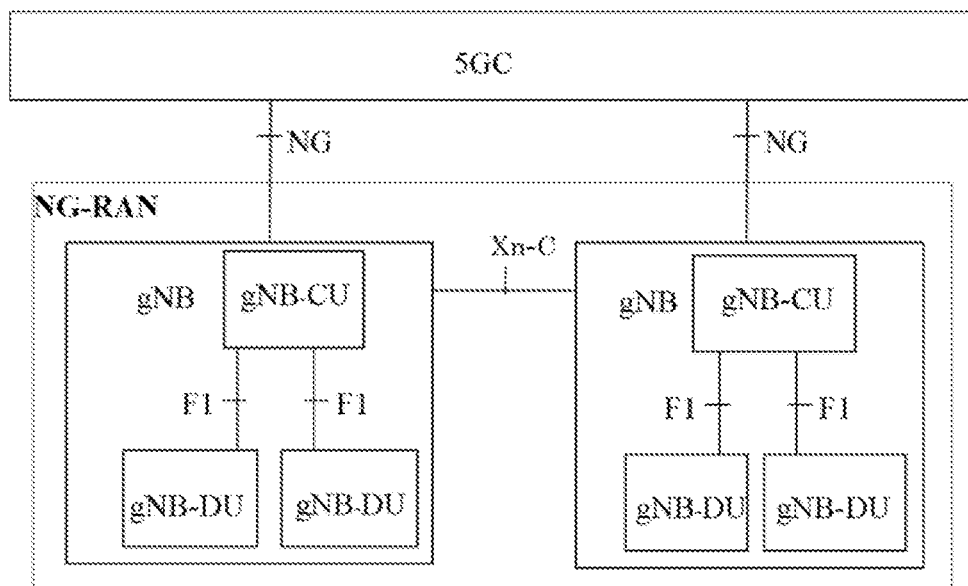


FIG. 1

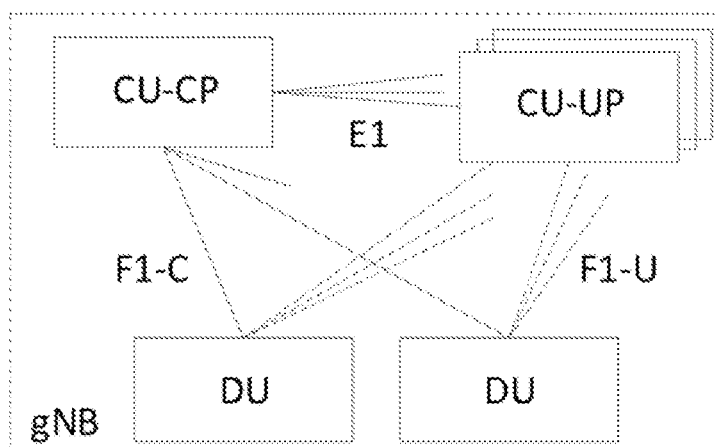


FIG. 2

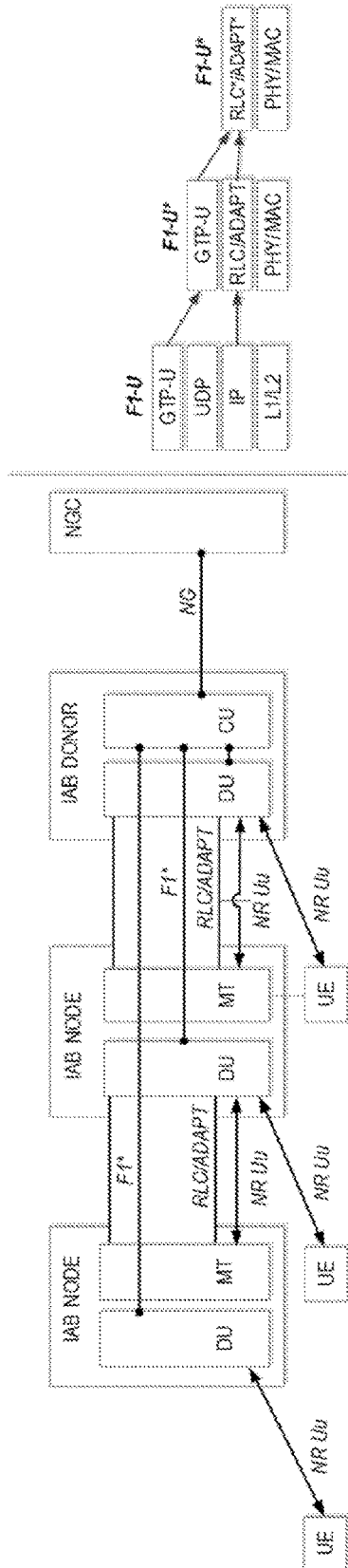


FIG. 3

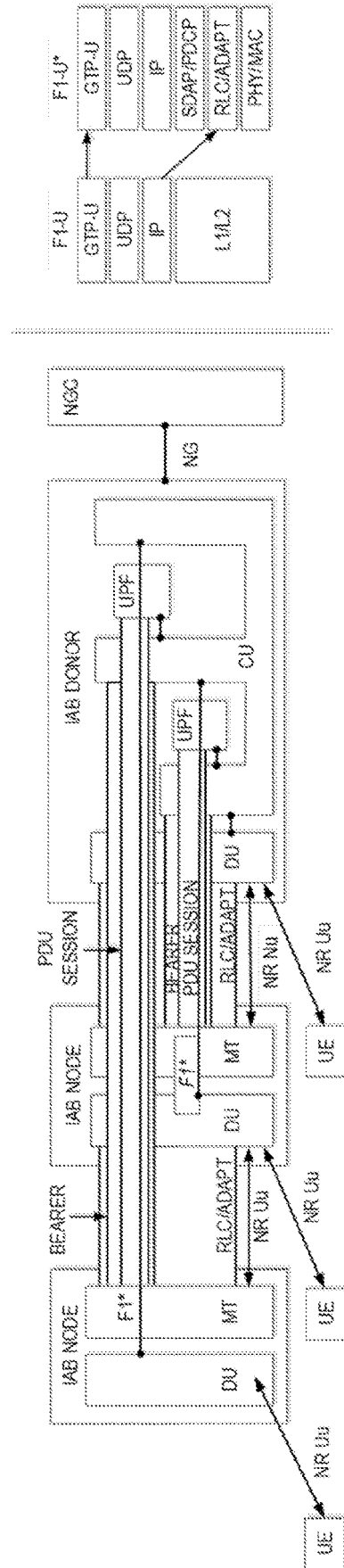
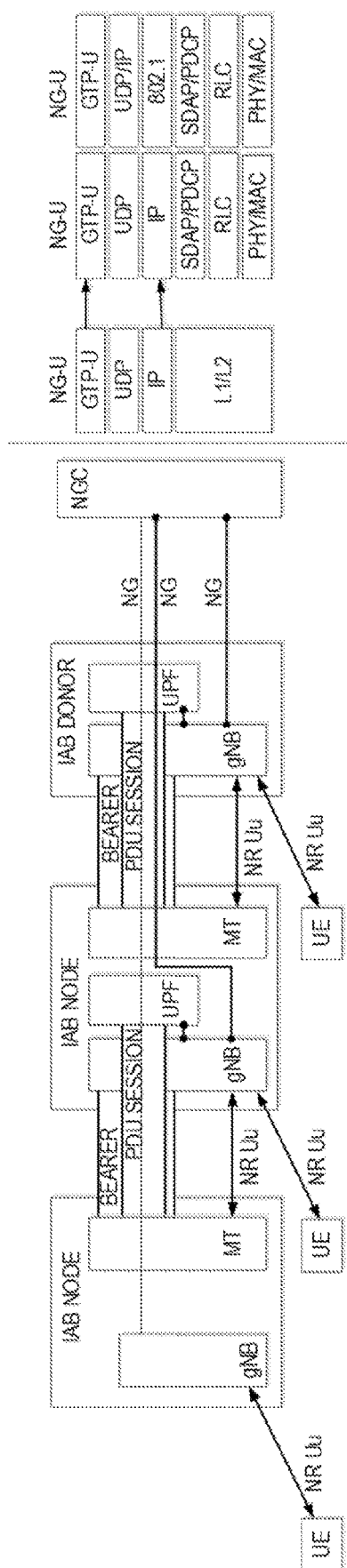
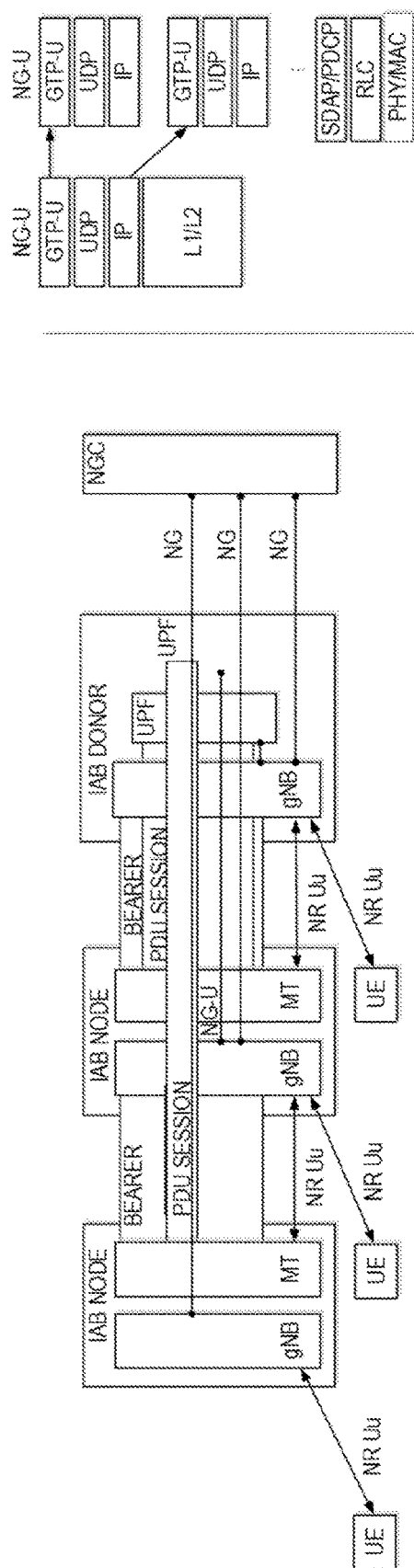


FIG. 4



**FIG. 5**



**FIG. 6**

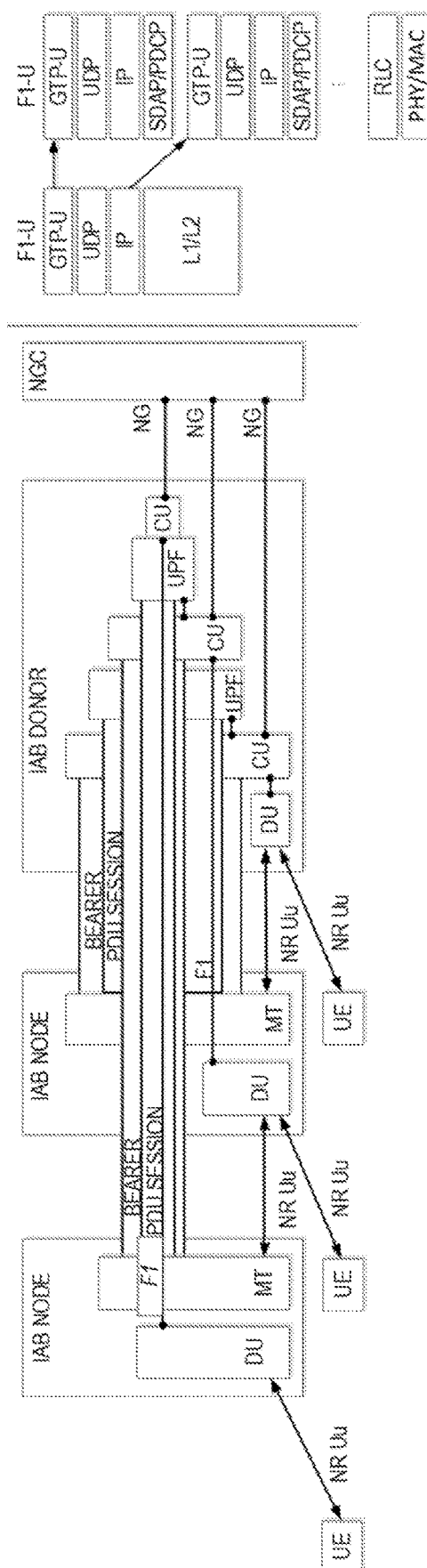
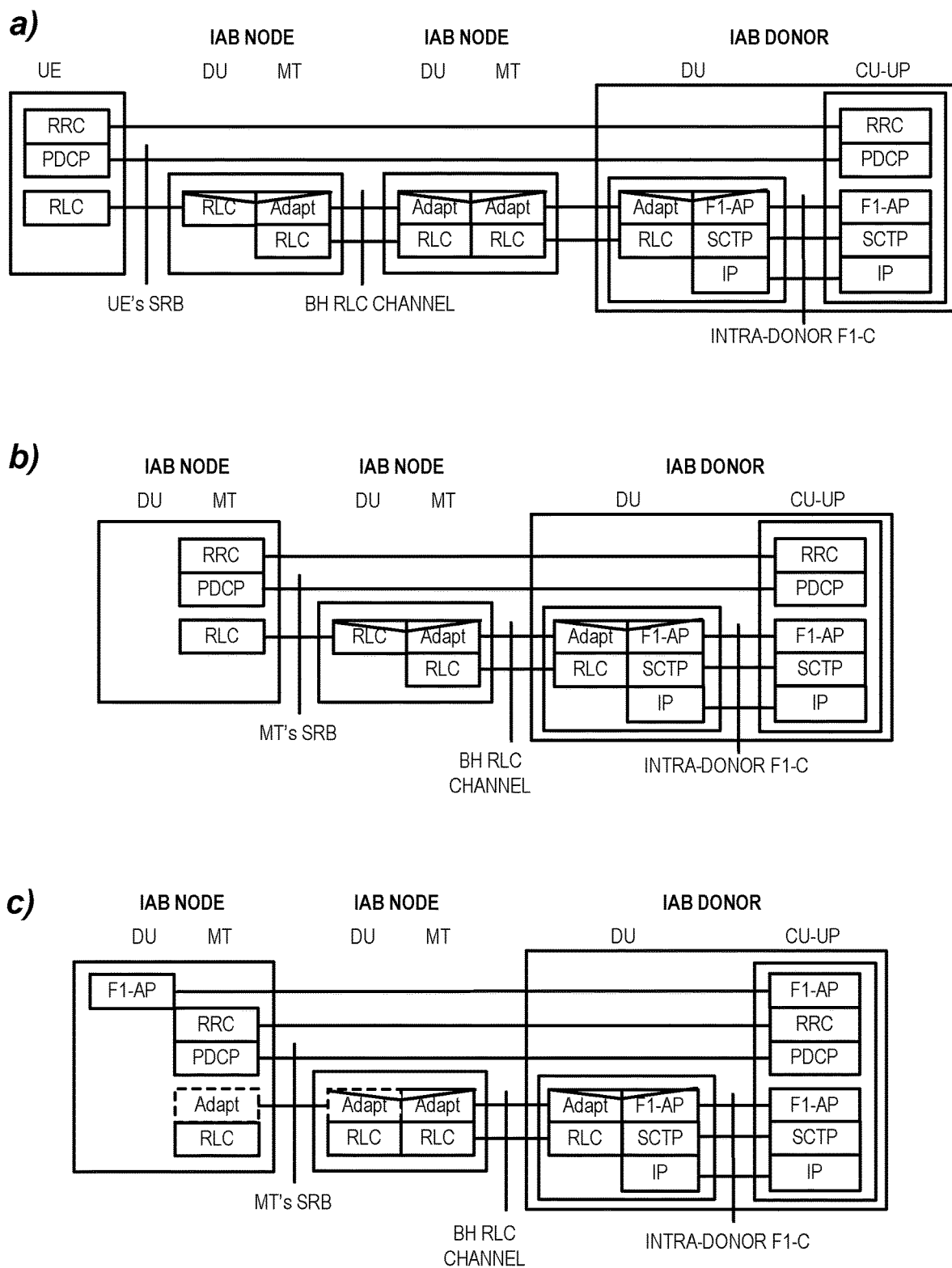
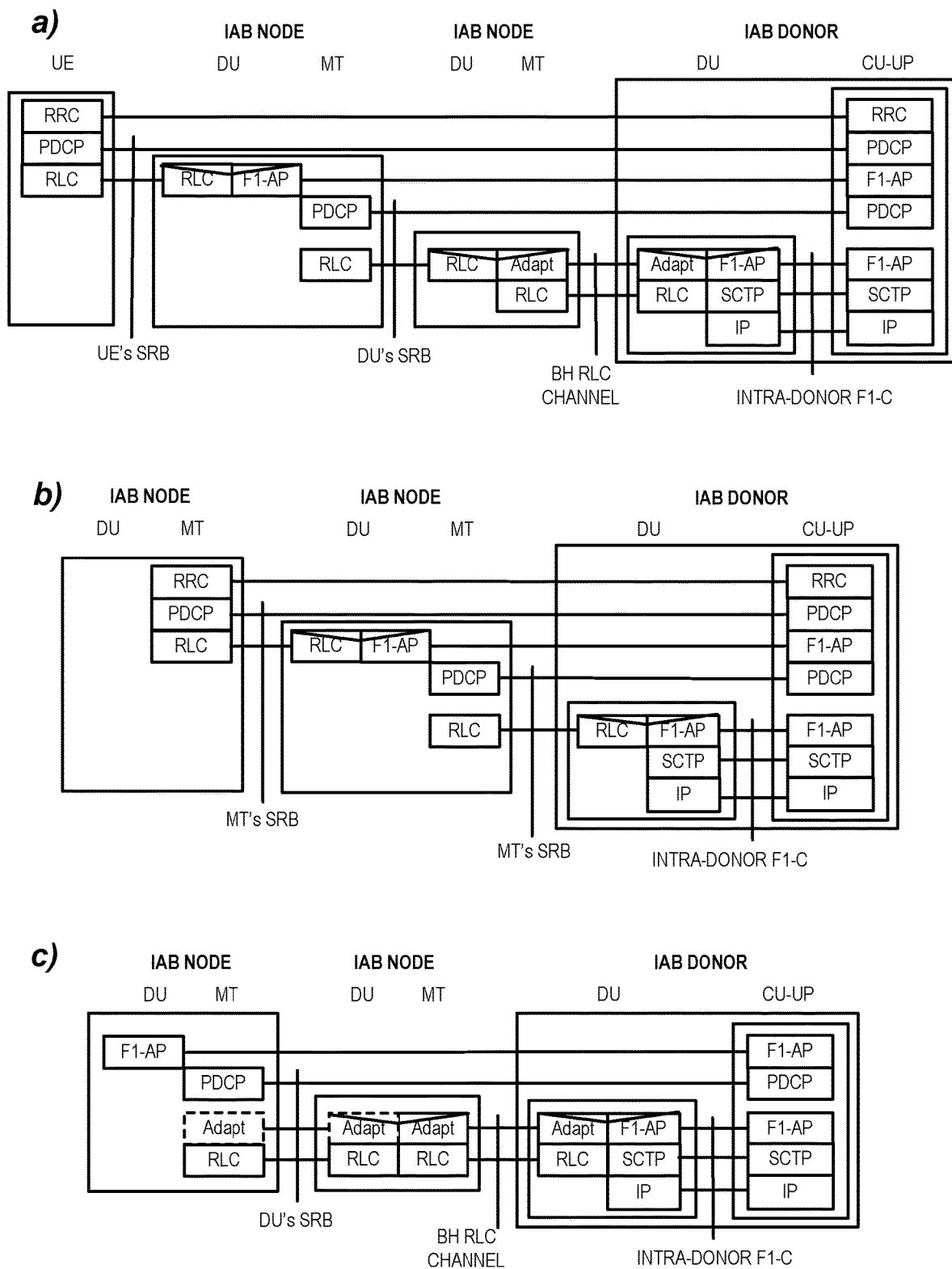


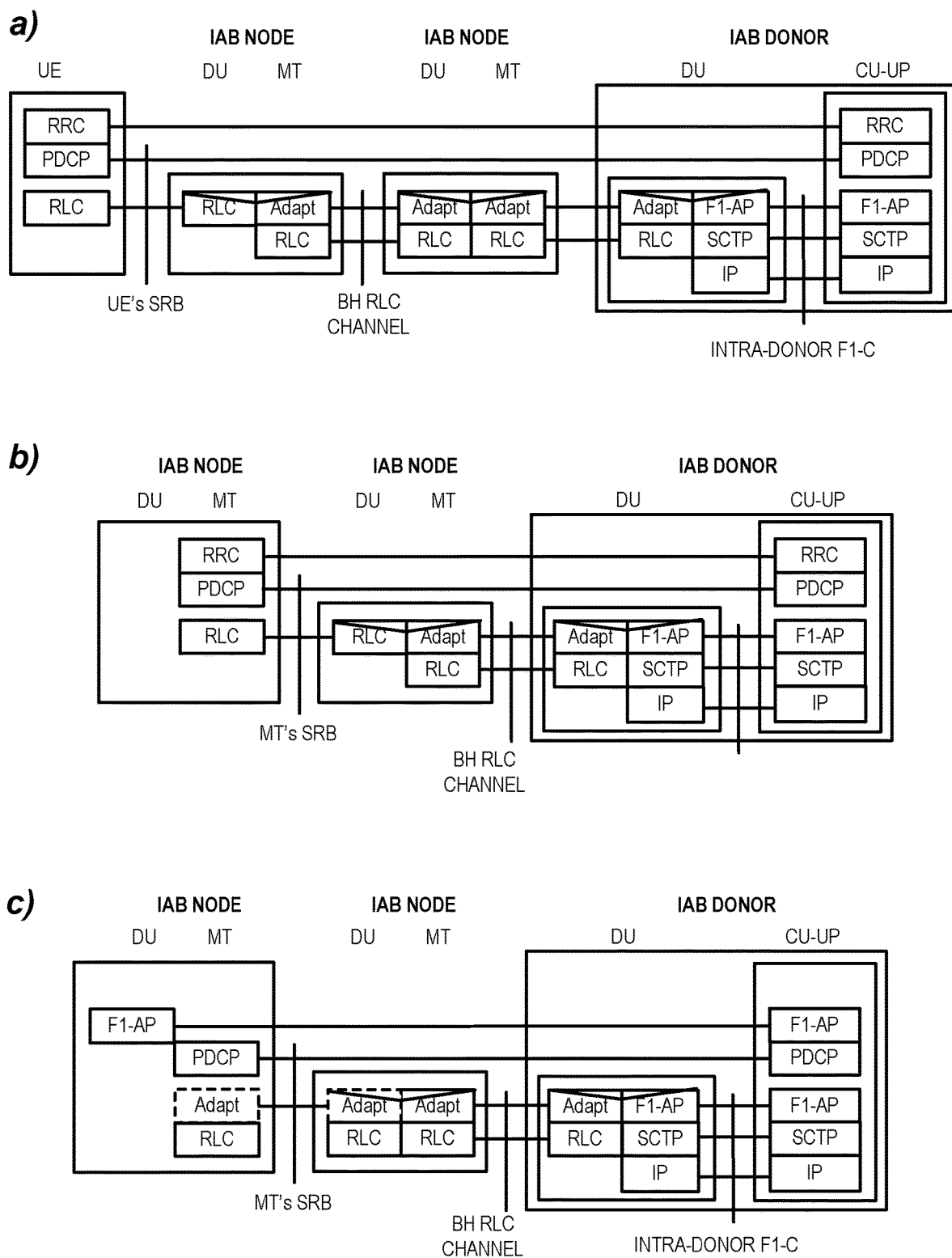
FIG. 7



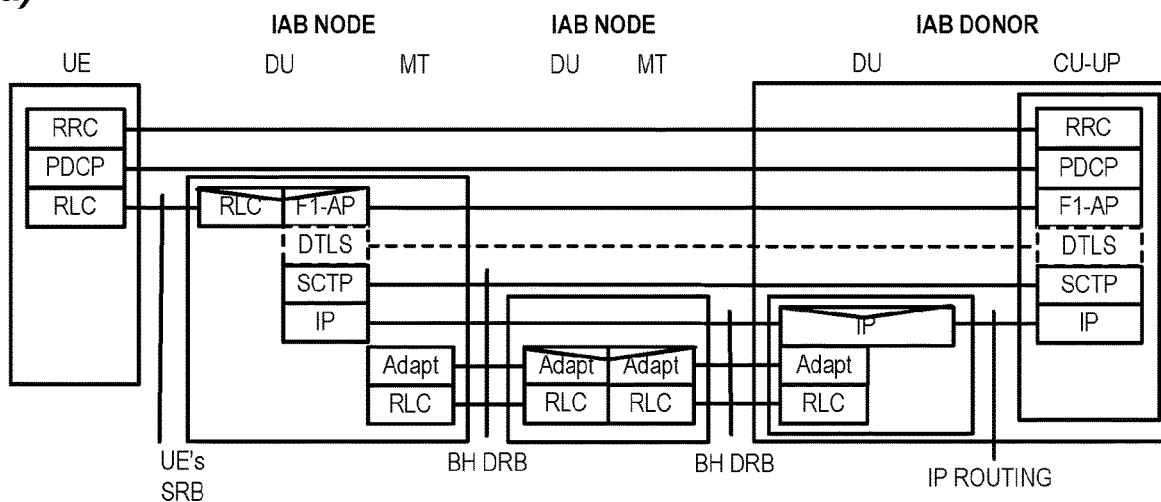
**FIG. 8**



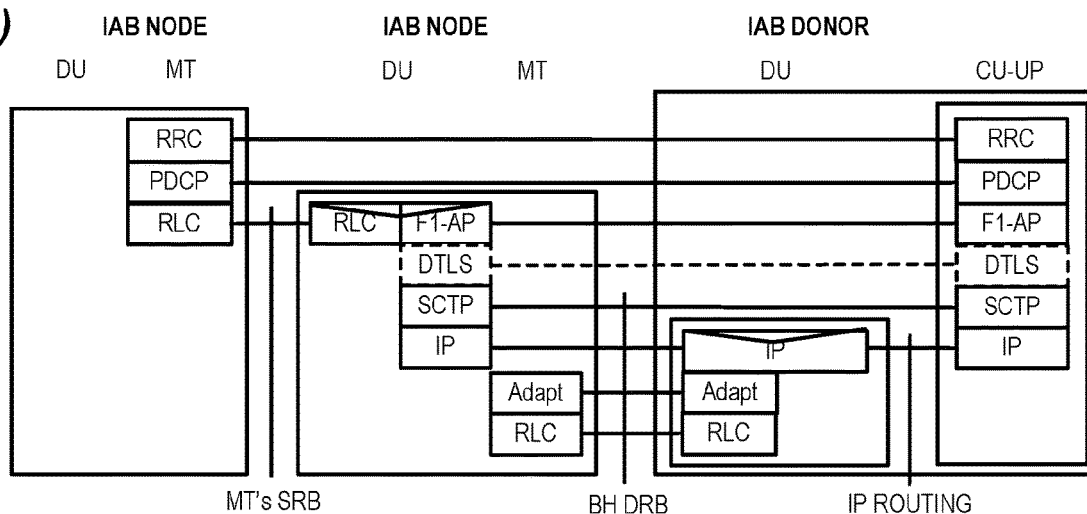
**FIG. 9**



a)



b)



c)

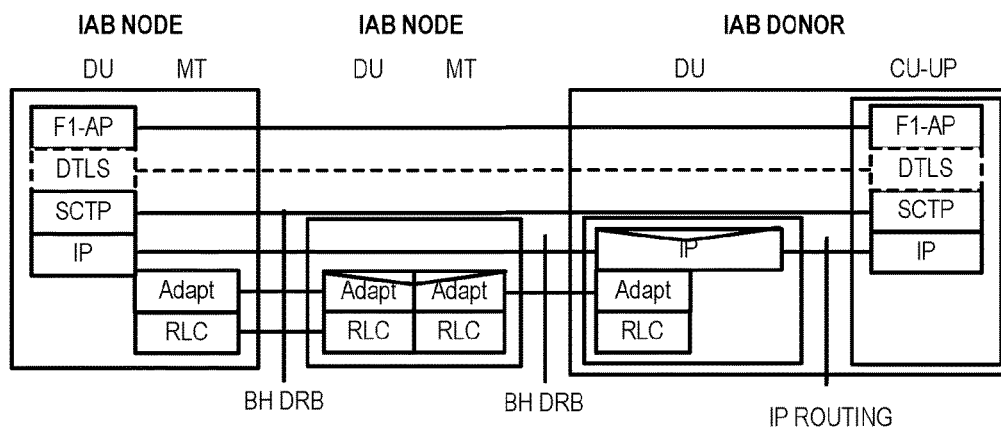


FIG. 11

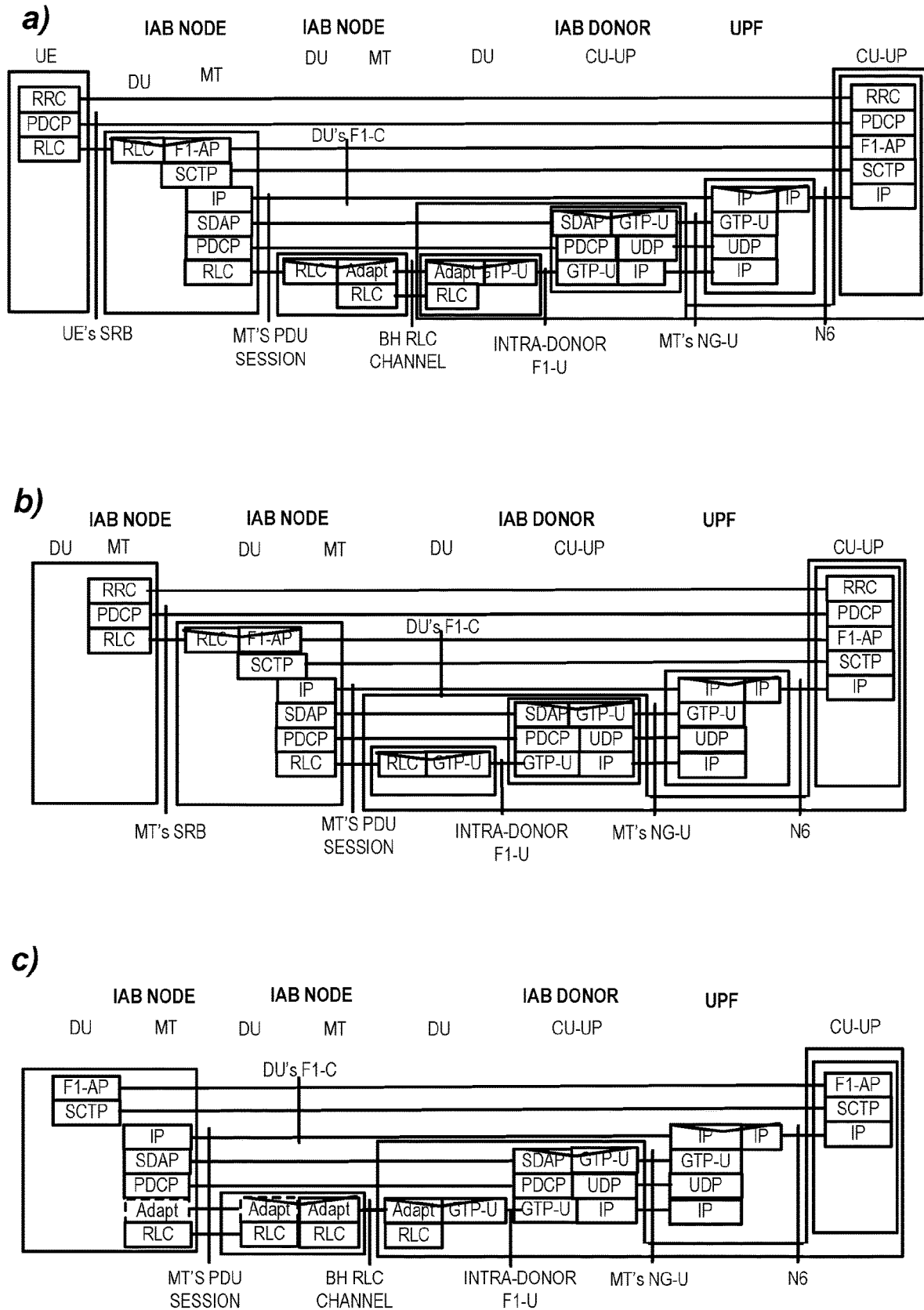
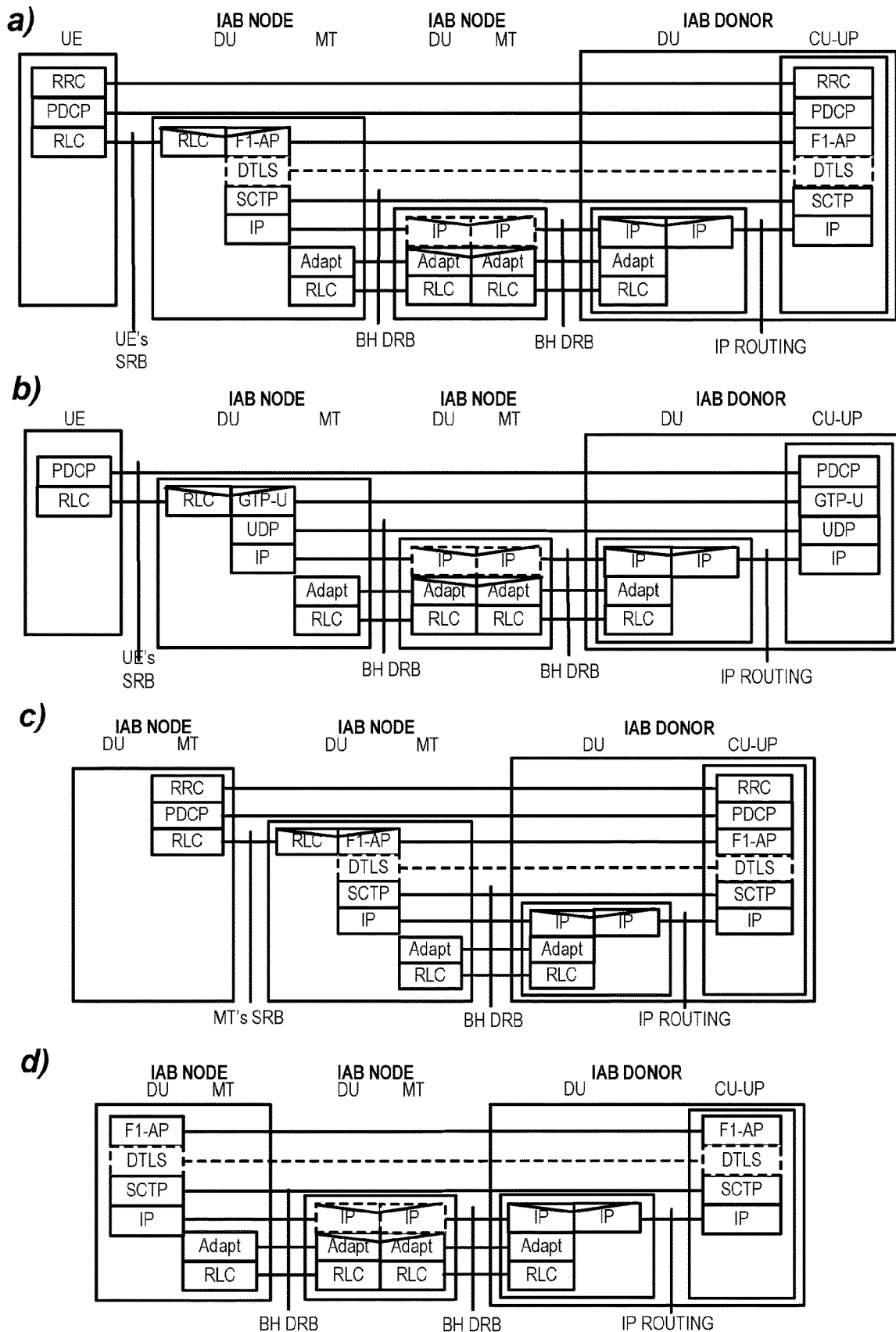
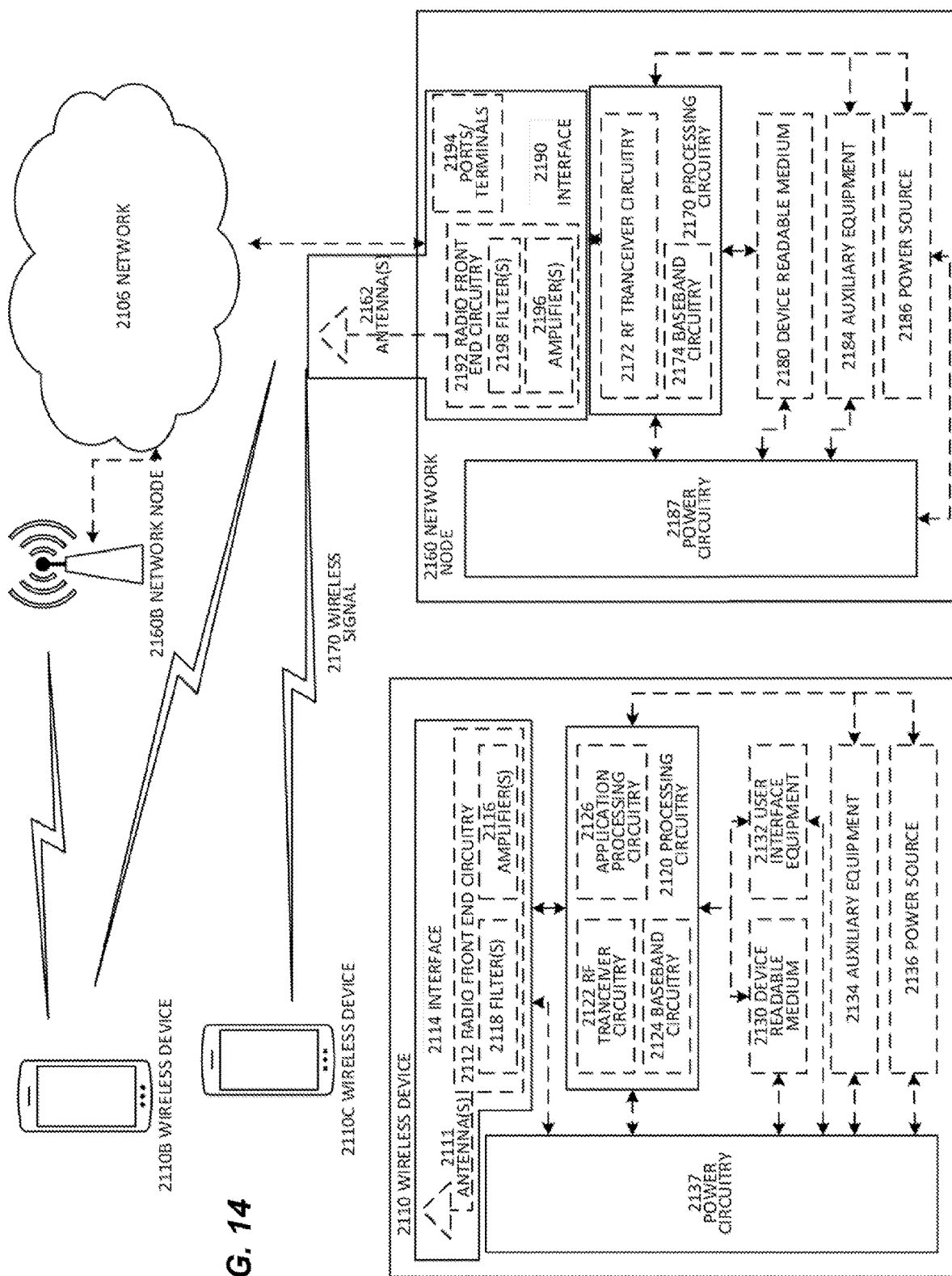


FIG. 12



**FIG. 13**



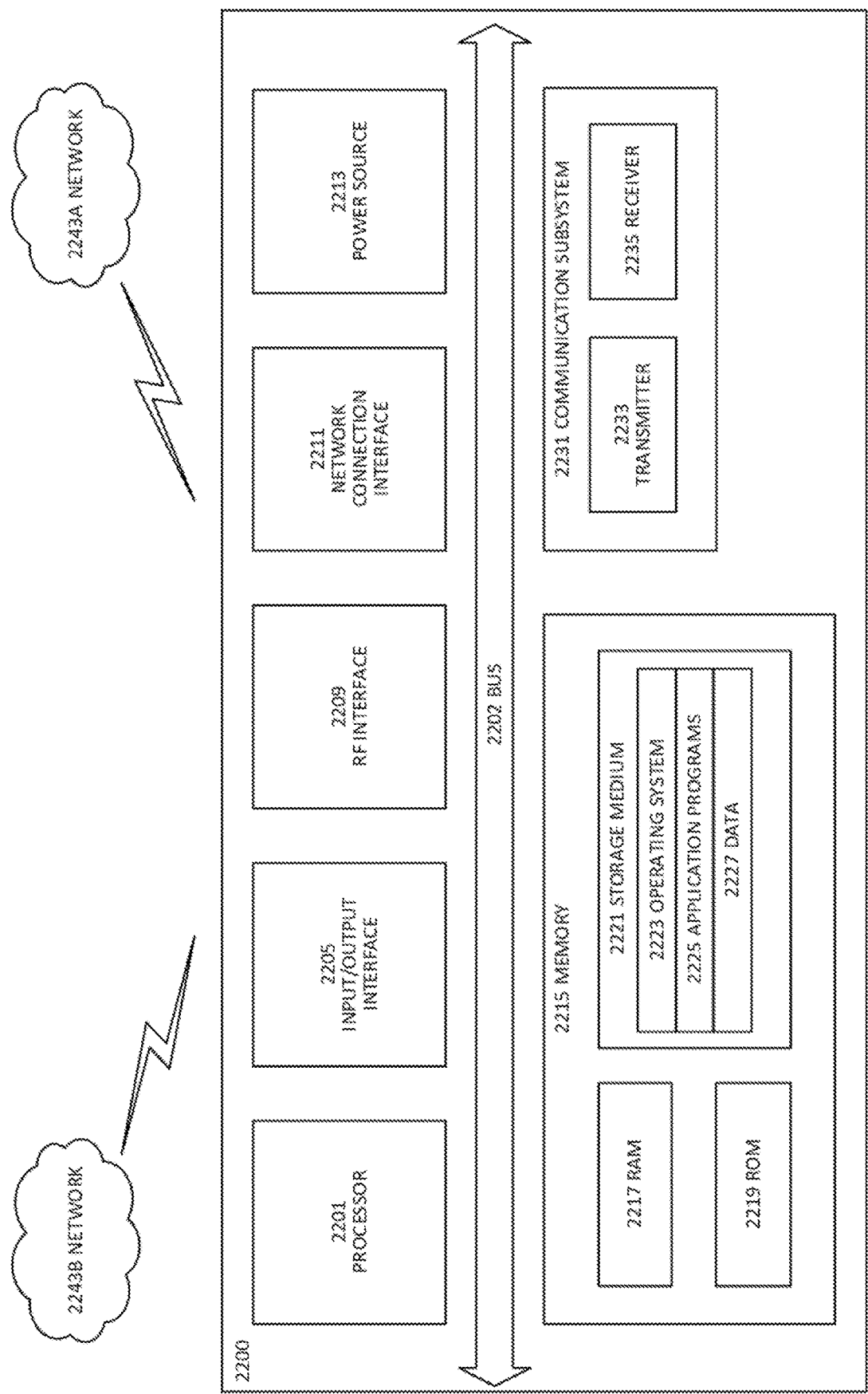


FIG. 15

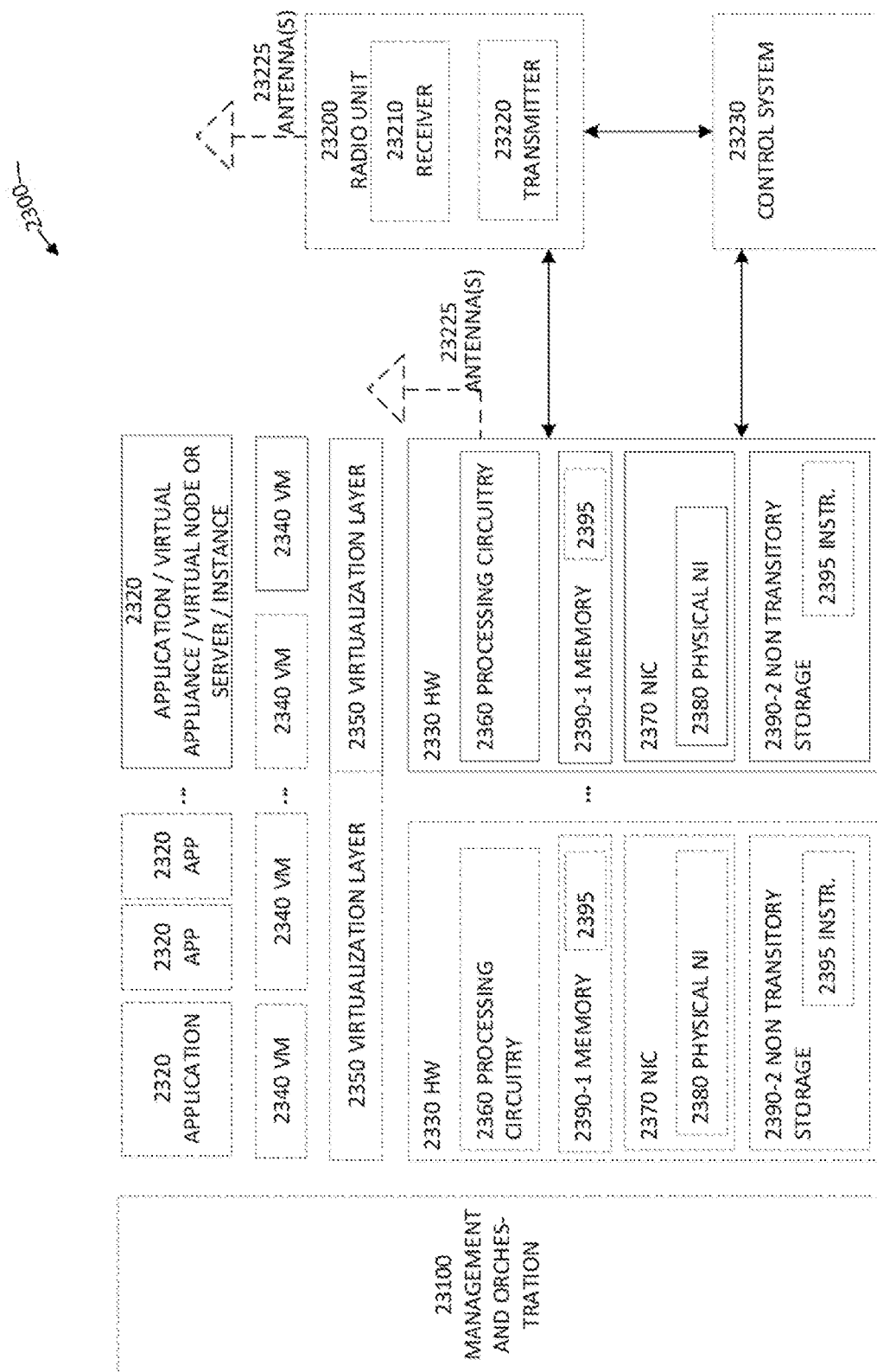


FIG. 16

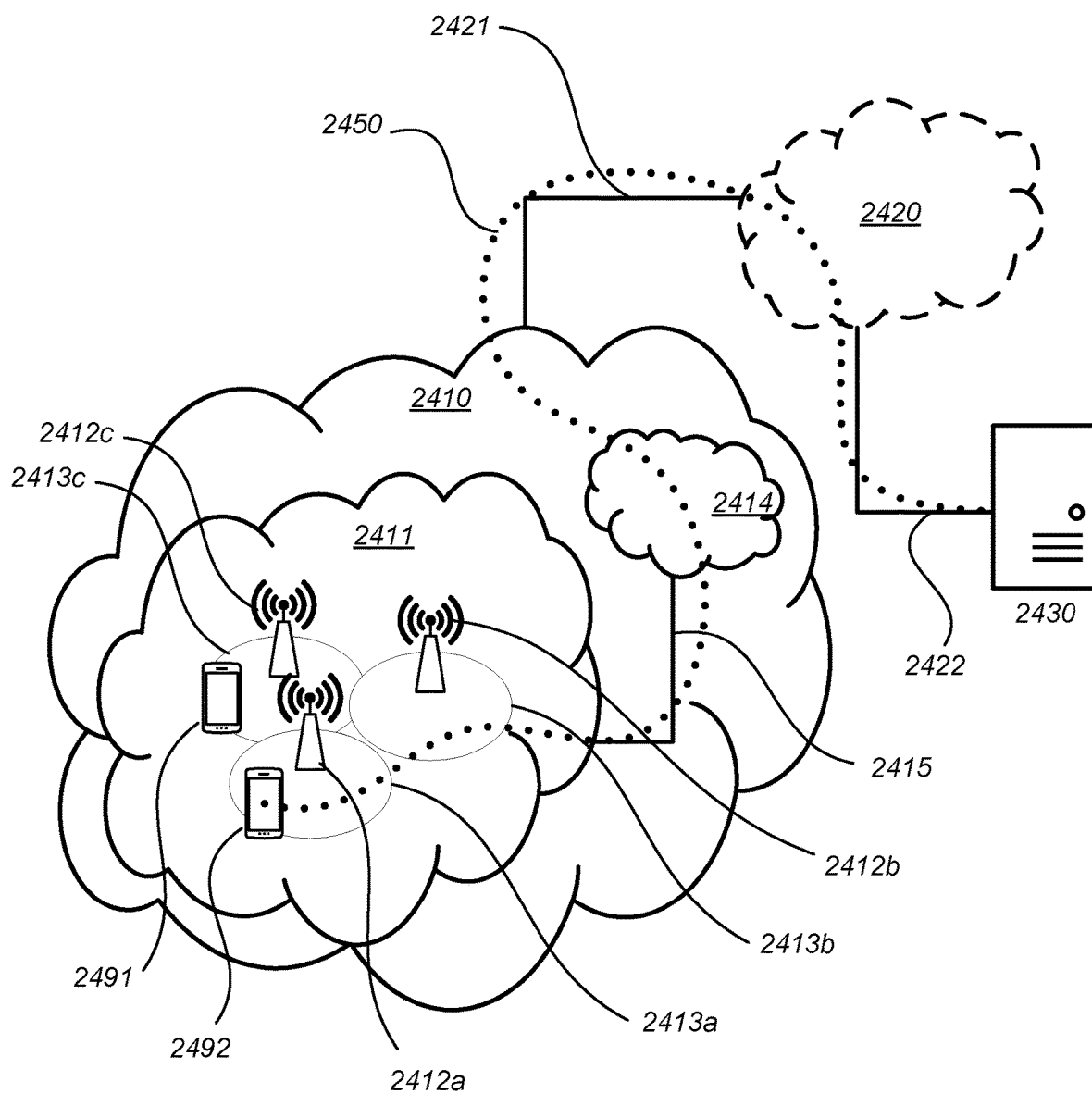


FIG. 17

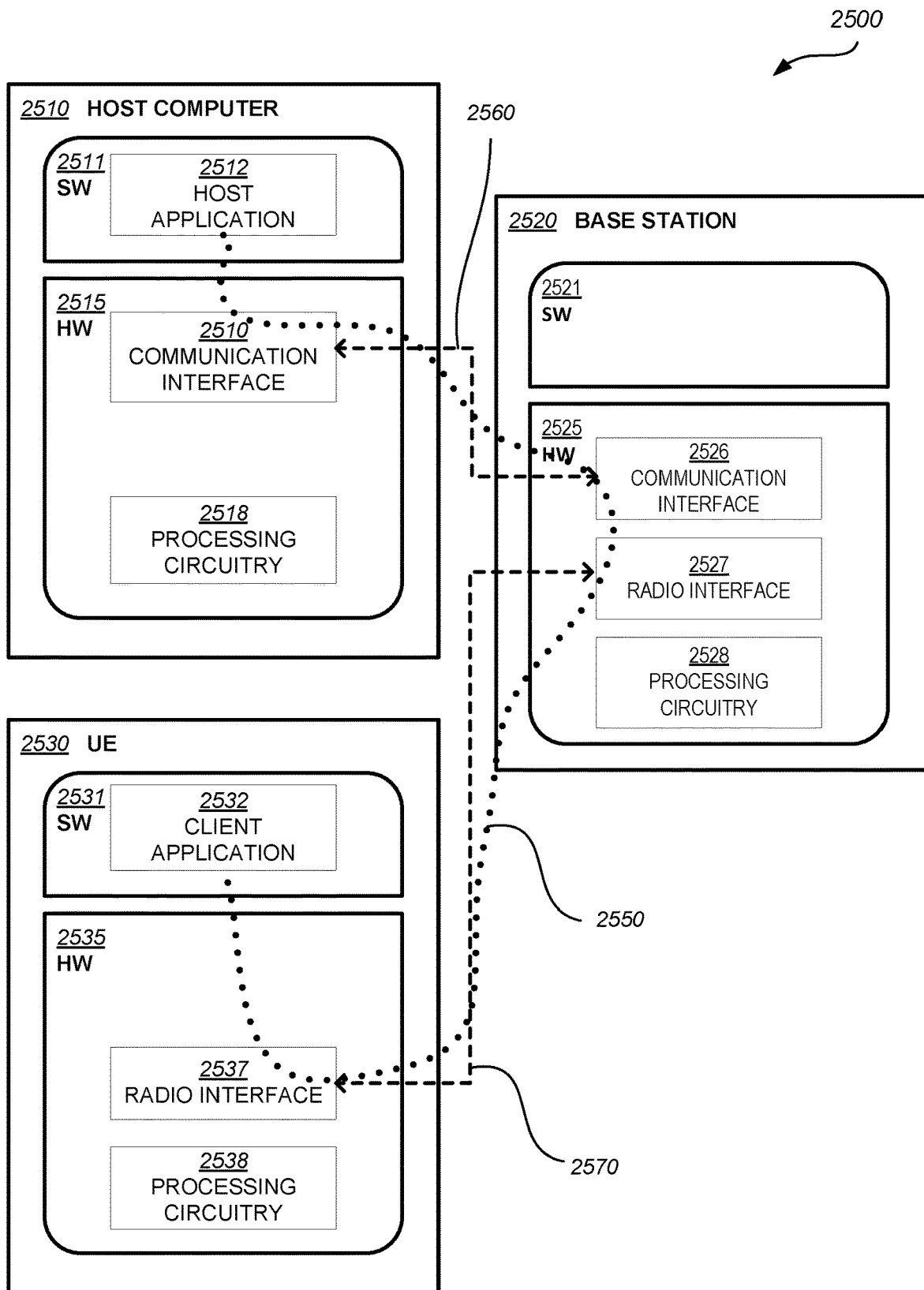
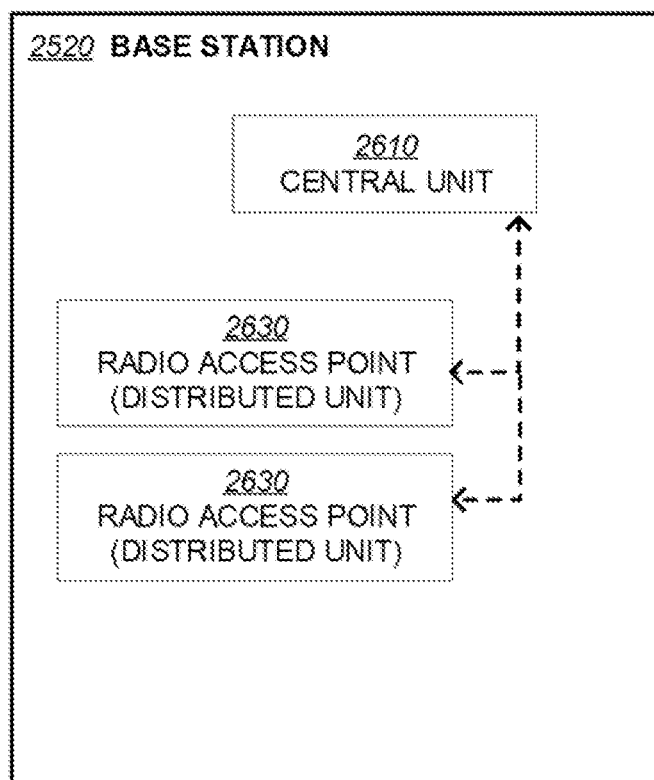
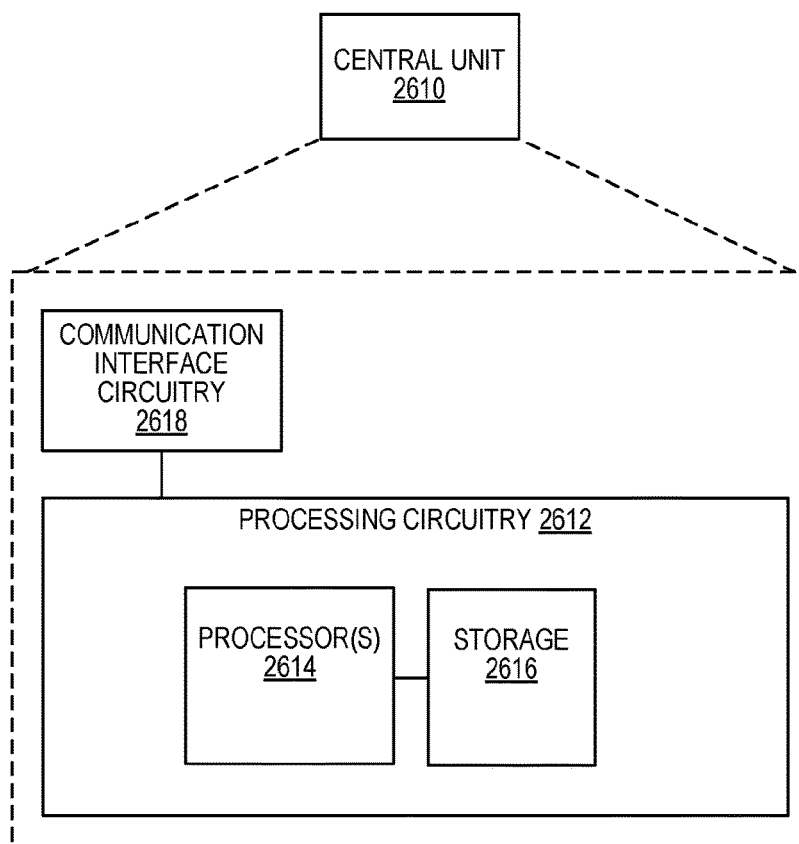


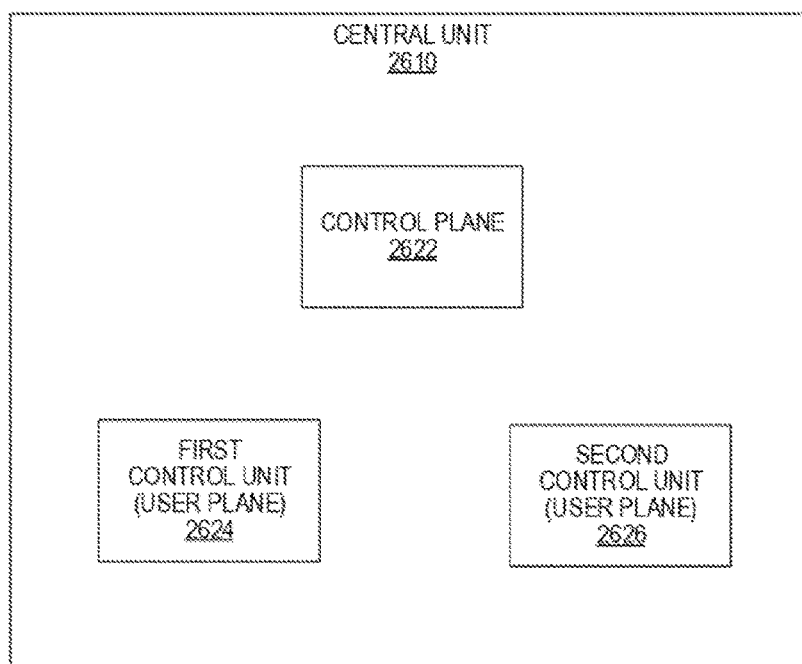
FIG. 18



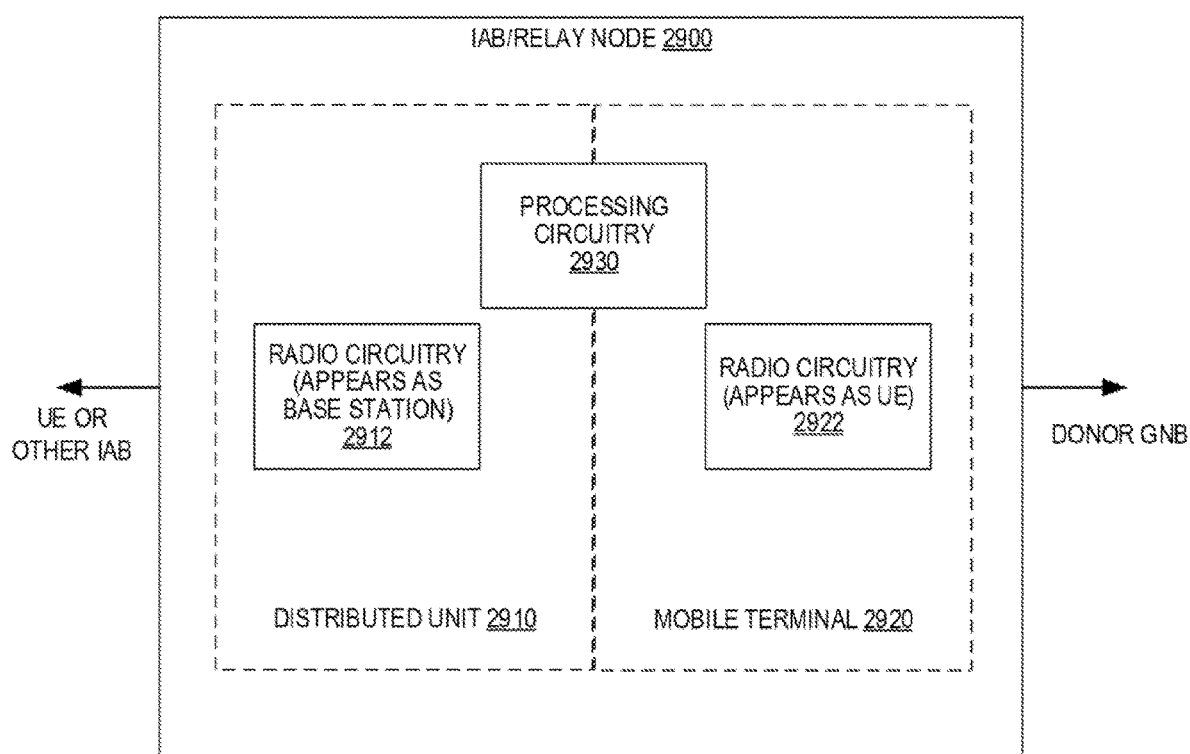
**FIG. 19**



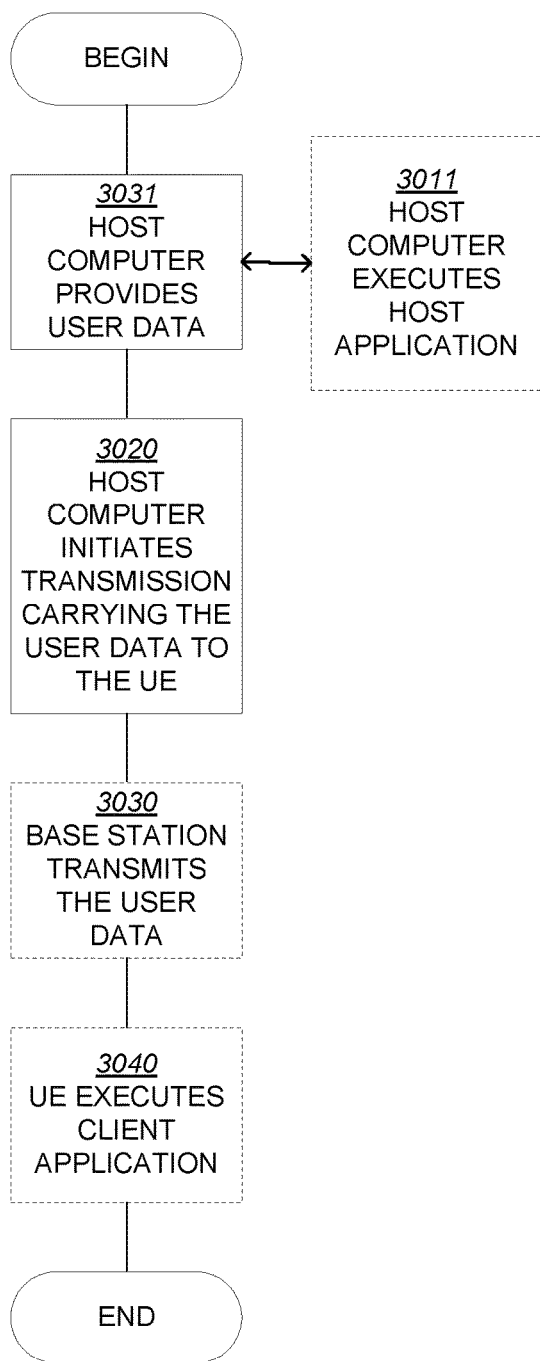
**FIG. 20**



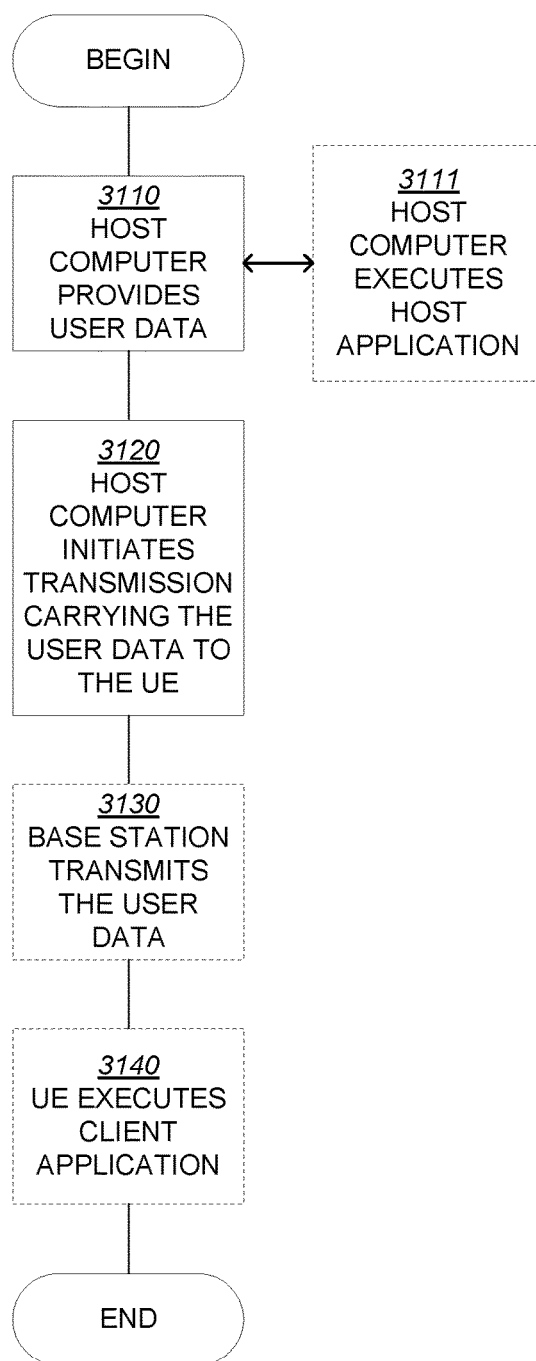
**FIG. 21**



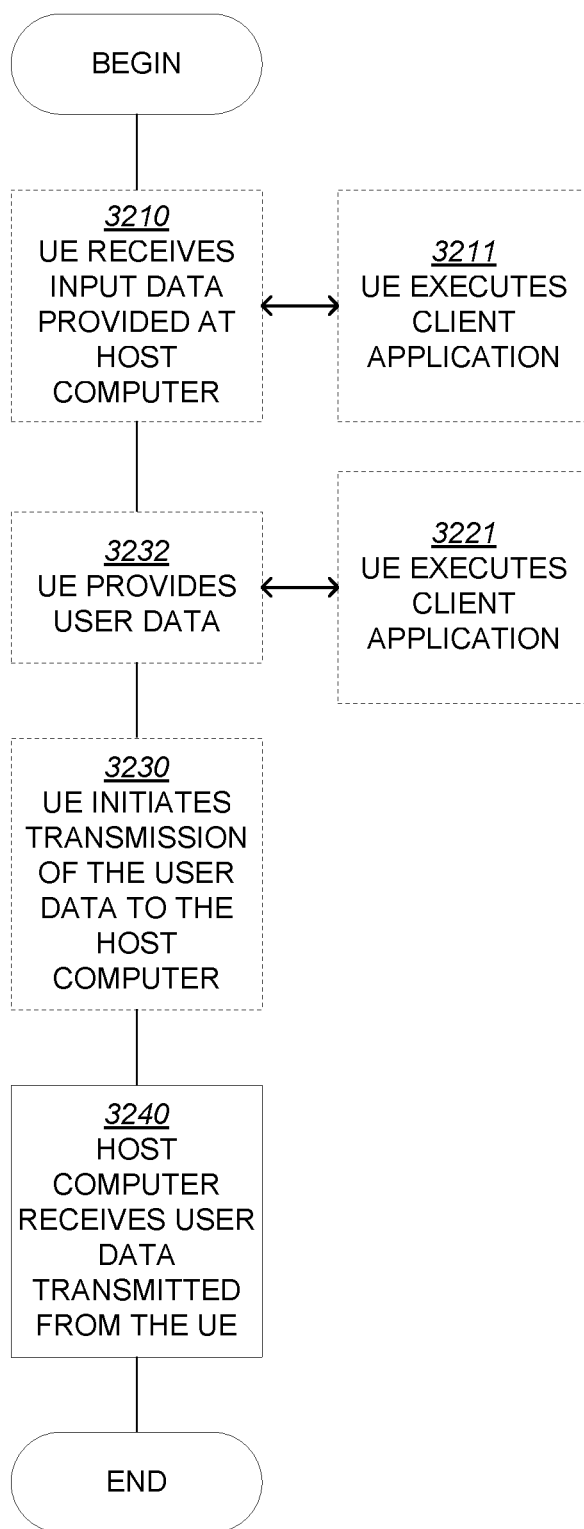
**FIG. 22**



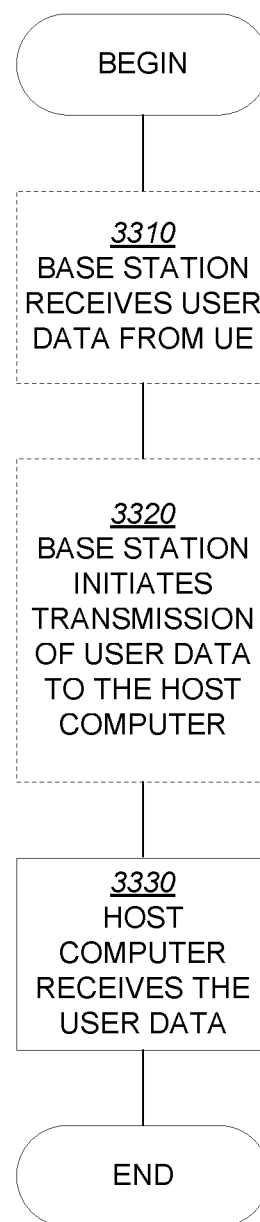
**FIG. 23**



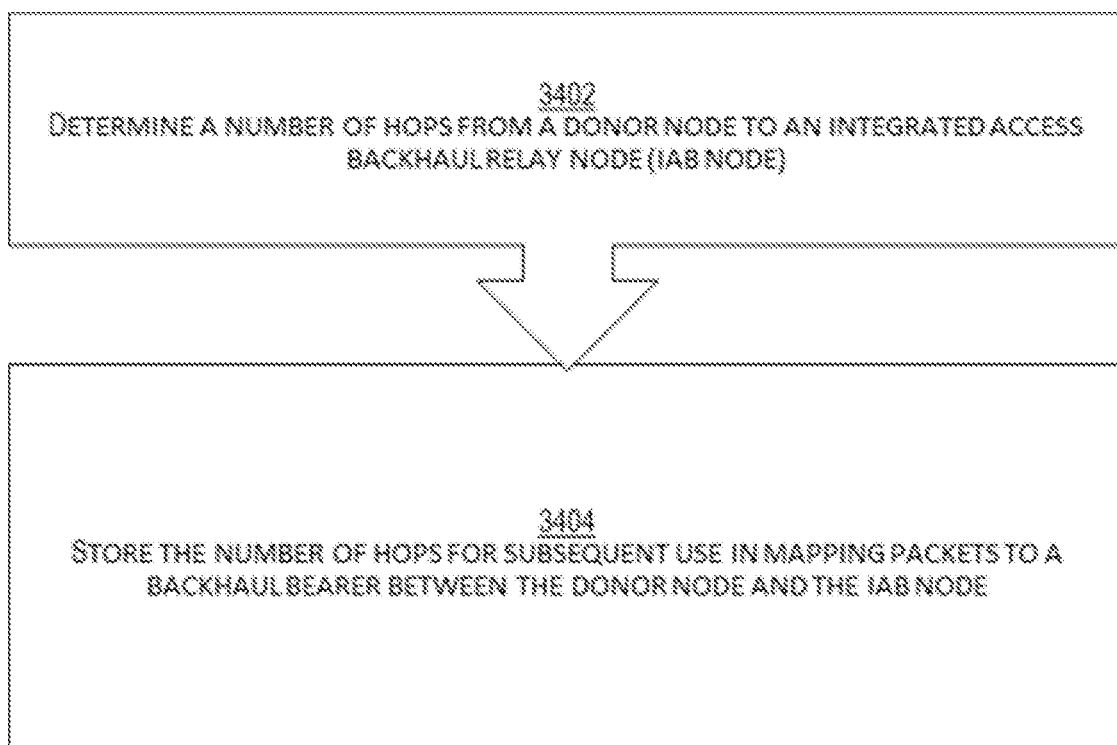
**FIG. 24**



**FIG. 25**



**FIG. 26**



**FIG. 27**

## QOS MAPPING FOR INTEGRATED ACCESS BACKHAUL SYSTEMS

### TECHNICAL FIELD

[0001] The present disclosure is generally related to wireless communication networks and is more particularly related to techniques for mapping packets to backhaul bearers in a wireless system utilizing integrated access backhaul relay nodes.

### BACKGROUND

[0002] FIG. 1 illustrates a high-level view of the fifth-generation (5G) network architecture for the 5G wireless communications system currently under development by the 3<sup>rd</sup>-Generation Partnership Project (3GPP), consisting of a Next Generation Radio Access Network (NG-RAN) and a 5G Core (5GC). The NG-RAN can comprise a set of gNodeB's (gNBs) connected to the 5GC via one or more NG interfaces, whereas the gNBs can be connected to each other via one or more Xn interfaces. Each of the gNBs can support frequency division duplexing (FDD), time division duplexing (TDD), or a combination thereof. The radio technology for the NG-RAN is often referred to as "New Radio" (NR).

[0003] The NG RAN logical nodes shown in FIG. 1 (and described in 3GPP TS 38.401 and 3GPP TR 38.801) include a Central Unit (CU or gNB-CU) and one or more Distributed Units (DU or gNB-DU). The CU is a logical node that is a centralized unit that hosts high layer protocols, including terminating the PDCP and RRC protocols towards the UE, and includes a number of gNB functions, including controlling the operation of DUs. A DU is a decentralized logical node that hosts lower layer protocols, including the RLC, MAC, and physical layer protocols, and can include, depending on the functional split option, various subsets of the gNB functions. (As used herein, the terms "central unit" and "centralized unit" are used interchangeably, and the terms "distributed unit" and "decentralized unit" are used interchangeably.) The gNB-CU connects to gNB-DUs over respective F1 logical interfaces, using the F1 application part protocol (F1-AP) which is defined in 3GPP TS 38.473. The gNB-CU and connected gNB-DUs are only visible to other gNBs and the 5GC as a gNB, the F1 interface is not visible beyond gNB-CU.

[0004] Furthermore, the F1 interface between the gNB-CU and gNB-DU is specified, or based on, the following general principles:

[0005] F1 is an open interface;

[0006] F1 supports the exchange of signaling information between respective endpoints, as well as data transmission to the respective endpoints;

[0007] from a logical standpoint, F1 is a point-to-point interface between the endpoints (even in the absence of a physical direct connection between the endpoints);

[0008] F1 supports control plane (CP) and user plane (UP) separation, such that a gNB-CU may be separated in CP and UP;

[0009] F1 separates Radio Network Layer (RNL) and Transport Network Layer (TN L);

[0010] F1 enables exchange of user-equipment (UE) associated information and non-UE associated information;

[0011] F1 is defined to be future proof with respect to new requirements, services, and functions;

[0012] A gNB terminates X2, Xn, NG and S1-U interfaces and, for the F1 interface between DU and CU, utilizes the F1 application part protocol (F1-AP) which is defined in 3GPP TS 38.473 and which is incorporated by reference herein in its entirety.

[0013] As noted above, the CU can host protocols such as RRC and PDCP, while a DU can host protocols such as RLC, MAC and PHY. Other variants of protocol distributions between CU and DU can exist, however, such as hosting the RRC, PDCP and part of the RLC protocol in the CU (e.g., Automatic Retransmission Request (ARQ) function), while hosting the remaining parts of the RLC protocol in the DU, together with MAC and PHY. In some exemplary embodiments, the CU can host RRC and PDCP, where PDCP is assumed to handle both UP traffic and CP traffic. Nevertheless, other exemplary embodiments may utilize other protocol splits that by hosting certain protocols in the CU and certain others in the DU. Exemplary embodiments can also locate centralized control plane protocols (e.g., PDCP-C and RRC) in a different CU with respect to the centralized user plane protocols (e.g., PDCP-U).

[0014] It has also been agreed in 3GPP RAN3 Working Group (WG) to support a separation of the gNB-CU into a CU-CP (control plane) function (including RRC and PDCP for signaling radio bearers) and CU-UP (user plane) function (including PDCP for user plane). The CU-CP and CU-UP parts communicate with each other using the E1-AP protocol over the E1 interface. The CU-CP/UP separation is illustrated in FIG. 2.

[0015] The NG-RAN is layered into a Radio Network Layer (RNL) and a Transport Network Layer (TNL). The NG-RAN architecture, i.e., the NG-RAN logical nodes and interfaces between them, is defined as part of the RNL. For each NG-RAN interface (NG, Xn, F1) the related TNL protocol and the functionality are specified. The TNL provides services for user plane transport and signaling transport. In NG-F1 ex configuration, each gNB is connected to all 5GC nodes within a pool area. The pool area is defined in 3GPP TS 23.501. If security protection for control plane and user plane data on TNL of NG-RAN interfaces has to be supported, NDS/IP (3GPP TS 33.401) shall be applied.

[0016] Densefification via the deployment of more and more base stations (e.g., macro or micro base stations) is one of the mechanisms that can be employed to satisfy the increasing demand for bandwidth and/or capacity in mobile networks, which is mainly driven by the increasing use of video streaming services. Due to the availability of more spectrum in the millimeter wave (mmw) band, deploying small cells that operate in this band is an attractive deployment option for these purposes. However, the normal approach of connecting the small cells to an operator's backhaul network with optical fiber can end up being very expensive and impractical. Employing wireless links for connecting the small cells to the operator's network is a cheaper and more practical alternative. One such approach is an integrated access backhaul (IAB) network, where the operator can utilize part of the available radio resources for the backhaul link.

[0017] IAB has been studied earlier in 3GPP in the scope of Long Term Evolution (LTE) Rel-10. In that work, an architecture was adopted where a Relay Node (RN) has the functionality of an LTE eNB and UE modem. The RN is connected to a donor eNB which has a S1/X2 proxy functionality hiding the RN from the rest of the network. That

architecture enabled the Donor eNB to also be aware of the UEs behind the RN and hide any UE mobility between Donor eNB and Relay Node on the same Donor eNB from the CN. During the Rel-10 study, other architectures were also considered including, e.g., where the RNs are more transparent to the Donor gNB and allocated a separate stand-alone P/S-GW node.

**[0018]** For 5G/NR, similar options utilizing IAB can also be considered. One difference compared to LTE is the gNB-CU/DU split described above, which separates time-critical RLC/MAC/PHY protocols from less time-critical RRC/PDCP protocols. It is anticipated that a similar split could also be applied for the IAB case. Other IAB-related differences anticipated in NR as compared to LTE are the support of multiple hops and the support of redundant paths.

**[0019]** During the RAN3 #99 meeting in Athens (February 2018), several IAB multi-hop designs were proposed, and summarized under five architecture reference diagrams (available at [www.3gpp.org/ftp/tsg\\_ran/wg3\\_iu/TSGR3\\_99/Docs/R3-181502.zip](http://www.3gpp.org/ftp/tsg_ran/wg3_iu/TSGR3_99/Docs/R3-181502.zip)). These reference diagrams differ with respect to the modification needed on interfaces or additional functionality needed, e.g., to accomplish multi-hop forwarding. These five architectures are divided into two architecture groups. The main features of these architectures can be summarized as follows:

**[0020]** Architecture group 1: Consists of architectures 1a and 1b. Both architectures leverage CU/DU split architecture.

**[0021]** Architecture 1a:

**[0022]** Backhauling of F1-U uses an adaptation layer or GTP-U combined with an adaptation layer.

**[0023]** Hop-by-hop forwarding across intermediate nodes uses the adaptation layer.

**[0024]** Architecture 1b:

**[0025]** Backhauling of F1-U on access node uses GTP-U/UDP/IP.

**[0026]** Hop-by-hop forwarding across intermediate node uses the adaptation layer.

**[0027]** Architecture group 2: Consists of architectures 2a, 2b and 2c

**[0028]** Architecture 2a:

**[0029]** Backhauling of F1-U or NG-U on access node uses GTP-U/UDP/IP.

**[0030]** Hop-by-hop forwarding across intermediate node uses PDU-session-layer routing.

**[0031]** Architecture 2b:

**[0032]** Backhauling of F1-U or NG-U on access node uses GTP-U/UDP/IP.

**[0033]** Hop-by-hop forwarding across intermediate node uses GTP-U/UDP/IP nested tunnelling.

**[0034]** Architecture 2c:

**[0035]** Backhauling of F1-U or NG-U on access node uses GTP-U/UDP/IP.

**[0036]** Hop-by-hop forwarding across intermediate node uses GTP-U/UDP/IP/PDCP nested tunnelling.

**[0037]** Architecture 1a leverages CU/DU-split architecture. FIG. 3 shows the reference diagram for a two-hop chain of IAB-nodes underneath an IAB-donor. In this architecture, each IAB node holds a DU and a Mobile Termination (MT), the latter of which is a function residing on the IAB-node that terminates the radio interface layers of the backhaul Uu interface toward the IAB-donor or other IAB-nodes. Effectively, the MT stands in for a UE on the Uu interface to the upstream relay node. Via the MT, the IAB-node connects to

an upstream IAB-node or the IAB-donor. Via the DU, the IAB-node establishes RLC-channels to UEs and to MTs of downstream IAB-nodes. For MTs, this RLC-channel may refer to a modified RLC\*.

**[0038]** The donor also holds a DU to support UEs and MTs of downstream IAB-nodes. The IAB-donor holds a CU for the DUs of all IAB-nodes and for its own DU. Each DU on an IAB-node connects to the CU in the IAB-donor using a modified form of F1, which is referred to as F1\*. F1\*-U runs over RLC channels on the wireless backhaul between the MT on the serving IAB-node and the DU on the donor. F1\*-U provides transport between MT and DU on the serving IAB-node as well as between DU and CU on the donor. An adaptation layer is added, which holds routing information, enabling hop-by-hop forwarding. It replaces the IP functionality of the standard F1-stack. F1\*-U may carry a GTP-U header for the end-to-end association between CU and DU. In a further enhancement, information carried inside the GTP-U header may be included in the adaption layer. Further, optimizations to RLC may be considered such as applying ARQ only on the end-to-end connection opposed to hop-by-hop. The right side of FIG. 3 shows two examples of such F1\*-U protocol stacks. In this figure, enhancements of RLC are referred to as RLC\*. The MT of each IAB-node further sustains NAS connectivity to the NGC, e.g., for authentication of the IAB-node. It further sustains a PDU-session via the NGC, e.g., to provide the IAB-node with connectivity to the OAM.

**[0039]** Architecture 1b also leverages CU/DU-split architecture. FIG. 4 shows the reference diagram for a two-hop chain of IAB-nodes underneath an IAB-donor. Note that the IAB-donor only holds one logical CU.

**[0040]** In this architecture, each IAB-node and the IAB-donor hold the same functions as in architecture 1a. Also, as in architecture 1a, every backhaul link establishes an RLC-channel, and an adaptation layer is inserted to enable hop-by-hop forwarding of F1\*.

**[0041]** As opposed to architecture 1a, the MT on each IAB-node establishes a PDU-session with a UPF residing on the donor. The MT's PDU-session carries F1\* for the collocated DU. In this manner, the PDU-session provides a point-to-point link between CU and DU. On intermediate hops, the PDCP-PDUs of F1\* are forwarded via adaptation layer in the same manner as described for architecture 1a. The right side of FIG. 4 shows an example of the F1\*-U protocol stack.

**[0042]** In architecture 2a, the IAB-node holds an MT to establish an NR Uu link with a gNB on the parent IAB-node or IAB-donor. Via this NR-Uu link, the MT sustains a PDU-session with a UPF that is collocated with the gNB. In this manner, an independent PDU-session is created on every backhaul link. Each IAB-node further supports a routing function to forward data between PDU-sessions of adjacent links. This creates a forwarding plane across the wireless backhaul. Based on PDU-session type, this forwarding plane supports IP or Ethernet. In case PDU-session type is Ethernet, an IP layer can be established on top. In this manner, each IAB-node obtains IP-connectivity to the wireline backhaul network.

**[0043]** All IP-based interfaces such as NG, Xn, F1, N4, etc. are carried over this forwarding plane. In the case of F1, the UE-serving IAB-Node would contain a DU rather than a full gNB, and the CU would be in or beyond the IAB

Donor. The right side of FIG. 5 shows an example of the NG-U protocol stack for IP-based and for Ethernet-based PDU-session type.

**[0044]** In case the IAB-node holds a DU for UE-access, it may not be required to support PDCP-based protection on each hop since the end user data will already be protected using end to end PDCP between the UE and the CU.

**[0045]** In architecture 2b, the IAB-node holds an MT to establish an NR Uu link with a gNB on the parent IAB-node or IAB-donor. Via this NR-Uu link, the MT sustains a PDU-session with a UPF. Opposed to architecture 2a, this UPF is located at the IAB-donor. Also, forwarding of PDUs across upstream IAB-nodes is accomplished via tunnelling. The forwarding across multiple hops, therefore, creates a stack of nested tunnels. As in architecture 2a, each IAB-node obtains IP-connectivity to the wireline backhaul network. All IP-based interfaces such as NG, Xn, F1, N4, etc. are carried over this forwarding IP plane. The right side of FIG. 6 shows a protocol stack example for NG-U.

**[0046]** Architecture 2c leverages DU-CU split. The IAB-node holds an MT which sustains an RLC-channel with a DU on the parent IAB-node or IAB-donor. The IAB donor holds a CU and a UPF for each IAB-node's DU. The MT on each IAB-node sustains an NR-Uu link with a CU and a PDU session with a UPF on the donor. Forwarding on intermediate nodes is accomplished via tunneling. The forwarding across multiple hops creates a stack of nested tunnels. As in architecture 2a and 2b, each IAB-node obtains IP-connectivity to the wireline backhaul network. Opposed to architecture 2b, however, each tunnel includes an SDAP/PDCP layer. All IP-based interfaces such as NG, Xn, F1, N4, etc. are carried over this forwarding plane. The right side of FIG. 7 shows a protocol stack example for NG-U.

**[0047]** Referring again to architecture 1a shown in FIG. 3, user plane (UP) and control-plane (CP, e.g., RRC) traffic can be protected via PDCP over the wireless backhaul. A mechanism is also needed for protecting F1-AP traffic over the wireless backhaul. Four alternatives are shown in FIGS. 8-11.

**[0048]** FIG. 8 shows exemplary protocol stacks for a first alternative, also referred to as "alternative 1." UE RRC, MT RRC, and DU F1-AP protocol stacks are shown in parts a), b), and c) of FIG. 8, respectively. In this alternative, the adaptation layer is placed on top of RLC, and RRC connections for UE RRC and MT RRC are carried over a signalling radio bearer (SRB). On the UE's or MT's access link, the SRB uses an RLC-channel; whether the RLC channel has an adaptation layer is for further study.

**[0049]** On the wireless backhaul links, the SRB's PDCP layer is carried over RLC-channels with adaptation layer. The adaptation layer placement in the RLC channel is the same for CP as for UP. The information carried on the adaptation layer may be different for SRB than for data radio bearer (DRB). The DU's F1-AP is encapsulated in RRC of the collocated MT. F1-AP is therefore protected by the PDCP of the underlying SRB. Within the IAB-donor, the baseline is to use native F1-C stack.

**[0050]** FIG. 9 shows exemplary protocol stacks for a second alternative, also referred to as "alternative 2". Again, UE RRC, MT RRC, and DU F1-AP protocol stacks are shown in parts a), b), and c) of FIG. 9, respectively. Similar to alternative 1, RRC connections for UE RRC and MT RRC are carried over a signalling radio bearer (SRB), and the SRB uses an RLC-channel on the UE's or MT's access link.

**[0051]** In contrast, on the wireless backhaul links, the SRB's PDCP layer is encapsulated into F1-AP. The DU's F1-AP is carried over an SRB of the collocated MT. F1-AP is protected by this SRB's PDCP. On the wireless backhaul links, the PDCP of the F1-AP's SRB is carried over RLC-channels with adaptation layer. The adaptation layer placement in the RLC channel is the same for CP as for UP. The information carried on the adaptation layer may be different for SRB than for DRB. Within the IAB-donor, the baseline is to use native F1-C stack.

**[0052]** FIG. 10 shows exemplary protocol stacks for a third alternative, also referred to as "alternative 3". Once more, UE RRC, MT RRC, and DU F1-AP protocol stacks are shown in parts a), b), and c) of FIG. 10, respectively. In this alternative, the adaptation layer is placed on top of RLC, and RRC connections for UE and MT are carried over a signalling radio bearer (SRB). On the UE's or MT's access link, the SRB uses an RLC-channel; whether the RLC channel has an adaptation layer is for further study.

**[0053]** In alternative 3, the wireless backhaul links, the SRB's PDCP layer is carried over RLC-channels with adaptation layer. The adaptation layer placement in the RLC channel is the same for CP as for UP. The information carried on the adaptation layer may be different for SRB than for data radio bearer (DRB). The DU's F1-AP is also carried over an SRB of the collocated MT. F1-AP is therefore protected by the PDCP of this SRB. On the wireless backhaul links, the PDCP of the this SRB is also carried over RLC-channels with adaptation layer. Within the IAB-donor, the baseline is to use native F1-C stack.

**[0054]** FIG. 11 shows exemplary UE RRC, MT RRC, and DU F1-AP protocol stacks for a fourth alternative, also referred to as "alternative 4," in parts a), b), and c), respectively. In this alternative, the adaptation layer is placed on top of RLC, and all F1-AP signaling is carried over SCTP/IP to the target node. The IAB-donor maps DL packets based on target node IP to adaptation layer used on backhaul DRB. Separate backhaul DRBs can be used to carry F1-AP signalling from F1-U related content. For example, mapping to backhaul DRBs can be based on target node IP address and IP layer Diffserv Code Points (DSCP) supported over F1 as specified in 3GPP TS 38.474.

**[0055]** In alternative 4, a DU will also forward other IP traffic to the IAB node (e.g., OAM interfaces). The IAB node terminates the same interfaces as a normal DU except that the L2/L1 protocols are replaced by adaptation/RLC/MAC/PHY-layer protocols. F1-AP and other signaling are protected using NDS (e.g., IPSec, DTLS over SCTP) operating in the conventional way between DU and CU. For example, SA3 has recently adopted the usage of DTLS over SCTP (as specified in IETF RFC6083) for protecting F1-AP.

**[0056]** FIG. 12 shows exemplary protocol stacks for a mechanism for protecting F1-AP traffic over the wireless backhaul in architecture 1 b, which was shown in FIG. 4. UE RRC, MT RRC, and DU F1-AP protocol stacks are shown in parts a), b), and c) of FIG. 12, respectively. As discussed above for architecture 1a, the UE's or MT's RRC is carried over SRB. On the wireless backhaul, this SRB's PDCP is carried over native F1-C, with the DUs on IAB-node and IAB-donor using their native F1-C stacks. Over the wireless backhaul links, the IP-layer of this native F1-C stack is provided by a PDU-session. This PDU-session is established between the MT collocated with the DU and a UPF. The PDU-session is carried by a DRB between the MT and the

CU-UP. Between CU-UP and UPF, the PDU-session is carried via NG-U. IP transport between UPF and CU-CP is provided by the PDU-session's DN. The baseline assumption is that this transport is protected. In the exemplary alternative shown in FIG. 12, the adaptation layer carrying the DRB's PDCP resides on top of RLC.

#### SUMMARY

**[0057]** As noted above, for alternative 4 of architecture 1a, the IP address of the destination IAB node and the DiffServ code point (DSCP) in the IP header could be used for mapping incoming IP packets to the proper backhaul bearer between the donor DU and the first IAB node. However, how exactly that is to be done has not previously been determined. In particular, techniques for performing the mapping so as to ensure fairness for users connected via different number of wireless backhaul hops are needed. Some embodiments of the presently disclosed techniques and apparatus address these issues by providing for a mapping of incoming IP packets at the donor DU in an IAB system to proper backhaul bearers based on the destination IAB node IP address and the DSCP on the IP header.

**[0058]** According to some embodiments, a method performed by at least one node in a radio access network (RAN) in a wireless communication network that also comprises a core network (CN) includes determining a number of hops from a donor node to an integrated access backhaul relay node (IAB node) and storing the number of hops for subsequent use in mapping packets to a backhaul bearer between the donor node and the IAB node.

**[0059]** According to some embodiments, a donor node in a RAN in a wireless communication network that also comprises a CN includes processing circuitry and a memory comprising computer instructions that when executed by the processing circuitry, cause the donor node to determine a number of hops from the donor node to an IAB node and store the number of hops for subsequent use in mapping packets to a backhaul bearer between the donor node and the IAB node.

**[0060]** According to some embodiments, an IAB node in a RAN in a wireless communication network that also comprises a CN includes processing circuitry and a memory comprising computer instructions that when executed by the processing circuitry, cause the IAB node to receive a packet for forwarding to a donor node and map the packet to one of a plurality of backhaul bearers at the IAB node, for transfer to the donor node, based at least in part on the stored number of hops.

**[0061]** An advantage that may be realized by at least some implementations of the solutions described herein is that already currently existing information elements in the IP header (IP address and DSCP code point) are utilized to make it possible to map/route incoming packets to a proper backhaul bearer that is able to fulfill the QoS requirements of the bearer. The IP address in particular could be used to determine how many (wireless) hops the packet requires to reach target node, which is useful information when deciding the priority that a packet should have and on which bearer it should be sent.

**[0062]** Of course, the present invention is not limited to the above features and advantages. Those of ordinary skill in the art will recognize additional features and advantages upon reading the following detailed description, and upon viewing the accompanying drawings.

#### BRIEF DESCRIPTION OF THE FIGURES

**[0063]** FIG. 1 illustrates an example of 5G logical network architecture.

**[0064]** FIG. 2 shows the separation between the control-unit-control-plane (CU-CP) and control-unit-user-plane (CU-UP) functions.

**[0065]** FIG. 3 is a reference diagram for integrated access backhaul (IAB) architecture 1a.

**[0066]** FIG. 4 is a reference diagram for architecture 1b.

**[0067]** FIG. 5 is a reference diagram for architecture 2a.

**[0068]** FIG. 6 is a reference diagram for architecture 2b.

**[0069]** FIG. 7 is a reference diagram for architecture 2c.

**[0070]** FIG. 8 illustrates protocol stacks for alternative 1 of architecture 1a.

**[0071]** FIG. 9 illustrates protocol stacks for alternative 2 of architecture 1a.

**[0072]** FIG. 10 illustrates protocol stacks for alternative 3 of architecture 1a.

**[0073]** FIG. 11 shows protocol stacks for alternative 4 of architecture 1a.

**[0074]** FIG. 12 illustrates example protocol stacks for architecture 1b.

**[0075]** FIG. 13 shows signaling for UE RRC, UE user data, IAB node RRC, and IAB node F1-AP in an example architecture.

**[0076]** FIG. 14 illustrates components of an example wireless network.

**[0077]** FIG. 15 illustrates an example UE in accordance with some embodiments of the presently disclosed techniques and apparatus.

**[0078]** FIG. 16 is a schematic diagram illustrating a virtualization environment in which functions implemented by some embodiments can be virtualized.

**[0079]** FIG. 17 illustrates an example telecommunication network connected to a host via an intermediate network, in accordance with some embodiments.

**[0080]** FIG. 18 illustrates a host computer communicating over a partially wireless connection with, in accordance with some embodiments.

**[0081]** FIG. 19 shows a base station with a distributed 5G architecture.

**[0082]** FIG. 20 illustrates an example central unit, according to some embodiments.

**[0083]** FIG. 21 illustrates an example design for a central unit.

**[0084]** FIG. 22 is a block diagram illustrating an example IAB/relay node.

**[0085]** FIG. 23 is a flowchart illustrating methods implemented in a communication system that includes a host computer, a base station, and a user equipment, in accordance with some embodiments.

**[0086]** FIG. 24 is another flowchart illustrating methods implemented in a communication system that includes a host computer, a base station, and a user equipment, in accordance with some embodiments.

**[0087]** FIG. 25 shows another flowchart illustrating methods implemented in a communication system that includes a host computer, a base station, and a user equipment, in accordance with some embodiments.

**[0088]** FIG. 26 shows still another flowchart illustrating methods implemented in a communication system that includes a host computer, a base station, and a user equipment, in accordance with some embodiments.

[0089] FIG. 27 is a process flow diagram illustrating an example method performed in at least node of a RAN, in a wireless communication network that also comprises a CN.

#### DETAILED DESCRIPTION

[0090] Exemplary embodiments briefly summarized above will now be described more fully with reference to the accompanying drawings. These descriptions are provided by way of example to explain the subject matter to those skilled in the art and should not be construed as limiting the scope of the subject matter to only the embodiments described herein. More specifically, examples are provided below that illustrate the operation of various embodiments according to the advantages discussed above.

[0091] Generally, all terms used herein are to be interpreted according to their ordinary meaning in the relevant technical field, unless a different meaning is clearly given and/or is implied from the context in which it is used. All references to a/an/the element, apparatus, component, means, step, etc. are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, step, etc., unless explicitly stated otherwise. The steps of any methods and/or procedures disclosed herein do not have to be performed in the exact order disclosed, unless a step is explicitly described as following or preceding another step and/or where it is implicit that a step must follow or precede another step. Any feature of any of the embodiments disclosed herein can be applied to any other embodiment, wherever appropriate. Likewise, any advantage of any of the embodiments can apply to any other embodiments, and vice versa. Other objectives, features and advantages of the enclosed embodiments will be apparent from the following description.

[0092] Several of the techniques described herein are based on allowing IP traffic all the way between the CU and the IAB node. In this way all F1 traffic (user plane/signaling) can be supported in a similar way. FIG. 13 shows how a) UE RRC, b) UE user data, c) IAB node RRC, and d) IAB node F1-AP signaling are supported in the proposed architecture.

[0093] At least some of the solutions described herein share the following characteristics:

[0094] All F1 traffic (F1-AP, user plane) is carried over IP to the target node.

[0095] The IAB-donor maps DL packets based on target node IP to adaptation layer used on backhaul DRB.

[0096] Separate backhaul DRBs can be used to carry F1-AP signalling from F1-U related content. The mapping to BH DRBs could be based on target node IP address and IP layer Diffserv Code Points (DSCP) supported over F1 as specified in TS 38.474. Other methods for mapping are not excluded.

[0097] The DU will also forward other IP traffic to the IAB node (E.g. OAM interfaces)

[0098] The IAB terminates the same interfaces as a normal DU except that the L2/L1 protocols is replaced by adapt/RLC/MAC/PHY protocol.

[0099] The F1-AP and other signalling are protected using NDS (e.g. IPSec, DTLS over SCTP) operating in the same way as between DU and CU today. SA3 has recently adopted the usage of DTLS over SCTP [RFC6083] for protecting F1-AP [S3-182047]. The details on NDS operating over wireless backhaul are FFS.

[0100] It should be noted that there is no need for NAT (network address translation) functionality at the IAB donor DU (and also intermediate IAB nodes), and the two IP protocol boxes shown are just for routing purposes. Also, IP routing can be used instead of and/or on top of adaptation layer in intermediate IAB nodes.

[0101] The embodiments described may utilize either or both of IPv4 and IPv6. For IPv6, IP address, DSCP and/or Flow Label fields will be used for backhaul DRB mapping. However, the description below is focused only on the usage of the IP address and DSCP code fields.

[0102] The description below is focused on the QoS mapping aspect and not in routing. That is, it is assumed that the donor DU will use the destination IAB node IP address to determine the next node to which it will pass the data onwards. The QoS mapping aspect discussed here is then applied with the backhaul links in that path. The intermediate IAB nodes perform a similar procedure, but they may use the adaptation layer header information instead of the IP header, since IP routing may not be present in the intermediate IAB nodes.

[0103] Following is a list of example features that may be included in various non-limiting embodiments of the presently disclosed techniques.

[0104] (a): When an IAB node is set up, the number of hops from the donor node to the IAB node is determined and stored. In various embodiments, the storing could be in the DU and/or CU and/or IAB node.

[0105] (b): A method according to (a), where the storage of the number of hops is performed by keeping a mapping/table of IAB node IP addresses and corresponding hop counts.

[0106] (c): A method according to (a) or (b), where the number of hops determination is performed by the Donor CU. In some embodiments, this determining may be based on knowledge about which node the IAB node is connected to, i.e., which radio node serve the IAB node. An example solution could be to assign the hop count=hop count of node serving IAB node+1.

[0107] (d): A method according to (a) or (b), where the number of hops determination is performed by the Donor DU. In some embodiments, this determining may be based on signaling information in the adaptation layer. For example, the adaptation layer may include a hop count; when the IAB node connects to the network it will send a message to the DU, and each IAB node serving the IAB node will add 1 to the hop count in the message header. The DU will then be able to determine the number of hops by reading adaptation layer header.

[0108] (e): A method according to (c), where the Donor CU communicates the number of hops to the Donor DU. This can be performed on a per IAB node basis (e.g., during or immediately after IAB node setup procedure), or multiple mapping entries of IAB node IP address to hop count can be sent at the same time. In some embodiments, this communication could be via some other node, like the IAB node.

[0109] (f): A method according to (e), where the mapping information is sent to the DU via the F1-AP signaling. This can use the enhancement of existing messages (e.g. gNB-CU/DU configuration update messages) or the introduction of new messages.

[0110] (g): A method according to any of (a)-(f), where the IAB node is informed about the number of hops (i.e., how many hops between itself and the donor) by the node that

determines the number of hops (e.g., donor CU or donor DU), either directly or via an intermediate node (e.g., donor CU determines the number of hops, it communicates it to the donor DU as in (e), which communicates it further to the IAB node).

**[0111]** (h): A method according to any of (a)-(g), where there is a one to one mapping between hop counts and backhaul bearers between the donor DU and the first IAB node connected to it. The donor DU checks, from the IP-address-hop count table, how many hops the packets have to traverse, and then forwards the packet to the backhaul bearer associated with that hop). In some of these embodiments, the backhaul bearer could be associated with a QoS class determined by the DiffServ codepoint of similar information in the IP header. Which set of backhaul bearers (where each backhaul bearer within a set have different QoS class) should be used is determined by the IP address.

**[0112]** (i): A method according to (h), where the higher the hop count, the higher the QoS/priority of the backhaul bearer associated with the hop count.

**[0113]** (j): A method according to any of (a)-(g), where there is more than one backhaul bearer associated with a given hop count, where one backhaul bearer is used for packets with a given hop count and one or more DSCP codes. Example, backhaul bearer QCI 1 could be associated with hop count 1 and DSCP code x, bearer with QCI (QoS Class Identifier) 2 associated with hop count 1 and DSCP codes y and z, bearer with QCI 3 is associated with hop count 2 and DSCP codes x,y,z, etc.

**[0114]** (k): A method according to any of (a)-(j), where there is a one to one mapping between DSCP codes and backhaul bearers between the donor DU and the first IAB node connected to it. The donor DU forwards the packet to the backhaul bearer associated with that DSCP code.

**[0115]** (l): A method according to (k), where the QoS/priority of the backhaul bearer associated with the DSCP code follows standard DSCP to service class mappings (e.g., guidelines in rfc4594) or based on proprietary DSCP to service class mapping.

**[0116]** (m): A method according to any of (a)-(g), where there is more than one backhaul bearer associated with a given DSCP code, where one backhaul bearer is used for packets with a given DSCP code and one or more hop counts. For example, backhaul bearer with QCI 1 could be associated with DSCP code x and hop count 1; bearer with QCI 2 associated with DSCP code y and hop counts 1 and 2; bearer with QCI 3 is associated with DSCP code y, and hop counts 1,2, and 3; etc.

**[0117]** (n): A method according to any of (a)-(g), where one backhaul bearer is mapped to one or more hop counts and one or more DSCP codes. For example, backhaul bearer with QCI 1 could be associated with DSCP codes x,y and hop count 1,2; bearer with QCI 2 associated with DSCP code y and hop counts 2 and 3; bearer with QCI 3 is associated with DSCP code a (regardless of the hop count); bearer with QCI 4 is associated with hop count 4 (and all DSCP codes except code a); QCI 5 is associated with DSCP code b (and all hop counts greater than 1) etc.

**[0118]** (o): A method according to (h)-(n), where the mapping rules between hop and/or DSCP code and backhaul bearer QCIs is communicated to the DU from the CU.

**[0119]** (p): A method according to (o), where the mapping information is sent to the DU via the F1-AP signaling. This can be using the enhancement of existing messages (e.g.

F1-setup, gNB-CU/DU configuration update, etc.) or the introduction of new messages.

**[0120]** (q): A method according to any of (h)-(n), where the mapping rules between hop and/or DSCP code and backhaul bearer QCIs is communicated to the DU from the CN (e.g., OAM).

**[0121]** (r): A method according to any of (h)-(n), where the mapping rules between hop and/or DSCP code and backhaul bearer QCIs is hardcoded in the DU from the CN (e.g. OAM).

**[0122]** (s): Where the configuration of the mapping between IP address and IP layer QoS (DSCP), and backhaul bearers is performed by the CU, taking into consideration the number of hops each IAB node is connected via; and where this mapping is signalled to the DU enabling the DU to perform the mapping without explicit knowledge about the number of hops each IAB node is connected via.

**[0123]** (t): A method according to any of (a)-(s), where the CU tags the IP packets carrying control plane data with a special high priority DSCP value (or values), and dedicated backhaul bearer or bearers are associated/reserved with/for this DSCP values, ensuring that control plane data will not be mixed with user plane data over the backhaul links, which might cause head of line blocking of control plane signaling by user plane data. In some embodiments, some high priority user plane data can be mapped to the same DSCP value (or a DSCP value that is of equivalent priority) as CP data. An example mapping could be that a UP data with a similar DSCP priority than a CP data will be mapped to the same backhaul bearer if it is going to be transported for several hops as compared to the CP data (e.g. CP data to be transported for one hop can be mapped on the same backhaul bearer as a high priority UP to be transported for four hops)

**[0124]** (u): A method according to any of (a)-(t), where once the mapping to the right backhaul bearer is determined, adaptation layer header information (i.e. L2 IAB node address, QCI, hop count, etc.) is added to the packet, before the packet is forwarded, so that this information can be subsequently used by intermediate nodes/hops.

**[0125]** (v): A method according to any of (a)-(u), where the IAB node keeps reflective QoS mapping for each DRB of the UEs that it is serving, via the GTP tunnel ID, and tags the UL UP data packets with the same DSCP code point as the corresponding DL data for that bearer. In some embodiments, an IAB node uses the DSCP and the hop count to determine which backhaul bearer it should map the UL UP data packets.

**[0126]** (w): A method according to any of (a)-(v), where the IAB node keeps reflective QoS mapping for control plane data (via SCTP streams/association IDs) and tags the UL control plane packets with the same DSCP code point as the corresponding DL control plane data. In some embodiments, an IAB node uses the DSCP and the hop count to determine which backhaul bearer it should map the UL control plane packets. It will be appreciated that these IAB node-related techniques may be implemented independently of the methods in (a)-(v), in some embodiments.

**[0127]** Several variants of the above are also contemplated. For example, in some embodiments, the mapping of packets to backhaul bearers may be based on a DSCP value in the packet but not (at least not directly) on the number of hops. As noted above, in some embodiments, one backhaul bearer is mapped to one or more hop counts and one or more DSCP codes. For example, a backhaul bearer with QCI 1

could be associated with DSCP codes x,y and hop count 1,2; a bearer with QCI 2 associated with DSCP code y and hop counts 2 and 3; a bearer with QCI 3 is associated with DSCP code a (regardless of the hop count); a bearer with QCI 4 is associated with hop count 4 (and all DSCP codes except code a); a bearer with QCI 5 is associated with DSCP code b (and all hop counts greater than 1); etc. In other words, a backhaul bearer may be mapped to one or more hop count values and one or more DSCP values or any DSCP value, or the other way around. Thus, for example, the mapping could be based on a mapping table with entries like “hop count=1 or 2; DSCP=any” or “DSCP=x, hop count=any” corresponding to each of several backhaul bearers.

**[0128]** The various techniques listed above may be implemented in one or more of several nodes in a communication network that also comprises a core network (CN), such as in a donor node, e.g., in a DU or CU or a combination of both, or in an IAB relay node, or in some combination of a donor node and an IAB relay node. In addition to the methods summarized above, embodiments of the presently disclosed invention include donor node and/or IAB relay node apparatuses adapted to carry out any one or more of the above methods.

**[0129]** Although the subject matter described herein can be implemented in any appropriate type of system using any suitable components, the embodiments disclosed herein are described in relation to a wireless network, such as the example wireless network illustrated in FIG. 14. For simplicity, the wireless network of FIG. 14 only depicts network 2106, network nodes 2160 and 2160b, and WDs 2110, 2110b, and 2110c. In practice, a wireless network can further include any additional elements suitable to support communication between wireless devices or between a wireless device and another communication device, such as a land-line telephone, a service provider, or any other network node or end device. Of the illustrated components, network node 2160 and wireless device (WD) 2110 are depicted with additional detail. The wireless network can provide communication and other types of services to one or more wireless devices to facilitate the wireless devices' access to and/or use of the services provided by, or via, the wireless network.

**[0130]** The wireless network can comprise and/or interface with any type of communication, telecommunication, data, cellular, and/or radio network or other similar type of system. In some embodiments, the wireless network can be configured to operate according to specific standards or other types of predefined rules or procedures. Thus, particular embodiments of the wireless network can implement communication standards, such as Global System for Mobile Communications (GSM), Universal Mobile Telecommunications System (UMTS), Long Term Evolution (LTE), and/or other suitable 2G, 3G, 4G, or 5G standards; wireless local area network (WLAN) standards, such as the IEEE 802.11 standards; and/or any other appropriate wireless communication standard, such as the Worldwide Interoperability for Microwave Access (WiMax), Bluetooth, Z-Wave and/or ZigBee standards.

**[0131]** Network 2106 can comprise one or more backhaul networks, core networks, IP networks, public switched telephone networks (PSTNs), packet data networks, optical networks, wide-area networks (WANs), local area networks (LANs), wireless local area networks (WLANs), wired

networks, wireless networks, metropolitan area networks, and other networks to enable communication between devices.

**[0132]** Network node 2160 and WD 2110 comprise various components described in more detail below. These components work together in order to provide network node and/or wireless device functionality, such as providing wireless connections in a wireless network. In different embodiments, the wireless network can comprise any number of wired or wireless networks, network nodes, base stations, controllers, wireless devices, relay stations, and/or any other components or systems that can facilitate or participate in the communication of data and/or signals whether via wired or wireless connections.

**[0133]** As used herein, network node refers to equipment capable, configured, arranged and/or operable to communicate directly or indirectly with a wireless device and/or with other network nodes or equipment in the wireless network to enable and/or provide wireless access to the wireless device and/or to perform other functions (e.g., administration) in the wireless network. Examples of network nodes include, but are not limited to, access points (APs) (e.g., radio access points), base stations (BSs) (e.g., radio base stations, Node Bs, evolved Node Bs (eNBs) and NR NodeBs (gNBs)). Base stations can be categorized based on the amount of coverage they provide (or, stated differently, their transmit power level) and can then also be referred to as femto base stations, pico base stations, micro base stations, or macro base stations. A base station can be a relay node or a relay donor node controlling a relay. A network node can also include one or more (or all) parts of a distributed radio base station such as centralized digital units and/or remote radio units (RRUs), sometimes referred to as Remote Radio Heads (RRHs). Such remote radio units may or may not be integrated with an antenna as an antenna integrated radio. Parts of a distributed radio base station can also be referred to as nodes in a distributed antenna system (DAS).

**[0134]** Further examples of network nodes include multi-standard radio (MSR) equipment such as MSR BSs, network controllers such as radio network controllers (RNCs) or base station controllers (BSCs), base transceiver stations (BTSs), transmission points, transmission nodes, multi-cell/multicast coordination entities (MCEs), core network nodes (e.g., MSCs, MMEs), O&M nodes, OSS nodes, SON nodes, positioning nodes (e.g., E-SMLCs), and/or MDTs. As another example, a network node can be a virtual network node as described in more detail below. More generally, however, network nodes can represent any suitable device (or group of devices) capable, configured, arranged, and/or operable to enable and/or provide a wireless device with access to the wireless network or to provide some service to a wireless device that has accessed the wireless network.

**[0135]** In FIG. 14, network node 2160 includes processing circuitry 2170, device readable medium 2180, interface 2190, auxiliary equipment 2184, power source 2186, power circuitry 2187, and antenna 2162. Although network node 2160 illustrated in the example wireless network of FIG. 14 can represent a device that includes the illustrated combination of hardware components, other embodiments can comprise network nodes with different combinations of components. It is to be understood that a network node comprises any suitable combination of hardware and/or software needed to perform the tasks, features, functions and methods and/or procedures disclosed herein. Moreover,

while the components of network node **2160** are depicted as single boxes located within a larger box, or nested within multiple boxes, in practice, a network node can comprise multiple different physical components that make up a single illustrated component (e.g., device readable medium **2180** can comprise multiple separate hard drives as well as multiple RAM modules).

[0136] Similarly, network node **2160** can be composed of multiple physically separate components (e.g., a NodeB component and a RNC component, or a BTS component and a BSC component, etc.), which can each have their own respective components. In certain scenarios in which network node **2160** comprises multiple separate components (e.g., BTS and BSC components), one or more of the separate components can be shared among several network nodes. For example, a single RNC can control multiple NodeB's. In such a scenario, each unique NodeB and RNC pair, can in some instances be considered a single separate network node. In some embodiments, network node **2160** can be configured to support multiple radio access technologies (RATs). In such embodiments, some components can be duplicated (e.g., separate device readable medium **2180** for the different RATs) and some components can be reused (e.g., the same antenna **2162** can be shared by the RATs). Network node **2160** can also include multiple sets of the various illustrated components for different wireless technologies integrated into network node **2160**, such as, for example, GSM, WCDMA, LTE, NR, WiFi, or Bluetooth wireless technologies. These wireless technologies can be integrated into the same or different chip or set of chips and other components within network node **2160**.

[0137] Processing circuitry **2170** can be configured to perform any determining, calculating, or similar operations (e.g., certain obtaining operations) described herein as being provided by a network node. These operations performed by processing circuitry **2170** can include processing information obtained by processing circuitry **2170** by, for example, converting the obtained information into other information, comparing the obtained information or converted information to information stored in the network node, and/or performing one or more operations based on the obtained information or converted information, and as a result of said processing making a determination.

[0138] Processing circuitry **2170** can comprise a combination of one or more of a microprocessor, controller, microcontroller, central processing unit, digital signal processor, application-specific integrated circuit, field programmable gate array, or any other suitable computing device, resource, or combination of hardware, software and/or encoded logic operable to provide, either alone or in conjunction with other network node **2160** components, such as device readable medium **2180**, network node **2160** functionality. For example, processing circuitry **2170** can execute instructions stored in device readable medium **2180** or in memory within processing circuitry **2170**. Such functionality can include providing any of the various wireless features, functions, or benefits discussed herein. In some embodiments, processing circuitry **2170** can include a system on a chip (SOC).

[0139] In some embodiments, processing circuitry **2170** can include one or more of radio frequency (RF) transceiver circuitry **2172** and baseband processing circuitry **2174**. In some embodiments, radio frequency (RF) transceiver circuitry **2172** and baseband processing circuitry **2174** can be

on separate chips (or sets of chips), boards, or units, such as radio units and digital units. In alternative embodiments, part or all of RF transceiver circuitry **2172** and baseband processing circuitry **2174** can be on the same chip or set of chips, boards, or units

[0140] In certain embodiments, some or all of the functionality described herein as being provided by a network node, base station, eNB or other such network device can be performed by processing circuitry **2170** executing instructions stored on device readable medium **2180** or memory within processing circuitry **2170**. In alternative embodiments, some or all of the functionality can be provided by processing circuitry **2170** without executing instructions stored on a separate or discrete device readable medium, such as in a hard-wired manner. In any of those embodiments, whether executing instructions stored on a device readable storage medium or not, processing circuitry **2170** can be configured to perform the described functionality. The benefits provided by such functionality are not limited to processing circuitry **2170** alone or to other components of network node **2160**, but are enjoyed by network node **2160** as a whole, and/or by end users and the wireless network generally.

[0141] Device readable medium **2180** can comprise any form of volatile or non-volatile computer readable memory including, without limitation, persistent storage, solid-state memory, remotely mounted memory, magnetic media, optical media, random access memory (RAM), read-only memory (ROM), mass storage media (for example, a hard disk), removable storage media (for example, a flash drive, a Compact Disk (CD) or a Digital Video Disk (DVD)), and/or any other volatile or non-volatile, non-transitory device readable and/or computer-executable memory devices that store information, data, and/or instructions that can be used by processing circuitry **2170**. Device readable medium **2180** can store any suitable instructions, data or information, including a computer program, software, an application including one or more of logic, rules, code, tables, etc. and/or other instructions capable of being executed by processing circuitry **2170** and, utilized by network node **2160**. Device readable medium **2180** can be used to store any calculations made by processing circuitry **2170** and/or any data received via interface **2190**. In some embodiments, processing circuitry **2170** and device readable medium **2180** can be considered to be integrated.

[0142] Interface **2190** is used in the wired or wireless communication of signaling and/or data between network node **2160**, network **2106**, and/or WDS **2110**. As illustrated, interface **2190** comprises port(s)/terminal(s) **2194** to send and receive data, for example to and from network **2106** over a wired connection. Interface **2190** also includes radio front end circuitry **2192** that can be coupled to, or in certain embodiments a part of, antenna **2162**. Radio front end circuitry **2192** comprises filters **2198** and amplifiers **2196**. Radio front end circuitry **2192** can be connected to antenna **2162** and processing circuitry **2170**. Radio front end circuitry can be configured to condition signals communicated between antenna **2162** and processing circuitry **2170**. Radio front end circuitry **2192** can receive digital data that is to be sent out to other network nodes or WDS via a wireless connection. Radio front end circuitry **2192** can convert the digital data into a radio signal having the appropriate channel and bandwidth parameters using a combination of filters **2198** and/or amplifiers **2196**. The radio signal can then be

transmitted via antenna **2162**. Similarly, when receiving data, antenna **2162** can collect radio signals which are then converted into digital data by radio front end circuitry **2192**. The digital data can be passed to processing circuitry **2170**. In other embodiments, the interface can comprise different components and/or different combinations of components.

[0143] In certain alternative embodiments, network node **2160** may not include separate radio front end circuitry **2192**, instead, processing circuitry **2170** can comprise radio front end circuitry and can be connected to antenna **2162** without separate radio front end circuitry **2192**. Similarly, in some embodiments, all or some of RF transceiver circuitry **2172** can be considered a part of interface **2190**. In still other embodiments, interface **2190** can include one or more ports or terminals **2194**, radio front end circuitry **2192**, and RF transceiver circuitry **2172**, as part of a radio unit (not shown), and interface **2190** can communicate with baseband processing circuitry **2174**, which is part of a digital unit (not shown).

[0144] Antenna **2162** can include one or more antennas, or antenna arrays, configured to send and/or receive wireless signals. Antenna **2162** can be coupled to radio front end circuitry **2190** and can be any type of antenna capable of transmitting and receiving data and/or signals wirelessly. In some embodiments, antenna **2162** can comprise one or more omni-directional, sector or panel antennas operable to transmit/receive radio signals between, for example, 2 GHz and 66 GHz. An omni-directional antenna can be used to transmit/receive radio signals in any direction, a sector antenna can be used to transmit/receive radio signals from devices within a particular area, and a panel antenna can be a line of sight antenna used to transmit/receive radio signals in a relatively straight line. In some instances, the use of more than one antenna can be referred to as MIMO. In certain embodiments, antenna **2162** can be separate from network node **2160** and can be connectable to network node **2160** through an interface or port.

[0145] Antenna **2162**, interface **2190**, and/or processing circuitry **2170** can be configured to perform any receiving operations and/or certain obtaining operations described herein as being performed by a network node. Any information, data and/or signals can be received from a wireless device, another network node and/or any other network equipment. Similarly, antenna **2162**, interface **2190**, and/or processing circuitry **2170** can be configured to perform any transmitting operations described herein as being performed by a network node. Any information, data and/or signals can be transmitted to a wireless device, another network node and/or any other network equipment.

[0146] Power circuitry **2187** can comprise, or be coupled to, power management circuitry and can be configured to supply the components of network node **2160** with power for performing the functionality described herein. Power circuitry **2187** can receive power from power source **2186**. Power source **2186** and/or power circuitry **2187** can be configured to provide power to the various components of network node **2160** in a form suitable for the respective components (e.g., at a voltage and current level needed for each respective component). Power source **2186** can either be included in, or external to, power circuitry **2187** and/or network node **2160**. For example, network node **2160** can be connectable to an external power source (e.g., an electricity outlet) via an input circuitry or interface such as an electrical cable, whereby the external power source supplies power to

power circuitry **2187**. As a further example, power source **2186** can comprise a source of power in the form of a battery or battery pack which is connected to, or integrated in, power circuitry **2187**. The battery can provide backup power should the external power source fail. Other types of power sources, such as photovoltaic devices, can also be used.

[0147] Alternative embodiments of network node **2160** can include additional components beyond those shown in FIG. 14 that can be responsible for providing certain aspects of the network node's functionality, including any of the functionality described herein and/or any functionality necessary to support the subject matter described herein. For example, network node **2160** can include user interface equipment to allow and/or facilitate input of information into network node **2160** and to allow and/or facilitate output of information from network node **2160**. This can allow and/or facilitate a user to perform diagnostic, maintenance, repair, and other administrative functions for network node **2160**.

[0148] As used herein, wireless device (WD) refers to a device capable, configured, arranged and/or operable to communicate wirelessly with network nodes and/or other wireless devices. Unless otherwise noted, the term WD can be used interchangeably herein with user equipment (UE). Communicating wirelessly can involve transmitting and/or receiving wireless signals using electromagnetic waves, radio waves, infrared waves, and/or other types of signals suitable for conveying information through air. In some embodiments, a WD can be configured to transmit and/or receive information without direct human interaction. For instance, a WD can be designed to transmit information to a network on a predetermined schedule, when triggered by an internal or external event, or in response to requests from the network. Examples of a WD include, but are not limited to, a smart phone, a mobile phone, a cell phone, a voice over IP (VoIP) phone, a wireless local loop phone, a desktop computer, a personal digital assistant (PDA), a wireless cameras, a gaming console or device, a music storage device, a playback appliance, a wearable terminal device, a wireless endpoint, a mobile station, a tablet, a laptop, a laptop-embedded equipment (LEE), a laptop-mounted equipment (LME), a smart device, a wireless customer-premise equipment (CPE), a vehicle-mounted wireless terminal device, etc.

[0149] A WD can support device-to-device (D2D) communication, for example by implementing a 3GPP standard for sidelink communication, vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), vehicle-to-everything (V2X) and can in this case be referred to as a D2D communication device. As yet another specific example, in an Internet of Things (IoT) scenario, a WD can represent a machine or other device that performs monitoring and/or measurements, and transmits the results of such monitoring and/or measurements to another WD and/or a network node. The WD can in this case be a machine-to-machine (M2M) device, which can in a 3GPP context be referred to as an MTC device. As one particular example, the WD can be a UE implementing the 3GPP narrow band internet of things (NB-IoT) standard. Particular examples of such machines or devices are sensors, metering devices such as power meters, industrial machinery, or home or personal appliances (e.g., refrigerators, televisions, etc.) personal wearables (e.g., watches, fitness trackers, etc.). In other scenarios, a WD can represent a vehicle or other equipment that is capable of

monitoring and/or reporting on its operational status or other functions associated with its operation. A WD as described above can represent the endpoint of a wireless connection, in which case the device can be referred to as a wireless terminal. Furthermore, a WD as described above can be mobile, in which case it can also be referred to as a mobile device or a mobile terminal.

[0150] As illustrated, wireless device 2110 includes antenna 2111, interface 2114, processing circuitry 2120, device readable medium 2130, user interface equipment 2132, auxiliary equipment 2134, power source 2136 and power circuitry 2137. WD 2110 can include multiple sets of one or more of the illustrated components for different wireless technologies supported by WD 2110, such as, for example, GSM, WCDMA, LTE, NR, WiFi, WiMAX, or Bluetooth wireless technologies, just to mention a few. These wireless technologies can be integrated into the same or different chips or set of chips as other components within WD 2110.

[0151] Antenna 2111 can include one or more antennas or antenna arrays, configured to send and/or receive wireless signals, and is connected to interface 2114. In certain alternative embodiments, antenna 2111 can be separate from WD 2110 and be connectable to WD 2110 through an interface or port. Antenna 2111, interface 2114, and/or processing circuitry 2120 can be configured to perform any receiving or transmitting operations described herein as being performed by a WD. Any information, data and/or signals can be received from a network node and/or another WD. In some embodiments, radio front end circuitry and/or antenna 2111 can be considered an interface.

[0152] As illustrated, interface 2114 comprises radio front end circuitry 2112 and antenna 2111. Radio front end circuitry 2112 comprise one or more filters 2118 and amplifiers 2116. Radio front end circuitry 2114 is connected to antenna 2111 and processing circuitry 2120 and can be configured to condition signals communicated between antenna 2111 and processing circuitry 2120. Radio front end circuitry 2112 can be coupled to or a part of antenna 2111. In some embodiments, WD 2110 may not include separate radio front end circuitry 2112; rather, processing circuitry 2120 can comprise radio front end circuitry and can be connected to antenna 2111. Similarly, in some embodiments, some or all of RF transceiver circuitry 2122 can be considered a part of interface 2114. Radio front end circuitry 2112 can receive digital data that is to be sent out to other network nodes or WDs via a wireless connection. Radio front end circuitry 2112 can convert the digital data into a radio signal having the appropriate channel and bandwidth parameters using a combination of filters 2118 and/or amplifiers 2116. The radio signal can then be transmitted via antenna 2111. Similarly, when receiving data, antenna 2111 can collect radio signals which are then converted into digital data by radio front end circuitry 2112. The digital data can be passed to processing circuitry 2120. In other embodiments, the interface can comprise different components and/or different combinations of components.

[0153] Processing circuitry 2120 can comprise a combination of one or more of a microprocessor, controller, microcontroller, central processing unit, digital signal processor, application-specific integrated circuit, field programmable gate array, or any other suitable computing device, resource, or combination of hardware, software, and/or encoded logic operable to provide, either alone or in con-

junction with other WD 2110 components, such as device readable medium 2130, WD 2110 functionality. Such functionality can include providing any of the various wireless features or benefits discussed herein. For example, processing circuitry 2120 can execute instructions stored in device readable medium 2130 or in memory within processing circuitry 2120 to provide the functionality disclosed herein.

[0154] As illustrated, processing circuitry 2120 includes one or more of RF transceiver circuitry 2122, baseband processing circuitry 2124, and application processing circuitry 2126. In other embodiments, the processing circuitry can comprise different components and/or different combinations of components. In certain embodiments processing circuitry 2120 of WD 2110 can comprise a SOC. In some embodiments, RF transceiver circuitry 2122, baseband processing circuitry 2124, and application processing circuitry 2126 can be on separate chips or sets of chips. In alternative embodiments, part or all of baseband processing circuitry 2124 and application processing circuitry 2126 can be combined into one chip or set of chips, and RF transceiver circuitry 2122 can be on a separate chip or set of chips. In still alternative embodiments, part or all of RF transceiver circuitry 2122 and baseband processing circuitry 2124 can be on the same chip or set of chips, and application processing circuitry 2126 can be on a separate chip or set of chips. In yet other alternative embodiments, part or all of RF transceiver circuitry 2122, baseband processing circuitry 2124, and application processing circuitry 2126 can be combined in the same chip or set of chips. In some embodiments, RF transceiver circuitry 2122 can be a part of interface 2114. RF transceiver circuitry 2122 can condition RF signals for processing circuitry 2120.

[0155] In certain embodiments, some or all of the functionality described herein as being performed by a WD can be provided by processing circuitry 2120 executing instructions stored on device readable medium 2130, which in certain embodiments can be a computer-readable storage medium. In alternative embodiments, some or all of the functionality can be provided by processing circuitry 2120 without executing instructions stored on a separate or discrete device readable storage medium, such as in a hard-wired manner. In any of those particular embodiments, whether executing instructions stored on a device readable storage medium or not, processing circuitry 2120 can be configured to perform the described functionality. The benefits provided by such functionality are not limited to processing circuitry 2120 alone or to other components of WD 2110, but are enjoyed by WD 2110 as a whole, and/or by end users and the wireless network generally.

[0156] Processing circuitry 2120 can be configured to perform any determining, calculating, or similar operations (e.g., certain obtaining operations) described herein as being performed by a WD. These operations, as performed by processing circuitry 2120, can include processing information obtained by processing circuitry 2120 by, for example, converting the obtained information into other information, comparing the obtained information or converted information to information stored by WD 2110, and/or performing one or more operations based on the obtained information or converted information, and as a result of said processing making a determination.

[0157] Device readable medium 2130 can be operable to store a computer program, software, an application including one or more of logic, rules, code, tables, etc. and/or other

instructions capable of being executed by processing circuitry 2120. Device readable medium 2130 can include computer memory (e.g., Random Access Memory (RAM) or Read Only Memory (ROM)), mass storage media (e.g., a hard disk), removable storage media (e.g., a Compact Disk (CD) or a Digital Video Disk (DVD)), and/or any other volatile or non-volatile, non-transitory device readable and/or computer executable memory devices that store information, data, and/or instructions that can be used by processing circuitry 2120. In some embodiments, processing circuitry 2120 and device readable medium 2130 can be considered to be integrated.

[0158] User interface equipment 2132 can include components that allow and/or facilitate a human user to interact with WD 2110. Such interaction can be of many forms, such as visual, aural, tactile, etc. User interface equipment 2132 can be operable to produce output to the user and to allow and/or facilitate the user to provide input to WD 2110. The type of interaction can vary depending on the type of user interface equipment 2132 installed in WD 2110. For example, if WD 2110 is a smart phone, the interaction can be via a touch screen; if WD 2110 is a smart meter, the interaction can be through a screen that provides usage (e.g., the number of gallons used) or a speaker that provides an audible alert (e.g., if smoke is detected). User interface equipment 2132 can include input interfaces, devices and circuits, and output interfaces, devices and circuits. User interface equipment 2132 can be configured to allow and/or facilitate input of information into WD 2110 and is connected to processing circuitry 2120 to allow and/or facilitate processing circuitry 2120 to process the input information. User interface equipment 2132 can include, for example, a microphone, a proximity or other sensor, keys/buttons, a touch display, one or more cameras, a USB port, or other input circuitry. User interface equipment 2132 is also configured to allow and/or facilitate output of information from WD 2110, and to allow and/or facilitate processing circuitry 2120 to output information from WD 2110. User interface equipment 2132 can include, for example, a speaker, a display, vibrating circuitry, a USB port, a headphone interface, or other output circuitry. Using one or more input and output interfaces, devices, and circuits, of user interface equipment 2132, WD 2110 can communicate with end users and/or the wireless network and allow and/or facilitate them to benefit from the functionality described herein.

[0159] Auxiliary equipment 2134 is operable to provide more specific functionality which may not be generally performed by WDs. This can comprise specialized sensors for doing measurements for various purposes, interfaces for additional types of communication such as wired communications etc. The inclusion and type of components of auxiliary equipment 2134 can vary depending on the embodiment and/or scenario.

[0160] Power source 2136 can, in some embodiments, be in the form of a battery or battery pack. Other types of power sources, such as an external power source (e.g., an electricity outlet), photovoltaic devices or power cells, can also be used. WD 2110 can further comprise power circuitry 2137 for delivering power from power source 2136 to the various parts of WD 2110 which need power from power source 2136 to carry out any functionality described or indicated herein. Power circuitry 2137 can in certain embodiments comprise power management circuitry. Power circuitry 2137 can additionally or alternatively be operable to receive

power from an external power source; in which case WD 2110 can be connectable to the external power source (such as an electricity outlet) via input circuitry or an interface such as an electrical power cable. Power circuitry 2137 can also in certain embodiments be operable to deliver power from an external power source to power source 2136. This can be, for example, for the charging of power source 2136. Power circuitry 2137 can perform any converting or other modification to the power from power source 2136 to make it suitable for supply to the respective components of WD 2110.

[0161] FIG. 15 illustrates one embodiment of a UE in accordance with various aspects described herein. As used herein, a user equipment or UE may not necessarily have a user in the sense of a human user who owns and/or operates the relevant device. Instead, a UE can represent a device that is intended for sale to, or operation by, a human user but which may not, or which may not initially, be associated with a specific human user (e.g., a smart sprinkler controller). Alternatively, a UE can represent a device that is not intended for sale to, or operation by, an end user but which can be associated with or operated for the benefit of a user (e.g., a smart power meter). UE 2200 can be any UE identified by the 3rd Generation Partnership Project (3GPP), including a NB-IoT UE, a machine type communication (MTC) UE, and/or an enhanced MTC (eMTC) UE. UE 2200, as illustrated in FIG. 15, is one example of a WD configured for communication in accordance with one or more communication standards promulgated by the 3rd Generation Partnership Project (3GPP), such as 3GPP's GSM, UMTS, LTE, and/or 5G standards. As mentioned previously, the term WD and UE can be used interchangeably. Accordingly, although FIG. 15 is a UE, the components discussed herein are equally applicable to a WD, and vice-versa.

[0162] In FIG. 15, UE 2200 includes processing circuitry 2201 that is operatively coupled to input/output interface 2205, radio frequency (RF) interface 2209, network connection interface 2211, memory 2215 including random access memory (RAM) 2217, read-only memory (ROM) 2219, and storage medium 2221 or the like, communication subsystem 2231, power source 2233, and/or any other component, or any combination thereof. Storage medium 2221 includes operating system 2223, application program 2225, and data 2227. In other embodiments, storage medium 2221 can include other similar types of information. Certain UEs can utilize all of the components shown in FIG. 15, or only a subset of the components. The level of integration between the components can vary from one UE to another UE. Further, certain UEs can contain multiple instances of a component, such as multiple processors, memories, transceivers, transmitters, receivers, etc.

[0163] In FIG. 15, processing circuitry 2201 can be configured to process computer instructions and data. Processing circuitry 2201 can be configured to implement any sequential state machine operative to execute machine instructions stored as machine-readable computer programs in the memory, such as one or more hardware-implemented state machines (e.g., in discrete logic, FPGA, ASIC, etc.); programmable logic together with appropriate firmware; one or more stored program, general-purpose processors, such as a microprocessor or Digital Signal Processor (DSP), together with appropriate software; or any combination of the above. For example, the processing circuitry 2201 can

include two central processing units (CPUs). Data can be information in a form suitable for use by a computer.

[0164] In the depicted embodiment, input/output interface 2205 can be configured to provide a communication interface to an input device, output device, or input and output device. UE 2200 can be configured to use an output device via input/output interface 2205. An output device can use the same type of interface port as an input device. For example, a USB port can be used to provide input to and output from UE 2200. The output device can be a speaker, a sound card, a video card, a display, a monitor, a printer, an actuator, an emitter, a smartcard, another output device, or any combination thereof. UE 2200 can be configured to use an input device via input/output interface 2205 to allow and/or facilitate a user to capture information into UE 2200. The input device can include a touch-sensitive or presence-sensitive display, a camera (e.g., a digital camera, a digital video camera, a web camera, etc.), a microphone, a sensor, a mouse, a trackball, a directional pad, a trackpad, a scroll wheel, a smartcard, and the like. The presence-sensitive display can include a capacitive or resistive touch sensor to sense input from a user. A sensor can be, for instance, an accelerometer, a gyroscope, a tilt sensor, a force sensor, a magnetometer, an optical sensor, a proximity sensor, another like sensor, or any combination thereof. For example, the input device can be an accelerometer, a magnetometer, a digital camera, a microphone, and an optical sensor.

[0165] In FIG. 15, RF interface 2209 can be configured to provide a communication interface to RF components such as a transmitter, a receiver, and an antenna. Network connection interface 2211 can be configured to provide a communication interface to network 2243a. Network 2243a can encompass wired and/or wireless networks such as a local-area network (LAN), a wide-area network (WAN), a computer network, a wireless network, a telecommunications network, another like network or any combination thereof. For example, network 2243a can comprise a Wi-Fi network. Network connection interface 2211 can be configured to include a receiver and a transmitter interface used to communicate with one or more other devices over a communication network according to one or more communication protocols, such as Ethernet, TCP/IP, SONET, ATM, or the like. Network connection interface 2211 can implement receiver and transmitter functionality appropriate to the communication network links (e.g., optical, electrical, and the like). The transmitter and receiver functions can share circuit components, software or firmware, or alternatively can be implemented separately.

[0166] RAM 2217 can be configured to interface via bus 2202 to processing circuitry 2201 to provide storage or caching of data or computer instructions during the execution of software programs such as the operating system, application programs, and device drivers. ROM 2219 can be configured to provide computer instructions or data to processing circuitry 2201. For example, ROM 2219 can be configured to store invariant low-level system code or data for basic system functions such as basic input and output (I/O), startup, or reception of keystrokes from a keyboard that are stored in a non-volatile memory. Storage medium 2221 can be configured to include memory such as RAM, ROM, programmable read-only memory (PROM), erasable programmable read-only memory (EPROM), electrically erasable programmable read-only memory (EEPROM), magnetic disks, optical disks, floppy disks, hard disks,

removable cartridges, or flash drives. In one example, storage medium 2221 can be configured to include operating system 2223, application program 2225 such as a web browser application, a widget or gadget engine or another application, and data file 2227. Storage medium 2221 can store, for use by UE 2200, any of a variety of various operating systems or combinations of operating systems.

[0167] Storage medium 2221 can be configured to include a number of physical drive units, such as redundant array of independent disks (RAID), floppy disk drive, flash memory, USB flash drive, external hard disk drive, thumb drive, pen drive, key drive, high-density digital versatile disc (HD-DVD) optical disc drive, internal hard disk drive, Blu-Ray optical disc drive, holographic digital data storage (HDDS) optical disc drive, external mini-dual in-line memory module (DIMM), synchronous dynamic random access memory (SDRAM), external micro-DIMM SDRAM, smartcard memory such as a subscriber identity module or a removable user identity (SIM/RUIM) module, other memory, or any combination thereof. Storage medium 2221 can allow and/or facilitate UE 2200 to access computer-executable instructions, application programs or the like, stored on transitory or non-transitory memory media, to off-load data, or to upload data. An article of manufacture, such as one utilizing a communication system can be tangibly embodied in storage medium 2221, which can comprise a device readable medium.

[0168] In FIG. 15, processing circuitry 2201 can be configured to communicate with network 2243b using communication subsystem 2231. Network 2243a and network 2243b can be the same network or networks or different network or networks. Communication subsystem 2231 can be configured to include one or more transceivers used to communicate with network 2243b. For example, communication subsystem 2231 can be configured to include one or more transceivers used to communicate with one or more remote transceivers of another device capable of wireless communication such as another WD, UE, or base station of a radio access network (RAN) according to one or more communication protocols, such as IEEE 802.22, CDMA, WCDMA, GSM, LTE, UTRAN, WiMax, or the like. Each transceiver can include transmitter 2233 and/or receiver 2235 to implement transmitter or receiver functionality, respectively, appropriate to the RAN links (e.g., frequency allocations and the like). Further, transmitter 2233 and receiver 2235 of each transceiver can share circuit components, software or firmware, or alternatively can be implemented separately.

[0169] In the illustrated embodiment, the communication functions of communication subsystem 2231 can include data communication, voice communication, multimedia communication, short-range communications such as Bluetooth, near-field communication, location-based communication such as the use of the global positioning system (GPS) to determine a location, another like communication function, or any combination thereof. For example, communication subsystem 2231 can include cellular communication, Wi-Fi communication, Bluetooth communication, and GPS communication. Network 2243b can encompass wired and/or wireless networks such as a local-area network (LAN), a wide-area network (WAN), a computer network, a wireless network, a telecommunications network, another like network or any combination thereof. For example, network 2243b can be a cellular network, a Wi-Fi network, and/or a

near-field network. Power source **2213** can be configured to provide alternating current (AC) or direct current (DC) power to components of UE **2200**.

[0170] The features, benefits and/or functions described herein can be implemented in one of the components of UE **2200** or partitioned across multiple components of UE **2200**. Further, the features, benefits, and/or functions described herein can be implemented in any combination of hardware, software or firmware. In one example, communication subsystem **2231** can be configured to include any of the components described herein. Further, processing circuitry **2201** can be configured to communicate with any of such components over bus **2202**. In another example, any of such components can be represented by program instructions stored in memory that when executed by processing circuitry **2201** perform the corresponding functions described herein. In another example, the functionality of any of such components can be partitioned between processing circuitry **2201** and communication subsystem **2231**. In another example, the non-computationally intensive functions of any of such components can be implemented in software or firmware and the computationally intensive functions can be implemented in hardware.

[0171] FIG. 16 is a schematic block diagram illustrating a virtualization environment **2300** in which functions implemented by some embodiments can be virtualized. In the present context, virtualizing means creating virtual versions of apparatuses or devices which can include virtualizing hardware platforms, storage devices and networking resources. As used herein, virtualization can be applied to a node (e.g., a virtualized base station or a virtualized radio access node) or to a device (e.g., a UE, a wireless device or any other type of communication device) or components thereof and relates to an implementation in which at least a portion of the functionality is implemented as one or more virtual components (e.g., via one or more applications, components, functions, virtual machines or containers executing on one or more physical processing nodes in one or more networks).

[0172] In some embodiments, some or all of the functions described herein can be implemented as virtual components executed by one or more virtual machines implemented in one or more virtual environments **2300** hosted by one or more of hardware nodes **2330**. Further, in embodiments in which the virtual node is not a radio access node or does not require radio connectivity (e.g., a core network node), then the network node can be entirely virtualized.

[0173] The functions can be implemented by one or more applications **2320** (which can alternatively be called software instances, virtual appliances, network functions, virtual nodes, virtual network functions, etc.) operative to implement some of the features, functions, and/or benefits of some of the embodiments disclosed herein. Applications **2320** are run in virtualization environment **2300** which provides hardware **2330** comprising processing circuitry **2360** and memory **2390**. Memory **2390** contains instructions **2395** executable by processing circuitry **2360** whereby application **2320** is operative to provide one or more of the features, benefits, and/or functions disclosed herein.

[0174] Virtualization environment **2300**, comprises general-purpose or special-purpose network hardware devices **2330** comprising a set of one or more processors or processing circuitry **2360**, which can be commercial off-the-shelf (COTS) processors, dedicated Application Specific

Integrated Circuits (ASICs), or any other type of processing circuitry including digital or analog hardware components or special purpose processors. Each hardware device can comprise memory **2390-1** which can be non-persistent memory for temporarily storing instructions **2395** or software executed by processing circuitry **2360**. Each hardware device can comprise one or more network interface controllers (NICs) **2370**, also known as network interface cards, which include physical network interface **2380**. Each hardware device can also include non-transitory, persistent, machine-readable storage media **2390-2** having stored therein software **2395** and/or instructions executable by processing circuitry **2360**. Software **2395** can include any type of software including software for instantiating one or more virtualization layers **2350** (also referred to as hypervisors), software to execute virtual machines **2340** as well as software allowing it to execute functions, features and/or benefits described in relation with some embodiments described herein.

[0175] Virtual machines **2340**, comprise virtual processing, virtual memory, virtual networking or interface and virtual storage, and can be run by a corresponding virtualization layer **2350** or hypervisor. Different embodiments of the instance of virtual appliance **2320** can be implemented on one or more of virtual machines **2340**, and the implementations can be made in different ways.

[0176] During operation, processing circuitry **2360** executes software **2395** to instantiate the hypervisor or virtualization layer **2350**, which can sometimes be referred to as a virtual machine monitor (VMM). Virtualization layer **2350** can present a virtual operating platform that appears like networking hardware to virtual machine **2340**.

[0177] As shown in FIG. 16, hardware **2330** can be a standalone network node with generic or specific components. Hardware **2330** can comprise antenna **23225** and can implement some functions via virtualization. Alternatively, hardware **2330** can be part of a larger cluster of hardware (e.g. such as in a data center or customer premise equipment (CPE)) where many hardware nodes work together and are managed via management and orchestration (MANO) **23100**, which, among others, oversees lifecycle management of applications **2320**.

[0178] Virtualization of the hardware is in some contexts referred to as network function virtualization (NFV). NFV can be used to consolidate many network equipment types onto industry standard high-volume server hardware, physical switches, and physical storage, which can be located in data centers, and customer premise equipment.

[0179] In the context of NFV, virtual machine **2340** can be a software implementation of a physical machine that runs programs as if they were executing on a physical, non-virtualized machine. Each of virtual machines **2340**, and that part of hardware **2330** that executes that virtual machine, be it hardware dedicated to that virtual machine and/or hardware shared by that virtual machine with others of the virtual machines **2340**, forms a separate virtual network elements (VNE).

[0180] Still in the context of NFV, Virtual Network Function (VNF) is responsible for handling specific network functions that run in one or more virtual machines **2340** on top of hardware networking infrastructure **2330** and corresponds to application **2320** in FIG. 16.

[0181] In some embodiments, one or more radio units **23200** that each include one or more transmitters **23220** and

one or more receivers **23210** can be coupled to one or more antennas **23225**. Radio units **23200** can communicate directly with hardware nodes **2330** via one or more appropriate network interfaces and can be used in combination with the virtual components to provide a virtual node with radio capabilities, such as a radio access node or a base station.

[0182] In some embodiments, some signaling can be effected with the use of control system **23230** which can alternatively be used for communication between the hardware nodes **2330** and radio units **23200**.

[0183] With reference to FIG. 17, in accordance with an embodiment, a communication system includes telecommunication network **2410**, such as a 3GPP-type cellular network, which comprises access network **2411**, such as a radio access network, and core network **2414**. Access network **2411** comprises a plurality of base stations **2412a**, **2412b**, **2412c**, such as NBs, eNBs, gNBs or other types of wireless access points, each defining a corresponding coverage area **2413a**, **2413b**, **2413c**. Each base station **2412a**, **2412b**, **2412c** is connectable to core network **2414** over a wired or wireless connection **2415**. A first UE **2491** located in coverage area **2413c** can be configured to wirelessly connect to, or be paged by, the corresponding base station **2412c**. A second UE **2492** in coverage area **2413a** is wirelessly connectable to the corresponding base station **2412a**. While a plurality of UEs **2491**, **2492** are illustrated in this example, the disclosed embodiments are equally applicable to a situation where a sole UE is in the coverage area or where a sole UE is connecting to the corresponding base station **2412**.

[0184] Telecommunication network **2410** is itself connected to host computer **2430**, which can be embodied in the hardware and/or software of a standalone server, a cloud-implemented server, a distributed server or as processing resources in a server farm. Host computer **2430** can be under the ownership or control of a service provider or can be operated by the service provider or on behalf of the service provider. Connections **2421** and **2422** between telecommunication network **2410** and host computer **2430** can extend directly from core network **2414** to host computer **2430** or can go via an optional intermediate network **2420**. Intermediate network **2420** can be one of, or a combination of more than one of, a public, private or hosted network; intermediate network **2420**, if any, can be a backbone network or the Internet; in particular, intermediate network **2420** can comprise two or more sub-networks (not shown).

[0185] The communication system of FIG. 17 as a whole enables connectivity between the connected UEs **2491**, **2492** and host computer **2430**. The connectivity can be described as an over-the-top (OTT) connection **2450**. Host computer **2430** and the connected UEs **2491**, **2492** are configured to communicate data and/or signaling via OTT connection **2450**, using access network **2411**, core network **2414**, any intermediate network **2420** and possible further infrastructure (not shown) as intermediaries. OTT connection **2450** can be transparent in the sense that the participating communication devices through which OTT connection **2450** passes are unaware of routing of uplink and downlink communications. For example, base station **2412** may not or need not be informed about the past routing of an incoming downlink communication with data originating from host computer **2430** to be forwarded (e.g., handed over) to a connected UE **2491**. Similarly, base station **2412** need not be

aware of the future routing of an outgoing uplink communication originating from the UE **2491** towards the host computer **2430**.

[0186] Example implementations, in accordance with an embodiment, of the UE, base station and host computer discussed in the preceding paragraphs will now be described with reference to FIG. 18. In communication system **2500**, host computer **2510** comprises hardware **2515** including communication interface **2516** configured to set up and maintain a wired or wireless connection with an interface of a different communication device of communication system **2500**. Host computer **2510** further comprises processing circuitry **2518**, which can have storage and/or processing capabilities. In particular, processing circuitry **2518** can comprise one or more programmable processors, application-specific integrated circuits, field programmable gate arrays or combinations of these (not shown) adapted to execute instructions. Host computer **2510** further comprises software **2511**, which is stored in or accessible by host computer **2510** and executable by processing circuitry **2518**. Software **2511** includes host application **2512**. Host application **2512** can be operable to provide a service to a remote user, such as UE **2530** connecting via OTT connection **2550** terminating at UE **2530** and host computer **2510**. In providing the service to the remote user, host application **2512** can provide user data which is transmitted using OTT connection **2550**.

[0187] Communication system **2500** can also include base station **2520** provided in a telecommunication system and comprising hardware **2525** enabling it to communicate with host computer **2510** and with UE **2530**. Hardware **2525** can include communication interface **2526** for setting up and maintaining a wired or wireless connection with an interface of a different communication device of communication system **2500**, as well as radio interface **2527** for setting up and maintaining at least wireless connection **2570** with UE **2530** located in a coverage area (not shown in FIG. 18) served by base station **2520**. Communication interface **2526** can be configured to facilitate connection **2560** to host computer **2510**. Connection **2560** can be direct, or it can pass through a core network (not shown in FIG. 18) of the telecommunication system and/or through one or more intermediate networks outside the telecommunication system. In the embodiment shown, hardware **2525** of base station **2520** can also include processing circuitry **2528**, which can comprise one or more programmable processors, application-specific integrated circuits, field programmable gate arrays or combinations of these (not shown) adapted to execute instructions. Base station **2520** further has software **2521** stored internally or accessible via an external connection.

[0188] Communication system **2500** can also include UE **2530** already referred to. Its hardware **2535** can include radio interface **2537** configured to set up and maintain wireless connection **2570** with a base station serving a coverage area in which UE **2530** is currently located. Hardware **2535** of UE **2530** can also include processing circuitry **2538**, which can comprise one or more programmable processors, application-specific integrated circuits, field programmable gate arrays or combinations of these (not shown) adapted to execute instructions. UE **2530** further comprises software **2531**, which is stored in or accessible by UE **2530** and executable by processing circuitry **2538**. Software **2531** includes client application **2532**. Client

application **2532** can be operable to provide a service to a human or non-human user via UE **2530**, with the support of host computer **2510**. In host computer **2510**, an executing host application **2512** can communicate with the executing client application **2532** via OTT connection **2550** terminating at UE **2530** and host computer **2510**. In providing the service to the user, client application **2532** can receive request data from host application **2512** and provide user data in response to the request data. OTT connection **2550** can transfer both the request data and the user data. Client application **2532** can interact with the user to generate the user data that it provides.

[**0189**] It is noted that host computer **2510**, base station **2520** and UE **2530** illustrated in FIG. **18** can be similar or identical to host computer **2430**, one of base stations **2412a**, **2412b**, **2412c** and one of UEs **2491**, **2492** of FIG. **17**, respectively. This is to say, the inner workings of these entities can be as shown in FIG. **18** and independently, the surrounding network topology can be that of FIG. **17**.

[**0190**] In FIG. **18**, OTT connection **2550** has been drawn abstractly to illustrate the communication between host computer **2510** and UE **2530** via base station **2520**, without explicit reference to any intermediary devices and the precise routing of messages via these devices. Network infrastructure can determine the routing, which it can be configured to hide from UE **2530** or from the service provider operating host computer **2510**, or both. While OTT connection **2550** is active, the network infrastructure can further take decisions by which it dynamically changes the routing (e.g., on the basis of load balancing consideration or reconfiguration of the network).

[**0191**] Wireless connection **2570** between UE **2530** and base station **2520** is in accordance with the teachings of the embodiments described throughout this disclosure. One or more of the various embodiments improve the performance of OTT services provided to UE **2530** using OTT connection **2550**, in which wireless connection **2570** forms the last segment. More precisely, the exemplary embodiments disclosed herein enable proper routing of the incoming packets to the proper path (i.e., a next IAB node or the destination UE), as well as the mapping to the proper bearer in that path by enhancing the F1-AP and RRC protocols. The techniques described herein take advantage of existing RRC and F1-AP protocols, or even existing procedures, to realize the setup and reconfiguration of adaptation layers that are needed for routing packets to the right path (i.e., next node) and mapping them to the right bearer within the correct path. These and other advantages can facilitate more timely design, implementation, and deployment of 5G/NR solutions. Furthermore, such embodiments can facilitate flexible and timely control of data session QoS, which can lead to improvements in capacity, throughput, latency, etc. that are envisioned by 5G/NR and important for the growth of OTT services.

[**0192**] A measurement procedure can be provided for the purpose of monitoring data rate, latency and other network operational aspects on which the one or more embodiments improve. There can further be an optional network functionality for reconfiguring OTT connection **2550** between host computer **2510** and UE **2530**, in response to variations in the measurement results. The measurement procedure and/or the network functionality for reconfiguring OTT connection **2550** can be implemented in software **2511** and hardware **2515** of host computer **2510** or in software **2531**

and hardware **2535** of UE **2530**, or both. In embodiments, sensors (not shown) can be deployed in or in association with communication devices through which OTT connection **2550** passes; the sensors can participate in the measurement procedure by supplying values of the monitored quantities exemplified above or supplying values of other physical quantities from which software **2511**, **2531** can compute or estimate the monitored quantities. The reconfiguring of OTT connection **2550** can include message format, retransmission settings, preferred routing etc.; the reconfiguring need not affect base station **2520**, and it can be unknown or imperceptible to base station **2520**. Such procedures and functionalities can be known and practiced in the art. In certain embodiments, measurements can involve proprietary UE signaling facilitating host computer **2510**'s measurements of throughput, propagation times, latency and the like. The measurements can be implemented in that software **2511** and **2531** causes messages to be transmitted, in particular empty or 'dummy' messages, using OTT connection **2550** while it monitors propagation times, errors etc. [**0193**] In some exemplary embodiments, the base station **2520** in FIG. **18** comprises the distributed architecture of 5G, such as reflected in FIGS. **1** and **2**. For example, FIG. **19** below shows the base station **2520** with a central unit **2610** (e.g., gNB-CU) and at least one distributed unit **2630** (e.g., gNB-DUs).

[**0194**] The base station **2520** may be a donor gNB in some exemplary embodiments, with an F1 interface defined between the central unit **2610** and each of the distributed units **2630**. The central unit **2610** may have processing circuitry configured, for example, to determine a number of hops from the donor node **2520** to an integrated access backhaul relay node (IAB node) and store the number of hops for subsequent use in mapping packets to a backhaul bearer between the donor node **2520** and the IAB node. The donor node **2520** may store the number of hops by storing the number of hops in association with an IP address for the IAB node. Storing the number of hops in association with the IP address for the IAB node may include storing the number of hops and the IP address for the IAB node in a table containing a mapping of each of a plurality of IP addresses for IAB nodes to corresponding numbers of hops.

[**0195**] The number of hops may be stored in the donor node **2520** and the donor node **2520** may be configured to receive a packet for forwarding to the IAB node and map the packet to one of a plurality of backhaul bearers at the donor node **2520**, for transfer to the IAB node, based at least in part on the stored number of hops.

[**0196**] The packet may be a control plane (CP) packet targeted to the IAB node and the packet may be a user plane (UP) packet for relaying, by the IAB node, to a UE.

[**0197**] The donor node **2520** may map the packet by retrieving the stored number of hops for the IAB node, based on an IP address for the IAB node.

[**0198**] There may be a one-to-one mapping between hop counts and backhaul bearers.

[**0199**] There may be more than one backhaul bearer associated with the number of hops, and the donor node **2520** may map the packet by to the one of the plurality of backhaul bearers further based on a diffserv code point (DSCP) parameter in a header of the packet. The packet may be a CP packet and the donor node **9520** may tag the CP packet with a DSCP parameter value that indicates a dedicated backhaul bearer or dedicated backhaul bearers for

carrying control plane data. The packet may be a user plane UP packet corresponding to a high priority user, and the donor node **2520** may tag the UP packet with a DSCP parameter value that indicates that a dedicated high-priority backhaul bearer or dedicated high-priority backhaul bearers are to be used.

[0200] The donor node **2520** may, after the packet is mapped to the one of the plurality of backhaul bearers, add adaptation layer header information to the packet before forwarding, the added adaptation layer header information including a layer 2 IAB node address, a quality control indicator (QCI) value and/or a hop count value.

[0201] FIG. 20 illustrates an exemplary embodiment of a central unit **2610**. The central unit **2610** may be part of a base station, such as a donor gNB. The central unit **2610** (e.g., gNB-CU) may be connected to and control radio access points, or distributed units (e.g., gNB-DUs). The central unit **2610** may include communication circuitry **2618** for communicating with radio access points (e.g., gNB-DUs **2630**) and with other equipment in the core network (e.g., 5GC).

[0202] The central unit **2610** may include processing circuitry **2612** that is operatively associated with the communication circuitry **2618**. In an example embodiment, the processing circuitry **2612** comprises one or more digital processors **2614**, e.g., one or more microprocessors, microcontrollers, Digital Signal Processors (DSPs), Field Programmable Gate Arrays (FPGAs), Complex Programmable Logic Devices (CPLDs), Application Specific Integrated Circuits (ASICs), or any mix thereof. More generally, the processing circuitry **2612** may comprise fixed circuitry, or programmable circuitry that is specially configured via the execution of program instructions implementing the functionality taught herein.

[0203] The processing circuitry **2612** also includes or is associated with storage **2616**. The storage **2616**, in some embodiments, stores one or more computer programs and, optionally, configuration data. The storage **2616** provides non-transitory storage for the computer program and it may comprise one or more types of computer-readable media, such as disk storage, solid-state memory storage, or any mix thereof. By way of non-limiting example, the storage **2616** comprises any one or more of SRAM, DRAM, EEPROM, and FLASH memory.

[0204] In general, the storage **2616** comprises one or more types of computer-readable storage media providing non-transitory storage of the computer program and any configuration data used by the base station. Here, “non-transitory” means permanent, semi-permanent, or at least temporarily persistent storage and encompasses both long-term storage in non-volatile memory and storage in working memory, e.g., for program execution.

[0205] In some embodiments, the processing circuitry **2612** is configured to perform the method shown in FIG. 27. In some embodiments, the determine operation is performed in the CU portion of the donor node **2520** and is based on information indicating which radio node serves the IAB node.

[0206] In some embodiments, the method in FIG. 27 is performed in one or more DU portions, where the DU comprises communication circuitry and processing circuitry similar to that described above for the CU **2610**, and where the DU further comprises a radio transceiver operatively coupled to the processing circuitry and configured for radio

communication with one or more UEs and/or one or more relay nodes. The determine operation described above may be performed in the DU portion of the donor node **2520**, in some embodiments, e.g., based on signaling information in an adaptation layer in the DU portion of the donor node **2520**.

[0207] As explained earlier, a gNB-CU may be split into multiple entities. This includes gNB-CU-UPs, which serve the user plane and host the PDCP protocol, and one gNB-CU-CP, which serves the control plane and hosts the PDCP and RRC protocol. These two entities are shown as separate control units in FIG. 21, as control plane **2622** and first and second (user plane) control units **2624** and **2626**. Control plane **2622** and control units **2624**, **2626** may be comparable to CU-CP and CU-UP in FIG. 2. While FIG. 19 shows both the control plane **2622** and control units **2624**, **2626** within central unit **2610**, as if located with the same unit of a network node, in other embodiments, the control units **2624**, **2626** may be located outside the unit where the control plane **2622** resides, or even in another network node. Without regard to the exact arrangement, the processing circuitry **2612** may be considered to be the processing circuitry in one or more network nodes necessary to carry out the techniques described herein for the central unit **2610**, whether the processing circuitry **2612** is together in one unit or whether the processing circuitry **2612** is distributed in some fashion.

[0208] FIG. 22 illustrates an exemplary embodiment of an IAB/relay node **2900**. The IAB/relay node **2900** may be configured to relay communications between a donor gNB and UEs or other IABs. The IAB/relay node **2900** may include radio circuitry **2912** for facing UEs or other IABs and appearing as a base station to these elements. This radio circuitry **2912** may be considered part of distributed unit **2910**. The IAB/relay node **2900** may also include a mobile terminal (MT) part **2920** that includes radio circuitry **2922** for facing a donor gNB. The donor gNB may house the central unit **2610** corresponding to the distributed unit **2910**.

[0209] The IAB/relay node **2900** may include processing circuitry **2930** that is operatively associated with or controls the radio circuitry **2912**, **2922**. In an example embodiment, the processing circuitry **2930** comprises one or more digital processors, e.g., one or more microprocessors, microcontrollers, Digital Signal Processors (DSPs), Field Programmable Gate Arrays (FPGAs), Complex Programmable Logic Devices (CPLDs), Application Specific Integrated Circuits (ASICs), or any mix thereof. More generally, the processing circuitry **2930** may comprise fixed circuitry, or programmable circuitry that is specially configured via the execution of program instructions implementing the functionality taught herein.

[0210] The processing circuitry **2930** also includes or is associated with storage. The storage, in some embodiments, stores one or more computer programs and, optionally, configuration data. The storage provides non-transitory storage for the computer program and it may comprise one or more types of computer-readable media, such as disk storage, solid-state memory storage, or any mix thereof. By way of non-limiting example, the storage comprises any one or more of SRAM, DRAM, EEPROM, and FLASH memory.

[0211] In general, the storage comprises one or more types of computer-readable storage media providing non-transitory storage of the computer program and any configuration data used by the base station. Here, “non-transitory” means permanent, semi-permanent, or at least temporarily persis-

tent storage and encompasses both long-term storage in non-volatile memory and storage in working memory, e.g., for program execution.

[0212] According to some embodiments, the processing circuitry 2930 of the IAB/relay node 2900 is configured to receive a packet for forwarding to a donor node (e.g., gNB) and map the packet to one of a plurality of backhaul bearers at the IAB node/relay node 2900, for transfer to the donor node, based at least in part on a stored number of hops from the donor node to the IAB node.

[0213] In some embodiments, the packet is a control plane (CP) packet. In other embodiments, the packet is a user plane (UP) packet received from a user equipment (UE), for forwarding to the CN.

[0214] The processing circuitry 2930 may be configured to determine the number of hops by receiving an indication of the number of hops. The processing circuitry 2930 may be configured to maintain reflective quality-of-service (QoS) mapping for control plane data and tag uplink CP packets with a diffserv code point (DSCP) value from corresponding downlink CP data.

[0215] The processing circuitry 2930 may be configured to map the packet by retrieving the stored number of hops for the IAB node, based on an IP address for the IAB node. There may be a one-to-one mapping between hop counts and backhaul bearers. There may be more than one backhaul bearer associated with the number of hops, and the processing circuitry 2930 may be configured to map the packet to the one of the plurality of backhaul bearers further based on a DSCP parameter in a header of the packet.

[0216] In some embodiments, the processing circuitry is configured to, after the packet is mapped to the one of the plurality of backhaul bearers, add adaptation layer header information to the packet before forwarding, the added adaptation layer header information comprising a layer 2 IAB node address, a quality control indicator (QCI) value and/or a hop count value.

[0217] In some embodiments, the processing circuitry 2930 is configured to perform the method shown in FIG. 27.

[0218] FIG. 23 is a flowchart illustrating an exemplary method and/or procedure implemented in a communication system, in accordance with one embodiment. The communication system includes a host computer, a base station and a UE which, in some exemplary embodiments, can be those described with reference to FIGS. 24 and 25. For simplicity of the present disclosure, only drawing references to FIG. 23 will be included in this section. In step 3010, the host computer provides user data. In substep 3011 (which can be optional) of step 3010, the host computer provides the user data by executing a host application. In step 3020, the host computer initiates a transmission carrying the user data to the UE. In step 3030 (which can be optional), the base station transmits to the UE the user data which was carried in the transmission that the host computer initiated, in accordance with the teachings of the embodiments described throughout this disclosure. In step 3040 (which can also be optional), the UE executes a client application associated with the host application executed by the host computer.

[0219] FIG. 24 is a flowchart illustrating an exemplary method and/or procedure implemented in a communication system, in accordance with one embodiment. The communication system includes a host computer, a base station and a UE which can be those described with reference to FIGS. 24 and 25. For simplicity of the present disclosure, only

drawing references to FIG. 24 will be included in this section. In step 3110 of the method, the host computer provides user data. In an optional substep (not shown) the host computer provides the user data by executing a host application. In step 3120, the host computer initiates a transmission carrying the user data to the UE. The transmission can pass via the base station, in accordance with the teachings of the embodiments described throughout this disclosure. In step 3130 (which can be optional), the UE receives the user data carried in the transmission.

[0220] FIG. 25 is a flowchart illustrating an exemplary method and/or procedure implemented in a communication system, in accordance with one embodiment. The communication system includes a host computer, a base station and a UE which can be those described with reference to FIGS. 24 and 25. For simplicity of the present disclosure, only drawing references to FIG. 25 will be included in this section. In step 3210 (which can be optional), the UE receives input data provided by the host computer. Additionally or alternatively, in step 3220, the UE provides user data. In substep 3221 (which can be optional) of step 3220, the UE provides the user data by executing a client application. In substep 3211 (which can be optional) of step 3210, the UE executes a client application which provides the user data in reaction to the received input data provided by the host computer. In providing the user data, the executed client application can further consider user input received from the user. Regardless of the specific manner in which the user data was provided, the UE initiates, in substep 3230 (which can be optional), transmission of the user data to the host computer. In step 3240 of the method, the host computer receives the user data transmitted from the UE, in accordance with the teachings of the embodiments described throughout this disclosure.

[0221] FIG. 26 is a flowchart illustrating an exemplary method and/or procedure implemented in a communication system, in accordance with one embodiment. The communication system includes a host computer, a base station and a UE which can be those described with reference to FIGS. 24 and 25. For simplicity of the present disclosure, only drawing references to FIG. 26 will be included in this section. In step 3310 (which can be optional), in accordance with the teachings of the embodiments described throughout this disclosure, the base station receives user data from the UE. In step 3320 (which can be optional), the base station initiates transmission of the received user data to the host computer. In step 3330 (which can be optional), the host computer receives the user data carried in the transmission initiated by the base station.

[0222] FIG. 27 illustrates an exemplary method and/or procedure performed by at least one node in a RAN in a wireless communication network that also comprises a CN.

[0223] The term unit can have conventional meaning in the field of electronics, electrical devices and/or electronic devices and can include, for example, electrical and/or electronic circuitry, devices, modules, processors, memories, logic solid state and/or discrete devices, computer programs or instructions for carrying out respective tasks, procedures, computations, outputs, and/or displaying functions, and so on, as such as those that are described herein.

## Example Embodiments

[0224] Example embodiments of the techniques and apparatus described herein include, but are not limited to, the following enumerated examples:

[0225] i. A method performed by at least one node in a radio access network (RAN) in a wireless communication network that also comprises a core network (CN), the method comprising:

[0226] determining a number of hops from a donor node to an integrated access backhaul relay node (IAB node); and

[0227] storing the number of hops for subsequent use in mapping packets to a backhaul bearer between the donor node and the IAB node.

[0228] ii. The method of example embodiment i, wherein storing the number of hops comprises storing the number of hops in association with an IP address for the IAB node.

[0229] iii. The method of example embodiment ii, wherein storing the number of hops in association with the IP address for the IAB node comprising storing the number of hops and the IP address for the IAB node in a table containing a mapping of each of a plurality of IP addresses for IAB nodes to corresponding numbers of hops.

[0230] iv. The method of any of example embodiments i-iii, wherein the number of hops is stored in the donor node and wherein the method further comprises:

[0231] receiving, at the donor node, a packet for forwarding to the IAB node; and

[0232] mapping the packet to one of a plurality of backhaul bearers at the donor node, for transfer to the IAB node, based at least in part on the stored number of hops.

[0233] v. The method of example embodiment iv, wherein the packet is a control plane (CP) packet targeted to the IAB node.

[0234] vi. The method of example embodiment iv, wherein the packet is a user plane (UP) packet for relaying, by the IAB node, to a user equipment (UE).

[0235] vii. The method of any of example embodiments i-iii, wherein the number of hops is stored in the IAB node and wherein the method further comprises:

[0236] receiving, at the IAB node, a packet for forwarding to the donor node; and

[0237] mapping the packet to one of a plurality of backhaul bearers at the IAB node, for transfer to the donor node, based at least in part on the stored number of hops.

[0238] viii. The method of example embodiment vii, wherein the packet is a control plane (CP) packet.

[0239] ix. The method of example embodiment vii, wherein the packet is a user plane (UP) packet received from a user equipment (UE), for forwarding to the CN.

[0240] x. The method of any of example embodiments vii-ix, wherein determining the number of hops comprises receiving, at the IAB node, an indication of the number of hops.

[0241] xi. The method of any of example embodiments vii-x, wherein the method further comprises, at the IAB node, maintaining reflective quality-of-service (QoS) mapping for control plane data and tagging uplink control plane (CP) packets with a diffserv code point (DSCP) value from corresponding downlink CP data.

[0242] xii. The method of any of example embodiments iv-xi, wherein mapping the packet comprises retrieving the stored number of hops for the IAB node, based on an IP address for the IAB node.

[0243] xiii. The method of any of example embodiments iv-xii, wherein there is a one-to-one mapping between hop counts and backhaul bearers.

[0244] xiv. The method of any of example embodiments iv-xii, wherein there is more than one backhaul bearer associated with the number of hops, and wherein mapping the packet to the one of the plurality of backhaul bearers is further based on a diffserv code point (DSCP) parameter in a header of the packet.

[0245] xv. The method of any of example embodiments i-xiv, wherein said determining or storing, or both, is performed in the donor node.

[0246] xvi. The method of example embodiment xv, wherein said determining, or storing, or both, is performed in a central unit (CU) portion of a donor node that is split between the CU portion and one or more distributed unit (DU) portions.

[0247] xvii. The method of example embodiment xvi, wherein said determining is performed in the CU portion of the donor node and is based on information indicating which radio node serves the IAB node.

[0248] xviii. The method of example embodiment xv, wherein said determining, or storing, or both, is performed in a distributed unit (DU) portion of a donor node that is split between a central unit (CU) portion and one or more DU portions.

[0249] xix. The method of example embodiment xviii, wherein said determining is performed in the DU portion of the donor node and is based on signaling information in an adaptation layer in the DU portion of the donor node.

[0250] xx. The method of any of example embodiments iv-vi, wherein the packet is a control plane (CP) packet and wherein the method comprises, at the donor node, tagging the CP packet with a diffserv code point (DSCP) parameter value that indicates a dedicated backhaul bearer or dedicated backhaul bearers for carrying control plane data.

[0251] xxi. The method of any of example embodiments iv-vi, wherein the packet is a user plane (UP) packet corresponding to a high priority user, and wherein the method comprises, at the donor node, tagging the UP packet with a diffserv code point (DSCP) parameter value that indicates that a dedicated high-priority backhaul bearer or dedicated high-priority backhaul bearers are to be used.

[0252] xxii. The method of any of example embodiments iv-xx, wherein the method further comprises, after the packet is mapped to the one of the plurality of backhaul bearers, adding adaptation layer header information to the packet before forwarding, the added adaptation layer header information comprising one or more of any of the following:

[0253] a layer 2 IAB node address;

[0254] a quality control indicator (QCI) value; and

[0255] a hop count value.

[0256] xxiii. A donor node in a radio access network (RAN) in a wireless communication network that also comprises a core network (CN), the donor node comprising:

[0257] processing circuitry; and

[0258] a memory comprising computer instructions that when executed by the processing circuitry, cause the donor node to:

[0259] determine a number of hops from the donor node to an integrated access backhaul relay node (IAB node); and

[0260] store the number of hops for subsequent use in mapping packets to a backhaul bearer between the donor node and the IAB node.

[0261] xxiv. The donor node of example embodiment xxiii, wherein the memory comprises computer instructions that cause the donor node to store the number of hops by storing the number of hops in association with an IP address for the IAB node.

[0262] xxv. The donor node of example embodiment xxiv, wherein storing the number of hops in association with the IP address for the IAB node comprises storing the number of hops and the IP address for the IAB node in a table containing a mapping of each of a plurality of IP addresses for IAB nodes to corresponding numbers of hops.

[0263] xxvi. The donor node of any of example embodiments xxiii-xxv, wherein the number of hops is stored in the donor node and wherein the memory comprises computer instructions that cause the donor node to:

[0264] receive a packet for forwarding to the IAB node; and

[0265] map the packet to one of a plurality of backhaul bearers at the donor node, for transfer to the IAB node, based at least in part on the stored number of hops.

[0266] xxvii. The donor node of example embodiment xxvi, wherein the packet is a control plane (CP) packet targeted to the IAB node.

[0267] xxviii. The donor node of example embodiment xxvi, wherein the packet is a user plane (UP) packet for relaying, by the IAB node, to a user equipment (UE).

[0268] xxix. The donor node of any of example embodiments xxiii-xxviii, wherein the memory comprises computer instructions that cause the donor node to map the packet by retrieving the stored number of hops for the IAB node, based on an IP address for the IAB node.

[0269] xxx. The donor node of any of example embodiments xxiii-xxix, wherein there is a one-to-one mapping between hop counts and backhaul bearers.

[0270] xxxi. The donor node of any of example embodiments xxiii-xxix, wherein there is more than one backhaul bearer associated with the number of hops, and wherein the memory comprises computer instructions that cause the donor node to map the packet by to the one of the plurality of backhaul bearers further based on a diffserv code point (DSCP) parameter in a header of the packet.

[0271] xxxii. The donor node of example embodiment xxii, wherein the donor node is split between a central unit (CU) portion and one or more distributed unit (DU) portions, and wherein the determine operation, or store operation, or both, is performed in the CU portion.

[0272] xxxiii. The donor node of example embodiment xxxii, wherein the determine operation is performed in the CU portion of the donor node and is based on information indicating which radio node serves the IAB node.

[0273] xxxiv. The donor node of example embodiment xxiii, wherein the donor node is split between a central unit (CU) portion and one or more distributed unit (DU) portions, and wherein the determine operation, or store operation, or both, is performed in the DU portion of the donor node.

[0274] xxxv. The donor node of example embodiment xxxiv, wherein the determine operation is performed in the

DU portion of the donor node and is based on signaling information in an adaptation layer in the DU portion of the donor node.

[0275] xxxvi. The donor node of any of example embodiments xxvi-xxviii, wherein the packet is a control plane (CP) packet and wherein the memory comprises computer instructions that cause the donor node to tag the CP packet with a diffserv code point (DSCP) parameter value that indicates a dedicated backhaul bearer or dedicated backhaul bearers for carrying control plane data.

[0276] xxxvii. The donor node of any of example embodiments xxvi-xxviii, wherein the packet is a user plane (UP) packet corresponding to a high priority user, and wherein the memory comprises computer instructions that cause the donor node to tag the UP packet with a diffserv code point (DSCP) parameter value that indicates that a dedicated high-priority backhaul bearer or dedicated high-priority backhaul bearers are to be used.

[0277] xxxviii. The donor node of any of example embodiments xxvi-xxxvi, wherein the memory comprises computer instructions that cause the donor node to, after the packet is mapped to the one of the plurality of backhaul bearers, add adaptation layer header information to the packet before forwarding, the added adaptation layer header information comprising one or more of any of the following:

[0278] a layer 2 IAB node address;

[0279] a quality control indicator (QCI) value; and

[0280] a hop count value.

[0281] xxxix. An integrated access backhaul relay node (IAB node) in a radio access network (RAN) in a wireless communication network that also comprises a core network (CN), the IAB node comprising:

[0282] processing circuitry; and

[0283] a memory comprising computer instructions that when executed by the processing circuitry, cause the IAB node to:

[0284] receive a packet for forwarding to a donor node; and

[0285] map the packet to one of a plurality of backhaul bearers at the IAB node, for transfer to the donor node, based at least in part on a stored number of hops from the donor node to the IAB node.

[0286] xl. The IAB node of example embodiment xxxix, wherein the packet is a control plane (CP) packet.

[0287] xli. The IAB node of example embodiment xxxix, wherein the packet is a user plane (UP) packet received from a user equipment (UE), for forwarding to the CN.

[0288] xlii. The IAB node of any of example embodiments xxxix-xli, wherein the memory comprises computer instructions that cause the IAB node to determine the number of hops by receiving an indication of the number of hops.

[0289] xliii. The IAB node of any of example embodiments xxxix-xlii, wherein the memory comprises computer instructions that cause the IAB node to maintain reflective quality-of-service (QoS) mapping for control plane data and tag uplink control plane (CP) packets with a diffserv code point (DSCP) value from corresponding downlink CP data.

[0290] xliv. The IAB node of any of example embodiments xxxix-xliii, wherein the memory comprises computer instructions that cause the IAB node to map the packet by retrieving the stored number of hops for the IAB node, based on an IP address for the IAB node.

[0291] xlv. The IAB node of any of example embodiments xxxix-xliv, wherein there is a one-to-one mapping between hop counts and backhaul bearers.

[0292] xlvi. The IAB node of any of example embodiments xliv, wherein there is more than one backhaul bearer associated with the number of hops, and wherein the memory comprises computer instructions that cause the IAB node to map the packet to the one of the plurality of backhaul bearers further based on a diffserv code point (DSCP) parameter in a header of the packet.

[0293] xlvi. The IAB node of any of example embodiments xxxix-xlvi, wherein the memory comprises computer instructions that cause the IAB node to, after the packet is mapped to the one of the plurality of backhaul bearers, add adaptation layer header information to the packet before forwarding, the added adaptation layer header information comprising one or more of any of the following:

[0294] a layer 2 IAB node address;

[0295] a quality control indicator (QCI) value; and

[0296] a hop count value.

[0297] xlviii. One or more nodes adapted to perform the method of any of the example embodiments i-xxii.

[0298] xlix. A computer program comprising instructions that, when executed on at least one processing circuit, cause the at least one processing circuit to carry out the method according to any one of example embodiments i-xxii.

[0299] 1. A carrier containing the computer program of example embodiment xlix, wherein the carrier is one of an electronic signal, optical signal, radio signal, or computer readable storage medium.

[0300] li. A communication system including a host computer comprising:

[0301] processing circuitry configured to provide user data; and

[0302] a communication interface configured to forward the user data to a cellular network for transmission to a user equipment (UE),

[0303] wherein the cellular network comprises one or more nodes having a radio interface and processing circuitry; and

[0304] the one or more nodes' processing circuitry is configured to perform operations corresponding to any of the methods of example embodiments 1-22.

[0305] lii. The communication system of example embodiment li, further including the UE configured to communicate with the one or more nodes.

[0306] liii. The communication system of any of example embodiments li-lii, wherein:

[0307] the processing circuitry of the host computer is configured to execute a host application, thereby providing the user data; and

[0308] the UE comprises processing circuitry configured to execute a client application associated with the host application.

[0309] liv. The communication system of any of example embodiments li-liii, further comprising ones of the one or more nodes arranged in a multi-hop integrated access backhaul (IAB) configuration and configured to communicate with the UE.

[0310] lv. A method implemented in a communication system including a host computer, one or more nodes, and a user equipment (UE), the method comprising:

[0311] at the host computer, providing user data;

[0312] at the host computer, initiating a transmission carrying the user data to the UE via a cellular network comprising the one or more nodes; and

[0313] operations, performed by the one or more nodes, corresponding to any of the methods of example embodiments i-xxii.

[0314] lv. The method of example embodiment lv, further comprising, transmitting the user data by ones of the one or more nodes.

[0315] lvii. The method of any of example embodiments lv-lvi, wherein the user data is provided at the host computer by executing a host application, the method further comprising, at the UE, executing a client application associated with the host application.

[0316] lviii. The method of any of example embodiments lv-lvii, further comprising operations, performed by ones of the one or more nodes arranged in a multi-hop integrated access backhaul (IAB) configuration with other ones of the one or more nodes, corresponding to any of the methods of example embodiments i-xxii.

[0317] lix. A communication system including a host computer comprising a communication interface configured to receive user data originating from a transmission from a user equipment (UE) to a first network node comprising a radio interface and processing circuitry configured to perform operations corresponding to any of the methods of example embodiments i-xxii.

[0318] lx. The communication system of example embodiment lix, further including one or more nodes.

[0319] lxi. The communication system of example embodiments lix-lx, further including other ones of the one or more nodes arranged in a multi-hop integrated access backhaul (IAB) configuration with ones of the one or more nodes, and comprising radio interface circuitry and processing circuitry configured to perform operations corresponding to any of the methods of example embodiments i-xxii.

[0320] lxii. The communication system of any of example embodiments lix-lxi, further including the UE, wherein the UE is configured to communicate with at least one of the one or more nodes.

[0321] lxiii. The communication system of any of example embodiments lix-lxii, wherein:

[0322] the processing circuitry of the host computer is configured to execute a host application;

[0323] the UE is configured to execute a client application associated with the host application, thereby providing the user data to be received by the host computer.

[0324] Notably, modifications and other embodiments of the disclosed invention(s) will come to mind to one skilled in the art having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the invention(s) is/are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of this disclosure. Although specific terms may be employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

1-30. (canceled)

31. A method performed by at least one node in a radio access network (RAN) in a wireless communication network that also comprises a core network (CN), the method comprising:

determining a number of hops from a donor node to an integrated access backhaul relay node (IAB node); and storing the number of hops for subsequent use in mapping packets to a backhaul bearer between the donor node and the IAB node.

**32.** The method of claim **31**, wherein storing the number of hops comprises storing the number of hops in association with an IP address for the IAB node.

**33.** The method of claim **31**, wherein the number of hops is stored in the donor node and wherein the method further comprises:

receiving, at the donor node, a packet for forwarding to the IAB node; and

mapping the packet to one of a plurality of backhaul bearers at the donor node, for transfer to the IAB node, based at least in part on the stored number of hops.

**34.** The method of claim **31**, wherein the number of hops is stored in the IAB node and wherein the method further comprises:

receiving, at the IAB node, a packet for forwarding to the donor node; and

mapping the packet to one of a plurality of backhaul bearers at the IAB node, for transfer to the donor node, based at least in part on the stored number of hops.

**35.** The method of claim **34**, wherein determining the number of hops comprises receiving, at the IAB node, an indication of the number of hops.

**36.** A donor node for use in a radio access network (RAN) in a wireless communication network that also comprises a core network (CN), the donor node comprising:

processing circuitry; and

a memory comprising computer instructions that when executed by the processing circuitry, cause the donor node to:

determine a number of hops from the donor node to an integrated access backhaul relay node (IAB node); and

store the number of hops for subsequent use in mapping packets to a backhaul bearer between the donor node and the IAB node.

**37.** The donor node of claim **36**, wherein the memory comprises computer instructions that cause the donor node to store the number of hops in association with an IP address for the IAB node.

**38.** The donor node of claim **36**, wherein the number of hops is stored in the donor node and wherein the memory comprises computer instructions that cause the donor node to:

receive a packet for forwarding to the IAB node; and

map the packet to one of a plurality of backhaul bearers at the donor node, for transfer to the IAB node, based at least in part on the stored number of hops.

**39.** The donor node of claim **36**, wherein the memory comprises computer instructions that cause the donor node to map the packet by retrieving the stored number of hops for the IAB node, based on an IP address for the IAB node.

**40.** The donor node of claim **36**, wherein there is a one-to-one mapping between hop counts and backhaul bearers.

**41.** The donor node of claim **36**, wherein there is more than one backhaul bearer associated with the number of hops, and wherein the memory comprises computer instructions that cause the donor node to map the packet by to the

one of the plurality of backhaul bearers further based on a diffserv code point (DSCP) parameter in a header of the packet.

**42.** The donor node of claim **38**, wherein the packet is a control plane (CP) packet and wherein the memory comprises computer instructions that cause the donor node to tag the CP packet with a diffserv code point (DSCP) parameter value that indicates a dedicated backhaul bearer or dedicated backhaul bearers for carrying control plane data.

**43.** The donor node of claim **38**, wherein the packet is a user plane (UP) packet corresponding to a high priority user, and wherein the memory comprises computer instructions that cause the donor node to tag the UP packet with a diffserv code point (DSCP) parameter value that indicates that a dedicated high-priority backhaul bearer or dedicated high-priority backhaul bearers are to be used.

**44.** An integrated access backhaul relay node (IAB node) for use in a radio access network (RAN) in a wireless communication network that also comprises a core network (CN), the IAB node comprising:

processing circuitry; and

a memory comprising computer instructions that when executed by the processing circuitry, cause the IAB node to:

receive a packet for forwarding to a donor node; and map the packet to one of a plurality of backhaul bearers at the IAB node, for transfer to the donor node, based at least in part on a stored number of hops from the donor node to the IAB node.

**45.** The IAB node of claim **44**, wherein the memory comprises computer instructions that cause the IAB node to determine the number of hops by receiving an indication of the number of hops.

**46.** The IAB node of claim **44**, wherein the memory comprises computer instructions that cause the IAB node to maintain reflective quality-of-service (QoS) mapping for control plane data and tag uplink control plane (CP) packets with a diffserv code point (DSCP) value from corresponding downlink CP data.

**47.** The IAB node of claim **44**, wherein the memory comprises computer instructions that cause the IAB node to map the packet by retrieving the stored number of hops for the IAB node, based on an IP address for the IAB node.

**48.** The IAB node of claim **44**, wherein there is a one-to-one mapping between hop counts and backhaul bearers.

**49.** The IAB node of claim **44**, wherein there is more than one backhaul bearer associated with the number of hops, and wherein the memory comprises computer instructions that cause the IAB node to map the packet to the one of the plurality of backhaul bearers further based on a diffserv code point (DSCP) parameter in a header of the packet.

**50.** The IAB node of claim **44**, wherein the memory comprises computer instructions that cause the IAB node to, after the packet is mapped to the one of the plurality of backhaul bearers, add adaptation layer header information to the packet before forwarding, the added adaptation layer header information comprising one or more of any of the following:

a layer 2 IAB node address;

a quality control indicator (QCI) value; and

a hop count value.

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