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(71) Applicant: **INTEL CORPORATION** [US/US]; 2200 Mission College Blvd., Santa Clara, California 95054 (US).

(72) Inventors: **WANG, Yi**; 6B, 103 building, BAOXINGYUANYIQU Chaoyang district, Beijing, Beijing 10000 (CN). **LI, Yingyang**; 8F, Raycom InfoTech Park A, 2 Kexueyuan South Rd, Haidian District, Beijing, Beijing 100190 (CN). **PANTELEEV, Sergey**; 6 The Close, Mullen Park, Maynooth, W23 T86C (IE).

(74) Agent: **PERDOK, Monique M.** et al.; Schwegman Lundberg & Woessner, P.A., P.O. Box 2938, Minneapolis, Minnesota 55402 (US).

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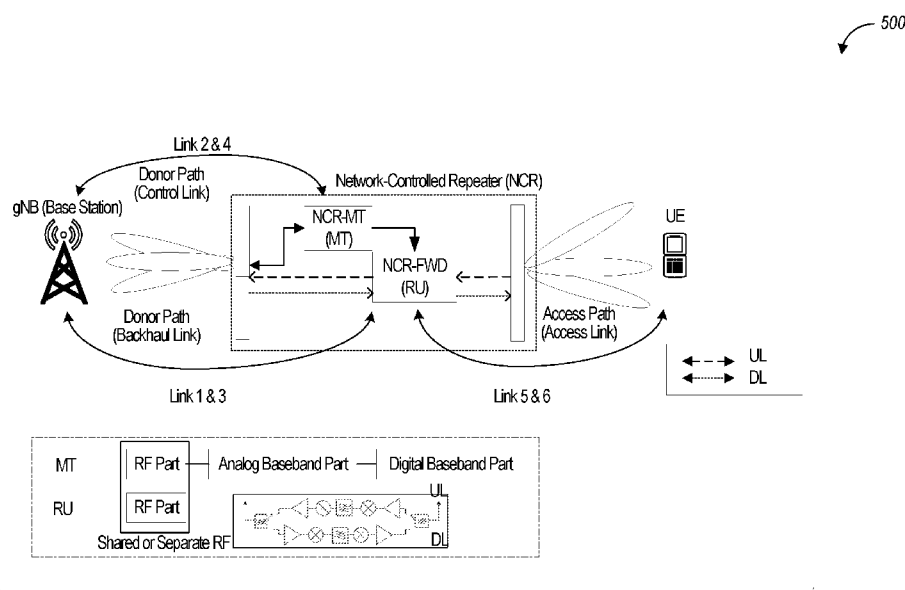


FIG. 5

(57) **Abstract:** A computer-readable storage medium stores instructions to configure a Network-Controlled Repeater (NCR) for communication with a base station in a 5G NR network, and to cause the NCR to perform operations including decoding configuration signaling received from the base station. The configuration signaling is received at an NCR-MT unit of the NCR and includes TDD UL-DL configurations. DL data is encoded for transmission by an NCR-FWD unit of the NCR to a UE in a first TDD resource. The operations include switching from transmission of the DL data to reception by the NCR-FWD unit of UL data transmitted by the UE in a second TDD resource. The first TDD resource and the second TDD resource are configured by the TDD UL-DL configurations.



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TDD CONFIGURATION AND TIMING AT A REPEATER

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PRIORITY CLAIM

[0001] This application claims the benefit of priority to the following patent applications:

10 [0002] International Application No. PCT/CN2022/087648, filed April 19, 2022, and entitled “TIME-DIVISION DUPLEX (TDD) CONFIGURATION AND TIMING AT A REPEATER;”

[0003] International Application No. PCT/CN2022/106453, filed July 19, 2022, and entitled “TIME-DIVISION DUPLEX (TDD) CONFIGURATION AND TIMING AT A REPEATER;” and

15 [0004] International Application No. PCT/CN2022/114803, filed August 25, 2022, and entitled “TIME-DIVISION DUPLEX (TDD) CONFIGURATION AND TIMING AT A REPEATER.”

[0005] Each of the above-listed applications is incorporated herein by reference in its entirety.

20

TECHNICAL FIELD

[0006] Aspects pertain to wireless communications. Some aspects relate to wireless networks including 3GPP (Third Generation Partnership Project) networks, 3GPP LTE (Long Term Evolution) networks, 3GPP LTE-A (LTE
25 Advanced) networks, (MultaFire, LTE-U), and fifth-generation (5G) networks including 5G new radio (NR) (or 5G-NR) networks, 5G-LTE networks such as 5G NR unlicensed spectrum (NR-U) networks and other unlicensed networks including Wi-Fi, CBRS (OnGo), etc. Other aspects are directed to techniques for time division duplex (TDD) configuration and timing at a repeater.

30

BACKGROUND

[0007] Mobile communications have evolved significantly from early voice systems to today’s highly sophisticated integrated communication platform. With the increase in different types of devices communicating with various

network devices, the usage of 3GPP LTE systems has increased. The penetration of mobile devices (user equipment or UEs) in modern society has continued to drive demand for a wide variety of networked devices in many disparate environments. Fifth-generation (5G) wireless systems are forthcoming
5 and are expected to enable even greater speed, connectivity, and usability. Next-generation 5G networks (or NR networks) are expected to increase throughput, coverage, and robustness and reduce latency and operational and capital expenditures. 5G-NR networks will continue to evolve based on 3GPP LTE-Advanced with additional potential new radio access technologies (RATs) to
10 enrich people's lives with seamless wireless connectivity solutions delivering fast, rich content and services. As the current cellular network frequency is saturated, higher frequencies, such as millimeter wave (mmWave) frequency, can be beneficial due to their high bandwidth.

[0008] Potential LTE operation in the unlicensed spectrum includes (and is
15 not limited to) the LTE operation in the unlicensed spectrum via dual connectivity (DC), or DC-based LAA, and the standalone LTE system in the unlicensed spectrum, according to which LTE-based technology solely operates in the unlicensed spectrum without requiring an "anchor" in the licensed spectrum, called MulteFire. Further enhanced operation of LTE and NR systems
20 in the licensed, as well as unlicensed spectrum, is expected in future releases and 5G systems. Such enhanced operations can include techniques for TDD configuration and timing at a repeater (e.g., a network-controlled repeater or NCR).

BRIEF DESCRIPTION OF THE FIGURES

- [0009] In the figures, which are not necessarily drawn to scale, like numerals may describe similar components in different views. Like numerals having different letter suffixes may represent different instances of similar components.
- 5 The figures illustrate generally, by way of example, but not by way of limitation, various aspects discussed in the present document.
- [0010] FIG. 1A illustrates an architecture of a network, in accordance with some aspects.
- [0011] FIG. 1B and FIG. 1C illustrate a non-roaming 5G system architecture
10 in accordance with some aspects.
- [0012] FIG. 2, FIG. 3, and FIG. 4 illustrate various systems, devices, and components that may implement aspects of disclosed embodiments.
- [0013] FIG. 5 is a diagram of a network-controlled repeater (NCR) used in the communication path between a base station and user equipment, in
15 accordance with some aspects.
- [0014] FIG. 6, FIG. 7, and FIG. 8 illustrate UL transmission coordination between NCR mobile terminal (MT) unit (also referred to as NCR-MT unit and NCR radio unit (RU) (also referred to as NCR-FWD unit), in accordance with some aspects.
- 20 [0015] FIG. 9 illustrates a block diagram of a communication device such as an evolved Node-B (eNB), a new generation Node-B (gNB) (or another RAN node), an NCR, an access point (AP), a wireless station (STA), a mobile station (MS), or user equipment (UE), in accordance with some aspects.

DETAILED DESCRIPTION

[0016] The following description and the drawings sufficiently illustrate aspects to enable those skilled in the art to practice them. Other aspects may incorporate structural, logical, electrical, process, and other changes. Portions
5 and features of some aspects may be included in or substituted for, those of other aspects. Aspects outlined in the claims encompass all available equivalents of those claims.

[0017] FIG. 1A illustrates an architecture of a network in accordance with some aspects. The network 140A is shown to include user equipment (UE) 101
10 and UE 102. The UEs 101 and 102 are illustrated as smartphones (e.g., handheld touchscreen mobile computing devices connectable to one or more cellular networks) but may also include any mobile or non-mobile computing device, such as Personal Data Assistants (PDAs), pagers, laptop computers, desktop computers, wireless handsets, drones, or any other computing device
15 including a wired and/or wireless communications interface. The UEs 101 and 102 can be collectively referred to herein as UE 101, and UE 101 can be used to perform one or more of the techniques disclosed herein.

[0018] Any of the radio links described herein (e.g., as used in the network 140A or any other illustrated network) may operate according to any exemplary
20 radio communication technology and/or standard.

[0019] LTE and LTE-Advanced are standards for wireless communications of high-speed data for UE such as mobile telephones. In LTE-Advanced and various wireless systems, carrier aggregation is a technology according to which multiple carrier signals operating on different frequencies may be used to carry
25 communications for a single UE, thus increasing the bandwidth available to a single device. In some aspects, carrier aggregation may be used where one or more component carriers operate on unlicensed frequencies.

[0020] Aspects described herein can be used in the context of any spectrum management scheme including, for example, dedicated licensed spectrum,
30 unlicensed spectrum, (licensed) shared spectrum (such as Licensed Shared Access (LSA) in 2.3-2.4 GHz, 3.4-3.6 GHz, 3.6-3.8 GHz, and further frequencies and Spectrum Access System (SAS) in 3.55-3.7 GHz and further frequencies).

[0021] Aspects described herein can also be applied to different Single Carrier or OFDM flavors (CP-OFDM, SC-FDMA, SC-OFDM, filter bank-based multicarrier (FBMC), OFDMA, etc.) and in particular 3GPP NR (New Radio) by allocating the OFDM carrier data bit vectors to the corresponding symbol
5 resources.

[0022] In some aspects, any of the UEs 101 and 102 can comprise an Internet-of-Things (IoT) UE or a Cellular IoT (CIoT) UE, which can comprise a network access layer designed for low-power IoT applications utilizing short-lived UE connections. In some aspects, any of the UEs 101 and 102 can include
10 a narrowband (NB) IoT UE (e.g., such as an enhanced NB-IoT (eNB-IoT) UE and Further Enhanced (FeNB-IoT) UE). An IoT UE can utilize technologies such as machine-to-machine (M2M) or machine-type communications (MTC) for exchanging data with an MTC server or device via a public land mobile network (PLMN), Proximity-Based Service (ProSe), or device-to-device (D2D)
15 communication, sensor networks, or IoT networks. The M2M or MTC exchange of data may be a machine-initiated exchange of data. An IoT network includes interconnecting IoT UEs, which may include uniquely identifiable embedded computing devices (within the Internet infrastructure), with short-lived connections. The IoT UEs may execute background applications (e.g., keep-
20 alive messages, status updates, etc.) to facilitate the connections of the IoT network.

[0023] In some aspects, any of the UEs 101 and 102 can include enhanced MTC (eMTC) UEs or further enhanced MTC (FeMTC) UEs.

[0024] The UEs 101 and 102 may be configured to connect, e.g.,
25 communicatively coupled, with a radio access network (RAN) 110. The RAN 110 may be, for example, a Universal Mobile Telecommunications System (UMTS), an Evolved Universal Terrestrial Radio Access Network (E-UTRAN), a NextGen RAN (NG RAN), or some other type of RAN. The UEs 101 and 102 utilize connections 103 and 104, respectively, each of which comprises a
30 physical communications interface or layer (discussed in further detail below); in this example, the connections 103 and 104 are illustrated as an air interface to enable communicative coupling and can be consistent with cellular communications protocols, such as a Global System for Mobile Communications

(GSM) protocol, a code-division multiple access (CDMA) network protocol, a Push-to-Talk (PTT) protocol, a PTT over Cellular (POC) protocol, a Universal Mobile Telecommunications System (UMTS) protocol, a 3GPP Long Term Evolution (LTE) protocol, a fifth-generation (5G) protocol, a New Radio (NR) protocol, and the like.

[0025] In an aspect, the UEs 101 and 102 may further directly exchange communication data via a ProSe interface 105. The ProSe interface 105 may alternatively be referred to as a sidelink interface comprising one or more logical channels, including but not limited to a Physical Sidelink Control Channel (PSCCH), a Physical Sidelink Shared Channel (PSSCH), a Physical Sidelink Discovery Channel (PSDCH), and a Physical Sidelink Broadcast Channel (PSBCH).

[0026] The UE 102 is shown to be configured to access an access point (AP) 106 via connection 107. The connection 107 can comprise a local wireless connection, such as, for example, a connection consistent with any IEEE 802.11 protocol, according to which the AP 106 can comprise a wireless fidelity (WiFi®) router. In this example, the AP 106 is shown to be connected to the Internet without connecting to the core network of the wireless system (described in further detail below).

[0027] The RAN 110 can include one or more access nodes that enable connections 103 and 104. These access nodes (ANs) can be referred to as base stations (BSs), NodeBs, evolved NodeBs (eNBs), Next Generation NodeBs (gNBs), RAN network nodes, and the like, and can comprise ground stations (e.g., terrestrial access points) or satellite stations providing coverage within a geographic area (e.g., a cell). In some aspects, communication nodes 111 and 112 can be transmission/reception points (TRPs). In instances when the communication nodes 111 and 112 are NodeBs (e.g., eNBs or gNBs), one or more TRPs can function within the communication cell of the NodeBs. The RAN 110 may include one or more RAN nodes for providing macrocells, e.g., macro RAN node 111, and one or more RAN nodes for providing femtocells or picocells (e.g., cells having smaller coverage areas, smaller user capacity, or higher bandwidth compared to macrocells), e.g., low power (LP) RAN node 112 or an unlicensed spectrum based secondary RAN node 112.

- [0028]** Any of the RAN nodes 111 and 112 can terminate the air interface protocol and can be the first point of contact for the UEs 101 and 102. In some aspects, any of the RAN nodes 111 and 112 can fulfill various logical functions for the RAN 110 including, but not limited to, the radio network controller
- 5 (RNC) functions such as radio bearer management, uplink and downlink dynamic radio resource management, and data packet scheduling, and mobility management. In an example, any of the nodes 111 and/or 112 can be a new generation Node-B (gNB), an evolved node-B (eNB), or another type of RAN node.
- 10 **[0029]** The RAN 110 is shown to be communicatively coupled to a core network (CN) 120 via an S1 interface 113. In aspects, the CN 120 may be an evolved packet core (EPC) network, a NextGen Packet Core (NPC) network, or some other type of CN (e.g., as illustrated in FIGS. 1B-1C). In this aspect, the S1 interface 113 is split into two parts: the S1-U interface 114, which carries
- 15 user traffic data between the RAN nodes 111 and 112 and the serving gateway (S-GW) 122, and the S1-mobility management entity (MME) interface 115, which is a signaling interface between the RAN nodes 111 and 112 and MMEs 121.
- [0030]** In this aspect, the CN 120 comprises the MMEs 121, the S-GW 122,
- 20 the Packet Data Network (PDN) Gateway (P-GW) 123, and a home subscriber server (HSS) 124. The MMEs 121 may be similar in function to the control plane of legacy Serving General Packet Radio Service (GPRS) Support Nodes (SGSN). The MMEs 121 may manage mobility aspects in access such as gateway selection and tracking area list management. The HSS 124 may
- 25 comprise a database for network users, including subscription-related information to support the network entities' handling of communication sessions. The CN 120 may comprise one or several HSSs 124, depending on the number of mobile subscribers, the capacity of the equipment, the organization of the network, etc. For example, the HSS 124 can provide support for
- 30 routing/roaming, authentication, authorization, naming/addressing resolution, location dependencies, etc.
- [0031]** The S-GW 122 may terminate the S1 interface 113 towards the RAN 110, and route data packets between the RAN 110 and the CN 120. In addition,

the S-GW 122 may be a local mobility anchor point for inter-RAN node handovers and also may provide an anchor for inter-3GPP mobility. Other responsibilities of the S-GW 122 may include lawful intercept, charging, and some policy enforcement.

5 **[0032]** The P-GW 123 may terminate an SGi interface toward a PDN. The P-GW 123 may route data packets between the EPC network 120 and external networks such as a network including the application server 184 (alternatively referred to as application function (AF)) via an Internet Protocol (IP) interface 125. The P-GW 123 can also communicate data to other external networks
10 131A, which can include the Internet, IP multimedia subsystem (IPS) network, and other networks. Generally, the application server 184 may be an element offering applications that use IP bearer resources with the core network (e.g., UMTS Packet Services (PS) domain, LTE PS data services, etc.). In this aspect, the P-GW 123 is shown to be communicatively coupled to an application server
15 184 via an IP interface 125. The application server 184 can also be configured to support one or more communication services (e.g., Voice-over-Internet Protocol (VoIP) sessions, PTT sessions, group communication sessions, social networking services, etc.) for the UEs 101 and 102 via the CN 120.

[0033] The P-GW 123 may further be a node for policy enforcement and
20 charging data collection. Policy and Charging Rules Function (PCRF) 126 is the policy and charging control element of the CN 120. In a non-roaming scenario, in some aspects, there may be a single PCRF in the Home Public Land Mobile Network (HPLMN) associated with a UE's Internet Protocol Connectivity Access Network (IP-CAN) session. In a roaming scenario with a local breakout
25 of traffic, there may be two PCRFs associated with a UE's IP-CAN session: a Home PCRF (H-PCRF) within an HPLMN and a Visited PCRF (V-PCRF) within a Visited Public Land Mobile Network (VPLMN). The PCRF 126 may be communicatively coupled to the application server 184 via the P-GW 123.

[0034] In some aspects, the communication network 140A can be an IoT
30 network or a 5G network, including a 5G new radio network using communications in the licensed (5G NR) and the unlicensed (5G NR-U) spectrum. One of the current enablers of IoT is the narrowband IoT (NB-IoT).

[0035] An NG system architecture can include the RAN 110 and a 5G core network 120. RAN 110 in an NG system can be referred to as NG-RAN 110. The NG-RAN 110 can include a plurality of nodes, such as gNBs and NG-eNBs. The core network 120 (also referred to as a 5G core network or 5GC) can
5 include an access and mobility function (AMF) and/or a user plane function (UPF). The AMF and the UPF can be communicatively coupled to the gNBs and the NG-eNBs via NG interfaces. More specifically, in some aspects, the gNBs and the NG-eNBs can be connected to the AMF by NG-C interfaces, and the UPF by NG-U interfaces. The gNBs and the NG-eNBs can be coupled to
10 each other via Xn interfaces.

[0036] In some aspects, the NG system architecture can use reference points between various nodes as provided by 3GPP Technical Specification (TS) 23.501 (e.g., V15.4.0, 2018-12). In some aspects, each of the gNBs and the NG-eNBs can be implemented as a base station, a mobile edge server, a small cell, a
15 home eNB, a RAN network node, and so forth. In some aspects, a gNB can be a master node (MN) and NG-eNB can be a secondary node (SN) in a 5G architecture. In some aspects, the master/primary node may operate in a licensed band and the secondary node may operate in an unlicensed band.

[0037] FIG. 1B illustrates a non-roaming 5G system architecture in
20 accordance with some aspects. Referring to FIG. 1B, there is illustrated a 5G system architecture 140B in a reference point representation. More specifically, UE 102 can be in communication with RAN 110 as well as one or more other 5G core (5GC) network entities. The 5G system architecture 140B includes a plurality of network functions (NFs), such as access and mobility management
25 function (AMF) 132, location management function (LMF) 133, session management function (SMF) 136, policy control function (PCF) 148, application function (AF) 150, user plane function (UPF) 134, network slice selection function (NSSF) 142, authentication server function (AUSF) 144, and unified data management (UDM)/home subscriber server (HSS) 146. The UPF 134 can
30 provide a connection to a data network (DN) 152, which can include, for example, operator services, Internet access, or third-party services. The AMF 132 can be used to manage access control and mobility and can also include network slice selection functionality. The SMF 136 can be configured to set up

and manage various sessions according to network policy. The UPF 134 can be deployed in one or more configurations according to the desired service type.

The PCF 148 can be configured to provide a policy framework using network slicing, mobility management, and roaming (similar to PCRF in a 4G

5 communication system). The UDM can be configured to store subscriber profiles and data (similar to an HSS in a 4G communication system).

[0038] The LMF 133 may be used in connection with 5G positioning functionalities. In some aspects, LMF 133 receives measurements and assistance information from the next-generation radio access network (NG-RAN) 110 and the mobile device (e.g., UE 101) via the AMF 132 over the NL interface to compute the position of the UE 101. In some aspects, NR positioning protocol A (NRPPa) may be used to carry the positioning information between NG-RAN and LMF 133 over a next-generation control plane interface (NG-C). In some aspects, LMF 133 configures the UE using the
10 LTE positioning protocol (LPP) via AMF 132. The NG-RAN 110 configures the UE 101 using radio resource control (RRC) protocol over LTE-Uu and NR-Uu interfaces.

[0039] In some aspects, the 5G system architecture 140B configures different reference signals to enable positioning measurements. Example reference
20 signals that may be used for positioning measurements include the positioning reference signal (NR PRS) in the downlink and the sounding reference signal (SRS) for positioning in the uplink. The downlink positioning reference signal (PRS) is a reference signal configured to support downlink-based positioning methods.

[0040] In some aspects, the 5G system architecture 140B includes an IP multimedia subsystem (IMS) 168B as well as a plurality of IP multimedia core network subsystem entities, such as call session control functions (CSCFs). More specifically, the IMS 168B includes a CSCF, which can act as a proxy CSCF (P-CSCF) 162BE, a serving CSCF (S-CSCF) 164B, an emergency CSCF (E-CSCF) (not illustrated in FIG. 1B), or interrogating CSCF (I-CSCF) 166B.
30 The P-CSCF 162B can be configured to be the first contact point for the UE 102 within the IMS 168B. The S-CSCF 164B can be configured to handle the session states in the network, and the E-CSCF can be configured to handle

certain aspects of emergency sessions such as routing an emergency request to the correct emergency center or PSAP. The I-CSCF 166B can be configured to function as the contact point within an operator's network for all IMS connections destined to a subscriber of that network operator, or a roaming
 5 subscriber currently located within that network operator's service area. In some aspects, the I-CSCF 166B can be connected to another IP multimedia network 170, e.g. an IMS operated by a different network operator.

[0041] In some aspects, the UDM/HSS 146 can be coupled to an application server (AS) 160B, which can include a telephony application server (TAS) or
 10 another AS. The AS 160B can be coupled to the IMS 168B via the S-CSCF 164B or the I-CSCF 166B.

[0042] A reference point representation shows that interaction can exist between corresponding NF services. For example, FIG. 1B illustrates the following reference points: N1 (between the UE 102 and the AMF 132), N2
 15 (between the RAN 110 and the AMF 132), N3 (between the RAN 110 and the UPF 134), N4 (between the SMF 136 and the UPF 134), N5 (between the PCF 148 and the AF 150, not shown), N6 (between the UPF 134 and the DN 152), N7 (between the SMF 136 and the PCF 148, not shown), N8 (between the UDM 146 and the AMF 132, not shown), N9 (between two UPFs 134, not shown),
 20 N10 (between the UDM 146 and the SMF 136, not shown), N11 (between the AMF 132 and the SMF 136, not shown), N12 (between the AUSF 144 and the AMF 132, not shown), N13 (between the AUSF 144 and the UDM 146, not shown), N14 (between two AMFs 132, not shown), N15 (between the PCF 148 and the AMF 132 in case of a non-roaming scenario, or between the PCF 148
 25 and a visited network and AMF 132 in case of a roaming scenario, not shown), N16 (between two SMFs, not shown), and N22 (between AMF 132 and NSSF 142, not shown). Other reference point representations not shown in FIG. 1B can also be used.

[0043] FIG. 1C illustrates a 5G system architecture 140C and a service-based representation. In addition to the network entities illustrated in FIG. 1B, system
 30 architecture 140C can also include a network exposure function (NEF) 154 and a network repository function (NRF) 156. In some aspects, 5G system architectures can be service-based and interaction between network functions

can be represented by corresponding point-to-point reference points N_i or as service-based interfaces.

[0044] In some aspects, as illustrated in FIG. 1C, service-based representations can be used to represent network functions within the control plane that enable other authorized network functions to access their services. In this regard, 5G system architecture 140C can include the following service-based interfaces: Namf 158H (a service-based interface exhibited by the AMF 132), Nsmf 158I (a service-based interface exhibited by the SMF 136), Nnef 158B (a service-based interface exhibited by the NEF 154), Npcf 158D (a service-based interface exhibited by the PCF 148), a Nudm 158E (a service-based interface exhibited by the UDM 146), Naf 158F (a service-based interface exhibited by the AF 150), Nnrf 158C (a service-based interface exhibited by the NRF 156), Nnssf 158A (a service-based interface exhibited by the NSSF 142), Nausf 158G (a service-based interface exhibited by the AUSF 144). Other service-based interfaces (e.g., Nudr, N5g-eir, and Nudsf) not shown in FIG. 1C can also be used.

[0045] FIGS. 2-13 illustrate various systems, devices, and components that may implement aspects of disclosed embodiments in different communication systems, such as 5G-NR networks including 5G non-terrestrial networks (NTNs). UEs, base stations (such as gNBs), and/or other nodes (e.g., satellites or other NTN nodes) discussed herein can be configured to perform the disclosed techniques.

[0046] FIG. 2 illustrates a network 200 in accordance with various embodiments. The network 200 may operate in a manner consistent with 3GPP technical specifications for LTE or 5G/NR systems. However, the example embodiments are not limited in this regard and the described embodiments may apply to other networks that benefit from the principles described herein, such as future 3GPP systems, or the like.

[0047] The network 200 may include a UE 202, which may include any mobile or non-mobile computing device designed to communicate with a RAN 204 via an over-the-air connection. The UE 202 may be but is not limited to, a smartphone, tablet computer, wearable computing device, desktop computer, laptop computer, in-vehicle infotainment, in-car entertainment device,

instrument cluster, a head-up display device, onboard diagnostic device, dashtop mobile equipment, mobile data terminal, electronic engine management system, electronic/engine control unit, electronic/engine control module, embedded system, sensor, microcontroller, control module, engine management system, networked appliance, machine-type communication device, M2M or D2D device, IoT device, etc.

[0048] In some embodiments, network 200 may include a plurality of UEs coupled directly with one another via a sidelink interface. The UEs may be M2M/D2D devices that communicate using physical sidelink channels such as but not limited to, PSBCH, PSDCH, PSSCH, PSCCH, PSFCH, etc.

[0049] In some embodiments, the UE 202 may additionally communicate with an AP 206 via an over-the-air connection. The AP 206 may manage a WLAN connection, which may serve to offload some/all network traffic from the RAN 204. The connection between the UE 202 and the AP 206 may be consistent with any IEEE 802.11 protocol, wherein the AP 206 could be a wireless fidelity (Wi-Fi®) router. In some embodiments, the UE 202, RAN 204, and AP 206 may utilize cellular-WLAN aggregation (for example, LWA/LWIP). Cellular-WLAN aggregation may involve the UE 202 configured by the RAN 204 to utilize both cellular radio resources and WLAN resources.

[0050] The RAN 204 may include one or more access nodes, for example, access node (AN) 208. AN 208 may terminate air-interface protocols for the UE 202 by providing access stratum protocols including RRC, Packet Data Convergence Protocol (PDCP), Radio Link Control (RLC), MAC, and L1 protocols. In this manner, the AN 208 may enable data/voice connectivity between the core network (CN) 220 and the UE 202. In some embodiments, the AN 208 may be implemented in a discrete device or as one or more software entities running on server computers as part of, for example, a virtual network, which may be referred to as a CRAN or virtual baseband unit pool. The AN 208 may be referred to as a BS, gNB, RAN node, eNB, ng-eNB, NodeB, RSU, TRxP, TRP, etc. The AN 208 may be a macrocell base station or a low-power base station for providing femtocells, picocells, or other like cells having smaller coverage areas, smaller user capacity, or higher bandwidth compared to macrocells.

[0051] In embodiments in which the RAN 204 includes a plurality of ANs, they may be coupled with one another via an X2 interface (if the RAN 204 is an LTE RAN) or an Xn interface (if the RAN 204 is a 5G RAN). The X2/Xn interfaces, which may be separated into control/user plane interfaces in some
5 embodiments, may allow the ANs to communicate information related to handovers, data/context transfers, mobility, load management, interference coordination, etc.

[0052] The ANs of the RAN 204 may each manage one or more cells, cell groups, component carriers, etc. to provide the UE 202 with an air interface for
10 network access. The UE 202 may be simultaneously connected with a plurality of cells provided by the same or different ANs of the RAN 204. For example, the UE 202 and RAN 204 may use carrier aggregation to allow the UE 202 to connect with a plurality of component carriers, each corresponding to a Pcell or Scell. In dual connectivity scenarios, a first AN may be a master node that
15 provides an MCG, and a second AN may be a secondary node that provides an SCG. The first/second ANs may be any combination of eNB, gNB, ng-eNB, etc.

[0053] The RAN 204 may provide the air interface over a licensed spectrum or an unlicensed spectrum. To operate in the unlicensed spectrum, the nodes may use LAA, eLAA, and/or feLAA mechanisms based on CA technology with
20 PCells/SCells. Before accessing the unlicensed spectrum, the nodes may perform medium/carrier-sensing operations based on, for example, a listen-before-talk (LBT) protocol.

[0054] In V2X scenarios, the UE 202 or AN 208 may be or act as a roadside unit (RSU), which may refer to any transportation infrastructure entity used for
25 V2X communications. An RSU may be implemented in or by a suitable AN or a stationary (or relatively stationary) UE. An RSU implemented in or by a UE may be referred to as a “UE-type RSU”; an eNB may be referred to as an “eNB-type RSU”; a gNB may be referred to as a “gNB-type RSU”; and the like. In one example, an RSU is a computing device coupled with radio frequency
30 circuitry located on a roadside that provides connectivity support to passing vehicle UEs. The RSU may also include internal data storage circuitry to store intersection map geometry, traffic statistics, and media, as well as applications/software to sense and control ongoing vehicular and pedestrian

traffic. The RSU may provide very low latency communications required for high-speed events, such as crash avoidance, traffic warnings, and the like. Additionally, or alternatively, the RSU may provide other cellular/WLAN communications services. The components of the RSU may be packaged in a weatherproof enclosure suitable for outdoor installation and may include a network interface controller to provide a wired connection (e.g., Ethernet) to a traffic signal controller or a backhaul network.

[0055] In some embodiments, the RAN 204 may be an LTE RAN 210 with eNBs, for example, eNB 212. The LTE RAN 210 may provide an LTE air interface with the following characteristics: sub-carrier spacing (SCS) of 15 kHz; CP-OFDM waveform for downlink (DL) and SC-FDMA waveform for uplink (UL); turbo codes for data and TBCC for control; etc. The LTE air interface may rely on CSI-RS for CSI acquisition and beam management; PDSCH/PDCCH DMRS for PDSCH/PDCCH demodulation; and CRS for cell search and initial acquisition, channel quality measurements, and channel estimation for coherent demodulation/detection at the UE. The LTE air interface may operate on sub-6 GHz bands.

[0056] In some embodiments, the RAN 204 may be an NG-RAN 214 with gNBs, for example, gNB 216, or ng-eNBs, for example, ng-eNB 218. The gNB 216 may connect with 5G-enabled UEs using a 5G NR interface. The gNB 216 may connect with a 5G core through an NG interface, which may include an N2 interface or an N3 interface. The ng-eNB 218 may also connect with the 5G core through an NG interface but may connect with a UE via an LTE air interface. The gNB 216 and the ng-eNB 218 may connect over an Xn interface.

[0057] In some embodiments, the NG interface may be split into two parts, an NG user plane (NG-U) interface, which carries traffic data between the nodes of the NG-RAN 214 and a UPF 248 (e.g., N3 interface), and an NG control plane (NG-C) interface, which is a signaling interface between the nodes of the NG-RAN214 and an AMF 244 (e.g., N2 interface).

[0058] The NG-RAN 214 may provide a 5G-NR air interface with the following characteristics: variable SCS; CP-OFDM for DL, CP-OFDM, and DFT-s-OFDM for UL; polar, repetition, simplex, and Reed-Muller codes for control and LDPC for data. The 5G-NR air interface may rely on CSI-RS,

PDSCH/PDCCH DMRS similar to the LTE air interface. The 5G-NR air interface may not use a CRS but may use PBCH DMRS for PBCH demodulation; PTRS for phase tracking for PDSCH and tracking reference signal for time tracking. The 5G-NR air interface may operate on FR1 bands that include sub-6 GHz bands or FR2 bands that include bands from 24.25 GHz to 52.6 GHz. The 5G-NR air interface may include a synchronization signal and physical broadcast channel (SS/PBCH) block (SSB) which is an area of a downlink resource grid that includes PSS/SSS/PBCH.

[0059] In some embodiments, the 5G-NR air interface may utilize BWPs (bandwidth parts) for various purposes. For example, BWP can be used for dynamic adaptation of the SCS. For example, the UE 202 can be configured with multiple BWPs where each BWP configuration has a different SCS. When a BWP change is indicated to the UE 202, the SCS of the transmission is changed as well. Another use case example of BWP is related to power saving. In particular, multiple BWPs can be configured for the UE 202 with different amounts of frequency resources (for example, PRBs) to support data transmission under different traffic loading scenarios. A BWP containing a smaller number of PRBs can be used for data transmission with a small traffic load while allowing power saving at the UE 202 and in some cases at the gNB 216. A BWP containing a larger number of PRBs can be used for scenarios with higher traffic loads.

[0060] The RAN 204 is communicatively coupled to CN 220 which includes network elements to provide various functions to support data and telecommunications services to customers/subscribers (for example, users of UE 202). The components of the CN 220 may be implemented in one physical node or separate physical nodes. In some embodiments, NFV may be utilized to virtualize any or all of the functions provided by the network elements of the CN 220 onto physical compute/storage resources in servers, switches, etc. A logical instantiation of the CN 220 may be referred to as a network slice, and a logical instantiation of a portion of the CN 220 may be referred to as a network sub-slice.

[0061] In some embodiments, the CN 220 may be connected to the LTE radio network as part of the Enhanced Packet System (EPS) 222, which may also be

referred to as an EPC (or enhanced packet core). The EPC 222 may include MME 224, SGW 226, SGSN 228, HSS 230, PGW 232, and PCRF 234 coupled with one another over interfaces (or “reference points”) as shown. Functions of the elements of the EPC 222 may be briefly introduced as follows.

- 5 **[0062]** The MME 224 may implement mobility management functions to track the current location of the UE 202 to facilitate paging, bearer activation/deactivation, handovers, gateway selection, authentication, etc.
- 10 **[0063]** The SGW 226 may terminate an S1 interface toward the RAN and route data packets between the RAN and the EPC 222. The SGW 226 may be a local mobility anchor point for inter-RAN node handovers and also may provide an anchor for inter-3GPP mobility. Other responsibilities may include lawful intercept, charging, and some policy enforcement.
- 15 **[0064]** The SGSN 228 may track the location of the UE 202 and perform security functions and access control. In addition, the SGSN 228 may perform inter-EPC node signaling for mobility between different RAT networks; PDN and S-GW selection as specified by MME 224; MME selection for handovers; etc. The S3 reference point between the MME 224 and the SGSN 228 may enable user and bearer information exchange for inter-3GPP access network mobility in idle/active states.
- 20 **[0065]** The HSS 230 may include a database for network users, including subscription-related information to support the network entities’ handling of communication sessions. The HSS 230 can provide support for routing/roaming, authentication, authorization, naming/addressing resolution, location dependencies, etc. An S6a reference point between the HSS 230 and the MME
- 25 224 may enable the transfer of subscription and authentication data for authenticating/authorizing user access to the LTE CN 220.
- 30 **[0066]** The PGW 232 may terminate an SGi interface toward a data network (DN) 236 that may include an application/content server 238. The PGW 232 may route data packets between the LTE CN 220 and the data network 236. The PGW 232 may be coupled with the SGW 226 by an S5 reference point to facilitate user plane tunneling and tunnel management. The PGW 232 may further include a node for policy enforcement and charging data collection (for example, PCEF). Additionally, the SGi reference point between the PGW 232

and the data network 236 may be an operator external public, a private PDN, or an intra-operator packet data network, for example, for the provision of IMS services. The PGW 232 may be coupled with a PCRF 234 via a Gx reference point.

- 5 **[0067]** The PCRF 234 is the policy and charging control element of the LTE CN 220. The PCRF 234 may be communicatively coupled to the app/content server 238 to determine appropriate QoS and charging parameters for service flows. The PCRF 234 may provision associated rules into a PCEF (via Gx reference point) with appropriate TFT and QCI.
- 10 **[0068]** In some embodiments, the CN 220 may be a 5GC 240. The 5GC 240 may include an AUSF 242, AMF 244, SMF 246, UPF 248, NSSF 250, NEF 252, NRF 254, PCF 256, UDM 258, and AF 260 coupled with one another over interfaces (or “reference points”) as shown. Functions of the elements of the 5GC 240 may be briefly introduced as follows.
- 15 **[0069]** The AUSF 242 may store data for the authentication of UE 202 and handle authentication-related functionality. The AUSF 242 may facilitate a common authentication framework for various access types. In addition to communicating with other elements of the 5GC 240 over reference points as shown, the AUSF 242 may exhibit a Nausf service-based interface.
- 20 **[0070]** The AMF 244 may allow other functions of the 5GC 240 to communicate with the UE 202 and the RAN 204 and to subscribe to notifications about mobility events with respect to the UE 202. The AMF 244 may be responsible for registration management (for example, for registering UE 202), connection management, reachability management, mobility management,
- 25 lawful interception of AMF-related events, and access authentication and authorization. The AMF 244 may provide transport for SM messages between the UE 202 and the SMF 246, and act as a transparent proxy for routing SM messages. AMF 244 may also provide transport for SMS messages between UE 202 and an SMSF. AMF 244 may interact with the AUSF 242 and the UE 202
- 30 to perform various security anchor and context management functions. Furthermore, AMF 244 may be a termination point of a RAN CP interface, which may include or be an N2 reference point between the RAN 204 and the AMF 244; and the AMF 244 may be a termination point of NAS (N1) signaling,

and perform NAS ciphering and integrity protection. AMF 244 may also support NAS signaling with the UE 202 over an N3 IWF interface.

[0071] The SMF 246 may be responsible for SM (for example, session establishment, tunnel management between UPF 248 and AN 208); UE IP address allocation and management (including optional authorization); selection and control of UP function; configuring traffic steering at UPF 248 to route traffic to proper destination; termination of interfaces toward policy control functions; controlling part of policy enforcement, charging, and QoS; lawful intercept (for SM events and interface to LI system); termination of SM parts of NAS messages; downlink data notification; initiating AN specific SM information, sent via AMF 244 over N2 to AN 208; and determining SSC mode of a session. SM may refer to the management of a PDU session, and a PDU session or “session” may refer to a PDU connectivity service that provides or enables the exchange of PDUs between the UE 202 and the data network 236.

[0072] The UPF 248 may act as an anchor point for intra-RAT and inter-RAT mobility, an external PDU session point of interconnecting to data network 236, and a branching point to support multi-homed PDU sessions. The UPF 248 may also perform packet routing and forwarding, perform packet inspection, enforce the user plane part of policy rules, lawfully intercept packets (UP collection), perform traffic usage reporting, perform QoS handling for a user plane (e.g., packet filtering, gating, UL/DL rate enforcement), perform uplink traffic verification (e.g., SDF-to-QoS flow mapping), transport level packet marking in the uplink and downlink, and perform downlink packet buffering and downlink data notification triggering. UPF 248 may include an uplink classifier to support routing traffic flows to a data network.

[0073] The NSSF 250 may select a set of network slice instances serving the UE 202. The NSSF 250 may also determine allowed NSSAI and the mapping to the subscribed S-NSSAIs if needed. The NSSF 250 may also determine the AMF set to be used to serve the UE 202, or a list of candidate AMFs based on a suitable configuration and possibly by querying the NRF 254. The selection of a set of network slice instances for the UE 202 may be triggered by the AMF 244 with which the UE 202 is registered by interacting with the NSSF 250, which may lead to a change of AMF. The NSSF 250 may interact with the AMF 244

via an N22 reference point and may communicate with another NSSF in a visited network via an N31 reference point (not shown). Additionally, the NSSF 250 may exhibit an Nnssf service-based interface.

[0074] The NEF 252 may securely expose services and capabilities provided by 3GPP network functions for the third party, internal exposure/re-exposure, AFs (e.g., AF 260), edge computing or fog computing systems, etc. In such embodiments, the NEF 252 may authenticate, authorize, or throttle the AFs. NEF 252 may also translate information exchanged with the AF 260 and information exchanged with internal network functions. For example, the NEF 252 may translate between an AF-Service-Identifier and an internal 5GC information. NEF 252 may also receive information from other NFs based on the exposed capabilities of other NFs. This information may be stored at the NEF 252 as structured data, or a data storage NF using standardized interfaces. The stored information can then be re-exposed by the NEF 252 to other NFs and AFs, or used for other purposes such as analytics. Additionally, the NEF 252 may exhibit a Nnef service-based interface.

[0075] The NRF 254 may support service discovery functions, receive NF discovery requests from NF instances, and provide information on the discovered NF instances to the NF instances. NRF 254 also maintains information on available NF instances and their supported services. As used herein, the terms “instantiate,” “instantiation,” and the like may refer to the creation of an instance, and an “instance” may refer to a concrete occurrence of an object, which may occur, for example, during the execution of program code. Additionally, the NRF 254 may exhibit the Nnrf service-based interface.

[0076] The PCF 256 may provide policy rules to control plane functions to enforce them, and may also support a unified policy framework to govern network behavior. The PCF 256 may also implement a front end to access subscription information relevant to policy decisions in a UDR of the UDM 258. In addition to communicating with functions over reference points as shown, the PCF 256 exhibits an Npcf service-based interface.

[0077] The UDM 258 may handle subscription-related information to support the network entities' handling of communication sessions and may store the subscription data of UE 202. For example, subscription data may be

communicated via an N8 reference point between the UDM 258 and the AMF 244. The UDM 258 may include two parts, an application front end, and a UDR. The UDR may store subscription data and policy data for the UDM 258 and the PCF 256, and/or structured data for exposure and application data
5 (including PFDs for application detection, and application request information for multiple UEs 202) for the NEF 252. The Nudr service-based interface may be exhibited by the UDR to allow the UDM 258, PCF 256, and NEF 252 to access a particular set of the stored data, as well as to read, update (e.g., add, modify), delete, and subscribe to the notification of relevant data changes in the
10 UDR. The UDM may include a UDM-FE, which is in charge of processing credentials, location management, subscription management, and so on. Several different front ends may serve the same user in different transactions. The UDM-FE accesses subscription information stored in the UDR and performs authentication credential processing, user identification handling, access
15 authorization, registration/mobility management, and subscription management. In addition to communicating with other NFs over reference points as shown, the UDM 258 may exhibit the Nudm service-based interface.

[0078] The AF 260 may provide application influence on traffic routing, provide access to NEF, and interact with the policy framework for policy
20 control.

[0079] In some embodiments, the 5GC 240 may enable edge computing by selecting operator/3rd party services to be geographically close to a point that the UE 202 is attached to the network. This may reduce latency and load on the network. To provide edge-computing implementations, the 5GC 240 may select
25 a UPF 248 close to the UE 202 and execute traffic steering from the UPF 248 to data network 236 via the N6 interface. This may be based on the UE subscription data, UE location, and information provided by the AF 260. In this way, the AF 260 may influence UPF (re)selection and traffic routing. Based on operator deployment, when AF 260 is considered to be a trusted entity, the
30 network operator may permit AF 260 to interact directly with relevant NFs. Additionally, the AF 260 may exhibit a Naf service-based interface.

[0080] The data network 236 may represent various network operator services, Internet access, or third-party services that may be provided by one or more servers including, for example, application/content server 238.

[0081] In some aspects, network 200 is configured for NR positioning using the location management function (LMF) 245, which can be configured as an LMF node or as functionality in a different type of node. In some embodiments, LMF 245 is configured to receive measurements and assistance information from NG-RAN 214 and UE 202 via the AMF 244 (e.g., using an N1 interface) to compute the position of the UE. In some embodiments, NR positioning protocol A (NRPPa) protocol can be used for carrying the positioning information between NG-RAN 214 and LMF 245 over a next-generation control plane interface (NG-C). In some embodiments, LMF 245 configures the UE 202 using LTE positioning protocol (LPP) (e.g., LPP-based communication link) via the AMF 244. In some aspects, NG-RAN 214 configures the UE 202 using, e.g., radio resource control (RRC) protocol signaling over, e.g., LTE-Uu and NR-Uu interfaces. In some aspects, UE 202 uses the LTE-Uu interface to communicate with the ng-eNB 218 and the NR-Uu interface to communicate with the gNB 216. In some aspects, ng-eNB 218 and gNB 216 use NG-C interfaces to communicate with the AMF 244.

[0082] In some embodiments, the following reference signals can be used to achieve positioning measurements in NR communication networks: NR positioning reference signal (NR PRS) in the downlink and sounding reference signal (SRS) for positioning in the uplink. The downlink positioning reference signal (PRS) can be used as a reference signal supporting downlink-based positioning techniques. In some aspects, the entire NR bandwidth can be covered by transmitting PRS over multiple symbols that can be aggregated to accumulate power.

[0083] FIG. 3 schematically illustrates a wireless network 300 in accordance with various embodiments. The wireless network 300 may include a UE 302 in wireless communication with AN 304. The UE 302 and AN 304 may be similar to, and substantially interchangeable with, like-named components described elsewhere herein.

- 5 **[0084]** The UE 302 may be communicatively coupled with the AN 304 via connection 306. Connection 306 is illustrated as an air interface to enable communicative coupling and can be consistent with cellular communications protocols such as an LTE protocol or a 5G NR protocol operating at mmWave or sub-6 GHz frequencies.
- 10 **[0085]** The UE 302 may include a host platform 308 coupled with a modem platform 310. The host platform 308 may include application processing circuitry 312, which may be coupled with protocol processing circuitry 314 of the modem platform 310. The application processing circuitry 312 may run various applications for the UE 302 that source/sink application data. The application processing circuitry 312 may further implement one or more layer operations to transmit/receive application data to/from a data network. These layer operations may include transport (for example UDP) and the Internet (for example IP) operations.
- 15 **[0086]** The protocol processing circuitry 314 may implement one or more layer operations to facilitate the transmission or reception of data over connection 306. The layer operations implemented by the protocol processing circuitry 314 may include, for example, MAC, RLC, PDCP, RRC, and NAS operations.
- 20 **[0087]** The modem platform 310 may further include digital baseband circuitry 316 that may implement one or more layer operations that are “below” layer operations performed by the protocol processing circuitry 314 in a network protocol stack. These operations may include, for example, PHY operations including one or more of HARQ-ACK functions, scrambling/descrambling, encoding/decoding, layer mapping/de-mapping, modulation symbol mapping, received symbol/bit metric determination, multi-antenna port precoding/decoding, which may include one or more of space-time, space-frequency or spatial coding, reference signal generation/detection, preamble sequence generation and/or decoding, synchronization sequence generation/detection, control channel signal blind decoding, and other related functions.
- 30 **[0088]** The modem platform 310 may further include transmit circuitry 318, receive circuitry 320, RF circuitry 322, and RF front end (RFFE) 324, which

may include or connect to one or more antenna panels 326. Briefly, the transmit circuitry 318 may include a digital-to-analog converter, mixer, intermediate frequency (IF) components, etc.; the receive circuitry 320 may include an analog-to-digital converter, mixer, IF components, etc.; the RF circuitry 322 may include a low-noise amplifier, a power amplifier, power tracking components, etc.; RFFE 324 may include filters (for example, surface/bulk acoustic wave filters), switches, antenna tuners, beamforming components (for example, phase-array antenna components), etc. The selection and arrangement of the components of the transmit circuitry 318 receive circuitry 320, RF circuitry 322, RFFE 324, and antenna panels 326 (referred to generically as “transmit/receive components”) may be specific to details of a specific implementation such as, for example, whether the communication is TDM or FDM, in mmWave or sub-6 GHz frequencies, etc. In some embodiments, the transmit/receive components may be arranged in multiple parallel transmit/receive chains, may be disposed of in the same or different chips/modules, etc.

[0089] In some embodiments, the protocol processing circuitry 314 may include one or more instances of control circuitry (not shown) to provide control functions for the transmit/receive components.

[0090] A UE reception may be established by and via the antenna panels 326, RFFE 324, RF circuitry 322, receive circuitry 320, digital baseband circuitry 316, and protocol processing circuitry 314. In some embodiments, the antenna panels 326 may receive a transmission from the AN 304 by receive-beamforming signals received by a plurality of antennas/antenna elements of the one or more antenna panels 326.

[0091] A UE transmission may be established by and via the protocol processing circuitry 314, digital baseband circuitry 316, transmit circuitry 318, RF circuitry 322, RFFE 324, and antenna panels 326. In some embodiments, the transmit components of the UE 302 may apply a spatial filter to the data to be transmitted to form a transmit beam emitted by the antenna elements of the antenna panels 326.

[0092] Similar to the UE 302, the AN 304 may include a host platform 328 coupled with a modem platform 330. The host platform 328 may include application processing circuitry 332 coupled with protocol processing circuitry

334 of the modem platform 330. The modem platform may further include digital baseband circuitry 336, transmit circuitry 338, receive circuitry 340, RF circuitry 342, RFFE circuitry 344, and antenna panels 346. The components of the AN 304 may be similar to and substantially interchangeable with the like-named components of the UE 302. In addition to performing data transmission/reception as described above, the components of the AN 304 may perform various logical functions that include, for example, RNC functions such as radio bearer management, uplink and downlink dynamic radio resource management, and data packet scheduling.

10 **[0093]** FIG. 4 is a block diagram illustrating components, according to some example embodiments, able to read instructions from a machine-readable or computer-readable medium (e.g., a non-transitory machine-readable storage medium) and perform any one or more of the methodologies discussed herein. Specifically, FIG. 4 shows a diagrammatic representation of hardware resources
15 400 including one or more processors (or processor cores) 410, one or more memory/storage devices 420, and one or more communication resources 430, each of which may be communicatively coupled via a bus 440 or other interface circuitry. For embodiments where node virtualization (e.g., NFV) is utilized, a hypervisor 402 may be executed to provide an execution environment for one or
20 more network slices/sub-slices to utilize the hardware resources 400.

[0094] The one or more processors 410 may include, for example, a processor 412 and a processor 414. The one or more processors 410 may be, for example, a central processing unit (CPU), a reduced instruction set computing (RISC) processor, a complex instruction set computing (CISC) processor, a
25 graphics processing unit (GPU), a DSP such as a baseband processor, an ASIC, an FPGA, a radio-frequency integrated circuit (RFIC), another processor (including those discussed herein), or any suitable combination thereof.

[0095] The memory/storage devices 420 may include a main memory, disk storage, or any suitable combination thereof. The memory/storage devices 420
30 may include but are not limited to, any type of volatile, non-volatile, or semi-volatile memory such as dynamic random access memory (DRAM), static random access memory (SRAM), erasable programmable read-only memory

(EPROM), electrically erasable programmable read-only memory (EEPROM), Flash memory, solid-state storage, etc.

[0096] The communication resources 430 may include interconnection or network interface controllers, components, or other suitable devices to communicate with one or more peripheral devices 404 or one or more databases 406 or other network elements via a network 408. For example, the communication resources 430 may include wired communication components (e.g., for coupling via USB, Ethernet, etc.), cellular communication components, NFC components, Bluetooth® (or Bluetooth® Low Energy) components, Wi-Fi® components, and other communication components.

[0097] Instructions 450 may comprise software, a program, an application, an applet, an app, or other executable code for causing at least any of the one or more processors 410 to perform any one or more of the methodologies discussed herein. The instructions 450 may reside, completely or partially, within at least one of the one or more processors 410 (e.g., within the processor's cache memory), the memory/storage devices 420, or any suitable combination thereof. Furthermore, any portion of the instructions 450 may be transferred to the hardware resources 400 from any combination of the peripheral devices 404 or the databases 406. Accordingly, the memory of the one or more processors 410, the memory/storage devices 420, the peripheral devices 404, and the databases 406 are examples of computer-readable and machine-readable media.

[0098] For one or more embodiments, at least one of the components outlined in one or more of the preceding figures may be configured to perform one or more operations, techniques, processes, and/or methods as outlined in the example sections below. For example, baseband circuitry associated with one or more of the preceding figures may be configured to operate in accordance with one or more of the examples set forth below. For another example, circuitry associated with a UE, base station, satellite, network element, etc. as described above in connection with one or more of the preceding figures may be configured to operate in accordance with one or more of the examples set forth below in the example section.

[0099] The term “application” may refer to a complete and deployable package, or environment to achieve a certain function in an operational

environment. The term “AI/ML application” or the like may be an application that contains some artificial intelligence (AI)/machine learning (ML) models and application-level descriptions. In some embodiments, an AI/ML application may be used for configuring or implementing one or more of the disclosed

5 aspects.

[00100] The term “machine learning” or “ML” refers to the use of computer systems implementing algorithms and/or statistical models to perform a specific task(s) without using explicit instructions but instead relying on patterns and inferences. ML algorithms build or estimate mathematical model(s) (referred to as “ML models” or the like) based on sample data (referred to as “training data,” “model training information,” or the like) to make predictions or decisions without being explicitly programmed to perform such tasks. Generally, an ML algorithm is a computer program that learns from experience concerning some task and some performance measure, and an ML model may be any object or data structure created after an ML algorithm is trained with one or more training datasets. After training, an ML model may be used to make predictions on new datasets. Although the term “ML algorithm” refers to different concepts than the term “ML model,” these terms as discussed herein may be used interchangeably for the present disclosure.

[00101] The term “machine learning model,” “ML model,” or the like may also refer to ML methods and concepts used by an ML-assisted solution. An “ML-assisted solution” is a solution that addresses a specific use case using ML algorithms during operation. ML models include supervised learning (e.g., linear regression, k-nearest neighbor (KNN), decision tree algorithms, support machine vectors, Bayesian algorithm, ensemble algorithms, etc.) unsupervised learning (e.g., K-means clustering, principal component analysis (PCA), etc.), reinforcement learning (e.g., Q-learning, multi-armed bandit learning, deep RL, etc.), neural networks, and the like. Depending on the implementation a specific ML model could have many sub-models as components and the ML model may train all sub-models together. Separately trained ML models can also be chained together in an ML pipeline during inference. An “ML pipeline” is a set of functionalities, functions, or functional entities specific to an ML-assisted solution; an ML pipeline may include one or several data sources in a data

pipeline, a model training pipeline, a model evaluation pipeline, and an actor.

The “actor” is an entity that hosts an ML-assisted solution using the output of the ML model inference). The term “ML training host” refers to an entity, such as a network function, that hosts the training of the model. The term “ML inference host” refers to an entity, such as a network function, that hosts the model during inference mode (which includes both the model execution as well as any online learning if applicable). The ML host informs the actor about the output of the ML algorithm, and the actor decides on an action (an “action” is performed by an actor as a result of the output of an ML-assisted solution). The term “model inference information” refers to information used as an input to the ML model for determining inference(s); the data used to train an ML model and the data used to determine inferences may overlap, however, “training data” and “inference data” refer to different concepts.

[00102] Coverage is a fundamental aspect of cellular network deployments. Mobile operators rely on different types of network nodes to offer blanket coverage in their deployments. One type of network node is the radio frequency (RF) repeater which is configured to amplify-and-forward any signal that they receive. While an RF repeater presents a cost-effective means of extending network coverage, it has its limitations. An RF repeater does an amplify-and-forward operation without being able to take into account various factors that could improve performance, e.g., adaptive transmitter/receiver spatial beamforming, etc. A network-controlled repeater (NCR) is an enhancement over conventional RF repeaters with the capability to receive and process side control information from the network. Side control information could allow a network-controlled repeater to perform its amplify-and-forward operation more efficiently. Potential benefits could include mitigation of unnecessary noise amplification, transmissions and receptions with better spatial directivity, and simplified network integration.

[00103] The disclosed techniques include system and methods for time division duplex (TDD) uplink-downlink (UL-DL) and DL-UL timing determination at a repeater controlled by a gNB (e.g., an NCR). More specifically, the disclosed techniques include TDD UL/DL determination for the repeater radio unit (RU) (also referred to as NCR forwarding unit or NCR-FWD

unit), and UL transmission coordination between the NCR mobile terminal (MT) unit (also referred to as NCR-MT unit) and the RU.

[00104] FIG. 5 is a diagram of a network-controlled repeater (NCR) 500 used in the communication path between a base station and user equipment, in accordance with some aspects.

[00105] In some embodiments, NCR 500 includes a control part (e.g., NCR-MT unit or MT) and a forwarding part (e.g., MCR-FWD unit or RU).

[00106] The control unit (denoted as MT in the following description) is used to receive the control signaling from the gNB side, and it may also provide feedback to the gNB side (e.g., the confirmation of the control signaling).

[00107] The forwarding unit (denoted as RU in the following description) is configured to amplify-and-forward the signal received from the gNB to the UE, or the signal received from the UE to the gNB.

[00108] The path between the gNB and the NCR is denoted as a donor path. The donor path includes the following four communication links:

[00109] (a) gNB – repeater RU (link 1);

[00110] (b) gNB – repeater MT (link 2);

[00111] (c) repeater RU – gNB (link 3); and

[00112] (d) repeater MT – gNB (link 4).

[00113] The path between the NCR and the UE is denoted as an access path. The access path includes the following two communication links:

[00114] (a) repeater RU – UE (link 5); and

[00115] (b) UE – repeater RU (link 6).

[00116] In some aspects, links 1 and 3 in the donor path are also referred to as backhaul communication links, links 2 and 4 in the donor path are also referred to as control communication links, and links 5 and 6 of the access path are also referred to as access communication links.

[00117] In some aspects, the repeater receives RF signals from the gNB via link 1 and then forwards the RF signals to the UE via link 5 without decoding the signals. The repeater receives RF signals from the UE via link 6 and then forwards the RF signals to the gNB via link 3 without decoding the signals.

- [00118] In some aspects, the repeater receives and decodes control information from the gNB via link 2, and the repeater may communicate feedback to the gNB via link 4 (e.g., the NCR 500 sends L1 or L2 ACK to the gNB for the received control information). The repeater can adjust parameters for the
- 5 repeater RU part according to the received control information (e.g., the repeater switches between DL and UL RU link communication according to TDD UL/DL configuration, the repeater adjusts reception and forwarding timing, and the repeater determines whether and how to transmit UL generated by repeater MT and forwarded by repeater RU).
- 10 [00119] In some aspects, at the repeater side, a single RF is shared for link 1 and link 2, and a single RF is shared for link 3 and link 4. In another aspect, at the repeater side, a separate RF is applied for link 1 and link 2, and a separate RF is applied for link 3 and link 4.

TDD UL/DL Configuration Determination

- 15 [00120] For a TDD repeater, UL and DL are both using the same frequency range, and separating DL and UL by time as an FDD repeater is not applicable. Therefore, in practical implementation, the repeater has to know the time domain behavior of the network to achieve synchronization with the gNB and the UE. Otherwise, the repeater could not know when and how to determine the switch
- 20 of DL and UL RU parts/units which will result in DL-UL cross-link interference that degrades the signal quality.

- [00121] In some embodiments, the repeater obtains cell-specific TDD UL/DL configuration by reading system information block-1 (SIB1). In one option, the same TDD UL/DL configuration, e.g., provided by tdd-UL-DL-
- 25 ConfigurationCommon IE, is applied for all links (e.g., links 1-6 in FIG. 5) in both the access path and the donor path. In some aspects, separate TDD UL/DL configuration for the UE and the repeater can be indicated by SIB (e.g., tdd-UL-DL-ConfigurationCommon for the UE and the links between the repeater MT unit and the gNB, tdd-UL-DL-ConfigurationRepeater for links between the
- 30 repeater RU and the gNB, and the repeater RU and the UE). In some embodiments, at least TDD UL/DL configuration for repeater can be obtained by Operations, Administration, and Management (OAM) configurations.

[00122] In some embodiments, the repeater may obtain TDD UL/DL configuration for the repeater RU by dedicated signaling. The dedicated signaling can be existing RRC signaling, e.g., similar to tdd-UL-DL-ConfigurationDedicated, or new side control information.

- 5 [00123] In some aspects, the side control information can be L1, L2, or L3 signaling. For example, TDD UL/DL configuration for the repeater can be carried by a media access control (MAC) control element (CE).

[00124] In some embodiments, TDD UL/DL configuration for the repeater RU only indicates DL or UL symbol/slots. For a symbol/slot without DL or UL
10 indication, the repeater considers it as an invalid symbol that the repeater does not forward in any direction (DL/UL), e.g., the repeater RU is off in the invalid symbol. Alternatively, the repeater considers it a flexible symbol.

[00125] In some embodiments, TDD UL/DL configuration for repeater RU indicates DL or UL or an invalid/flexible symbol.

- 15 [00126] For both options, for a set of symbols of a slot indicated as DL/UL by tdd-UL-DL-ConfigurationCommon, it is not expected that the set of symbols is indicated as UL/DL by dedicated signaling for the repeater.

[00127] In some aspects, if the repeater does not receive the TDD UL/DL configuration for the repeater RU by dedicated signaling, the repeater assumes
20 TDD UL/DL configuration configured by tdd-UL-DL-ConfigurationCommon or tdd-UL-DL-ConfigurationDedicated or Slot format indicator (SFI) if provided also applies to repeater RU links.

[00128] In some embodiments, it is not expected that the DL slot/symbol for the repeater MT conflicts with the UL slot/symbol for the repeater RU, and the
25 UL slot/symbol for the repeater MT conflicts with a DL slot/symbol for the repeater RU.

[00129] In some embodiments, the signaling for the TDD UL/DL configuration for the repeater RU can include a single TDD UL/DL configuration, which applies to all carriers forwarded by the repeater RU.
30 Alternatively, the signaling for the TDD UL/DL configuration for the repeater RU can include multiple TDD UL/DL configurations, which apply to different carriers forwarded by the repeater RU respectively. For example, if a repeater

RU forwards X carriers in a different frequency band or a frequency range, the gNB may indicate Y TDD UL/DL configurations for the repeater. The signaling indicates each TDD UL/DL configuration and the carrier which uses the TDD UL/DL configuration, e.g., indicating one or multiple serving cell IDs for y-th TDD UL/DL configuration, or indicating one or multiple frequency band/range information for y-th TDD UL/DL configuration with the assumption that all carriers within the same frequency band/range using the same y-th TDD UL/DL configuration.

[00130] In some embodiments, the repeater turns on the UL forwarding chain for the UL slot/symbol, and the repeater turns on the DL forwarding chain for the DL slot/symbol. For flexible or invalid symbols, the repeater does not forward any DL from gNB to UE and UL from UE to gNB. In other words, the repeater turns off both the DL and the UL RU links.

[00131] Alternatively, for a flexible symbol, if the MT has DL signals/channels to receive, the repeater forwards the DL from the gNB to the UE. For a flexible symbol, if the MT has UL signals/channels to transmit, the repeater does not forward DL or UL.

[00132] Alternatively, for flexible symbols without specific channels/signals, the repeater does not forward any DL from gNB to UE and UL from UE to gNB. For flexible symbols with at least one symbol of specific channels/signals, the repeater forward DL from gNB to UE, or forward UL from UE to gNB, according to at least one of the following options:

[00133] (a) If the specific signal includes cell-specific SS/PBCH, e.g., SS/PBCH indicated by *ssb-PositionsInBurst* in SIB1, the repeater forwards the DL from the gNB to the UE.

[00134] (b) If the specific signal includes CORESET for Type0-PDCCH CSS set indicated by *pdccch-ConfigSIB1* in MIB, the repeater forwards the DL from the gNB to the UE.

[00135] (c) If the specific signal includes valid RACH or PUSCH occasion derived by SIB1 and the specific signal does not include cell-specific SS/PBCH, the repeater forwards UL from UE to gNB.

[00136] (d) If the specific signal includes valid RACH or PUSCH occasion derived by SIB1 and the specific signal does not include cell-specific SS/PBCH, and the MT does not transmit UL to the gNB, the repeater forwards the UL from the UE to the gNB.

- 5 **[00137]** (e) If the specific signal includes valid RACH or PUSCH occasion derived by SIB1 and the specific signal does not include cell-specific SS/PBCH or CORESET for Type0-PDCCH CSS set indicated by `pdccch-ConfigSIB1` in MIB, the repeater forwards the UL from the UE to the gNB.

- 10 **[00138]** (f) If the specific signal includes valid RACH or PUSCH occasion derived by SIB1 and the specific signal does not include cell-specific SS/PBCH or CORESET for Type0-PDCCH CSS set indicated by `pdccch-ConfigSIB1` in MIB, and the MT does not transmit UL to gNB, the repeater forwards the UL from the UE to the gNB.

- 15 **[00139]** (g) If the specific signal includes a PDCCH, a PDSCH, a CSI-RS, or a DL PRS which is configured by higher layers to receive by MT, and if the MT does not detect a DCI format that indicates MT to transmit a PUSCH, a PUCCH, a PRACH, or an SRS in at least one symbol of the set of symbols of the PDCCH, or the PDSCH, or the CSI-RS, or the DL PRS, the repeater forwards the DL from the gNB to the UE.

- 20 **[00140]** (h) If the specific signal includes a PDCCH, a PDSCH, a CSI-RS, or a DL PRS which is scheduled to receive by MT, the repeater forwards the DL from the gNB to the UE.

UL/DL Timing Determination

- 25 **[00141]** In some aspects, to avoid UL-to-DL interference, and also avoid DL-to-DL interference or UL-to-UL interference, the UL/DL timing for all 6 links can be controlled.

- 30 **[00142]** In some aspects, for DL reception timing at the repeater RU in the donor path, the DL reception timing at the repeater MT in the donor path is applied. For DL transmission timing at the repeater RU in the access path, the DL transmission timing is based on the DL reception timing at the repeater RU in the donor path plus an offset. In some aspects, the offset is determined by the

processing delay at repeater RU. In some aspects, the offset is configured by the gNB, which is no smaller than the processing delay at the repeater RU.

[00143] In some embodiments, for UL reception timing at the repeater RU in the access path, the UL reception timing is based on the UL transmission timing at the repeater MT in the donor path minus an offset. In some aspects, the offset is determined by the processing delay at the repeater RU. In some embodiments, the offset is configured by the gNB, which is no smaller than the processing delay at repeater RU.

[00144] For UL transmission timing at the repeater RU in the donor path, in one option, the UL transmission timing at the repeater MT in the donor path is applied. In some embodiments, the UL transmission timing is based on the UL reception timing at the repeater RU in the access path plus an offset. The offset is determined based on the processing delay at the repeater RU.

[00145] In some embodiments, the UL transmission timing at the repeater MT in the donor path is determined by the timing advance signaling as a normal UE. In some embodiments, the UL transmission timing at the repeater MT in the donor path is indicated by the side control information.

[00146] In some embodiments, the repeater reports the processing delay at the repeater RU. In some embodiments, at least two different capabilities with different values for maximum processing delay are specified, and the repeater reports the capability. In another option, the repeater reports the processing delay value.

[00147] In some aspects, the UL/DL timing for different carriers of the repeater RU can be different, which may require separate determination of UL/DL timing for the carriers. For example, the set of carriers of the repeater RU may be divided into different groups. The UL/DL timing for carriers within the same group is the same, while the UL/DL timing for carriers in different groups may be different. The repeater may obtain the UL/DL timing for each carrier or each group respectively, from the gNB. For example, the gNB indicates which carrier or which group of carriers to reuse the UL/DL timing of the repeater MT, and the gNB indicates additional timing for other carriers. The additional timing can be a DL timing offset with reference to the DL timing of the repeater MT, or a UL timing advance with reference to the DL timing of the

carrier or with reference to the DL timing of repeater MT or with reference to the UL timing of the repeater MT.

UL Transmission Coordination Between the Repeater MT and the Repeater RU

5 [00148] In some aspects, at the repeater side, a single RF is shared for the repeater MT and the repeater RU in the donor path. In some embodiments, a separate RF is applied for the repeater MT and the repeater RU in the donor path.

[00149] In some embodiments, if a single RF is shared for the repeater MT and the repeater RU, the UL transmission generated by the repeater MT and the
10 UL transmission forwarded by the repeater RU (link 3 and 4) can be transmitted in a TDM manner.

[00150] In some aspects, the repeater stops the UL forwarding, if the symbol to forward overlaps with the UL transmission generated by repeater MT, as shown in diagram 600 of FIG. 6. In some embodiments, the repeater stops the
15 UL forwarding, if the symbol to forward is no earlier than an offset before the start of the UL transmission generated by the repeater MT, and/or no later than an offset after the end of the UL transmission generated by the repeater MT, as shown in diagram 700 of FIG. 7 and diagram 800 of FIG. 8.

[00151] FIG. 6, FIG. 7, and FIG. 8 illustrate UL transmission coordination
20 between NCR mobile terminal (MT) unit (also referred to as NCR-MT unit and NCR radio unit (RU) (also referred to as NCR-FWD unit), in accordance with some aspects.

[00152] In some embodiments, the UL forwarding and the UL transmission generated by the repeater MT are transmitted according to a time pattern.

25 [00153] For example, the gNB configures a time pattern for the UL forwarding, then, the UL forwarding can be transmitted only in slots/symbols indicated by the time pattern, while the UL transmission generated by the repeater MT is transmitted in other slots/symbols. Alternatively, the gNB configures a time pattern for the UL transmission generated by the repeater MT,
30 then, the UL transmission generated by the repeater MT can be transmitted only in slots/symbols indicated by the time pattern, while the UL forwarding is transmitted in other slots/symbols.

[00154] In some aspects, the UL forwarding is transmitted in slots/symbols associated with the ON state, while the UL transmission generated by the repeater MT is transmitted in other slots/symbols.

[00155] As another example, the gNB configures Type-1 slot/symbol and Type-2 slot/symbol. In Type-1 slot/symbol, the UL forwarding can be transmitted only if there is no UL transmission generated by the repeater MT. In the Type -2 slot/symbol, the UL forwarding cannot be transmitted regardless of the UL transmission generated by repeater MT.

[00156] In some embodiments, if a single RF is shared for the repeater MT and the repeater RU, the UL transmission generated by the repeater MT and the UL transmission forwarded by the repeater RU (link 3 and 4) can be transmitted in an FDM manner.

[00157] In some aspects, if a separate RF is applied for the repeater MT and the repeater RU, the UL transmission generated by the repeater MT and the UL transmission forwarded by the repeater RU (link 3 and 4) can be transmitted in TDM or FDM manner per gNB configuration/scheduling. The repeater may determine the Tx power for link 3 and link 4 respectively. If the total Tx power for link 3 and link 4 exceeds the maximum Tx power at the repeater, the power is scaled according to a pre-defined rule, e.g., prioritize Tx power for link 3 or prioritize Tx power for link 4, equally scale the power for both links, or prioritize Tx power for link 3 or link 4 according to the UL signal/channel type of UL transmission generated by repeater MT, or the prioritization is indicated by gNB.

[00158] In some embodiments, a system and method of wireless communication for a fifth generation (5G) or new radio (NR) system are configured based on the following functions, such as decoding, by the repeater, a downlink control information that is used to control DL/UL at the repeater, or UL transmission coordination for repeater MT and repeater RU. The repeater may determine whether to switch to DL/UL links or not forward any signals for a slot/symbol.

[00159] In some aspects, the downlink control information consists of DL or UL state for a slot/symbol.

- [00160] In some aspects, the downlink control information consists of DL or UL or flexible state for a slot/symbol.
- [00161] In some embodiments, for the slot/symbol without indication of DL or UL state, the repeater is not expected to forward any of DL or UL.
- 5 [00162] In some embodiments, for the slot/symbol without indication of DL or UL state, the repeater is not expected to forward any of DL or UL, unless the slot/symbol is at least part of a specific channel/signal.
- [00163] In some aspects, the repeater is expected for forward DL, if the specific signal/channel includes cell-specific SS/PBCH.
- 10 [00164] In some aspects, the repeater is expected for forward UL, if the specific signal/channel includes valid RACH or PUSCH occasion derived by SIB1 and the specific signal/channel does not include cell-specific SS/PBCH.
- [00165] In some embodiments, the repeater is expected for forward DL, if the specific signal/channel includes CORESET 0 for type-0 CSS configured by
- 15 MIB.
- [00166] In some embodiments, the repeater determines the UL timing to forward UL according to UL timing for repeater MT with or without an offset.
- [00167] In some aspects, the repeater determines UL transmission coordination for repeater MT and repeater RU, where the repeater stops UL
- 20 forwarding if the UL forwarding signal/channel would overlap with the UL transmission generated by repeater MT.
- [00168] In some embodiments, the repeater determines the UL transmission coordination for repeater MT and repeater RU, where the repeater determines whether to stop UL forwarding according to the time pattern configured by gNB.
- 25 [00169] In some embodiments, the repeater determines UL transmission coordination for repeater MT and repeater RU, wherein the repeater determines the Tx power for UL forwarding and UL transmission generated by repeater MT according to a pre-defined rule if the total Tx power exceeds the maximum Tx power at the repeater.
- 30 [00170] FIG. 9 illustrates a block diagram of a communication device such as an evolved Node-B (eNB), a new generation Node-B (gNB) (or another RAN node such as a base station), a network-controlled repeater (NCR), an access

point (AP), a wireless station (STA), a mobile station (MS), or user equipment (UE), in accordance with some aspects and to perform one or more of the techniques disclosed herein. In alternative aspects, the communication device 900 may operate as a standalone device or may be connected (e.g., networked) to other communication devices.

[00171] Circuitry (e.g., processing circuitry) is a collection of circuits implemented in tangible entities of the device 900 that include hardware (e.g., simple circuits, gates, logic, etc.). Circuitry membership may be flexible over time. Circuitries include members that may, alone or in combination, perform specified operations when operating. In an example, the hardware of the circuitry may be immutably designed to carry out a specific operation (e.g., hardwired). In an example, the hardware of the circuitry may include variably connected physical components (e.g., execution units, transistors, simple circuits, etc.) including a machine-readable medium physically modified (e.g., magnetically, electrically, moveable placement of invariant massed particles, etc.) to encode instructions of the specific operation.

[00172] In connecting the physical components, the underlying electrical properties of a hardware constituent are changed, for example, from an insulator to a conductor or vice versa. The instructions enable embedded hardware (e.g., the execution units or a loading mechanism) to create members of the circuitry in hardware via the variable connections to carry out portions of the specific operation when in operation. Accordingly, in an example, the machine-readable medium elements are part of the circuitry or are communicatively coupled to the other components of the circuitry when the device is operating. In an example, any of the physical components may be used in more than one member of more than one circuitry. For example, under operation, execution units may be used in the first circuit of a first circuitry at one point in time and reused by a second circuit in the first circuitry, or by a third circuit in a second circuitry at a different time. Additional examples of these components with respect to the device 900 follow.

[00173] In some aspects, the device 900 may operate as a standalone device or may be connected (e.g., networked) to other devices. In a networked deployment, the communication device 900 may operate in the capacity of a

server communication device, a client communication device, or both in server-client network environments. In an example, the communication device 900 may act as a peer communication device in a peer-to-peer (P2P) (or other distributed) network environment. The communication device 900 may be a
5 UE, eNB, PC, a tablet PC, STB, PDA, mobile telephone, smartphone, a web appliance, network router, a switch or bridge, or any communication device capable of executing instructions (sequential or otherwise) that specify actions to be taken by that communication device. Further, while only a single communication device is illustrated, the term "communication device" shall also
10 be taken to include any collection of communication devices that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein, such as cloud computing, software as a service (SaaS), and other computer cluster configurations.

[00174] Examples, as described herein, may include, or may operate on, logic
15 or several components, modules, or mechanisms. Modules are tangible entities (e.g., hardware) capable of performing specified operations and may be configured or arranged in a certain manner. In an example, circuits may be arranged (e.g., internally or with respect to external entities such as other circuits) in a specified manner as a module. In an example, the whole or part of
20 one or more computer systems (e.g., a standalone, client, or server computer system) or one or more hardware processors may be configured by firmware or software (e.g., instructions, an application portion, or an application) as a module that operates to perform specified operations. In an example, the software may reside on a communication device-readable medium. In an example, the
25 software, when executed by the underlying hardware of the module, causes the hardware to perform the specified operations.

[00175] Accordingly, the term "module" is understood to encompass a tangible entity, be that an entity that is physically constructed, specifically configured (e.g., hardwired), or temporarily (e.g., transitorily) configured (e.g.,
30 programmed) to operate in a specified manner or to perform part or all of any operation described herein. Considering examples in which modules are temporarily configured, each of the modules needs not to be instantiated at any one moment in time. For example, where the modules comprise a general-

purpose hardware processor configured using the software, the general-purpose hardware processor may be configured as respective different modules at different times. The software may accordingly configure a hardware processor, for example, to constitute a particular module at one instance of time and to
5 constitute a different module at a different instance of time.

[00176] The communication device (e.g., UE) 900 may include a hardware processor 902 (e.g., a central processing unit (CPU), a graphics processing unit (GPU), a hardware processor core, or any combination thereof), a main memory 904, a static memory 906, and a storage device 916 (e.g., hard drive, tape drive,
10 flash storage, or other block or storage devices), some or all of which may communicate with each other via an interlink (e.g., bus) 908.

[00177] The communication device 900 may further include a display device 910, an alphanumeric input device 912 (e.g., a keyboard), and a user interface (UI) navigation device 914 (e.g., a mouse). In an example, the display device
15 910, input device 912, and UI navigation device 914 may be a touchscreen display. The communication device 900 may additionally include a signal generation device 918 (e.g., a speaker), a network interface device 920, and one or more sensors 921, such as a global positioning system (GPS) sensor, compass, accelerometer, or another sensor. The communication device 900 may include
20 an output controller 928, such as a serial (e.g., universal serial bus (USB), parallel, or other wired or wireless (e.g., infrared (IR), near field communication (NFC), etc.) connection to communicate or control one or more peripheral devices (e.g., a printer, card reader, etc.).

[00178] The storage device 916 may include a communication device-readable
25 medium 922, on which is stored one or more sets of data structures or instructions 924 (e.g., software) embodying or utilized by any one or more of the techniques or functions described herein. In some aspects, registers of the processor 902, the main memory 904, the static memory 906, and/or the storage device 916 may be, or include (completely or at least partially), the device-
30 readable medium 922, on which is stored the one or more sets of data structures or instructions 924, embodying or utilized by any one or more of the techniques or functions described herein. In an example, one or any combination of the

hardware processor 902, the main memory 904, the static memory 906, or the storage device 916 may constitute the device-readable medium 922.

[00179] As used herein, the term “device-readable medium” is interchangeable with “computer-readable medium” or “machine-readable medium”. While the communication device-readable medium 922 is illustrated as a single medium, the term “communication device-readable medium” may include a single medium or multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) configured to store the one or more instructions 924. The term “communication device-readable medium” is inclusive of the terms “machine-readable medium” or “computer-readable medium”, and may include any medium that is capable of storing, encoding, or carrying instructions (e.g., instructions 924) for execution by the communication device 900 and that causes the communication device 900 to perform any one or more of the techniques of the present disclosure, or that is capable of storing, encoding or carrying data structures used by or associated with such instructions. Non-limiting communication device-readable medium examples may include solid-state memories and optical and magnetic media. Specific examples of communication device-readable media may include non-volatile memory, such as semiconductor memory devices (e.g., Electrically Programmable Read-Only Memory (EPROM), Electrically Erasable Programmable Read-Only Memory (EEPROM)) and flash memory devices; magnetic disks, such as internal hard disks and removable disks; magneto-optical disks; Random Access Memory (RAM); and CD-ROM and DVD-ROM disks. In some examples, communication device-readable media may include non-transitory communication device-readable media. In some examples, communication device-readable media may include communication device-readable media that is not a transitory propagating signal.

[00180] Instructions 924 may further be transmitted or received over a communications network 926 using a transmission medium via the network interface device 920 utilizing any one of several transfer protocols. In an example, the network interface device 920 may include one or more physical jacks (e.g., Ethernet, coaxial, or phone jacks) or one or more antennas to connect to the communications network 926. In an example, the network interface

device 920 may include a plurality of antennas to wirelessly communicate using at least one of the single-input-multiple-output (SIMO), MIMO, or multiple-input-single-output (MISO) techniques. In some examples, the network interface device 920 may wirelessly communicate using Multiple User MIMO techniques.

[00181] The term "transmission medium" shall be taken to include any intangible medium that is capable of storing, encoding, or carrying instructions for execution by the communication device 900, and includes digital or analog communications signals or another intangible medium to facilitate communication of such software. In this regard, a transmission medium in the context of this disclosure is a device-readable medium.

[00182] The terms "machine-readable medium," "computer-readable medium," and "device-readable medium" mean the same thing and may be used interchangeably in this disclosure. The terms are defined to include both machine-storage media and transmission media. Thus, the terms include both storage devices/media and carrier waves/modulated data signals.

[00183] Described implementations of the subject matter can include one or more features, alone or in combination as illustrated below by way of examples.

[00184] Example 1 is an apparatus of a Network-Controlled Repeater (NCR) configured for operation in a Fifth Generation New Radio (5G NR) network, the apparatus comprising: processing circuitry, wherein to configure the NCR for communication with a base station and a user equipment (UE) in the 5G NR network, the processing circuitry is to: decode configuration signaling received from the base station, the configuration signaling received at an NCR-mobile terminal (NCR-MT) unit of the NCR, and the configuration signaling including time division duplex (TDD) uplink (UL)-downlink (DL) configurations; encode DL data for transmission by an NCR-forwarding (NCR-FWD) unit of the NCR to the UE in a first TDD resource; and switch from transmission of the DL data to reception by the NCR-FWD unit of UL data transmitted by the UE in a second TDD resource, the first TDD resource and the second TDD resource configured by the TDD UL-DL configurations; and a memory coupled to the processing circuitry and configured to store the configuration signaling.

[00185] In Example 2, the subject matter of Example 1 includes subject matter where the processing circuitry is to: decode system information block (SIB) signaling received by the NCR-MT unit from the base station, the SIB signaling including the TDD UL-DL configurations.

5 [00186] In Example 3, the subject matter of Examples 1–2 includes subject matter where the processing circuitry is to: decode the configuration signaling to obtain a UL-DL-Common-Configuration information element (IE) with the TDD UL-DL configurations.

[00187] In Example 4, the subject matter of Example 3 includes subject matter
10 where the processing circuitry is to: configure switching between UL and DL communications in at least one donor communication path and at least one access communication path using the TDD UL-DL configurations in the UL-DL-Common-Configuration IE.

[00188] In Example 5, the subject matter of Example 4 includes subject matter
15 where the at least one donor communication path comprises: a backhaul UL communication path between the NCR-FWD unit of the NCR and the base station; a backhaul DL communication path between the NCR-FWD unit of the NCR and the base station; a control UL communication path between the NCR-MT unit of the NCR and the base station; and a control DL communication path
20 between the NCR-MT unit of the NCR and the base station.

[00189] In Example 6, the subject matter of Examples 4–5 includes subject matter where the at least one access communication path comprises: an access UL communication path between the NCR-FWD unit of the NCR and the UE; and an access DL communication path between the NCR-FWD unit of the NCR
25 and the UE.

[00190] In Example 7, the subject matter of Examples 1–6 includes subject matter where the processing circuitry is to: determine DL reception timing for a control DL communication path between the base station and the NCR-MT unit of the NCR using the TDD UL-DL configurations; and decode second DL data
30 received at the NCR-FWD unit of the NCR from the base station, the second DL data received using the DL reception timing for the control DL communication path.

[00191] In Example 8, the subject matter of Examples 1–7 includes subject matter where the processing circuitry is to: determine DL reception timing for a backhaul DL communication path between the base station and the NCR-FWD unit of the NCR using the TDD UL-DL configurations; and encode the DL data for transmission by the NCR-FWD unit of the NCR to the UE using the DL reception timing for the backhaul DL communication path plus a pre-configured offset.

[00192] In Example 9, the subject matter of Examples 1–8 includes subject matter where the processing circuitry is to: determine UL transmission timing for a control UL communication path between the NCR-MT unit of the NCR and the base station using the TDD UL-DL configurations; and decode the UL data received at the NCR-FWD unit of the NCR from the UE, the UL data received using the UL transmission timing for the control UL communication path minus a pre-configured offset.

[00193] In Example 10, the subject matter of Examples 1–9 includes, transceiver circuitry coupled to the processing circuitry; and one or more antennas coupled to the transceiver circuitry.

[00194] Example 11 is a computer-readable storage medium that stores instructions for execution by one or more processors of a base station, the instructions to configure the base station for communication with a Network-Controlled Repeater (NCR) in a Fifth Generation New Radio (5G NR) network, and to cause the base station to perform operations comprising: encoding configuration signaling for transmission to an NCR-mobile terminal (NCR-MT) unit of the NCR, the configuration signaling including time division duplex (TDD) uplink (UL)-downlink (DL) configurations, the TDD UL-DL configurations indicating: a first TDD resource associated with a DL data transmission of DL data from an NCR-forwarding (NCR-FWD) unit of the NCR to a user equipment (UE); and a second TDD resource associated with a UL data reception of UL data received by the NCR-FWD unit of the NCR from the UE.

[00195] In Example 12, the subject matter of Example 11 includes, the operations further comprising: encoding system information block (SIB) signaling for transmission to the NCR-MT unit, the SIB signaling including the TDD UL-DL configurations.

[00196] Example 13 is a computer-readable storage medium that stores instructions for execution by one or more processors of a Network-Controlled Repeater (NCR), the instructions to configure the NCR for communication with a base station in a Fifth Generation New Radio (5G NR) network, and to cause
5 the NCR to perform operations comprising: decoding configuration signaling received from the base station, the configuration signaling received at an NCR-mobile terminal (NCR-MT) unit of the NCR, and the configuration signaling including time division duplex (TDD) uplink (UL)-downlink (DL) configurations; encoding DL data for transmission by an NCR-forwarding
10 (NCR-FWD) unit of the NCR to a user equipment (UE) in a first TDD resource; and switching from transmission of the DL data to reception by the NCR-FWD unit of UL data transmitted by the UE in a second TDD resource, the first TDD resource and the second TDD resource configured by the TDD UL-DL configurations.

15 [00197] In Example 14, the subject matter of Example 13 includes, the operations further comprising: decoding system information block (SIB) signaling received by the NCR-MT unit from the base station, the SIB signaling including the TDD UL-DL configurations.

[00198] In Example 15, the subject matter of Examples 13–14 includes, the
20 operations further comprising: decoding the configuration signaling to obtain a UL-DL-Common-Configuration information element (IE) with the TDD UL-DL configurations.

[00199] In Example 16, the subject matter of Example 15 includes, the operations further comprising: configuring switching between UL and DL
25 communications in at least one donor communication path and at least one access communication path using the TDD UL-DL configurations in the UL-DL-Common-Configuration IE.

[00200] In Example 17, the subject matter of Example 16 includes subject
matter where the at least one donor communication path comprises: a backhaul
30 UL communication path between the NCR-FWD unit of the NCR and the base station; a backhaul DL communication path between the NCR-FWD unit of the NCR and the base station; a control UL communication path between the NCR-

MT unit of the NCR and the base station; and a control DL communication path between the NCR-MT unit of the NCR and the base station.

[00201] In Example 18, the subject matter of Examples 16–17 includes subject matter where the at least one access communication path comprises: an access
5 UL communication path between the NCR-FWD unit of the NCR and the UE; and an access DL communication path between the NCR-FWD unit of the NCR and the UE.

[00202] In Example 19, the subject matter of Examples 13–18 includes, the operations further comprising: determining DL reception timing for a control DL
10 communication path between the base station and the NCR-MT unit of the NCR using the TDD UL-DL configurations; and decoding second DL data received at the NCR-FWD unit of the NCR from the base station, the second DL data received using the DL reception timing for the control DL communication path.

[00203] In Example 20, the subject matter of Examples 13–19 includes, the
15 operations further comprising: determining DL reception timing for a backhaul DL communication path between the base station and the NCR-FWD unit of the NCR using the TDD UL-DL configurations; and encoding the DL data for transmission by the NCR-FWD unit of the NCR to the UE using the DL reception timing for the backhaul DL communication path plus a pre-configured
20 offset.

[00204] Example 21 is at least one machine-readable medium including instructions that, when executed by processing circuitry, cause the processing circuitry to perform operations to implement any of Examples 1–20.

[00205] Example 22 is an apparatus comprising means to implement any of
25 Examples 1–20.

[00206] Example 23 is a system to implement any of Examples 1–20.

[00207] Example 24 is a method to implement any of Examples 1–20.

[00208] Although an aspect has been described concerning specific exemplary aspects, it will be evident that various modifications and changes may be made
30 to these aspects without departing from the broader scope of the present disclosure. Accordingly, the specification and drawings are to be regarded in an illustrative rather than a restrictive sense. This Detailed Description, therefore,

is not to be taken in a limiting sense, and the scope of various aspects is defined only by the appended claims, along with the full range of equivalents to which such claims are entitled.

CLAIMS

What is claimed is:

1. An apparatus of a Network-Controlled Repeater (NCR) configured for
5 operation in a Fifth Generation New Radio (5G NR) network, the apparatus
comprising:

processing circuitry, wherein to configure the NCR for communication
with a base station and a user equipment (UE) in the 5G NR network, the
processing circuitry is to:

10 decode configuration signaling received from the base station, the
configuration signaling received at an NCR-mobile terminal (NCR-MT)
unit of the NCR, and the configuration signaling including time division
duplex uplink-downlink (TDD UL-DL) configurations;

encode DL data for transmission by an NCR-forwarding (NCR-
15 FWD) unit of the NCR to the UE in a first TDD resource; and

switch from transmission of the DL data to reception by the
NCR-FWD unit of UL data transmitted by the UE in a second TDD
resource, the first TDD resource and the second TDD resource
configured by the TDD UL-DL configurations; and

20 a memory coupled to the processing circuitry and configured to store the
configuration signaling.
2. The apparatus of claim 1, wherein the processing circuitry is to:

decode system information block (SIB) signaling received by the NCR-
25 MT unit from the base station, the SIB signaling including the TDD UL-DL
configurations.
3. The apparatus of claim 1, wherein the processing circuitry is to:

decode the configuration signaling to obtain a UL-DL-Common-
30 Configuration information element (IE) with the TDD UL-DL configurations.

4. The apparatus of claim 3, wherein the processing circuitry is to:
configure switching between UL and DL communications in at least one donor communication path and at least one access communication path using the
5 TDD UL-DL configurations in the UL-DL-Common-Configuration IE.
5. The apparatus of claim 4, wherein the at least one donor communication path comprises:
a backhaul UL communication path between the NCR-FWD unit of the
10 NCR and the base station;
a backhaul DL communication path between the NCR-FWD unit of the NCR and the base station;
a control UL communication path between the NCR-MT unit of the NCR and the base station; and
15 a control DL communication path between the NCR-MT unit of the NCR and the base station.
6. The apparatus of claim 4, wherein the at least one access communication path comprises:
20 an access UL communication path between the NCR-FWD unit of the NCR and the UE; and
an access DL communication path between the NCR-FWD unit of the NCR and the UE.
- 25 7. The apparatus of claim 1, wherein the processing circuitry is to:
determine DL reception timing for a control DL communication path between the base station and the NCR-MT unit of the NCR using the TDD UL-DL configurations; and

decode second DL data received at the NCR-FWD unit of the NCR from the base station, the second DL data received using the DL reception timing for the control DL communication path.

- 5 8. The apparatus of claim 1, wherein the processing circuitry is to:
- determine DL reception timing for a backhaul DL communication path between the base station and the NCR-FWD unit of the NCR using the TDD UL-DL configurations; and
- encode the DL data for transmission by the NCR-FWD unit of the NCR
10 to the UE using the DL reception timing for the backhaul DL communication path plus a pre-configured offset.
9. The apparatus of claim 1, wherein the processing circuitry is to:
- determine UL transmission timing for a control UL communication path
15 between the NCR-MT unit of the NCR and the base station using the TDD UL-DL configurations; and
- decode the UL data received at the NCR-FWD unit of the NCR from the UE, the UL data received using the UL transmission timing for the control UL communication path minus a pre-configured offset.
- 20
10. The apparatus of any of claims 1-9, further comprising transceiver circuitry coupled to the processing circuitry; and one or more antennas coupled to the transceiver circuitry.
- 25 11. A computer-readable storage medium that stores instructions for execution by one or more processors of a base station, the instructions to configure the base station for communication with a Network-Controlled Repeater (NCR) in a Fifth Generation New Radio (5G NR) network, and to cause the base station to perform operations comprising:

encoding configuration signaling for transmission to an NCR-mobile terminal (NCR-MT) unit of the NCR, the configuration signaling including time division duplex uplink-downlink (TDD UL-DL) configurations, the TDD UL-DL configurations indicating:

5 a first TDD resource associated with a DL data transmission of DL data from an NCR-forwarding (NCR-FWD) unit of the NCR to a user equipment (UE); and

 a second TDD resource associated with a UL data reception of UL data received by the NCR-FWD unit of the NCR from the UE.

10

12. The computer-readable storage medium of claim 11, the operations further comprising:

 encoding system information block (SIB) signaling for transmission to the NCR-MT unit, the SIB signaling including the TDD UL-DL configurations.

15

13. A computer-readable storage medium that stores instructions for execution by one or more processors of a Network-Controlled Repeater (NCR), the instructions to configure the NCR for communication with a base station in a Fifth Generation New Radio (5G NR) network, and to cause the NCR to perform

20 operations comprising:

 decoding configuration signaling received from the base station, the configuration signaling received at an NCR-mobile terminal (NCR-MT) unit of the NCR, and the configuration signaling including time division duplex uplink-downlink (TDD UL-DL) configurations;

25 encoding DL data for transmission by an NCR-forwarding (NCR-FWD) unit of the NCR to a user equipment (UE) in a first TDD resource; and

 switching from transmission of the DL data to reception by the NCR-FWD unit of UL data transmitted by the UE in a second TDD resource, the first TDD resource and the second TDD resource configured by the TDD UL-DL

30 configurations.

14. The computer-readable storage medium of claim 13, the operations further comprising:

5 decoding system information block (SIB) signaling received by the NCR-MT unit from the base station, the SIB signaling including the TDD UL-DL configurations.

15. The computer-readable storage medium of any of claims 13-14, the operations further comprising:

10 decoding the configuration signaling to obtain a UL-DL-Common-Configuration information element (IE) with the TDD UL-DL configurations.

16. The computer-readable storage medium of claim 15, the operations further comprising:

15 configuring switching between UL and DL communications in at least one donor communication path and at least one access communication path using the TDD UL-DL configurations in the UL-DL-Common-Configuration IE.

17. The computer-readable storage medium of claim 16, wherein the at least one donor communication path comprises:

a backhaul UL communication path between the NCR-FWD unit of the NCR and the base station;

a backhaul DL communication path between the NCR-FWD unit of the NCR and the base station;

25 a control UL communication path between the NCR-MT unit of the NCR and the base station; and

a control DL communication path between the NCR-MT unit of the NCR and the base station.

18. The computer-readable storage medium of claim 16, wherein the at least one access communication path comprises:

an access UL communication path between the NCR-FWD unit of the NCR and the UE; and

5 an access DL communication path between the NCR-FWD unit of the NCR and the UE.

19. The computer-readable storage medium of claim 13, the operations further comprising:

10 determining DL reception timing for a control DL communication path between the base station and the NCR-MT unit of the NCR using the TDD UL-DL configurations; and

decoding second DL data received at the NCR-FWD unit of the NCR from the base station, the second DL data received using the DL reception
15 timing for the control DL communication path.

20. The computer-readable storage medium of any of claims 13-19, the operations further comprising:

determining DL reception timing for a backhaul DL communication path
20 between the base station and the NCR-FWD unit of the NCR using the TDD UL-DL configurations; and

encoding the DL data for transmission by the NCR-FWD unit of the NCR to the UE using the DL reception timing for the backhaul DL communication path plus a pre-configured offset.

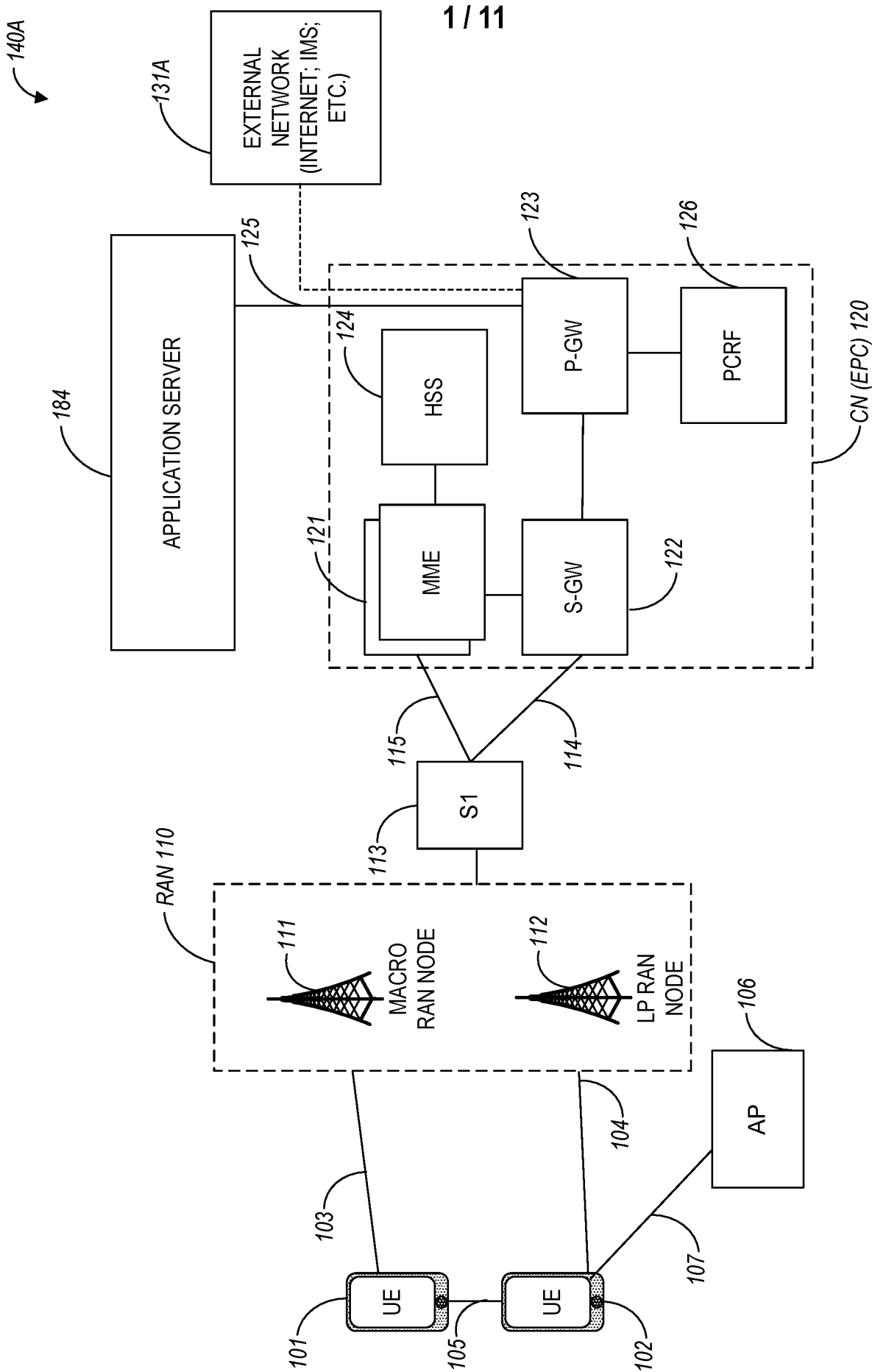


FIG. 1A

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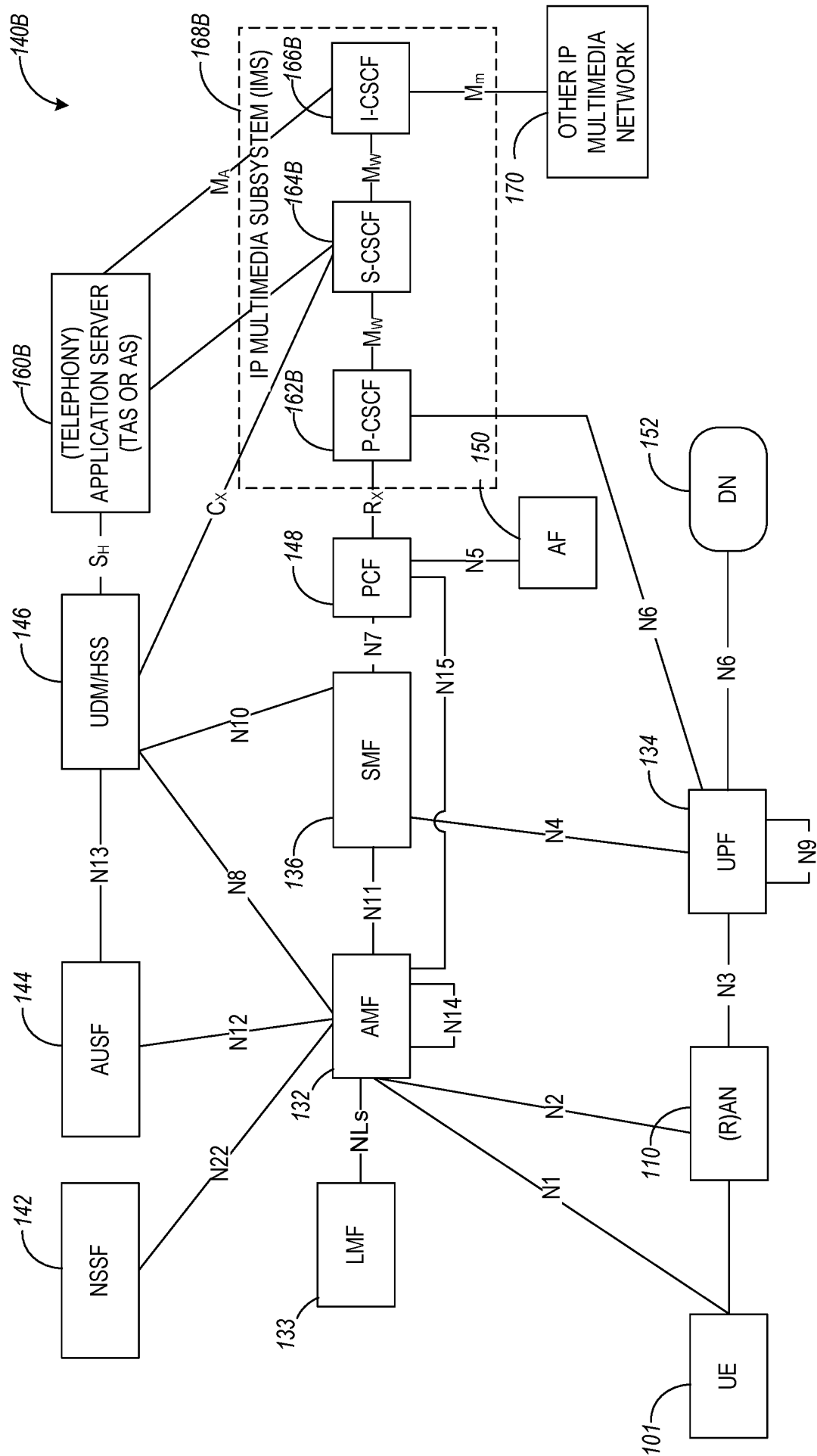


FIG. 1B

140C

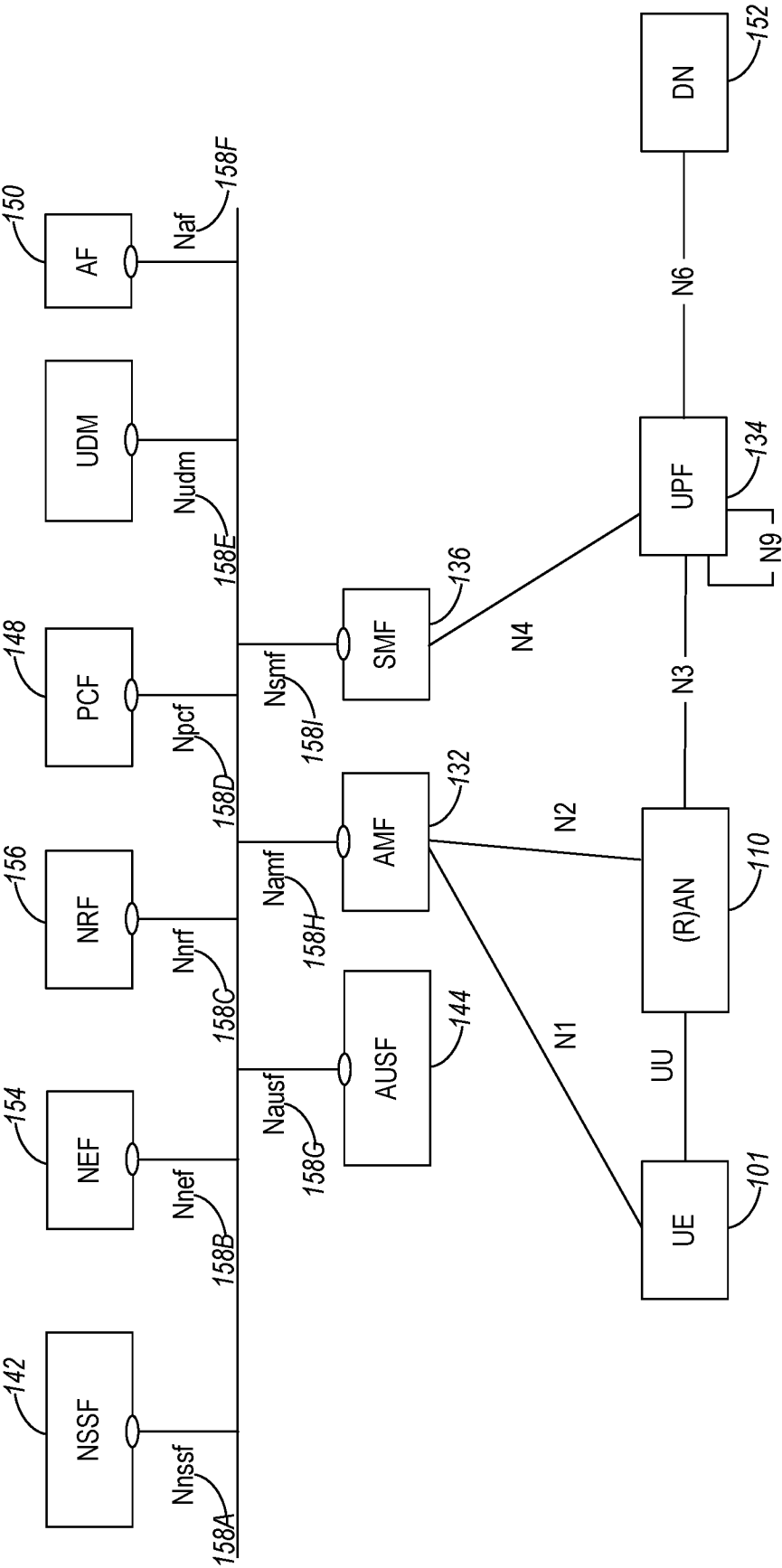


FIG. 1C

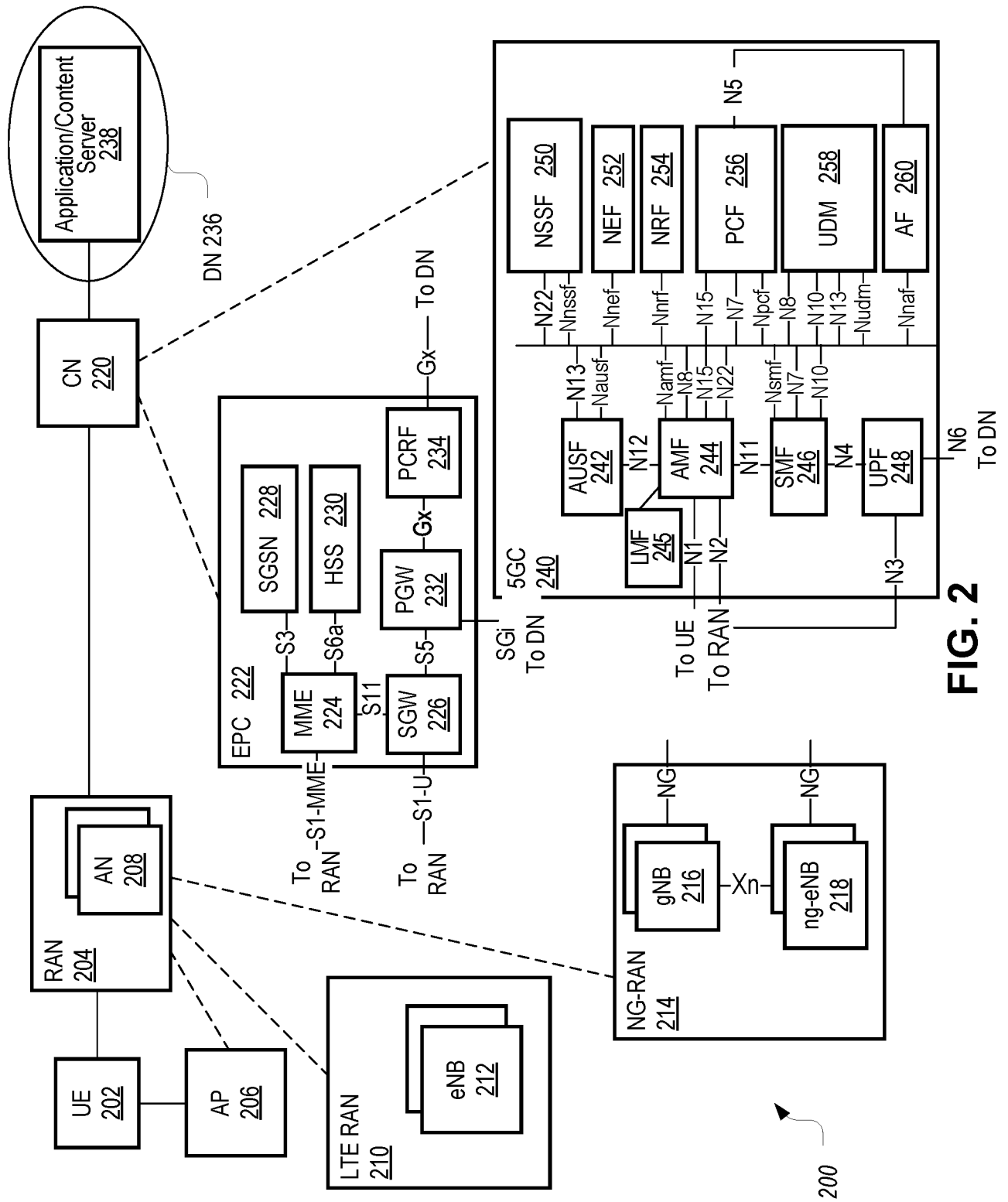


FIG. 2

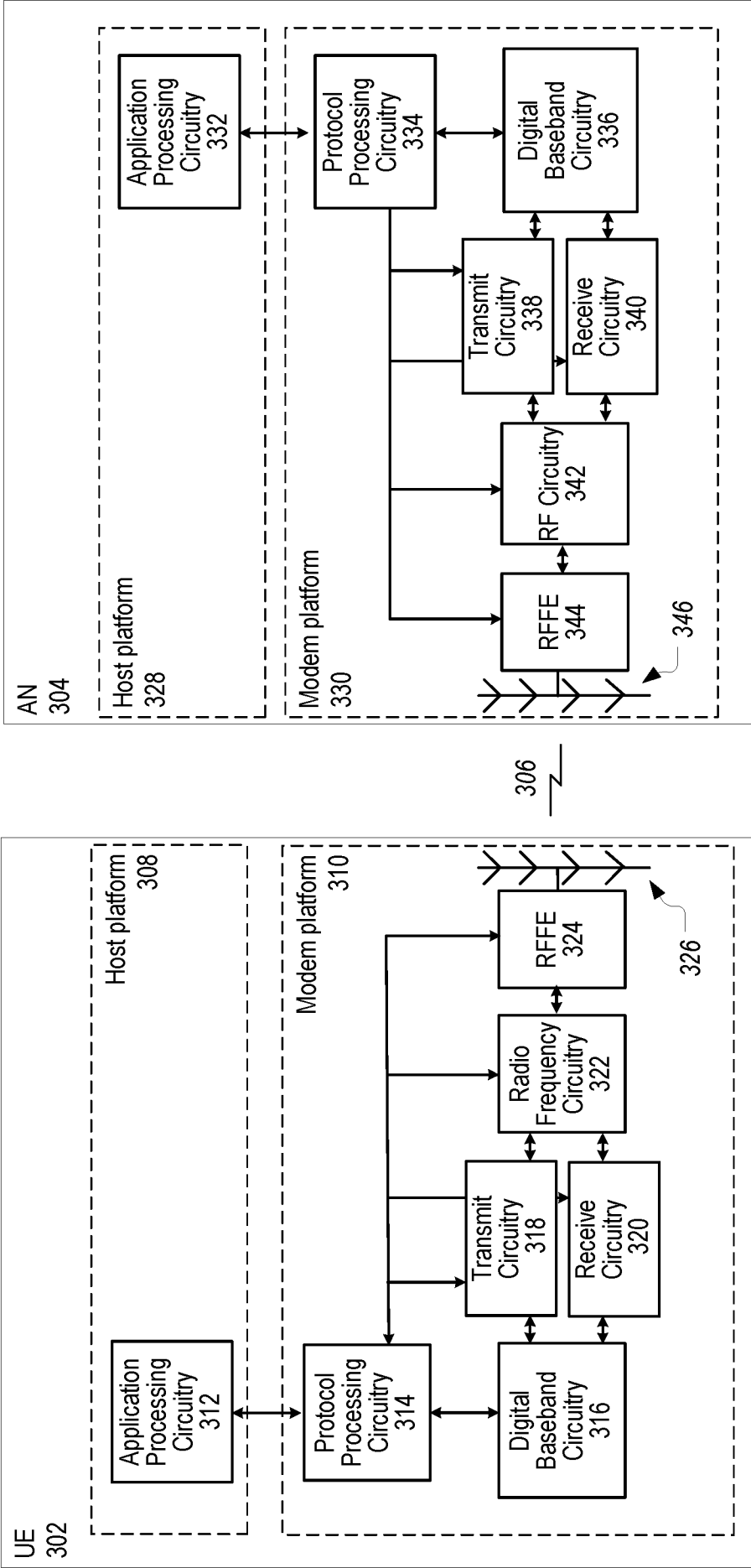


FIG. 3

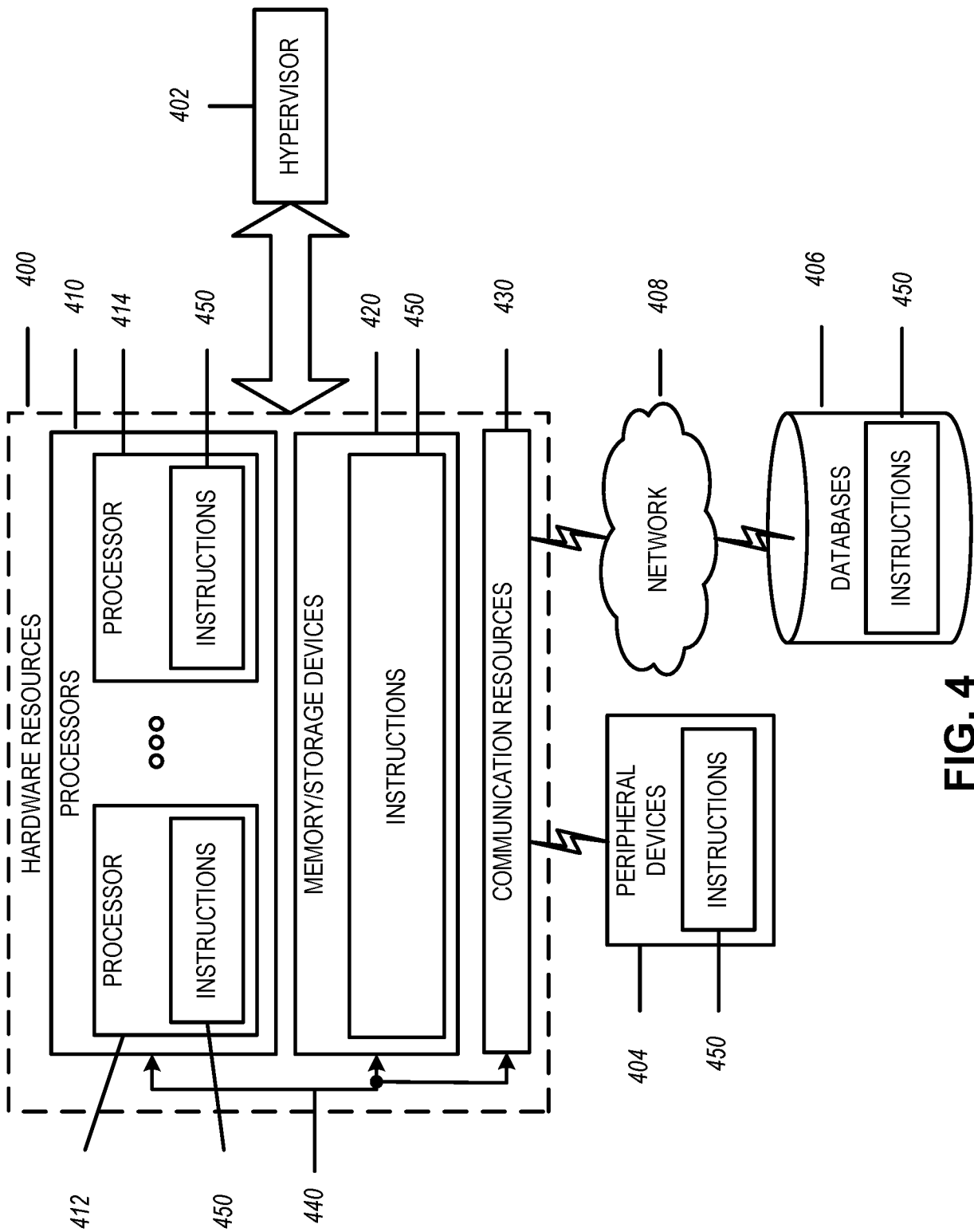
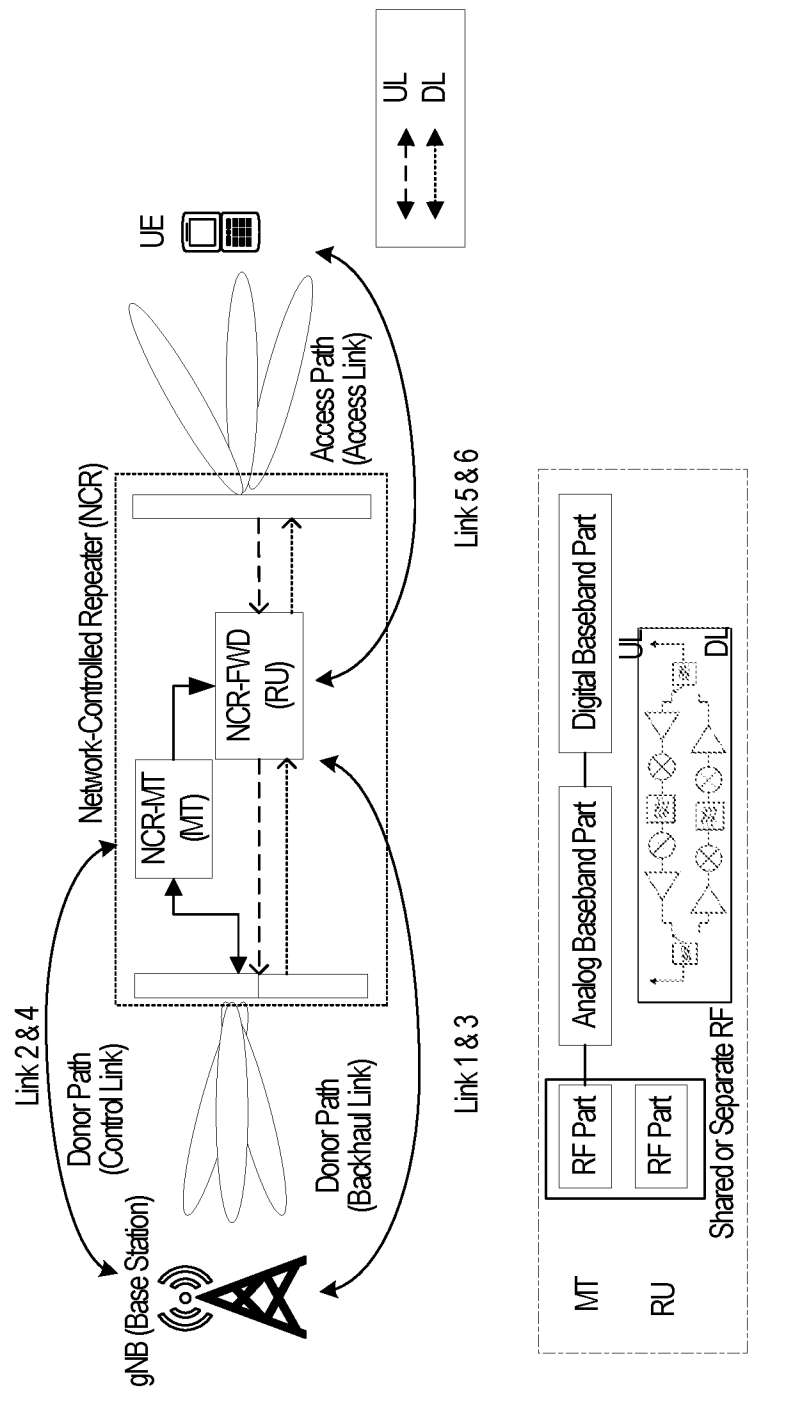


FIG. 4

**FIG. 5**

600

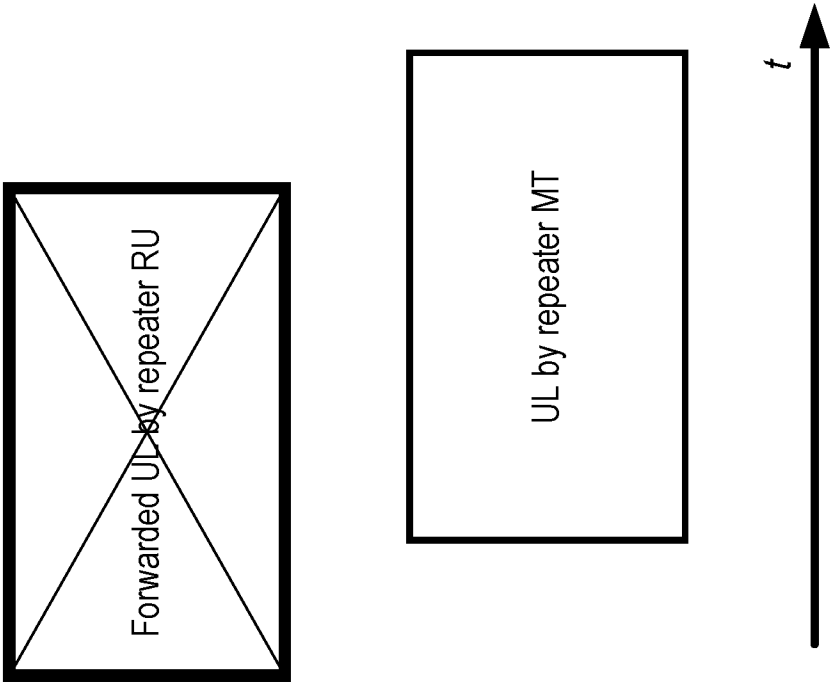


FIG. 6

700

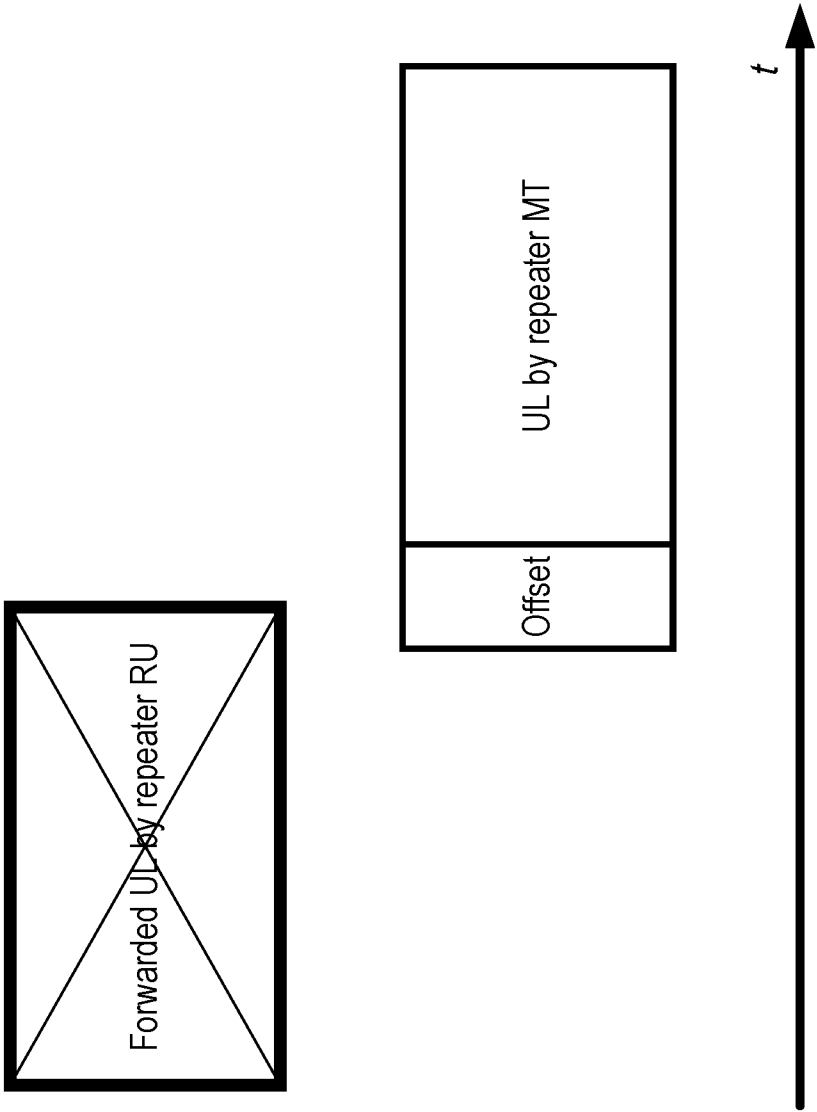


FIG. 7

800

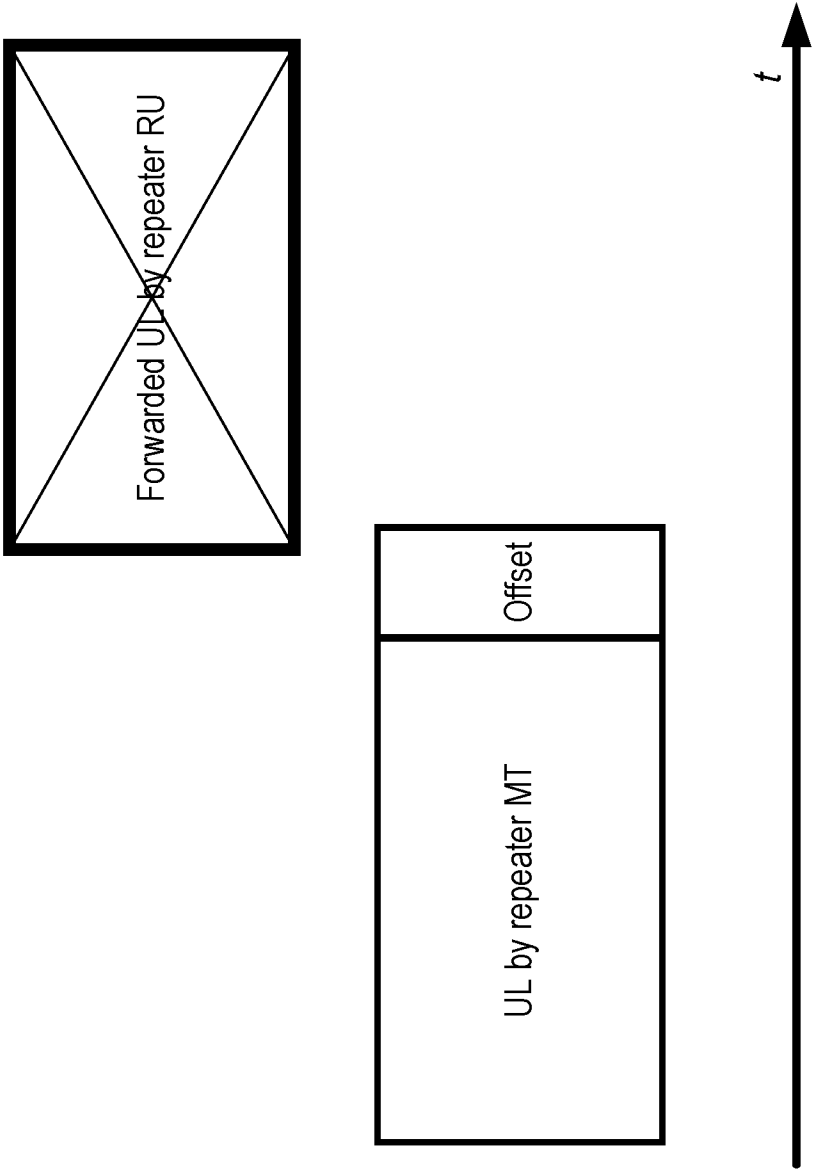


FIG. 8

11 / 11

900

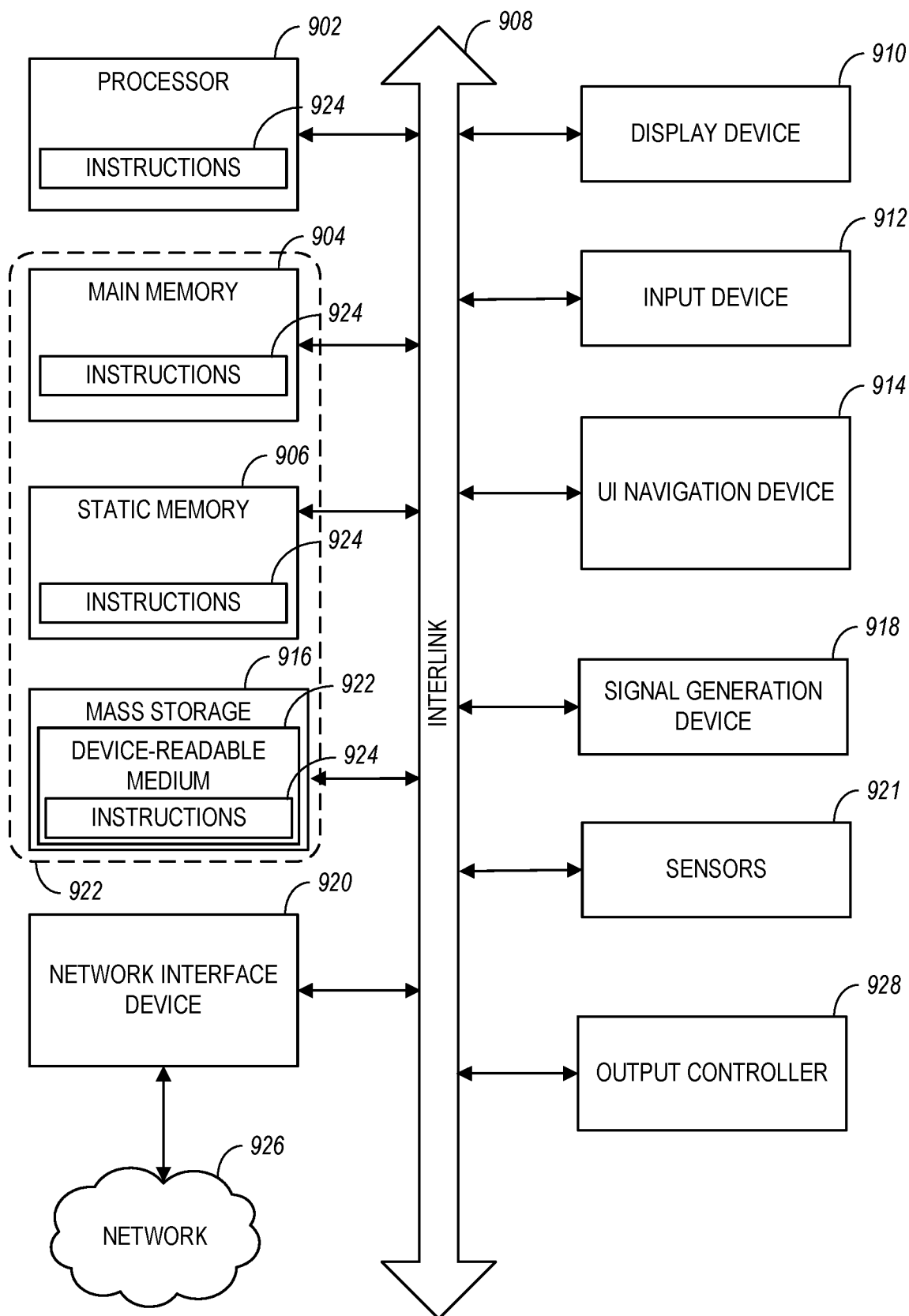


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2023/019049

A. CLASSIFICATION OF SUBJECT MATTER H04W 48/08(2009.01)i; H04W 72/04(2009.01)i; H04L 5/14(2006.01)i; H04B 7/155(2006.01)i; H04W 84/04(2009.01)i According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) H04W 48/08(2009.01); H04B 7/15(2006.01); H04B 7/155(2006.01); H04B 7/26(2006.01); H04L 27/26(2006.01); H04W 56/00(2009.01) Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Korean utility models and applications for utility models Japanese utility models and applications for utility models Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) eKOMPASS(KIPO internal) & Keywords: NCR, TDD, UL/DL, configuration		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2004-056013 A1 (NORTEL NETWORKS LIMITED et al.) 01 July 2004 (2004-07-01) page 14, line 6 - page 17, line 18; and claims 1-15	1-20
A	US 8953503 B2 (BOJAN SUBASIC et al.) 10 February 2015 (2015-02-10) column 6, line 42 - column 8, line 35; and claims 1-19	1-20
A	EP 1779551 B1 (SK TELECOM. CO., LTD.) 04 September 2013 (2013-09-04) paragraphs [0071]-[0073]; and claims 1-28	1-20
A	EP 3944514 A2 (WILSON ELECTRONICS, LLC) 26 January 2022 (2022-01-26) paragraphs [0047]-[0097]; and claims 1-15	1-20
A	KR 10-0702605 B1 (ORTHOTRON CO., LTD.) 02 April 2007 (2007-04-02) paragraphs [0002]-[0005]; and claims 1-2	1-20
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "D" document cited by the applicant in the international application "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 03 August 2023		Date of mailing of the international search report 03 August 2023
Name and mailing address of the ISA/KR Korean Intellectual Property Office 189 Cheongsu-ro, Seo-gu, Daejeon 35208, Republic of Korea Facsimile No. +82-42-481-8578		Authorized officer BYUN, SUNG CHEAL Telephone No. +82-42-481-8262

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2023/019049

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	ZTE, 'Discussion on side control information to enable NR network-controlled repeaters', R1-2203237, 3GPP TSG RAN WG1 Meeting #109-e, 29 April 2022 sections 2-3	1,11,13

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/US2023/019049

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)		Publication date (day/month/year)	
WO	2004-056013	A1	01 July 2004	AU	2003-292400	A1	09 July 2004
				US	2004-0114545	A1	17 June 2004
				US	2010-0165893	A1	01 July 2010
				US	2011-0310776	A1	22 December 2011
				US	2014-0133368	A1	15 May 2014
				US	7583619	B2	01 September 2009
				US	7983202	B2	19 July 2011
				US	8654725	B2	18 February 2014
US	8953503	B2	10 February 2015	US	2009-0285147	A1	19 November 2009
				US	2012-0188919	A1	26 July 2012
				US	8175028	B2	08 May 2012
EP	1779551	B1	04 September 2013	CN	1985449	A	20 June 2007
				CN	1985449	B	05 May 2010
				EP	1779551	A1	02 May 2007
				JP	2008-507192	A	06 March 2008
				JP	4572236	B2	04 November 2010
				KR	10-2006-0005925	A	18 January 2006
				US	2007-0201402	A1	30 August 2007
				US	7979022	B2	12 July 2011
				WO	2006-006828	A1	19 January 2006
EP	3944514	A2	26 January 2022	CA	3123347	A1	26 December 2021
				EP	3944513	A2	26 January 2022
				EP	3944513	A3	20 April 2022
				EP	3944514	A3	18 May 2022
				EP	3944515	A2	26 January 2022
				EP	3944515	A3	18 May 2022
				US	2021-0409104	A1	30 December 2021
				US	2021-0409105	A1	30 December 2021
				US	2021-0409106	A1	30 December 2021
KR	10-0702605	B1	02 April 2007	KR	10-2005-0082352	A	23 August 2005