



- (51) International Patent Classification:
H04W 76/18 (2018.01)
- (21) International Application Number:
PCT/US2018/043163
- (22) International Filing Date:
20 July 2018 (20.07.2018)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
62/536,459 24 July 2017 (24.07.2017) US
16/040,178 19 July 2018 (19.07.2018) US
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(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,

(54) Title: PARAMETER ADJUSTMENT FOR RADIO LINK FAILURE (RLF) PROCEDURE ENHANCED BY APERIODIC BEAM FAILURE RECOVERY (BFR) TRIGGERS

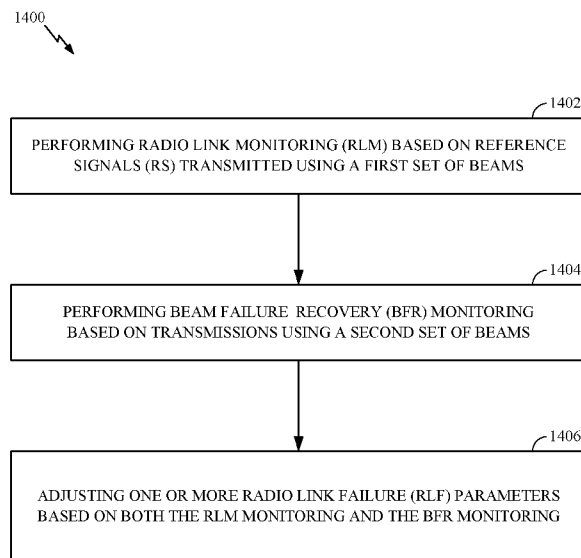


FIG. 14

(57) Abstract: Aspects of the present disclosure relate to techniques that may enhance radio link failure (RLF) procedures. In some cases, a UE may perform radio link monitoring (RLM) based on reference signals (RS) transmitted using a first set of beams, perform beam failure recovery (BFR) monitoring based on transmissions using a second set of beams, and adjust one or more radio link failure (RLF) parameters based on both the RLM monitoring and the BFR monitoring.



HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

**PARAMETER ADJUSTMENT FOR RADIO LINK FAILURE (RLF)
PROCEDURE ENHANCED BY APERIODIC BEAM FAILURE RECOVERY
(BFR) TRIGGERS**

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application Serial No. 62/536,459, filed July 24, 2017, and U.S. Patent Application No. 16/040,178, filed July 19, 2018, both of which are herein incorporated by reference in their entirety.

Introduction

[0002] Aspects of the present disclosure relate to wireless communications, and more particularly, radio link failure (RLF) monitoring.

[0003] Wireless communication systems are widely deployed to provide various telecommunication services such as telephony, video, data, messaging, and broadcasts. Typical wireless communication systems may employ multiple-access technologies capable of supporting communication with multiple users by sharing available system resources (e.g., bandwidth, transmit power). Examples of such multiple-access technologies include code division multiple access (CDMA) systems, time division multiple access (TDMA) systems, frequency division multiple access (FDMA) systems, orthogonal frequency division multiple access (OFDMA) systems, single-carrier frequency division multiple access (SC-FDMA) systems, and time division synchronous code division multiple access (TD-SCDMA) systems.

[0004] In some examples, a wireless multiple-access communication system may include a number of base stations, each simultaneously supporting communication for multiple communication devices, otherwise known as user equipment (UEs). In a Long Term Evolution (LTE) or LTE Advanced (LTE-A) network, a set of one or more base stations may define an eNodeB (eNB). In other examples (e.g., in a next generation or 5G network), a wireless multiple access communication system may include a number of distributed units (DUs) (e.g., edge units (EUs), edge nodes (ENs), radio heads (RHs), smart radio heads (SRHs), transmission reception points (TRPs), etc.) in communication with a number of central units (CUs) (e.g., central nodes (CNs), access node controllers (ANCs), etc.), where a set of one or more distributed units, in communication with a

central unit, may define an access node (e.g., a new radio base station (NR BS), a new radio node-B (NR NB), a network node, 5G NB, gNB, gNodeB, etc.). A base station or DU may communicate with a set of UEs on downlink channels (e.g., for transmissions from a base station or to a UE) and uplink channels (e.g., for transmissions from a UE to a base station or distributed unit).

[0005] These multiple access technologies have been adopted in various telecommunication standards to provide a common protocol that enables different wireless devices to communicate on a municipal, national, regional, and even global level. An example of an emerging telecommunication standard is new radio (NR), for example, 5G radio access. NR is a set of enhancements to the LTE mobile standard promulgated by Third Generation Partnership Project (3GPP). It is designed to better support mobile broadband Internet access by improving spectral efficiency, lowering costs, improving services, making use of new spectrum, and better integrating with other open standards using OFDMA with a cyclic prefix (CP) on the downlink (DL) and on the uplink (UL) as well as support beamforming, multiple-input multiple-output (MIMO) antenna technology, and carrier aggregation.

[0006] However, as the demand for mobile broadband access continues to increase, there exists a need for further improvements in NR technology. Preferably, these improvements should be applicable to other multi-access technologies and the telecommunication standards that employ these technologies.

SUMMARY

[0007] As described herein, certain wireless systems may employ directional beams for transmission and reception.

[0008] Certain aspects of the present disclosure provide a method for wireless communication that may be performed, for example, by a UE. The method generally includes performing radio link monitoring (RLM) based on reference signals (RS) transmitted using a first set of beams, performing beam failure recovery (BFR) monitoring based on transmissions using a second set of beams, and adjust one or more radio link failure (RLF) parameters based on both the RLM and the BFR monitoring.

[0009] Aspects generally include methods, apparatus, systems, computer readable mediums, and processing systems, as substantially described herein with reference to and as illustrated by the accompanying drawings.

[0010] Other aspects, features, and embodiments of the present invention will become apparent to those of ordinary skill in the art, upon reviewing the following description of specific, exemplary embodiments of the present invention in conjunction with the accompanying figures. While features of the present invention may be discussed relative to certain embodiments and figures below, all embodiments of the present invention can include one or more of the advantageous features discussed herein. In other words, while one or more embodiments may be discussed as having certain advantageous features, one or more of such features may also be used in accordance with the various embodiments of the invention discussed herein. In similar fashion, while exemplary embodiments may be discussed below as device, system, or method embodiments it should be understood that such exemplary embodiments can be implemented in various devices, systems, and methods.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 is a block diagram conceptually illustrating an example telecommunications system, in accordance with certain aspects of the present disclosure.

[0012] FIG. 2 is a block diagram illustrating an example logical architecture of a distributed RAN, in accordance with certain aspects of the present disclosure.

[0013] FIG. 3 is a diagram illustrating an example physical architecture of a distributed RAN, in accordance with certain aspects of the present disclosure.

[0014] FIG. 4 is a block diagram conceptually illustrating a design of an example BS and UE, in accordance with certain aspects of the present disclosure.

[0015] FIG. 5 is a diagram showing examples for implementing a communication protocol stack, in accordance with certain aspects of the present disclosure.

[0016] FIG. 6A illustrates an example of a DL-centric subframe, in accordance with certain aspects of the present disclosure.

[0017] FIG. 6B illustrates an example of an UL-centric subframe, in accordance with certain aspects of the present disclosure.

[0018] FIG. 7 illustrates an example of a frame format for a new radio (NR) system, in accordance with certain aspects of the present disclosure.

[0019] FIG. 8 illustrates an example of a P1, P2, and P3 procedure, in accordance with certain aspects of the present disclosure.

[0020] FIG. 9 illustrates example considerations that may affect a radio link failure (RLF) procedure.

[0021] FIG. 10 illustrates an example RLF timer and triggers for initiating the RLF timer.

[0022] FIG. 11 illustrates an example scenario where a UE is reachable by certain beams and unreachable by others.

[0023] FIG. 12 illustrates an example RLF timer and triggers for terminating the RLF timer.

[0024] FIG. 13 illustrates an example scenario where a UE is unreachable by different types of beams.

[0025] FIG. 14 illustrates example operations that may be performed by a user equipment (UE), in accordance with aspects of the present disclosure.

[0026] FIG. 15 illustrates an example of how an RLF timer may be initiated early, in accordance with aspects of the present disclosure.

[0027] FIG. 16 illustrates an example of how an RLF timer may be terminated early, in accordance with aspects of the present disclosure.

[0028] FIG. 17 illustrates another example of how an RLF timer may be terminated early, in accordance with aspects of the present disclosure.

[0029] FIG. 18 illustrates how in synchronization (IS) detection boundary thresholds may be lowered, in accordance with aspects of the present disclosure.

[0030] FIG. 19 illustrates how different RLF threshold values may be used in different conditions, in accordance with aspects of the present disclosure.

[0031] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements disclosed in one aspect may be beneficially utilized on other aspects without specific recitation.

DETAILED DESCRIPTION

[0032] Aspects of the present disclosure provide apparatus, methods, processing systems, and computer readable mediums for new radio (NR) (new radio access technology or 5G technology).

[0033] NR may support various wireless communication services, such as Enhanced mobile broadband (eMBB) targeting wide bandwidth (e.g. 80 MHz beyond), millimeter wave (mmW) targeting high carrier frequency (e.g. 60 GHz), massive MTC (mMTC) targeting non-backward compatible MTC techniques, and/or mission critical targeting ultra reliable low latency communications (URLLC). These services may include latency and reliability requirements. These services may also have different transmission time intervals (TTI) to meet respective quality of service (QoS) requirements. In addition, these services may co-exist in the same subframe.

[0034] Certain multi-beam wireless systems, such as mmW systems, bring gigabit speeds to cellular networks, due to availability of large amounts of bandwidth. However, the unique challenges of heavy path-loss faced by millimeter-wave systems necessitate new techniques such as hybrid beamforming (analog and digital), which are not present in 3G and 4G systems. Hybrid beamforming may enhance link budget/signal to noise ratio (SNR) that may be exploited during the RACH.

[0035] In such systems, the node B (NB) and the user equipment (UE) may communicate using beam-formed transmissions. In order for beamforming to function correctly, the NB may need to monitor beams using beam measurements performed (e.g., based on reference signals transmitted by the NB) and feedback generated at the UE. However, since the direction of a reference signal is unknown to the UE, the UE may need to evaluate several beams to obtain the best Rx beam for a given NB Tx beam. Accordingly, if the UE has to “sweep” through all of its Rx beams to perform the

measurements (e.g., to determine the best Rx beam for a given NB Tx beam), the UE may incur significant delay in measurement and battery life impact. Moreover, having to sweep through all Rx beams is highly resource inefficient. Thus, aspects of the present disclosure provide techniques to assist a UE when performing measurements of serving and neighbor cells when using Rx beamforming.

[0036] The following description provides examples, and is not limiting of the scope, applicability, or examples set forth in the claims. Changes may be made in the function and arrangement of elements discussed without departing from the scope of the disclosure. Various examples may omit, substitute, or add various procedures or components as appropriate. For instance, the methods described may be performed in an order different from that described, and various steps may be added, omitted, or combined. Also, features described with respect to some examples may be combined in some other examples. For example, an apparatus may be implemented or a method may be practiced using any number of the aspects set forth herein. In addition, the scope of the disclosure is intended to cover such an apparatus or method which is practiced using other structure, functionality, or structure and functionality in addition to or other than the various aspects of the disclosure set forth herein. It should be understood that any aspect of the disclosure disclosed herein may be embodied by one or more elements of a claim. The word “exemplary” is used herein to mean “serving as an example, instance, or illustration.” Any aspect described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other aspects.

[0037] The techniques described herein may be used for various wireless communication networks such as LTE, CDMA, TDMA, FDMA, OFDMA, SC-FDMA and other networks. The terms “network” and “system” are often used interchangeably. A CDMA network may implement a radio technology such as Universal Terrestrial Radio Access (UTRA), cdma2000, etc. UTRA includes Wideband CDMA (WCDMA) and other variants of CDMA. cdma2000 covers IS-2000, IS-95 and IS-856 standards. A TDMA network may implement a radio technology such as Global System for Mobile Communications (GSM). An OFDMA network may implement a radio technology such as NR (e.g. 5G RA), Evolved UTRA (E-UTRA), Ultra Mobile Broadband (UMB), IEEE 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, Flash-OFDMA, etc. UTRA and E-UTRA are part of Universal Mobile Telecommunication

System (UMTS). NR is an emerging wireless communications technology under development in conjunction with the 5G Technology Forum (5GTF). 3GPP Long Term Evolution (LTE) and LTE-Advanced (LTE-A) are releases of UMTS that use E-UTRA. UTRA, E-UTRA, UMTS, LTE, LTE-A and GSM are described in documents from an organization named “3rd Generation Partnership Project” (3GPP). cdma2000 and UMB are described in documents from an organization named “3rd Generation Partnership Project 2” (3GPP2). The techniques described herein may be used for the wireless networks and radio technologies mentioned above as well as other wireless networks and radio technologies. For clarity, while aspects may be described herein using terminology commonly associated with 3G and/or 4G wireless technologies, aspects of the present disclosure can be applied in other generation-based communication systems, such as 5G and later, including NR technologies.

EXAMPLE WIRELESS SYSTEM

[0038] FIG. 1 illustrates an example wireless network 100 in which aspects of the present disclosure may be performed. According to an example, the wireless network may be a NR or 5G network which may support mmW communication. mmW communication depends on beamforming to meet link margin. mmW communication may use directional beamforming, so transmission of signaling is directional. Accordingly, a transmitter may focus transmission energy in a certain narrow direction (e.g., beams may have a narrow angle), as illustrated in FIG. 8. A receiving entity may use receiver beamforming to receive the transmitted signaling.

[0039] In order to more efficiently use resources and conserve power when communicating using beamforming, the UEs 120 may be configured to perform the operations 900 and methods described herein for UE receiver beamforming. BS 110 may comprise a transmission reception point (TRP), Node B (NB), 5G NB, access point (AP), new radio (NR) BS, Master BS, primary BS, etc.). The NR network 100 may include the central unit.

[0040] As illustrated in FIG. 1, the wireless network 100 may include a number of BSs 110 and other network entities. According to one example, the network entities including the BS and UEs may communicate on high frequencies (e.g., > 6 GHz) using beams.

[0041] A BS may be a station that communicates with UEs. Each BS 110 may provide communication coverage for a particular geographic area. In 3GPP, the term “cell” can refer to a coverage area of a Node B and/or a Node B subsystem serving this coverage area, depending on the context in which the term is used. In NR systems, the term “cell” and gNB, Node B, 5G NB, AP, NR BS, NR BS, or TRP may be interchangeable. In some examples, a cell may not necessarily be stationary, and the geographic area of the cell may move according to the location of a mobile base station. In some examples, the base stations may be interconnected to one another and/or to one or more other base stations or network nodes (not shown) in the wireless network 100 through various types of backhaul interfaces such as a direct physical connection, a virtual network, or the like using any suitable transport network.

[0042] In general, any number of wireless networks may be deployed in a given geographic area. Each wireless network may support a particular radio access technology (RAT) and may operate on one or more frequencies. A RAT may also be referred to as a radio technology, an air interface, etc. A frequency may also be referred to as a carrier, a frequency channel, etc. Each frequency may support a single RAT in a given geographic area in order to avoid interference between wireless networks of different RATs. In some cases, NR or 5G RAT networks may be deployed.

[0043] A BS may provide communication coverage for a macro cell, a pico cell, a femto cell, and/or other types of cell. A macro cell may cover a relatively large geographic area (e.g., several kilometers in radius) and may allow unrestricted access by UEs with service subscription. A pico cell may cover a relatively small geographic area and may allow unrestricted access by UEs with service subscription. A femto cell may cover a relatively small geographic area (e.g., a home) and may allow restricted access by UEs having association with the femto cell (e.g., UEs in a Closed Subscriber Group (CSG), UEs for users in the home, etc.). A BS for a macro cell may be referred to as a macro BS. A BS for a pico cell may be referred to as a pico BS. A BS for a femto cell may be referred to as a femto BS or a home BS. In the example shown in FIG. 1, the BSs 110a, 110b and 110c may be macro BSs for the macro cells 102a, 102b and 102c, respectively. The BS 110x may be a pico BS for a pico cell 102x. The BSs 110y and 110z may be femto BS for the femto cells 102y and 102z, respectively. A BS may support one or multiple (e.g., three) cells.

[0044] The wireless network 100 may also include relay stations. A relay station is a station that receives a transmission of data and/or other information from an upstream station (e.g., a BS or a UE) and sends a transmission of the data and/or other information to a downstream station (e.g., a UE or a BS). A relay station may also be a UE that relays transmissions for other UEs. In the example shown in FIG. 1, a relay station 110r may communicate with the BS 110a and a UE 120r to facilitate communication between the BS 110a and the UE 120r. A relay station may also be referred to as a relay BS, a relay, etc.

[0045] The wireless network 100 may be a heterogeneous network that includes BSs of different types, e.g., macro BS, pico BS, femto BS, relays, etc. These different types of BSs may have different transmit power levels, different coverage areas, and different impact on interference in the wireless network 100. For example, macro BS may have a high transmit power level (e.g., 20 Watts) whereas pico BS, femto BS, and relays may have a lower transmit power level (e.g., 1 Watt).

[0046] The wireless network 100 may support synchronous or asynchronous operation. For synchronous operation, the BSs may have similar frame timing, and transmissions from different BSs may be approximately aligned in time. For asynchronous operation, the BSs may have different frame timing, and transmissions from different BSs may not be aligned in time. The techniques described herein may be used for both synchronous and asynchronous operation.

[0047] A network controller 130 may couple to a set of BSs and provide coordination and control for these BSs. The network controller 130 may communicate with the BSs 110 via a backhaul. The BSs 110 may also communicate with one another, e.g., directly or indirectly via wireless or wireline backhaul.

[0048] The UEs 120 (e.g., 120x, 120y, etc.) may be dispersed throughout the wireless network 100, and each UE may be stationary or mobile. A UE may also be referred to as a mobile station, a terminal, an access terminal, a subscriber unit, a station, a Customer Premises Equipment (CPE), a cellular phone, a smart phone, a personal digital assistant (PDA), a wireless modem, a wireless communication device, a handheld device, a laptop computer, a cordless phone, a wireless local loop (WLL) station, a tablet, a camera, a gaming device, a netbook, a smartbook, an ultrabook, a

medical device or medical equipment, a biometric sensor/device, a wearable device such as a smart watch, smart clothing, smart glasses, a smart wrist band, smart jewelry (e.g., a smart ring, a smart bracelet, etc.), an entertainment device (e.g., a music device, a video device, a satellite radio, etc.), a vehicular component or sensor, a smart meter/sensor, industrial manufacturing equipment, a global positioning system device, or any other suitable device that is configured to communicate via a wireless or wired medium. Some UEs may be considered evolved or machine-type communication (MTC) devices or evolved MTC (eMTC) devices. MTC and eMTC UEs include, for example, robots, drones, remote devices, sensors, meters, monitors, location tags, etc., that may communicate with a BS, another device (e.g., remote device), or some other entity. A wireless node may provide, for example, connectivity for or to a network (e.g., a wide area network such as Internet or a cellular network) via a wired or wireless communication link. Some UEs may be considered Internet-of-Things (IoT) devices.

[0049] In FIG. 1, a solid line with double arrows indicates desired transmissions between a UE and a serving BS, which is a BS designated to serve the UE on the downlink and/or uplink. A dashed line with double arrows indicates interfering transmissions between a UE and a BS.

[0050] Certain wireless networks (e.g., LTE) utilize orthogonal frequency division multiplexing (OFDM) on the downlink and single-carrier frequency division multiplexing (SC-FDM) on the uplink. OFDM and SC-FDM partition the system bandwidth into multiple (K) orthogonal subcarriers, which are also commonly referred to as tones, bins, etc. Each subcarrier may be modulated with data. In general, modulation symbols are sent in the frequency domain with OFDM and in the time domain with SC-FDM. The spacing between adjacent subcarriers may be fixed, and the total number of subcarriers (K) may be dependent on the system bandwidth. For example, the spacing of the subcarriers may be 15 kHz and the minimum resource allocation (called a 'resource block') may be 12 subcarriers (or 180 kHz). Consequently, the nominal FFT size may be equal to 128, 256, 512, 1024 or 2048 for system bandwidth of 1.25, 2.5, 5, 10 or 20 megahertz (MHz), respectively. The system bandwidth may also be partitioned into subbands. For example, a subband may cover 1.08 MHz (i.e., 6 resource blocks), and there may be 1, 2, 4, 8 or 16 subbands for system bandwidth of 1.25, 2.5, 5, 10 or 20 MHz, respectively.

[0051] While aspects of the examples described herein may be associated with LTE technologies, aspects of the present disclosure may be applicable with other wireless communications systems, such as NR.

[0052] NR may utilize OFDM with a CP on the uplink and downlink and include support for half-duplex operation using TDD. A single component carrier bandwidth of 100 MHz may be supported. NR resource blocks may span 12 sub-carriers with a sub-carrier bandwidth of 75 kHz over a 0.1 ms duration. In one aspect, each radio frame may consist of 50 subframes with a length of 10 ms. Consequently, each subframe may have a length of 0.2 ms. In another aspect, each radio frame may consist of 10 subframes with a length of 10 ms, where each subframe may have a length of 1 ms. Each subframe may indicate a link direction (i.e., DL or UL) for data transmission and the link direction for each subframe may be dynamically switched. Each subframe may include DL/UL data as well as DL/UL control data. UL and DL subframes for NR may be as described in more detail below with respect to FIGs. 6 and 7. Beamforming may be supported and beam direction may be dynamically configured. MIMO transmissions with precoding may also be supported. MIMO configurations in the DL may support up to 8 transmit antennas with multi-layer DL transmissions up to 8 streams and up to 2 streams per UE. Multi-layer transmissions with up to 2 streams per UE may be supported. Aggregation of multiple cells may be supported with up to 8 serving cells. Alternatively, NR may support a different air interface, other than an OFDM-based. NR networks may include entities such CUs and/or DUs.

[0053] In some examples, access to the air interface may be scheduled, wherein a scheduling entity (e.g., a base station) allocates resources for communication among some or all devices and equipment within its service area or cell. Within the present disclosure, as discussed further below, the scheduling entity may be responsible for scheduling, assigning, reconfiguring, and releasing resources for one or more subordinate entities. That is, for scheduled communication, subordinate entities utilize resources allocated by the scheduling entity. Base stations are not the only entities that may function as a scheduling entity. That is, in some examples, a UE may function as a scheduling entity, scheduling resources for one or more subordinate entities (e.g., one or more other UEs). In this example, the UE is functioning as a scheduling entity, and other UEs utilize resources scheduled by the UE for wireless communication.

A UE may function as a scheduling entity in a peer-to-peer (P2P) network, and/or in a mesh network. In a mesh network example, UEs may optionally communicate directly with one another in addition to communicating with the scheduling entity.

[0054] Thus, in a wireless communication network with a scheduled access to time-frequency resources and having a cellular configuration, a P2P configuration, and a mesh configuration, a scheduling entity and one or more subordinate entities may communicate utilizing the scheduled resources.

[0055] As noted above, a RAN may include a CU and DUs. A NR BS (e.g., gNB, 5G Node B, Node B, transmission reception point (TRP), access point (AP)) may correspond to one or multiple BSs. NR cells can be configured as access cells (ACells) or data only cells (DCells). For example, the RAN (e.g., a central unit or distributed unit) can configure the cells. DCells may be cells used for carrier aggregation or dual connectivity, but not used for initial access, cell selection/reselection, or handover. In some cases, DCells may not transmit synchronization signals – in some case cases DCells may transmit SS. NR BSs may transmit downlink signals to UEs indicating the cell type. Based on the cell type indication, the UE may communicate with the NR BS. For example, the UE may determine NR BSs to consider for cell selection, access, handover, and/or measurement based on the indicated cell type.

[0056] FIG. 2 illustrates an example logical architecture of a distributed radio access network (RAN) 200, which may be implemented in the wireless communication system illustrated in FIG. 1. A 5G access node 206 may include an access node controller (ANC) 202. The ANC may be a central unit (CU) of the distributed RAN 200. The backhaul interface to the next generation core network (NG-CN) 204 may terminate at the ANC. The backhaul interface to neighboring next generation access nodes (NG ANs) may terminate at the ANC. The ANC may include one or more TRPs 208 (which may also be referred to as BSs, NR BSs, Node Bs, 5G NBs, APs, or some other term). As described above, a TRP may be used interchangeably with “cell.”

[0057] The TRPs 208 may be a DU. The TRPs may be connected to one ANC (ANC 202) or more than one ANC (not illustrated). For example, for RAN sharing, radio as a service (RaaS), and service specific AND deployments, the TRP may be connected to more than one ANC. A TRP may include one or more antenna ports. The

TRPs may be configured to individually (e.g., dynamic selection) or jointly (e.g., joint transmission) serve traffic to a UE.

[0058] The local architecture 200 may be used to illustrate fronthaul definition. The architecture may be defined that support fronthauling solutions across different deployment types. For example, the architecture may be based on transmit network capabilities (e.g., bandwidth, latency, and/or jitter).

[0059] The architecture may share features and/or components with LTE. According to aspects, the next generation AN (NG-AN) 210 may support dual connectivity with NR. The NG-AN may share a common fronthaul for LTE and NR.

[0060] The architecture may enable cooperation between and among TRPs 208. For example, cooperation may be preset within a TRP and/or across TRPs via the ANC 202. According to aspects, no inter-TRP interface may be needed/present.

[0061] According to aspects, a dynamic configuration of split logical functions may be present within the architecture 200. As will be described in more detail with reference to FIG. 5, the Radio Resource Control (RRC) layer, Packet Data Convergence Protocol (PDCP) layer, Radio Link Control (RLC) layer, Medium Access Control (MAC) layer, and a Physical (PHY) layers may be adaptably placed at the DU or CU (e.g., TRP or ANC, respectively). According to certain aspects, a BS may include a central unit (CU) (e.g., ANC 202) and/or one or more distributed units (e.g., one or more TRPs 208).

[0062] FIG. 3 illustrates an example physical architecture of a distributed RAN 300, according to aspects of the present disclosure. A centralized core network unit (C-CU) 302 may host core network functions. The C-CU may be centrally deployed. C-CU functionality may be offloaded (e.g., to advanced wireless services (AWS)), to handle peak capacity.

[0063] A centralized RAN unit (C-RU) 304 may host one or more ANC functions. Optionally, the C-RU may host core network functions locally. The C-RU may have distributed deployment. The C-RU may be closer to the network edge.

[0064] A DU 306 may host one or more TRPs (edge node (EN), an edge unit (EU), a radio head (RH), a smart radio head (SRH), or the like). The DU may be located at edges of the network with radio frequency (RF) functionality.

[0065] FIG. 4 illustrates example components of the BS 110 and UE 120 illustrated in FIG. 1, which may be used to implement aspects of the present disclosure. The BS may include a TRP or gNB.

[0066] According to an example, antennas 452, DEMOD/MOD 454, processors 466, 458, 464, and/or controller/processor 480 of the UE 120 may be used to perform the operations described herein and illustrated with reference to FIGs. 9 and 11-12. According to an example, antennas 434, DEMOD/MOD 432, processors 430, 420, 438 and/or controller/processor 440 of the BS 110 may be used to perform the operations described herein and illustrated with reference to FIGs. 10-12.

[0067] As an example, one or more of the antennas 452, DEMOD/MOD 454, processors 466, 458, 464, and/or controller/processor 480 of the UE 120 may be configured to perform the operations described herein for UE beam-based tagging. Similarly, one or more of the 434, DEMOD/MOD 432, processors 430, 420, 438 and/or controller/processor 440 of the BS 110 may be configured to perform the operations described herein.

[0068] For a restricted association scenario, the base station 110 may be the macro BS 110c in FIG. 1, and the UE 120 may be the UE 120y. The base station 110 may also be a base station of some other type. The base station 110 may be equipped with antennas 434a through 434t, and the UE 120 may be equipped with antennas 452a through 452r.

[0069] At the base station 110, a transmit processor 420 may receive data from a data source 412 and control information from a controller/processor 440. The control information may be for the Physical Broadcast Channel (PBCH), Physical Control Format Indicator Channel (PCFICH), Physical Hybrid ARQ Indicator Channel (PHICH), Physical Downlink Control Channel (PDCCH), etc. The data may be for the Physical Downlink Shared Channel (PDSCH), etc. The processor 420 may process (e.g., encode and symbol map) the data and control information to obtain data symbols and control symbols, respectively. The processor 420 may also generate reference

symbols, e.g., for the PSS, SSS, and cell-specific reference signal (CRS). A transmit (TX) multiple-input multiple-output (MIMO) processor 430 may perform spatial processing (e.g., precoding) on the data symbols, the control symbols, and/or the reference symbols, if applicable, and may provide output symbol streams to the modulators (MODs) 432a through 432t. Each modulator 432 may process a respective output symbol stream (e.g., for OFDM, etc.) to obtain an output sample stream. Each modulator 432 may further process (e.g., convert to analog, amplify, filter, and upconvert) the output sample stream to obtain a downlink signal. Downlink signals from modulators 432a through 432t may be transmitted via the antennas 434a through 434t, respectively.

[0070] At the UE 120, the antennas 452a through 452r may receive the downlink signals from the base station 110 and may provide received signals to the demodulators (DEMODs) 454a through 454r, respectively. Each demodulator 454 may condition (e.g., filter, amplify, downconvert, and digitize) a respective received signal to obtain input samples. Each demodulator 454 may further process the input samples (e.g., for OFDM, etc.) to obtain received symbols. A MIMO detector 456 may obtain received symbols from all the demodulators 454a through 454r, perform MIMO detection on the received symbols if applicable, and provide detected symbols. A receive processor 458 may process (e.g., demodulate, deinterleave, and decode) the detected symbols, provide decoded data for the UE 120 to a data sink 460, and provide decoded control information to a controller/processor 480.

[0071] On the uplink, at the UE 120, a transmit processor 464 may receive and process data (e.g., for the Physical Uplink Shared Channel (PUSCH)) from a data source 462 and control information (e.g., for the Physical Uplink Control Channel (PUCCH)) from the controller/processor 480. The transmit processor 464 may also generate reference symbols for a reference signal. The symbols from the transmit processor 464 may be precoded by a TX MIMO processor 466 if applicable, further processed by the demodulators 454a through 454r (e.g., for SC-FDM, etc.), and transmitted to the base station 110. At the BS 110, the uplink signals from the UE 120 may be received by the antennas 434, processed by the modulators 432, detected by a MIMO detector 436 if applicable, and further processed by a receive processor 438 to obtain decoded data and control information sent by the UE 120. The receive processor

438 may provide the decoded data to a data sink 439 and the decoded control information to the controller/processor 440.

[0072] The controllers/processors 440 and 480 may direct the operation at the base station 110 and the UE 120, respectively. A scheduler 444 may schedule UEs for data transmission on the downlink and/or uplink. The processor 480 and/or other processors and modules at the UE 120 may perform or direct, e.g., the execution of the functional blocks illustrated in FIGs. 9 and 10, and/or other processes for the techniques described herein and those illustrated in the appended drawings. The processor 440 and/or other processors and modules at the BS 110 may perform or direct processes for the techniques described herein and those illustrated in the appended drawings. The memories 442 and 482 may store data and program codes for the BS 110 and the UE 120, respectively.

[0073] FIG. 5 illustrates a diagram 500 showing examples for implementing a communications protocol stack, according to aspects of the present disclosure. The illustrated communications protocol stacks may be implemented by devices operating in a 5G system. Diagram 500 illustrates a communications protocol stack including a Radio Resource Control (RRC) layer 510, a Packet Data Convergence Protocol (PDCP) layer 515, a Radio Link Control (RLC) layer 520, a Medium Access Control (MAC) layer 525, and a Physical (PHY) layer 530. In various examples the layers of a protocol stack may be implemented as separate modules of software, portions of a processor or ASIC, portions of non-located devices connected by a communications link, or various combinations thereof. Collocated and non-collocated implementations may be used, for example, in a protocol stack for a network access device (e.g., ANs, CUs, and/or DUs) or a UE.

[0074] A first option 505-a shows a split implementation of a protocol stack, in which implementation of the protocol stack is split between a centralized network access device (e.g., an ANC 202 in FIG. 2) and distributed network access device (e.g., DU 208 in FIG. 2). In the first option 505-a, an RRC layer 510 and a PDCP layer 515 may be implemented by the central unit, and an RLC layer 520, a MAC layer 525, and a PHY layer 530 may be implemented by the DU. In various examples the CU and the DU may be collocated or non-collocated. The first option 505-a may be useful in a macro cell, micro cell, or pico cell deployment.

[0075] A second option 505-b shows a unified implementation of a protocol stack, in which the protocol stack is implemented in a single network access device (e.g., access node (AN), new radio base station (NR BS), a new radio Node-B (NR NB), a network node (NN), or the like.). In the second option, the RRC layer 510, the PDCP layer 515, the RLC layer 520, the MAC layer 525, and the PHY layer 530 may each be implemented by the AN. The second option 505-b may be useful in a femto cell deployment.

[0076] Regardless of whether a network access device implements part or all of a protocol stack, a UE may implement an entire protocol stack (e.g., the RRC layer 510, the PDCP layer 515, the RLC layer 520, the MAC layer 525, and the PHY layer 530).

[0077] FIG. 6A is a diagram 600A showing an example of a DL-centric subframe. The DL-centric subframe may include a control portion 602A. The control portion 602A may exist in the initial or beginning portion of the DL-centric subframe. The control portion 602A may include various scheduling information and/or control information corresponding to various portions of the DL-centric subframe. In some configurations, the control portion 602A may be a physical DL control channel (PDCCH), as indicated in FIG. 6A. The DL-centric subframe may also include a DL data portion 604A. The DL data portion 604A may sometimes be referred to as the payload of the DL-centric subframe. The DL data portion 604A may include the communication resources utilized to communicate DL data from the scheduling entity (e.g., UE or BS) to the subordinate entity (e.g., UE). In some configurations, the DL data portion 604A may be a physical DL shared channel (PDSCH).

[0078] The DL-centric subframe may also include a common UL portion 606A. The common UL portion 606A may sometimes be referred to as an UL burst, a common UL burst, and/or various other suitable terms. The common UL portion 606A may include feedback information corresponding to various other portions of the DL-centric subframe. For example, the common UL portion 606A may include feedback information corresponding to the control portion 602A. Non-limiting examples of feedback information may include an ACK signal, a NACK signal, a HARQ indicator, and/or various other suitable types of information. The common UL portion 606A may include additional or alternative information, such as information pertaining to random access channel (RACH) procedures, scheduling requests (SRs), and various other

suitable types of information. As illustrated in FIG. 6A, the end of the DL data portion 604A may be separated in time from the beginning of the common UL portion 606A. This time separation may sometimes be referred to as a gap, a guard period, a guard interval, and/or various other suitable terms. This separation provides time for the switch-over from DL communication (e.g., reception operation by the subordinate entity (e.g., UE)) to UL communication (e.g., transmission by the subordinate entity (e.g., UE)). One of ordinary skill in the art will understand that the foregoing is merely one example of a DL-centric subframe and alternative structures having similar features may exist without necessarily deviating from the aspects described herein.

[0079] FIG. 6B is a diagram 600B showing an example of an UL-centric subframe. The UL-centric subframe may include a control portion 602B. The control portion 602B may exist in the initial or beginning portion of the UL-centric subframe. The control portion 602B in FIG. 6B may be similar to the control portion 602A described above with reference to FIG. 6A. The UL-centric subframe may also include an UL data portion 604B. The UL data portion 604B may sometimes be referred to as the payload of the UL-centric subframe. The UL portion may refer to the communication resources utilized to communicate UL data from the subordinate entity (e.g., UE) to the scheduling entity (e.g., UE or BS).

[0080] As illustrated in FIG. 6B, the end of the control portion 602B may be separated in time from the beginning of the UL data portion 604B. This time separation may sometimes be referred to as a gap, guard period, guard interval, and/or various other suitable terms. This separation provides time for the switch-over from DL communication (e.g., reception operation by the scheduling entity) to UL communication (e.g., transmission by the scheduling entity). The UL-centric subframe may also include a common UL portion 606B. The common UL portion 606B in FIG. 6B may be similar to the common UL portion 606A described above with reference to FIG. 6A. The common UL portion 606B may additionally or alternatively include information pertaining to channel quality indicator (CQI), sounding reference signals (SRSs), and various other suitable types of information. One of ordinary skill in the art will understand that the foregoing is merely one example of an UL-centric subframe and alternative structures having similar features may exist without necessarily deviating from the aspects described herein.

[0081] FIG. 7 is a diagram showing an example of a frame format 700 for NR. The transmission timeline for each of the downlink and uplink may be partitioned into units of radio frames. Each radio frame may have a predetermined duration (e.g., 10 ms) and may be partitioned into 10 subframes, each of 1 ms, with indices of 0 through 9. Each subframe may include a variable number of slots depending on the subcarrier spacing. Each slot may include a variable number of symbol periods (e.g., 7 or 14 symbols) depending on the subcarrier spacing. The symbol periods in each slot may be assigned indices. A mini-slot, which may be referred to as a sub-slot structure, refers to a transmit time interval having a duration less than a slot (e.g., 2, 3, or 4 symbols).

[0082] Each symbol in a slot may indicate a link direction (e.g., DL, UL, or flexible) for data transmission and the link direction for each subframe may be dynamically switched. The link directions may be based on the slot format. Each slot may include DL/UL data as well as DL/UL control information.

[0083] In NR, a synchronization signal (SS) block is transmitted. The SS block includes a PSS, a SSS, and a two symbol PBCH. The SS block can be transmitted in a fixed slot location, such as the symbols 0-3 as shown in FIG. 6. The PSS and SSS may be used by UEs for cell search and acquisition. The PSS may provide half-frame timing, the SS may provide the CP length and frame timing. The PSS and SSS may provide the cell identity. The PBCH carries some basic system information, such as downlink system bandwidth, timing information within radio frame, SS burst set periodicity, system frame number, etc. The SS blocks may be organized into SS bursts to support beam sweeping. Further system information such as, remaining minimum system information (RMSI), system information blocks (SIBs), other system information (OSI) can be transmitted on a physical downlink shared channel (PDSCH) in certain subframes.

[0084] A UE may operate in various radio resource configurations, including a configuration associated with transmitting pilots using a dedicated set of resources (e.g., a radio resource control (RRC) dedicated state, etc.) or a configuration associated with transmitting pilots using a common set of resources (e.g., an RRC common state, etc.). When operating in the RRC dedicated state, the UE may select a dedicated set of resources for transmitting a pilot signal to a network. When operating in the RRC common state, the UE may select a common set of resources for transmitting a pilot signal to the network. In either case, a pilot signal transmitted by the UE may be

received by one or more network access devices, such as an AN, or a DU, or portions thereof. Each receiving network access device may be configured to receive and measure pilot signals transmitted on the common set of resources, and also receive and measure pilot signals transmitted on dedicated sets of resources allocated to the UEs for which the network access device is a member of a monitoring set of network access devices for the UE. One or more of the receiving network access devices, or a CU to which receiving network access device(s) transmit the measurements of the pilot signals, may use the measurements to identify serving cells for the UEs, or to initiate a change of serving cell for one or more of the UEs.

EXAMPLE BEAM REFINEMENT PROCEDURES

[0085] As noted above, in certain multi-beam systems (e.g., millimeter wave (mmW) cellular systems), beam forming may be needed to overcome high path-losses. As described herein, beamforming may refer to establishing a link between a BS and UE, wherein both of the devices form a beam corresponding to each other. Both the BS and the UE find at least one adequate beam to form a communication link. BS-beam and UE-beam form what is known as a beam pair link (BPL). As an example, on the DL, a BS may use a transmit beam and a UE may use a receive beam corresponding to the transmit beam to receive the transmission. The combination of a transmit beam and corresponding receive beam may be a BPL.

[0086] As a part of beam management, beams which are used by BS and UE have to be refined from time to time because of changing channel conditions, for example, due to movement of the UE or other objects. Additionally, the performance of a BPL may be subject to fading due to Doppler spread. Because of changing channel conditions over time, the BPL should be periodically updated or refined. Accordingly, it may be beneficial if the BS and the UE monitor beams and new BPLs.

[0087] At least one BPL has to be established for network access. As described above, new BPLs may need to be discovered later for different purposes. The network may decide to use different BPLs for different channels, or for communicating with different BSs (TRPs) or as fall-back BPLs in case an existing BPL fails.

[0088] The UE typically monitors the quality of a BPL and the network may refine a BPL from time to time.

[0089] FIG. 8 illustrates example 800 for BPL discovery and refinement. In 5G-NR, the P1, P2, and P3 procedures are used for BPL discovery and refinement. The network uses a P1 procedure to enable the discovery of new BPLs. In the P1 procedure, as illustrated in FIG. 8, the BS transmits different symbols of a reference signal, each beam formed in a different spatial direction such that several (most, all) relevant places of the cell are reached. Stated otherwise, the BS transmits beams using different transmit beams over time in different directions.

[0090] For successful reception of at least a symbol of this “P1-signal”, the UE has to find an appropriate receive beam. It searches using available receive beams and applying a different UE-beam during each occurrence of the periodic P1-signal.

[0091] Once the UE has succeeded in receiving a symbol of the P1-signal it has discovered a BPL. The UE may not want to wait until it has found the best UE receive beam, since this may delay further actions. The UE may measure the reference signal receive power (RSRP) and report the symbol index together with the RSRP to the BS. Such a report will typically contain the findings of one or more BPLs.

[0092] In an example, the UE may determine a received signal having a high RSRP. The UE may not know which beam the BS used to transmit; however, the UE may report to the BS the time at which it observed the signal having a high RSRP. The BS may receive this report and may determine which BS beam the BS used at the given time.

[0093] The BS may then offer P2 and P3 procedures to refine an individual BPL. The P2 procedure refines the BS-beam of a BPL. The BS may transmit a few symbols of a reference signal with different BS-beams that are spatially close to the BS-beam of the BPL (the BS performs a sweep using neighboring beams around the selected beam). In P2, the UE keeps its beam constant. Thus, while the UE uses the same beam as in the BPL (as illustrated in P2 procedure in FIG. 8). The BS-beams used for P2 may be different from those for P1 in that they may be spaced closer together or they may be more focused. The UE may measure the RSRP for the various BS-beams and indicate the best one to the BS.

[0094] The P3 procedure refines the UE-beam of a BPL (see P3 procedure in FIG. 8). While the BS-beam stays constant, the UE scans using different receive beams

(the UE performs a sweep using neighboring beams). The UE may measure the RSRP of each beam and identify the best UE-beam. Afterwards, the UE may use the best UE-beam for the BPL and report the RSRP to the BS.

[0095] Overtime, the BS and UE establish several BPLs. When the BS transmits a certain channel or signal, it lets the UE know which BPL will be involved, such that the UE may tune in the direction of the correct UE receive beam before the signal starts. In this manner, every sample of that signal or channel may be received by the UE using the correct receive beam. In an example, the BS may indicate for a scheduled signal (SRS, CSI-RS) or channel (PDSCH, PDCCH, PUSCH, PUCCH) which BPL is involved. In NR this information is called QCL indication.

[0096] Two antenna ports are QCL if properties of the channel over which a symbol on one antenna port is conveyed may be inferred from the channel over which a symbol on the other antenna port is conveyed. QCL supports, at least, beam management functionality, frequency/timing offset estimation functionality, and RRM management functionality.

[0097] The BS may use a BPL which the UE has received in the past. The transmit beam for the signal to be transmitted and the previously-received signal both point in a same direction or are QCL. The QCL indication may be needed by the UE (in advance of signal to be received) such that the UE may use a correct receive beam for each signal or channel. Some QCL indications may be needed from time to time when the BPL for a signal or channel changes and some QCL indications are needed for each scheduled instance. The QCL indication may be transmitted in the downlink control information (DCI) which may be part of the PDCCH channel. Because DCI is needed to control the information, it may be desirable that the number of bits needed to indicate the QCL is not too big. The QCL may be transmitted in a medium access control-control element (MAC-CE) or radio resource control (RRC) message.

[0098] According to one example, whenever the UE reports a BS beam that it has received with sufficient RSRP, and the BS decides to use this BPL in the future, the BS assigns it a BPL tag. Accordingly, two BPLs having different BS beams may be associated with different BPL tags. BPLs that are based on the same BS beams may be

associated with the same BPL tag. Thus, according to this example, the tag is a function of the BS beam of the BPL.

[0099] As noted above, wireless systems, such as millimeter wave (mmW) systems, bring gigabit speeds to cellular networks, due to availability of large amounts of bandwidth. However, the unique challenges of heavy path-loss faced by such wireless systems necessitate new techniques such as hybrid beamforming (analog and digital), which are not present in 3G and 4G systems. Hybrid beamforming may enhance link budget/signal to noise ratio (SNR) that may be exploited during the RACH.

[0100] In such systems, the node B (NB) and the user equipment (UE) may communicate over active beam-formed transmission beams. Active beams may be considered paired transmission (Tx) and reception (Rx) beams between the NB and UE that carry data and control channels such as PDSCH, PDCCH, PUSCH, and PUCCH. As noted above, a transmit beam used by a NB and corresponding receive beam used by a UE for downlink transmissions may be referred to as a beam pair link (BPL). Similarly, a transmit beam used by a UE and corresponding receive beam used by a NB for uplink transmissions may also be referred to as a BPL.

[0101] In order for beamforming to function correctly, the NB may need to monitor beams using beam measurements performed (e.g., based on reference signals transmitted by the NB) and feedback generated at the UE. For example, the NB may monitor active beams using UE-performed measurements of signals such as NR-SS, CSI-RS, DMRS-CSS and DMRS-USS. For that, NB may send measurement request to the UE and may subsequently transmit one or more reference signals for measurement at the UE.

[0102] Since the direction of a reference signal is unknown to the UE, the UE may need to evaluate several beams to obtain the best Rx beam for a given NB Tx beam. However, if the UE has to “sweep” through all of its Rx beams to perform the measurements (e.g., to determine the best Rx beam for a given NB Tx beam), the UE may incur significant delay in measurement and battery life impact. Moreover, having to sweep through all Rx beams is highly resource inefficient. Thus, aspects of the present disclosure provide techniques to assist a UE when performing measurements of serving and neighbor cells when using Rx beamforming.

EXAMPLE PARAMETER ADJUSTMENT FOR RLF PROCEDURE
ENHANCED BY APERIODIC BFR TRIGGERS

[0103] Aspects of the present disclosure, however, provide techniques that may help improve RLF performance by adjusting parameters (e.g., thresholds for cell-quality metrics and rules for RLF timer triggers) based on aperiodic BFR triggers.

[0104] As illustrated in FIG. 9, in multi-beam systems, a radio link failure (RLF) procedure, based on radio link monitoring (RLM) measurements, may be enhanced by aperiodic in-sync (IS) and out-of-sync (OSS) triggers. The IS and OSS triggers may be initiated by a beam failure recovery (BFR) procedure. For RLM, at least periodic IS and OOS indications may be based on signal to interference and noise (SINR)-like metrics. Such metrics may include, for example, a hypothetical PDCCH block error rate (BLER) as in LTE. For a BFR procedure, at least aperiodic indication(s) may be provided to assist with the radio link failure (RLF) procedure. For example, such aperiodic indications may be provided if a same RS is used for beam failure recovery and RLM procedures. at least.

[0105] In some cases, there may be discrepancies between cell quality metrics used by the RLF procedure and beam quality metrics used by the BFR procedure. In some cases, these discrepancies may lead to inefficient RLF performance.

[0106] An example of such an inefficiency may be explained with reference to FIG. 10. FIG. 10 illustrates an example RLF timer and triggers for initiating the RLF timer. As illustrated, after a threshold number of consecutive OOS indications (referred to as N310) for the primary cell (Pcell), a timer (referred to as a T310 timer) may be activated. After expiration of the T310 timer (e.g., absent a number of detected IS events), an RLF may be declared.

[0107] As illustrated in FIG. 11, however, this may result in unnecessarily RLFs being declared. These unnecessary declarations may occur particularly in cases of “low SS-block geometry” where the UE is not reachable by beams carrying RS for RLM, but is reachable by narrower beams carrying SS.

[0108] As another example of inefficiency, in some cases, RLFs may be unnecessarily delayed. For example, as illustrated in FIG. 12, the RLF timer may be

stopped upon receiving a threshold number (N311) of consecutive IS indications for Pcell. Unfortunately, this may delay an RLF from being declared in cases when beam failure detection actually occurs and there are no candidate beams for recovery. This scenario is illustrated in FIG. 13.

[0109] FIG. 14, however, illustrates example operations 1400 that may be performed by a UE to enhance an RLF procedure and possibly avoid one or both of the inefficiencies described above. Operations 1400 may be performed, for example, by a user equipment (e.g., UE 120) participating in beamformed communications with a base station (e.g., a gNB).

[0110] Operations 1400 begin, at 1402, by performing radio link monitoring (RLM) based on reference signals (RS) transmitted using a first set of beams. At 1404, the UE performs beam failure recovery (BFR) monitoring based on transmissions using a second set of beams.

[0111] At 1406, the UE adjusts one or more radio link failure (RLF) parameters based on both the RLM monitoring and the BFR monitoring.

[0112] Whether RLF parameters are adjusted before RLF detection or adjusted in response to RLF detection may depend on the particular scenario. For example, in some cases, the RLF parameters are adjusted in response to detecting at least one of an out of synchronization (OOS) or in synchronization (IS) BFR event. In other cases, the parameters may be adjusted and an event detected using the adjusted parameters (the parameters may then be further adjusted).

[0113] FIG. 15 illustrates an example of how an RLF timer may be initiated early, as an example of an adjusted RLF parameter, in accordance with aspects of the present disclosure. As illustrated, the RLF procedure may be triggered early (e.g., an early start of T310 timer) by an aperiodic OOS event detected via BFR. The RLF procedure may be triggered early by immediately starting the RLF timer or, in some cases, by starting the RLF timer sooner than usual (e.g., by reducing the threshold number of OOS needed to trigger the RLF procedure).

[0114] As illustrated in FIG. 16, in addition (or as an alternative), early RLF detection (e.g., early termination of T310 timer) may be triggered by aperiodic OOS via

BFR. Again, the early termination may be immediate or just caused to occur sooner. In some cases, early RLF trigger (per FIG. 15) and early RLF detection (per FIG. 16) may be combined in a single procedure.

[0115] As illustrated in FIG. 17, in some cases, the RLF timer may be terminated early for RLF recovery (early termination of the T310 timer), based on aperiodic in sync (IS) detection via BFR. The early termination may be immediate or may just cause the termination to be sooner (e.g., by reducing a number of consecutive IS detections needed to terminate the RLF procedure).

[0116] In some cases, one or more RLM parameters may be adjusted, based on BFR triggers. For example, there may be situations when aperiodic IS/OOS triggers from BFR procedures indicate an underlying discrepancy between cell metric calculations from RLM and beam quality metric calculations from BFR.

[0117] In some cases, periodic IS indications from RLM procedure may be based on SS-beams with a high detection threshold. For example, detection thresholds Q_{in} and Q_{out} may be used to monitor RLF. Q_{out} may be defined as the level at which the downlink radio link cannot be reliably received, while Q_{in} may be defined as the level at which the downlink radio link quality can be significantly more reliably received than at Q_{out} . Due to the high detection threshold, these beams may be hard to detect for a UE located at a cell edge.

[0118] As illustrated in FIG. 18, however, the same cell-edge UE may be served by a narrow PDCCH beam, which may be detected strongly via BFR procedure. Therefore, lowering the RLF detection threshold for SS-beam detection may help in faster RLF recovery. FIG. 18 illustrates the boundaries for the different thresholds. Another option may be to adjust the cell metric calculation to include narrower CSI-RS beams.

[0119] In another example, periodic OOS indications from an RLM procedure may be based on SS-beam transmissions with a long duty cycle, which may take a long time to trigger the T310 timer (e.g., especially with a high value of N310). In such cases, a cell-edge UE may have a higher probability of losing its beams faster compared to a cell-center UE. Therefore, different settings of N310 may be used by different UEs.

[0120] For example, as illustrated in FIG. 19, cell-center UEs may use higher N310 values, while cell-edge UEs have lower N310 values. In some cases, the gNB may explicitly signal N310 values using RRC signaling (e.g., based on UE measurement reports). In some cases, a list of possible N310 values may be advertised by the gNB, with guidelines (based on UE measurements) to which value to use under different cell quality metric calculations.

[0121] In some cases, groups of values may be adjusted. For example, in some cases, not just N310, but also N311 values, may be UE-specific (e.g., and signaled using RRC signaling).

[0122] Furthermore, N311 values may also depend on whether the T310 was started based on N310 OOS or based on aperiodic OOS. Some UEs may trigger the T310 timer based on aperiodic OOS indication from BFR procedure. In such cases, those UEs may use smaller N311 for faster transition to RLF event.

[0123] As described above, if an aperiodic OOS indication arrives while T310 is running, this may “speed up” or “immediately end” the T310 timer. Similarly, the aperiodic OOS arriving prior to T310 start may either immediately start the T310, or may just cause a temporary reduction in N310 value to allow potential earlier start of T310.

[0124] The methods disclosed herein comprise one or more steps or actions for achieving the described method. The method steps and/or actions may be interchanged with one another without departing from the scope of the claims. In other words, unless a specific order of steps or actions is specified, the order and/or use of specific steps and/or actions may be modified without departing from the scope of the claims.

[0125] As used herein, a phrase referring to “at least one of” a list of items refers to any combination of those items, including single members. As an example, “at least one of: a, b, or c” is intended to cover a, b, c, a-b, a-c, b-c, and a-b-c, as well as any combination with multiples of the same element (e.g., a-a, a-a-a, a-a-b, a-a-c, a-b-b, a-c-c, b-b, b-b-b, b-b-c, c-c, and c-c-c or any other ordering of a, b, and c).

[0126] As used herein, the term “determining” encompasses a wide variety of actions. For example, “determining” may include calculating, computing, processing,

deriving, investigating, looking up (e.g., looking up in a table, a database or another data structure), ascertaining and the like. Also, “determining” may include receiving (e.g., receiving information), accessing (e.g., accessing data in a memory) and the like. Also, “determining” may include resolving, selecting, choosing, establishing and the like.

[0127] The previous description is provided to enable any person skilled in the art to practice the various aspects described herein. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects. Thus, the claims are not intended to be limited to the aspects shown herein, but is to be accorded the full scope consistent with the language of the claims, wherein reference to an element in the singular is not intended to mean “one and only one” unless specifically so stated, but rather “one or more.” Unless specifically stated otherwise, the term “some” refers to one or more. All structural and functional equivalents to the elements of the various aspects described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims. No claim element is to be construed under the provisions of 35 U.S.C. §112, sixth paragraph, unless the element is expressly recited using the phrase “means for” or, in the case of a method claim, the element is recited using the phrase “step for.”

[0128] The various operations of methods described above may be performed by any suitable means capable of performing the corresponding functions. The means may include various hardware and/or software component(s) and/or module(s), including, but not limited to a circuit, an application specific integrated circuit (ASIC), or processor. Generally, where there are operations illustrated in figures, those operations may have corresponding counterpart means-plus-function components with similar numbering.

[0129] The various illustrative logical blocks, modules and circuits described in connection with the present disclosure may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic

device (PLD), discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any commercially available processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[0130] If implemented in hardware, an example hardware configuration may comprise a processing system in a wireless node. The processing system may be implemented with a bus architecture. The bus may include any number of interconnecting buses and bridges depending on the specific application of the processing system and the overall design constraints. The bus may link together various circuits including a processor, machine-readable media, and a bus interface. The bus interface may be used to connect a network adapter, among other things, to the processing system via the bus. The network adapter may be used to implement the signal processing functions of the PHY layer. In the case of a user terminal 120 (see FIG. 1), a user interface (e.g., keypad, display, mouse, joystick, etc.) may also be connected to the bus. The bus may also link various other circuits such as timing sources, peripherals, voltage regulators, power management circuits, and the like, which are well known in the art, and therefore, will not be described any further. The processor may be implemented with one or more general-purpose and/or special-purpose processors. Examples include microprocessors, microcontrollers, DSP processors, and other circuitry that can execute software. Those skilled in the art will recognize how best to implement the described functionality for the processing system depending on the particular application and the overall design constraints imposed on the overall system.

[0131] If implemented in software, the functions may be stored or transmitted over as one or more instructions or code on a computer readable medium. Software shall be construed broadly to mean instructions, data, or any combination thereof, whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise. Computer-readable media include both computer storage media and communication media including any medium that facilitates transfer of a computer

program from one place to another. The processor may be responsible for managing the bus and general processing, including the execution of software modules stored on the machine-readable storage media. A computer-readable storage medium may be coupled to a processor such that the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor. By way of example, the machine-readable media may include a transmission line, a carrier wave modulated by data, and/or a computer readable storage medium with instructions stored thereon separate from the wireless node, all of which may be accessed by the processor through the bus interface. Alternatively, or in addition, the machine-readable media, or any portion thereof, may be integrated into the processor, such as the case may be with cache and/or general register files. Examples of machine-readable storage media may include, by way of example, RAM (Random Access Memory), flash memory, ROM (Read Only Memory), PROM (Programmable Read-Only Memory), EPROM (Erasable Programmable Read-Only Memory), EEPROM (Electrically Erasable Programmable Read-Only Memory), registers, magnetic disks, optical disks, hard drives, or any other suitable storage medium, or any combination thereof. The machine-readable media may be embodied in a computer-program product.

[0132] A software module may comprise a single instruction, or many instructions, and may be distributed over several different code segments, among different programs, and across multiple storage media. The computer-readable media may comprise a number of software modules. The software modules include instructions that, when executed by an apparatus such as a processor, cause the processing system to perform various functions. The software modules may include a transmission module and a receiving module. Each software module may reside in a single storage device or be distributed across multiple storage devices. By way of example, a software module may be loaded into RAM from a hard drive when a triggering event occurs. During execution of the software module, the processor may load some of the instructions into cache to increase access speed. One or more cache lines may then be loaded into a general register file for execution by the processor. When referring to the functionality of a software module below, it will be understood that such functionality is implemented by the processor when executing instructions from that software module.

[0133] Also, any connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared (IR), radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, include compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk, and Blu-ray® disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Thus, in some aspects computer-readable media may comprise non-transitory computer-readable media (e.g., tangible media). In addition, for other aspects computer-readable media may comprise transitory computer-readable media (e.g., a signal). Combinations of the above should also be included within the scope of computer-readable media.

[0134] Thus, certain aspects may comprise a computer program product for performing the operations presented herein. For example, such a computer program product may comprise a computer-readable medium having instructions stored (and/or encoded) thereon, the instructions being executable by one or more processors to perform the operations described herein. For example, instructions for perform the operations described herein and the appended figures.

[0135] Further, it should be appreciated that modules and/or other appropriate means for performing the methods and techniques described herein can be downloaded and/or otherwise obtained by a user terminal and/or base station as applicable. For example, such a device can be coupled to a server to facilitate the transfer of means for performing the methods described herein. Alternatively, various methods described herein can be provided via storage means (e.g., RAM, ROM, a physical storage medium such as a compact disc (CD) or floppy disk, etc.), such that a user terminal and/or base station can obtain the various methods upon coupling or providing the storage means to the device. Moreover, any other suitable technique for providing the methods and techniques described herein to a device can be utilized.

[0136] It is to be understood that the claims are not limited to the precise configuration and components illustrated above. Various modifications, changes and

variations may be made in the arrangement, operation and details of the methods and apparatus described above without departing from the scope of the claims.

CLAIMS

1. A method for wireless communications by a user equipment (UE), comprising:
performing radio link monitoring (RLM) based on reference signals (RS) transmitted using a first set of beams;
performing beam failure recovery (BFR) monitoring based on transmissions using a second set of beams; and
adjusting one or more radio link failure (RLF) parameters based on both the RLM monitoring and the BFR monitoring.
2. The method of claim 1, further comprising:
performing RLF detection based on the adjusted RLF parameters.
3. The method of claim 1, wherein:
the RLF parameters are adjusted in response to detecting at least one of an out of synchronization (OOS) or in synchronization (IS) BFR event.
4. The method of claim 1, wherein performing radio link failure (RLF) detection based on both the RLM and the BFR monitoring comprises:
adjusting an RLF detection threshold in response to detecting an IS BRF event.
5. The method of claim 1, wherein the adjusting comprises:
adjusting cell metric calculations to include narrower CSI-RS beams in response to detecting an IS BRF event.
6. The method of claim 1, wherein the adjusting comprises:
using RLF detection parameters determined based on measurements taken by the UE.
7. The method of claim 6, wherein the RLF detection parameters comprise at least one of a threshold number of RLM out of synchronization (OOS) events to trigger initiation of an RLF timer or a threshold number of RLM in synchronization (IS) events to trigger termination of the RLF timer.

8. The method of claim 7, wherein one or more values are signaled by a base station.
9. The method of claim 8, wherein:
the UE selects from the signaled values based on cell quality metric calculations.
10. An apparatus for wireless communications by a user equipment (UE), comprising:
means for performing radio link monitoring (RLM) based on reference signals (RS) transmitted using a first set of beams;
means for performing beam failure recovery (BFR) monitoring based on transmissions using a second set of beams; and
means for adjusting one or more radio link failure (RLF) parameters based on both the RLM monitoring and the BFR monitoring.
11. The apparatus of claim 10, further comprising:
means for performing RLF detection based on the adjusted RLF parameters.
12. The apparatus of claim 10, wherein:
the RLF parameters are adjusted in response to detecting at least one of an out of synchronization (OOS) or in synchronization (IS) BFR event.
13. The apparatus of claim 10, wherein means for performing radio link failure (RLF) detection based on both the RLM and the BFR monitoring comprises:
means for adjusting an RLF detection threshold in response to detecting an IS BRF event.
14. The apparatus of claim 10, wherein the means for adjusting comprises:
means for adjusting cell metric calculations to include narrower CSI-RS beams in response to detecting an IS BRF event.
15. The apparatus of claim 10, wherein the means for adjusting comprises:
means for using RLF detection parameters determined based on measurements taken by the UE.

16. The apparatus of claim 15, wherein the RLF detection parameters comprise at least one of a threshold number of RLM out of synchronization (OOS) events to trigger initiation of an RLF timer or a threshold number of RLM in synchronization (IS) events to trigger termination of the RLF timer.

17. The apparatus of claim 16, wherein one or more values are signaled by a base station.

18. The apparatus of claim 17, wherein:
the UE selects from the signaled values based on cell quality metric calculations.

19. An apparatus for wireless communications by a user equipment (UE), comprising:

a receiver configured to receive reference signals (RS) transmitted using a first set of beams; and

at least one processor configured to perform radio link monitoring (RLM) based on the RS, perform beam failure recovery (BFR) monitoring based on transmissions using a second set of beams, and adjust one or more radio link failure (RLF) parameters based on both the RLM monitoring and the BFR monitoring.

20. The apparatus of claim 19, wherein the at least one processor is further configured to perform RLF detection based on the adjusted RLF parameters.

21. The apparatus of claim 19, wherein:

the RLF parameters are adjusted in response to detecting at least one of an out of synchronization (OOS) or in synchronization (IS) BFR event.

22. The apparatus of claim 19, wherein the at least one processor is configured to perform radio link failure (RLF) detection based on both the RLM and the BFR monitoring by adjusting an RLF detection threshold in response to detecting an IS BFR event.

23. The apparatus of claim 19, wherein the at least one processor is configured to adjust cell metric calculations to include narrower CSI-RS beams in response to detecting an IS BRF event.
24. The apparatus of claim 19, wherein the adjusting comprises:
using RLF detection parameters determined based on measurements taken by the UE.
25. The apparatus of claim 24, wherein the RLF detection parameters comprise at least one of a threshold number of RLM out of synchronization (OOS) events to trigger initiation of an RLF timer or a threshold number of RLM in synchronization (IS) events to trigger termination of the RLF timer.
26. The apparatus of claim 25, wherein one or more values are signaled by a base station.
27. The apparatus of claim 26, wherein:
the UE selects from the signaled values based on cell quality metric calculations.
28. A computer readable medium having instructions stored thereon for:
performing radio link monitoring (RLM) based on reference signals (RS) transmitted using a first set of beams;
performing beam failure recovery (BFR) monitoring based on transmissions using a second set of beams; and
adjusting one or more radio link failure (RLF) parameters based on both the RLM monitoring and the BFR monitoring.

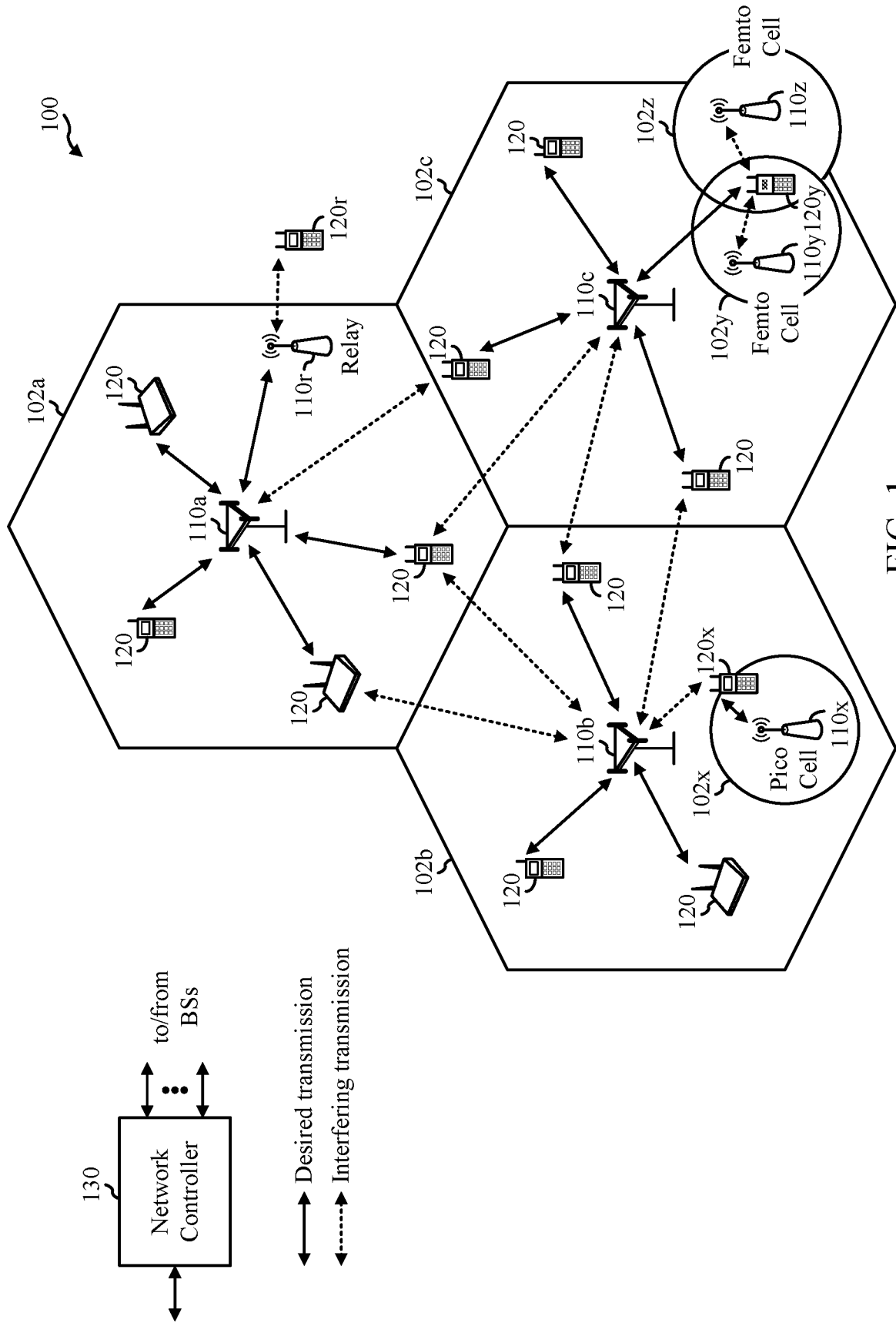


FIG. 1

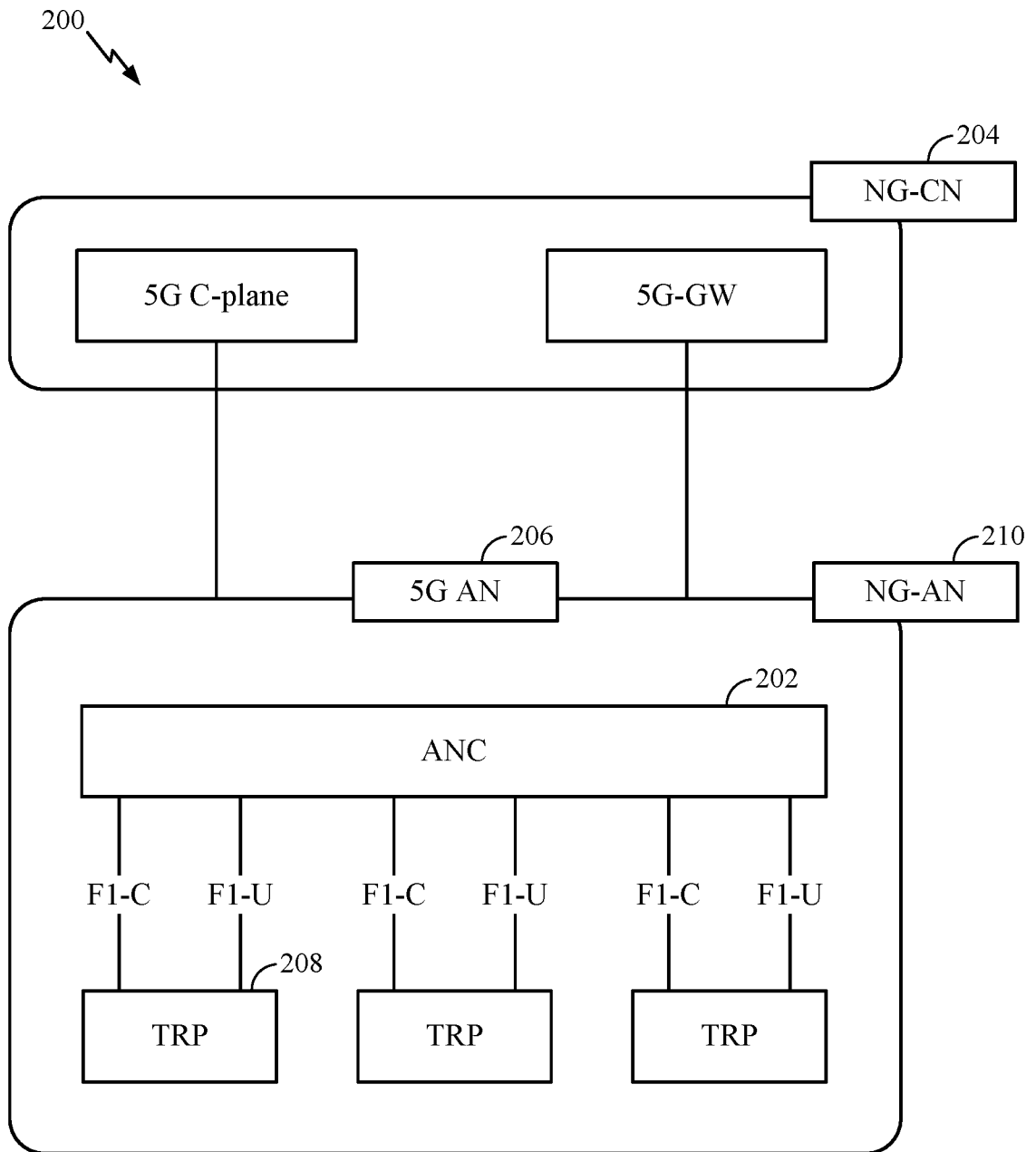


FIG. 2

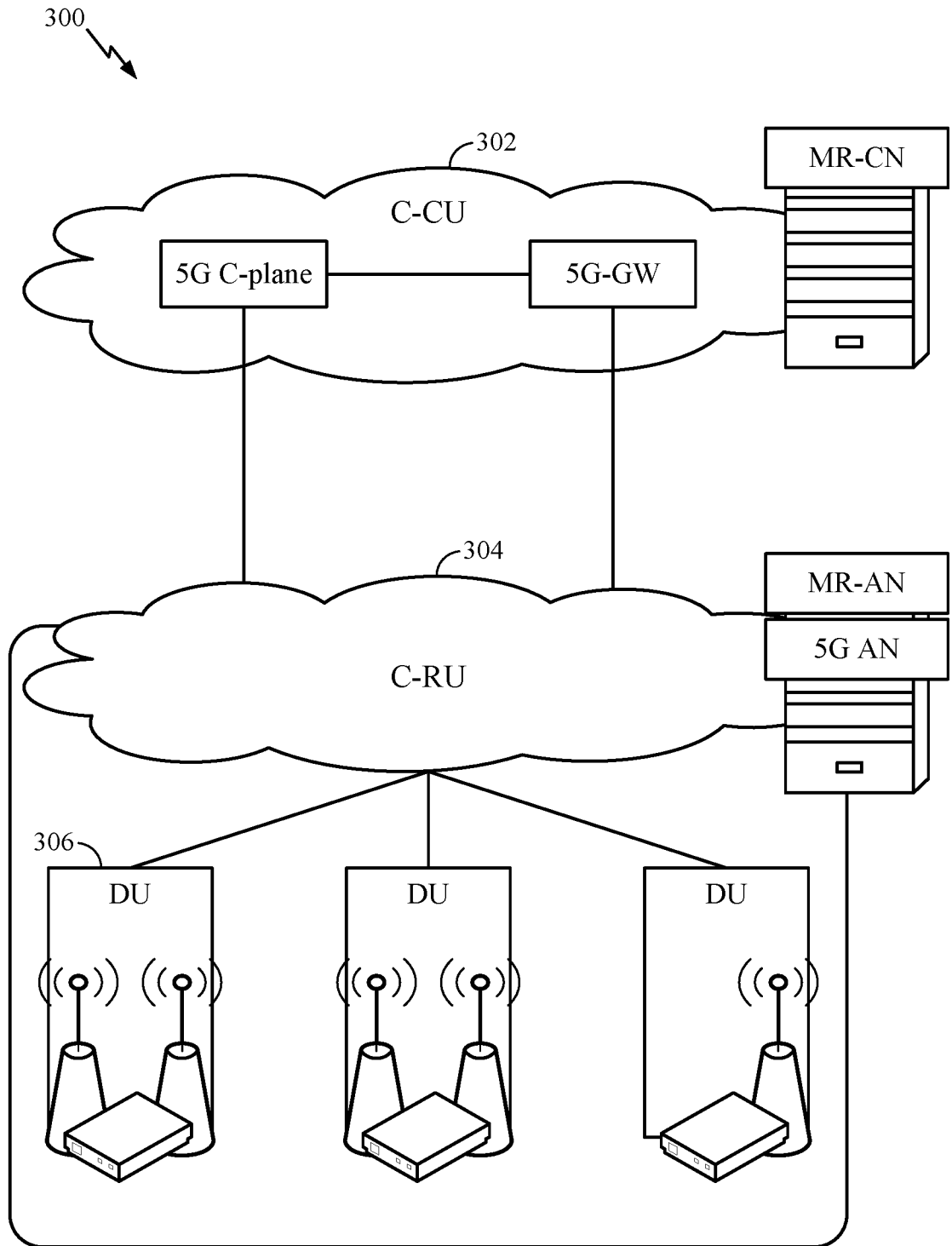


FIG. 3

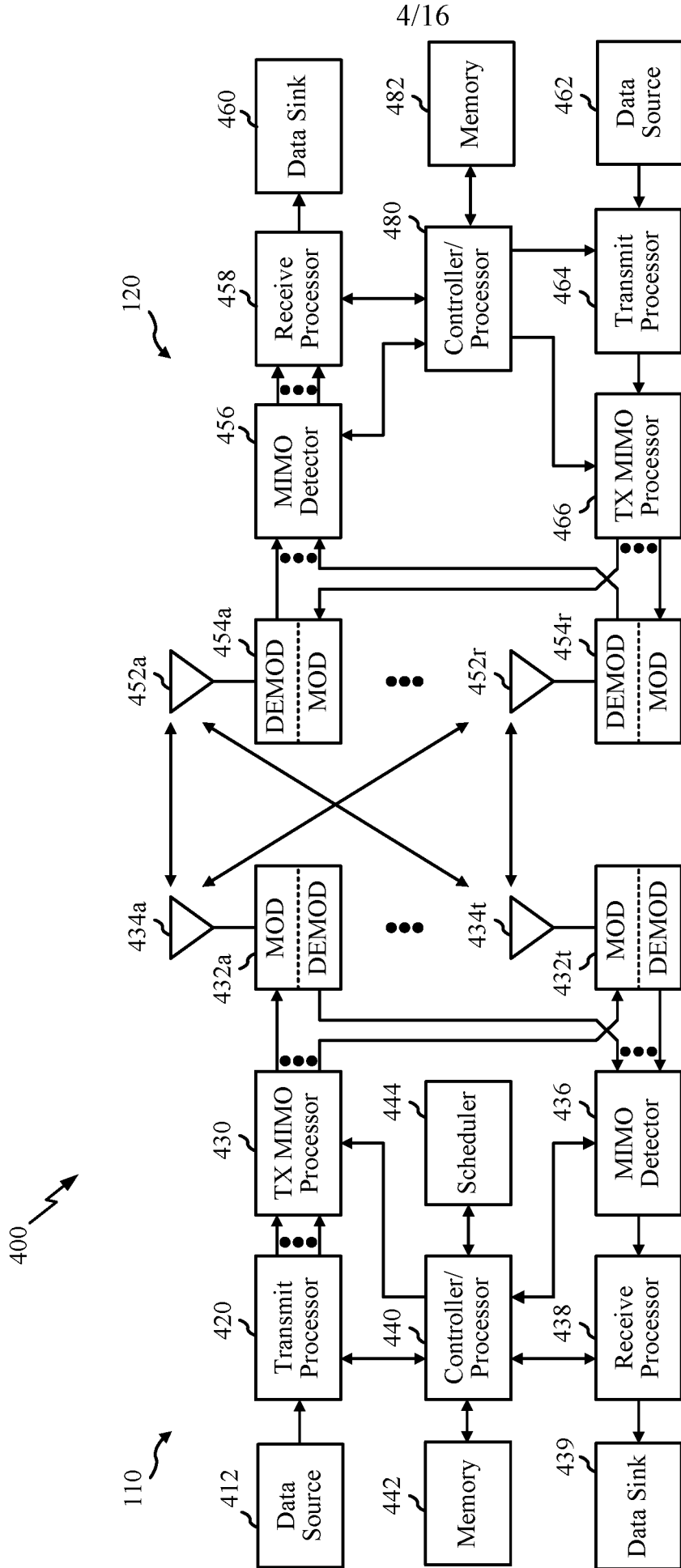


FIG. 4

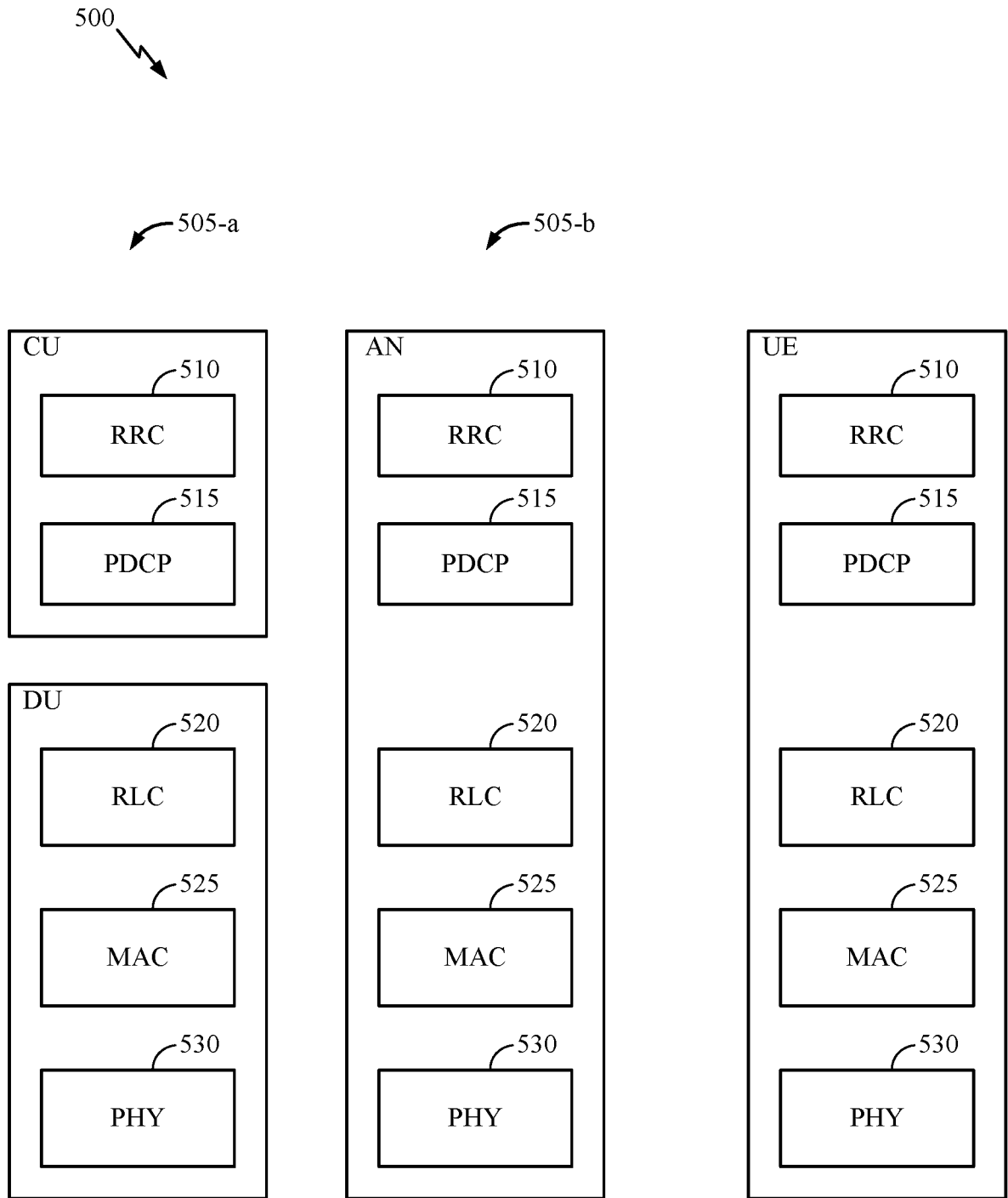


FIG. 5

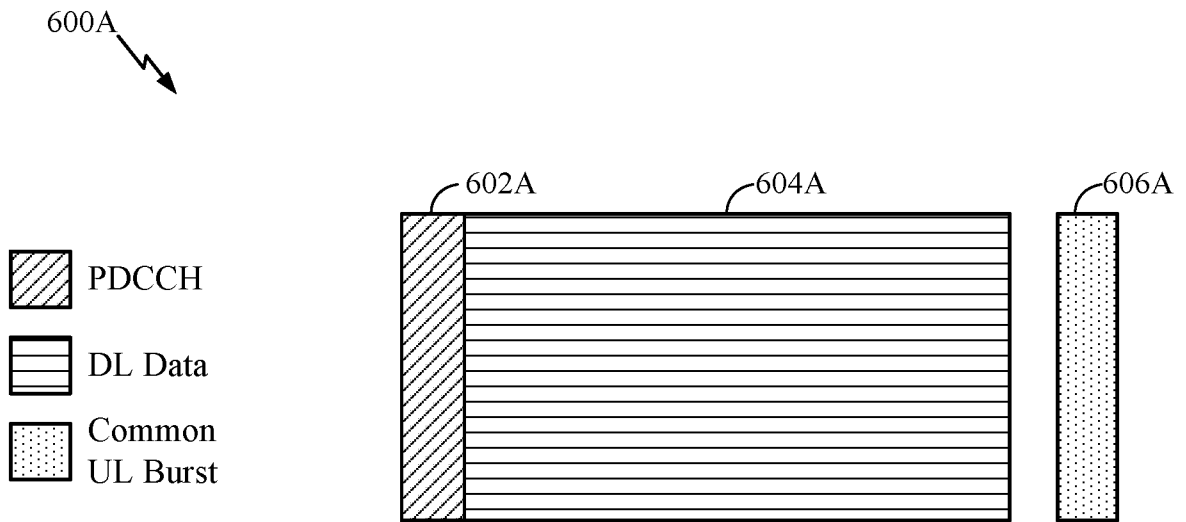


FIG. 6A

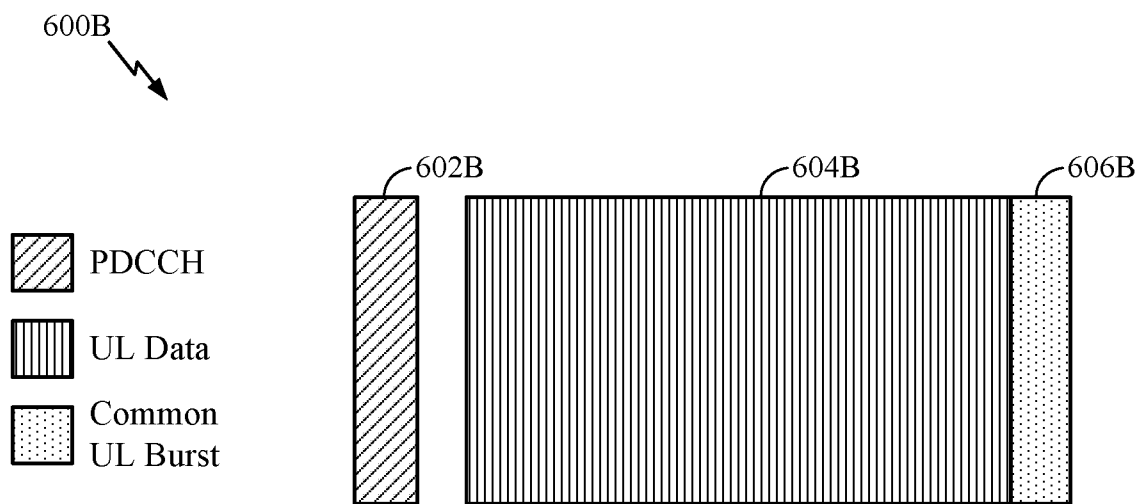


FIG. 6B

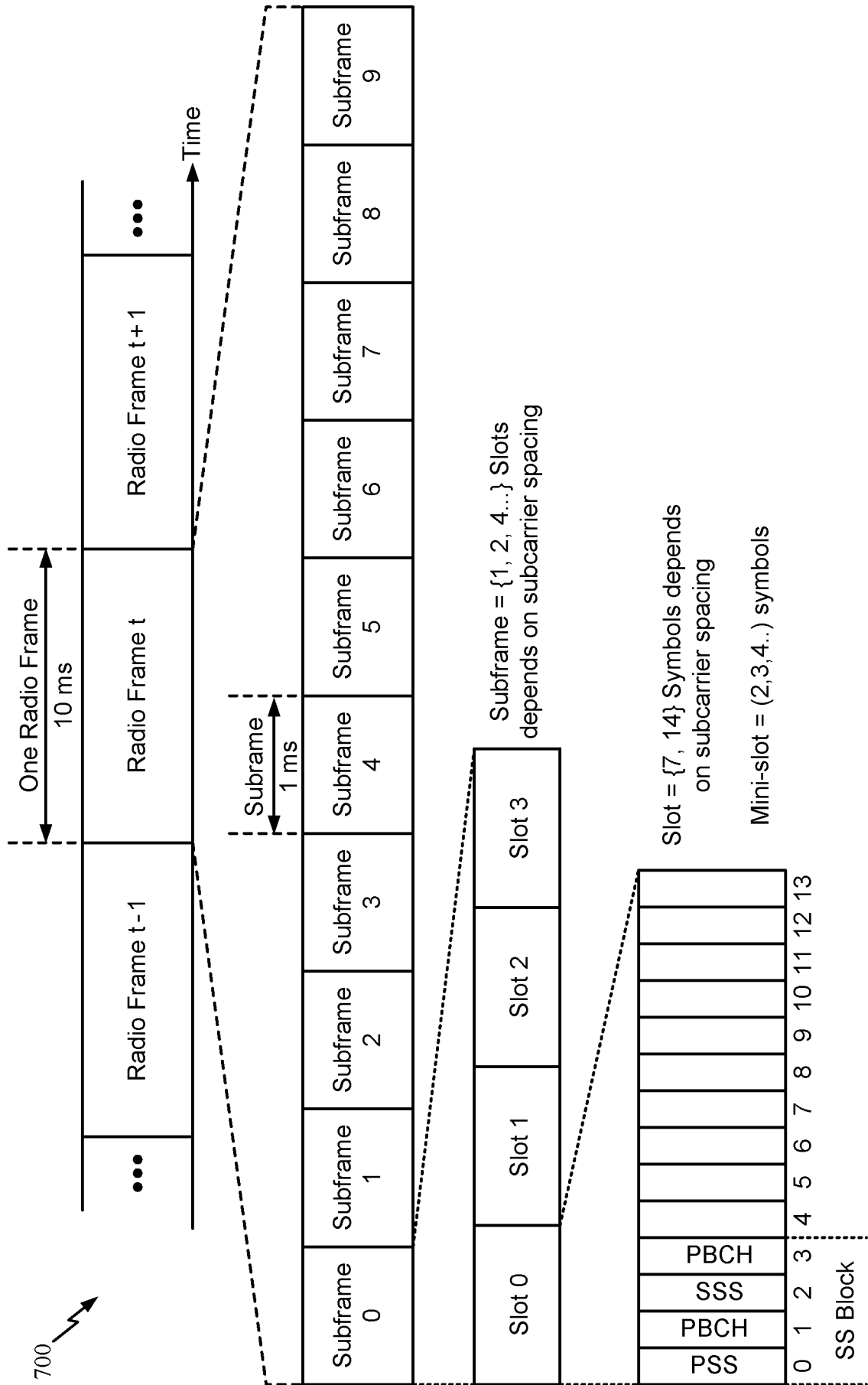


FIG. 7

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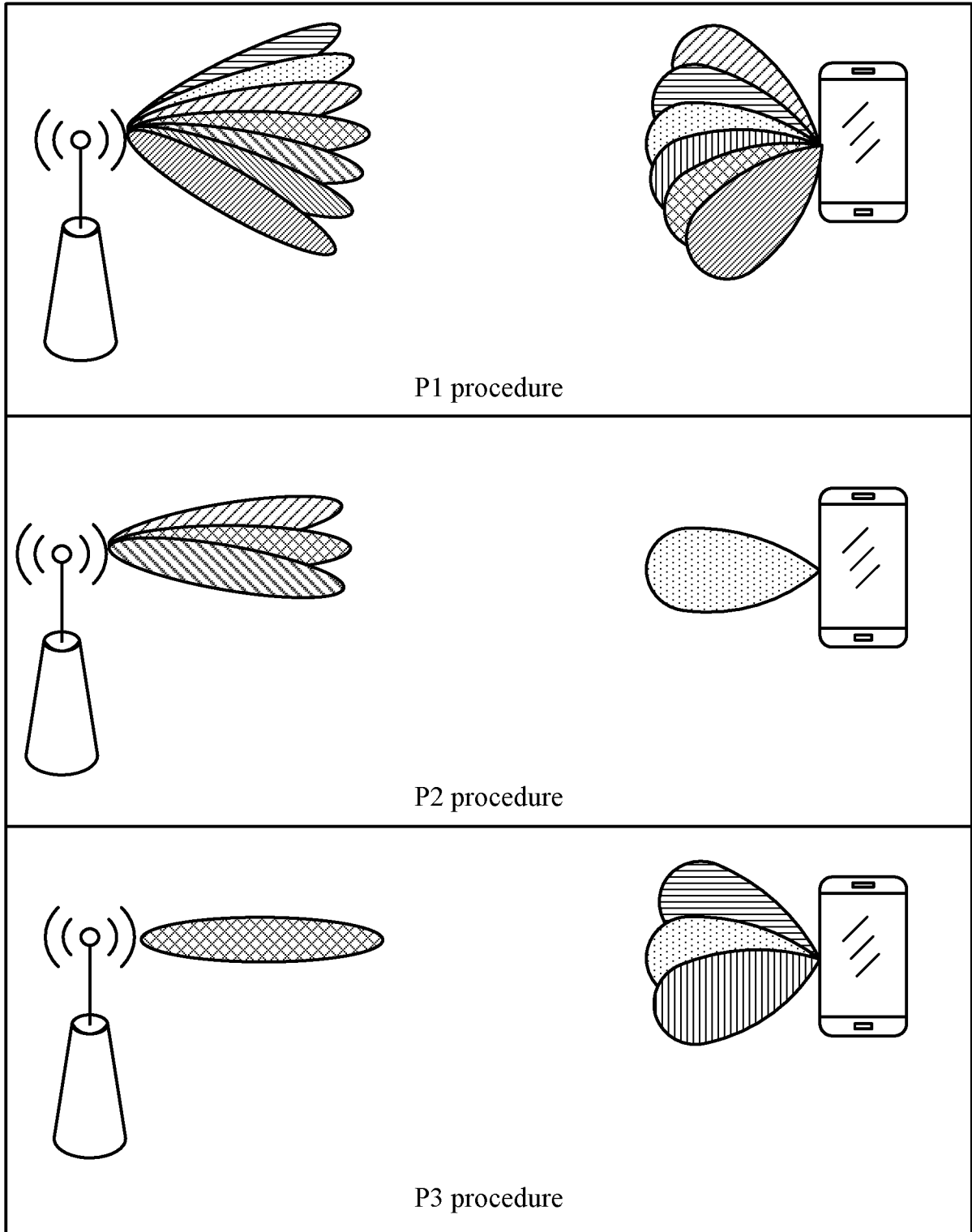


FIG. 8

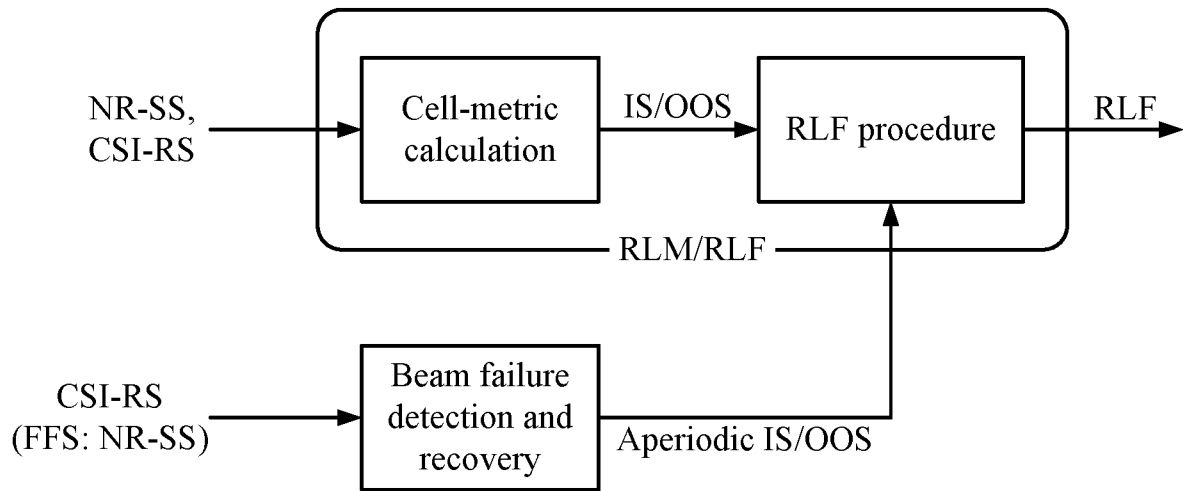


FIG. 9

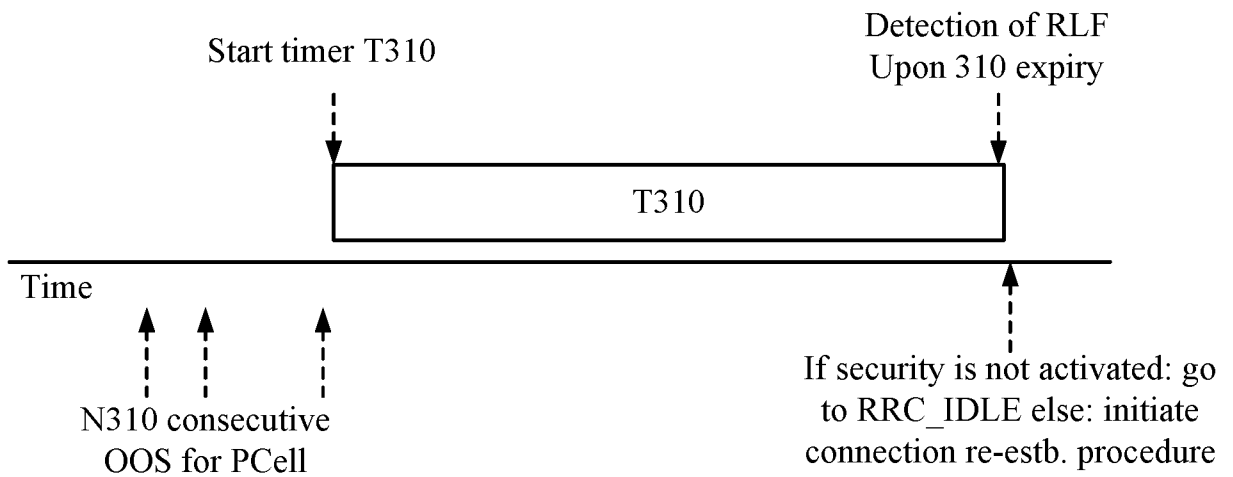


FIG. 10

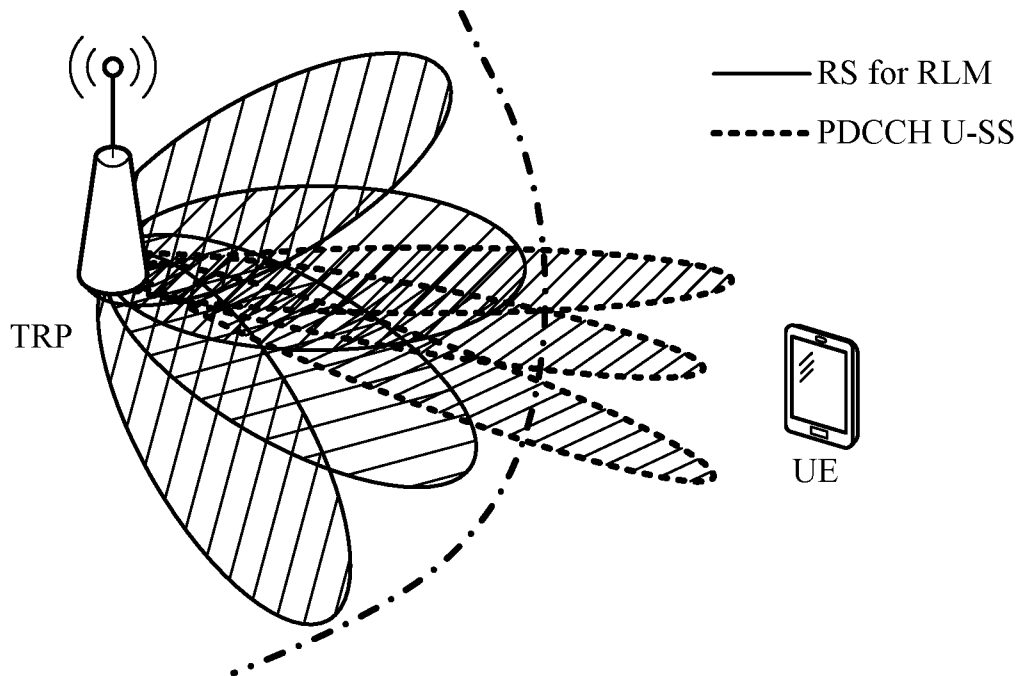


FIG. 11

11/16

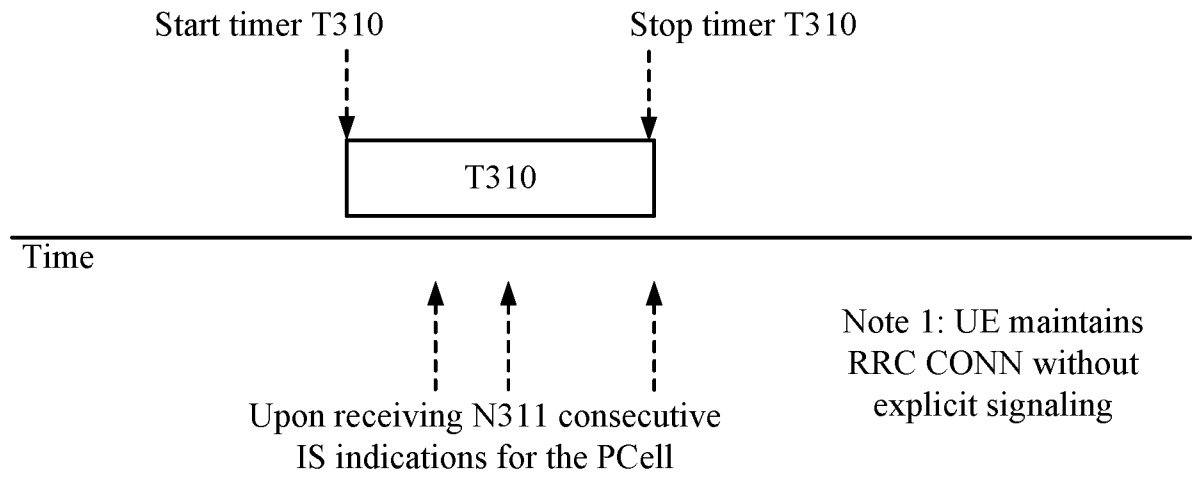


FIG. 12

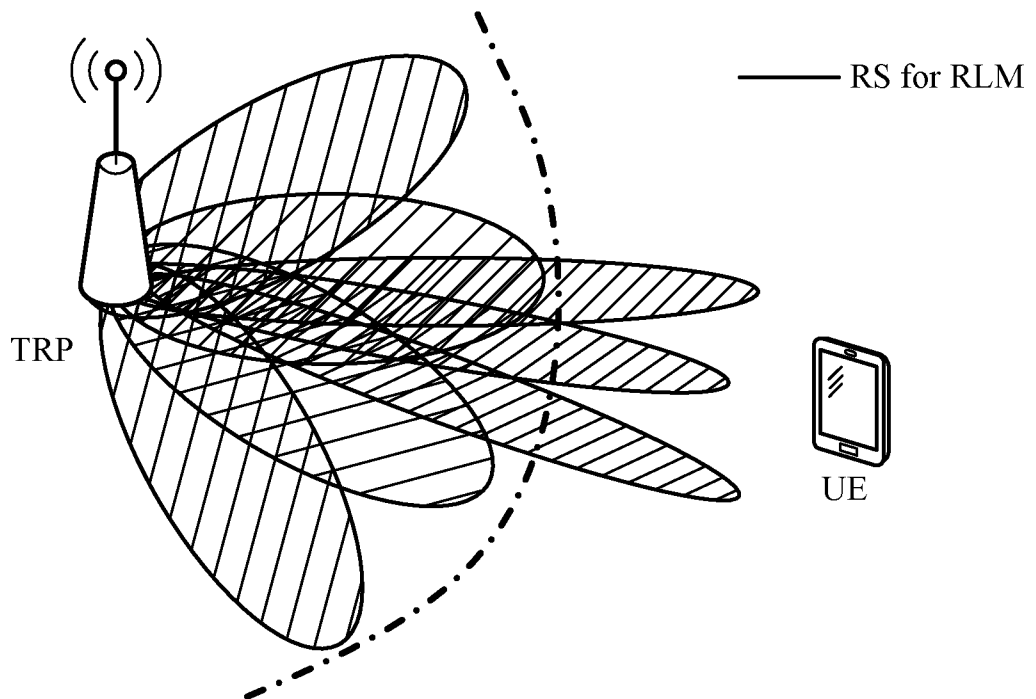


FIG. 13

12/16

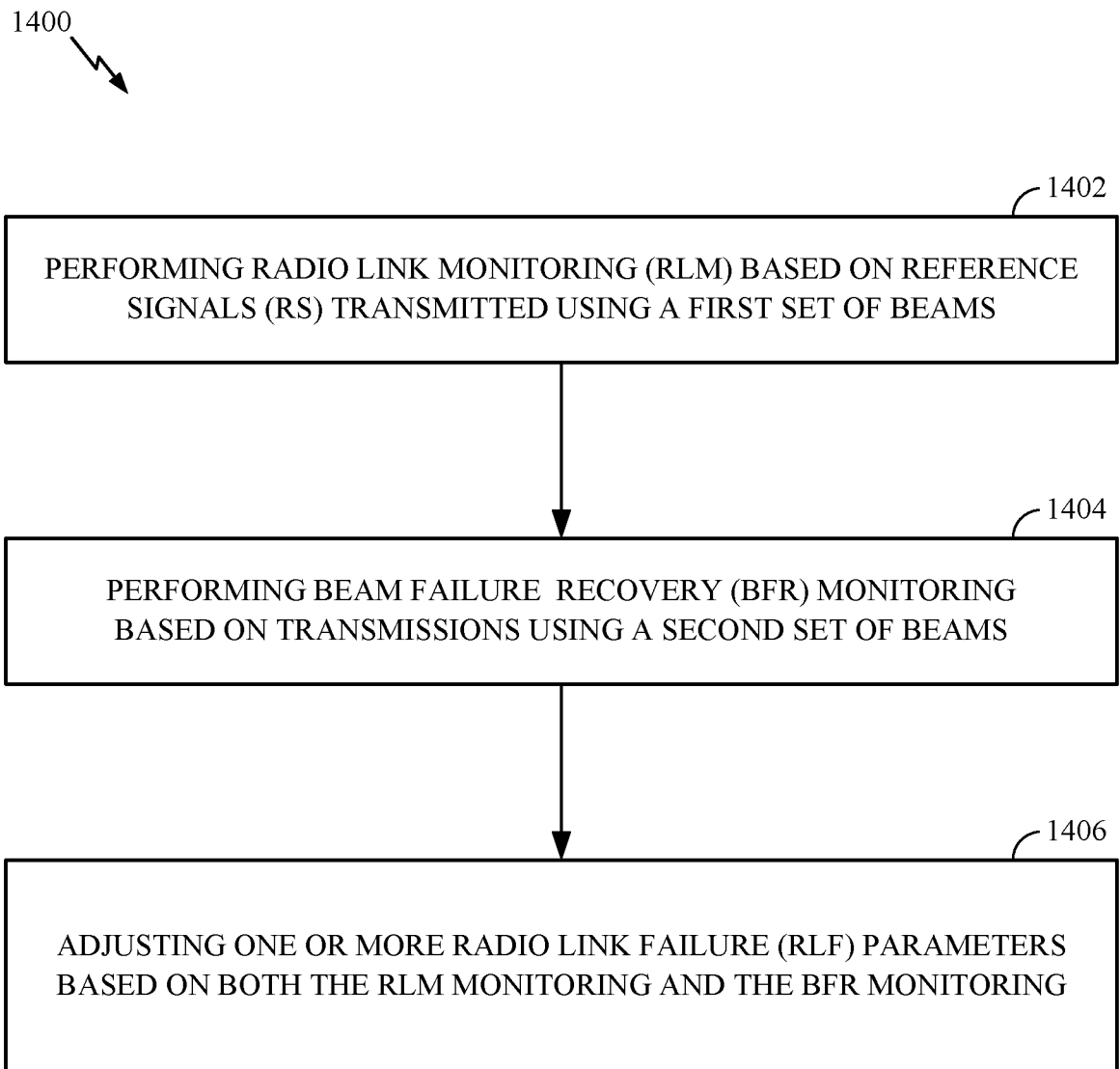


FIG. 14

13/16

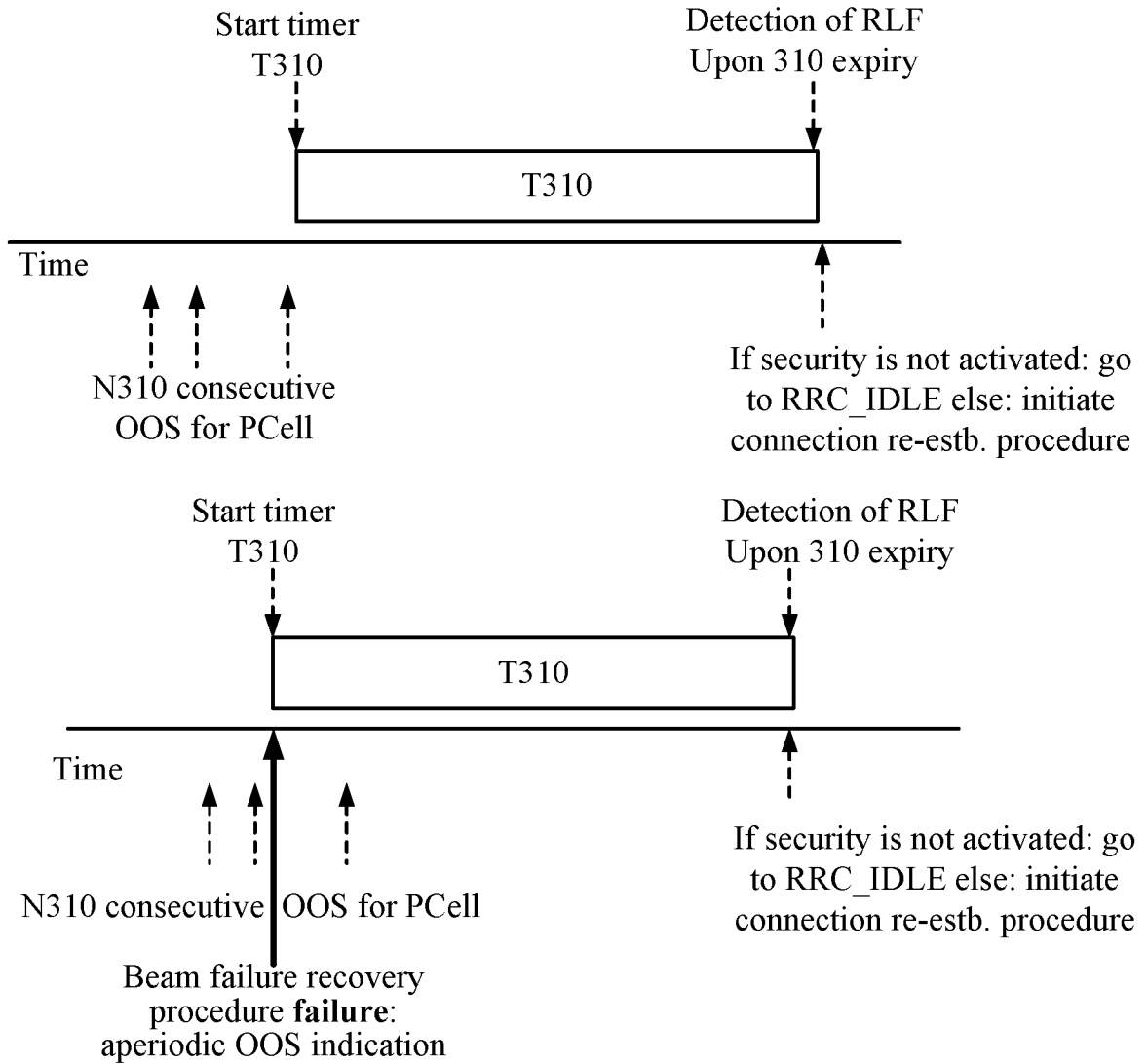


FIG. 15

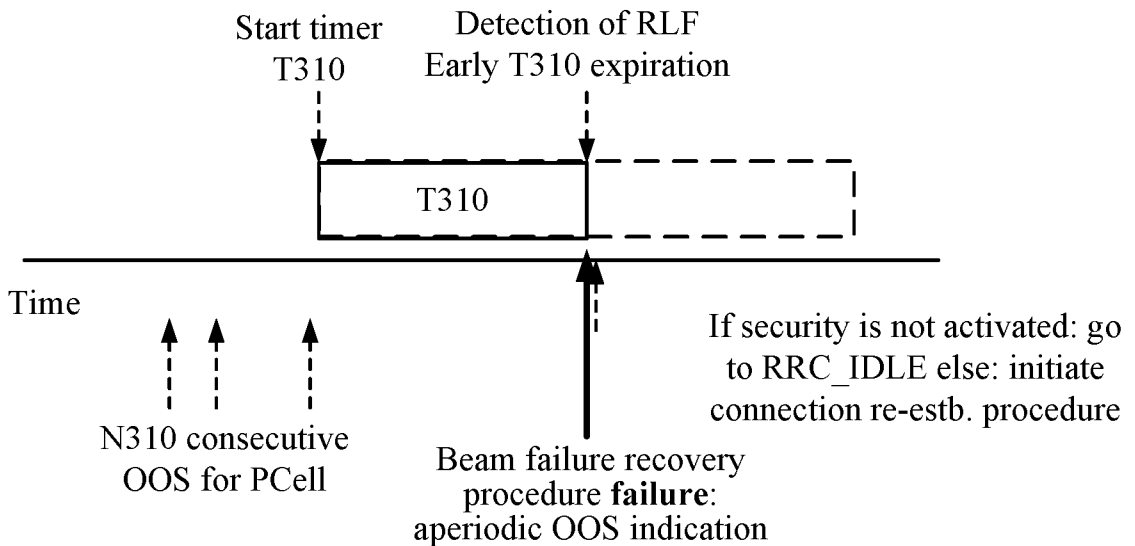


FIG. 16

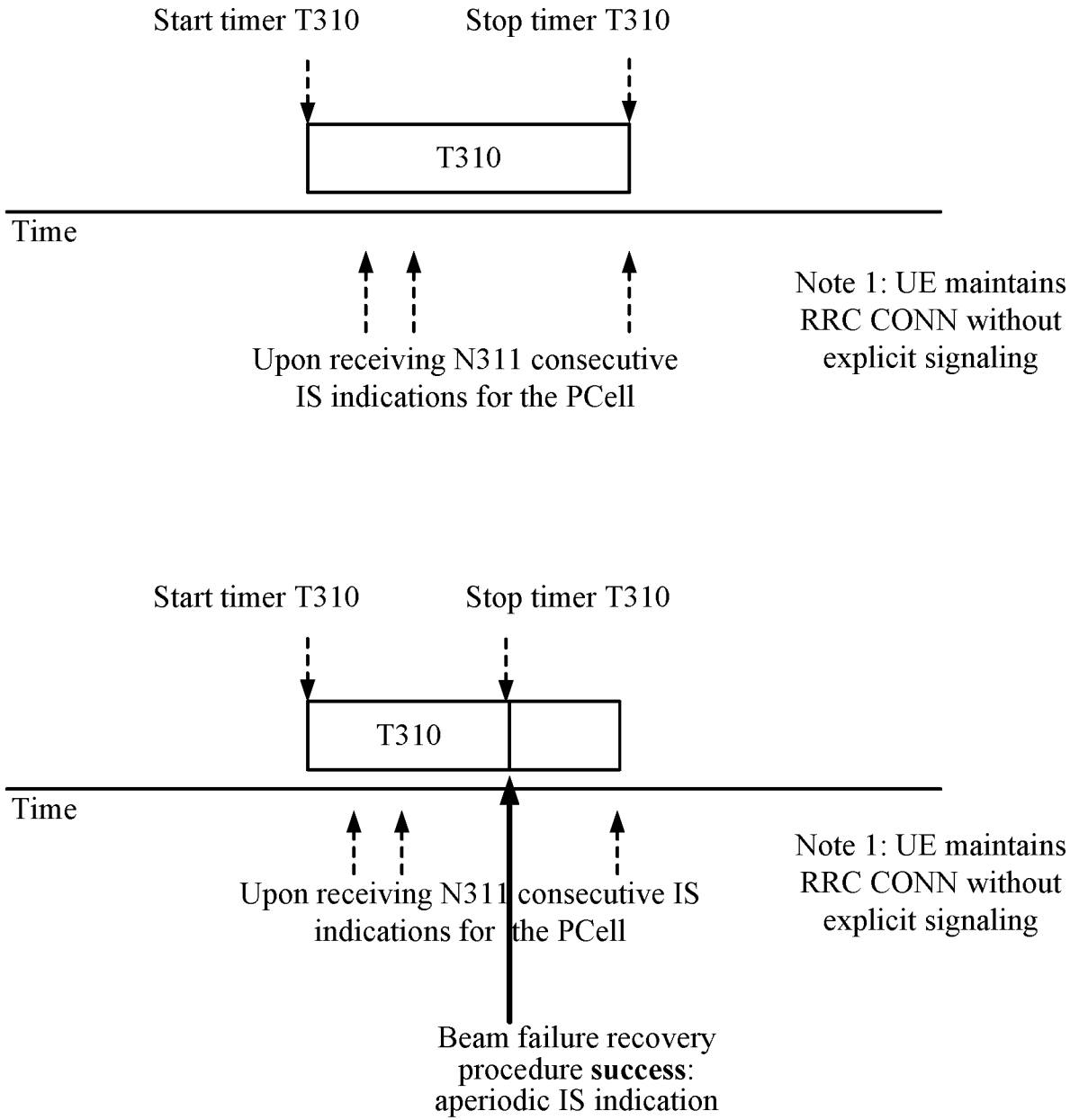


FIG. 17

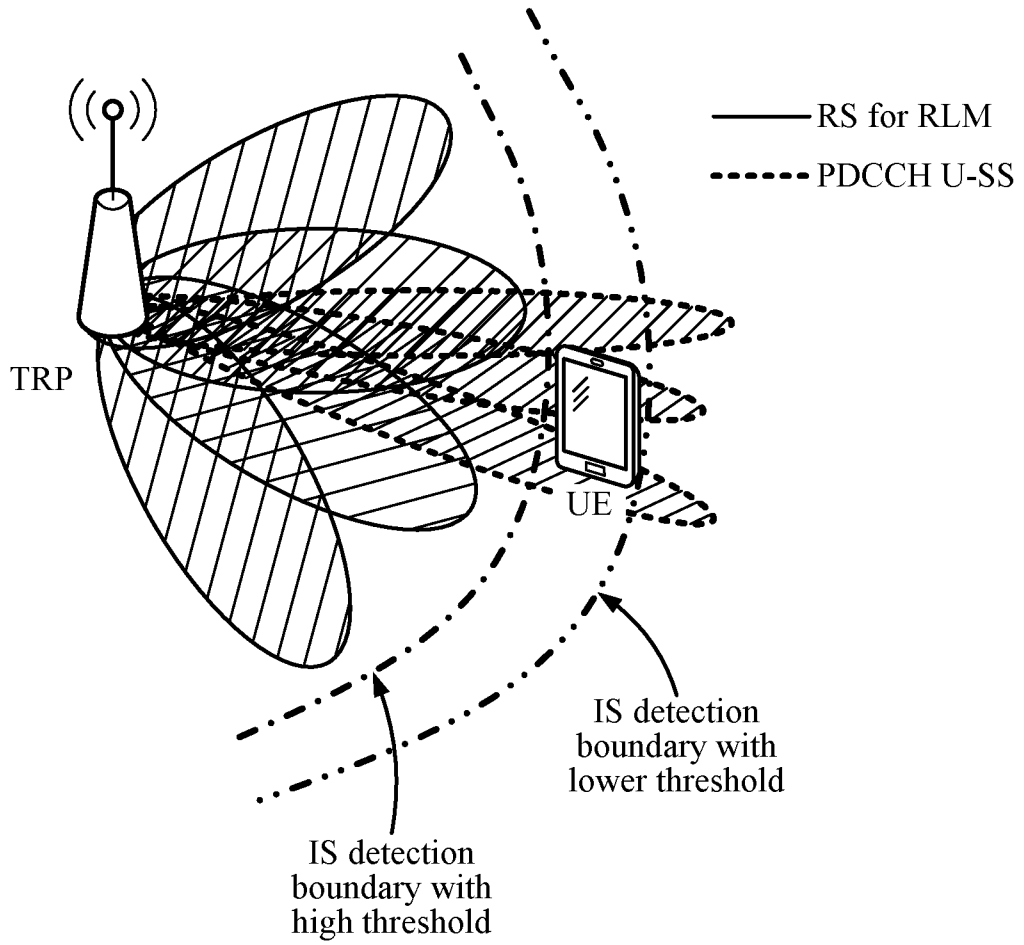


FIG. 18

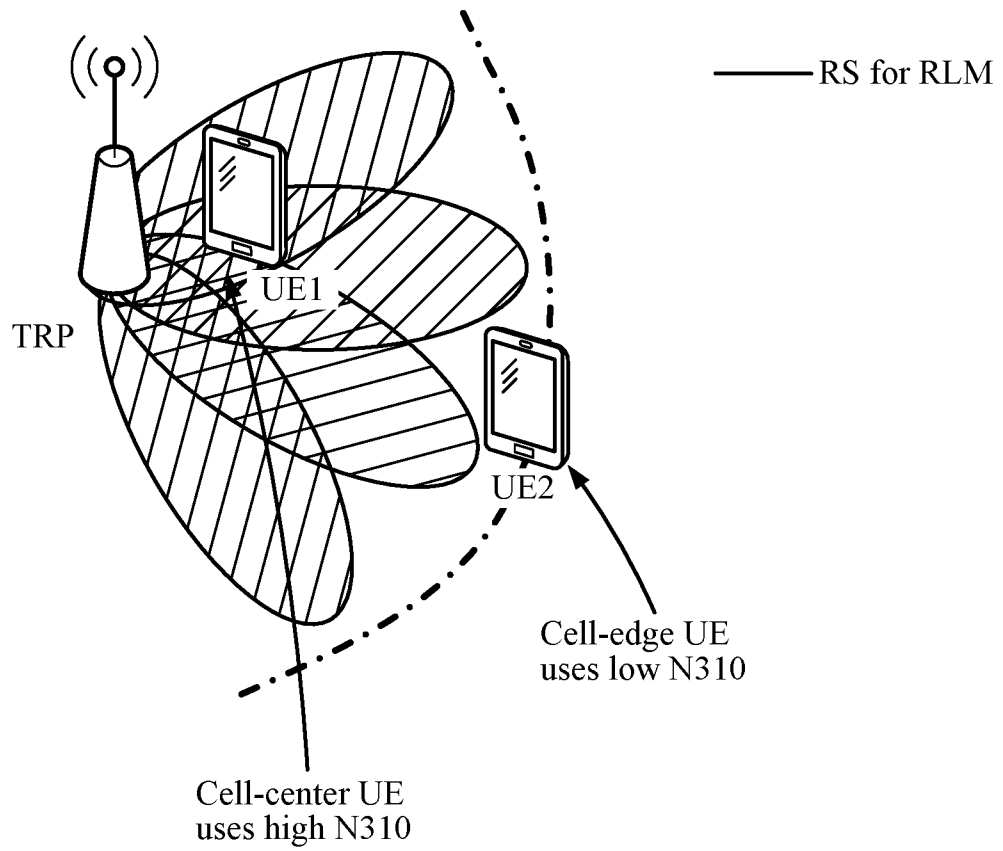


FIG. 19

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2018/043163

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W76/18
ADD.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
H04W
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|-----------|---|-----------------------|
| T | ERICSSON: "Beam recovery impact to RLF triggering", 3GPP DRAFT; R2-1805380 - BEAM RECOVERY IMPACT TO RLF TRIGGERING, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG2, no. Sanya, China; 20180416 - 20180420 14 April 2018 (2018-04-14), XP051429048, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings%5F3GP P%5FSYNC/RAN2/Docs/ [retrieved on 2018-04-14] the whole document ----- -/-- | 1-28 |

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :

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- "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

24 October 2018

Date of mailing of the international search report

12/11/2018

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Carnerero Álvaro, F

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2018/043163

| C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT | | |
|--|--|-----------------------|
| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
| X | <p>HUAWEI ET AL: "Link recovery procedure for beam failure", 3GPP DRAFT; R1-1704230, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE</p> <p>, vol. RAN WG1, no. Spokane, USA; 20170403 - 20170407 2 April 2017 (2017-04-02), XP051242382, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN1/Docs/ [retrieved on 2017-04-02] the whole document</p> <p style="text-align: center;">-----</p> | 1-28 |
| A | <p>"RLM and RLF in HF NR", 3GPP DRAFT; R2-164899, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE</p> <p>, vol. RAN WG2, no. Gothenburg, Sweden; 20160822 - 20160826 21 August 2016 (2016-08-21), XP051140905, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN2/Docs/ [retrieved on 2016-08-21] the whole document</p> <p style="text-align: center;">-----</p> | 1-28 |
| A | <p>MEDIATEK INC: "RLM and RLF in HF NR", 3GPP DRAFT; R2-1702770, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE</p> <p>, vol. RAN WG2, no. Spokane, USA; 20170403 - 20170407 3 April 2017 (2017-04-03), XP051244758, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN2/Docs/ [retrieved on 2017-04-03] the whole document</p> <p style="text-align: center;">-----</p> | 1-28 |