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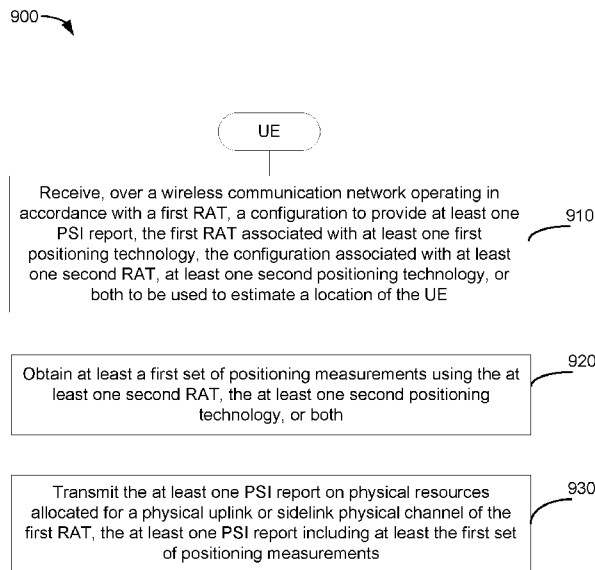


FIG. 9

(57) Abstract: Disclosed are techniques for wireless communication. In an aspect, a user equipment (UE) receives, over a wireless communication network operating in accordance with a first radio access technology (RAT), a configuration to provide at least one positioning state information (PSI) report, the first RAT associated with at least one first positioning technology, the configuration associated with at least one second RAT, at least one second positioning technology, or both to be used to estimate a location of the UE, obtains at least a first set of positioning measurements using the at least one second RAT, the at least one second positioning technology, or both, and transmits the at least one PSI report on physical resources allocated for a physical uplink or sidelink channel of the first RAT, the at least one PSI report including at least the first set of positioning measurements.



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## **LOW LAYER RADIO ACCESS TECHNOLOGY (RAT)-INDEPENDENT MEASUREMENT REPORTING**

### **CROSS-REFERENCE TO RELATED APPLICATIONS**

[0001] The present Application for Patent claims priority under 35 U.S.C. § 119 to Greek Patent Application No. 20200100118, entitled “LOW LAYER RADIO ACCESS TECHNOLOGY (RAT)-INDEPENDENT MEASUREMENT REPORTING,” filed March 3, 2020, and to Greek Patent Application No. 20200100221, entitled “LOW LAYER RADIO ACCESS TECHNOLOGY (RAT)-INDEPENDENT MEASUREMENT REPORTING,” filed May 4, 2020, which are assigned to the assignee hereof and expressly incorporated herein by reference in their entirety.

### **BACKGROUND OF THE DISCLOSURE**

#### *1. Field of the Disclosure*

[0002] Aspects of the disclosure relate generally to wireless communications.

#### *2. Description of the Related Art*

[0003] Wireless communication systems have developed through various generations, including a first-generation analog wireless phone service (1G), a second-generation (2G) digital wireless phone service (including interim 2.5G and 2.75G networks), a third-generation (3G) high speed data, Internet-capable wireless service and a fourth-generation (4G) service (e.g., Long Term Evolution (LTE) or WiMax). There are presently many different types of wireless communication systems in use, including cellular and personal communications service (PCS) systems. Examples of known cellular systems include the cellular analog advanced mobile phone system (AMPS), and digital cellular systems based on code division multiple access (CDMA), frequency division multiple access (FDMA), time division multiple access (TDMA), the Global System for Mobile communications (GSM), etc.

[0004] A fifth generation (5G) wireless standard, referred to as New Radio (NR), calls for higher data transfer speeds, greater numbers of connections, and better coverage, among other improvements. The 5G standard, according to the Next Generation Mobile Networks Alliance, is designed to provide data rates of several tens of megabits per second to each

of tens of thousands of users, with 1 gigabit per second to tens of workers on an office floor. Several hundreds of thousands of simultaneous connections should be supported in order to support large sensor deployments. Consequently, the spectral efficiency of 5G mobile communications should be significantly enhanced compared to the current 4G standard. Furthermore, signaling efficiencies should be enhanced and latency should be substantially reduced compared to current standards.

### SUMMARY

- [0005] The following presents a simplified summary relating to one or more aspects disclosed herein. Thus, the following summary should not be considered an extensive overview relating to all contemplated aspects, nor should the following summary be considered to identify key or critical elements relating to all contemplated aspects or to delineate the scope associated with any particular aspect. Accordingly, the following summary has the sole purpose to present certain concepts relating to one or more aspects relating to the mechanisms disclosed herein in a simplified form to precede the detailed description presented below.
- [0006] In an aspect, a method of wireless communication performed by a user equipment (UE) includes receiving, over a wireless communication network operating in accordance with a first radio access technology (RAT), a configuration to provide at least one positioning state information (PSI) report, the first RAT associated with at least one first positioning technology, the configuration associated with at least one second RAT, at least one second positioning technology, or both to be used to estimate a location of the UE, obtaining at least a first set of positioning measurements using the at least one second RAT, the at least one second positioning technology, or both, and transmitting the at least one PSI report on physical resources allocated for a physical uplink or sidelink channel of the first RAT, the at least one PSI report including at least the first set of positioning measurements.
- [0007] In an aspect, a UE includes a memory, at least one transceiver, and at least one processor communicatively coupled to the memory and the at least one transceiver, the at least one processor configured to: receive, via the at least one transceiver over a wireless communication network operating in accordance with a first RAT, a configuration to provide at least one PSI report, the first RAT associated with at least one first positioning technology, the configuration associated with at least one second RAT, at least one second

positioning technology, or both to be used to estimate a location of the UE, obtain, via the at least one transceiver, at least a first set of positioning measurements using the at least one second RAT, the at least one second positioning technology, or both, and cause the at least one transceiver to transmit the at least one PSI report on physical resources allocated for a physical uplink or sidelink channel of the first RAT, the at least one PSI report including at least the first set of positioning measurements.

[0008] In an aspect, a UE includes means for receiving, over a wireless communication network operating in accordance with a first RAT, a configuration to provide at least one PSI report, the first RAT associated with at least one first positioning technology, the configuration associated with at least one second RAT, at least one second positioning technology, or both to be used to estimate a location of the UE, means for obtaining at least a first set of positioning measurements using the at least one second RAT, the at least one second positioning technology, or both, and means for transmitting the at least one PSI report on physical resources allocated for a physical uplink or sidelink channel of the first RAT, the at least one PSI report including at least the first set of positioning measurements.

[0009] In an aspect, a non-transitory computer-readable medium storing computer-executable instructions includes computer-executable instructions comprising at least one instruction instructing a UE to receive, over a wireless communication network operating in accordance with a first RAT, a configuration to provide at least one PSI report, the first RAT associated with at least one first positioning technology, the configuration associated with at least one second RAT, at least one second positioning technology, or both to be used to estimate a location of the UE, at least one instruction instructing the UE to obtain at least a first set of positioning measurements using the at least one second RAT, the at least one second positioning technology, or both, and at least one instruction instructing the UE to transmit the at least one PSI report on physical resources allocated for a physical uplink or sidelink channel of the first RAT, the at least one PSI report including at least the first set of positioning measurements.

[0010] Other objects and advantages associated with the aspects disclosed herein will be apparent to those skilled in the art based on the accompanying drawings and detailed description.

## **BRIEF DESCRIPTION OF THE DRAWINGS**

- [0011] The accompanying drawings are presented to aid in the description of various aspects of the disclosure and are provided solely for illustration of the aspects and not limitation thereof.
- [0012] FIG. 1 illustrates an example wireless communications system, according to aspects of the disclosure.
- [0013] FIGS. 2A and 2B illustrate example wireless network structures, according to aspects of the disclosure.
- [0014] FIGS. 3A to 3C are simplified block diagrams of several sample aspects of components that may be employed in a user equipment (UE), a base station, and a network entity, respectively, and configured to support communications as taught herein.
- [0015] FIGS. 4A and 4B illustrate user plane and control plane protocol stacks, according to aspects of the disclosure.
- [0016] FIGS. 5A to 5D are diagrams illustrating example frame structures and channels within the frame structures, according to aspects of the disclosure.
- [0017] FIG. 6 illustrates example Long-Term Evolution (LTE) positioning protocol (LPP) reference sources for positioning.
- [0018] FIGS. 7 and 8 are diagrams illustrating example downlink control information (DCI) triggers for PSI reporting, according to aspects of the disclosure.
- [0019] FIG. 9 illustrates an example method of wireless communication, according to aspects of the disclosure.

#### **DETAILED DESCRIPTION**

- [0020] Aspects of the disclosure are provided in the following description and related drawings directed to various examples provided for illustration purposes. Alternate aspects may be devised without departing from the scope of the disclosure. Additionally, well-known elements of the disclosure will not be described in detail or will be omitted so as not to obscure the relevant details of the disclosure.
- [0021] The words “exemplary” and/or “example” are used herein to mean “serving as an example, instance, or illustration.” Any aspect described herein as “exemplary” and/or “example” is not necessarily to be construed as preferred or advantageous over other aspects. Likewise, the term “aspects of the disclosure” does not require that all aspects of the disclosure include the discussed feature, advantage or mode of operation.

- [0022] Those of skill in the art will appreciate that the information and signals described below may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the description below may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof, depending in part on the particular application, in part on the desired design, in part on the corresponding technology, etc.
- [0023] Further, many aspects are described in terms of sequences of actions to be performed by, for example, elements of a computing device. It will be recognized that various actions described herein can be performed by specific circuits (e.g., application specific integrated circuits (ASICs)), by program instructions being executed by one or more processors, or by a combination of both. Additionally, the sequence(s) of actions described herein can be considered to be embodied entirely within any form of non-transitory computer-readable storage medium having stored therein a corresponding set of computer instructions that, upon execution, would cause or instruct an associated processor of a device to perform the functionality described herein. Thus, the various aspects of the disclosure may be embodied in a number of different forms, all of which have been contemplated to be within the scope of the claimed subject matter. In addition, for each of the aspects described herein, the corresponding form of any such aspects may be described herein as, for example, “logic configured to” perform the described action.
- [0024] As used herein, the terms “user equipment” (UE) and “base station” are not intended to be specific or otherwise limited to any particular radio access technology (RAT), unless otherwise noted. In general, a UE may be any wireless communication device (e.g., a mobile phone, router, tablet computer, laptop computer, commercially-available tracking device, wearable (e.g., smartwatch, glasses, augmented reality (AR) / virtual reality (VR) headset, etc.), vehicle (e.g., automobile, motorcycle, bicycle, etc.), Internet of Things (IoT) device, etc.) used by a user to communicate over a wireless communications network. A UE may be mobile or may (e.g., at certain times) be stationary, and may communicate with a radio access network (RAN). As used herein, the term “UE” may be referred to interchangeably as an “access terminal” or “AT,” a “client device,” a “wireless device,” a “subscriber device,” a “subscriber terminal,” a “subscriber station,” a “user terminal” or “UT,” a “mobile device,” a “mobile terminal,” a “mobile station,” or variations thereof. Generally, UEs can communicate with a core network via a RAN, and

through the core network the UEs can be connected with external networks such as the Internet and with other UEs. Of course, other mechanisms of connecting to the core network and/or the Internet are also possible for the UEs, such as over wired access networks, wireless local area network (WLAN) networks (e.g., based on the Institute of Electrical and Electronics Engineers (IEEE) 802.11 specification, etc.) and so on.

[0025] A base station may operate according to one of several RATs in communication with UEs depending on the network in which it is deployed, and may be alternatively referred to as an access point (AP), a network node, a NodeB, an evolved NodeB (eNB), a next generation eNB (ng-eNB), a New Radio (NR) Node B (also referred to as a gNB or gNodeB), etc. A base station may be used primarily to support wireless access by UEs, including supporting data, voice, and/or signaling connections for the supported UEs. In some systems a base station may provide purely edge node signaling functions while in other systems it may provide additional control and/or network management functions. A communication link through which UEs can send signals to a base station is called an uplink (UL) channel (e.g., a reverse traffic channel, a reverse control channel, an access channel, etc.). A communication link through which the base station can send signals to UEs is called a downlink (DL) or forward link channel (e.g., a paging channel, a control channel, a broadcast channel, a forward traffic channel, etc.). As used herein the term traffic channel (TCH) can refer to either an uplink / reverse or downlink / forward traffic channel.

[0026] The term “base station” may refer to a single physical transmission-reception point (TRP) or to multiple physical TRPs that may or may not be co-located. For example, where the term “base station” refers to a single physical TRP, the physical TRP may be an antenna of the base station corresponding to a cell (or several cell sectors) of the base station. Where the term “base station” refers to multiple co-located physical TRPs, the physical TRPs may be an array of antennas (e.g., as in a multiple-input multiple-output (MIMO) system or where the base station employs beamforming) of the base station. Where the term “base station” refers to multiple non-co-located physical TRPs, the physical TRPs may be a distributed antenna system (DAS) (a network of spatially separated antennas connected to a common source via a transport medium) or a remote radio head (RRH) (a remote base station connected to a serving base station). Alternatively, the non-co-located physical TRPs may be the serving base station receiving the measurement report from the UE and a neighbor base station whose reference RF signals the UE is measuring. Because

a TRP is the point from which a base station transmits and receives wireless signals, as used herein, references to transmission from or reception at a base station are to be understood as referring to a particular TRP of the base station.

- [0027] In some implementations that support positioning of UEs, a base station may not support wireless access by UEs (e.g., may not support data, voice, and/or signaling connections for UEs), but may instead transmit reference signals to UEs to be measured by the UEs, and/or may receive and measure signals transmitted by the UEs. Such a base station may be referred to as a positioning beacon (e.g., when transmitting signals to UEs) and/or as a location measurement unit (e.g., when receiving and measuring signals from UEs).
- [0028] An “RF signal” comprises an electromagnetic wave of a given frequency that transports information through the space between a transmitter and a receiver. As used herein, a transmitter may transmit a single “RF signal” or multiple “RF signals” to a receiver. However, the receiver may receive multiple “RF signals” corresponding to each transmitted RF signal due to the propagation characteristics of RF signals through multipath channels. The same transmitted RF signal on different paths between the transmitter and receiver may be referred to as a “multipath” RF signal.
- [0029] **FIG. 1** illustrates an example wireless communications system 100. The wireless communications system 100 (which may also be referred to as a wireless wide area network (WWAN)) may include various base stations 102 and various UEs 104. The base stations 102 may include macro cell base stations (high power cellular base stations) and/or small cell base stations (low power cellular base stations). In an aspect, the macro cell base station may include eNBs and/or ng-eNBs where the wireless communications system 100 corresponds to an LTE network, or gNBs where the wireless communications system 100 corresponds to a NR network, or a combination of both, and the small cell base stations may include femtocells, picocells, microcells, etc.
- [0030] The base stations 102 may collectively form a RAN and interface with a core network 170 (e.g., an evolved packet core (EPC) or a 5G core (5GC)) through backhaul links 122, and through the core network 170 to one or more location servers 172 (which may be part of core network 170 or may be external to core network 170). In addition to other functions, the base stations 102 may perform functions that relate to one or more of transferring user data, radio channel ciphering and deciphering, integrity protection, header compression, mobility control functions (e.g., handover, dual connectivity), inter-cell interference coordination, connection setup and release, load balancing, distribution

for non-access stratum (NAS) messages, NAS node selection, synchronization, RAN sharing, multimedia broadcast multicast service (MBMS), subscriber and equipment trace, RAN information management (RIM), paging, positioning, and delivery of warning messages. The base stations 102 may communicate with each other directly or indirectly (e.g., through the EPC / 5GC) over backhaul links 134, which may be wired or wireless.

[0031] The base stations 102 may wirelessly communicate with the UEs 104. Each of the base stations 102 may provide communication coverage for a respective geographic coverage area 110. In an aspect, one or more cells may be supported by a base station 102 in each geographic coverage area 110. A “cell” is a logical communication entity used for communication with a base station (e.g., over some frequency resource, referred to as a carrier frequency, component carrier, carrier, band, or the like), and may be associated with an identifier (e.g., a physical cell identifier (PCI), a virtual cell identifier (VCI), a cell global identifier (CGI)) for distinguishing cells operating via the same or a different carrier frequency. In some cases, different cells may be configured according to different protocol types (e.g., machine-type communication (MTC), narrowband IoT (NB-IoT), enhanced mobile broadband (eMBB), or others) that may provide access for different types of UEs. Because a cell is supported by a specific base station, the term “cell” may refer to either or both of the logical communication entity and the base station that supports it, depending on the context. In some cases, the term “cell” may also refer to a geographic coverage area of a base station (e.g., a sector), insofar as a carrier frequency can be detected and used for communication within some portion of geographic coverage areas 110.

[0032] While neighboring macro cell base station 102 geographic coverage areas 110 may partially overlap (e.g., in a handover region), some of the geographic coverage areas 110 may be substantially overlapped by a larger geographic coverage area 110. For example, a small cell base station 102' may have a geographic coverage area 110' that substantially overlaps with the geographic coverage area 110 of one or more macro cell base stations 102. A network that includes both small cell and macro cell base stations may be known as a heterogeneous network. A heterogeneous network may also include home eNBs (HeNBs), which may provide service to a restricted group known as a closed subscriber group (CSG).

[0033] The communication links 120 between the base stations 102 and the UEs 104 may include uplink (also referred to as reverse link) transmissions from a UE 104 to a base station 102

and/or downlink (also referred to as forward link) transmissions from a base station 102 to a UE 104. The communication links 120 may use MIMO antenna technology, including spatial multiplexing, beamforming, and/or transmit diversity. The communication links 120 may be through one or more carrier frequencies. Allocation of carriers may be asymmetric with respect to downlink and uplink (e.g., more or less carriers may be allocated for downlink than for uplink).

- [0034] The wireless communications system 100 may further include a wireless local area network (WLAN) access point (AP) 150 in communication with WLAN stations (STAs) 152 via communication links 154 in an unlicensed frequency spectrum (e.g., 5 GHz). When communicating in an unlicensed frequency spectrum, the WLAN STAs 152 and/or the WLAN AP 150 may perform a clear channel assessment (CCA) or listen before talk (LBT) procedure prior to communicating in order to determine whether the channel is available.
- [0035] The small cell base station 102' may operate in a licensed and/or an unlicensed frequency spectrum. When operating in an unlicensed frequency spectrum, the small cell base station 102' may employ LTE or NR technology and use the same 5 GHz unlicensed frequency spectrum as used by the WLAN AP 150. The small cell base station 102', employing LTE / 5G in an unlicensed frequency spectrum, may boost coverage to and/or increase capacity of the access network. NR in unlicensed spectrum may be referred to as NR-U. LTE in an unlicensed spectrum may be referred to as LTE-U, licensed assisted access (LAA), or MulteFire.
- [0036] The wireless communications system 100 may further include a millimeter wave (mmW) base station 180 that may operate in mmW frequencies and/or near mmW frequencies in communication with a UE 182. Extremely high frequency (EHF) is part of the RF in the electromagnetic spectrum. EHF has a range of 30 GHz to 300 GHz and a wavelength between 1 millimeter and 10 millimeters. Radio waves in this band may be referred to as a millimeter wave. Near mmW may extend down to a frequency of 3 GHz with a wavelength of 100 millimeters. The super high frequency (SHF) band extends between 3 GHz and 30 GHz, also referred to as centimeter wave. Communications using the mmW/near mmW radio frequency band have high path loss and a relatively short range. The mmW base station 180 and the UE 182 may utilize beamforming (transmit and/or receive) over a mmW communication link 184 to compensate for the extremely high path loss and short range. Further, it will be appreciated that in alternative configurations, one

or more base stations 102 may also transmit using mmW or near mmW and beamforming. Accordingly, it will be appreciated that the foregoing illustrations are merely examples and should not be construed to limit the various aspects disclosed herein.

[0037] Transmit beamforming is a technique for focusing an RF signal in a specific direction. Traditionally, when a network node (e.g., a base station) broadcasts an RF signal, it broadcasts the signal in all directions (omni-directionally). With transmit beamforming, the network node determines where a given target device (e.g., a UE) is located (relative to the transmitting network node) and projects a stronger downlink RF signal in that specific direction, thereby providing a faster (in terms of data rate) and stronger RF signal for the receiving device(s). To change the directionality of the RF signal when transmitting, a network node can control the phase and relative amplitude of the RF signal at each of the one or more transmitters that are broadcasting the RF signal. For example, a network node may use an array of antennas (referred to as a “phased array” or an “antenna array”) that creates a beam of RF waves that can be “steered” to point in different directions, without actually moving the antennas. Specifically, the RF current from the transmitter is fed to the individual antennas with the correct phase relationship so that the radio waves from the separate antennas add together to increase the radiation in a desired direction, while cancelling to suppress radiation in undesired directions.

[0038] Transmit beams may be quasi-co-located, meaning that they appear to the receiver (e.g., a UE) as having the same parameters, regardless of whether or not the transmitting antennas of the network node themselves are physically co-located. In NR, there are four types of quasi-co-location (QCL) relations. Specifically, a QCL relation of a given type means that certain parameters about a target reference RF signal on a target beam can be derived from information about a source reference RF signal on a source beam. If the source reference RF signal is QCL Type A, the receiver can use the source reference RF signal to estimate the Doppler shift, Doppler spread, average delay, and delay spread of a target reference RF signal transmitted on the same channel. If the source reference RF signal is QCL Type B, the receiver can use the source reference RF signal to estimate the Doppler shift and Doppler spread of a target reference RF signal transmitted on the same channel. If the source reference RF signal is QCL Type C, the receiver can use the source reference RF signal to estimate the Doppler shift and average delay of a target reference RF signal transmitted on the same channel. If the source reference RF signal is QCL

Type D, the receiver can use the source reference RF signal to estimate the spatial receive parameter of a target reference RF signal transmitted on the same channel.

- [0039] In receive beamforming, the receiver uses a receive beam to amplify RF signals detected on a given channel. For example, the receiver can increase the gain setting and/or adjust the phase setting of an array of antennas in a particular direction to amplify (e.g., to increase the gain level of) the RF signals received from that direction. Thus, when a receiver is said to beamform in a certain direction, it means the beam gain in that direction is high relative to the beam gain along other directions, or the beam gain in that direction is the highest compared to the beam gain in that direction of all other receive beams available to the receiver. This results in a stronger received signal strength (e.g., reference signal received power (RSRP), reference signal received quality (RSRQ), signal-to-interference-plus-noise ratio (SINR), etc.) of the RF signals received from that direction.
- [0040] Receive beams may be spatially related. A spatial relation means that parameters for a transmit beam for a second reference signal can be derived from information about a receive beam for a first reference signal. For example, a UE may use a particular receive beam to receive one or more reference downlink reference signals (e.g., positioning reference signals (PRS), tracking reference signals (TRS), phase tracking reference signal (PTRS), cell-specific reference signals (CRS), channel state information reference signals (CSI-RS), primary synchronization signals (PSS), secondary synchronization signals (SSS), synchronization signal blocks (SSBs), etc.) from a base station. The UE can then form a transmit beam for sending one or more uplink reference signals (e.g., uplink positioning reference signals (UL-PRS), sounding reference signal (SRS), demodulation reference signals (DMRS), PTRS, etc.) to that base station based on the parameters of the receive beam.
- [0041] Note that a “downlink” beam may be either a transmit beam or a receive beam, depending on the entity forming it. For example, if a base station is forming the downlink beam to transmit a reference signal to a UE, the downlink beam is a transmit beam. If the UE is forming the downlink beam, however, it is a receive beam to receive the downlink reference signal. Similarly, an “uplink” beam may be either a transmit beam or a receive beam, depending on the entity forming it. For example, if a base station is forming the uplink beam, it is an uplink receive beam, and if a UE is forming the uplink beam, it is an uplink transmit beam.

[0042] In 5G, the frequency spectrum in which wireless nodes (e.g., base stations 102/180, UEs 104/182) operate is divided into multiple frequency ranges, FR1 (from 450 to 6000 MHz), FR2 (from 24250 to 52600 MHz), FR3 (above 52600 MHz), and FR4 (between FR1 and FR2). In a multi-carrier system, such as 5G, one of the carrier frequencies is referred to as the “primary carrier” or “anchor carrier” or “primary serving cell” or “PCell,” and the remaining carrier frequencies are referred to as “secondary carriers” or “secondary serving cells” or “SCells.” In carrier aggregation, the anchor carrier is the carrier operating on the primary frequency (e.g., FR1) utilized by a UE 104/182 and the cell in which the UE 104/182 either performs the initial radio resource control (RRC) connection establishment procedure or initiates the RRC connection re-establishment procedure. The primary carrier carries all common and UE-specific control channels, and may be a carrier in a licensed frequency (however, this is not always the case). A secondary carrier is a carrier operating on a second frequency (e.g., FR2) that may be configured once the RRC connection is established between the UE 104 and the anchor carrier and that may be used to provide additional radio resources. In some cases, the secondary carrier may be a carrier in an unlicensed frequency. The secondary carrier may contain only necessary signaling information and signals, for example, those that are UE-specific may not be present in the secondary carrier, since both primary uplink and downlink carriers are typically UE-specific. This means that different UEs 104/182 in a cell may have different downlink primary carriers. The same is true for the uplink primary carriers. The network is able to change the primary carrier of any UE 104/182 at any time. This is done, for example, to balance the load on different carriers. Because a “serving cell” (whether a PCell or an SCell) corresponds to a carrier frequency / component carrier over which some base station is communicating, the term “cell,” “serving cell,” “component carrier,” “carrier frequency,” and the like can be used interchangeably.

[0043] For example, still referring to FIG. 1, one of the frequencies utilized by the macro cell base stations 102 may be an anchor carrier (or “PCell”) and other frequencies utilized by the macro cell base stations 102 and/or the mmW base station 180 may be secondary carriers (“SCells”). The simultaneous transmission and/or reception of multiple carriers enables the UE 104/182 to significantly increase its data transmission and/or reception rates. For example, two 20 MHz aggregated carriers in a multi-carrier system would theoretically lead to a two-fold increase in data rate (i.e., 40 MHz), compared to that attained by a single 20 MHz carrier.

- [0044] The wireless communications system 100 may further include a UE 164 that may communicate with a macro cell base station 102 over a communication link 120 and/or the mmW base station 180 over a mmW communication link 184. For example, the macro cell base station 102 may support a PCell and one or more SCells for the UE 164 and the mmW base station 180 may support one or more SCells for the UE 164.
- [0045] In the example of FIG. 1, one or more Earth orbiting satellite positioning system (SPS) space vehicles (SVs) 112 (e.g., satellites) may be used as an independent source of location information for any of the illustrated UEs (shown in FIG. 1 as a single UE 104 for simplicity). A UE 104 may include one or more dedicated SPS receivers specifically designed to receive SPS signals 124 for deriving geo location information from the SVs 112. An SPS typically includes a system of transmitters (e.g., SVs 112) positioned to enable receivers (e.g., UEs 104) to determine their location on or above the Earth based, at least in part, on signals (e.g., SPS signals 124) received from the transmitters. Such a transmitter typically transmits a signal marked with a repeating pseudo-random noise (PN) code of a set number of chips. While typically located in SVs 112, transmitters may sometimes be located on ground-based control stations, base stations 102, and/or other UEs 104.
- [0046] The use of SPS signals 124 can be augmented by various satellite-based augmentation systems (SBAS) that may be associated with or otherwise enabled for use with one or more global and/or regional navigation satellite systems. For example an SBAS may include an augmentation system(s) that provides integrity information, differential corrections, etc., such as the Wide Area Augmentation System (WAAS), the European Geostationary Navigation Overlay Service (EGNOS), the Multi-functional Satellite Augmentation System (MSAS), the Global Positioning System (GPS) Aided Geo Augmented Navigation or GPS and Geo Augmented Navigation system (GAGAN), and/or the like. Thus, as used herein, an SPS may include any combination of one or more global and/or regional navigation satellite systems and/or augmentation systems, and SPS signals 124 may include SPS, SPS-like, and/or other signals associated with such one or more SPS.
- [0047] The wireless communications system 100 may further include one or more UEs, such as UE 190, that connects indirectly to one or more communication networks via one or more device-to-device (D2D) peer-to-peer (P2P) links (referred to as “sidelinks”). In the example of FIG. 1, UE 190 has a D2D P2P link 192 with one of the UEs 104 connected

to one of the base stations 102 (e.g., through which UE 190 may indirectly obtain cellular connectivity) and a D2D P2P link 194 with WLAN STA 152 connected to the WLAN AP 150 (through which UE 190 may indirectly obtain WLAN-based Internet connectivity). In an example, the D2D P2P links 192 and 194 may be supported with any well-known D2D RAT, such as LTE Direct (LTE-D), WiFi Direct (WiFi-D), Bluetooth®, and so on.

[0048] **FIG. 2A** illustrates an example wireless network structure 200. For example, a 5GC 210 (also referred to as a Next Generation Core (NGC)) can be viewed functionally as control plane functions 214 (e.g., UE registration, authentication, network access, gateway selection, etc.) and user plane functions 212, (e.g., UE gateway function, access to data networks, IP routing, etc.) which operate cooperatively to form the core network. User plane interface (NG-U) 213 and control plane interface (NG-C) 215 connect the gNB 222 to the 5GC 210 and specifically to the control plane functions 214 and user plane functions 212. In an additional configuration, an ng-eNB 224 may also be connected to the 5GC 210 via NG-C 215 to the control plane functions 214 and NG-U 213 to user plane functions 212. Further, ng-eNB 224 may directly communicate with gNB 222 via a backhaul connection 223. In some configurations, the New RAN 220 may only have one or more gNBs 222, while other configurations include one or more of both ng-eNBs 224 and gNBs 222. Either gNB 222 or ng-eNB 224 may communicate with UEs 204 (e.g., any of the UEs depicted in FIG. 1). Another optional aspect may include location server 230, which may be in communication with the 5GC 210 to provide location assistance for UEs 204. The location server 230 can be implemented as a plurality of separate servers (e.g., physically separate servers, different software modules on a single server, different software modules spread across multiple physical servers, etc.), or alternately may each correspond to a single server. The location server 230 can be configured to support one or more location services for UEs 204 that can connect to the location server 230 via the core network, 5GC 210, and/or via the Internet (not illustrated). Further, the location server 230 may be integrated into a component of the core network, or alternatively may be external to the core network.

[0049] **FIG. 2B** illustrates another example wireless network structure 250. For example, a 5GC 260 can be viewed functionally as control plane functions, provided by an access and mobility management function (AMF) 264, and user plane functions, provided by a user plane function (UPF) 262, which operate cooperatively to form the core network (i.e.,

5GC 260). User plane interface 263 and control plane interface 265 connect the ng-eNB 224 to the 5GC 260 and specifically to UPF 262 and AMF 264, respectively. In an additional configuration, a gNB 222 may also be connected to the 5GC 260 via control plane interface 265 to AMF 264 and user plane interface 263 to UPF 262. Further, ng-eNB 224 may directly communicate with gNB 222 via the backhaul connection 223, with or without gNB direct connectivity to the 5GC 260. In some configurations, the New RAN 220 may only have one or more gNBs 222, while other configurations include one or more of both ng-eNBs 224 and gNBs 222. Either gNB 222 or ng-eNB 224 may communicate with UEs 204 (e.g., any of the UEs depicted in FIG. 1). The base stations of the New RAN 220 communicate with the AMF 264 over the N2 interface and with the UPF 262 over the N3 interface.

- [0050]** The functions of the AMF 264 include registration management, connection management, reachability management, mobility management, lawful interception, transport for session management (SM) messages between the UE 204 and a session management function (SMF) 266, transparent proxy services for routing SM messages, access authentication and access authorization, transport for short message service (SMS) messages between the UE 204 and the short message service function (SMSF) (not shown), and security anchor functionality (SEAF). The AMF 264 also interacts with an authentication server function (AUSF) (not shown) and the UE 204, and receives the intermediate key that was established as a result of the UE 204 authentication process. In the case of authentication based on a UMTS (universal mobile telecommunications system) subscriber identity module (USIM), the AMF 264 retrieves the security material from the AUSF. The functions of the AMF 264 also include security context management (SCM). The SCM receives a key from the SEAF that it uses to derive access-network specific keys. The functionality of the AMF 264 also includes location services management for regulatory services, transport for location services messages between the UE 204 and a location management function (LMF) 270 (which acts as a location server 230), transport for location services messages between the New RAN 220 and the LMF 270, evolved packet system (EPS) bearer identifier allocation for interworking with the EPS, and UE 204 mobility event notification. In addition, the AMF 264 also supports functionalities for non-3GPP (Third Generation Partnership Project) access networks.
- [0051]** Functions of the UPF 262 include acting as an anchor point for intra-/inter-RAT mobility (when applicable), acting as an external protocol data unit (PDU) session point of

interconnect to a data network (not shown), providing packet routing and forwarding, packet inspection, user plane policy rule enforcement (e.g., gating, redirection, traffic steering), lawful interception (user plane collection), traffic usage reporting, quality of service (QoS) handling for the user plane (e.g., uplink/ downlink rate enforcement, reflective QoS marking in the downlink), uplink traffic verification (service data flow (SDF) to QoS flow mapping), transport level packet marking in the uplink and downlink, downlink packet buffering and downlink data notification triggering, and sending and forwarding of one or more “end markers” to the source RAN node. The UPF 262 may also support transfer of location services messages over a user plane between the UE 204 and a location server, such as a secure user plane location (SUPL) location platform (SLP) 272.

- [0052] The functions of the SMF 266 include session management, UE Internet protocol (IP) address allocation and management, selection and control of user plane functions, configuration of traffic steering at the UPF 262 to route traffic to the proper destination, control of part of policy enforcement and QoS, and downlink data notification. The interface over which the SMF 266 communicates with the AMF 264 is referred to as the N11 interface.
- [0053] Another optional aspect may include an LMF 270, which may be in communication with the 5GC 260 to provide location assistance for UEs 204. The LMF 270 can be implemented as a plurality of separate servers (e.g., physically separate servers, different software modules on a single server, different software modules spread across multiple physical servers, etc.), or alternately may each correspond to a single server. The LMF 270 can be configured to support one or more location services for UEs 204 that can connect to the LMF 270 via the core network, 5GC 260, and/or via the Internet (not illustrated). The SLP 272 may support similar functions to the LMF 270, but whereas the LMF 270 may communicate with the AMF 264, New RAN 220, and UEs 204 over a control plane (e.g., using interfaces and protocols intended to convey signaling messages and not voice or data), the SLP 272 may communicate with UEs 204 and external clients (not shown in FIG. 2B) over a user plane (e.g., using protocols intended to carry voice and/or data like the transmission control protocol (TCP) and/or IP).
- [0054] **FIGS. 3A, 3B, and 3C** illustrate several example components (represented by corresponding blocks) that may be incorporated into a UE 302 (which may correspond to any of the UEs described herein), a base station 304 (which may correspond to any of the

base stations described herein), and a network entity 306 (which may correspond to or embody any of the network functions described herein, including the location server 230 and the LMF 270) to support the file transmission operations as taught herein. It will be appreciated that these components may be implemented in different types of apparatuses in different implementations (e.g., in an ASIC, in a system-on-chip (SoC), etc.). The illustrated components may also be incorporated into other apparatuses in a communication system. For example, other apparatuses in a system may include components similar to those described to provide similar functionality. Also, a given apparatus may contain one or more of the components. For example, an apparatus may include multiple transceiver components that enable the apparatus to operate on multiple carriers and/or communicate via different technologies.

[0055] The UE 302 and the base station 304 each include wireless wide area network (WWAN) transceiver 310 and 350, respectively, providing means for communicating (e.g., means for transmitting, means for receiving, means for measuring, means for tuning, means for refraining from transmitting, etc.) via one or more wireless communication networks (not shown), such as an NR network, an LTE network, a GSM network, and/or the like. The WWAN transceivers 310 and 350 may be connected to one or more antennas 316 and 356, respectively, for communicating with other network nodes, such as other UEs, access points, base stations (e.g., eNBs, gNBs), etc., via at least one designated RAT (e.g., NR, LTE, GSM, etc.) over a wireless communication medium of interest (e.g., some set of time/frequency resources in a particular frequency spectrum). The WWAN transceivers 310 and 350 may be variously configured for transmitting and encoding signals 318 and 358 (e.g., messages, indications, information, and so on), respectively, and, conversely, for receiving and decoding signals 318 and 358 (e.g., messages, indications, information, pilots, and so on), respectively, in accordance with the designated RAT. Specifically, the WWAN transceivers 310 and 350 include one or more transmitters 314 and 354, respectively, for transmitting and encoding signals 318 and 358, respectively, and one or more receivers 312 and 352, respectively, for receiving and decoding signals 318 and 358, respectively.

[0056] The UE 302 and the base station 304 also include, at least in some cases, wireless local area network (WLAN) transceivers 320 and 360, respectively. The WLAN transceivers 320 and 360 may be connected to one or more antennas 326 and 366, respectively, and provide means for communicating (e.g., means for transmitting, means for receiving,

means for measuring, means for tuning, means for refraining from transmitting, etc.) with other network nodes, such as other UEs, access points, base stations, etc., via at least one designated RAT (e.g., WiFi, LTE-D, Bluetooth®, etc.) over a wireless communication medium of interest. The WLAN transceivers 320 and 360 may be variously configured for transmitting and encoding signals 328 and 368 (e.g., messages, indications, information, and so on), respectively, and, conversely, for receiving and decoding signals 328 and 368 (e.g., messages, indications, information, pilots, and so on), respectively, in accordance with the designated RAT. Specifically, the WLAN transceivers 320 and 360 include one or more transmitters 324 and 364, respectively, for transmitting and encoding signals 328 and 368, respectively, and one or more receivers 322 and 362, respectively, for receiving and decoding signals 328 and 368, respectively.

[0057] Transceiver circuitry including at least one transmitter and at least one receiver may comprise an integrated device (e.g., embodied as a transmitter circuit and a receiver circuit of a single communication device) in some implementations, may comprise a separate transmitter device and a separate receiver device in some implementations, or may be embodied in other ways in other implementations. In an aspect, a transmitter may include or be coupled to a plurality of antennas (e.g., antennas 316, 326, 356, 366), such as an antenna array, that permits the respective apparatus to perform transmit “beamforming,” as described herein. Similarly, a receiver may include or be coupled to a plurality of antennas (e.g., antennas 316, 326, 356, 366), such as an antenna array, that permits the respective apparatus to perform receive beamforming, as described herein. In an aspect, the transmitter and receiver may share the same plurality of antennas (e.g., antennas 316, 326, 356, 366), such that the respective apparatus can only receive or transmit at a given time, not both at the same time. A wireless communication device (e.g., one or both of the transceivers 310 and 320 and/or 350 and 360) of the UE 302 and/or the base station 304 may also comprise a network listen module (NLM) or the like for performing various measurements.

[0058] The UE 302 and the base station 304 also include, at least in some cases, satellite positioning systems (SPS) receivers 330 and 370. The SPS receivers 330 and 370 may be connected to one or more antennas 336 and 376, respectively, and may provide means for receiving and/or measuring SPS signals 338 and 378, respectively, such as global positioning system (GPS) signals, global navigation satellite system (GLONASS) signals, Galileo signals, Beidou signals, Indian Regional Navigation Satellite System (NAVIC),

Quasi-Zenith Satellite System (QZSS), etc. The SPS receivers 330 and 370 may comprise any suitable hardware and/or software for receiving and processing SPS signals 338 and 378, respectively. The SPS receivers 330 and 370 request information and operations as appropriate from the other systems, and performs calculations necessary to determine positions of the UE 302 and the base station 304 using measurements obtained by any suitable SPS algorithm.

**[0059]** The base station 304 and the network entity 306 each include at least one network interfaces 380 and 390, respectively, providing means for communicating (e.g., means for transmitting, means for receiving, etc.) with other network entities. For example, the network interfaces 380 and 390 (e.g., one or more network access ports) may be configured to communicate with one or more network entities via a wire-based or wireless backhaul connection. In some aspects, the network interfaces 380 and 390 may be implemented as transceivers configured to support wire-based or wireless signal communication. This communication may involve, for example, sending and receiving messages, parameters, and/or other types of information.

**[0060]** The UE 302, the base station 304, and the network entity 306 also include other components that may be used in conjunction with the operations as disclosed herein. The UE 302 includes processor circuitry implementing a processing system 332 for providing functionality relating to, for example, wireless positioning, and for providing other processing functionality. The base station 304 includes a processing system 384 for providing functionality relating to, for example, wireless positioning as disclosed herein, and for providing other processing functionality. The network entity 306 includes a processing system 394 for providing functionality relating to, for example, wireless positioning as disclosed herein, and for providing other processing functionality. The processing systems 332, 384, and 394 may therefore provide means for processing, such as means for determining, means for calculating, means for receiving, means for transmitting, means for indicating, etc. In an aspect, the processing systems 332, 384, and 394 may include, for example, one or more general purpose processors, multi-core processors, ASICs, digital signal processors (DSPs), field programmable gate arrays (FPGA), or other programmable logic devices or processing circuitry.

**[0061]** The UE 302, the base station 304, and the network entity 306 include memory circuitry implementing memory components 340, 386, and 396 (e.g., each including a memory device), respectively, for maintaining information (e.g., information indicative of

reserved resources, thresholds, parameters, and so on). The memory components 340, 386, and 396 may therefore provide means for storing, means for retrieving, means for maintaining, etc. In some cases, the UE 302, the base station 304, and the network entity 306 may include positioning components 342, 388, and 398, respectively. The positioning components 342, 388, and 398 may be hardware circuits that are part of or coupled to the processing systems 332, 384, and 394, respectively, that, when executed, cause the UE 302, the base station 304, and the network entity 306 to perform the functionality described herein. In other aspects, the positioning components 342, 388, and 398 may be external to the processing systems 332, 384, and 394 (e.g., part of a modem processing system, integrated with another processing system, etc.). Alternatively, the positioning components 342, 388, and 398 may be memory modules stored in the memory components 340, 386, and 396, respectively, that, when executed by the processing systems 332, 384, and 394 (or a modem processing system, another processing system, etc.), cause the UE 302, the base station 304, and the network entity 306 to perform the functionality described herein. FIG. 3A illustrates possible locations of the positioning component 342, which may be part of the WWAN transceiver 310, the memory component 340, the processing system 332, or any combination thereof, or may be a standalone component. FIG. 3B illustrates possible locations of the positioning component 388, which may be part of the WWAN transceiver 350, the memory component 386, the processing system 384, or any combination thereof, or may be a standalone component. FIG. 3C illustrates possible locations of the positioning component 398, which may be part of the network interface(s) 390, the memory component 396, the processing system 394, or any combination thereof, or may be a standalone component.

[0062] The UE 302 may include one or more sensors 344 coupled to the processing system 332 to provide means for sensing or detecting movement and/or orientation information that is independent of motion data derived from signals received by the WWAN transceiver 310, the WLAN transceiver 320, and/or the SPS receiver 330. By way of example, the sensor(s) 344 may include an accelerometer (e.g., a micro-electrical mechanical systems (MEMS) device), a gyroscope, a geomagnetic sensor (e.g., a compass), an altimeter (e.g., a barometric pressure altimeter), and/or any other type of movement detection sensor. Moreover, the sensor(s) 344 may include a plurality of different types of devices and combine their outputs in order to provide motion information. For example, the sensor(s)

344 may use a combination of a multi-axis accelerometer and orientation sensors to provide the ability to compute positions in 2D and/or 3D coordinate systems.

- [0063] In addition, the UE 302 includes a user interface 346 providing means for providing indications (e.g., audible and/or visual indications) to a user and/or for receiving user input (e.g., upon user actuation of a sensing device such a keypad, a touch screen, a microphone, and so on). Although not shown, the base station 304 and the network entity 306 may also include user interfaces.
- [0064] Referring to the processing system 384 in more detail, in the downlink, IP packets from the network entity 306 may be provided to the processing system 384. The processing system 384 may implement functionality for an RRC layer, a packet data convergence protocol (PDCP) layer, a radio link control (RLC) layer, and a medium access control (MAC) layer. The processing system 384 may provide RRC layer functionality associated with broadcasting of system information (e.g., master information block (MIB), system information blocks (SIBs)), RRC connection control (e.g., RRC connection paging, RRC connection establishment, RRC connection modification, and RRC connection release), inter-RAT mobility, and measurement configuration for UE measurement reporting; PDCP layer functionality associated with header compression/decompression, security (ciphering, deciphering, integrity protection, integrity verification), and handover support functions; RLC layer functionality associated with the transfer of upper layer PDUs, error correction through automatic repeat request (ARQ), concatenation, segmentation, and reassembly of RLC service data units (SDUs), re-segmentation of RLC data PDUs, and reordering of RLC data PDUs; and MAC layer functionality associated with mapping between logical channels and transport channels, scheduling information reporting, error correction, priority handling, and logical channel prioritization.
- [0065] The transmitter 354 and the receiver 352 may implement Layer-1 (L1) functionality associated with various signal processing functions. Layer-1, which includes a physical (PHY) layer, may include error detection on the transport channels, forward error correction (FEC) coding/decoding of the transport channels, interleaving, rate matching, mapping onto physical channels, modulation/demodulation of physical channels, and MIMO antenna processing. The transmitter 354 handles mapping to signal constellations based on various modulation schemes (e.g., binary phase-shift keying (BPSK), quadrature phase-shift keying (QPSK), M-phase-shift keying (M-PSK), M-quadrature amplitude modulation (M-QAM)). The coded and modulated symbols may then be split into parallel

streams. Each stream may then be mapped to an orthogonal frequency division multiplexing (OFDM) subcarrier, multiplexed with a reference signal (e.g., pilot) in the time and/or frequency domain, and then combined together using an inverse fast Fourier transform (IFFT) to produce a physical channel carrying a time domain OFDM symbol stream. The OFDM symbol stream is spatially precoded to produce multiple spatial streams. Channel estimates from a channel estimator may be used to determine the coding and modulation scheme, as well as for spatial processing. The channel estimate may be derived from a reference signal and/or channel condition feedback transmitted by the UE 302. Each spatial stream may then be provided to one or more different antennas 356. The transmitter 354 may modulate an RF carrier with a respective spatial stream for transmission.

- [0066] At the UE 302, the receiver 312 receives a signal through its respective antenna(s) 316. The receiver 312 recovers information modulated onto an RF carrier and provides the information to the processing system 332. The transmitter 314 and the receiver 312 implement Layer-1 functionality associated with various signal processing functions. The receiver 312 may perform spatial processing on the information to recover any spatial streams destined for the UE 302. If multiple spatial streams are destined for the UE 302, they may be combined by the receiver 312 into a single OFDM symbol stream. The receiver 312 then converts the OFDM symbol stream from the time-domain to the frequency domain using a fast Fourier transform (FFT). The frequency domain signal comprises a separate OFDM symbol stream for each subcarrier of the OFDM signal. The symbols on each subcarrier, and the reference signal, are recovered and demodulated by determining the most likely signal constellation points transmitted by the base station 304. These soft decisions may be based on channel estimates computed by a channel estimator. The soft decisions are then decoded and de-interleaved to recover the data and control signals that were originally transmitted by the base station 304 on the physical channel. The data and control signals are then provided to the processing system 332, which implements Layer-3 (L3) and Layer-2 (L2) functionality.
- [0067] In the uplink, the processing system 332 provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, and control signal processing to recover IP packets from the core network. The processing system 332 is also responsible for error detection.

- [0068] Similar to the functionality described in connection with the downlink transmission by the base station 304, the processing system 332 provides RRC layer functionality associated with system information (e.g., MIB, SIBs) acquisition, RRC connections, and measurement reporting; PDCP layer functionality associated with header compression/decompression, and security (ciphering, deciphering, integrity protection, integrity verification); RLC layer functionality associated with the transfer of upper layer PDUs, error correction through ARQ, concatenation, segmentation, and reassembly of RLC SDUs, re-segmentation of RLC data PDUs, and reordering of RLC data PDUs; and MAC layer functionality associated with mapping between logical channels and transport channels, multiplexing of MAC SDUs onto transport blocks (TBs), demultiplexing of MAC SDUs from TBs, scheduling information reporting, error correction through hybrid automatic repeat request (HARQ), priority handling, and logical channel prioritization.
- [0069] Channel estimates derived by the channel estimator from a reference signal or feedback transmitted by the base station 304 may be used by the transmitter 314 to select the appropriate coding and modulation schemes, and to facilitate spatial processing. The spatial streams generated by the transmitter 314 may be provided to different antenna(s) 316. The transmitter 314 may modulate an RF carrier with a respective spatial stream for transmission.
- [0070] The uplink transmission is processed at the base station 304 in a manner similar to that described in connection with the receiver function at the UE 302. The receiver 352 receives a signal through its respective antenna(s) 356. The receiver 352 recovers information modulated onto an RF carrier and provides the information to the processing system 384.
- [0071] In the uplink, the processing system 384 provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, control signal processing to recover IP packets from the UE 302. IP packets from the processing system 384 may be provided to the core network. The processing system 384 is also responsible for error detection.
- [0072] For convenience, the UE 302, the base station 304, and/or the network entity 306 are shown in FIGS. 3A-C as including various components that may be configured according to the various examples described herein. It will be appreciated, however, that the illustrated blocks may have different functionality in different designs.

- [0073] The various components of the UE 302, the base station 304, and the network entity 306 may communicate with each other over data buses 334, 382, and 392, respectively. The components of FIGS. 3A-C may be implemented in various ways. In some implementations, the components of FIGS. 3A-C may be implemented in one or more circuits such as, for example, one or more processors and/or one or more ASICs (which may include one or more processors). Here, each circuit may use and/or incorporate at least one memory component for storing information or executable code used by the circuit to provide this functionality. For example, some or all of the functionality represented by blocks 310 to 346 may be implemented by processor and memory component(s) of the UE 302 (e.g., by execution of appropriate code and/or by appropriate configuration of processor components). Similarly, some or all of the functionality represented by blocks 350 to 388 may be implemented by processor and memory component(s) of the base station 304 (e.g., by execution of appropriate code and/or by appropriate configuration of processor components). Also, some or all of the functionality represented by blocks 390 to 398 may be implemented by processor and memory component(s) of the network entity 306 (e.g., by execution of appropriate code and/or by appropriate configuration of processor components). For simplicity, various operations, acts, and/or functions are described herein as being performed “by a UE,” “by a base station,” “by a network entity,” etc. However, as will be appreciated, such operations, acts, and/or functions may actually be performed by specific components or combinations of components of the UE 302, base station 304, network entity 306, etc., such as the processing systems 332, 384, 394, the transceivers 310, 320, 350, and 360, the memory components 340, 386, and 396, the positioning components 342, 388, and 398, etc.
- [0074] **FIG. 4A** illustrates a user plane protocol stack, according to aspects of the disclosure. As illustrated in FIG. 4A, a UE 404 and a base station 402 (which may correspond to any of the UEs and base stations, respectively, described herein) implement, from highest layer to lowest, a service data adaptation protocol (SDAP) layer 410, a packet data convergence protocol (PDCP) layer 415, a radio link control (RLC) layer 420, a medium access control (MAC) layer 425, and a physical (PHY) layer 430. Particular instances of a protocol layer are referred to as protocol “entities.” As such, the terms “protocol layer” and “protocol entity” may be used interchangeably.
- [0075] As illustrated by the double-arrow lines in FIG. 4A, each layer of the protocol stack implemented by the UE 404 communicates with the same layer of the base station 402,

and vice versa. The two corresponding protocol layers/entities of the UE 404 and the base station 402 are referred to as “peers,” “peer entities,” and the like. Collectively, the SDAP layer 410, the PDCP layer 415, the RLC layer 420, and the MAC layer 425 are referred to as “Layer 2” or “L2.” The PHY layer 430 is referred to as “Layer 1” or “L1.”

[0076] **FIG. 4B** illustrates a control plane protocol stack, according to aspects of the disclosure. In addition to the PDCP layer 415, the RLC layer 420, the MAC layer 425, and the PHY layer 430, the UE 404 and the base station 402 also implement a radio resource control (RRC) layer 445. Further, the UE 404 and an AMF 406 implement a non-access stratum (NAS) layer 440.

[0077] The RLC layer 420 supports three transmission modes for packets: transparent mode (TM), unacknowledged mode (UM), and acknowledged mode (AM). In TM mode, there is no RLC header, no segmentation/reassembly, and no feedback (i.e., no acknowledgment (ACK) or negative acknowledgment (NACK)). In addition, there is buffering at the transmitter only. In UM mode, there is an RLC header, buffering at both the transmitter and the receiver, and segmentation/reassembly, but no feedback (i.e., a data transmission does not require any reception response (e.g., ACK/NACK) from the receiver). In AM mode, there is an RLC header, buffering at both the transmitter and the receiver, segmentation/reassembly, and feedback (i.e., a data transmission requires a reception response (e.g., ACK/NACK) from the receiver). Each of these modes can be used to both transmit and receive data. In TM and UM modes, a separate RLC entity is used for transmission and reception, whereas in AM mode, a single RLC entity performs both transmission and reception. Note that each logical channel uses a specific RLC mode. That is, the RLC configuration is per logical channel with no dependency on numerologies and/or transmission time interval (TTI) duration (i.e., the duration of a transmission on the radio link). Specifically, the broadcast control channel (BCCH), paging control channel (PCCH), and common control channel (CCCH) use TM mode only, the dedicated control channel (DCCH) uses AM mode only, and the dedicated traffic channel (DTCH) uses UM or AM mode. Whether the DTCH uses UM or AM is determined by RRC messaging.

[0078] The main services and functions of the RLC layer 420 depend on the transmission mode and include transfer of upper layer protocol data units (PDUs), sequence numbering independent of the one in the PDCP layer 415, error correction through automatic repeat request (ARQ), segmentation and re-segmentation, reassembly of service data units

(SDUs), RLC SDU discard, and RLC re-establishment. The ARQ functionality provides error correction in AM mode, and has the following characteristics: ARQ retransmissions of RLC PDUs or RLC PDU segments based on RLC status reports, polling for an RLC status report when needed by RLC, and RLC receiver triggering of an RLC status report after detection of a missing RLC PDU or RLC PDU segment.

- [0079] The main services and functions of the PDCP layer 415 for the user plane include sequence numbering, header compression and decompression (for robust header compression (ROHC)), transfer of user data, reordering and duplicate detection (if in-order delivery to layers above the PDCP layer 415 is required), PDCP PDU routing (in case of split bearers), retransmission of PDCP SDUs, ciphering and deciphering, PDCP SDU discard, PDCP re-establishment and data recovery for RLC AM, and duplication of PDCP PDUs. The main services and functions of the PDCP layer 415 for the control plane include ciphering, deciphering, and integrity protection, transfer of control plane data, and duplication of PDCP PDUs.
- [0080] The SDAP layer 410 is an access stratum (AS) layer, the main services and functions of which include mapping between a quality of service (QoS) flow and a data radio bearer and marking QoS flow identifier in both downlink and uplink packets. A single protocol entity of SDAP is configured for each individual PDU session.
- [0081] The main services and functions of the RRC layer 445 include broadcast of system information related to AS and NAS, paging initiated by the 5GC (e.g., NGC 210 or 260) or RAN (e.g., New RAN 220), establishment, maintenance, and release of an RRC connection between the UE and RAN, security functions including key management, establishment, configuration, maintenance, and release of signaling radio bearers (SRBs) and data radio bearers (DRBs), mobility functions (including handover, UE cell selection and reselection and control of cell selection and reselection, context transfer at handover), QoS management functions, UE measurement reporting and control of the reporting, and NAS message transfer to/from the NAS from/to the UE.
- [0082] The NAS layer 440 is the highest stratum of the control plane between the UE 404 and the AMF 406 at the radio interface. The main functions of the protocols that are part of the NAS layer 440 are the support of mobility of the UE 404 and the support of session management procedures to establish and maintain Internet protocol (IP) connectivity between the UE 404 and the packet data network (PDN). The NAS layer 440 performs evolved packet system (EPS) bearer management, authentication, EPS connection

management (ECM)-IDLE mobility handling, paging origination in ECM-IDLE, and security control.

[0083] Various frame structures may be used to support downlink and uplink transmissions between network nodes (e.g., base stations and UEs). **FIG. 5A** is a diagram 500 illustrating an example of a downlink frame structure, according to aspects of the disclosure. **FIG. 5B** is a diagram 530 illustrating an example of channels within the downlink frame structure, according to aspects of the disclosure. **FIG. 5C** is a diagram 550 illustrating an example of an uplink frame structure, according to aspects of the disclosure. **FIG. 5D** is a diagram 570 illustrating an example of channels within an uplink frame structure, according to aspects of the disclosure. Other wireless communications technologies may have different frame structures and/or different channels.

[0084] LTE, and in some cases NR, utilizes OFDM on the downlink and single-carrier frequency division multiplexing (SC-FDM) on the uplink. Unlike LTE, however, NR has an option to use OFDM on the uplink as well. 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 kilohertz (kHz) and the minimum resource allocation (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.

[0085] LTE supports a single numerology (subcarrier spacing (SCS), symbol length, etc.). In contrast, NR may support multiple numerologies ( $\mu$ ), for example, subcarrier spacings of 15 kHz ( $\mu=0$ ), 30 kHz ( $\mu=1$ ), 60 kHz ( $\mu=2$ ), 120 kHz ( $\mu=3$ ), and 240 kHz ( $\mu=4$ ) or greater may be available. In each subcarrier spacing, there are 14 symbols per slot. For 15 kHz SCS ( $\mu=0$ ), there is one slot per subframe, 10 slots per frame, the slot duration is 1 millisecond (ms), the symbol duration is 66.7 microseconds ( $\mu$ s), and the maximum nominal system bandwidth (in MHz) with a 4K FFT size is 50. For 30 kHz SCS ( $\mu=1$ ),

there are two slots per subframe, 20 slots per frame, the slot duration is 0.5 ms, the symbol duration is 33.3  $\mu$ s, and the maximum nominal system bandwidth (in MHz) with a 4K FFT size is 100. For 60 kHz SCS ( $\mu=2$ ), there are four slots per subframe, 40 slots per frame, the slot duration is 0.25 ms, the symbol duration is 16.7  $\mu$ s, and the maximum nominal system bandwidth (in MHz) with a 4K FFT size is 200. For 120 kHz SCS ( $\mu=3$ ), there are eight slots per subframe, 80 slots per frame, the slot duration is 0.125 ms, the symbol duration is 8.33  $\mu$ s, and the maximum nominal system bandwidth (in MHz) with a 4K FFT size is 400. For 240 kHz SCS ( $\mu=4$ ), there are 16 slots per subframe, 160 slots per frame, the slot duration is 0.0625 ms, the symbol duration is 4.17  $\mu$ s, and the maximum nominal system bandwidth (in MHz) with a 4K FFT size is 800.

- [0086] In the example of FIGS. 5A to 5D, a numerology of 15 kHz is used. Thus, in the time domain, a 10 ms frame is divided into 10 equally sized subframes of 1 ms each, and each subframe includes one time slot. In FIGS. 5A to 5D, time is represented horizontally (on the X axis) with time increasing from left to right, while frequency is represented vertically (on the Y axis) with frequency increasing (or decreasing) from bottom to top.
- [0087] A resource grid may be used to represent time slots, each time slot including one or more time-concurrent resource blocks (RBs) (also referred to as physical RBs (PRBs)) in the frequency domain. The resource grid is further divided into multiple resource elements (REs). An RE may correspond to one symbol length in the time domain and one subcarrier in the frequency domain. In the numerology of FIGS. 5A to 5D, for a normal cyclic prefix, an RB may contain 12 consecutive subcarriers in the frequency domain and seven consecutive symbols in the time domain, for a total of 84 REs. For an extended cyclic prefix, an RB may contain 12 consecutive subcarriers in the frequency domain and six consecutive symbols in the time domain, for a total of 72 REs. The number of bits carried by each RE depends on the modulation scheme.
- [0088] Some of the REs carry downlink reference (pilot) signals (DL-RS). The DL-RS may include PRS, TRS, PTRS, CRS, CSI-RS, DMRS, PSS, SSS, SSB, etc. FIG. 5A illustrates example locations of REs carrying PRS (labeled "R").
- [0089] A collection of resource elements (REs) that are used for transmission of PRS is referred to as a "PRS resource." The collection of resource elements can span multiple PRBs in the frequency domain and 'N' (such as 1 or more) consecutive symbol(s) within a slot in the time domain. In a given OFDM symbol in the time domain, a PRS resource occupies consecutive PRBs in the frequency domain.

- [0090] The transmission of a PRS resource within a given PRB has a particular comb size (also referred to as the “comb density”). A comb size ‘N’ represents the subcarrier spacing (or frequency/tone spacing) within each symbol of a PRS resource configuration. Specifically, for a comb size ‘N,’ PRS are transmitted in every Nth subcarrier of a symbol of a PRB. For example, for comb-4, for each symbol of the PRS resource configuration, REs corresponding to every fourth subcarrier (such as subcarriers 0, 4, 8) are used to transmit PRS of the PRS resource. Currently, comb sizes of comb-2, comb-4, comb-6, and comb-12 are supported for DL-PRS. FIG. 5A illustrates an example PRS resource configuration for comb-6 (which spans six symbols). That is, the locations of the shaded REs (labeled “R”) indicate a comb-6 PRS resource configuration.
- [0091] Currently, a DL-PRS resource may span 2, 4, 6, or 12 consecutive symbols within a slot with a fully frequency-domain staggered pattern. A DL-PRS resource can be configured in any higher layer configured downlink or flexible (FL) symbol of a slot. There may be a constant energy per resource element (EPRE) for all REs of a given DL-PRS resource. The following are the frequency offsets from symbol to symbol for comb sizes 2, 4, 6, and 12 over 2, 4, 6, and 12 symbols. 2-symbol comb-2: {0, 1}; 4-symbol comb-2: {0, 1, 0, 1}; 6-symbol comb-2: {0, 1, 0, 1, 0, 1}; 12-symbol comb-2: {0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1}; 4-symbol comb-4: {0, 2, 1, 3}; 12-symbol comb-4: {0, 2, 1, 3, 0, 2, 1, 3, 0, 2, 1, 3}; 6-symbol comb-6: {0, 3, 1, 4, 2, 5}; 12-symbol comb-6: {0, 3, 1, 4, 2, 5, 0, 3, 1, 4, 2, 5}; and 12-symbol comb-12: {0, 6, 3, 9, 1, 7, 4, 10, 2, 8, 5, 11}.
- [0092] A “PRS resource set” is a set of PRS resources used for the transmission of PRS signals, where each PRS resource has a PRS resource ID. In addition, the PRS resources in a PRS resource set are associated with the same TRP. A PRS resource set is identified by a PRS resource set ID and is associated with a particular TRP (identified by a TRP ID). In addition, the PRS resources in a PRS resource set have the same periodicity, a common muting pattern configuration, and the same repetition factor (such as “PRS-ResourceRepetitionFactor”) across slots. The periodicity is the time from the first repetition of the first PRS resource of a first PRS instance to the same first repetition of the same first PRS resource of the next PRS instance. The periodicity may have a length selected from  $2^{\mu} \cdot \{4, 5, 8, 10, 16, 20, 32, 40, 64, 80, 160, 320, 640, 1280, 2560, 5120, 10240\}$  slots, with  $\mu = 0, 1, 2, 3$ . The repetition factor may have a length selected from  $\{1, 2, 4, 6, 8, 16, 32\}$  slots.

- [0093] A PRS resource ID in a PRS resource set is associated with a single beam (or beam ID) transmitted from a single TRP (where a TRP may transmit one or more beams). That is, each PRS resource of a PRS resource set may be transmitted on a different beam, and as such, a “PRS resource,” or simply “resource,” also can be referred to as a “beam.” Note that this does not have any implications on whether the TRPs and the beams on which PRS are transmitted are known to the UE.
- [0094] A “PRS instance” or “PRS occasion” is one instance of a periodically repeated time window (such as a group of one or more consecutive slots) where PRS are expected to be transmitted. A PRS occasion also may be referred to as a “PRS positioning occasion,” a “PRS positioning instance, a “positioning occasion,” “a positioning instance,” a “positioning repetition,” or simply an “occasion,” an “instance,” or a “repetition.”
- [0095] A “positioning frequency layer” (also referred to simply as a “frequency layer”) is a collection of one or more PRS resource sets across one or more TRPs that have the same values for certain parameters. Specifically, the collection of PRS resource sets has the same subcarrier spacing and cyclic prefix (CP) type (meaning all numerologies supported for the PDSCH are also supported for PRS), the same Point A, the same value of the downlink PRS bandwidth, the same start PRB (and center frequency), and the same comb-size. The Point A parameter takes the value of the parameter “ARFCN-ValueNR” (where “ARFCN” stands for “absolute radio-frequency channel number”) and is an identifier/code that specifies a pair of physical radio channel used for transmission and reception. The downlink PRS bandwidth may have a granularity of four PRBs, with a minimum of 24 PRBs and a maximum of 272 PRBs. Currently, up to four frequency layers have been defined, and up to two PRS resource sets may be configured per TRP per frequency layer.
- [0096] The concept of a frequency layer is somewhat like the concept of component carriers and bandwidth parts (BWPs), but different in that component carriers and BWPs are used by one base station (or a macro cell base station and a small cell base station) to transmit data channels, while frequency layers are used by several (usually three or more) base stations to transmit PRS. A UE may indicate the number of frequency layers it can support when it sends the network its positioning capabilities, such as during an LTE positioning protocol (LPP) session. For example, a UE may indicate whether it can support one or four positioning frequency layers.

- [0097] FIG. 5B illustrates an example of various channels within a downlink slot of a radio frame. In NR, the channel bandwidth, or system bandwidth, is divided into multiple BWPs. A BWP is a contiguous set of PRBs selected from a contiguous subset of the common RBs for a given numerology on a given carrier. Generally, a maximum of four BWPs can be specified in the downlink and uplink. That is, a UE can be configured with up to four BWPs on the downlink, and up to four BWPs on the uplink. Only one BWP (uplink or downlink) may be active at a given time, meaning the UE may only receive or transmit over one BWP at a time. On the downlink, the bandwidth of each BWP should be equal to or greater than the bandwidth of the SSB, but it may or may not contain the SSB.
- [0098] Referring to FIG. 5B, a primary synchronization signal (PSS) is used by a UE to determine subframe/symbol timing and a physical layer identity. A secondary synchronization signal (SSS) is used by a UE to determine a physical layer cell identity group number and radio frame timing. Based on the physical layer identity and the physical layer cell identity group number, the UE can determine a PCI. Based on the PCI, the UE can determine the locations of the aforementioned DL-RS. The physical broadcast channel (PBCH), which carries an MIB, may be logically grouped with the PSS and SSS to form an SSB (also referred to as an SS/PBCH). The MIB provides a number of RBs in the downlink system bandwidth and a system frame number (SFN). The physical downlink shared channel (PDSCH) carries user data, broadcast system information not transmitted through the PBCH, such as system information blocks (SIBs), and paging messages.
- [0099] The physical downlink control channel (PDCCH) carries downlink control information (DCI) within one or more control channel elements (CCEs), each CCE including one or more RE group (REG) bundles (which may span multiple symbols in the time domain), each REG bundle including one or more REGs, each REG corresponding to 12 resource elements (one resource block) in the frequency domain and one OFDM symbol in the time domain. The set of physical resources used to carry the PDCCH/DCI is referred to in NR as the control resource set (CORESET). In NR, a PDCCH is confined to a single CORESET and is transmitted with its own DMRS. This enables UE-specific beamforming for the PDCCH.
- [0100] In the example of FIG. 5B, there is one CORESET per BWP, and the CORESET spans three symbols (although it may be only one or two symbols) in the time domain. Unlike

LTE control channels, which occupy the entire system bandwidth, in NR, PDCCH channels are localized to a specific region in the frequency domain (i.e., a CORESET). Thus, the frequency component of the PDCCH shown in FIG. 5B is illustrated as less than a single BWP in the frequency domain. Note that although the illustrated CORESET is contiguous in the frequency domain, it need not be. In addition, the CORESET may span less than three symbols in the time domain.

- [0101] The DCI within the PDCCH carries information about uplink resource allocation (persistent and non-persistent) and descriptions about downlink data transmitted to the UE, referred to as uplink and downlink grants, respectively. More specifically, the DCI indicates the resources scheduled for the downlink data channel (e.g., PDSCH) and the uplink data channel (e.g., PUSCH). Multiple (e.g., up to eight) DCIs can be configured in the PDCCH, and these DCIs can have one of multiple formats. For example, there are different DCI formats for uplink scheduling, for downlink scheduling, for uplink transmit power control (TPC), etc. A PDCCH may be transported by 1, 2, 4, 8, or 16 CCEs in order to accommodate different DCI payload sizes or coding rates.
- [0102] The following are the currently supported DCI formats. Format 0-0: fallback for scheduling of PUSCH; Format 0-1: non-fallback for scheduling of PUSCH; Format 1-0: fallback for scheduling of PDSCH; Format 1-1: non-fallback for scheduling of PDSCH; Format 2-0: notifying a group of UEs of the slot format; Format 2-1: notifying a group of UEs of the PRB(s) and OFDM symbol(s) where the UEs may assume no transmissions are intended for the UEs; Format 2-2: transmission of TPC commands for PUCCH and PUSCH; and Format 2-3: transmission of a group of SRS requests and TPC commands for SRS transmissions. Note that a fallback format is a default scheduling option that has non-configurable fields and supports basic NR operations. In contrast, a non-fallback format is flexible to accommodate NR features.
- [0103] As will be appreciated, a UE needs to be able to demodulate (also referred to as “decode”) the PDCCH in order to read the DCI, and thereby to obtain the scheduling of resources allocated to the UE on the PDSCH and PUSCH. If the UE fails to demodulate the PDCCH, then the UE will not know the locations of the PDSCH resources and it will keep attempting to demodulate the PDCCH using a different set of PDCCH candidates in subsequent PDCCH monitoring occasions. If the UE fails to demodulate the PDCCH after some number of attempts, the UE declares a radio link failure (RLF). To overcome

PDCCH demodulation issues, search spaces are configured for efficient PDCCH detection and demodulation.

- [0104] Generally, a UE does not attempt to demodulate each and every PDCCH candidate that may be scheduled in a slot. To reduce restrictions on the PDCCH scheduler, and at the same time to reduce the number of blind demodulation attempts by the UE, search spaces are configured. Search spaces are indicated by a set of contiguous CCEs that the UE is supposed to monitor for scheduling assignments/grants relating to a certain component carrier. There are two types of search spaces used for the PDCCH to control each component carrier, a common search space (CSS) and a UE-specific search space (USS).
- [0105] A common search space is shared across all UEs, and a UE-specific search space is used per UE (i.e., a UE-specific search space is specific to a specific UE). For a common search space, a DCI cyclic redundancy check (CRC) is scrambled with a system information radio network temporary identifier (SI-RNTI), random access RNTI (RA-RNTI), temporary cell RNTI (TC-RNTI), paging RNTI (P-RNTI), interruption RNTI (INT-RNTI), slot format indication RNTI (SFI-RNTI), TPC-PUCCH-RNTI, TPC-PUSCH-RNTI, TPC-SRS-RNTI, cell RNTI (C-RNTI), or configured scheduling RNTI (CS-RNTI) for all common procedures. For a UE-specific search space, a DCI CRC is scrambled with a C-RNTI or CS-RNTI, as these are specifically targeted to individual UE.
- [0106] A UE demodulates the PDCCH using the four UE-specific search space aggregation levels (1, 2, 4, and 8) and the two common search space aggregation levels (4 and 8). Specifically, for the UE-specific search spaces, aggregation level '1' has six PDCCH candidates per slot and a size of six CCEs. Aggregation level '2' has six PDCCH candidates per slot and a size of 12 CCEs. Aggregation level '4' has two PDCCH candidates per slot and a size of eight CCEs. Aggregation level '8' has two PDCCH candidates per slot and a size of 16 CCEs. For the common search spaces, aggregation level '4' has four PDCCH candidates per slot and a size of 16 CCEs. Aggregation level '8' has two PDCCH candidates per slot and a size of 16 CCEs.
- [0107] Each search space comprises a group of consecutive CCEs that could be allocated to a PDCCH, referred to as a PDCCH candidate. A UE demodulates all of the PDCCH candidates in these two search spaces (USS and CSS) to discover the DCI for that UE. For example, the UE may demodulate the DCI to obtain the scheduled uplink grant information on the PUSCH and the downlink resources on the PDSCH. Note that the

aggregation level is the number of REs of a CORESET that carry a PDCCH DCI message, and is expressed in terms of CCEs. There is a one-to-one mapping between the aggregation level and the number of CCEs per aggregation level. That is, for aggregation level ‘4,’ there are four CCEs. Thus, as shown above, if the aggregation level is ‘4’ and the number of PDCCH candidates in a slot is ‘2,’ then the size of the search space is ‘8’ (i.e.,  $4 \times 2 = 8$ ).

- [0108] As illustrated in FIG. 5C, some of the REs (labeled “R”) carry DMRS for channel estimation at the receiver (e.g., a base station, another UE, etc.). A UE may additionally transmit SRS in, for example, the last symbol of a slot. The SRS may have a comb structure, and a UE may transmit SRS on one of the combs. In the example of FIG. 5C, the illustrated SRS is comb-2 over one symbol. The SRS may be used by a base station to obtain the channel state information (CSI) for each UE. CSI describes how an RF signal propagates from the UE to the base station and represents the combined effect of scattering, fading, and power decay with distance. The system uses the SRS for resource scheduling, link adaptation, massive MIMO, beam management, etc.
- [0109] Currently, an SRS resource may span 1, 2, 4, 8, or 12 consecutive symbols within a slot with a comb size of comb-2, comb-4, or comb-8. The following are the frequency offsets from symbol to symbol for the SRS comb patterns that are currently supported. 1-symbol comb-2: {0}; 2-symbol comb-2: {0, 1}; 4-symbol comb-2: {0, 1, 0, 1}; 4-symbol comb-4: {0, 2, 1, 3}; 8-symbol comb-4: {0, 2, 1, 3, 0, 2, 1, 3}; 12-symbol comb-4: {0, 2, 1, 3, 0, 2, 1, 3, 0, 2, 1, 3}; 4-symbol comb-8: {0, 4, 2, 6}; 8-symbol comb-8: {0, 4, 2, 6, 1, 5, 3, 7}; and 12-symbol comb-8: {0, 4, 2, 6, 1, 5, 3, 7, 0, 4, 2, 6}.
- [0110] A collection of resource elements that are used for transmission of SRS is referred to as an “SRS resource,” and may be identified by the parameter “SRS-ResourceId.” The collection of resource elements can span multiple PRBs in the frequency domain and N (e.g., one or more) consecutive symbol(s) within a slot in the time domain. In a given OFDM symbol, an SRS resource occupies consecutive PRBs. An “SRS resource set” is a set of SRS resources used for the transmission of SRS signals, and is identified by an SRS resource set ID (“SRS-ResourceSetId”).
- [0111] Generally, a UE transmits SRS to enable the receiving base station (either the serving base station or a neighboring base station) to measure the channel quality between the UE and the base station. However, SRS also can be used as uplink positioning reference signals for uplink positioning procedures, such as UL-TDOA, multi-RTT, DL-AoA, etc.

- [0112] Several enhancements over the previous definition of SRS have been proposed for SRS-for-positioning (also referred to as “UL-PRS”), such as a new staggered pattern within an SRS resource (except for single-symbol/comb-2), a new comb type for SRS, new sequences for SRS, a higher number of SRS resource sets per component carrier, and a higher number of SRS resources per component carrier. In addition, the parameters “SpatialRelationInfo” and “PathLossReference” are to be configured based on a downlink reference signal or SSB from a neighboring TRP. Further still, one SRS resource may be transmitted outside the active BWP, and one SRS resource may span across multiple component carriers. Also, SRS may be configured in RRC connected state and only transmitted within an active BWP. Further, there may be no frequency hopping, no repetition factor, a single antenna port, and new lengths for SRS (e.g., 8 and 12 symbols). There also may be open-loop power control and not closed-loop power control, and comb-8 (i.e., an SRS transmitted every eighth subcarrier in the same symbol) may be used. Lastly, the UE may transmit through the same transmit beam from multiple SRS resources for UL-AoA. All of these are features that are additional to the current SRS framework, which is configured through RRC higher layer signaling (and potentially triggered or activated through MAC control element (CE) or DCI).
- [0113] FIG. 5D illustrates an example of various channels within an uplink slot of a frame, according to aspects of the disclosure. A random-access channel (RACH), also referred to as a physical random-access channel (PRACH), may be within one or more slots within a frame based on the PRACH configuration. The PRACH may include six consecutive RB pairs within a slot. The PRACH allows the UE to perform initial system access and achieve uplink synchronization. A physical uplink control channel (PUCCH) may be located on edges of the uplink system bandwidth. The PUCCH carries uplink control information (UCI), such as scheduling requests, CSI reports, a channel quality indicator (CQI), a precoding matrix indicator (PMI), a rank indicator (RI), and HARQ ACK/NACK feedback. The physical uplink shared channel (PUSCH) carries data, and may additionally be used to carry a buffer status report (BSR), a power headroom report (PHR), and/or UCI.
- [0114] Note that the terms “positioning reference signal” and “PRS” generally refer to specific reference signals that are used for positioning in NR and LTE systems. However, as used herein, the terms “positioning reference signal” and “PRS” may also refer to any type of reference signal that can be used for positioning, such as but not limited to, PRS as defined

in LTE and NR, TRS, PTRS, CRS, CSI-RS, DMRS, PSS, SSS, SSB, SRS, UL-PRS, etc. In addition, the terms “positioning reference signal” and “PRS” may refer to downlink or uplink positioning reference signals, unless otherwise indicated by the context. If needed to further distinguish the type of PRS, a downlink positioning reference signal may be referred to as a “DL-PRS,” and an uplink positioning reference signal (e.g., an SRS-for-positioning, PTRS) may be referred to as an “UL-PRS.” In addition, for signals that may be transmitted in both the uplink and downlink (e.g., DMRS, PTRS), the signals may be prepended with “UL” or “DL” to distinguish the direction. For example, “UL-DMRS” may be differentiated from “DL-DMRS.”

- [0115] NR supports a number of cellular network-based positioning technologies, including downlink-based, uplink-based, and downlink-and-uplink-based positioning methods. Downlink-based positioning methods include observed time difference of arrival (OTDOA) in LTE, downlink time difference of arrival (DL-TDOA) in NR, and downlink angle-of-departure (DL-AoD) in NR. In an OTDOA or DL-TDOA positioning procedure, a UE measures the differences between the times of arrival (ToAs) of reference signals (e.g., PRS, TRS, CSI-RS, SSB, etc.) received from pairs of base stations, referred to as reference signal time difference (RSTD) or time difference of arrival (TDOA) measurements, and reports them to a positioning entity. More specifically, the UE receives the identifiers (IDs) of a reference base station (e.g., a serving base station) and multiple non-reference base stations in assistance data. The UE then measures the RSTD between the reference base station and each of the non-reference base stations. Based on the known locations of the involved base stations and the RSTD measurements, the positioning entity can estimate the UE’s location. For DL-AoD positioning, a base station measures the angle and other channel properties (e.g., signal strength) of the downlink transmit beam used to communicate with a UE to estimate the location of the UE.
- [0116] Uplink-based positioning methods include uplink time difference of arrival (UL-TDOA) and uplink angle-of-arrival (UL-AoA). UL-TDOA is similar to DL-TDOA, but is based on uplink reference signals (e.g., SRS) transmitted by the UE. For UL-AoA positioning, a base station measures the angle and other channel properties (e.g., gain level) of the uplink receive beam used to communicate with a UE to estimate the location of the UE.
- [0117] Downlink-and-uplink-based positioning methods include enhanced cell-ID (E-CID) positioning and multi-round-trip-time (RTT) positioning (also referred to as “multi-cell RTT”). In an RTT procedure, an initiator (a base station or a UE) transmits an RTT

measurement signal (e.g., a PRS or SRS) to a responder (a UE or base station), which transmits an RTT response signal (e.g., an SRS or PRS) back to the initiator. The RTT response signal includes the difference between the ToA of the RTT measurement signal and the transmission time of the RTT response signal, referred to as the reception-to-transmission (Rx-Tx) measurement. The initiator calculates the difference between the transmission time of the RTT measurement signal and the ToA of the RTT response signal, referred to as the “Tx-Rx” measurement. The propagation time (also referred to as the “time of flight”) between the initiator and the responder can be calculated from the Tx-Rx and Rx-Tx measurements. Based on the propagation time and the known speed of light, the distance between the initiator and the responder can be determined. For multi-RTT positioning, a UE performs an RTT procedure with multiple base stations to enable its location to be triangulated based on the known locations of the base stations. RTT and multi-RTT methods can be combined with other positioning techniques, such as UL-AoA and DL-AoD, to improve location accuracy.

- [0118] The E-CID positioning method is based on radio resource management (RRM) measurements. In E-CID, the UE reports the serving cell ID, the timing advance (TA), and the identifiers, estimated timing, and signal strength of detected neighbor base stations. The location of the UE is then estimated based on this information and the known locations of the base stations.
- [0119] To assist positioning operations, a location server (e.g., location server 230, LMF 270, SLP 272) may provide assistance data to the UE. For example, the assistance data may include identifiers of the base stations (or the cells/TRPs of the base stations) from which to measure reference signals, the reference signal configuration parameters (e.g., the number of consecutive positioning subframes, periodicity of positioning subframes, muting sequence, frequency hopping sequence, reference signal identifier, reference signal bandwidth, etc.), and/or other parameters applicable to the particular positioning method. Alternatively, the assistance data may originate directly from the base stations themselves (e.g., in periodically broadcasted overhead messages, etc.). In some cases, the UE may be able to detect neighbor network nodes itself without the use of assistance data.
- [0120] In the case of an OTDOA or DL-TDOA positioning procedure, the assistance data may further include an expected RSTD value and an associated uncertainty, or search window, around the expected RSTD. In some cases, the value range of the expected RSTD may be +/- 500 microseconds ( $\mu$ s). In some cases, when any of the resources used for the

positioning measurement are in FR1, the value range for the uncertainty of the expected RSTD may be +/- 32  $\mu$ s. In other cases, when all of the resources used for the positioning measurement(s) are in FR2, the value range for the uncertainty of the expected RSTD may be +/- 8  $\mu$ s.

- [0121] A location estimate may be referred to by other names, such as a position estimate, location, position, position fix, fix, or the like. A location estimate may be geodetic and comprise coordinates (e.g., latitude, longitude, and possibly altitude) or may be civic and comprise a street address, postal address, or some other verbal description of a location. A location estimate may further be defined relative to some other known location or defined in absolute terms (e.g., using latitude, longitude, and possibly altitude). A location estimate may include an expected error or uncertainty (e.g., by including an area or volume within which the location is expected to be included with some specified or default level of confidence).
- [0122] In LTE and, at least in some cases, NR, positioning measurements are reported through higher layer signaling, specifically, LTE positioning protocol (LPP) and/or RRC. LPP is used point-to-point between a location server (e.g., location server 230, LMF 270, SLP 272) and a UE (e.g., any of the UEs described herein) in order to position the UE using location related measurements obtained from one or more reference sources. FIG. 6 is a diagram 600 illustrating example LPP reference sources for positioning. In the example of FIG. 6, a target device, specifically a UE 604 (e.g., any of the UEs described herein), is engaged in an LPP session with a location server 630 (labeled as an “E-SMLC/SLP” in the specific example of FIG. 6). The UE 604 is also receiving/measuring wireless positioning signals from a first reference source, specifically one or more base stations 602 (which may correspond to any of the base stations described herein, and which is labelled as an “eNode B” in the specific example of FIG. 6), and a second reference source, specifically one or more SPS satellites 620 (which may correspond to SVs 112 in FIG. 1).
- [0123] An LPP session is used between a location server 630 and a UE 604 in order to obtain location-related measurements or a location estimate or to transfer assistance data. A single LPP session is used to support a single location request (e.g., for a single mobile-terminated location request (MT-LR), mobile originated location request (MO-LR), or network induced location request (NI-LR)). Multiple LPP sessions can be used between the same endpoints to support multiple different location requests. Each LPP session

comprises one or more LPP transactions, with each LPP transaction performing a single operation (e.g., capability exchange, assistance data transfer, location information transfer). LPP transactions are referred to as LPP procedures. The instigator of an LPP session instigates the first LPP transaction, but subsequent transactions may be instigated by either endpoint. LPP transactions within a session may occur serially or in parallel. LPP transactions are indicated at the LPP protocol level with a transaction identifier in order to associate messages with one another (e.g., request and response). Messages within a transaction are linked by a common transaction identifier.

**[0124]** LPP positioning methods and associated signaling content are defined in the 3GPP LPP standard (3GPP Technical Specification (TS) 36.355, which is publicly available and incorporated by reference herein in its entirety). LPP signaling can be used to request and report measurements related to the following positioning methods: observed time difference of arrival (OTDOA), downlink time difference of arrival (DL-TDOA), assisted global navigation satellite system (A-GNSS), LTE enhanced cell identity (E-CID), NR E-CID, sensor, terrestrial beacon system (TBS), WLAN, Bluetooth, downlink angle of departure (DL-AoD), uplink angle of arrival (UL-AoA), and multi-round-trip-time (RTT). Currently, LPP measurement reports may contain the following measurements: (1) one or more time of arrival (ToA), time difference of arrival (TDOA), reference signal time difference (RSTD), or reception-to-transmission (Rx-Tx) measurements, (2) one or more AoA and/or AoD measurements (currently only for a base station to report UL-AoA and DL-AoD to the location server 630), (3) one or more multipath measurements (per-path ToA, reference signal received power (RSRP), AoA/AoD), (4) one or more motion states (e.g., walking, driving, etc.) and trajectories (currently only for the UE 604), and (5) one or more report quality indications. In the present disclosure, positioning measurements, such as the example measurements just listed, and regardless of the positioning technology, may be referred to collectively as positioning state information (PSI).

**[0125]** The UE 604 and/or the location server 630 may derive location information from one or more reference sources, illustrated in the example of FIG. 6 as SPS satellite(s) 620 and the base station(s) 602. Each reference source can be used to calculate an independent estimate of the location of the UE 604 using associated positioning techniques. In the example of FIG. 6, the UE 604 is measuring characteristics (e.g., ToA, RSRP, RSTD, etc.) of positioning signals received from the base station(s) 602 to calculate, or to assist

the location server 630 to calculate, an estimate of the location of the UE 604 using one or more cellular network-based positioning methods (e.g., multi-RTT, OTDOA, DL-TDOA, DL-AoD, E-CID, etc.). Similarly, the UE 604 is measuring characteristics (e.g., ToA) of GNSS signals received from the SPS satellites 620 to triangulate its location in two or three dimensions, depending on the number of SPS satellites 620 measured. In some cases, the UE 604 or the location server 630 may combine the location solutions derived from each of the different positioning techniques to improve the accuracy of the final location estimate.

- [0126] As noted above, the UE 604 uses LPP to report location related measurements obtained from different of reference sources (e.g., base stations 602, Bluetooth beacons, SPS satellites 620, WLAN access points, motion sensors, etc.). As an example, for GNSS-based positioning, the UE 604 uses the LPP information element (IE) “A-GNSS-ProvideLocationInformation” to provide location measurements (e.g., pseudo ranges, location estimate, velocity, etc.) to the location server 630, together with time information. It may also be used to provide a GNSS positioning-specific error reason. The “A-GNSS-ProvideLocationInformation” IE includes IEs such as “GNSS-SignalMeasurementInformation,” “GNSS-LocationInformation,” “GNSS-MeasurementList,” and “GNSS-Error.” The UE 604 includes the “GNSS-LocationInformation” IE when it provides location and optionally velocity information derived using GNSS or hybrid GNSS and other measurements to the location server 630. The UE 604 uses the “GNSS-SignalMeasurementInformation” IE to provide GNSS signal measurement information to the location server 630 and the GNSS network time association if requested by the location server 630. This information includes the measurements of code phase, Doppler, C/No, and optionally accumulated carrier phase, also referred to as accumulated delta range (ADR), which enable the UE assisted GNSS method where location is computed in the location server 630. The UE 604 uses the “GNSS-MeasurementList” IE to provide measurements of code phase, Doppler, C/No, and optionally accumulated carrier phase (or ADR).
- [0127] As another example, for motion sensor-based positioning, the currently supported positioning methods use a barometric pressure sensor and a motion sensor, as described in 3GPP TS 36.305 (which is publicly available and incorporated by reference herein in its entirety). The UE 604 uses the LPP IE “Sensor-ProvideLocationInformation” to provide location information for sensor-based methods to the location server 630. It may

also be used to provide a sensor-specific error reason. The UE 604 uses the “Sensor-MeasurementInformation” IE to provide sensor measurements (e.g., barometric readings) to the location server 630. The UE 604 uses the “Sensor-MotionInformation” to provide movement information to the location server 630. The movement information may comprise an ordered series of points. This information may be obtained by the UE 604 using one or more motion sensors (e.g., accelerometers, barometers, magnetometers, etc.).

- [0128] As yet another example, for Bluetooth-based positioning, the UE 604 uses the “BT-ProvideLocationInformation” IE to provide measurements of one or more Bluetooth beacons to the location server 630. This IE may also be used to provide Bluetooth positioning specific error reason.
- [0129] NR positioning techniques enable high accuracy positioning by using, for example, large bandwidth positioning signals, beam sweeping in mmW frequency ranges, AoA and/or AoD measurements and reporting, and multi-cell RTT. NR positioning techniques do not, however, specifically address the low latency requirements of commercial use cases (e.g., industrial IoT (IIoT)).
- [0130] Some NR positioning techniques do provide lower latency than others. For example, UE-based positioning techniques (which are currently only implemented on the downlink) and locating the LMF in the RAN (for UE-assisted positioning techniques) provide lower latency. However, all measurement reporting is still via LPP and/or RRC (e.g., RRC layer 445) using mechanisms similar to those in LTE; there is no low latency reporting mechanism. As such, it would be beneficial to provide low(er) latency reporting mechanisms for existing positioning techniques. For example, it would be beneficial to provide a latency of less than 100 ms, or even 10 ms in some IIoT cases.
- [0131] To achieve such a latency target, it would be beneficial to report positioning measurements at the L1 (e.g., PHY layer 430) and/or L2 (e.g., SDAP layer 410, PDCP layer 415, RLC layer 420, and MAC layer 425). Note that L1/L2 reporting reduces latency between the UE and the serving base station; the latency between the serving base station and the location server can be addressed by locating the location server in the RAN (e.g., as a component of the serving base station).
- [0132] At the physical layer, a UE is configured to transmit a CSI report with a certain periodicity or when triggered by the network (e.g., the serving base station, a location server). A CSI report includes information indicating the quality of a given channel at a specific time.

As described in 3GPP TS 38.212 (which is publicly available and incorporated by reference herein in its entirety), a CSI report consists of a set of fields in a pre-specified order. Specifically, a CSI report can include the following parameters: a CQI, a PMI, a CSI-RS resource indicator (CRI), an SS/PBCH resource block indicator (SSBRI), an RI and/or a Layer 1 reference signal received power (L1-RSRP), and a layer indicator (LI).

- [0133] The reported parameters of a CSI report are encoded in UCI and mapped to the PUSCH or PUCCH, and the encoding format used is different depending both on the physical channel used and the frequency-granularity of the CSI report. The reason for the different encoding schemes is that the payload size of a CSI report generally varies with the UE's selection of CRI and RI. That is, the codebook size for PMI reporting is different for different RIs, especially for Type II CSI reporting and subband PMI reporting in general, where it can vary drastically. Similarly, as one codeword is used for up to rank-4, and two codewords are used for higher ranks, the number of CQI parameters (which is given per codeword) included in the CSI report will vary depending on the selection of rank.
- [0134] For PUCCH-based CSI reporting with wideband frequency-granularity, the variation of a PMI/CQI payload (which depends on the selected rank) is not too large, and therefore, a single packet encoding of all CSI parameters in UCI is used. Since the base station needs to know the payload size (length) of the UCI in order to decode the transmission, the UCI is padded with a number of dummy bits (e.g., '0's) corresponding to the difference between the maximum UCI payload size (i.e., corresponding to the RI that results in the largest PMI/CQI overhead) and the actual payload size of the CSI report. This ensures that the payload size is fixed regardless of the UE's RI selection. If this measure was not taken, the base station would have to blindly detect the UCI payload size and try to decode for all possible UCI payload sizes, which is not practicable.
- [0135] However, for PUCCH-based CSI with subband frequency-granularity as well as PUSCH-based CSI reporting, always padding the CSI report to the worst-case UCI payload size would result in too large an overhead. For these cases, the CSI content / report is instead divided into two CSI parts, Part 1 and Part 2. CSI Part1 has a fixed payload size (and can therefore be decoded by the base station without prior information) and CSI Part 2 has a variable payload size. The information about the payload size of the CSI Part 2 can be derived from the CSI parameters in the CSI Part 1. That is, the base station first decodes the CSI Part 1 to obtain a subset of the CSI parameters, and then based on these CSI

parameters, the base station can infer the payload size of the CSI Part 2. The base station can then decode the CSI Part 2 to obtain the remainder of the CSI parameters.

- [0136] A UE may be configured with a CSI report setting in RRC signaling, where the CSI report setting may contain a parameter (e.g., “ReportQuantity”) to indicate one or more CSI-related quantities to report in which component carrier (e.g., CRI, RI, PMI, CQI, L1-RSRP, etc.), as well as which uplink channel should be used to carry the reported CSI-related quantities (e.g., PUSCH or PUCCH).
- [0137] The CSI report setting may also specify reference signal resource settings. Each resource setting includes a BWP index and a tag indicating whether the CSI-RS resources are aperiodic (A), periodic (P), or semi-persistent (SP). Each resource setting contains one or multiple CSI-RS/SSB resource sets. Specifically, for L1-RSRP, there is only one CSI-RS/SSB resource set, whereas for CSI estimation, there can be two or three CSI-RS resource sets, one for channel measurements, the remaining for interference measurements.
- [0138] Each CSI-RS resource set may contain one or multiple CSI-RS resources. Each CSI-RS resource may contain one or multiple antenna ports (the specific time and frequency resources) over which the UE is expected to perform the channel estimation measurement(s). If a resource set has multiple CSI-RS resources, the UE may also report the CRI of the best CSI-RS resource of the set.
- [0139] The present disclosure describes techniques for reporting RAT-independent (i.e., non-NR) PSI using RAT-dependent (NR) lower layers (e.g., L1/L2). More specifically, a UE can be configured to provide a PSI report that includes measurements derived using RAT-independent technologies on low layer (e.g., PHY or MAC-CE) channels of the NR RAT. A PSI report may use the same framework as a CSI report (e.g., be configured by “ReportQuantity,” have a fixed-size Part 1 and a variable-size Part 2, etc.) except that it includes PSI instead of CSI. In addition, the UE may transmit a PSI report on a PUSCH or PUCCH, as it does a CSI report. Alternatively, the UE may transmit the PSI report to another UE over a sidelink (i.e., a wireless communication link between two UEs configured in accordance with a cellular RAT, such as NR).
- [0140] A PSI report may include RAT-dependent measurements, that is, measurements based on NR reference signals (e.g., DL/UL-PRS, CSI-RS, TRS, SSB, etc.), or RAT-independent measurements, that is, measurements or other information derived from reference sources other than NR reference sources (e.g., Bluetooth, barometric sensor, motion sensor,

GNSS, OTDOA based on LTE PHY signals, and E-CID based on LTE PHY signals). The information that would need to be conveyed in the PSI reports for both RAT-dependent and RAT-independent PSI reports would be the same as is currently reported via LPP, such as the information conveyed by the “A-GNSS-ProvideLocationInformation,” “Sensor-ProvideLocationInformation,” and “BT-ProvideLocationInformation” IEs. For each type of positioning method, whether RAT-dependent or RAT-independent, a UE can report, in capability information, whether or not it supports PSI reporting for that positioning method.

- [0141] In an aspect, each PSI report may be associated with measurements from one positioning technology. Thus, for example, NR-based measurements can be reported in one PSI report, Bluetooth-based measurements can be reported in another PSI report, GNSS-based measurements can be reported in another PSI report, and so on. The configuration of each PSI report may include the necessary configuration parameters to enable the corresponding PSI report. For example, the configuration for an A-GNSS PSI report may include assistance data for A-GNSS, which will be different from assistance data for OTDOA, which will be different from assistance data for Bluetooth, and so on. The list of quantities (measurements) in a PSI report would therefore depend on the positioning technology that was configured to be reported. Note that there would be no associated RAT-dependent resource provided in the PSI report. That is, there would be no reference signal explicitly associated with the PSI report, since the report is associated with RAT-independent positioning methods.
- [0142] Where each PSI report is associated with one positioning technology, in the fixed-size Part 1 of the PSI report, the UE can report the size (e.g., the number of measurements) of each measurement vector, and also the type of the measurement vector, that are being reported in the variable-size Part 2 of the PSI report. For example, the UE may report the type of the measurement vectors using a bit string of ‘X’ bits, where each bit corresponds to a specific type of measurement (e.g., RSTD, RSRP, Rx-Tx, etc.). Then, ‘X’ numbers are reported in Part 1, each one indicating the size of one of the ‘X’ measurement vectors being reported in Part 2.
- [0143] For example, if the UE is going to report three measurement vectors ( $X=3$ ) for three different types of measurements, then the bit string will have a length of three bits. The first bit may indicate a first type of measurement (e.g., RSTD), the second bit may indicate a second type of measurement (e.g., ToA), and the third bit may indicate a third type of

measurement (e.g., RSRP). The PSI Part 1 will then include three additional numbers, one for each measurement vector, and representing the number of measurements in the measurement vector. The first number indicates the size of the measurement vector for the first type of measurement, the second number indicates the size of the measurement vector for the second type of measurement, and the third number indicates the size of the measurement vector for the third type of measurement.

[0144] FIG. 7 is a diagram 700 illustrating example DCI triggers for PSI reporting, according to aspects of the disclosure. Specifically, FIG. 7 provides an example of aperiodic PSI report triggering in which different codepoints in the DCI trigger one or more PSI reports of the same technology. As shown in FIG. 7, there are 64 DCI codepoints 710, some or all of which can be mapped to different PSI report configurations 720. That is, when the UE receives a particular codepoint, it can look up the corresponding configuration information for the triggered PSI report(s).

[0145] For example, the first codepoint 710 (labeled “1”) is mapped to configuration parameters identifying a first positioning technology (labeled “Chosen positioning technology #1”), specifying that the UE is to send two PSI reports (labeled “PSI report #1” and “PSI report #2”), and including, or pointing to, assistance data (labeled “Assistance Data #1”) for the specified positioning technology. As shown, the assistance data is only provided once. As another example, the second codepoint 710 (labeled “2”) is mapped to configuration parameters identifying a second positioning technology (labeled “Chosen positioning technology #2”), specifying that the UE is to send one PSI report (labeled “PSI report #4”), and including, or pointing to, assistance data (labeled “Assistance Data #2”) for the specified positioning technology. As yet another example, the third codepoint 710 (labeled “3”) is mapped to configuration parameters identifying a third positioning technology (labeled “Chosen positioning technology #3”), specifying that the UE is to send two PSI reports (labeled “PSI report #7” and “PSI report #8”), and including, or pointing to, assistance data (labeled “Assistance Data #3”) for the specified positioning technology.

[0146] In an aspect, the same PSI report may be configured to carry measurements for multiple positioning technologies. In this case, the PSI report configuration/trigger should include the assistance data (or a link/indicator to the assistance data) for each positioning technology being configured to be reported. The UE may include, in Part 1 of the PSI report, which positioning technologies are included in the PSI report. In Part 2, the UE

reports the actual measurements for each positioning technology in a specified ordering of sub-parts. The UE may choose the ordering to be used inside the Part 2 report, and indicate the ordering in the Part 1 report. Thus, if the PSI report is configured for multiple-technology reporting, the PSI report may be split into multiple parts and sub-parts. Specifically, Part 1 would indicate which sub-parts (one or more for each positioning technology) are included in Part 2. Part 2 would be divided into sub-parts, and each sub-part would contain the measurements of one technology. Each additional sub-part of Part 2 may be carried on a separate PUSCH or PUCCH.

[0147] **FIG. 8** is a diagram 800 illustrating example DCI triggers for PSI reporting, according to aspects of the disclosure. Specifically, FIG. 8 provides an example of aperiodic PSI report triggering in which different codepoints in the DCI trigger one or more PSI reports of different positioning technologies. As shown in FIG. 8, there are 64 DCI codepoints 810, some or all of which can be mapped to different PSI report configurations 820. That is, when the UE receives a particular codepoint, it can look up the corresponding configuration information for the triggered PSI report(s).

[0148] For example, the first codepoint 810 (labeled “1”) is mapped to configuration parameters identifying a first positioning technology (labeled “Chosen positioning technology #1”) and a second positioning technology (labeled “Chosen positioning technology #2”), specifying that the UE is to send two PSI reports (labeled “PSI report #1” and “PSI report #2”), one for each positioning technology, and including, or pointing to, assistance data for each specified positioning technology (labeled “Assistance Data #1” and “Assistance Data #2”). As another example, the second codepoint 810 (labeled “2”) is mapped to configuration parameters identifying the second positioning technology (labeled “Chosen positioning technology #2”), specifying that the UE is to send one PSI report (labeled “PSI report #4”), and including, or pointing to, assistance data (labeled “Assistance Data #2”) for the specified positioning technology. As yet another example, the third codepoint 810 (labeled “3”) is mapped to configuration parameters identifying a third positioning technology (labeled “Chosen positioning technology #3”), specifying that the UE is to send two PSI reports (labeled “PSI report #7” and “PSI report #8”), and including, or pointing to, assistance data (labeled “Assistance Data #3”) for the specified positioning technology. Thus, as will be appreciated, in this aspect, not every codepoint needs to be mapped to multiple positioning technologies, there is simply the option to do so. Also, as shown, the assistance data may only be provided once.

- [0149] For aperiodic PSI reporting, an additional bitfield may be configured in the DCI that can be used for RAT-independent positioning measurement reporting. For UE-based positioning, the UE can be configured to provide a PSI report that either (1) has a separate positioning fix, velocity, and/or orientation derived using a single positioning technology, or (2) has a joint positioning fix, velocity, and/or orientation derived using a collection of positioning technologies. In the second option, the UE may report which positioning technologies were used for the joint positioning fix. In an aspect, the UE may be configured with the positioning technologies it can use for the joint positioning fix. For example, if the UE has opened three positioning sessions, one for UE-based DL-TDOA, another for UE-assisted OTDOA, and another for UE-based GNSS, and the UE is configured to report one positioning fix, the UE may report which of the two UE-based methods were used for the derived positioning fix.
- [0150] In an aspect, if multiple PSI reports are configured to be transmitted on the same uplink channel, and it is not possible to fit them in the scheduled low layer container (e.g., CSI report, MAC-CE), then a priority rule may be applied that depends on the technology used for the measurements. For example, GNSS measurements may have a higher priority than NR measurements, which may have a higher priority than LTE measurements, which may have a higher priority than sensor measurements, which may have a higher priority than Bluetooth measurements. In an aspect, the chosen ordering may be configured by the location server. Alternatively, the chosen ordering may be according to the time that the corresponding positioning session began. For example, the first-begun positioning session may have the highest priority and the last-begun positioning session may have the lowest, or vice versa.
- [0151] In some cases, due to transmitting PSI reports based on their respective priorities, some parts of the lowest priority PSI report may have to be dropped (or, in some cases, the lowest priority one or more PSI reports may have to be dropped and some parts of a low priority PSI report may have to be dropped). For example, a UE may be attempting to transmit a low priority PSI report having multiple parts (e.g., “part-1,” “part-2,” “part-3”) carrying RAT-independent measurements (e.g., GNSS measurements, LTE measurements, Bluetooth measurements, etc.). If only a portion of the bits of a specific part (e.g., “part-3”) will fit in the scheduled low layer container (e.g., PHY layer container or MAC layer container), then the whole part (e.g., all of “part-3”) is dropped.

- [0152] Accordingly, if a RAT-independent positioning report (i.e., a PSI report containing measurements for a particular RAT) is configured to be reported in a low layer container (which may also be configured to include one or more other RAT-independent positioning reports), and if one or more parts of that positioning report are to be dropped/omitted, the UE may be configured to report certain information through higher layer signaling (e.g., LPP signaling). As a first option, the UE may report the parts that were dropped/omitted from the low layer container through the higher layer signaling, while not reporting those parts that were transmitted in the low layer container. As a second option, the UE may report the entire RAT-independent report through higher layer signaling. Note that the reports/parts to be dropped/omitted may not be based on having a lower priority than other positioning technologies, but instead, may be based on other factors for sending some reports/parts before others.
- [0153] In an aspect, the UE may also report an error message or warning message that identifies which report or which part(s) of the report were dropped/omitted and were instead reported through higher layer signaling. The error/warning message may be reported through the higher layer signaling, or as a bit in the low layer container. It may be beneficial to report the above information via an LPP session, since there will likely be an ongoing LPP session between the UE and the location server (e.g., location server 230, LMF 270, SLP 272) to obtain the UE's location.
- [0154] In an aspect, the UE may recommend the maximum size of each part of a report. The recommendation may be based on the type of RAT-independent measurements to be reported, wireless link quality, type of low layer container, and/or capabilities of the UE. The recommendation may be provided over high layer signaling (e.g., LPP signaling), such as during the UE's negotiation with the network to report RAT-independent measurements via low layer containers.
- [0155] **FIG. 9** illustrates an example method 900 of wireless communication, according to aspects of the disclosure. In an aspect, the method 900 may be performed by a UE (e.g., any of the UEs described herein).
- [0156] At 910, the UE receives, over a wireless communication network operating in accordance with a first RAT, a configuration to provide at least one PSI report, the first RAT associated with at least one first positioning technology, the configuration associated with at least one second RAT, at least one second positioning technology, or both to be used to estimate a location of the UE. In an aspect, operation 910 may be performed by

WWAN transceiver 310, processing system 332, memory component 340, and/or positioning component 342, any or all of which may be considered means for performing this operation.

- [0157] At 920, the UE obtains at least a first set of positioning measurements using the at least one second RAT, the at least one second positioning technology, or both. In an aspect, operation 920 may be performed by WWAN transceiver 310, WLAN transceiver 320, sensor(s) 344, processing system 332, memory component 340, and/or positioning component 342, any or all of which may be considered means for performing this operation.
- [0158] At 930, the UE transmits the at least one PSI report on physical resources allocated for a physical uplink or sidelink channel of the first RAT, the at least one PSI report including at least the first set of positioning measurements. In an aspect, operation 930 may be performed by WWAN transceiver 310, processing system 332, memory component 340, and/or positioning component 342, any or all of which may be considered means for performing this operation.
- [0159] As will be appreciated, a technical advantage of the method 900 is low(er) latency reporting (e.g., measurements, location estimate) for existing positioning techniques.
- [0160] In the detailed description above it can be seen that different features are grouped together in examples. This manner of disclosure should not be understood as an intention that the example clauses have more features than are explicitly mentioned in each clause. Rather, the various aspects of the disclosure may include fewer than all features of an individual example clause disclosed. Therefore, the following clauses should hereby be deemed to be incorporated in the description, wherein each clause by itself can stand as a separate example. Although each dependent clause can refer in the clauses to a specific combination with one of the other clauses, the aspect(s) of that dependent clause are not limited to the specific combination. It will be appreciated that other example clauses can also include a combination of the dependent clause aspect(s) with the subject matter of any other dependent clause or independent clause or a combination of any feature with other dependent and independent clauses. The various aspects disclosed herein expressly include these combinations, unless it is explicitly expressed or can be readily inferred that a specific combination is not intended (e.g., contradictory aspects, such as defining an element as both an insulator and a conductor). Furthermore, it is also intended that aspects

of a clause can be included in any other independent clause, even if the clause is not directly dependent on the independent clause.

[0161] Implementation examples are described in the following numbered clauses:

[0162] Clause 1. A method of wireless communication performed by a user equipment (UE), comprising: receiving, over a wireless communication network operating in accordance with a first radio access technology (RAT), a configuration to provide at least one positioning state information (PSI) report, the first RAT associated with at least one first positioning technology, the configuration associated with at least one second RAT, at least one second positioning technology, or both to be used to estimate a location of the UE; obtaining at least a first set of positioning measurements using the at least one second RAT, the at least one second positioning technology, or both; and transmitting the at least one PSI report on physical resources allocated for a physical uplink or sidelink channel of the first RAT, the at least one PSI report including at least the first set of positioning measurements.

[0163] Clause 2. The method of clause 1, wherein: the first RAT comprises a New Radio (NR) RAT, and the at least one second RAT, the at least one second positioning technology, or both comprise a non-NR RAT, a non-NR positioning technology.

[0164] Clause 3. The method of clause 2, wherein the non-NR positioning technology comprises a Bluetooth positioning technology, a barometric sensor positioning technology, a motion sensor positioning technology, an assisted global navigation satellite system (A-GNSS) positioning technology, a wireless local area network (WLAN) positioning technology, a terrestrial beacon system (TBS) positioning technology, or any combination thereof.

[0165] Clause 4. The method of clause 2, wherein: the non-NR RAT comprises a Long-Term Evolution (LTE), and the at least one second positioning technology comprises an observed time difference of arrival (OTDOA) positioning technology based on LTE physical layer reference signals, an enhanced cell identifier (E-CID) positioning technology based on LTE physical layer reference signals, or any combination thereof.

[0166] Clause 5. The method of any of clauses 2-4, wherein the at least one first positioning technology comprises a downlink time difference of arrival (DL-TDOA) positioning technology based on NR physical layer reference signals, an E-CID positioning technology based on NR physical layer reference signals, a downlink angle of departure (DL-AoD) positioning technology, an uplink angle-of-arrival (UL-AoA) positioning

technology, a multi-round-trip-time (multi-RTT) positioning technology, or any combination thereof.

- [0167] Clause 6. The method of any of clauses 1-5, wherein the at least one second positioning technology comprises at least two different positioning technologies.
- [0168] Clause 7. The method of clause 6, further comprising: transmitting capability information indicating an ability of the UE to provide a PSI report for each of the at least two different positioning technologies.
- [0169] Clause 8. The method of any of clauses 6-7, wherein the at least one PSI report comprises at least two PSI reports, one PSI report for each of the at least two different positioning technologies.
- [0170] Clause 9. The method of clause 8, wherein: each of the at least two PSI reports includes a plurality of parts, and at least one part of the plurality of parts of at least one second PSI report of the at least two PSI reports cannot be transmitted on the resources allocated for the physical uplink or sidelink channel of the first RAT.
- [0171] Clause 10. The method of clause 9, further comprising: transmitting the at least one part of the plurality of parts of the at least one second PSI report over higher layer signaling; or transmitting the at least one second PSI report over the higher layer signaling.
- [0172] Clause 11. The method of clause 10, wherein the higher layer signaling comprises Long-Term Evolution (LTE) positioning protocol (LPP) signaling.
- [0173] Clause 12. The method of clause 6, wherein the at least one PSI report comprises a single PSI report for two or more of the at least two different positioning technologies.
- [0174] Clause 13. The method of clause 12, wherein: a first part of the single PSI report identifies the two or more of the at least two different positioning technologies, and a second part of the single PSI report includes measurements obtained using the two or more of the at least two different positioning technologies.
- [0175] Clause 14. The method of clause 13, wherein the UE determines an ordering of the measurements obtained using the two or more of the at least two different positioning technologies in the second part of the single PSI report.
- [0176] Clause 15. The method of any of clauses 13-14, wherein the second part is split into at least two sub-parts, one sub-part for each of the two or more of the at least two different positioning technologies.
- [0177] Clause 16. The method of clause 15, wherein the at least two sub-parts are transmitted on different physical uplink or sidelink channels.

- [0178] Clause 17. The method of any of clauses 6-16, wherein: each of the at least two positioning technologies is associated with a priority, and a PSI report carrying measurements obtained using a positioning technology of the at least two positioning technologies having a higher priority than other positioning technologies of the at least two positioning technologies is reported before, or instead of, a PSI report carrying measurements obtained using the other positioning technologies.
- [0179] Clause 18. The method of clause 17, wherein the priority is set by a location server.
- [0180] Clause 19. The method of clause 17, wherein the priority is based on when the UE initiated positioning sessions for the at least two positioning technologies.
- [0181] Clause 20. The method of any of clauses 1-19, wherein the configuration is a downlink control information (DCI) codepoint mapped to a specific PSI report configuration.
- [0182] Clause 21. The method of clause 20, wherein the PSI report configuration triggers multiple PSI reports, including the at least one PSI report, for the at least one second positioning technology.
- [0183] Clause 22. The method of clause 21, wherein the PSI report configuration is associated with assistance data to enable the UE to obtain the one or more measurements, the assistance data associated with only a first PSI report of the multiple PSI reports.
- [0184] Clause 23. The method of clause 20, wherein: the PSI report configuration triggers a single PSI report, the single PSI report is the at least one PSI report, and the single PSI report is associated with multiple different positioning technologies, including the at least one second positioning technology.
- [0185] Clause 24. The method of any of clauses 20-23, wherein: the at least one PSI report is an aperiodic PSI report, and the DCI includes a single bit indicating that the at least one PSI report is for a non-NR positioning technology.
- [0186] Clause 25. The method of any of clauses 1-24, wherein the at least one second positioning technology comprises a UE-based positioning technology.
- [0187] Clause 26. The method of any of clauses 1-25, wherein the at least one PSI report includes a separate positioning fix, velocity, and/or orientation for each of the at least one positioning technologies.
- [0188] Clause 27. The method of any of clauses 1-25, wherein the at least one PSI report includes a combined positioning fix, velocity, and/or orientation based on a combination of the at least one positioning technologies.

- [0189] Clause 28. The method of clause 27, wherein the UE indicates which of the at least one positioning technologies were used to calculate the combined positioning fix, velocity, and/or orientation.
- [0190] Clause 29. The method of any of clauses 1-28, wherein the configuration is received over LTE positioning protocol (LPP) signaling.
- [0191] Clause 30. The method of any of clauses 1-29, wherein: the physical uplink channel comprises a physical uplink control channel (PUCCH) or a physical uplink shared channel (PUSCH), and the sidelink channel comprises a physical sidelink shared channel (PSSCH) or a physical sidelink feedback channel (PSFCH).
- [0192] Clause 31. The method of any of clauses 1-30, wherein the UE transmits the at least one PSI report to a positioning entity over the physical uplink channel.
- [0193] Clause 32. The method of clause 31, wherein the positioning entity is a serving base station of the UE.
- [0194] Clause 33. The method of clause 31, wherein the positioning entity is a location server integrated into a base station.
- [0195] Clause 34. The method of any of clauses 1-30, wherein the UE transmits the at least one PSI report to a second UE over the sidelink channel.
- [0196] Clause 35. An apparatus comprising a memory and at least one processor communicatively coupled to the memory, the memory and the at least one processor configured to perform a method according to any of clauses 1 to 34.
- [0197] Clause 36. An apparatus comprising means for performing a method according to any of clauses 1 to 34.
- [0198] Clause 37. A non-transitory computer-readable medium storing computer-executable instructions, the computer-executable comprising at least one instruction for causing a computer or processor to perform a method according to any of clauses 1 to 34.
- [0199] Those of skill in the art will appreciate that information and signals may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the above description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.
- [0200] Further, those of skill in the art will appreciate that the various illustrative logical blocks, modules, circuits, and algorithm steps described in connection with the aspects disclosed

herein may be implemented as electronic hardware, computer software, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Skilled artisans may implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the present disclosure.

- [0201]** The various illustrative logical blocks, modules, and circuits described in connection with the aspects disclosed herein may be implemented or performed with a general purpose processor, a DSP, an ASIC, an FPGA, or other programmable logic device, 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 conventional 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.
- [0202]** The methods, sequences and/or algorithms described in connection with the aspects disclosed herein may be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module may reside in random access memory (RAM), flash memory, read-only memory (ROM), erasable programmable ROM (EPROM), electrically erasable programmable ROM (EEPROM), registers, hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. An example storage medium is coupled to the 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. The processor and the storage medium may reside in an ASIC. The ASIC may reside in a user terminal (e.g., UE). In the alternative, the processor and the storage medium may reside as discrete components in a user terminal.
- [0203]** In one or more example aspects, the functions described may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software,

the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Computer-readable media includes both computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A storage media may be any available media that can be accessed by a computer. By way of example, and not limitation, such computer-readable media can comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to carry or store desired program code in the form of instructions or data structures and that can be accessed by a computer. 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, 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, includes 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. Combinations of the above should also be included within the scope of computer-readable media.

**[0204]** While the foregoing disclosure shows illustrative aspects of the disclosure, it should be noted that various changes and modifications could be made herein without departing from the scope of the disclosure as defined by the appended claims. The functions, steps and/or actions of the method claims in accordance with the aspects of the disclosure described herein need not be performed in any particular order. Furthermore, although elements of the disclosure may be described or claimed in the singular, the plural is contemplated unless limitation to the singular is explicitly stated.

## CLAIMS

What is claimed is:

1. A method of wireless communication performed by a user equipment (UE), comprising:

receiving, over a wireless communication network operating in accordance with a first radio access technology (RAT), a configuration to provide at least one positioning state information (PSI) report, the first RAT associated with at least one first positioning technology, the configuration associated with at least one second RAT and/or at least one second positioning technology, or both to be used to estimate a location of the UE;

obtaining at least a first set of positioning measurements using the at least one second RAT, the at least one second positioning technology, or both; and

transmitting the at least one PSI report on physical resources allocated for a physical uplink or sidelink channel of the first RAT, the at least one PSI report including at least the first set of positioning measurements.

2. The method of claim 1, wherein:

the first RAT comprises a New Radio (NR) RAT, and

the at least one second RAT, the at least one second positioning technology, or both comprise a non-NR RAT, a non-NR positioning technology, or both.

3. The method of claim 2, wherein the non-NR positioning technology comprises a Bluetooth positioning technology, a barometric sensor positioning technology, a motion sensor positioning technology, an assisted global navigation satellite system (A-GNSS) positioning technology, a wireless local area network (WLAN) positioning technology, a terrestrial beacon system (TBS) positioning technology, or any combination thereof.

4. The method of claim 2, wherein:

the non-NR RAT comprises a Long-Term Evolution (LTE), and

the at least one second positioning technology comprises an observed time difference of arrival (OTDOA) positioning technology based on LTE physical layer reference signals, an enhanced cell identifier (E-CID) positioning technology based on LTE physical layer reference signals, or any combination thereof.

5. The method of claim 2, wherein the at least one first positioning technology comprises a downlink time difference of arrival (DL-TDOA) positioning technology based on NR physical layer reference signals, an E-CID positioning technology based on NR physical layer reference signals, a downlink angle of departure (DL-AoD) positioning technology, an uplink angle-of-arrival (UL-AoA) positioning technology, a multi-round-trip-time (multi-RTT) positioning technology, or any combination thereof.

6. The method of claim 1, wherein the at least one second positioning technology comprises at least two different positioning technologies.

7. The method of claim 6, further comprising:  
transmitting capability information indicating an ability of the UE to provide a PSI report for each of the at least two different positioning technologies.

8. The method of claim 6, wherein the at least one PSI report comprises at least two PSI reports, one PSI report for each of the at least two different positioning technologies.

9. The method of claim 8, wherein:  
each of the at least two PSI reports includes a plurality of parts, and  
at least one part of the plurality of parts of at least one second PSI report of the at least two PSI reports cannot be transmitted on the resources allocated for the physical uplink or sidelink channel of the first RAT.

10. The method of claim 9, further comprising:  
transmitting the at least one part of the plurality of parts of the at least one second PSI report over higher layer signaling; or  
transmitting the at least one second PSI report over the higher layer signaling.

11. The method of claim 10, wherein the higher layer signaling comprises Long-Term Evolution (LTE) positioning protocol (LPP) signaling.

12. The method of claim 6, wherein the at least one PSI report comprises a single PSI report for two or more of the at least two different positioning technologies.

13. The method of claim 12, wherein:

a first part of the single PSI report identifies the two or more of the at least two different positioning technologies, and

a second part of the single PSI report includes measurements obtained using the two or more of the at least two different positioning technologies.

14. The method of claim 13, wherein the UE determines an ordering of the measurements obtained using the two or more of the at least two different positioning technologies in the second part of the single PSI report.

15. The method of claim 13, wherein the second part is split into at least two sub-parts, one sub-part for each of the two or more of the at least two different positioning technologies.

16. The method of claim 15, wherein the at least two sub-parts are transmitted on different physical uplink or sidelink channels.

17. The method of claim 6, wherein:

each of the at least two positioning technologies is associated with a priority, and a PSI report carrying measurements obtained using a positioning technology of the at least two positioning technologies having a higher priority than other positioning technologies of the at least two positioning technologies is reported before, or instead of, a PSI report carrying measurements obtained using the other positioning technologies.

18. The method of claim 17, wherein the priority is set by a location server.

19. The method of claim 17, wherein the priority is based on when the UE initiated positioning sessions for the at least two positioning technologies.

20. The method of claim 1, wherein the configuration is a downlink control information (DCI) codepoint mapped to a specific PSI report configuration.
21. The method of claim 20, wherein the PSI report configuration triggers multiple PSI reports, including the at least one PSI report, for the at least one second positioning technology.
22. The method of claim 21, wherein the PSI report configuration is associated with assistance data to enable the UE to obtain the one or more measurements, the assistance data associated with only a first PSI report of the multiple PSI reports.
23. The method of claim 20, wherein:  
the PSI report configuration triggers a single PSI report,  
the single PSI report is the at least one PSI report, and  
the single PSI report is associated with multiple different positioning technologies, including the at least one second positioning technology.
24. The method of claim 20, wherein:  
the at least one PSI report is an aperiodic PSI report, and  
the DCI includes a single bit indicating that the at least one PSI report is for a non-NR positioning technology.
25. The method of claim 1, wherein the at least one second positioning technology comprises a UE-based positioning technology.
26. The method of claim 1, wherein the at least one PSI report includes a separate positioning fix, velocity, and/or orientation for each of the at least one positioning technologies.
27. The method of claim 1, wherein the at least one PSI report includes a combined positioning fix, velocity, and/or orientation based on a combination of the at least one positioning technologies.

28. The method of claim 27, wherein the UE indicates which of the at least one positioning technologies were used to calculate the combined positioning fix, velocity, and/or orientation.
29. The method of claim 1, wherein the configuration is received over LTE positioning protocol (LPP) signaling.
30. The method of claim 1, wherein:  
the physical uplink channel comprises a physical uplink control channel (PUCCH) or a physical uplink shared channel (PUSCH), and  
the sidelink channel comprises a physical sidelink shared channel (PSSCH) or a physical sidelink feedback channel (PSFCH).
31. The method of claim 1, wherein the UE transmits the at least one PSI report to a positioning entity over the physical uplink channel.
32. The method of claim 31, wherein the positioning entity is a serving base station of the UE.
33. The method of claim 31, wherein the positioning entity is a location server integrated into a base station.
34. The method of claim 1, wherein the UE transmits the at least one PSI report to a second UE over the sidelink channel.
35. A user equipment (UE), comprising:  
a memory;  
at least one transceiver; and  
at least one processor communicatively coupled to the memory and the at least one transceiver, the at least one processor configured to:  
receive, via the at least one transceiver over a wireless communication network operating in accordance with a first radio access technology (RAT), a configuration to provide at least one positioning state information (PSI) report,

the first RAT associated with at least one first positioning technology, the configuration associated with at least one second RAT, at least one second positioning technology, or both to be used to estimate a location of the UE;

obtain, via the at least one transceiver, at least a first set of positioning measurements using the at least one second RAT, the at least one second positioning technology, or both; and

cause the at least one transceiver to transmit the at least one PSI report on physical resources allocated for a physical uplink or sidelink channel of the first RAT, the at least one PSI report including at least the first set of positioning measurements.

36. The UE of claim 35, wherein:

the first RAT comprises a New Radio (NR) RAT, and

the at least one second RAT, the at least one second positioning technology, or both comprise a non-NR RAT, a non-NR positioning technology, or both.

37. The UE of claim 36, wherein the non-NR positioning technology comprises a Bluetooth positioning technology, a barometric sensor positioning technology, a motion sensor positioning technology, an assisted global navigation satellite system (A-GNSS) positioning technology, a wireless local area network (WLAN) positioning technology, a terrestrial beacon system (TBS) positioning technology, or any combination thereof.

38. The UE of claim 36, wherein:

the non-NR RAT comprises a Long-Term Evolution (LTE), and

the at least one second positioning technology comprises an observed time difference of arrival (OTDOA) positioning technology based on LTE physical layer reference signals, an enhanced cell identifier (E-CID) positioning technology based on LTE physical layer reference signals, or any combination thereof.

39. The UE of claim 36, wherein the at least one first positioning technology comprises a downlink time difference of arrival (DL-TDOA) positioning technology based on NR physical layer reference signals, an E-CID positioning technology based on NR physical layer reference signals, a downlink angle of departure (DL-AoD)

positioning technology, an uplink angle-of-arrival (UL-AoA) positioning technology, a multi-round-trip-time (multi-RTT) positioning technology, or any combination thereof.

40. The UE of claim 35, wherein the at least one second positioning technology comprises at least two different positioning technologies.

41. The UE of claim 40, wherein the at least one processor is further configured to:  
cause the at least one transceiver to transmit capability information indicating an ability of the UE to provide a PSI report for each of the at least two different positioning technologies.

42. The UE of claim 40, wherein the at least one PSI report comprises at least two PSI reports, one PSI report for each of the at least two different positioning technologies.

43. The UE of claim 42, wherein:  
each of the at least two PSI reports includes a plurality of parts, and  
at least one part of the plurality of parts of at least one second PSI report of the at least two PSI reports cannot be transmitted on the resources allocated for the physical uplink or sidelink channel of the first RAT.

44. The UE of claim 43, wherein the at least one processor is further configured to:  
cause the at least one transceiver to transmit the at least one part of the plurality of parts of the at least one second PSI report over higher layer signaling; or  
cause the at least one transceiver to transmit the at least one second PSI report over the higher layer signaling.

45. The UE of claim 44, wherein the higher layer signaling comprises Long-Term Evolution (LTE) positioning protocol (LPP) signaling.

46. The UE of claim 40, wherein the at least one PSI report comprises a single PSI report for two or more of the at least two different positioning technologies.

47. The UE of claim 46, wherein:  
a first part of the single PSI report identifies the two or more of the at least two different positioning technologies, and  
a second part of the single PSI report includes measurements obtained using the two or more of the at least two different positioning technologies.
48. The UE of claim 47, wherein the at least one processor determines an ordering of the measurements obtained using the two or more of the at least two different positioning technologies in the second part of the single PSI report.
49. The UE of claim 47, wherein the second part is split into at least two sub-parts, one sub-part for each of the two or more of the at least two different positioning technologies.
50. The UE of claim 49, wherein the at least two sub-parts are transmitted on different physical uplink or sidelink channels.
51. The UE of claim 40, wherein:  
each of the at least two positioning technologies is associated with a priority, and  
a PSI report carrying measurements obtained using a positioning technology of the at least two positioning technologies having a higher priority than other positioning technologies of the at least two positioning technologies is reported before, or instead of, a PSI report carrying measurements obtained using the other positioning technologies.
52. The UE of claim 51, wherein the priority is set by a location server.
53. The UE of claim 51, wherein the priority is based on when the UE initiated positioning sessions for the at least two positioning technologies.
54. The UE of claim 35, wherein the configuration is a downlink control information (DCI) codepoint mapped to a specific PSI report configuration.

55. The UE of claim 54, wherein the PSI report configuration triggers multiple PSI reports, including the at least one PSI report, for the at least one second positioning technology.

56. The UE of claim 55, wherein the PSI report configuration is associated with assistance data to enable the UE to obtain the one or more measurements, the assistance data associated with only a first PSI report of the multiple PSI reports.

57. The UE of claim 54, wherein:  
the PSI report configuration triggers a single PSI report,  
the single PSI report is the at least one PSI report, and  
the single PSI report is associated with multiple different positioning technologies, including the at least one second positioning technology.

58. The UE of claim 54, wherein:  
the at least one PSI report is an aperiodic PSI report, and  
the DCI includes a single bit indicating that the at least one PSI report is for a non-NR positioning technology.

59. The UE of claim 35, wherein the at least one second positioning technology comprises a UE-based positioning technology.

60. The UE of claim 35, wherein the at least one PSI report includes a separate positioning fix, velocity, and/or orientation for each of the at least one positioning technologies.

61. The UE of claim 35, wherein the at least one PSI report includes a combined positioning fix, velocity, and/or orientation based on a combination of the at least one positioning technologies.

62. The UE of claim 61, wherein the UE indicates which of the at least one positioning technologies were used to calculate the combined positioning fix, velocity, and/or orientation.

63. The UE of claim 35, wherein the configuration is received over LTE positioning protocol (LPP) signaling.

64. The UE of claim 35, wherein:  
the physical uplink channel comprises a physical uplink control channel (PUCCH) or a physical uplink shared channel (PUSCH), and  
the sidelink channel comprises a physical sidelink shared channel (PSSCH) or a physical sidelink feedback channel (PSFCH).

65. The UE of claim 35, wherein the UE transmits the at least one PSI report to a positioning entity over the physical uplink channel.

66. The UE of claim 65, wherein the positioning entity is a serving base station of the UE.

67. The UE of claim 65, wherein the positioning entity is a location server integrated into a base station.

68. The UE of claim 35, wherein the UE transmits the at least one PSI report to a second UE over the sidelink channel.

69. A user equipment (UE), comprising:  
means for receiving, over a wireless communication network operating in accordance with a first radio access technology (RAT), a configuration to provide at least one positioning state information (PSI) report, the first RAT associated with at least one first positioning technology, the configuration associated with at least one second RAT, at least one second positioning technology, or both to be used to estimate a location of the UE;

means for obtaining at least a first set of positioning measurements using the at least one second RAT, the at least one second positioning technology, or both; and

means for transmitting the at least one PSI report on physical resources allocated for a physical uplink or sidelink channel of the first RAT, the at least one PSI report including at least the first set of positioning measurements.

70. A non-transitory computer-readable medium storing computer-executable instructions, the computer-executable instructions comprising:

at least one instruction instructing a user equipment (UE) to receive, over a wireless communication network operating in accordance with a first radio access technology (RAT), a configuration to provide at least one positioning state information (PSI) report, the first RAT associated with at least one first positioning technology, the configuration associated with at least one second RAT, at least one second positioning technology, or both to be used to estimate a location of the UE;

at least one instruction instructing the UE to obtain at least a first set of positioning measurements using the at least one second RAT, the at least one second positioning technology, or both; and

at least one instruction instructing the UE to transmit the at least one PSI report on physical resources allocated for a physical uplink or sidelink channel of the first RAT, the at least one PSI report including at least the first set of positioning measurements.

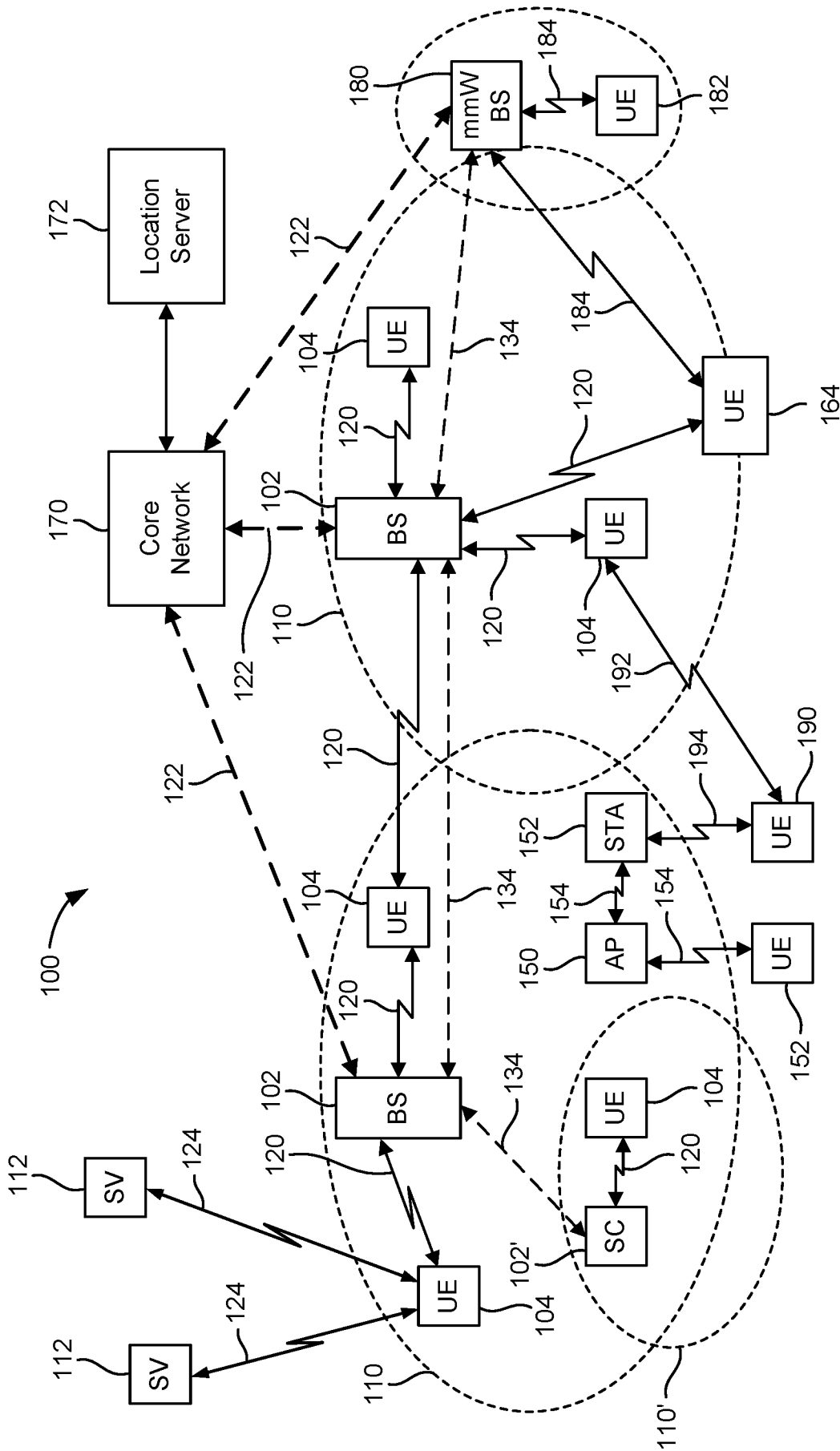


FIG. 1

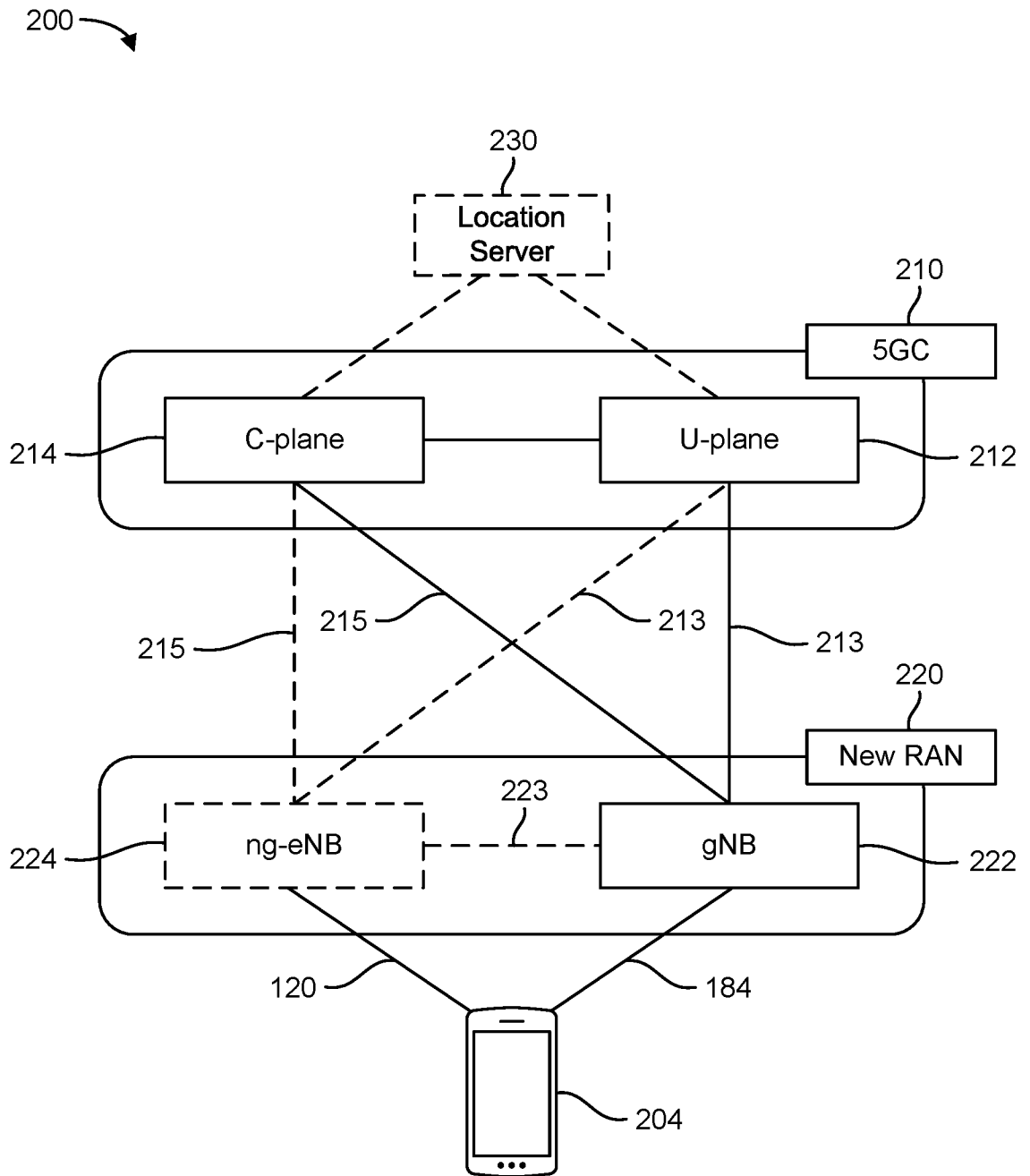


FIG. 2A

250

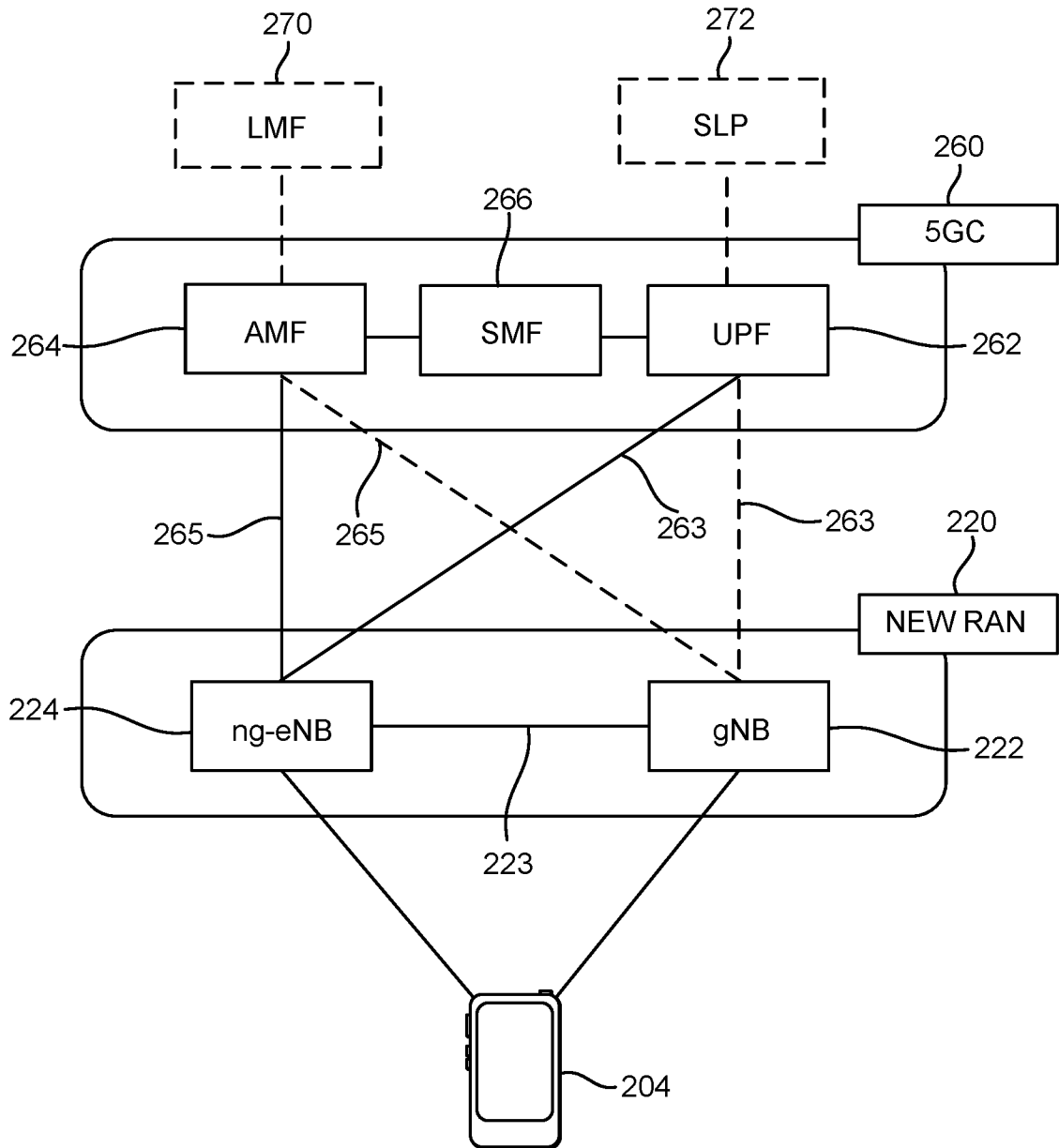


FIG. 2B

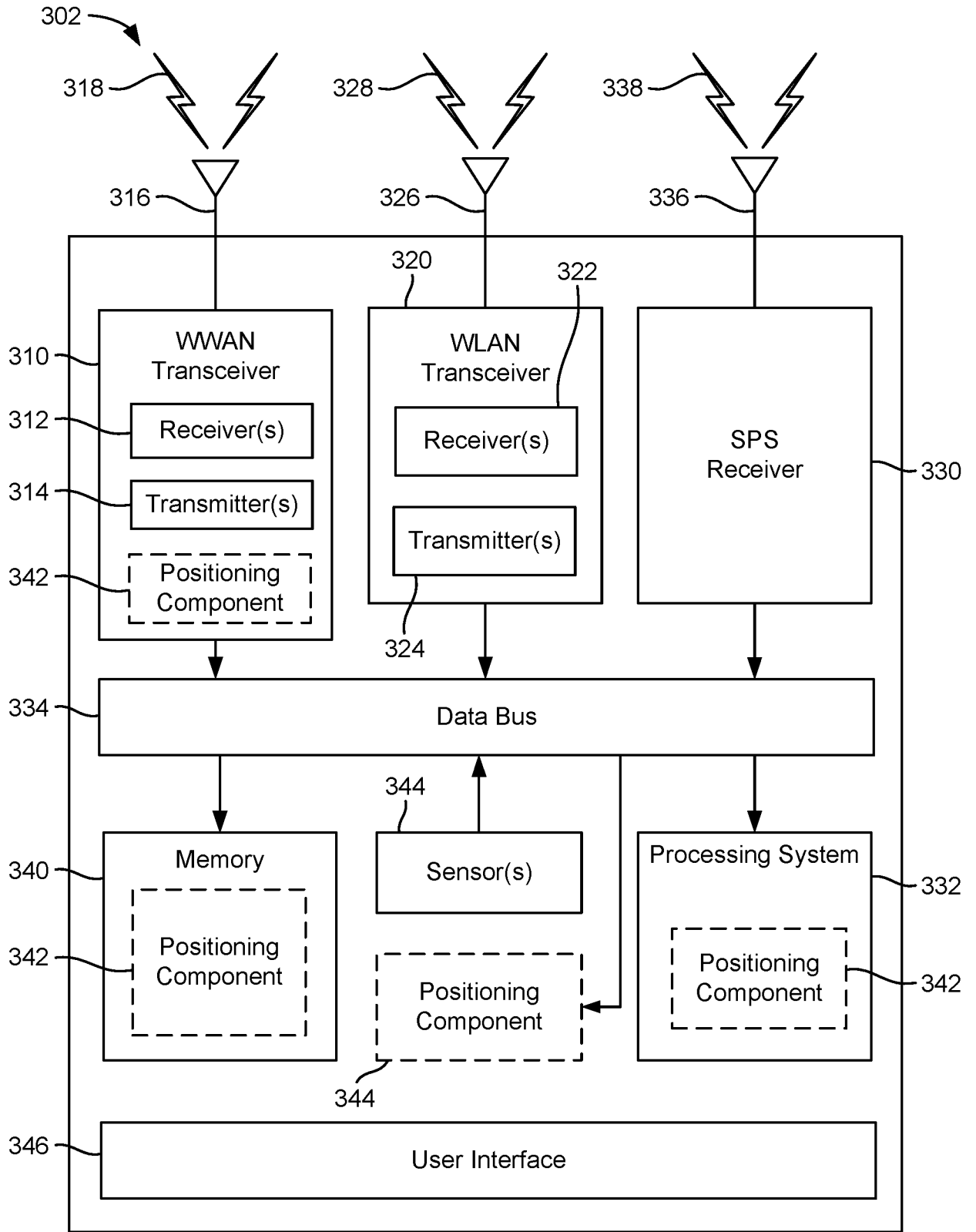


FIG. 3A

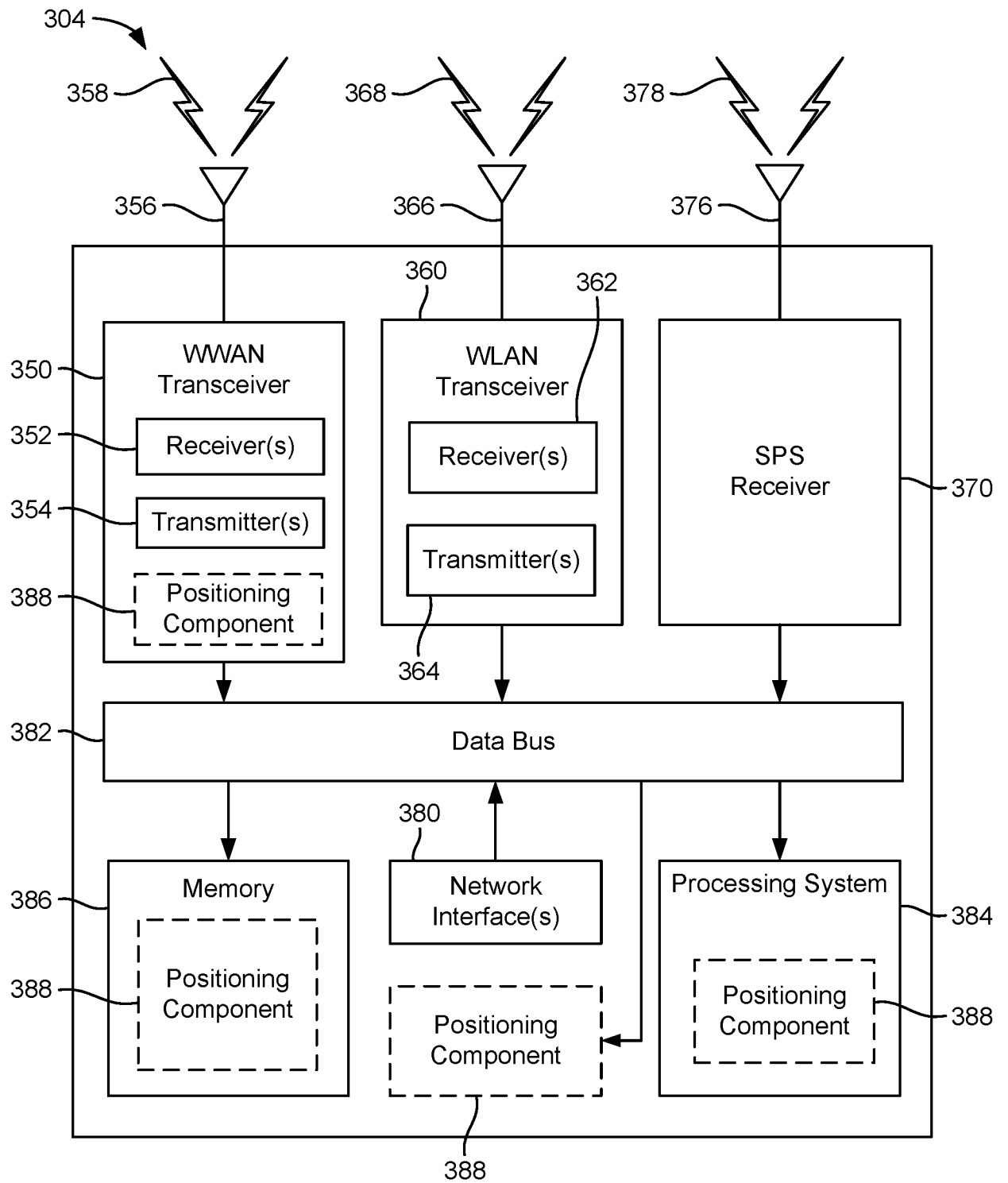


FIG. 3B

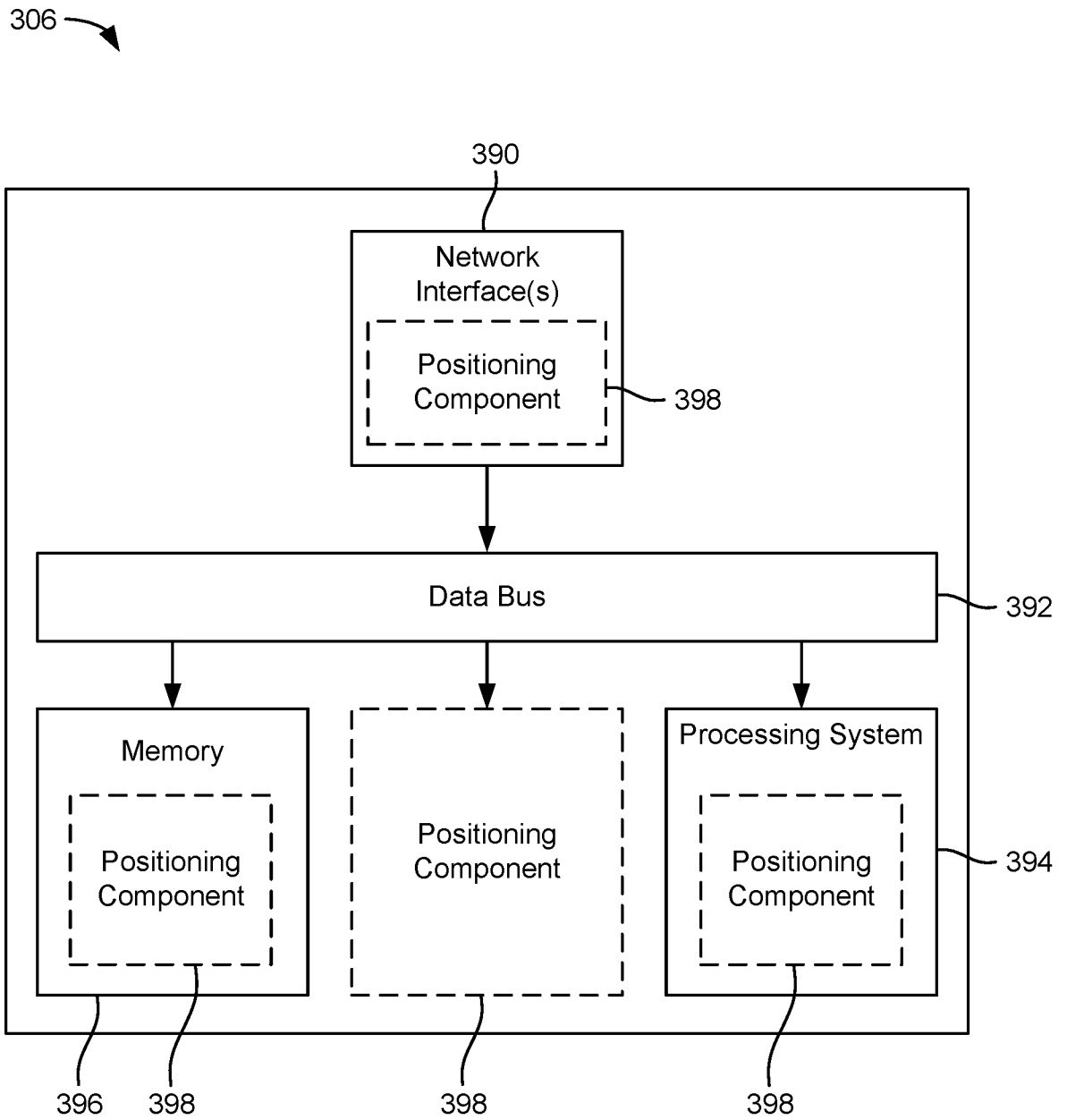
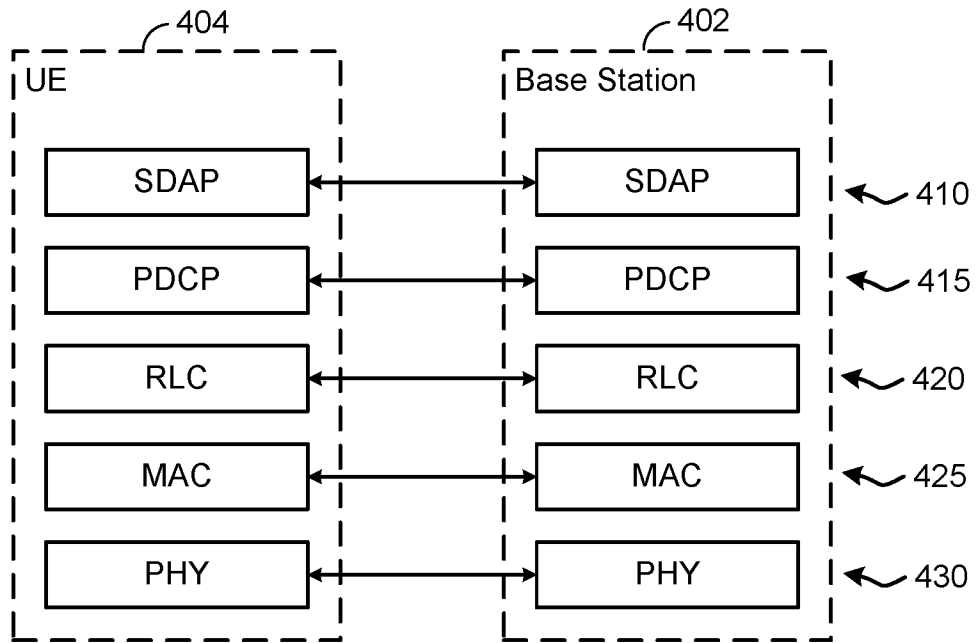
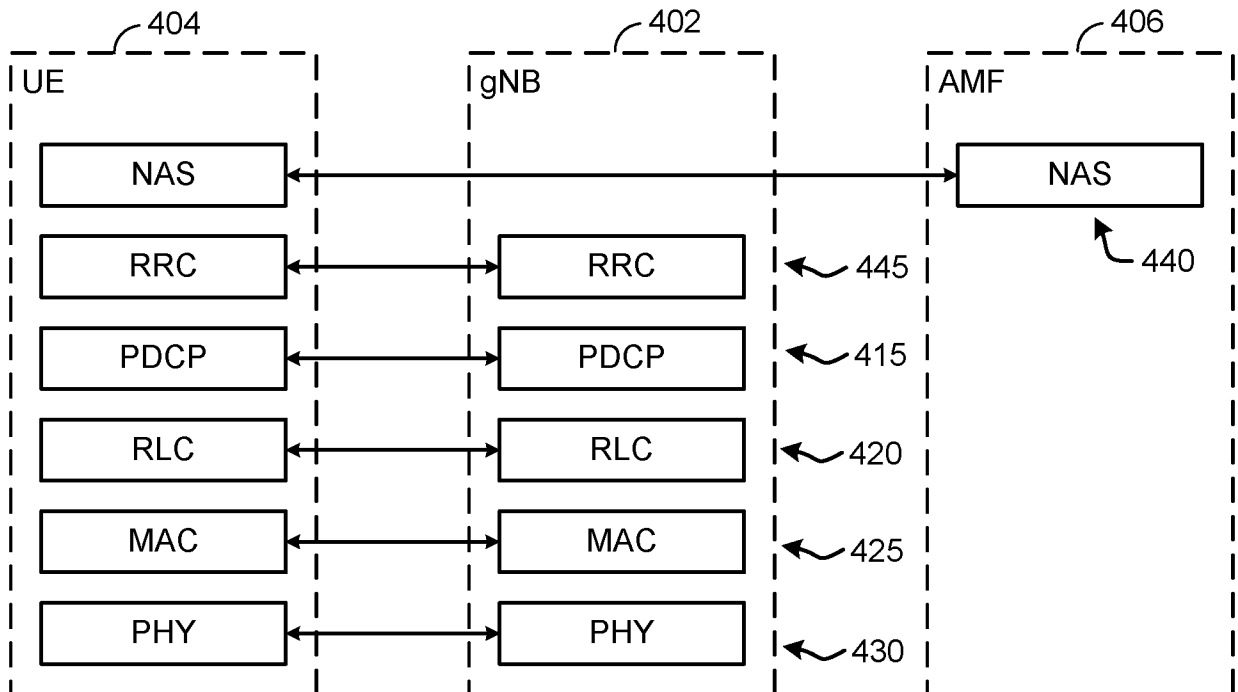


FIG. 3C



**FIG. 4A**  
User Plane Protocol Stack



**FIG. 4B**  
Control Plane Protocol Stack

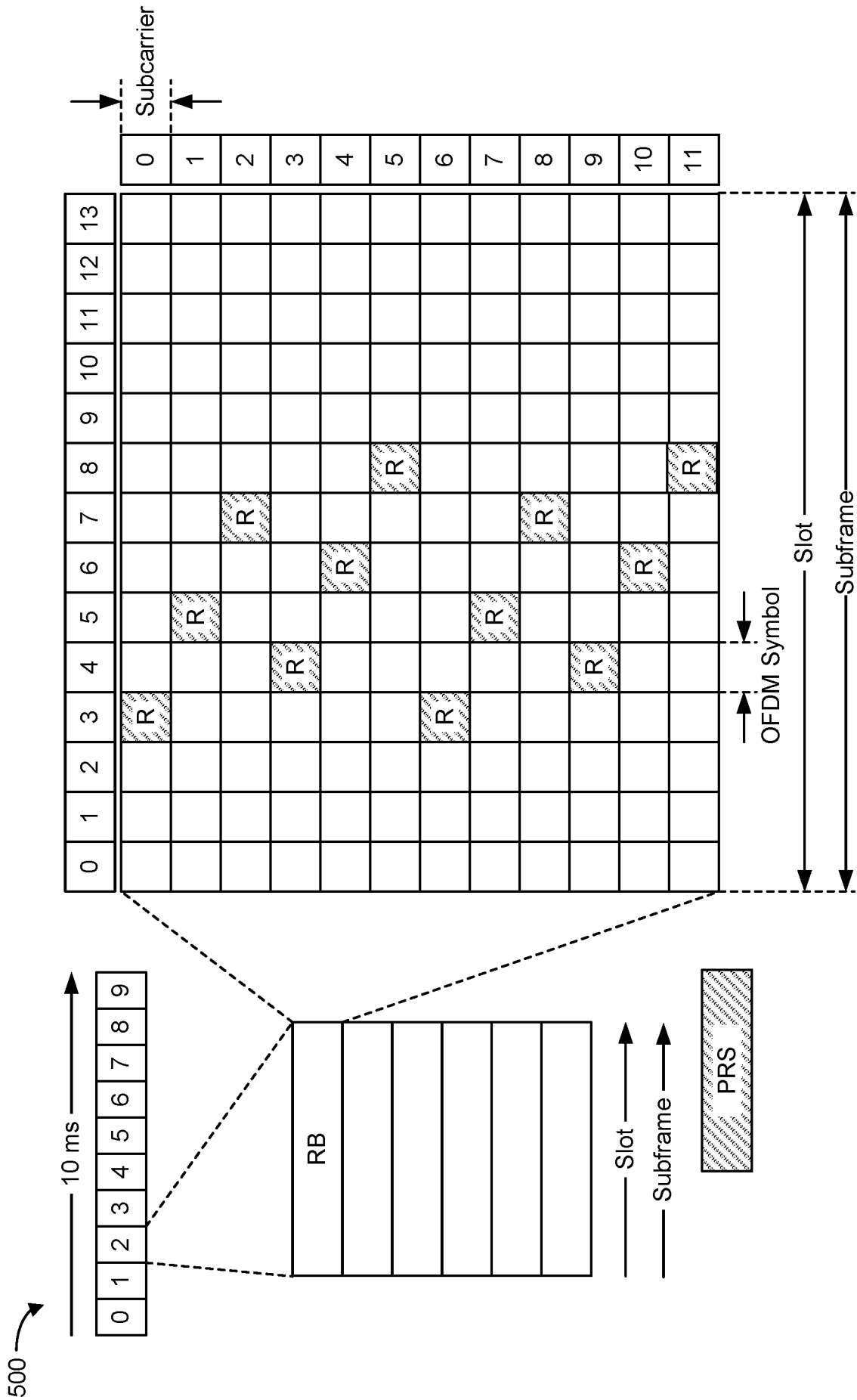


FIG. 5A

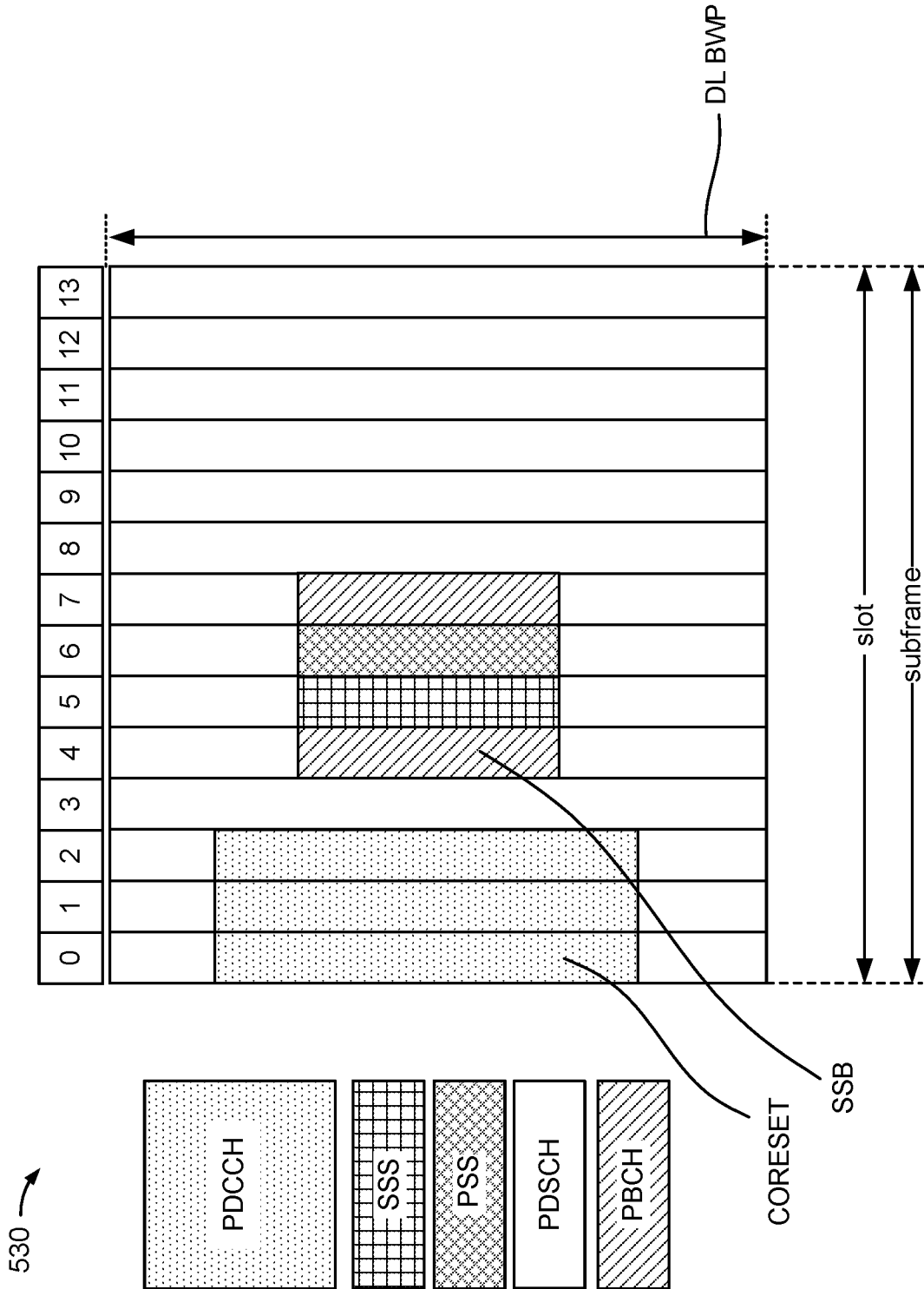


FIG. 5B

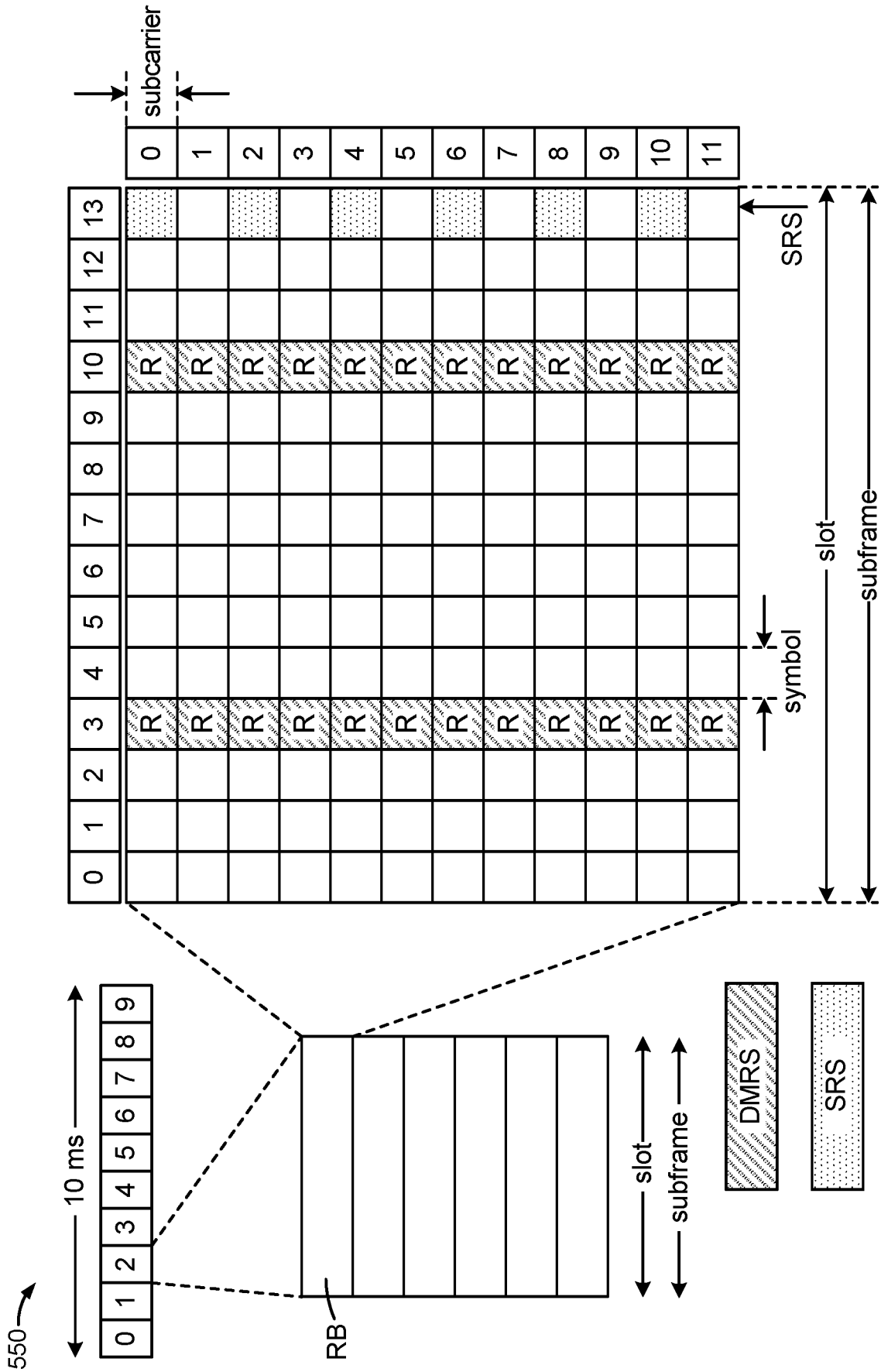


FIG. 5C

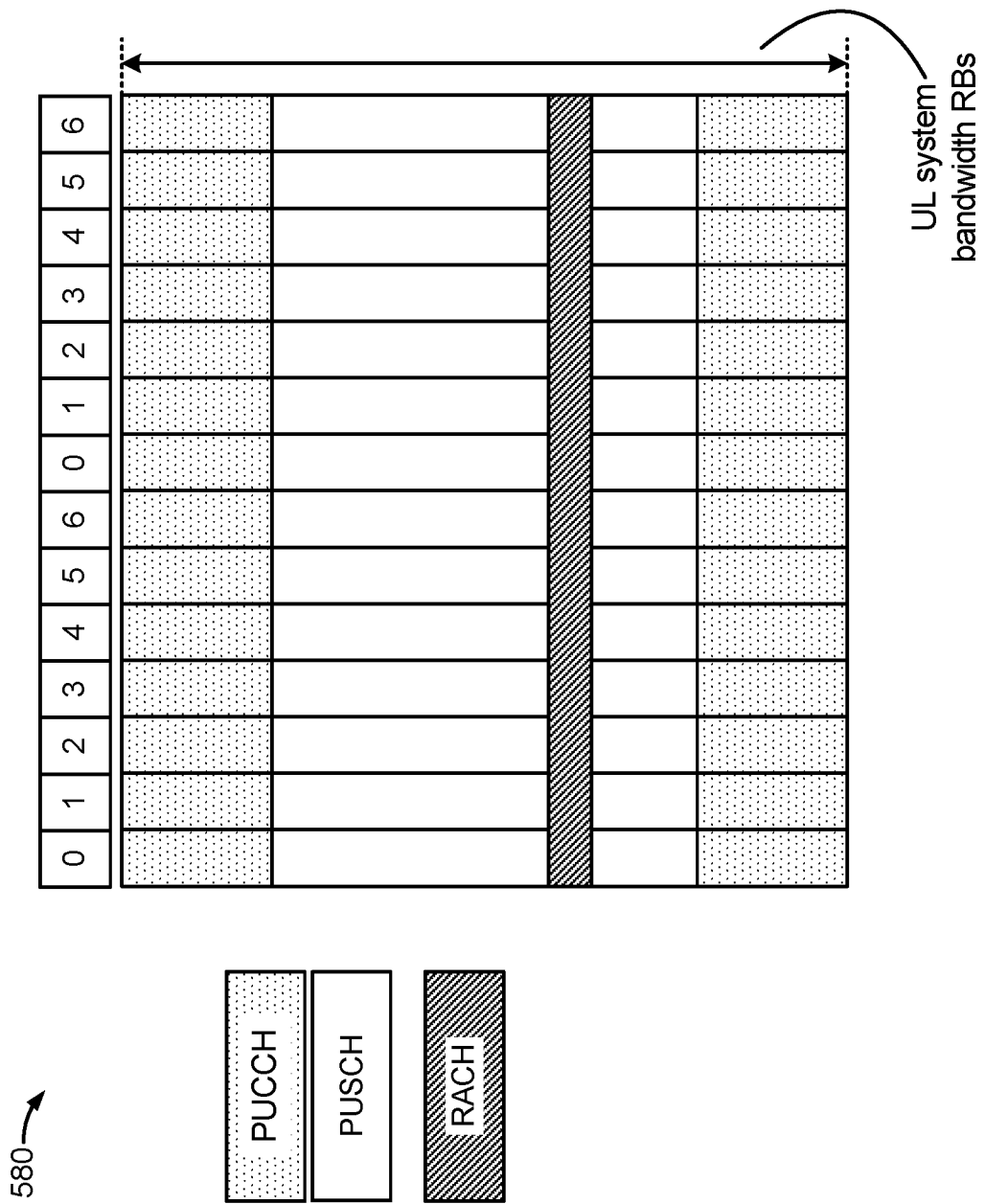


FIG. 5D

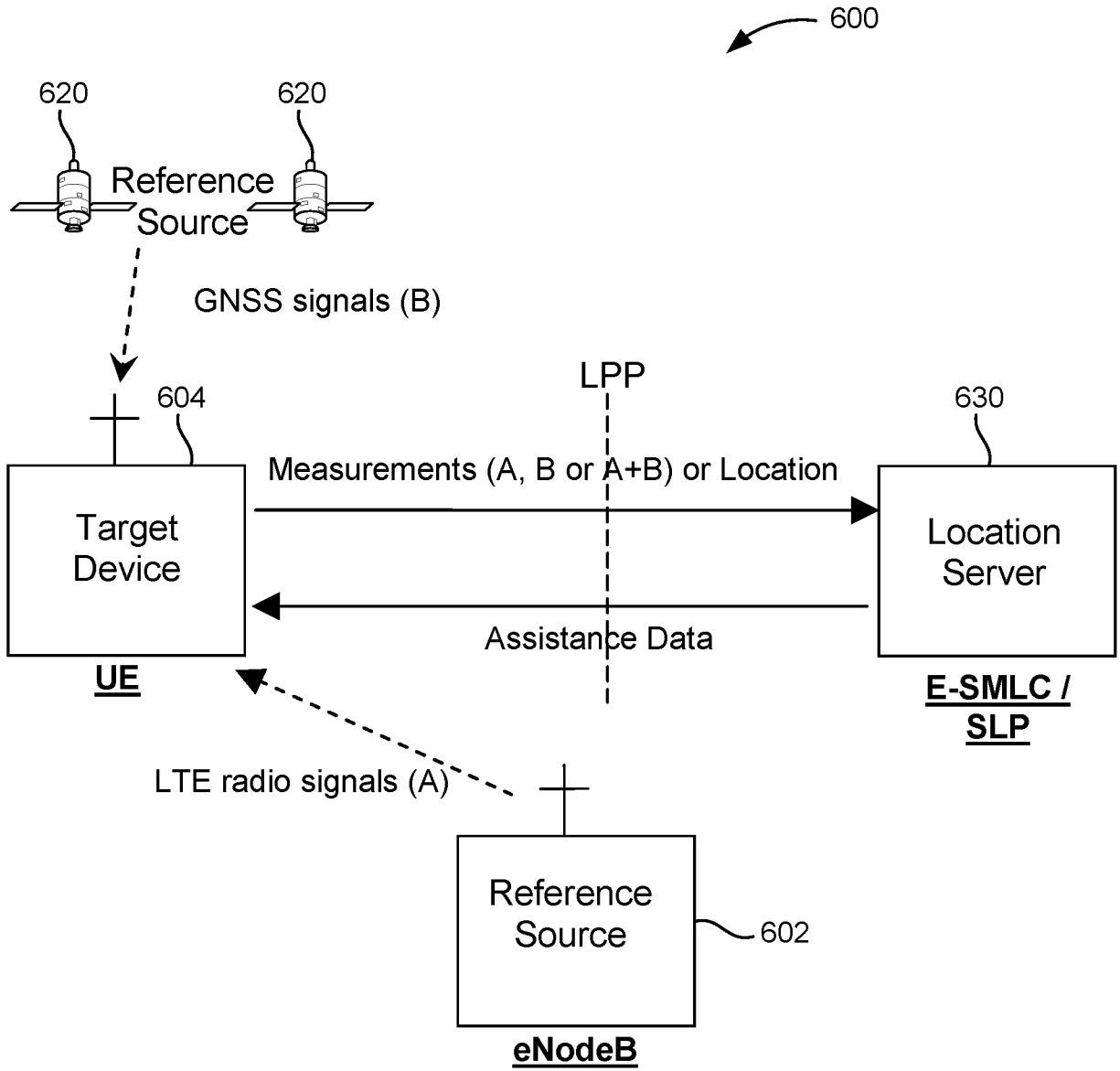


FIG. 6

700 ↗

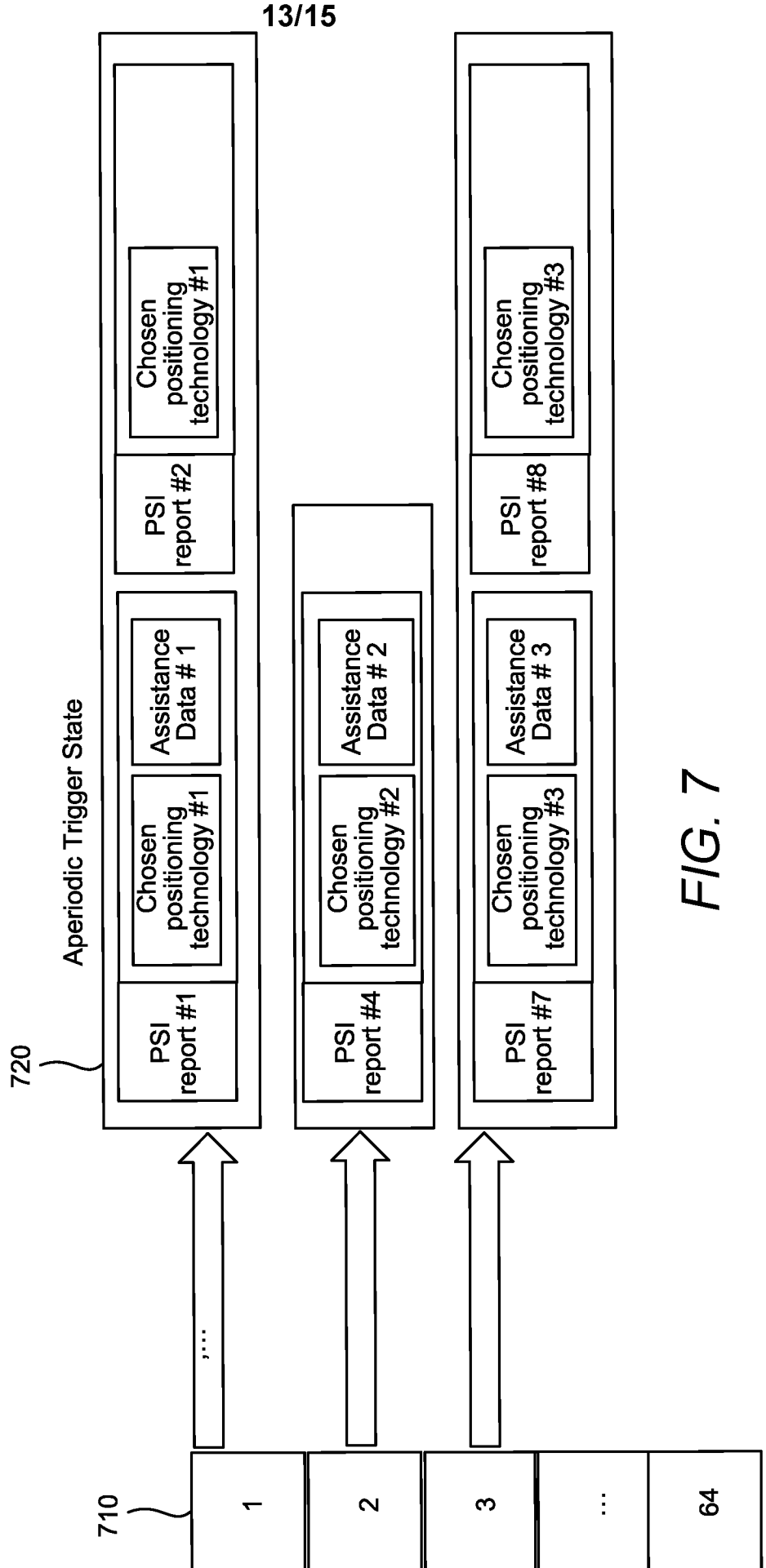


FIG. 7

800 ↗

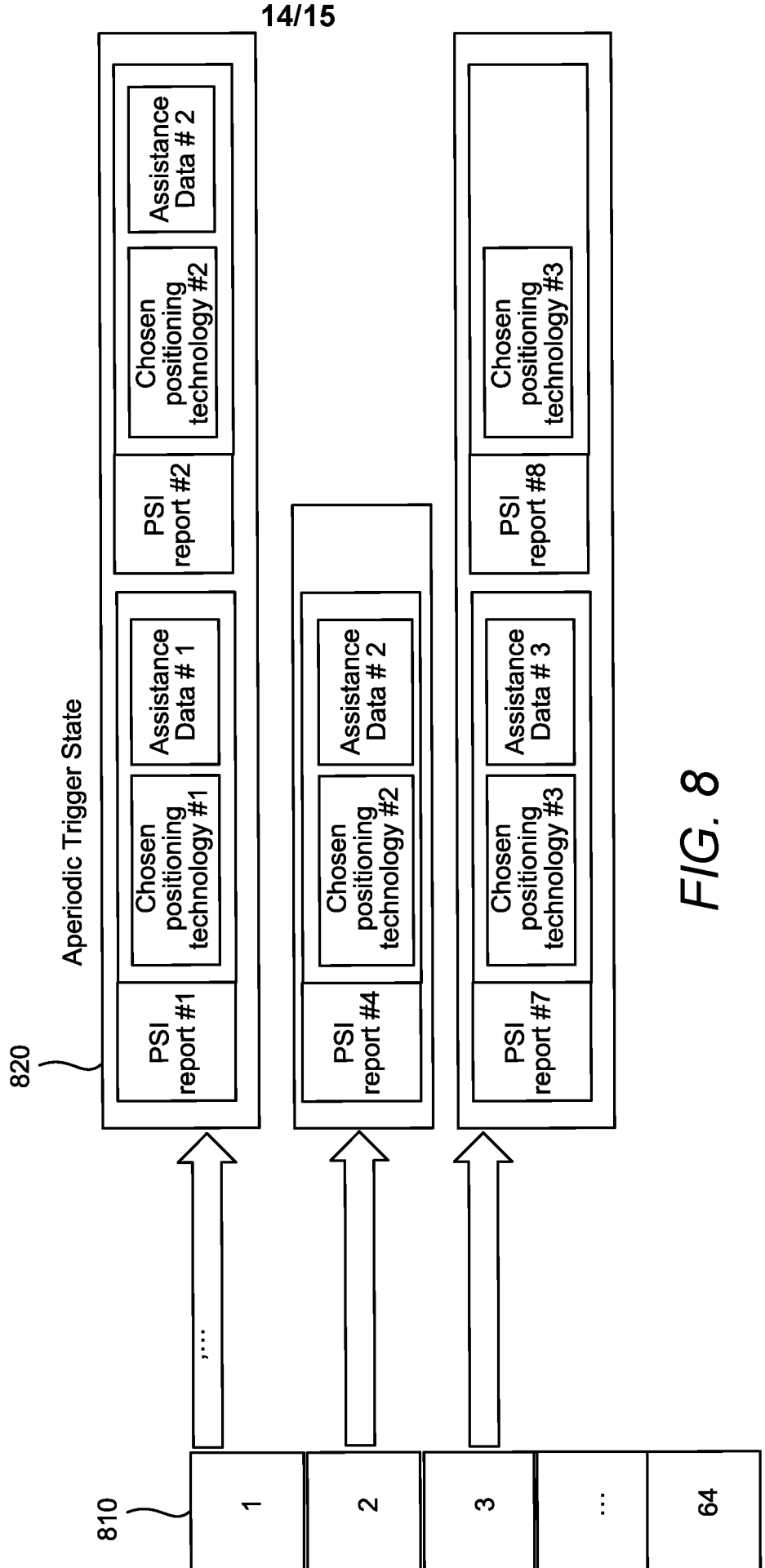


FIG. 8

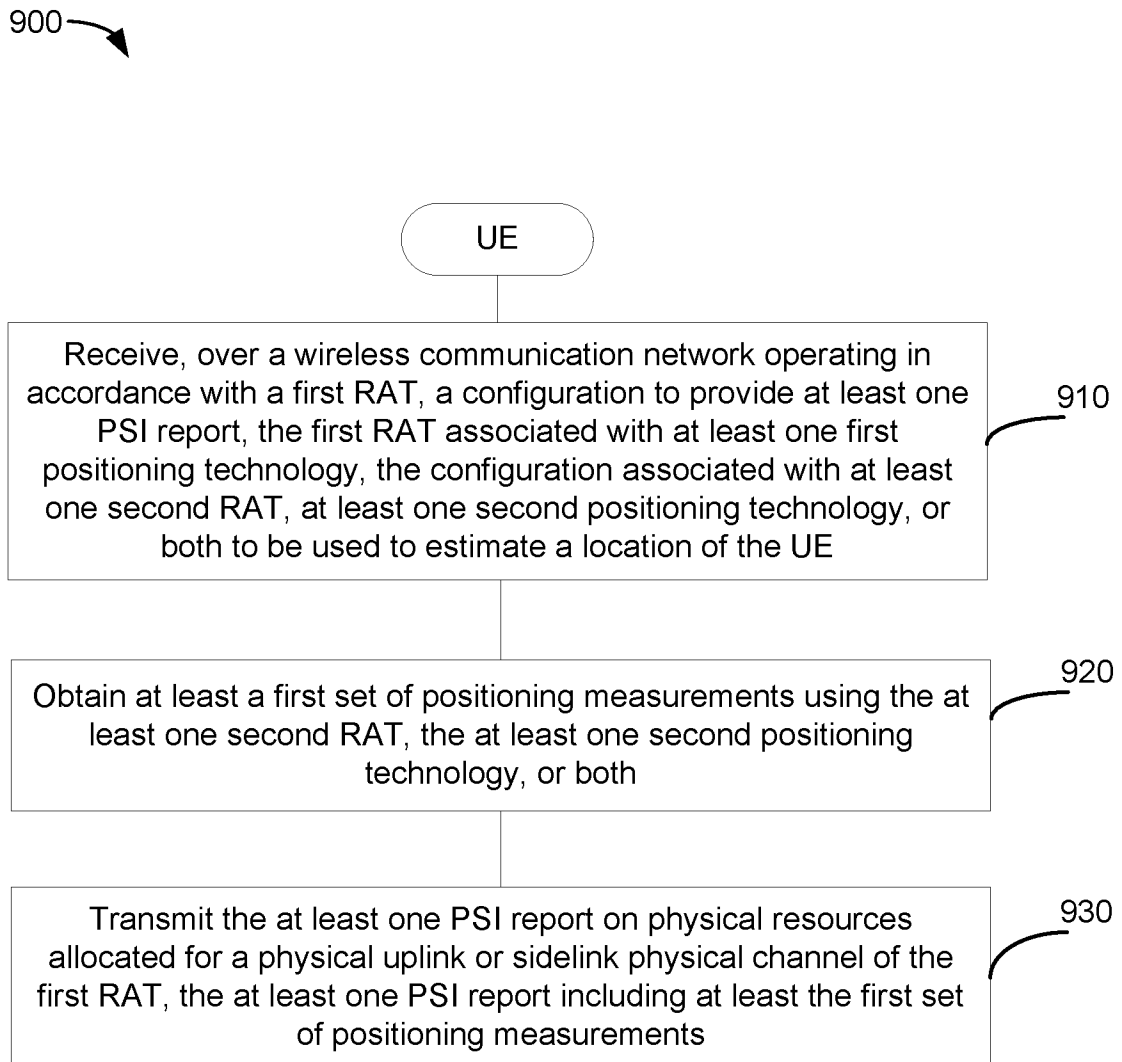


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No  
PCT/US2020/066350

A. CLASSIFICATION OF SUBJECT MATTER  
 INV. H04W64/00 H04L5/00  
 ADD. H04W4/02 H04W24/10 H04W88/06

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 H04L

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2019/074435 A1 (ERICSSON TELEFON AB L M [SE]) 18 April 2019 (2019-04-18) from page 4, second paragraph to page 6, second paragraph, inclusive; from page 9, third paragraph to page 11, second paragraph, inclusive; from page 13, sixth paragraph to page 17, second paragraph, inclusive; from page 20, third paragraph to page 22, third paragraph, inclusive; figures 6 - 11 ----- -/--	1-70

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

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"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  29 March 2021	Date of mailing of the international search report  08/04/2021
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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  Puiulet, Alexandru
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## INTERNATIONAL SEARCH REPORT

International application No  
PCT/US2020/066350

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013/188510 A1 (SIOMINA IANA [SE] ET AL) 25 July 2013 (2013-07-25) paragraph [0074] - paragraph [0077] paragraph [0083] - paragraph [0088] paragraph [0117] - paragraph [0159] paragraph [0220] - paragraph [0230] paragraph [0247] - paragraph [0279] paragraph [0348] - paragraph [0355] -----	1-70
X	US 2019/230619 A1 (CUI JIE [US] ET AL) 25 July 2019 (2019-07-25) paragraph [0025] - paragraph [0030] paragraph [0031] - paragraph [0045] paragraph [0049] - paragraph [0054] paragraph [0153] - paragraph [0164] -----	1-70

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2020/066350

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			US 2021084608 A1 18-03-2021
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