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(71) Applicant: **QUALCOMM INCORPORATED** [US/US]; ATTN: International IP Administration, 5775 Morehouse Drive, San Diego, California 92121-1714 (US).

(72) Inventors: **ZORGUI, Marwen**; QUALCOMM Incorporated, 5775 Morehouse Drive, San Diego, California 92121-1714 (US). **YERRAMALLI, Srinivas**; QUALCOMM Incorporated, 5775 Morehouse Drive, San Diego, California 92121-1714 (US). **HIRZALLAH, Mohammed Ali Mohammed**; QUALCOMM Incorporated, 5775 Morehouse Drive, San Diego, California 92121-1714 (US). **ZHANG, Xiaoxia**; QUALCOMM Incorporated, 5775 Morehouse Drive, San Diego, California 92121-1714 (US).

(74) Agent: **SANDERS, Aaron J.**; MG-IP Law, P.C., d/b/a MUNCY, GEISSLER, OLDS & LOWE, P.C., 125 S. Royal St., Alexandria, Virginia 22314 (US).

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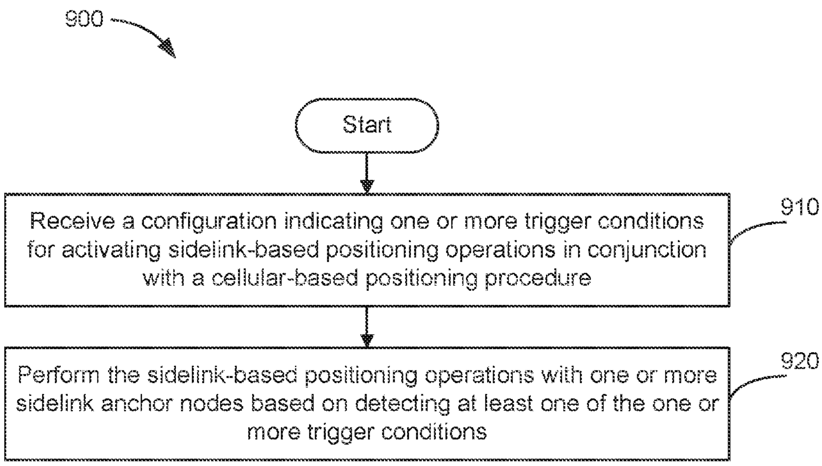

FIG. 9

(57) **Abstract:** Disclosed are techniques for wireless communication. In an aspect, a user equipment (UE) receives a configuration indicating one or more trigger conditions for activating sidelink-based positioning operations in conjunction with a cellular-based positioning procedure, and performs the sidelink-based positioning operations with one or more sidelink anchor nodes based on detecting at least one of the one or more trigger conditions.

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TECHNIQUES FOR JOINT UE AND SIDELINK POSITIONING

BACKGROUND OF THE DISCLOSURE

1. *Field of the Disclosure*

[0001] Aspects of the disclosure relate generally to wireless communications.

2. *Description of the Related Art*

[0002] 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.

[0003] A fifth generation (5G) wireless standard, referred to as New Radio (NR), enables 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 higher data rates as compared to previous standards, more accurate positioning (e.g., based on reference signals for positioning (RS-P), such as downlink, uplink, or sidelink positioning reference signals (PRS)) and other technical enhancements.

[0004] Leveraging the increased data rates and decreased latency of 5G, among other things, vehicle-to-everything (V2X) communication technologies are being implemented to support autonomous driving applications, such as wireless communications between vehicles, between vehicles and the roadside infrastructure, between vehicles and pedestrians, etc.

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 a configuration indicating one or more trigger conditions for activating sidelink-based positioning operations in conjunction with a cellular-based positioning procedure; and performing the sidelink-based positioning operations with one or more sidelink anchor nodes based on detecting at least one of the one or more trigger conditions.

[0007] In an aspect, a method of wireless communication performed by a user equipment (UE) includes engaging in a joint cellular-based and sidelink-based positioning session over a plurality of links between the UE and a plurality of anchor nodes, wherein the plurality of links comprise one or more cellular-based links between the UE and one or more cellular anchor nodes of the plurality of anchor nodes and one or more sidelink-based links between the UE and one or more sidelink anchor nodes of the plurality of nodes; and dropping at least one link of the plurality of links for the joint cellular-based and sidelink-based positioning session based on one or more criteria.

[0008] In an aspect, a method of wireless communication performed by a user equipment (UE) includes engaging in a cellular-based positioning session based on configuration information received from a network entity; performing one or more sidelink-based positioning operations with one or more sidelink anchor nodes during the cellular-based positioning session; and transmitting, to the network entity, a report including the sidelink-based positioning measurements.

[0009] In an aspect, a user equipment (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, a configuration indicating one or more trigger conditions for activating sidelink-based positioning operations in conjunction with a cellular-based positioning procedure; and perform the sidelink-based positioning operations with one or more sidelink anchor nodes based on detecting at least one of the one or more trigger conditions.

[0010] In an aspect, a user equipment (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: engage in a joint cellular-based and sidelink-based positioning session over a plurality of links between the UE and a plurality of anchor nodes, wherein the plurality of links comprises one or more cellular-based links between the UE and one or more cellular anchor nodes of the plurality of anchor nodes and one or more sidelink-based links between the UE and one or more sidelink anchor nodes of the plurality of anchor nodes; and drop at least one link of the plurality of links for the joint cellular-based and sidelink-based positioning session based on one or more criteria.

[0011] In an aspect, a user equipment (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: engage in a cellular-based positioning session based on configuration information received from a network entity; perform one or more sidelink-based positioning operations with one or more sidelink anchor nodes during the cellular-based positioning session; and transmit, via the at least one transceiver, to the network entity, a report including the sidelink-based positioning measurements.

[0012] In an aspect, a user equipment (UE) includes means for receiving a configuration indicating one or more trigger conditions for activating sidelink-based positioning operations in conjunction with a cellular-based positioning procedure; and means for performing the sidelink-based positioning operations with one or more sidelink anchor nodes based on detecting at least one of the one or more trigger conditions.

[0013] In an aspect, a user equipment (UE) includes means for engaging in a joint cellular-based and sidelink-based positioning session over a plurality of links between the UE and a plurality of anchor nodes, wherein the plurality of links comprises one or more cellular-based links between the UE and one or more cellular anchor nodes of the plurality of anchor nodes and one or more sidelink-based links between the UE and one or more sidelink anchor nodes of the plurality of anchor nodes; and means for dropping at least one link of the plurality of links for the joint cellular-based and sidelink-based positioning session based on one or more criteria.

[0014] In an aspect, a user equipment (UE) includes means for engaging in a cellular-based positioning session based on configuration information received from a network entity; means for performing one or more sidelink-based positioning operations with one or more sidelink anchor nodes during the cellular-based positioning session; and means for transmitting, to the network entity, a report including the sidelink-based positioning measurements.

[0015] In an aspect, a non-transitory computer-readable medium stores computer-executable instructions that, when executed by a user equipment (UE), cause the UE to: receive a configuration indicating one or more trigger conditions for activating sidelink-based positioning operations in conjunction with a cellular-based positioning procedure; and perform the sidelink-based positioning operations with one or more sidelink anchor nodes based on detecting at least one of the one or more trigger conditions.

[0016] In an aspect, a non-transitory computer-readable medium stores computer-executable instructions that, when executed by a user equipment (UE), cause the UE to: engage in a joint cellular-based and sidelink-based positioning session over a plurality of links between the UE and a plurality of anchor nodes, wherein the plurality of links comprises one or more cellular-based links between the UE and one or more cellular anchor nodes of the plurality of anchor nodes and one or more sidelink-based links between the UE and one or more sidelink anchor nodes of the plurality of anchor nodes; and drop at least one link of the plurality of links for the joint cellular-based and sidelink-based positioning session based on one or more criteria.

[0017] In an aspect, a non-transitory computer-readable medium stores computer-executable instructions that, when executed by a user equipment (UE), cause the UE to: engage in a cellular-based positioning session based on configuration information received from a network entity; perform one or more sidelink-based positioning operations with one or more sidelink anchor nodes during the cellular-based positioning session; and transmit, to the network entity, a report including the sidelink-based positioning measurements.

[0018] 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

[0019] 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.

[0020] FIG. 1 illustrates an example wireless communications system, according to aspects of the disclosure.

[0021] FIGS. 2A, 2B, and 2C illustrate example wireless network structures, according to aspects of the disclosure.

[0022] FIGS. 3A, 3B, and 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.

[0023] FIG. 4 illustrates examples of various positioning methods supported in New Radio (NR), according to aspects of the disclosure.

[0024] FIG. 5 is a diagram illustrating an example sidelink ranging and positioning procedure, according to aspects of the disclosure.

[0025] FIG. 6 illustrates an example Long-Term Evolution (LTE) positioning protocol (LPP) capability transfer procedure, assistance data transfer procedure, and location information transfer procedure between a target device and a location server, according to aspects of the disclosure.

[0026] FIGS. 7A and 7B illustrate various scenarios of interest for sidelink-only or joint Uu and sidelink positioning, according to aspects of the disclosure.

[0027] FIG. 8 illustrates an example scenario in which a sidelink link is triggered for a Uu-based positioning session, according to aspects of the disclosure.

[0028] FIGS. 9 – 11 illustrate example methods of wireless communication, according to aspects of the disclosure.

DETAILED DESCRIPTION

[0029] 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.

[0030] Various aspects relate generally to joint cellular-based and sidelink-based positioning. Some aspects more specifically relate to adaptive configuration and activation for joint cellular-based and sidelink-based positioning sessions. In some examples, a user equipment (UE) may receive configuration information (e.g., from a location server) indicating one or more trigger conditions for activating sidelink-based positioning operations (e.g., sidelink-based measurements and/or transmissions) in conjunction with a cellular-based positioning procedure. The UE performs the sidelink-based positioning operations with one or more sidelink anchor nodes (e.g., anchor UEs, infrastructure points, etc.) based on detecting at least one of the one or more trigger conditions. In some examples, the one or more trigger conditions may include a number of detectable cellular-based links for the cellular-based positioning procedure being less than a threshold, a change in location or serving cell of the UE, a confidence in a cellular-based position estimate of the UE being less than a threshold, or a combination thereof.

[0031] In some examples, a UE may engage in a joint cellular-based and sidelink-based positioning session over a plurality of links between the UE and a plurality of anchor nodes. The plurality of links may comprise one or more cellular-based links between the UE and one or more cellular anchor nodes and one or more sidelink-based links between the UE and one or more sidelink anchor nodes. The UE drops at least one link of the plurality of links for the joint cellular-based and sidelink-based positioning session based on one or more criteria. In some examples, the one or more criteria may include a determination that the at least one link does not contribute to a position estimate of the UE, a determination that the at least one link is a non-line-of-sight (NLOS) link, a signal strength of the at least one link being less than a threshold, power saving considerations at the UE, or a combination thereof.

[0032] In some examples, a UE may engage in a cellular-based positioning session based on configuration information received from a location server. The UE also opportunistically performs one or more sidelink-based positioning operations with one or more sidelink anchor nodes during the cellular-based positioning session. Subsequently, the UE transmits, to the location server, a report including the sidelink-based positioning measurements. The report may be the positioning report including the results of the cellular-based positioning session, or a separate report.

[0033] Particular aspects of the subject matter described in this disclosure can be implemented to realize one or more of the following potential advantages. In some examples, by utilizing the one or more trigger conditions for activating sidelink-based positioning operations, or by dropping at least one link of the joint cellular-based and sidelink-based positioning session, or by opportunistically performing one or more sidelink-based positioning operations, the described techniques can be used to improve over-the-air (OTA) resource utilization while maintaining or even improving positioning performance.

[0034] 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.

[0035] 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.

[0036] 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.

[0037] As used herein, the terms "user equipment" (UE), "vehicle UE" (V-UE), "pedestrian UE" (P-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., vehicle on-board computer, vehicle navigation device, mobile phone, router, tablet computer, laptop computer, asset locating 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 a "mobile device," 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 terminal," a "mobile station," or variations thereof.

[0038] A V-UE is a type of UE and may be any in-vehicle wireless communication device, such as a navigation system, a warning system, a heads-up display (HUD), an on-board computer, an in-vehicle infotainment system, an automated driving system (ADS), an advanced driver assistance system (ADAS), etc. Alternatively, a V-UE may be a portable wireless communication device (e.g., a cell phone, tablet computer, etc.) that is carried by the driver of the vehicle or a passenger in the vehicle. The term "V-UE" may refer to the in-vehicle wireless communication device or the vehicle itself, depending on the context. A P-UE is a type of UE and may be a portable wireless communication device that is carried by a pedestrian (i.e., a user that is not driving or riding in a vehicle). 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 Institute of Electrical and Electronics Engineers (IEEE) 802.11, etc.) and so on.

[0039] 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 UL / reverse or DL / forward traffic channel.

[0040] 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 radio frequency (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.

[0041] 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 RF signals to UEs to be measured by the UEs and/or may receive and measure signals transmitted by the UEs. Such base stations may be referred to as positioning beacons (e.g., when transmitting RF signals to UEs) and/or as location measurement units (e.g., when receiving and measuring RF signals from UEs).

[0042] 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. As used herein, an RF signal may also be referred to as a "wireless signal" or simply a "signal" where it is clear from the context that the term "signal" refers to a wireless signal or an RF signal.

[0043] **FIG. 1** illustrates an example wireless communications system 100, according to aspects of the disclosure. The wireless communications system 100 (which may also be referred to as a wireless wide area network (WWAN)) may include various base stations 102 (labelled "BS") 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 stations 102 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.

[0044] The base stations 102 may collectively form a RAN and interface with a core network 170 (e.g., an evolved packet core (EPC) or 5G core (5GC)) through backhaul links 122, and through the core network 170 to one or more location servers 172 (e.g., a location management function (LMF) or a secure user plane location (SUPL) location platform (SLP)). The location server(s) 172 may be part of core network 170 or may be external to core network 170. A location server 172 may be integrated with a base station 102. A UE 104 may communicate with a location server 172 directly or indirectly. For example, a UE 104 may communicate with a location server 172 via the base station 102 that is currently serving that UE 104. A UE 104 may also communicate with a location server 172 through another path, such as via an application server (not shown), via another network, such as via a wireless local area network (WLAN) access point (AP) (e.g., AP 150 described below), and so on. For signaling purposes, communication between a UE 104 and a location server 172 may be represented as an indirect connection (e.g., through the core network 170, etc.) or a direct connection (e.g., as shown via direct connection 128), with the intervening nodes (if any) omitted from a signaling diagram for clarity.

[0045] 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.

[0046] 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), an enhanced cell identifier (ECI), a virtual cell identifier (VCI), a cell global identifier (CGI), etc.) 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 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.

[0047] 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' (labelled "SC" for "small cell") 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).

[0048] 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 (DL) (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).

[0049] 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.

[0050] 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.

[0051] The wireless communications system 100 may further include a mmW base station 180 that may operate in millimeter wave (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.

[0052] 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.

[0053] 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 second reference RF signal on a second beam can be derived from information about a source reference RF signal on a source beam. Thus, 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 second 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 second 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 second 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 second reference RF signal transmitted on the same channel.

[0054] 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.

[0055] Transmit and receive beams may be spatially related. A spatial relation means that parameters for a second beam (e.g., a transmit or receive beam) for a second reference signal can be derived from information about a first beam (e.g., a receive beam or a transmit beam) for a first reference signal. For example, a UE may use a particular receive beam to receive a reference downlink reference signal (e.g., synchronization signal block (SSB)) from a base station. The UE can then form a transmit beam for sending an uplink reference signal (e.g., sounding reference signal (SRS)) to that base station based on the parameters of the receive beam.

[0056] 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.

[0057] The electromagnetic spectrum is often subdivided, based on frequency/wavelength, into various classes, bands, channels, etc. In 5G NR two initial operating bands have been identified as frequency range designations FR1 (410 MHz – 7.125 GHz) and FR2 (24.25 GHz – 52.6 GHz). It should be understood that although a portion of FR1 is greater than 6 GHz, FR1 is often referred to (interchangeably) as a "Sub-6 GHz" band in various documents and articles. A similar nomenclature issue sometimes occurs with regard to FR2, which is often referred to (interchangeably) as a "millimeter wave" band in documents and articles, despite being different from the extremely high frequency (EHF) band (30 GHz – 300 GHz) which is identified by the International Telecommunications Union (ITU) as a "millimeter wave" band.

[0058] The frequencies between FR1 and FR2 are often referred to as mid-band frequencies. Recent 5G NR studies have identified an operating band for these mid-band frequencies as frequency range designation FR3 (7.125 GHz – 24.25 GHz). Frequency bands falling within FR3 may inherit FR1 characteristics and/or FR2 characteristics, and thus may effectively extend features of FR1 and/or FR2 into mid-band frequencies. In addition, higher frequency bands are currently being explored to extend 5G NR operation beyond 52.6 GHz. For example, three higher operating bands have been identified as frequency range designations FR4a or FR4-1 (52.6 GHz – 71 GHz), FR4 (52.6 GHz – 114.25 GHz), and FR5 (114.25 GHz – 300 GHz). Each of these higher frequency bands falls within the EHF band.

[0059] With the above aspects in mind, unless specifically stated otherwise, it should be understood that the term "sub-6 GHz" or the like if used herein may broadly represent frequencies that may be less than 6 GHz, may be within FR1, or may include mid-band frequencies. Further, unless specifically stated otherwise, it should be understood that the term "millimeter wave" or the like if used herein may broadly represent frequencies that may include mid-band frequencies, may be within FR2, FR4, FR4-a or FR4-1, and/or FR5, or may be within the EHF band.

[0060] 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.

[0061] 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.

[0062] In the example of FIG. 1, any of the illustrated UEs (shown in FIG. 1 as a single UE 104 for simplicity) may receive signals 124 from one or more Earth orbiting space vehicles (SVs) 112 (e.g., satellites). In an aspect, the SVs 112 may be part of a satellite positioning system that a UE 104 can use as an independent source of location information. A satellite positioning system 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 positioning signals (e.g., 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. A UE 104 may include one or more dedicated receivers specifically designed to receive signals 124 for deriving geo location information from the SVs 112.

[0063] In a satellite positioning system, the use of 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, a satellite positioning system may include any combination of one or more global and/or regional navigation satellites associated with such one or more satellite positioning systems.

[0064] In an aspect, SVs 112 may additionally or alternatively be part of one or more non-terrestrial networks (NTNs). In an NTN, an SV 112 is connected to an earth station (also referred to as a ground station, NTN gateway, or gateway), which in turn is connected to an element in a 5G network, such as a modified base station 102 (without a terrestrial antenna) or a network node in a 5GC. This element would in turn provide access to other elements in the 5G network and ultimately to entities external to the 5G network, such as

Internet web servers and other user devices. In that way, a UE 104 may receive communication signals (e.g., signals 124) from an SV 112 instead of, or in addition to, communication signals from a terrestrial base station 102.

[0065] Leveraging the increased data rates and decreased latency of NR, among other things, vehicle-to-everything (V2X) communication technologies are being implemented to support intelligent transportation systems (ITS) applications, such as wireless communications between vehicles (vehicle-to-vehicle (V2V)), between vehicles and the roadside infrastructure (vehicle-to-infrastructure (V2I)), and between vehicles and pedestrians (vehicle-to-pedestrian (V2P)). The goal is for vehicles to be able to sense the environment around them and communicate that information to other vehicles, infrastructure, and personal mobile devices. Such vehicle communication will enable safety, mobility, and environmental advancements that current technologies are unable to provide. Once fully implemented, the technology is expected to reduce unimpaired vehicle crashes by 80%.

[0066] Still referring to FIG. 1, the wireless communications system 100 may include multiple V-UEs 160 that may communicate with base stations 102 over communication links 120 using the Uu interface (i.e., the air interface between a UE and a base station). V-UEs 160 may also communicate directly with each other over a wireless sidelink 162, with a roadside unit (RSU) 164 (a roadside access point) over a wireless sidelink 166, or with sidelink-capable UEs 104 over a wireless sidelink 168 using the PC5 interface (i.e., the air interface between sidelink-capable UEs). A wireless sidelink (or just "sidelink") is an adaptation of the core cellular (e.g., LTE, NR) standard that allows direct communication between two or more UEs without the communication needing to go through a base station. Sidelink communication may be unicast or multicast, and may be used for device-to-device (D2D) media-sharing, V2V communication, V2X communication (e.g., cellular V2X (cV2X) communication, enhanced V2X (eV2X) communication, etc.), emergency rescue applications, etc. One or more of a group of V-UEs 160 utilizing sidelink communications may be within the geographic coverage area 110 of a base station 102. Other V-UEs 160 in such a group may be outside the geographic coverage area 110 of a base station 102 or be otherwise unable to receive transmissions from a base station 102. In some cases, groups of V-UEs 160 communicating via sidelink communications may utilize a one-to-many (1:M) system in which each V-UE 160 transmits to every other V-

UE 160 in the group. In some cases, a base station 102 facilitates the scheduling of resources for sidelink communications. In other cases, sidelink communications are carried out between V-UEs 160 without the involvement of a base station 102.

[0067] In an aspect, the sidelinks 162, 166, 168 may operate over a wireless communication medium of interest, which may be shared with other wireless communications between other vehicles and/or infrastructure access points, as well as other RATs. A "medium" may be composed of one or more time, frequency, and/or space communication resources (e.g., encompassing one or more channels across one or more carriers) associated with wireless communication between one or more transmitter / receiver pairs.

[0068] In an aspect, the sidelinks 162, 166, 168 may be cV2X links. A first generation of cV2X has been standardized in LTE, and the next generation is expected to be defined in NR. cV2X is a cellular technology that also enables device-to-device communications. In the U.S. and Europe, cV2X is expected to operate in the licensed ITS band in sub-6GHz. Other bands may be allocated in other countries. Thus, as a particular example, the medium of interest utilized by sidelinks 162, 166, 168 may correspond to at least a portion of the licensed ITS frequency band of sub-6GHz. However, the present disclosure is not limited to this frequency band or cellular technology.

[0069] In an aspect, the sidelinks 162, 166, 168 may be dedicated short-range communications (DSRC) links. DSRC is a one-way or two-way short-range to medium-range wireless communication protocol that uses the wireless access for vehicular environments (WAVE) protocol, also known as IEEE 802.11p, for V2V, V2I, and V2P communications. IEEE 802.11p is an approved amendment to the IEEE 802.11 standard and operates in the licensed ITS band of 5.9 GHz (5.85-5.925 GHz) in the U.S. In Europe, IEEE 802.11p operates in the ITS G5A band (5.875 – 5.905 MHz). Other bands may be allocated in other countries. The V2V communications briefly described above occur on the Safety Channel, which in the U.S. is typically a 10 MHz channel that is dedicated to the purpose of safety. The remainder of the DSRC band (the total bandwidth is 75 MHz) is intended for other services of interest to drivers, such as road rules, tolling, parking automation, etc. Thus, as a particular example, the mediums of interest utilized by sidelinks 162, 166, 168 may correspond to at least a portion of the licensed ITS frequency band of 5.9 GHz.

[0070] Alternatively, the medium of interest may correspond to at least a portion of an unlicensed frequency band shared among various RATs. Although different licensed frequency bands have been reserved for certain communication systems (e.g., by a government entity such as the Federal Communications Commission (FCC) in the United States), these systems, in particular those employing small cell access points, have recently extended operation into unlicensed frequency bands such as the Unlicensed National Information Infrastructure (U-NII) band used by wireless local area network (WLAN) technologies, most notably IEEE 802.11x WLAN technologies generally referred to as "Wi-Fi." Example systems of this type include different variants of CDMA systems, TDMA systems, FDMA systems, orthogonal FDMA (OFDMA) systems, single-carrier FDMA (SC-FDMA) systems, and so on.

[0071] Communications between the V-UEs 160 are referred to as V2V communications, communications between the V-UEs 160 and the one or more RSUs 164 are referred to as V2I communications, and communications between the V-UEs 160 and one or more UEs 104 (where the UEs 104 are P-UEs) are referred to as V2P communications. The V2V communications between V-UEs 160 may include, for example, information about the position, speed, acceleration, heading, and other vehicle data of the V-UEs 160. The V2I information received at a V-UE 160 from the one or more RSUs 164 may include, for example, road rules, parking automation information, etc. The V2P communications between a V-UE 160 and a UE 104 may include information about, for example, the position, speed, acceleration, and heading of the V-UE 160 and the position, speed (e.g., where the UE 104 is carried by a user on a bicycle), and heading of the UE 104.

[0072] Note that although FIG. 1 only illustrates two of the UEs as V-UEs (V-UEs 160), any of the illustrated UEs (e.g., UEs 104, 152, 182, 190) may be V-UEs. In addition, while only the V-UEs 160 and a single UE 104 have been illustrated as being connected over a sidelink, any of the UEs illustrated in FIG. 1, whether V-UEs, P-UEs, etc., may be capable of sidelink communication. Further, although only UE 182 was described as being capable of beam forming, any of the illustrated UEs, including V-UEs 160, may be capable of beam forming. Where V-UEs 160 are capable of beam forming, they may beam form towards each other (i.e., towards other V-UEs 160), towards RSUs 164, towards other UEs (e.g., UEs 104, 152, 182, 190), etc. Thus, in some cases, V-UEs 160 may utilize beamforming over sidelinks 162, 166, and 168.

[0073] 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. 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. As another example, the D2D P2P links 192 and 194 may be sidelinks, as described above with reference to sidelinks 162, 166, and 168.

[0074] **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 (C-plane) functions 214 (e.g., UE registration, authentication, network access, gateway selection, etc.) and user plane (U-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 user plane functions 212 and control plane functions 214, respectively. 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, a Next Generation RAN (NG-RAN) 220 may have one or more gNBs 222, while other configurations include one or more of both ng-eNBs 224 and gNBs 222. Either (or both) gNB 222 or ng-eNB 224 may communicate with one or more UEs 204 (e.g., any of the UEs described herein).

[0075] Another optional aspect may include a location server 230, which may be in communication with the 5GC 210 to provide location assistance for UE(s) 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 (e.g., a third party server, such as an original equipment manufacturer (OEM) server or service server).

[0076] **FIG. 2B** illustrates another example wireless network structure 240. A 5GC 260 (which may correspond to 5GC 210 in FIG. 2A) 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). The functions of the AMF 264 include registration management, connection management, reachability management, mobility management, lawful interception, transport for session management (SM) messages between one or more UEs 204 (e.g., any of the UEs described herein) 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 NG-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.

[0077] 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 an SLP 272.

[0078] 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.

[0079] 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, NG-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 (e.g., third-party server 274) over a user plane (e.g., using protocols intended to carry voice and/or data like the transmission control protocol (TCP) and/or IP).

[0080] Yet another optional aspect may include a third-party server 274, which may be in communication with the LMF 270, the SLP 272, the 5GC 260 (e.g., via the AMF 264 and/or the UPF 262), the NG-RAN 220, and/or the UE 204 to obtain location information (e.g., a location estimate) for the UE 204. As such, in some cases, the third-party server 274 may be referred to as a location services (LCS) client or an external client. The third-party server 274 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.

[0081] User plane interface 263 and control plane interface 265 connect the 5GC 260, and specifically the UPF 262 and AMF 264, respectively, to one or more gNBs 222 and/or ng-eNBs 224 in the NG-RAN 220. The interface between gNB(s) 222 and/or ng-eNB(s) 224 and the AMF 264 is referred to as the "N2" interface, and the interface between gNB(s) 222 and/or ng-eNB(s) 224 and the UPF 262 is referred to as the "N3" interface. The gNB(s) 222 and/or ng-eNB(s) 224 of the NG-RAN 220 may communicate directly with each other via backhaul connections 223, referred to as the "Xn-C" interface. One or more of gNBs 222 and/or ng-eNBs 224 may communicate with one or more UEs 204 over a wireless interface, referred to as the "Uu" interface.

[0082] The functionality of a gNB 222 may be divided between a gNB central unit (gNB-CU) 226, one or more gNB distributed units (gNB-DUs) 228, and one or more gNB radio units (gNB-RUs) 229. A gNB-CU 226 is a logical node that includes the base station functions of transferring user data, mobility control, radio access network sharing, positioning, session management, and the like, except for those functions allocated exclusively to the gNB-DU(s) 228. More specifically, the gNB-CU 226 generally host the radio resource control (RRC), service data adaptation protocol (SDAP), and packet data convergence protocol (PDCP) protocols of the gNB 222. A gNB-DU 228 is a logical node that generally hosts the radio link control (RLC) and medium access control (MAC) layer of the gNB 222. Its operation is controlled by the gNB-CU 226. One gNB-DU 228 can support one or more cells, and one cell is supported by only one gNB-DU 228. The interface 232 between the gNB-CU 226 and the one or more gNB-DUs 228 is referred to as the "F1" interface. The physical (PHY) layer functionality of a gNB 222 is generally hosted by one or more standalone gNB-RUs 229 that perform functions such as power amplification and signal transmission/reception. The interface between a gNB-DU 228 and a gNB-RU 229 is referred to as the "Fx" interface. Thus, a UE 204 communicates with the gNB-CU 226 via the RRC, SDAP, and PDCP layers, with a gNB-DU 228 via the RLC and MAC layers, and with a gNB-RU 229 via the PHY layer.

[0083] Deployment of communication systems, such as 5G NR systems, may be arranged in multiple manners with various components or constituent parts. In a 5G NR system, or network, a network node, a network entity, a mobility element of a network, a RAN node, a core network node, a network element, or a network equipment, such as a base station, or one or more units (or one or more components) performing base station functionality, may be implemented in an aggregated or disaggregated architecture. For example, a base station (such as a Node B (NB), evolved NB (eNB), NR base station, 5G NB, access point (AP), a transmit receive point (TRP), or a cell, etc.) may be implemented as an aggregated base station (also known as a standalone base station or a monolithic base station) or a disaggregated base station.

[0084] An aggregated base station may be configured to utilize a radio protocol stack that is physically or logically integrated within a single RAN node. A disaggregated base station may be configured to utilize a protocol stack that is physically or logically distributed among two or more units (such as one or more central or centralized units (CUs), one or more distributed units (DUs), or one or more radio units (RUs)). In some aspects, a CU may be implemented within a RAN node, and one or more DUs may be co-located with the CU, or alternatively, may be geographically or virtually distributed throughout one or multiple other RAN nodes. The DUs may be implemented to communicate with one or more RUs. Each of the CU, DU and RU also can be implemented as virtual units, i.e., a virtual central unit (VCU), a virtual distributed unit (VDU), or a virtual radio unit (VRU).

[0085] Base station-type operation or network design may consider aggregation characteristics of base station functionality. For example, disaggregated base stations may be utilized in an integrated access backhaul (IAB) network, an open radio access network (O-RAN (such as the network configuration sponsored by the O-RAN Alliance)), or a virtualized radio access network (vRAN, also known as a cloud radio access network (C-RAN)). Disaggregation may include distributing functionality across two or more units at various physical locations, as well as distributing functionality for at least one unit virtually, which can enable flexibility in network design. The various units of the disaggregated base station, or disaggregated RAN architecture, can be configured for wired or wireless communication with at least one other unit.

[0086] **FIG. 2C** illustrates an example disaggregated base station architecture 250, according to aspects of the disclosure. The disaggregated base station architecture 250 may include one or more central units (CUs) 280 (e.g., gNB-CU 226) that can communicate directly with a core network 267 (e.g., 5GC 210, 5GC 260) via a backhaul link, or indirectly with the core network 267 through one or more disaggregated base station units (such as a Near-Real Time (Near-RT) RAN Intelligent Controller (RIC) 259 via an E2 link, or a Non-Real Time (Non-RT) RIC 257 associated with a Service Management and Orchestration (SMO) Framework 255, or both). A CU 280 may communicate with one or more distributed units (DUs) 285 (e.g., gNB-DUs 228) via respective midhaul links, such as an F1 interface. The DUs 285 may communicate with one or more radio units (RUs) 287 (e.g., gNB-RUs 229) via respective fronthaul links. The RUs 287 may communicate with respective UEs 204 via one or more radio frequency (RF) access links. In some implementations, the UE 204 may be simultaneously served by multiple RUs 287.

[0087] Each of the units, i.e., the CUs 280, the DUs 285, the RUs 287, as well as the Near-RT RICs 259, the Non-RT RICs 257 and the SMO Framework 255, may include one or more interfaces or be coupled to one or more interfaces configured to receive or transmit signals, data, or information (collectively, signals) via a wired or wireless transmission medium. Each of the units, or an associated processor or controller providing instructions to the communication interfaces of the units, can be configured to communicate with one or more of the other units via the transmission medium. For example, the units can include a wired interface configured to receive or transmit signals over a wired transmission medium to one or more of the other units. Additionally, the units can include a wireless interface, which may include a receiver, a transmitter or transceiver (such as a radio frequency (RF) transceiver), configured to receive or transmit signals, or both, over a wireless transmission medium to one or more of the other units.

[0088] In some aspects, the CU 280 may host one or more higher layer control functions. Such control functions can include radio resource control (RRC), packet data convergence protocol (PDCP), service data adaptation protocol (SDAP), or the like. Each control function can be implemented with an interface configured to communicate signals with other control functions hosted by the CU 280. The CU 280 may be configured to handle user plane functionality (i.e., Central Unit – User Plane (CU-UP)), control plane functionality (i.e., Central Unit – Control Plane (CU-CP)), or a combination thereof. In some implementations, the CU 280 can be logically split into one or more CU-UP units and one or more CU-CP units. The CU-UP unit can communicate bidirectionally with the CU-CP unit via an interface, such as the E1 interface when implemented in an O-RAN configuration. The CU 280 can be implemented to communicate with the DU 285, as necessary, for network control and signaling.

[0089] The DU 285 may correspond to a logical unit that includes one or more base station functions to control the operation of one or more RUs 287. In some aspects, the DU 285 may host one or more of a radio link control (RLC) layer, a medium access control (MAC) layer, and one or more high physical (PHY) layers (such as modules for forward error correction (FEC) encoding and decoding, scrambling, modulation and demodulation, or the like) depending, at least in part, on a functional split, such as those defined by the 3rd Generation Partnership Project (3GPP). In some aspects, the DU 285 may further host one or more low PHY layers. Each layer (or module) can be implemented with an interface configured to communicate signals with other layers (and modules) hosted by the DU 285, or with the control functions hosted by the CU 280.

[0090] Lower-layer functionality can be implemented by one or more RUs 287. In some deployments, an RU 287, controlled by a DU 285, may correspond to a logical node that hosts RF processing functions, or low-PHY layer functions (such as performing fast Fourier transform (FFT), inverse FFT (iFFT), digital beamforming, physical random access channel (PRACH) extraction and filtering, or the like), or both, based at least in part on the functional split, such as a lower layer functional split. In such an architecture, the RU(s) 287 can be implemented to handle over the air (OTA) communication with one or more UEs 204. In some implementations, real-time and non-real-time aspects of control and user plane communication with the RU(s) 287 can be controlled by the corresponding DU 285. In some scenarios, this configuration can enable the DU(s) 285 and the CU 280 to be implemented in a cloud-based RAN architecture, such as a vRAN architecture.

[0091] The SMO Framework 255 may be configured to support RAN deployment and provisioning of non-virtualized and virtualized network elements. For non-virtualized network elements, the SMO Framework 255 may be configured to support the deployment of dedicated physical resources for RAN coverage requirements which may be managed via an operations and maintenance interface (such as an O1 interface). For virtualized network elements, the SMO Framework 255 may be configured to interact with a cloud computing platform (such as an open cloud (O-Cloud) 269) to perform network element life cycle management (such as to instantiate virtualized network elements) via a cloud computing platform interface (such as an O2 interface). Such virtualized network elements can include, but are not limited to, CUs 280, DUs 285, RUs 287 and Near-RT RICs 259. In some implementations, the SMO Framework 255 can communicate with a hardware aspect of a 4G RAN, such as an open eNB (O-eNB) 261, via an O1 interface. Additionally, in some implementations, the SMO Framework 255 can communicate directly with one or more RUs 287 via an O1 interface. The SMO Framework 255 also may include a Non-RT RIC 257 configured to support functionality of the SMO Framework 255.

[0092] The Non-RT RIC 257 may be configured to include a logical function that enables non-real-time control and optimization of RAN elements and resources, Artificial Intelligence/Machine Learning (AI/ML) workflows including model training and updates, or policy-based guidance of applications/features in the Near-RT RIC 259. The Non-RT RIC 257 may be coupled to or communicate with (such as via an A1 interface) the Near-RT RIC 259. The Near-RT RIC 259 may be configured to include a logical function that enables near-real-time control and optimization of RAN elements and resources via data collection and actions over an interface (such as via an E2 interface) connecting one or more CUs 280, one or more DUs 285, or both, as well as an O-eNB, with the Near-RT RIC 259.

[0093] In some implementations, to generate AI/ML models to be deployed in the Near-RT RIC 259, the Non-RT RIC 257 may receive parameters or external enrichment information from external servers. Such information may be utilized by the Near-RT RIC 259 and may be received at the SMO Framework 255 or the Non-RT RIC 257 from non-network data sources or from network functions. In some examples, the Non-RT RIC 257 or the Near-RT RIC 259 may be configured to tune RAN behavior or performance. For example, the Non-RT RIC 257 may monitor long-term trends and patterns for performance and employ AI/ML models to perform corrective actions through the SMO

Framework 255 (such as reconfiguration via O1) or via creation of RAN management policies (such as A1 policies).

[0094] **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, or alternatively may be independent from the NG-RAN 220 and/or 5GC 210/260 infrastructure depicted in FIGS. 2A and 2B, such as a private network) to support the operations described 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.

[0095] The UE 302 and the base station 304 each include one or more wireless wide area network (WWAN) transceivers 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 each 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.

[0096] The UE 302 and the base station 304 each also include, at least in some cases, one or more short-range wireless transceivers 320 and 360, respectively. The short-range wireless 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®, Zigbee®, Z-Wave®, PC5, dedicated short-range communications (DSRC), wireless access for vehicular environments (WAVE), near-field communication (NFC), ultra-wideband (UWB), etc.) over a wireless communication medium of interest. The short-range wireless 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 short-range wireless 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. As specific examples, the short-range wireless transceivers 320 and 360 may be WiFi transceivers, Bluetooth® transceivers, Zigbee® and/or Z-Wave® transceivers, NFC transceivers, UWB transceivers, or vehicle-to-vehicle (V2V) and/or vehicle-to-everything (V2X) transceivers.

[0097] The UE 302 and the base station 304 also include, at least in some cases, satellite signal receivers 330 and 370. The satellite signal 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 satellite positioning/communication signals 338 and 378, respectively. Where the satellite signal receivers 330 and 370 are satellite positioning system receivers, the satellite positioning/communication signals 338 and 378 may be 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. Where the satellite signal receivers 330 and 370 are non-terrestrial network (NTN) receivers, the satellite positioning/communication signals 338 and 378 may be communication signals (e.g., carrying control and/or user data) originating from a 5G network. The satellite signal receivers 330 and 370 may comprise any suitable hardware and/or software for receiving and processing satellite positioning/communication signals 338 and 378, respectively. The satellite signal receivers 330 and 370 may request information and operations as appropriate from the other systems, and, at least in some cases, perform calculations to determine locations of the UE 302 and the base station 304, respectively, using measurements obtained by any suitable satellite positioning system algorithm.

[0098] The base station 304 and the network entity 306 each include one or more network transceivers 380 and 390, respectively, providing means for communicating (e.g., means for transmitting, means for receiving, etc.) with other network entities (e.g., other base stations 304, other network entities 306). For example, the base station 304 may employ the one or more network transceivers 380 to communicate with other base stations 304 or network entities 306 over one or more wired or wireless backhaul links. As another example, the network entity 306 may employ the one or more network transceivers 390 to communicate with one or more base station 304 over one or more wired or wireless backhaul links, or with other network entities 306 over one or more wired or wireless core network interfaces.

[0099] A transceiver may be configured to communicate over a wired or wireless link. A transceiver (whether a wired transceiver or a wireless transceiver) includes transmitter circuitry (e.g., transmitters 314, 324, 354, 364) and receiver circuitry (e.g., receivers 312, 322, 352, 362). A transceiver may be an integrated device (e.g., embodying transmitter circuitry and receiver circuitry in a single device) in some implementations, may comprise separate transmitter circuitry and separate receiver circuitry in some implementations, or may be embodied in other ways in other implementations. The transmitter circuitry and receiver circuitry of a wired transceiver (e.g., network transceivers 380 and 390 in some implementations) may be coupled to one or more wired network interface ports. Wireless transmitter circuitry (e.g., transmitters 314, 324, 354, 364) 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 (e.g., UE 302, base station 304) to perform transmit "beamforming," as described herein. Similarly, wireless receiver circuitry (e.g., receivers 312, 322, 352, 362) 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 (e.g., UE 302, base station 304) to perform receive beamforming, as described herein. In an aspect, the transmitter circuitry and receiver circuitry 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 transceiver (e.g., WWAN transceivers 310 and 350, short-range wireless transceivers 320 and 360) may also include a network listen module (NLM) or the like for performing various measurements.

[0100] As used herein, the various wireless transceivers (e.g., transceivers 310, 320, 350, and 360, and network transceivers 380 and 390 in some implementations) and wired transceivers (e.g., network transceivers 380 and 390 in some implementations) may generally be characterized as "a transceiver," "at least one transceiver," or "one or more transceivers." As such, whether a particular transceiver is a wired or wireless transceiver may be inferred from the type of communication performed. For example, backhaul communication between network devices or servers will generally relate to signaling via a wired transceiver, whereas wireless communication between a UE (e.g., UE 302) and a base station (e.g., base station 304) will generally relate to signaling via a wireless transceiver.

[0101] 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, the base station 304, and the network entity 306 include one or more processors 332, 384, and 394, respectively, for providing functionality relating to, for example, wireless communication, and for providing other processing functionality. The processors 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 processors 332, 384, and 394 may include, for example, one or more general purpose processors, multi-core processors, central processing units (CPUs), ASICs, digital signal processors (DSPs), field programmable gate arrays (FPGAs), other programmable logic devices or processing circuitry, or various combinations thereof.

[0102] The UE 302, the base station 304, and the network entity 306 include memory circuitry implementing memories 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 memories 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 component 342, 388, and 398, respectively. The positioning component 342, 388, and 398 may be hardware circuits that are part of or coupled to the processors 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 component 342, 388, and 398 may be external to the processors 332, 384, and 394 (e.g., part of a modem processing system, integrated with another processing system, etc.). Alternatively, the positioning component 342, 388, and 398 may be memory modules stored in the memories 340, 386, and 396, respectively, that, when executed by the processors 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, for example, part of the one or more WWAN transceivers 310, the memory 340, the one or more processors 332, or any combination thereof, or may be a standalone component. FIG. 3B illustrates possible locations of the positioning component 388, which may be, for example, part of the one or more WWAN transceivers 350, the memory 386, the one or more processors 384, or any combination thereof, or may be a standalone component. FIG. 3C illustrates possible locations of the positioning component 398, which may be, for example, part of the one or more network transceivers 390, the memory 396, the one or more processors 394, or any combination thereof, or may be a standalone component.

[0103] The UE 302 may include one or more sensors 344 coupled to the one or more processors 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 one or more WWAN transceivers 310, the one or more short-range wireless transceivers 320, and/or the satellite signal 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 two-dimensional (2D) and/or three-dimensional (3D) coordinate systems.

[0104] 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.

[0105] Referring to the one or more processors 384 in more detail, in the downlink, IP packets from the network entity 306 may be provided to the processor 384. The one or more processors 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 one or more processors 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.

[0106] 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.

[0107] 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 one or more processors 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 one or more processors 332, which implements Layer-3 (L3) and Layer-2 (L2) functionality.

[0108] In the downlink, the one or more processors 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 one or more processors 332 are also responsible for error detection.

[0109] Similar to the functionality described in connection with the downlink transmission by the base station 304, the one or more processors 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.

[0110] 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.

[0111] 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 one or more processors 384.

[0112] In the uplink, the one or more processors 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 one or more processors 384 may be provided to the core network. The one or more processors 384 are also responsible for error detection.

[0113] For convenience, the UE 302, the base station 304, and/or the network entity 306 are shown in FIGS. 3A, 3B, and 3C as including various components that may be configured according to the various examples described herein. It will be appreciated, however, that the illustrated components may have different functionality in different designs. In particular, various components in FIGS. 3A to 3C are optional in alternative configurations and the various aspects include configurations that may vary due to design choice, costs, use of the device, or other considerations. For example, in case of FIG. 3A, a particular implementation of UE 302 may omit the WWAN transceiver(s) 310 (e.g., a wearable device or tablet computer or PC or laptop may have Wi-Fi and/or Bluetooth capability without cellular capability), or may omit the short-range wireless transceiver(s) 320 (e.g., cellular-only, etc.), or may omit the satellite signal receiver 330, or may omit the sensor(s) 344, and so on. In another example, in case of FIG. 3B, a particular implementation of the base station 304 may omit the WWAN transceiver(s) 350 (e.g., a Wi-Fi "hotspot" access point without cellular capability), or may omit the short-range wireless transceiver(s) 360 (e.g., cellular-only, etc.), or may omit the satellite signal receiver 370, and so on. For brevity, illustration of the various alternative configurations is not provided herein, but would be readily understandable to one skilled in the art.

[0114] The various components of the UE 302, the base station 304, and the network entity 306 may be communicatively coupled to each other over data buses 334, 382, and 392, respectively. In an aspect, the data buses 334, 382, and 392 may form, or be part of, a communication interface of the UE 302, the base station 304, and the network entity 306, respectively. For example, where different logical entities are embodied in the same device (e.g., gNB and location server functionality incorporated into the same base station 304), the data buses 334, 382, and 392 may provide communication between them.

[0115] The components of FIGS. 3A, 3B, and 3C may be implemented in various ways. In some implementations, the components of FIGS. 3A, 3B, and 3C 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 processors 332, 384, 394, the transceivers 310, 320, 350, and 360, the memories 340, 386, and 396, the positioning component 342, 388, and 398, etc.

[0116] In some designs, the network entity 306 may be implemented as a core network component. In other designs, the network entity 306 may be distinct from a network operator or operation of the cellular network infrastructure (e.g., NG RAN 220 and/or 5GC 210/260). For example, the network entity 306 may be a component of a private network that may be configured to communicate with the UE 302 via the base station 304 or independently from the base station 304 (e.g., over a non-cellular communication link, such as WiFi).

[0117] 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. **FIG. 4** illustrates examples of various positioning methods, according to aspects of the disclosure. In an OTDOA or DL-TDOA positioning procedure, illustrated by scenario 410, a UE measures the differences between the times of arrival (ToAs) of reference signals (e.g., positioning reference signals (PRS)) 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 (e.g., the UE for UE-based positioning or a location server for UE-assisted positioning) can estimate the UE's location.

[0118] For DL-AoD positioning, illustrated by scenario 420, the positioning entity uses a measurement report from the UE of received signal strength measurements of multiple downlink transmit beams to determine the angle(s) between the UE and the transmitting base station(s). The positioning entity can then estimate the location of the UE based on the determined angle(s) and the known location(s) of the transmitting base station(s).

[0119] 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., sounding reference signals (SRS)) transmitted by the UE to multiple base stations. Specifically, a UE transmits one or more uplink reference signals that are measured by a reference base station and a plurality of non-reference base stations. Each base station then reports the reception time (referred to as the relative time of arrival (RTOA)) of the reference signal(s) to a positioning entity (e.g., a location server) that knows the locations and relative timing of the involved base stations. Based on the reception-to-reception (Rx-Rx) time difference between the reported RTOA of the reference base station and the reported RTOA of each non-reference base station, the known locations of the base stations, and their known timing offsets, the positioning entity can estimate the location of the UE using TDOA.

[0120] For UL-AoA positioning, one or more base stations measure the received signal strength of one or more uplink reference signals (e.g., SRS) received from a UE on one or more uplink receive beams. The positioning entity uses the signal strength measurements and the angle(s) of the receive beam(s) to determine the angle(s) between the UE and the base station(s). Based on the determined angle(s) and the known location(s) of the base station(s), the positioning entity can then estimate the location of the UE.

[0121] 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" and "multi-RTT"). In an RTT procedure, a first entity (e.g., a base station or a UE) transmits a first RTT-related signal (e.g., a PRS or SRS) to a second entity (e.g., a UE or base station), which transmits a second RTT-related signal (e.g., an SRS or PRS) back to the first entity. Each entity measures the time difference between the time of arrival (ToA) of the received RTT-related signal and the transmission time of the transmitted RTT-related signal. This time difference is referred to as a reception-to-transmission (Rx-Tx) time difference. The Rx-Tx time difference measurement may be made, or may be adjusted, to include only a time difference between nearest slot boundaries for the received and transmitted signals. Both entities may then send their Rx-Tx time difference measurement to a location server (e.g., an LMF 270), which calculates the round trip propagation time (i.e., RTT) between the two entities from the two Rx-Tx time difference measurements (e.g., as the sum of the two Rx-Tx time difference measurements). Alternatively, one entity may send its Rx-Tx time difference measurement to the other entity, which then calculates the RTT. The distance between the two entities can be determined from the RTT and the known signal speed (e.g., the speed of light). For multi-RTT positioning, illustrated by scenario 430, a first entity (e.g., a UE or base station) performs an RTT positioning procedure with multiple second entities (e.g., multiple base stations or UEs) to enable the location of the first entity to be determined (e.g., using multilateration) based on distances to, and the known locations of, the second entities. RTT and multi-RTT methods can be combined with other positioning techniques, such as UL-AoA and DL-AoD, to improve location accuracy, as illustrated by scenario 440.

[0122] 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 station(s).

[0123] 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 slots including PRS, periodicity of the consecutive slots including PRS, 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.

[0124] 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 (μs). 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 μs. 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 μs.

[0125] NR is also capable of supporting various sidelink ranging and positioning techniques. Sidelink-based ranging enables the determination of the relative distance(s) between UEs and optionally their absolute position(s), where the absolute position of at least one involved UE is known. This technique is valuable in situations where global navigation satellite system (GNSS) positioning is degraded or unavailable (e.g., tunnels, urban canyons, etc.) and can also enhance range and positioning accuracy when GNSS is available. Sidelink-based ranging can be accomplished using a three-way handshake for session establishment, followed by the exchange of positioning reference signals (PRS), and concluded by messaging to exchange measurements based on PRS transmission and receipt from peer UEs.

[0126] Sidelink ranging is based on calculating an inter-UE round-trip-time (RTT) measurement, as determined from the transmit and receive times of PRS (a wideband positioning signal defined in LTE and NR). Each UE reports an RTT measurement to all other participating UEs, along with its location (if known). For UEs having zero or inaccurate knowledge of their location, the RTT procedure yields an inter-UE range between the involved UEs. For UEs having accurate knowledge of their location, the range yields an absolute position. UE participation, PRS transmission, and subsequent RTT calculation is coordinated by an initial three-way messaging handshake (a PRS request, a PRS response, and a PRS confirmation), and a message exchange after PRS transmission (post PRS messages) to share measurements after receiving a peer UE's PRS.

[0127] **FIG. 5** illustrates an example sidelink ranging and positioning procedure 500, according to aspects of the disclosure. The sidelink ranging and positioning procedure 500 may also be referred to as a sidelink RTT (SL-RTT) positioning procedure. Sidelink ranging is based on calculating an inter-UE RTT measurement, as determined from the transmit and receive times of PRS (a wideband reference signal defined in LTE and NR for positioning). Each UE reports an RTT measurement to all other participating UEs, along with its location (if known). For UEs having zero or inaccurate knowledge of their location, the RTT procedure yields an inter-UE range between the involved UEs. For UEs having accurate knowledge of their location, the range yields an absolute location. UE participation, PRS transmission, and subsequent RTT calculation is coordinated by an initial three-way messaging handshake (a PRS request, a PRS response, and a PRS confirmation), and a message exchange after PRS transmission (post PRS messages) to share measurements after receiving a peer UE's PRS.

[0128] The sidelink ranging and positioning procedure 500 (or session) begins with the broadcast of capability information by the involved peer UEs at stage 505. As shown in FIG. 5, one of the peer UEs, UE 204-1 (e.g., any of the sidelink-capable UEs described herein), is capable of being an anchor UE for the sidelink ranging and positioning procedure 500, meaning it has a known location. As such, the anchor UE 204-1 includes an indication in its capability message(s) that it is capable of being an anchor UE for the sidelink ranging and positioning procedure 500. The capability message(s) may also include the location of the anchor UE 204-1, or this may be provided later. The other UE, UE 204-2 (e.g., any other of the sidelink-capable UEs described herein), is a target UE, meaning it has an unknown or inaccurate location and is attempting to be located. Based on the capability information received from the anchor UE 204-1, indicating that the anchor UE 204-1 is an anchor UE, the target UE 204-2 knows that it will be able to determine its location based on performing the sidelink ranging and positioning procedure 500 with the anchor UE 204-1.

[0129] After the initial capability exchange, the involved UEs 204 perform a three-way messaging handshake. At stage 510, the anchor UE 204-1 transmits a PRS request (labeled "PRSrequest") to the target UE 204-2. At stage 515, the target UE 204-2 transmits a PRS response (labeled "PRSresponse") to the anchor UE 204-1. At stage 520, the anchor UE 204-1 transmits a PRS confirmation to the target UE 204-2. At this point, the three-way messaging handshake is complete. Note that although FIG. 5 illustrates the anchor UE 204-1 initiating the three-way message handshake, it may instead be initiated by the target UE 204-2.

[0130] At stages 525 and 530, the involved peer UEs 204 transmit PRS to each other. The resources on which the PRS are transmitted may be configured / allocated by the network (e.g., one of the UE's 204 serving base station) or negotiated by the UEs 204 during the three-way messaging handshake. The anchor UE 204-1 measures the transmission-to-reception (Tx-Rx) time difference between the transmission time of PRS at stage 525 and the reception time of PRS at stage 530. The target UE 204-2 measures the reception-to-transmission (Rx-Tx) time difference between the reception time of PRS at stage 525 and the transmission time of PRS at stage 530. Note that although FIG. 5 illustrates the anchor UE 204-1 transmitting PRS first, the target UE 204-2 may instead transmit PRS first.

[0131] At stages 535 and 540, the peer UEs 204 exchange their respective time difference measurements in post PRS messages (labeled "postPRS"). If the anchor UE 204-1 has not yet provided its location to the target UE 204-2, it does so at this point. Each UE 204 is then able to determine the RTT between each UE 204 based on the Tx-Rx and Rx-Tx time difference measurements (specifically, the difference between the Tx-Rx and Rx-Tx time difference measurements). Based on the RTT measurement and the speed of light, each UE 204 can then estimate the distance (or range) between the two UEs 204 (specifically, half the RTT measurement multiplied by the speed of light). Since the target UE 204-2 also has the absolute location (e.g., geographic coordinates) of the anchor UE 204-1, the target UE 204-2 can use that location and the distance to the anchor UE 204-1 to determine its own absolute location.

[0132] Note that while FIG. 5 illustrates two UEs 204, a UE may perform, or attempt to perform, the sidelink ranging and positioning procedure 500 with multiple UEs.

[0133] 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).

[0134] Long-Term Evolution (LTE) positioning protocol (LPP) is used point-to-point between a location server (e.g., LMF 270) and a target device (e.g., a UE) in order to position the target device using position-related measurements obtained by one or more reference sources (physical entities or parts of physical entities that provide signals that can be measured by a target device in order to obtain the location of the target device). An LPP session is used between a location server and a target device in order to obtain location-related measurements or a location estimate or to transfer assistance data. Currently, a single LPP session is used to support a single location request and 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 (or procedures), with each LPP transaction performing a single operation (capability exchange, assistance data transfer, or location information transfer). Each LPP transaction involves the exchange of one or more LPP messages between the location server and the target device. The general format of an LPP message consists of a set of common fields followed by a body. The body (which may be empty) contains information specific to a particular message type. Each message type contains information specific to one or more positioning methods and/or information common to all positioning methods.

[0135] An LPP session generally includes at least a capability transfer or indication procedure, an assistance data transfer or delivery procedure, and a location information transfer or delivery procedure. **FIG. 6** illustrates an example LPP capability transfer procedure 610, LPP assistance data transfer procedure 630, and LPP location information transfer procedure 650 between a target device (labeled "Target") and a location server (labeled "Server"), according to aspects of the disclosure.

[0136] The purpose of an LPP capability transfer procedure 610 is to enable the transfer of capabilities from the target device (e.g., a UE 204) to the location server (e.g., an LMF 270). Capabilities in this context refer to positioning and protocol capabilities related to LPP and the positioning methods supported by LPP. In the LPP capability transfer procedure 610, the location server (e.g., an LMF 270) indicates the types of capabilities needed from the target device (e.g., UE 204) in an LPP Request Capabilities message. The target device responds with an LPP Provide Capabilities message. The capabilities included in the LPP Provide Capabilities message should correspond to any capability types specified in the LPP Request Capabilities message. Specifically, for each positioning method for which a request for capabilities is included in the LPP Request Capabilities message, if the target device supports this positioning method, the target device includes the capabilities of the target device for that supported positioning method in the LPP Provide Capabilities message. For an LPP capability indication procedure, the target device provides unsolicited (i.e., without receiving an LPP Request Capabilities message) capabilities to the location server in an LPP Provide Capabilities message.

[0137] The purpose of an LPP assistance data transfer procedure 630 is to enable the target device to request assistance data from the location server to assist in positioning, and to enable the location server to transfer assistance data to the target device in the absence of a request. In the LPP assistance data transfer procedure 630, the target device sends an LPP Request Assistance Data message to the location server. The location server responds to the target device with an LPP Provide Assistance Data message containing assistance data. The transferred assistance data should match or be a subset of the assistance data requested in the LPP Request Assistance Data. The location server may also provide any not requested information that it considers useful to the target device. The location server may also transmit one or more additional LPP Provide Assistance Data messages to the target device containing further assistance data. For an LPP assistance data delivery procedure, the location server provides unsolicited assistance data necessary for positioning. The assistance data may be provided periodically or non-periodically.

[0138] The purpose of an LPP location information transfer procedure 650 is to enable the location server to request location measurement data and/or a location estimate from the target device, and to enable the target device to transfer location measurement data and/or a location estimate to a location server in the absence of a request. In an LPP location information transfer procedure 650, the location server sends an LPP Request Location Information message to the target device to request location information, indicating the type of location information needed and potentially the associated QoS. The target device responds with an LPP Provide Location Information message to the location server to transfer location information. The location information transferred should match or be a subset of the location information requested by the LPP Request Location Information unless the location server explicitly allows additional location information. More specifically, if the requested information is compatible with the target device's capabilities and configuration, the target device includes the requested information in an LPP Provide Location Information message. Otherwise, if the target device does not support one or more of the requested positioning methods, the target device continues to process the message as if it contained only information for the supported positioning methods and handles the signaling content of the unsupported positioning methods by LPP error detection. If requested by the LPP Request Lactation Information message, the target device sends additional LPP Provide Location Information messages to the location server to transfer additional location information. An LPP location information delivery procedure supports the delivery of positioning estimations based on unsolicited service.

[0139] LPP also defines procedures related to error indication for when a receiving endpoint (target device or location server) receives erroneous or unexpected data or detects that certain data are missing. Specifically, when a receiving endpoint determines that a received LPP message contains an error, it can return an Error message to the transmitting endpoint indicating the error or errors and discard the received/erroneous message. If the receiving endpoint is able to determine that the erroneous LPP message is an LPP Error or Abort Message, then the receiving endpoint discards the received message without returning an Error message to the transmitting endpoint.

[0140] LPP also defines procedures related to abort indication to allow a target device or location server to abort an ongoing procedure due to some unexpected event (e.g., cancellation of a location request by an LCS client). An Abort procedure can also be used to stop an ongoing procedure (e.g., periodic location reporting from the target device). In an Abort procedure, a first endpoint determines that procedure P must be aborted and sends an Abort message to a second endpoint carrying the transaction ID for procedure P. The second endpoint then aborts procedure P.

[0141] NR supports, or enables, various sidelink positioning techniques. Positioning methods supported using at least sidelink measurements may include, but are not limited to, RTT-type solutions using sidelink measurements, sidelink AoA (SL-AoA), and sidelink TDOA (SL-TDOA). The content of the sidelink positioning measurement report may include, but is not limited to, one or more sidelink positioning measurements, one or more timestamps associated with a sidelink positioning measurement, one or more quality metrics associated with a sidelink positioning measurement, and identification information for a sidelink positioning measurement.

[0142] In a positioning session, sidelink measurements can contribute to the positioning information as part of a standalone sidelink session, where only sidelink measurements are involved in the determination of the positioning information, or a joint (also referred to as "hybrid") positioning session, where the positioning information is the result of using Uu measurements (of downlink reference signals) and sidelink measurements (of sidelink reference signals). The positioning information may be location (of the target UE), relative location, (relative) direction, range, and/or the like.

[0143] Using both Uu and sidelink measurements has many useful use cases, such as a sidelink anchor (a sidelink UE with a known position) providing an extra anchor for Uu links, or SL-PRS replacing SRS-for-positioning transmission for uplink-limited UEs. **FIG. 7A** illustrates various scenarios of interest for sidelink-only or joint Uu and sidelink positioning, according to aspects of the disclosure. In scenario 710, at least one peer UE with a known location can improve the Uu-based positioning (e.g., multi-cell RTT, DL-TDOA, etc.) of a target UE by providing an additional anchor (e.g., using SL-RTT). In scenario 720, a low-end (e.g., reduced capacity, or "RedCap") target UE may obtain the assistance of premium UEs to determine its location using, e.g., sidelink positioning and ranging procedures with the premium UEs. Compared to the low-end UE, the premium UEs may have more capabilities, such as more sensors, a faster processor, more memory, more antenna elements, higher transmit power capability, access to additional frequency bands, or any combination thereof. In scenario 730, a relay UE (e.g., with a known location) participates in the positioning estimation of a remote UE without transmitting UL-PRS/SRS over the Uu interface. Scenario 740 illustrates the joint positioning of multiple UEs. Specifically, in scenario 740, two UEs with unknown positions can be jointly located in non-line-of-sight (NLOS) conditions by utilizing constraints from nearby UEs.

[0144] **FIG. 7B** illustrates additional scenarios of interest for sidelink-only or joint Uu and sidelink positioning, according to aspects of the disclosure. In scenario 750, UEs used for public safety (e.g., by police, firefighters, and/or the like) may perform peer-to-peer (P2P) positioning and ranging for public safety and other uses. For example, in scenario

750, the public safety UEs may be out of coverage of a network and determine a location or a relative distance and a relative position among the public safety UEs using sidelink positioning techniques. Similarly, scenario 760 shows multiple UEs that are out of coverage and determine a location or a relative distance and a relative position using sidelink positioning techniques, such as SL-RTT.

[0145] In a joint Uu and sidelink positioning session, the location entity (the entity computing the UE positioning information) has access to multiple measurements that can improve the accuracy and performance. However, not all links may be needed. Some links may only provide incremental or negligible gain. For instance, in a good line-of-sight (LOS) environment where a UE has good LOS links to, for example, four TRPs, additional sidelink measurements would likely not bring much advantage from a positioning accuracy point of view. However, if all links are weighted similarly, an erroneous sidelink measurement can bias the positioning output, which otherwise would have been more accurate.

[0146] Moreover, from a UE and network energy savings perspective, and considering over-the-air (OTA) resource utilization efficiency, it is beneficial to use the right combination of Uu and sidelink links for a target accuracy level. For this purpose, Uu and/or sidelink links can be adaptively activated/de-activated depending on the need.

[0147] Accordingly, the present disclosure provides techniques for adaptive configuration and activation for joint Uu and sidelink positioning sessions. The present disclosure further provides techniques for determining different and multiple configurations for enabling adaptive joint Uu and sidelink links operations. The proposed solutions specifically address periodic or semi-persistent positioning sessions.

[0148] In an aspect, in a joint Uu and sidelink positioning session, the network (e.g., LMF 270) configures a target UE to perform/trigger sidelink transmissions and/or measurements based on one or more configured trigger events. The trigger events may be included in the UE configuration for the positioning session (e.g., received in an LPP Provide Assistance Data message or an LPP Request Location Information message). Examples of triggers include (1) the number of Uu links (e.g., DL-PRS) detectable at the target UE being lower than a threshold, denoted "N_Uu_links_min," (2) a location change and/or cell change of the target UE, and (3) the estimated UE position confidence being below a configurable threshold. With respect to the first trigger, the configuration may specify that a link is detectable if the signal strength (e.g., RSRP) of the link is greater than a threshold, denoted "RSRP_min_Uu."

[0149] Note that these performed/triggered sidelink transmissions/measurements may be carried out in addition to already-configured and operating sidelink operations for positioning, within the same positioning session. In addition, the sidelink measurements should be aligned or be close in time to the configured Uu measurements for them to be more useful.

[0150] The UE configuration may specify the type/method of the triggered sidelink transmissions and/or measurements. As noted above, examples of sidelink methods include SL-TDOA, SL-RTT, and SL-AoA. For a SL-TDOA positioning procedure, the target UE may be triggered to perform sidelink measurements, whereas for a SL-RTT positioning procedure, the target UE may be triggered to measure sidelink transmissions from one or more anchor nodes (e.g., other UEs, RSUs, etc.) and transmit sidelink transmissions to the one or more anchor nodes.

[0151] The list of sidelink anchor nodes to use to perform the configured sidelink positioning method can be (1) provided by the network or (2) selected by the UE. For the first option, the network may provide a list of anchor nodes and the target UE may choose all of them or a subset of them. For the second option, the target UE detects the surrounding anchor nodes and performs a sidelink positioning procedure with them. Note that the anchor node location needs to be known. The target UE can select anchor nodes whose location is known with a certain confidence.

[0152] The sidelink transmissions and/or measurements can be performed in either Mode 1 resource allocation (where the network allocates sidelink resources) or Mode 2 resource allocation (where the involved UEs select/negotiate the resources to use for sidelink communication). In Mode 2, upon detecting the trigger event, the target UE autonomously selects time and frequency resources for the additional sidelink positioning procedure and then activates the additional sidelink procedure. In Mode 1, upon detecting the trigger, the UE signals/indicates the detection of the trigger to the network through L1 signaling (e.g., uplink control information (UCI)), L2 signaling (e.g., MAC control elements (MAC-CEs)), L3 signaling (e.g., RRC), or LPP signaling. The network then allocates resources for the configured sidelink method. Note that the detection indication can include a list of anchor nodes (whose locations are known to the target UE).

[0153] The sidelink measurements/transmissions may be configured to be (1) one-shot (aperiodic), (2) periodic, with periodicity matching the PRS periodicity, and performing N occasions over a specified window of time (e.g., some number of slots, milliseconds, frames, etc.), or (3) periodic, with a stop when the network cancels the sidelink operations or until the trigger is no longer satisfied.

[0154] For UE-assisted positioning scenarios (where the UE reports the measurements to the location server and the location server estimates the UE position), the target UE can specify the trigger condition in its measurements report to the network (e.g., an LPP Provide Location Information message). The measurement report may include the location of the measured sidelink anchor UEs if not known to the network. In case of failure to perform the triggered measurements, the target UE can indicate the failure to the network, potentially with a cause (e.g., no available resources).

[0155] In an aspect, the triggered sidelink communication can be by modifying the resources of an already existing sidelink link. Such modification(s) can include (1) increasing the operating bandwidth of the existing sidelink link (e.g., increasing the bandwidth of a SL-RTT session from 40 MHz to 80 MHz) and/or (2) increasing the repetition factor, comb value, and/or periodicity of certain sidelink resources.

[0156] **FIG. 8** illustrates an example scenario in which a sidelink link is triggered for a Uu-based positioning session, according to aspects of the disclosure. As shown in diagram 800, a target UE is performing a positioning session involving four TRPs (labeled "TRP1" to "TRP4"). The positioning session may be, for example, a multi-RTT positioning session or a DL-TDOA positioning session. As shown in diagram 800, there is a link between the target UE and each TRP. The TRPs may transmit DL-PRS (or other downlink positioning reference signal) to the target UE over the respective links, and/or the target UE may transmit SRS (or other uplink positioning reference signal) to the TRPs over the respective links.

[0157] The term "link" may refer to the set of time and/or frequency resources over which a TRP (or other network node) and the target UE communicate. The term "link" may also refer to the signaling (e.g., DL-PRS, SL-PRS, SRS, etc.) between the target UE and a respective TRP (or other network node). Thus, a target UE may be described as "measuring" a link, meaning that the UE is measuring a reference signal (or other signaling) transmitted over the set of time and/or frequency resources of the link.

[0158] As shown in diagram 850, the link to TRP3 has become weak (i.e., the signal strength has dropped below a threshold, e.g., "RSRP_min_Uu") due to, for example, a blockage, UE mobility, overloading, or the like. This triggers the target UE to perform a sidelink positioning procedure (e.g., SL-RTT) with a nearby anchor UE. Note that there may have been a previously established link between the target UE and the anchor UE, but it was not used for positioning until the trigger condition was detected.

[0159] The present disclosure further provides techniques for Uu and/or sidelink measurement dropping and indication. In a joint Uu and sidelink positioning session, a UE can drop (cease) measuring certain Uu and/or sidelink links. The reasons for doing so may include, but are not limited to, (1) UE estimation that certain Uu/sidelink links do not sufficiently contribute (e.g., contribute less than some threshold) to the position estimation, or that certain Uu/sidelink links are NLOS, (2) weak signal strength (e.g., RSRP) of certain Uu/sidelink links, (3) the presence of a sufficient number (e.g., above some threshold) of sidelink anchor UEs with accurately known locations and good estimated LOS channels (motivating dropping Uu links), (4) power savings at the UE, while not sacrificing positioning accuracy by more than a threshold, and/or (5) a congested sidelink channel, motivating dropping sidelink links. The congestion on the sidelink channel may be determined based on the channel busy ratio (CBR) being above a threshold.

[0160] The UE may indicate the list of Uu/sidelink links it is dropping to the network using L1/L2/L3 signaling or LPP signaling. The indication may include the duration/window of time (specified in milliseconds, number of occasions, number of slots, number of frames, etc.) the UE is dropping (e.g., for periodic PRS resources). Such an indication can be used by the network to optimize OTA transmissions. For example, the network can stop/cease PRS transmissions on the indicated link(s), especially if resources are on-demand, semi-persistent, or periodic resources. In an aspect, the UE indication may also include the reason for dropping the links.

[0161] In an aspect, instead of the UE indicating which links it is dropping, the UE can recommend to the network to drop certain links. The recommended links can be either Uu links or sidelink links. The reasons for dropping the links may be the same or similar as discussed above. The UE may indicate to the network the list of links it may not use and the corresponding duration/window of time (specified in milliseconds, number of occasions, number of slots, number of frames, etc.). In an aspect, the recommended links may have some priority. The priority may be implicit (by the link order in the list) or explicit (by assigning a priority number to each link).

[0162] Based on the UE indication, the network may choose to drop some or all of the suggested links, based on network energy consumption, sidelink traffic congestion, UE location, and/or the like. The network drops the transmissions or releases resources (for sidelink) of the dropped links and indicates to the UE which links were dropped through L1/L2/L3/LPP signaling.

[0163] The present disclosure further provides techniques for opportunistic sidelink measurement reporting. In network-based positioning, a UE may opportunistically perform sidelink positioning measurements and report them to the network (e.g., an LPP Provide Location Information message). For a Uu-based positioning session, the target UE may perform additional sidelink measurements using Mode 2 resource allocation. However, these positioning sidelink measurements are not configured by the network. Instead, the anchor UEs involved in the sidelink measurements can be (1) selected from a set of UEs provided by the location server (e.g., LMF 270) to the target UE or (2) selected by the target UE. In the second option, the UE reports the location information of these anchor UEs to the location server.

[0164] The opportunistic sidelink measurements can be reported to the location server separately or together with Uu measurements reporting (if configured). The opportunistic sidelink measurements can be performed with downlink-based Uu positioning and/or uplink-based Uu positioning measurements. In an aspect, the opportunistic sidelink measurements can be activated/enabled or deactivated by the location server.

[0165] In an aspect, the location server may require that opportunistic sidelink measurements need to occur with X units of time from a designated reference time, such as the transmission time of a reference signal (RS). The reference RS may be a DL-PRS for downlink-based positioning or an SRS-for-positioning for uplink-based positioning. The value X can be specified in units of milliseconds, number of occasions, number of slots, number of frames, etc.

[0166] **FIG. 9** illustrates an example method 900 of wireless communication, according to aspects of the disclosure. In an aspect, method 900 may be performed by a UE (e.g., any of the UEs described herein).

[0167] At 910, the UE receives a configuration indicating one or more trigger conditions for activating sidelink-based positioning operations in conjunction with a cellular-based positioning procedure. In an aspect, operation 910 may be performed by the one or more WWAN transceivers 310, the one or more short-range wireless transceivers 320, the one or more processors 332, memory 340, and/or positioning component 342, any or all of which may be considered means for performing this operation.

[0168] At 920, the UE performs the sidelink-based positioning operations with one or more sidelink anchor nodes based on detecting at least one of the one or more trigger conditions. In an aspect, operation 920 may be performed by the one or more WWAN transceivers 310, the one or more short-range wireless transceivers 320, the one or more processors 332, memory 340, and/or positioning component 342, any or all of which may be considered means for performing this operation.

[0169] **FIG. 10** illustrates an example method 1000 of wireless communication, according to aspects of the disclosure. In an aspect, method 1000 may be performed by a UE (e.g., any of the UEs described herein).

[0170] At 1010, the UE engages in a joint cellular-based and sidelink-based positioning session over a plurality of links between the UE and a plurality of anchor nodes, wherein the plurality of links comprise one or more cellular-based links between the UE and one or more cellular anchor nodes of the plurality of anchor nodes and one or more sidelink-based links between the UE and one or more sidelink anchor nodes of the plurality of nodes. In an aspect, operation 1010 may be performed by the one or more WWAN transceivers 310, the one or more short-range wireless transceivers 320, the one or more processors 332, memory 340, and/or positioning component 342, any or all of which may be considered means for performing this operation.

[0171] At 1020, the UE drops at least one link of the plurality of links for the joint cellular-based and sidelink-based positioning session based on one or more criteria. In an aspect, operation 1020 may be performed by the one or more WWAN transceivers 310, the one or more short-range wireless transceivers 320, the one or more processors 332, memory 340, and/or positioning component 342, any or all of which may be considered means for performing this operation.

[0172] **FIG. 11** illustrates an example method 1100 of wireless communication, according to aspects of the disclosure. In an aspect, method 1100 may be performed by a UE (e.g., any of the UEs described herein).

[0173] At 1110, the UE engages in a cellular-based positioning session based on configuration information received from a network entity. In an aspect, operation 1110 may be performed by the one or more WWAN transceivers 310, the one or more short-range wireless transceivers 320, the one or more processors 332, memory 340, and/or positioning component 342, any or all of which may be considered means for performing this operation.

[0174] At 1120, the UE performs one or more sidelink-based positioning operations with one or more sidelink anchor nodes during the cellular-based positioning session. In an aspect, operation 1120 may be performed by the one or more WWAN transceivers 310, the one or more short-range wireless transceivers 320, the one or more processors 332, memory 340, and/or positioning component 342, any or all of which may be considered means for performing this operation.

[0175] At 1130, the UE transmits, to the network entity, a report including the sidelink-based positioning measurements. In an aspect, operation 1130 may be performed by the one or more WWAN transceivers 310, the one or more short-range wireless transceivers 320, the one or more processors 332, memory 340, and/or positioning component 342, any or all of which may be considered means for performing this operation.

[0176] As will be appreciated, a technical advantage of the methods 900 – 1100 is greater OTA resource utilization while maintaining or even improving positioning performance.

[0177] 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 electrical insulator and an electrical 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.

[0178] Implementation examples are described in the following numbered clauses:

[0179] Clause 1. A method of wireless communication performed by a user equipment (UE), comprising: receiving a configuration indicating one or more trigger conditions for activating sidelink-based positioning operations in conjunction with a cellular-based positioning procedure; and performing the sidelink-based positioning operations with one or more sidelink anchor nodes based on detecting at least one of the one or more trigger conditions.

[0180] Clause 2. The method of clause 1, wherein the one or more trigger conditions comprise: a number of detectable cellular-based links for the cellular-based positioning procedure being less than a threshold, a change in location of the UE, a change in serving cell of the UE, a confidence in a cellular-based position estimate of the UE being less than a confidence threshold, or any combination thereof.

[0181] Clause 3. The method of any of clauses 1 to 2, wherein the sidelink-based positioning operations are in addition to an ongoing sidelink-based positioning procedure performed by the UE.

[0182] Clause 4. The method of any of clauses 1 to 3, wherein the configuration further indicates a type of the sidelink-based positioning operations.

[0183] Clause 5. The method of any of clauses 1 to 4, further comprising: receiving, from a network entity, a list of sidelink anchor nodes with which to perform the sidelink-based positioning operations, the list of sidelink anchor nodes including at least the one or more sidelink anchor nodes; or selecting the one or more sidelink anchor nodes with which to perform the sidelink-based positioning operations.

[0184] Clause 6. The method of any of clauses 1 to 5, wherein the sidelink-based positioning operations are performed within a threshold period of time of positioning measurements performed for the cellular-based positioning procedure.

[0185] Clause 7. The method of any of clauses 1 to 6, wherein performing the sidelink-based positioning operations based on detecting the at least one of the one or more trigger conditions comprises: receiving, from a network entity, time and frequency resources for the sidelink-based positioning operations based on operating in Mode 1 resource allocation; or autonomously selecting the time and frequency resources for the sidelink-based positioning operations based on operating in Mode 2 resource allocation.

[0186] Clause 8. The method of any of clauses 1 to 7, further comprising: transmitting a notification to a network entity that that at least one of the one or more trigger conditions was detected.

[0187] Clause 9. The method of clause 8, wherein the notification includes a list of sidelink anchor nodes detected by the UE for the sidelink-based positioning operations, the list of sidelink anchor nodes including at least the one or more sidelink anchor nodes.

[0188] Clause 10. The method of clause 9, wherein the notification further includes locations of anchor nodes on the list of sidelink anchor nodes.

[0189] Clause 11. The method of any of clauses 1 to 10, wherein the sidelink-based positioning operations are configured to be: aperiodic, periodic with a periodicity matching a periodicity of positioning reference signals (PRS) measured or transmitted for the sidelink-based positioning operations, or periodic with a stop time.

[0190] Clause 12. The method of any of clauses 1 to 11, further comprising: transmitting, to a network entity, based on a failure of the sidelink-based positioning operations, a notification indicating the failure of the sidelink-based positioning operations.

[0191] Clause 13. The method of any of clauses 1 to 12, wherein performing the sidelink-based positioning operations based on detecting the at least one of the one or more trigger conditions comprises: modifying one or more resources of an ongoing sidelink-based positioning procedure performed by the UE.

[0192] Clause 14. The method of clause 13, wherein the one or more resources comprise: a bandwidth of the ongoing sidelink-based positioning procedure, a repetition factor of one or more sidelink resources of the ongoing sidelink-based positioning procedure, a comb value of the one or more sidelink resources of the ongoing sidelink-based positioning procedure, a periodicity of the one or more sidelink resources of the ongoing sidelink-based positioning procedure, or any combination thereof.

[0193] Clause 15. The method of any of clauses 1 to 14, wherein the sidelink-based positioning operations comprise: measuring one or more sidelink positioning reference signal (SL-PRS) resources transmitted by the one or more sidelink anchor nodes, transmitting one or more SL-PRS resources to the one or more sidelink anchor nodes, or a combination thereof.

[0194] Clause 16. A method of wireless communication performed by a user equipment (UE), comprising: engaging in a joint cellular-based and sidelink-based positioning session over a plurality of links between the UE and a plurality of anchor nodes, wherein the plurality of links comprises one or more cellular-based links between the UE and one or more cellular anchor nodes of the plurality of anchor nodes and one or more sidelink-based links between the UE and one or more sidelink anchor nodes of the plurality of anchor nodes; and dropping at least one link of the plurality of links for the joint cellular-based and sidelink-based positioning session based on one or more criteria.

[0195] Clause 17. The method of clause 16, wherein the one or more criteria comprise: a determination that the at least one link does not contribute to a position estimate of the UE, a determination that the at least one link is a non-line-of-sight (NLOS) link, a signal strength of the at least one link being less than a threshold, power saving considerations at the UE, or any combination thereof.

[0196] Clause 18. The method of any of clauses 16 to 17, wherein: a number of the one or more sidelink anchor nodes having known locations and line-of-sight (LOS) sidelink-based links is greater than a threshold, and the at least one link comprises at least one cellular-based link.

[0197] Clause 19. The method of any of clauses 16 to 18, wherein: a congestion level of at least one sidelink-based link of the one or more sidelink-based links is greater than a threshold, and the at least one link comprises the at least one sidelink-based link.

[0198] Clause 20. The method of any of clauses 16 to 19, further comprising: transmitting, to a network entity, a report indicating the at least one link.

[0199] Clause 21. The method of clause 20, wherein the report further includes: a time duration during which the at least one link is dropped, a reason for dropping the at least one link, or a combination thereof.

[0200] Clause 22. The method of any of clauses 16 to 21, further comprising: transmitting, to a network entity, a recommendation to drop one or more links of the plurality of links, wherein the at least one link is one of the one or more links.

[0201] Clause 23. The method of clause 22, wherein the recommendation includes: a time duration during which the UE will not use the one or more links, a reason for dropping the one or more links, priorities of the one or more links, or a combination thereof.

[0202] Clause 24. The method of any of clauses 22 to 23, further comprising: receiving, from the network entity, an indication that the one or more links have been dropped.

[0203] Clause 25. A method of wireless communication performed by a user equipment (UE), comprising: engaging in a cellular-based positioning session based on configuration information received from a network entity; performing one or more sidelink-based positioning operations with one or more sidelink anchor nodes during the cellular-based positioning session; and transmitting, to the network entity, a report including the sidelink-based positioning measurements.

[0204] Clause 26. The method of clause 25, wherein: the one or more sidelink anchor nodes are selected from a list of sidelink anchor nodes received from the network entity, or the one or more sidelink anchor nodes are selected by the UE and the report includes locations of the one or more sidelink anchor nodes.

[0205] Clause 27. The method of any of clauses 25 to 26, further comprising: receiving, from the network entity, an indication that the one or more sidelink-based positioning operations are to be performed within a threshold period of time of a reference transmission time.

[0206] Clause 28. The method of any of clauses 25 to 27, further comprising: receiving, from the network entity, an indication to activate opportunistic sidelink-based positioning operations.

[0207] Clause 29. The method of any of clauses 25 to 28, wherein the report further includes positioning information resulting from the cellular-based positioning session.

[0208] Clause 30. 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, a configuration indicating one or more trigger conditions for activating sidelink-based positioning operations in conjunction with a cellular-based positioning procedure; and perform the sidelink-based positioning operations with one or more sidelink anchor nodes based on detecting at least one of the one or more trigger conditions.

[0209] Clause 31. The UE of clause 30, wherein the one or more trigger conditions comprise: a number of detectable cellular-based links for the cellular-based positioning procedure being less than a threshold, a change in location of the UE, a change in serving cell of the UE, a confidence in a cellular-based position estimate of the UE being less than a confidence threshold, or any combination thereof.

[0210] Clause 32. The UE of any of clauses 30 to 31, wherein the sidelink-based positioning operations are in addition to an ongoing sidelink-based positioning procedure performed by the UE.

[0211] Clause 33. The UE of any of clauses 30 to 32, wherein the configuration further indicates a type of the sidelink-based positioning operations.

[0212] Clause 34. The UE of any of clauses 30 to 33, wherein the at least one processor is further configured to: receive, via the at least one transceiver, from a network entity, a list of sidelink anchor nodes with which to perform the sidelink-based positioning operations, the list of sidelink anchor nodes including at least the one or more sidelink anchor nodes; or select the one or more sidelink anchor nodes with which to perform the sidelink-based positioning operations.

[0213] Clause 35. The UE of any of clauses 30 to 34, wherein the sidelink-based positioning operations are performed within a threshold period of time of positioning measurements performed for the cellular-based positioning procedure.

[0214] Clause 36. The UE of any of clauses 30 to 35, wherein the at least one processor configured to perform the sidelink-based positioning operations based on detecting the at least one of the one or more trigger conditions comprises the at least one processor configured to: receive, via the at least one transceiver, from a network entity, time and frequency resources for the sidelink-based positioning operations based on operating in Mode 1 resource allocation; or autonomously select the time and frequency resources for the sidelink-based positioning operations based on operating in Mode 2 resource allocation.

[0215] Clause 37. The UE of any of clauses 30 to 36, wherein the at least one processor is further configured to: transmit, via the at least one transceiver, a notification to a network entity that that at least one of the one or more trigger conditions was detected.

[0216] Clause 38. The UE of clause 37, wherein the notification includes a list of sidelink anchor nodes detected by the UE for the sidelink-based positioning operations, the list of sidelink anchor nodes including at least the one or more sidelink anchor nodes.

[0217] Clause 39. The UE of clause 38, wherein the notification further includes locations of anchor nodes on the list of sidelink anchor nodes.

[0218] Clause 40. The UE of any of clauses 30 to 39, wherein the sidelink-based positioning operations are configured to be: aperiodic, periodic with a periodicity matching a periodicity of positioning reference signals (PRS) measured or transmitted for the sidelink-based positioning operations, or periodic with a stop time.

[0219] Clause 41. The UE of any of clauses 30 to 40, wherein the at least one processor is further configured to: transmit, via the at least one transceiver, to a network entity, based on a failure of the sidelink-based positioning operations, a notification indicating the failure of the sidelink-based positioning operations.

[0220] Clause 42. The UE of any of clauses 30 to 41, wherein the at least one processor configured to perform the sidelink-based positioning operations based on detecting the at least one of the one or more trigger conditions comprises the at least one processor configured to: modify one or more resources of an ongoing sidelink-based positioning procedure performed by the UE.

[0221] Clause 43. The UE of clause 42, wherein the one or more resources comprise: a bandwidth of the ongoing sidelink-based positioning procedure, a repetition factor of one or more sidelink resources of the ongoing sidelink-based positioning procedure, a comb value of the one or more sidelink resources of the ongoing sidelink-based positioning procedure, a periodicity of the one or more sidelink resources of the ongoing sidelink-based positioning procedure, or any combination thereof.

[0222] Clause 44. The UE of any of clauses 30 to 43, wherein the sidelink-based positioning operations comprise: measure one or more sidelink positioning reference signal (SL-PRS) resources transmitted by the one or more sidelink anchor nodes, transmit, via the at least one transceiver, one or more SL-PRS resources to the one or more sidelink anchor nodes, or a combination thereof.

[0223] Clause 45. 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: engage in a joint cellular-based and sidelink-based positioning session over a plurality of links between the UE and a plurality of anchor nodes, wherein the plurality of links comprises one or more cellular-based links between the UE and one or more cellular anchor nodes of the plurality of anchor nodes and one or more sidelink-based links between the UE and one or more sidelink anchor nodes of the plurality of anchor nodes; and drop at least one link of the plurality of links for the joint cellular-based and sidelink-based positioning session based on one or more criteria.

[0224] Clause 46. The UE of clause 45, wherein the one or more criteria comprise: a determination that the at least one link does not contribute to a position estimate of the UE, a determination that the at least one link is a non-line-of-sight (NLOS) link, a signal strength of the at least one link being less than a threshold, power saving considerations at the UE, or any combination thereof.

[0225] Clause 47. The UE of any of clauses 45 to 46, wherein: a number of the one or more sidelink anchor nodes having known locations and line-of-sight (LOS) sidelink-based links is greater than a threshold, and the at least one link comprises at least one cellular-based link.

[0226] Clause 48. The UE of any of clauses 45 to 47, wherein: a congestion level of at least one sidelink-based link of the one or more sidelink-based links is greater than a threshold, and the at least one link comprises the at least one sidelink-based link.

[0227] Clause 49. The UE of any of clauses 45 to 48, wherein the at least one processor is further configured to: transmit, via the at least one transceiver, to a network entity, a report indicating the at least one link.

[0228] Clause 50. The UE of clause 49, wherein the report further includes: a time duration during which the at least one link is dropped, a reason for dropping the at least one link, or a combination thereof.

[0229] Clause 51. The UE of any of clauses 45 to 50, wherein the at least one processor is further configured to: transmit, via the at least one transceiver, to a network entity, a recommendation to drop one or more links of the plurality of links, wherein the at least one link is one of the one or more links.

[0230] Clause 52. The UE of clause 51, wherein the recommendation includes: a time duration during which the UE will not use the one or more links, a reason for dropping the one or more links, priorities of the one or more links, or a combination thereof.

[0231] Clause 53. The UE of any of clauses 51 to 52, wherein the at least one processor is further configured to: receive, via the at least one transceiver, from the network entity, an indication that the one or more links have been dropped.

[0232] Clause 54. 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: engage in a cellular-based positioning session based on configuration information received from a network entity; perform one or more sidelink-based positioning operations with one or more sidelink anchor nodes during the cellular-based positioning session; and transmit, via the at least one transceiver, to the network entity, a report including the sidelink-based positioning measurements.

[0233] Clause 55. The UE of clause 54, wherein: the one or more sidelink anchor nodes are selected from a list of sidelink anchor nodes received from the network entity, or the one or more sidelink anchor nodes are selected by the UE and the report includes locations of the one or more sidelink anchor nodes.

[0234] Clause 56. The UE of any of clauses 54 to 55, wherein the at least one processor is further configured to: receive, via the at least one transceiver, from the network entity, an indication that the one or more sidelink-based positioning operations are to be performed within a threshold period of time of a reference transmission time.

[0235] Clause 57. The UE of any of clauses 54 to 56, wherein the at least one processor is further configured to: receive, via the at least one transceiver, from the network entity, an indication to activate opportunistic sidelink-based positioning operations.

[0236] Clause 58. The UE of any of clauses 54 to 57, wherein the report further includes positioning information resulting from the cellular-based positioning session.

[0237] Clause 59. A user equipment (UE), comprising: means for receiving a configuration indicating one or more trigger conditions for activating sidelink-based positioning operations in conjunction with a cellular-based positioning procedure; and means for performing the sidelink-based positioning operations with one or more sidelink anchor nodes based on detecting at least one of the one or more trigger conditions.

[0238] Clause 60. The UE of clause 59, wherein the one or more trigger conditions comprise: a number of detectable cellular-based links for the cellular-based positioning procedure being less than a threshold, a change in location of the UE, a change in serving cell of the

UE, a confidence in a cellular-based position estimate of the UE being less than a confidence threshold, or any combination thereof.

[0239] Clause 61. The UE of any of clauses 59 to 60, wherein the sidelink-based positioning operations are in addition to an ongoing sidelink-based positioning procedure performed by the UE.

[0240] Clause 62. The UE of any of clauses 59 to 61, wherein the configuration further indicates a type of the sidelink-based positioning operations.

[0241] Clause 63. The UE of any of clauses 59 to 62, further comprising: means for receiving, from a network entity, a list of sidelink anchor nodes with which to perform the sidelink-based positioning operations, the list of sidelink anchor nodes including at least the one or more sidelink anchor nodes; or means for selecting the one or more sidelink anchor nodes with which to perform the sidelink-based positioning operations.

[0242] Clause 64. The UE of any of clauses 59 to 63, wherein the sidelink-based positioning operations are performed within a threshold period of time of positioning measurements performed for the cellular-based positioning procedure.

[0243] Clause 65. The UE of any of clauses 59 to 64, wherein the means for performing the sidelink-based positioning operations based on detecting the at least one of the one or more trigger conditions comprises: means for receiving, from a network entity, time and frequency resources for the sidelink-based positioning operations based on operating in Mode 1 resource allocation; or means for autonomously selecting the time and frequency resources for the sidelink-based positioning operations based on operating in Mode 2 resource allocation.

[0244] Clause 66. The UE of any of clauses 59 to 65, further comprising: means for transmitting a notification to a network entity that that at least one of the one or more trigger conditions was detected.

[0245] Clause 67. The UE of clause 66, wherein the notification includes a list of sidelink anchor nodes detected by the UE for the sidelink-based positioning operations, the list of sidelink anchor nodes including at least the one or more sidelink anchor nodes.

[0246] Clause 68. The UE of clause 67, wherein the notification further includes locations of anchor nodes on the list of sidelink anchor nodes.

[0247] Clause 69. The UE of any of clauses 59 to 68, wherein the sidelink-based positioning operations are configured to be: aperiodic, means for periodicing with a periodicity matching a periodicity of positioning reference signals (PRS) measured or transmitted for the sidelink-based positioning operations, or means for periodicing with a stop time.

[0248] Clause 70. The UE of any of clauses 59 to 69, further comprising: means for transmitting, to a network entity, based on a failure of the sidelink-based positioning operations, a notification indicating the failure of the sidelink-based positioning operations.

[0249] Clause 71. The UE of any of clauses 59 to 70, wherein the means for performing the sidelink-based positioning operations based on detecting the at least one of the one or more trigger conditions comprises: means for modifying one or more resources of an ongoing sidelink-based positioning procedure performed by the UE.

[0250] Clause 72. The UE of clause 71, wherein the one or more resources comprise: a bandwidth of the ongoing sidelink-based positioning procedure, a repetition factor of one or more sidelink resources of the ongoing sidelink-based positioning procedure, a comb value of the one or more sidelink resources of the ongoing sidelink-based positioning procedure, a periodicity of the one or more sidelink resources of the ongoing sidelink-based positioning procedure, or any combination thereof.

[0251] Clause 73. The UE of any of clauses 59 to 72, wherein the sidelink-based positioning operations comprise: means for measuring one or more sidelink positioning reference signal (SL-PRS) resources transmitted by the one or more sidelink anchor nodes, means for transmitting one or more SL-PRS resources to the one or more sidelink anchor nodes, or a combination thereof.

[0252] Clause 74. A user equipment (UE), comprising: means for engaging in a joint cellular-based and sidelink-based positioning session over a plurality of links between the UE and a plurality of anchor nodes, wherein the plurality of links comprises one or more cellular-based links between the UE and one or more cellular anchor nodes of the plurality of anchor nodes and one or more sidelink-based links between the UE and one or more sidelink anchor nodes of the plurality of anchor nodes; and means for dropping at least one link of the plurality of links for the joint cellular-based and sidelink-based positioning session based on one or more criteria.

[0253] Clause 75. The UE of clause 74, wherein the one or more criteria comprise: a determination that the at least one link does not contribute to a position estimate of the UE, a determination that the at least one link is a non-line-of-sight (NLOS) link, a signal strength of the at least one link being less than a threshold, power saving considerations at the UE, or any combination thereof.

[0254] Clause 76. The UE of any of clauses 74 to 75, wherein: a number of the one or more sidelink anchor nodes having known locations and line-of-sight (LOS) sidelink-based links is greater than a threshold, and the at least one link comprises at least one cellular-based link.

[0255] Clause 77. The UE of any of clauses 74 to 76, wherein: a congestion level of at least one sidelink-based link of the one or more sidelink-based links is greater than a threshold, and the at least one link comprises the at least one sidelink-based link.

[0256] Clause 78. The UE of any of clauses 74 to 77, further comprising: means for transmitting, to a network entity, a report indicating the at least one link.

[0257] Clause 79. The UE of clause 78, wherein the report further includes: a time duration during which the at least one link is dropped, a reason for dropping the at least one link, or a combination thereof.

[0258] Clause 80. The UE of any of clauses 74 to 79, further comprising: means for transmitting, to a network entity, a recommendation to drop one or more links of the plurality of links, wherein the at least one link is one of the one or more links.

[0259] Clause 81. The UE of clause 80, wherein the recommendation includes: a time duration during which the UE will not use the one or more links, a reason for dropping the one or more links, priorities of the one or more links, or a combination thereof.

[0260] Clause 82. The UE of any of clauses 80 to 81, further comprising: means for receiving, from the network entity, an indication that the one or more links have been dropped.

[0261] Clause 83. A user equipment (UE), comprising: means for engaging in a cellular-based positioning session based on configuration information received from a network entity; means for performing one or more sidelink-based positioning operations with one or more sidelink anchor nodes during the cellular-based positioning session; and means for transmitting, to the network entity, a report including the sidelink-based positioning measurements.

[0262] Clause 84. The UE of clause 83, wherein: the one or more sidelink anchor nodes are selected from a list of sidelink anchor nodes received from the network entity, or the one or more sidelink anchor nodes are selected by the UE and the report includes locations of the one or more sidelink anchor nodes.

[0263] Clause 85. The UE of any of clauses 83 to 84, further comprising: means for receiving, from the network entity, an indication that the one or more sidelink-based positioning operations are to be performed within a threshold period of time of a reference transmission time.

[0264] Clause 86. The UE of any of clauses 83 to 85, further comprising: means for receiving, from the network entity, an indication to activate opportunistic sidelink-based positioning operations.

[0265] Clause 87. The UE of any of clauses 83 to 86, wherein the report further includes positioning information resulting from the cellular-based positioning session.

[0266] Clause 88. A non-transitory computer-readable medium storing computer-executable instructions that, when executed by a user equipment (UE), cause the UE to: receive a configuration indicating one or more trigger conditions for activating sidelink-based positioning operations in conjunction with a cellular-based positioning procedure; and perform the sidelink-based positioning operations with one or more sidelink anchor nodes based on detecting at least one of the one or more trigger conditions.

[0267] Clause 89. The non-transitory computer-readable medium of clause 88, wherein the one or more trigger conditions comprise: a number of detectable cellular-based links for the cellular-based positioning procedure being less than a threshold, a change in location of the UE, a change in serving cell of the UE, a confidence in a cellular-based position estimate of the UE being less than a confidence threshold, or any combination thereof.

[0268] Clause 90. The non-transitory computer-readable medium of any of clauses 88 to 89, wherein the sidelink-based positioning operations are in addition to an ongoing sidelink-based positioning procedure performed by the UE.

[0269] Clause 91. The non-transitory computer-readable medium of any of clauses 88 to 90, wherein the configuration further indicates a type of the sidelink-based positioning operations.

[0270] Clause 92. The non-transitory computer-readable medium of any of clauses 88 to 91, further comprising computer-executable instructions that, when executed by the UE, cause the UE to: receive, from a network entity, a list of sidelink anchor nodes with which to perform the sidelink-based positioning operations, the list of sidelink anchor nodes including at least the one or more sidelink anchor nodes; or select the one or more sidelink anchor nodes with which to perform the sidelink-based positioning operations.

[0271] Clause 93. The non-transitory computer-readable medium of any of clauses 88 to 92, wherein the sidelink-based positioning operations are performed within a threshold period of time of positioning measurements performed for the cellular-based positioning procedure.

[0272] Clause 94. The non-transitory computer-readable medium of any of clauses 88 to 93, wherein the computer-executable instructions that, when executed by the UE, cause the UE to perform the sidelink-based positioning operations based on detecting the at least one of the one or more trigger conditions comprise computer-executable instructions that, when executed by the UE, cause the UE to: receive, from a network entity, time and frequency resources for the sidelink-based positioning operations based on operating in Mode 1 resource allocation; or autonomously select the time and frequency resources for the sidelink-based positioning operations based on operating in Mode 2 resource allocation.

[0273] Clause 95. The non-transitory computer-readable medium of any of clauses 88 to 94, further comprising computer-executable instructions that, when executed by the UE, cause the UE to: transmit a notification to a network entity that that at least one of the one or more trigger conditions was detected.

[0274] Clause 96. The non-transitory computer-readable medium of clause 95, wherein the notification includes a list of sidelink anchor nodes detected by the UE for the sidelink-based positioning operations, the list of sidelink anchor nodes including at least the one or more sidelink anchor nodes.

[0275] Clause 97. The non-transitory computer-readable medium of clause 96, wherein the notification further includes locations of anchor nodes on the list of sidelink anchor nodes.

[0276] Clause 98. The non-transitory computer-readable medium of any of clauses 88 to 97, wherein the sidelink-based positioning operations are configured to be: aperiodic, periodic with a periodicity matching a periodicity of positioning reference signals (PRS) measured or transmitted for the sidelink-based positioning operations, or periodic with a stop time.

[0277] Clause 99. The non-transitory computer-readable medium of any of clauses 88 to 98, further comprising computer-executable instructions that, when executed by the UE, cause the UE to: transmit, to a network entity, based on a failure of the sidelink-based positioning operations, a notification indicating the failure of the sidelink-based positioning operations.

[0278] Clause 100. The non-transitory computer-readable medium of any of clauses 88 to 99, wherein the computer-executable instructions that, when executed by the UE, cause the UE to perform the sidelink-based positioning operations based on detecting the at least one of the one or more trigger conditions comprise computer-executable instructions that, when executed by the UE, cause the UE to: modify one or more resources of an ongoing sidelink-based positioning procedure performed by the UE.

[0279] Clause 101. The non-transitory computer-readable medium of clause 100, wherein the one or more resources comprise: a bandwidth of the ongoing sidelink-based positioning procedure, a repetition factor of one or more sidelink resources of the ongoing sidelink-based positioning procedure, a comb value of the one or more sidelink resources of the ongoing sidelink-based positioning procedure, a periodicity of the one or more sidelink resources of the ongoing sidelink-based positioning procedure, or any combination thereof.

[0280] Clause 102. The non-transitory computer-readable medium of any of clauses 88 to 101, wherein the sidelink-based positioning operations comprise: measure one or more sidelink positioning reference signal (SL-PRS) resources transmitted by the one or more sidelink anchor nodes, transmit one or more SL-PRS resources to the one or more sidelink anchor nodes, or a combination thereof.

[0281] Clause 103. A non-transitory computer-readable medium storing computer-executable instructions that, when executed by a user equipment (UE), cause the UE to: engage in a joint cellular-based and sidelink-based positioning session over a plurality of links between the UE and a plurality of anchor nodes, wherein the plurality of links comprises one or more cellular-based links between the UE and one or more cellular anchor nodes of the plurality of anchor nodes and one or more sidelink-based links between the UE and one or more sidelink anchor nodes of the plurality of anchor nodes; and drop at least one link of the plurality of links for the joint cellular-based and sidelink-based positioning session based on one or more criteria.

[0282] Clause 104. The non-transitory computer-readable medium of clause 103, wherein the one or more criteria comprise: a determination that the at least one link does not contribute to a position estimate of the UE, a determination that the at least one link is a non-line-of-sight (NLOS) link, a signal strength of the at least one link being less than a threshold, power saving considerations at the UE, or any combination thereof.

[0283] Clause 105. The non-transitory computer-readable medium of any of clauses 103 to 104, wherein: a number of the one or more sidelink anchor nodes having known locations and line-of-sight (LOS) sidelink-based links is greater than a threshold, and the at least one link comprises at least one cellular-based link.

[0284] Clause 106. The non-transitory computer-readable medium of any of clauses 103 to 105, wherein: a congestion level of at least one sidelink-based link of the one or more sidelink-based links is greater than a threshold, and the at least one link comprises the at least one sidelink-based link.

[0285] Clause 107. The non-transitory computer-readable medium of any of clauses 103 to 106, further comprising computer-executable instructions that, when executed by the UE, cause the UE to: transmit, to a network entity, a report indicating the at least one link.

[0286] Clause 108. The non-transitory computer-readable medium of clause 107, wherein the report further includes: a time duration during which the at least one link is dropped, a reason for dropping the at least one link, or a combination thereof.

[0287] Clause 109. The non-transitory computer-readable medium of any of clauses 103 to 108, further comprising computer-executable instructions that, when executed by the UE, cause the UE to: transmit, to a network entity, a recommendation to drop one or more links of the plurality of links, wherein the at least one link is one of the one or more links.

[0288] Clause 110. The non-transitory computer-readable medium of clause 109, wherein the recommendation includes: a time duration during which the UE will not use the one or more links, a reason for dropping the one or more links, priorities of the one or more links, or a combination thereof.

[0289] Clause 111. The non-transitory computer-readable medium of any of clauses 109 to 110, further comprising computer-executable instructions that, when executed by the UE, cause the UE to: receive, from the network entity, an indication that the one or more links have been dropped.

[0290] Clause 112. A non-transitory computer-readable medium storing computer-executable instructions that, when executed by a user equipment (UE), cause the UE to: engage in a cellular-based positioning session based on configuration information received from a network entity; perform one or more sidelink-based positioning operations with one or more sidelink anchor nodes during the cellular-based positioning session; and transmit, to the network entity, a report including the sidelink-based positioning measurements.

[0291] Clause 113. The non-transitory computer-readable medium of clause 112, wherein: the one or more sidelink anchor nodes are selected from a list of sidelink anchor nodes received from the network entity, or the one or more sidelink anchor nodes are selected by the UE and the report includes locations of the one or more sidelink anchor nodes.

[0292] Clause 114. The non-transitory computer-readable medium of any of clauses 112 to 113, further comprising computer-executable instructions that, when executed by the UE, cause the UE to: receive, from the network entity, an indication that the one or more sidelink-based positioning operations are to be performed within a threshold period of time of a reference transmission time.

[0293] Clause 115. The non-transitory computer-readable medium of any of clauses 112 to 114, further comprising computer-executable instructions that, when executed by the UE, cause the UE to: receive, from the network entity, an indication to activate opportunistic sidelink-based positioning operations.

[0294] Clause 116. The non-transitory computer-readable medium of any of clauses 112 to 115, wherein the report further includes positioning information resulting from the cellular-based positioning session.

[0295] 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.

[0296] 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.

[0297] 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 digital signal processor (DSP), an ASIC, a field-programable gate array (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, for example, 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.

[0298] 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.

[0299] 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.

[0300] 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 a configuration indicating one or more trigger conditions for activating sidelink-based positioning operations in conjunction with a cellular-based positioning procedure; and

performing the sidelink-based positioning operations with one or more sidelink anchor nodes based on detecting at least one of the one or more trigger conditions.

2. The method of claim 1, wherein the one or more trigger conditions comprise:

a number of detectable cellular-based links for the cellular-based positioning procedure being less than a threshold,

a change in location of the UE,

a change in serving cell of the UE,

a confidence in a cellular-based position estimate of the UE being less than a confidence threshold, or

any combination thereof.

3. The method of claim 1, wherein the sidelink-based positioning operations are in addition to an ongoing sidelink-based positioning procedure performed by the UE.

4. The method of claim 1, wherein the configuration further indicates a type of the sidelink-based positioning operations.

5. The method of claim 1, further comprising:

receiving, from a network entity, a list of sidelink anchor nodes with which to perform the sidelink-based positioning operations, the list of sidelink anchor nodes including at least the one or more sidelink anchor nodes; or

selecting the one or more sidelink anchor nodes with which to perform the sidelink-based positioning operations.

6. The method of claim 1, wherein the sidelink-based positioning operations are performed within a threshold period of time of positioning measurements performed for the cellular-based positioning procedure.

7. The method of claim 1, wherein performing the sidelink-based positioning operations based on detecting the at least one of the one or more trigger conditions comprises:

receiving, from a network entity, time and frequency resources for the sidelink-based positioning operations based on operating in Mode 1 resource allocation; or

autonomously selecting the time and frequency resources for the sidelink-based positioning operations based on operating in Mode 2 resource allocation.

8. The method of claim 1, further comprising:

transmitting a notification to a network entity that that at least one of the one or more trigger conditions was detected.

9. The method of claim 8, wherein the notification includes a list of sidelink anchor nodes detected by the UE for the sidelink-based positioning operations, the list of sidelink anchor nodes including at least the one or more sidelink anchor nodes.

10. The method of claim 9, wherein the notification further includes locations of anchor nodes on the list of sidelink anchor nodes.

11. The method of claim 1, wherein the sidelink-based positioning operations are configured to be:

aperiodic,

periodic with a periodicity matching a periodicity of positioning reference signals (PRS) measured or transmitted for the sidelink-based positioning operations, or

periodic with a stop time.

12. The method of claim 1, further comprising:

transmitting, to a network entity, based on a failure of the sidelink-based positioning operations, a notification indicating the failure of the sidelink-based positioning operations.

13. The method of claim 1, wherein performing the sidelink-based positioning operations based on detecting the at least one of the one or more trigger conditions comprises:

modifying one or more resources of an ongoing sidelink-based positioning procedure performed by the UE.

14. The method of claim 13, wherein the one or more resources comprise:

a bandwidth of the ongoing sidelink-based positioning procedure,

a repetition factor of one or more sidelink resources of the ongoing sidelink-based positioning procedure,

a comb value of the one or more sidelink resources of the ongoing sidelink-based positioning procedure,

a periodicity of the one or more sidelink resources of the ongoing sidelink-based positioning procedure, or

any combination thereof.

15. The method of claim 1, wherein the sidelink-based positioning operations comprise:

measuring one or more sidelink positioning reference signal (SL-PRS) resources transmitted by the one or more sidelink anchor nodes,

transmitting one or more SL-PRS resources to the one or more sidelink anchor nodes, or

a combination thereof.

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

engaging in a joint cellular-based and sidelink-based positioning session over a plurality of links between the UE and a plurality of anchor nodes, wherein the plurality of links comprises one or more cellular-based links between the UE and one or more cellular anchor nodes of the plurality of anchor nodes and one or more sidelink-based links between the UE and one or more sidelink anchor nodes of the plurality of anchor nodes; and

dropping at least one link of the plurality of links for the joint cellular-based and sidelink-based positioning session based on one or more criteria.

17. The method of claim 16, wherein the one or more criteria comprise:

a determination that the at least one link does not contribute to a position estimate of the UE,

a determination that the at least one link is a non-line-of-sight (NLOS) link,

a signal strength of the at least one link being less than a threshold,

power saving considerations at the UE, or

any combination thereof.

18. The method of claim 16, wherein:

a number of the one or more sidelink anchor nodes having known locations and line-of-sight (LOS) sidelink-based links is greater than a threshold, and

the at least one link comprises at least one cellular-based link.

19. The method of claim 16, wherein:

a congestion level of at least one sidelink-based link of the one or more sidelink-based links is greater than a threshold, and

the at least one link comprises the at least one sidelink-based link.

20. The method of claim 16, further comprising:

transmitting, to a network entity, a report indicating the at least one link.

21. The method of claim 20, wherein the report further includes:

a time duration during which the at least one link is dropped,

a reason for dropping the at least one link, or

a combination thereof.

22. The method of claim 16, further comprising:

transmitting, to a network entity, a recommendation to drop one or more links of the plurality of links, wherein the at least one link is one of the one or more links.

23. The method of claim 22, wherein the recommendation includes:

a time duration during which the UE will not use the one or more links,

a reason for dropping the one or more links,

priorities of the one or more links, or

a combination thereof.

24. The method of claim 22, further comprising:

receiving, from the network entity, an indication that the one or more links have been dropped.

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

engaging in a cellular-based positioning session based on configuration information received from a network entity;

performing one or more sidelink-based positioning operations with one or more sidelink anchor nodes during the cellular-based positioning session; and

transmitting, to the network entity, a report including the sidelink-based positioning measurements.

26. The method of claim 25, wherein:

the one or more sidelink anchor nodes are selected from a list of sidelink anchor nodes received from the network entity, or

the one or more sidelink anchor nodes are selected by the UE and the report includes locations of the one or more sidelink anchor nodes.

27. The method of claim 25, further comprising:

receiving, from the network entity, an indication that the one or more sidelink-based positioning operations are to be performed within a threshold period of time of a reference transmission time.

28. The method of claim 25, further comprising:

receiving, from the network entity, an indication to activate opportunistic sidelink-based positioning operations.

29. The method of claim 25, wherein the report further includes positioning information resulting from the cellular-based positioning session.

30. 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, a configuration indicating one or more trigger conditions for activating sidelink-based positioning operations in conjunction with a cellular-based positioning procedure; and

perform the sidelink-based positioning operations with one or more sidelink anchor nodes based on detecting at least one of the one or more trigger conditions.

31. The UE of claim 30, wherein the one or more trigger conditions comprise:

a number of detectable cellular-based links for the cellular-based positioning procedure being less than a threshold,

a change in location of the UE,

a change in serving cell of the UE,

a confidence in a cellular-based position estimate of the UE being less than a confidence threshold, or

any combination thereof.

32. The UE of claim 30, wherein the sidelink-based positioning operations are in addition to an ongoing sidelink-based positioning procedure performed by the UE.

33. The UE of claim 30, wherein the sidelink-based positioning operations are performed within a threshold period of time of positioning measurements performed for the cellular-based positioning procedure.

34. 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:

engage in a joint cellular-based and sidelink-based positioning session over a plurality of links between the UE and a plurality of anchor nodes, wherein the plurality of links comprises one or more cellular-based links between the UE and one or more cellular anchor nodes of the plurality of anchor nodes and one or more sidelink-based links between the UE and one or more sidelink anchor nodes of the plurality of anchor nodes; and

drop at least one link of the plurality of links for the joint cellular-based and sidelink-based positioning session based on one or more criteria.

35. The UE of claim 34, wherein the one or more criteria comprise:

a determination that the at least one link does not contribute to a position estimate of the UE,

a determination that the at least one link is a non-line-of-sight (NLOS) link,

a signal strength of the at least one link being less than a threshold,

power saving considerations at the UE, or

any combination thereof.

36. The UE of claim 34, wherein:

a number of the one or more sidelink anchor nodes having known locations and line-of-sight (LOS) sidelink-based links is greater than a threshold, and the at least one link comprises at least one cellular-based link.

37. The UE of claim 34, wherein:

a congestion level of at least one sidelink-based link of the one or more sidelink-based links is greater than a threshold, and

the at least one link comprises the at least one sidelink-based link.

38. 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:

engage in a cellular-based positioning session based on configuration information received from a network entity;

perform one or more sidelink-based positioning operations with one or more sidelink anchor nodes during the cellular-based positioning session; and

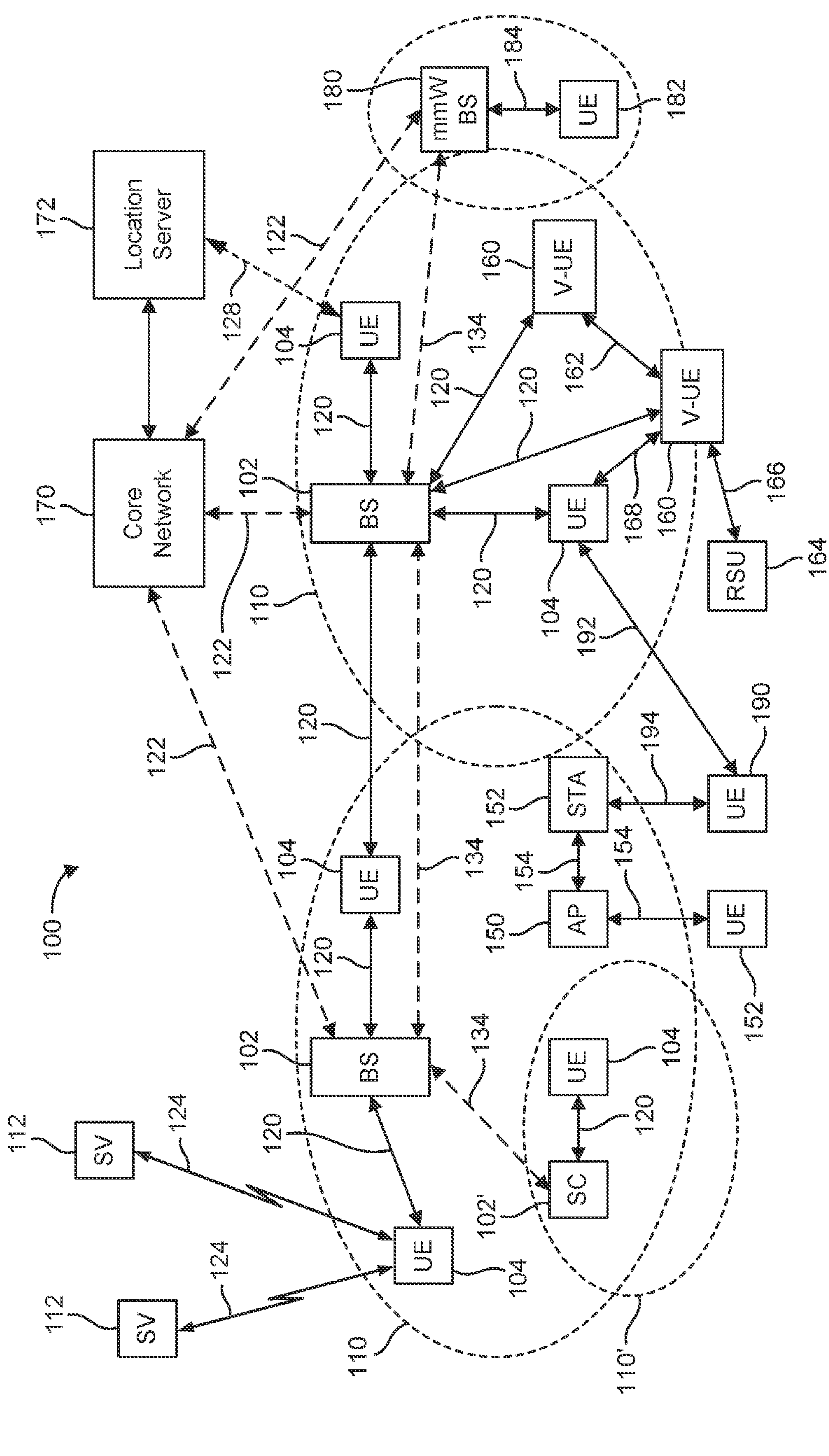
transmit, via the at least one transceiver, to the network entity, a report including the sidelink-based positioning measurements.

39. The UE of claim 38, wherein:

the one or more sidelink anchor nodes are selected from a list of sidelink anchor nodes received from the network entity, or

the one or more sidelink anchor nodes are selected by the UE and the report includes locations of the one or more sidelink anchor nodes.

40. The UE of claim 38, wherein the report further includes positioning information resulting from the cellular-based positioning session.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UE
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UE
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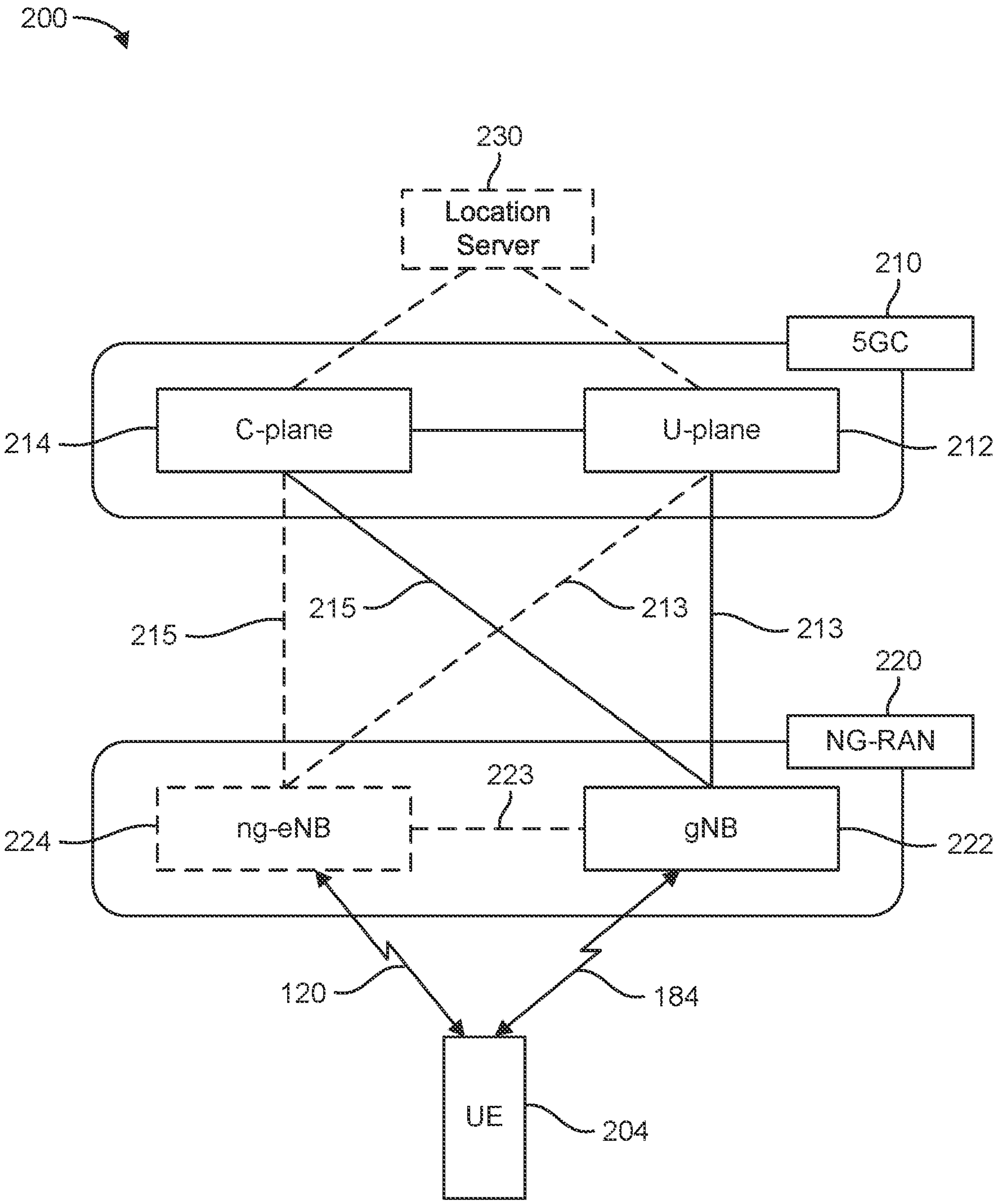
UE
104

FIG. 1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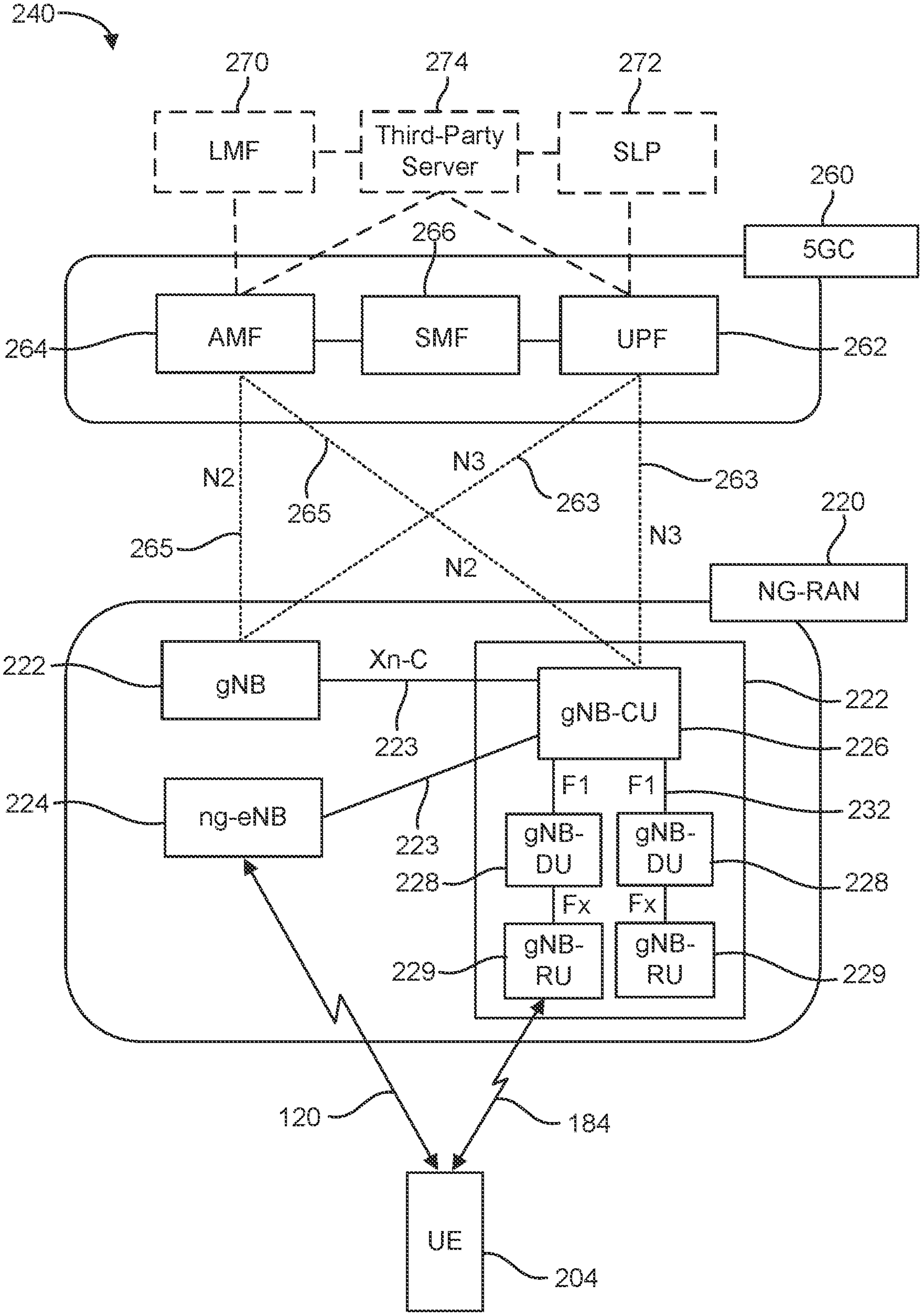
ng-eNB
gNB
222
120
184
UE
204

FIG. 2A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LMF
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SLP
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266
5GC
264
AMF
SMF
UPF
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N2
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263
263
265
N3
N2
220
NG-RAN
222
gNB
Xn-C
223
gNB-CU
222
226
224
ng-eNB
223
F1
F1
232
gNB-DU
gNB-DU
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228
Fx
Fx
229
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gNB-RU
229
120
184
UE
204

FIG. 2B

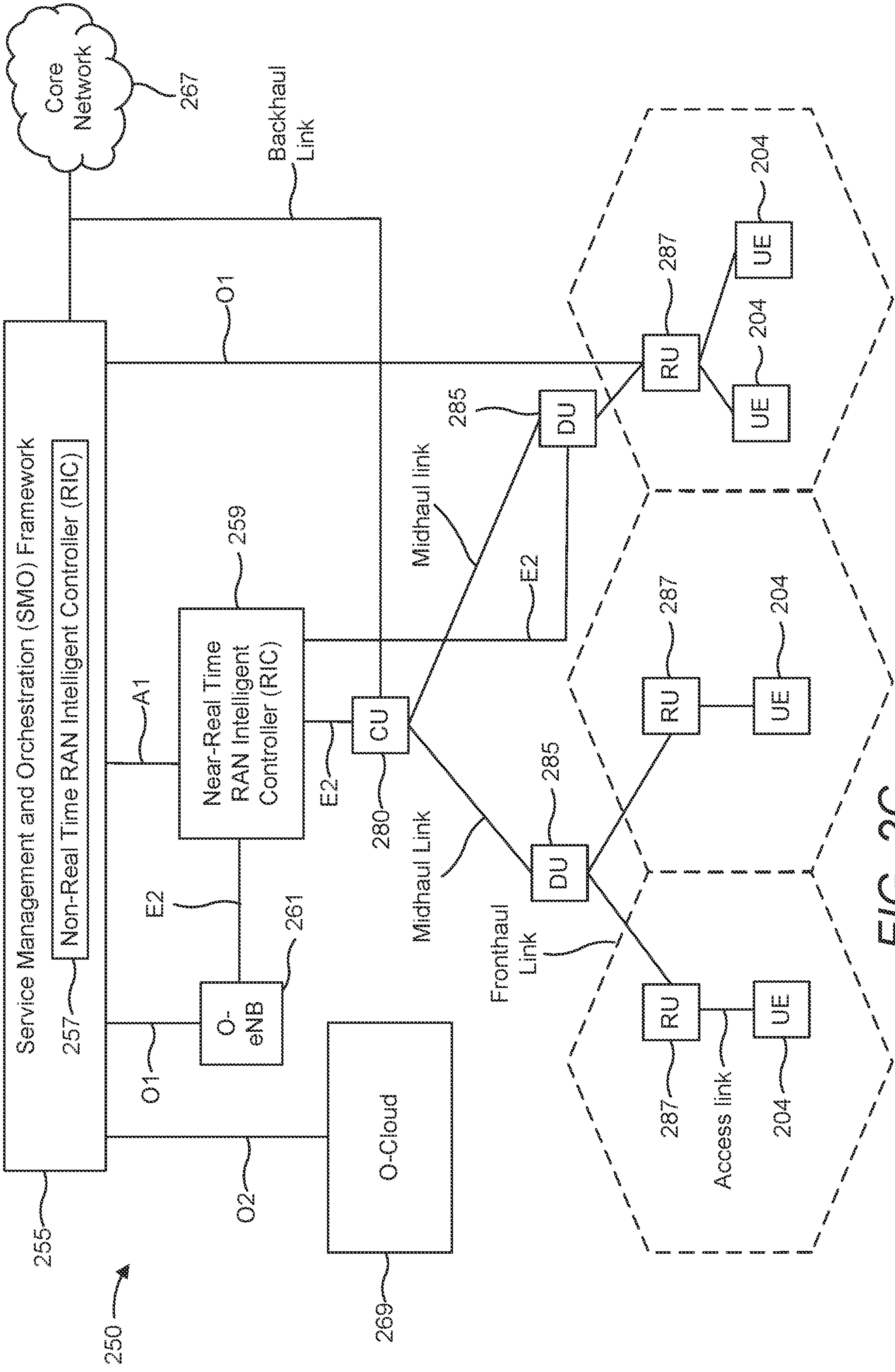
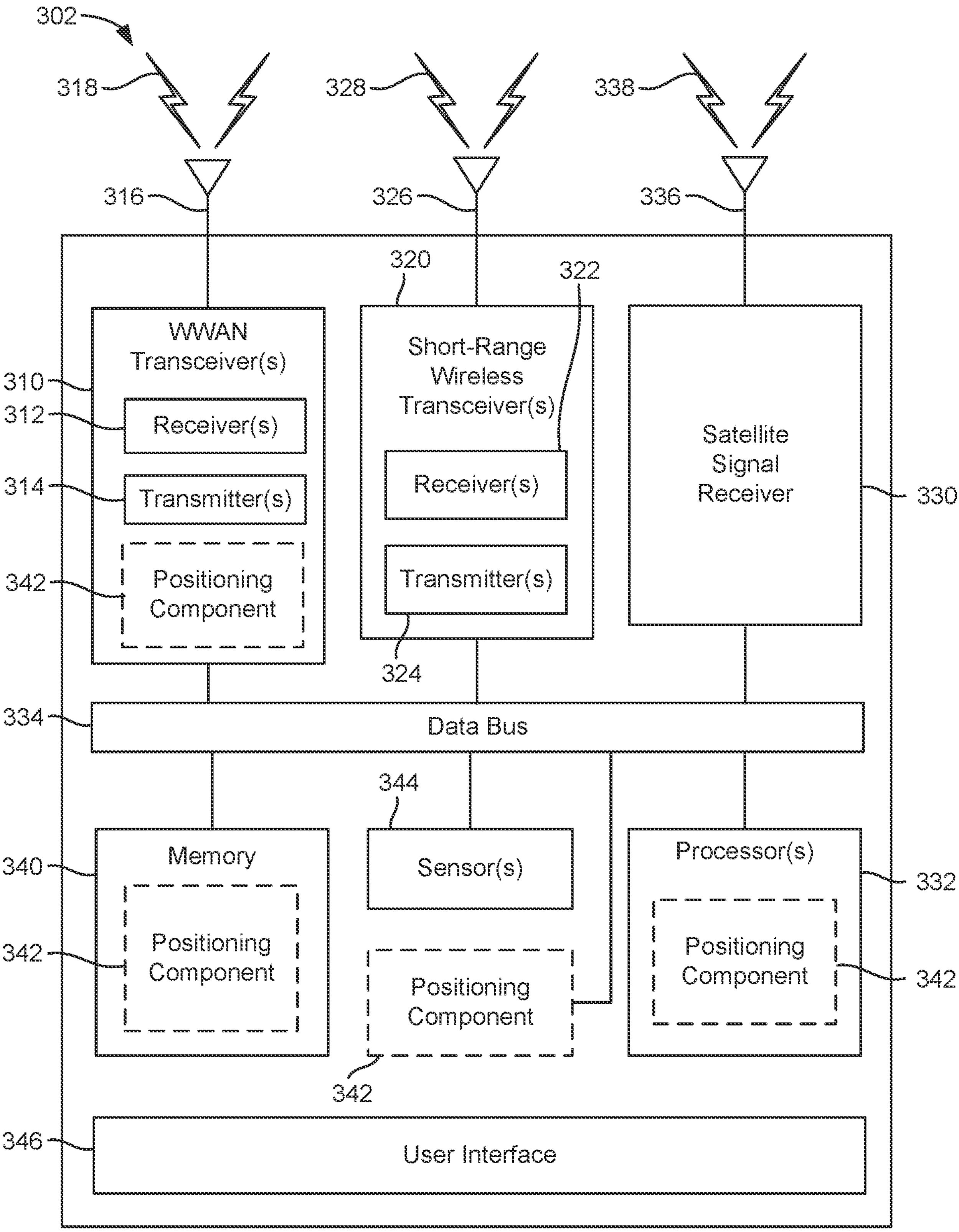

Core Network
267
Backhaul Link
Service Management and Orchestration (SMO) Framework
Non-Real Time RAN Intelligent Controller (RIC)
257
255
O1
A1
Near-Real Time RAN Intelligent Controller (RIC)
259
E2
CU
280
O-eNB
261
O2
O-Cloud
269
Midhaul link
Midhaul Link
DU
285
Fronthaul Link
RU
287
UE
204
Access link
250

FIG. 2C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318
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316
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336
320
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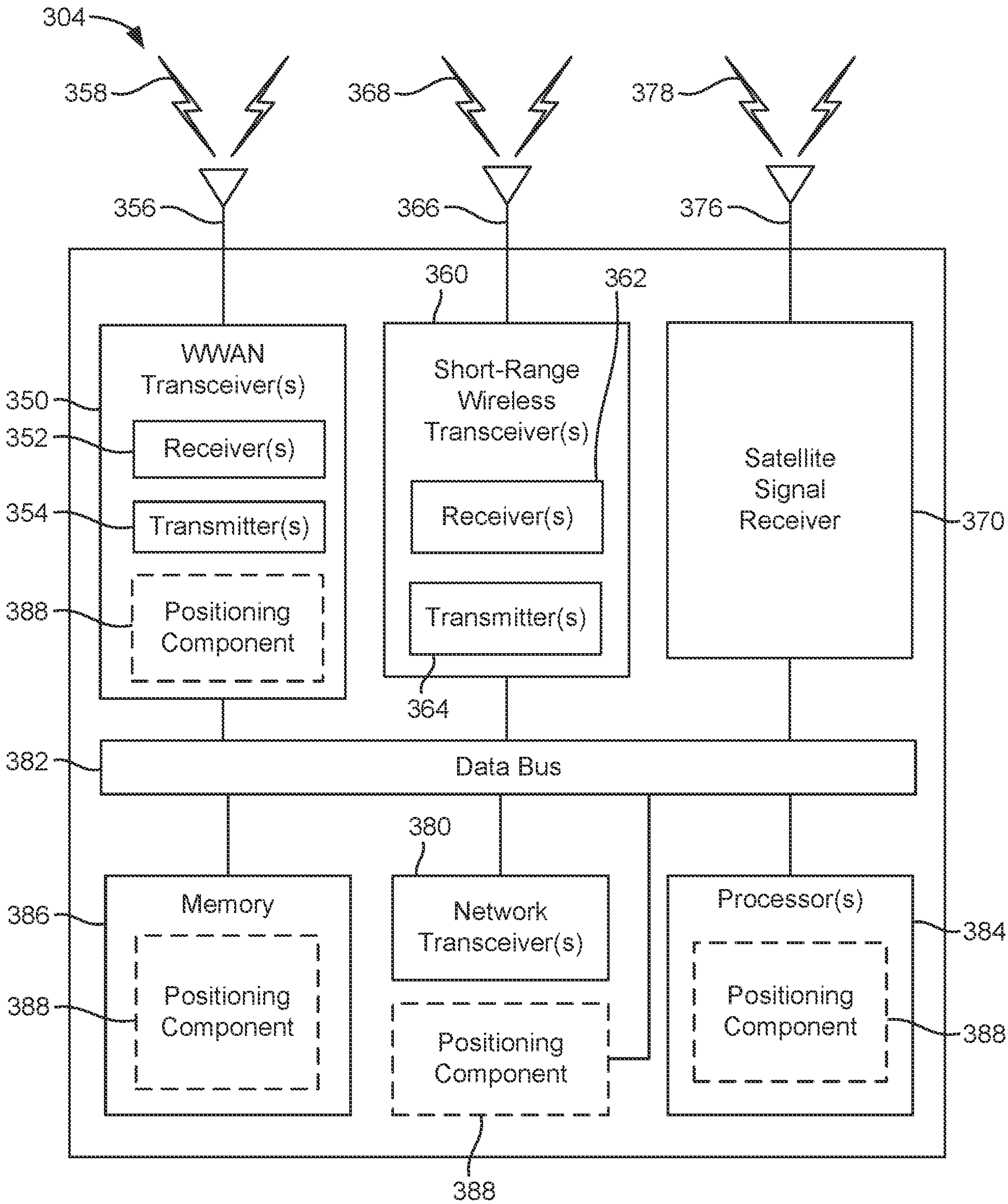
WWAN Transceiver(s)
310
312
Receiver(s)
314
Transmitter(s)
342
Positioning Component
Short-Range Wireless Transceiver(s)
Receiver(s)
Transmitter(s)
324
Satellite Signal Receiver
330
334
Data Bus
344
340
Memory
Positioning Component
Sensor(s)
Positioning Component
Processor(s)
332
Positioning Component
342
346
User Interface

FIG. 3A



304
358
368
378
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366
376
360
362
WWAN
Transceiver(s)
350
352
Receiver(s)
354
Transmitter(s)
388
Positioning
Component
Short-Range
Wireless
Transceiver(s)
Receiver(s)
Transmitter(s)
364
Satellite
Signal
Receiver
370
382
Data Bus
380
386
Memory
Positioning
Component
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Network
Transceiver(s)
Positioning
Component
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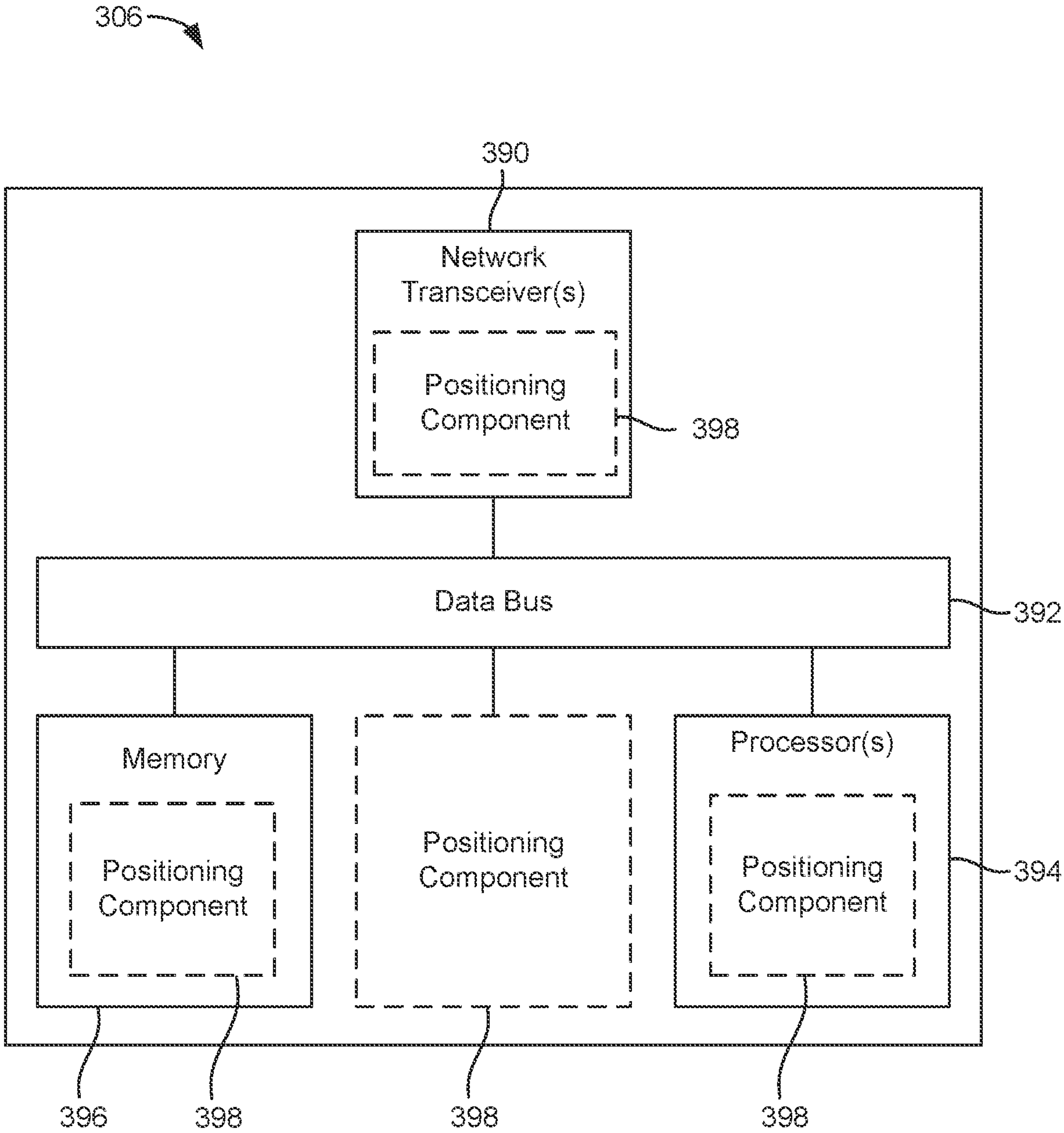
Processor(s)
384
Positioning
Component
388

FIG. 3B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Positioning Component
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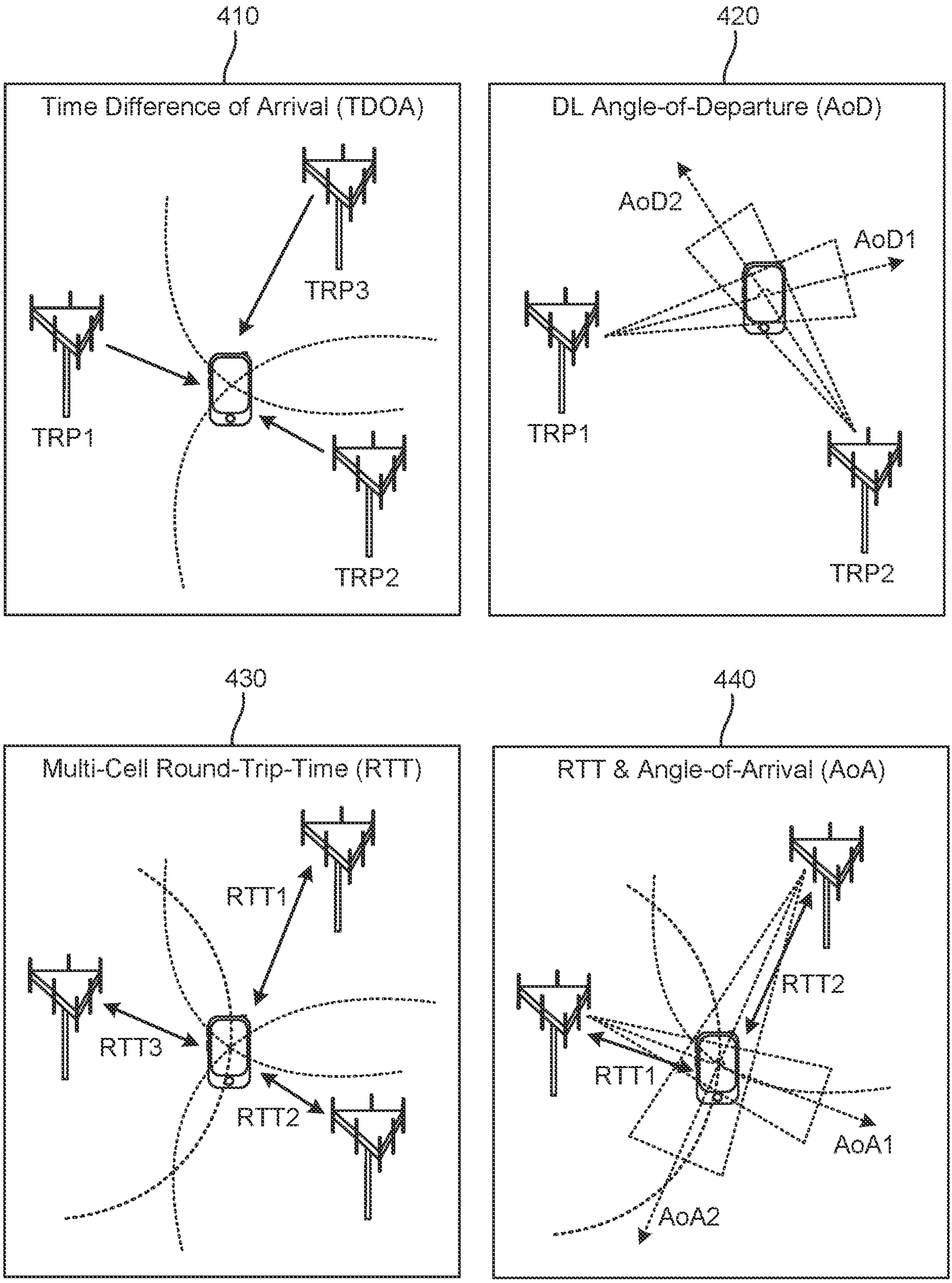
Data Bus
392
Memory
Positioning Component
Positioning Component
Processor(s)
Positioning Component
394
396
398
398
398

FIG. 3C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TRP1
TRP2
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DL Angle-of-Departure (AoD)
AoD2
AoD1
TRP1
TRP2
430
Multi-Cell Round-Trip-Time (RTT)
RTT1
RTT3
RTT2
440
RTT & Angle-of-Arrival (AoA)
RTT2
RTT1
AoA1
AoA2

FIG. 4

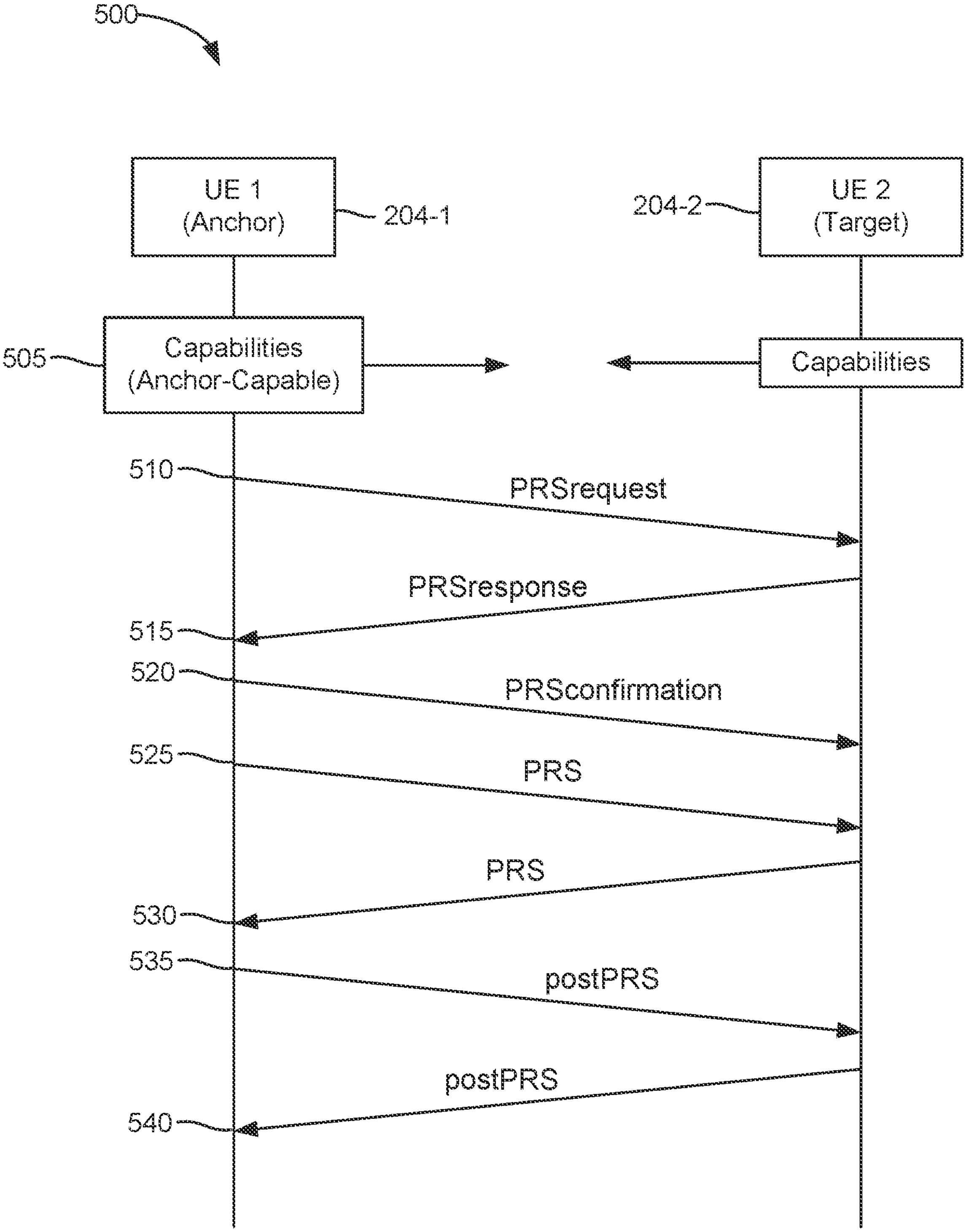
500
UE 1
(Anchor)
204-1
204-2
UE 2
(Target)
505
Capabilities
(Anchor-Capable)
Capabilities
510
PRSrequest
PRSresponse
515
520
PRSconfirmation
525
PRS
PRS
530
535
postPRS
postPRS
540

FIG. 5

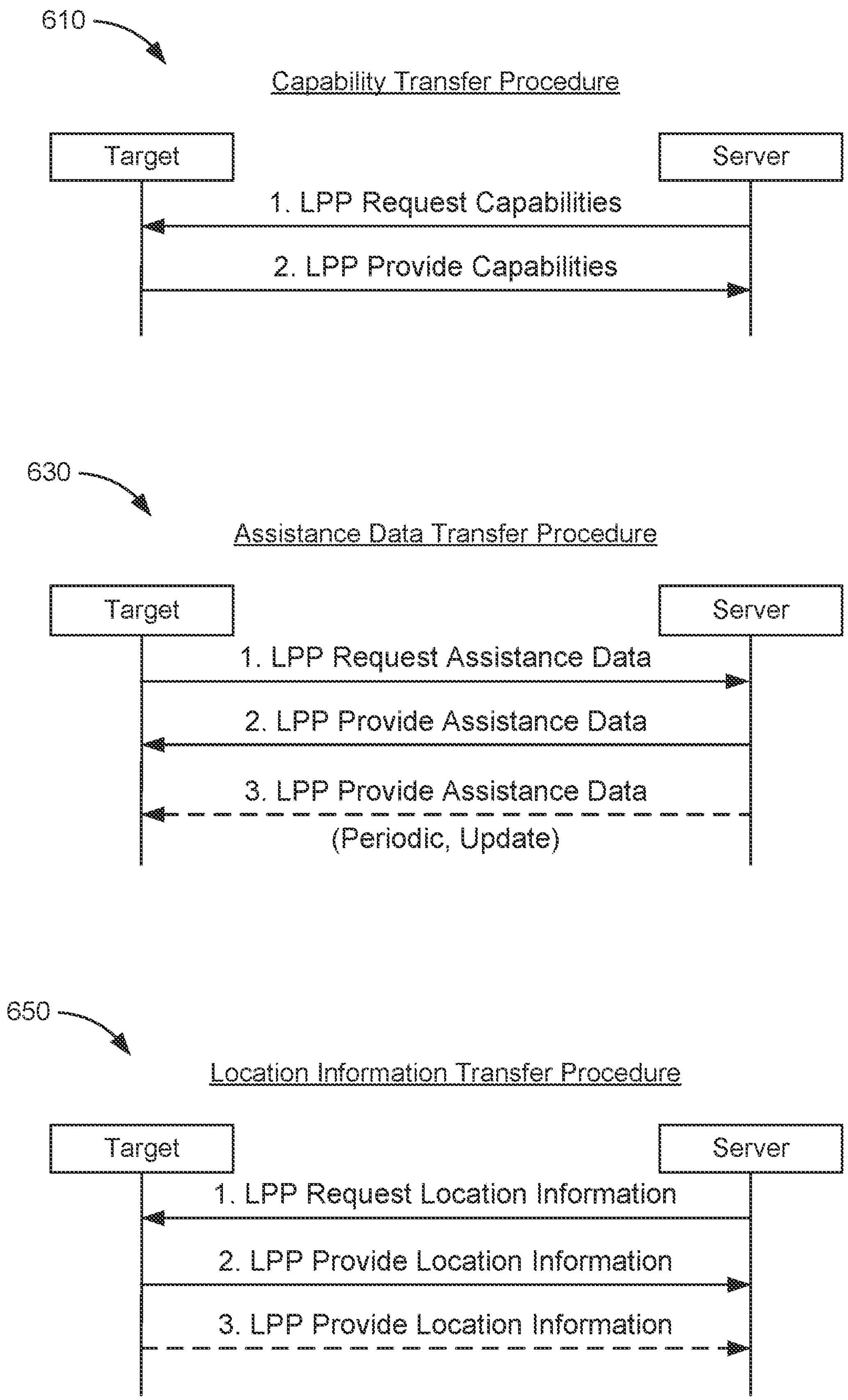
610
Capability Transfer Procedure
Target
Server
1. LPP Request Capabilities
2. LPP Provide Capabilities
630
Assistance Data Transfer Procedure
Target
Server
1. LPP Request Assistance Data
2. LPP Provide Assistance Data
3. LPP Provide Assistance Data
(Periodic, Update)
650
Location Information Transfer Procedure
Target
Server
1. LPP Request Location Information
2. LPP Provide Location Information
3. LPP Provide Location Information

FIG. 6

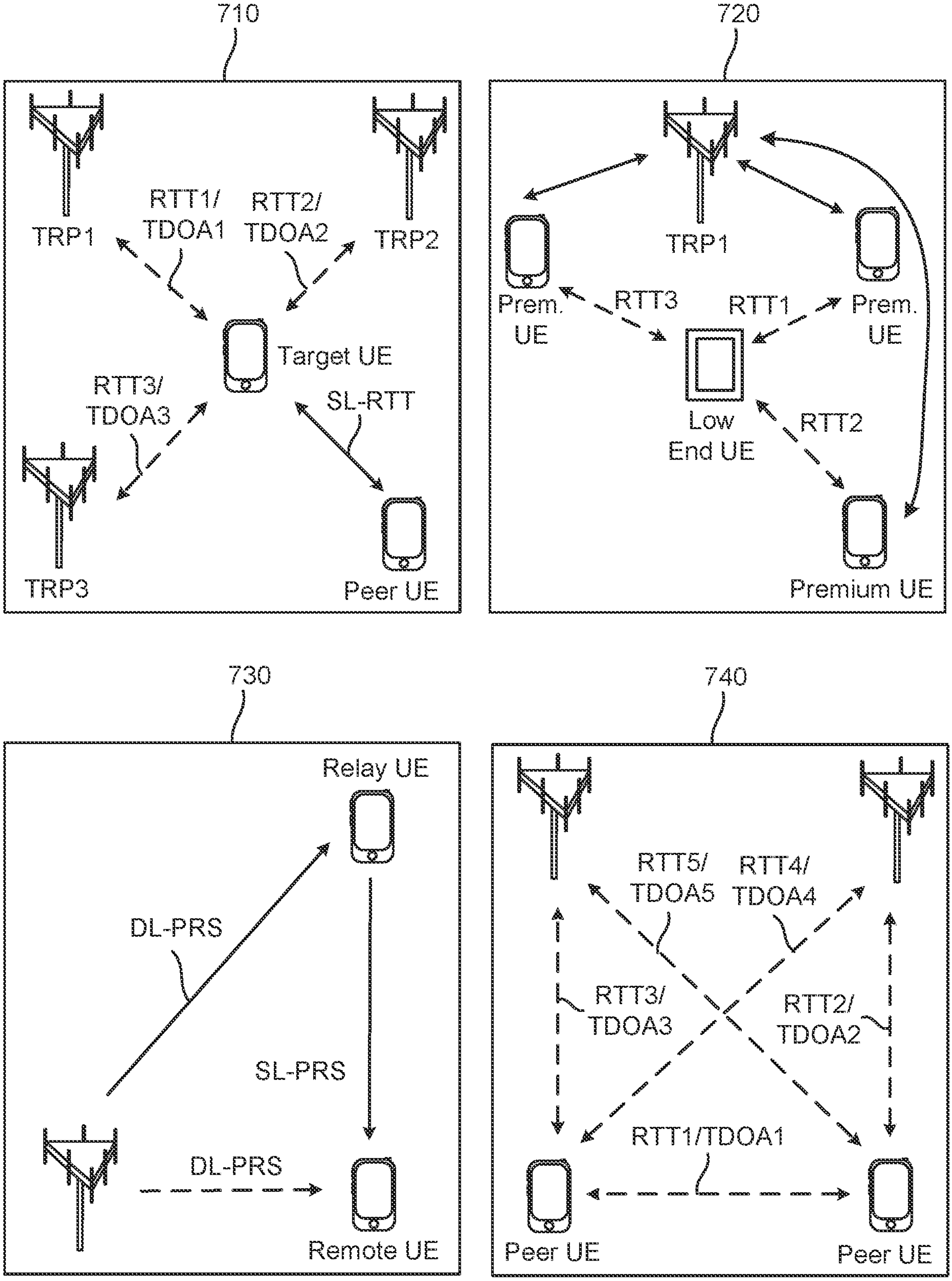
710
TRP1
RTT1/
TDOA1
RTT2/
TDOA2
TRP2
Target UE
RTT3/
TDOA3
SL-RTT
TRP3
Peer UE
720
TRP1
Prem.
UE
RTT3
RTT1
Prem.
UE
Low
End UE
RTT2
Premium UE
730
Relay UE
DL-PRS
SL-PRS
DL-PRS
Remote UE
740
RTT5/
TDOA5
RTT4/
TDOA4
RTT3/
TDOA3
RTT2/
TDOA2
RTT1/TDOA1
Peer UE
Peer UE

FIG. 7A

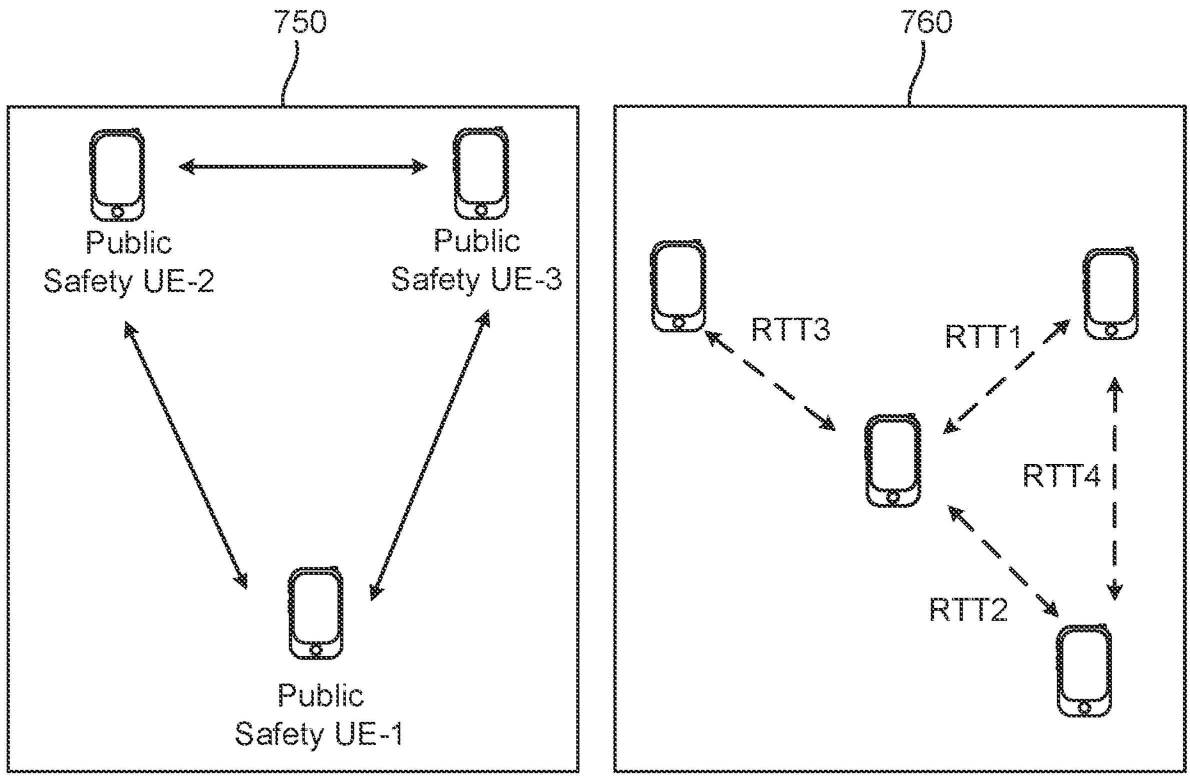
750
Public
Safety UE-2
Public
Safety UE-3
Public
Safety UE-1
760
RTT3
RTT1
RTT4
RTT2

FIG. 7B

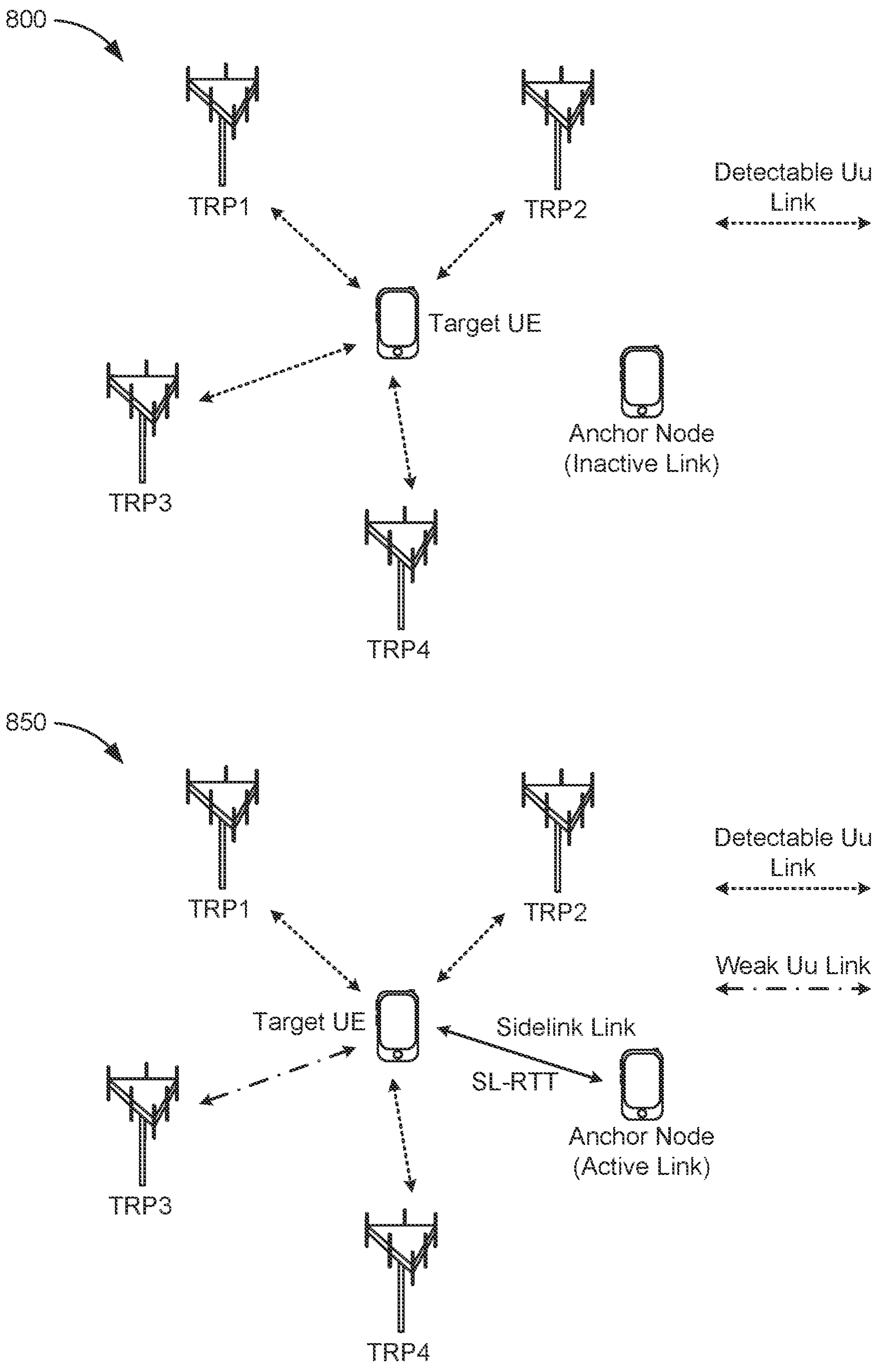
800
TRP1
TRP2
Detectable Uu Link
Target UE
TRP3
Anchor Node (Inactive Link)
TRP4
850
TRP1
TRP2
Detectable Uu Link
Weak Uu Link
Target UE
Sidelink Link
SL-RTT
TRP3
Anchor Node (Active Link)
TRP4

FIG. 8

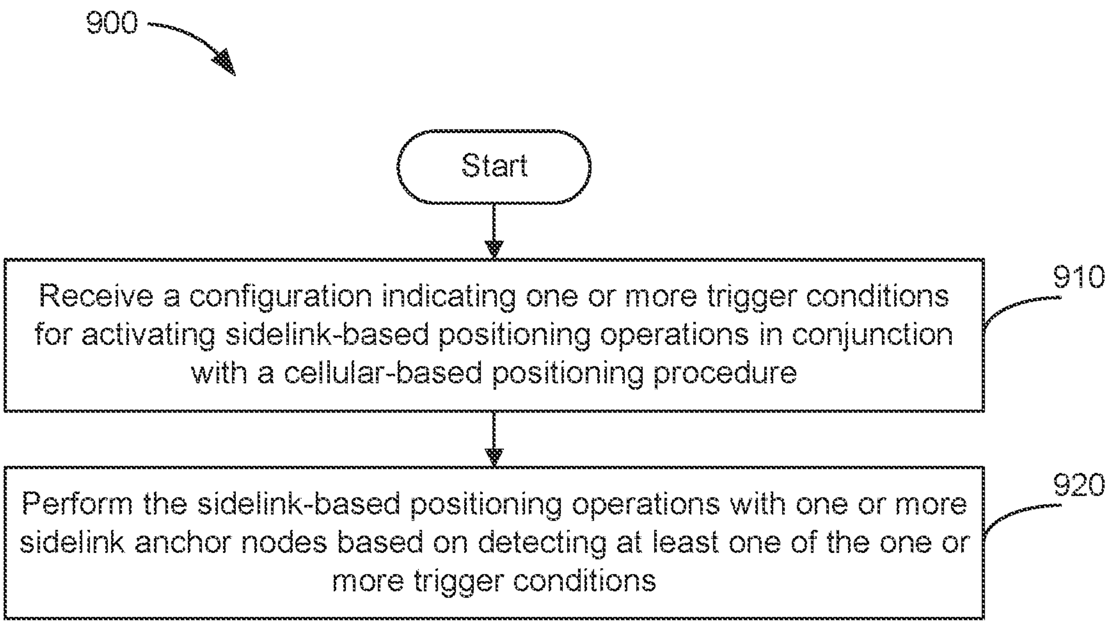
900
Start
Receive a configuration indicating one or more trigger conditions for activating sidelink-based positioning operations in conjunction with a cellular-based positioning procedure
910
Perform the sidelink-based positioning operations with one or more sidelink anchor nodes based on detecting at least one of the one or more trigger conditions
920

FIG. 9

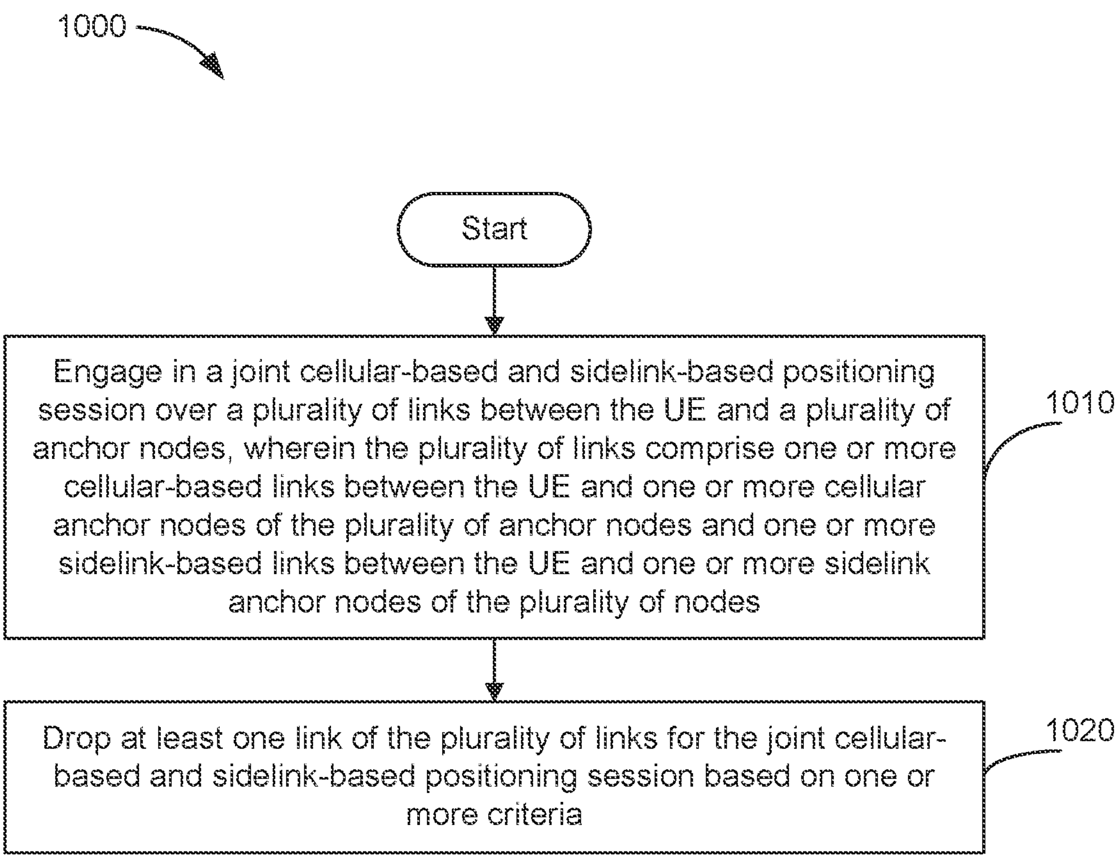
1000
Start
Engage in a joint cellular-based and sidelink-based positioning session over a plurality of links between the UE and a plurality of anchor nodes, wherein the plurality of links comprise one or more cellular-based links between the UE and one or more cellular anchor nodes of the plurality of anchor nodes and one or more sidelink-based links between the UE and one or more sidelink anchor nodes of the plurality of nodes
1010
Drop at least one link of the plurality of links for the joint cellular-based and sidelink-based positioning session based on one or more criteria
1020

FIG. 10

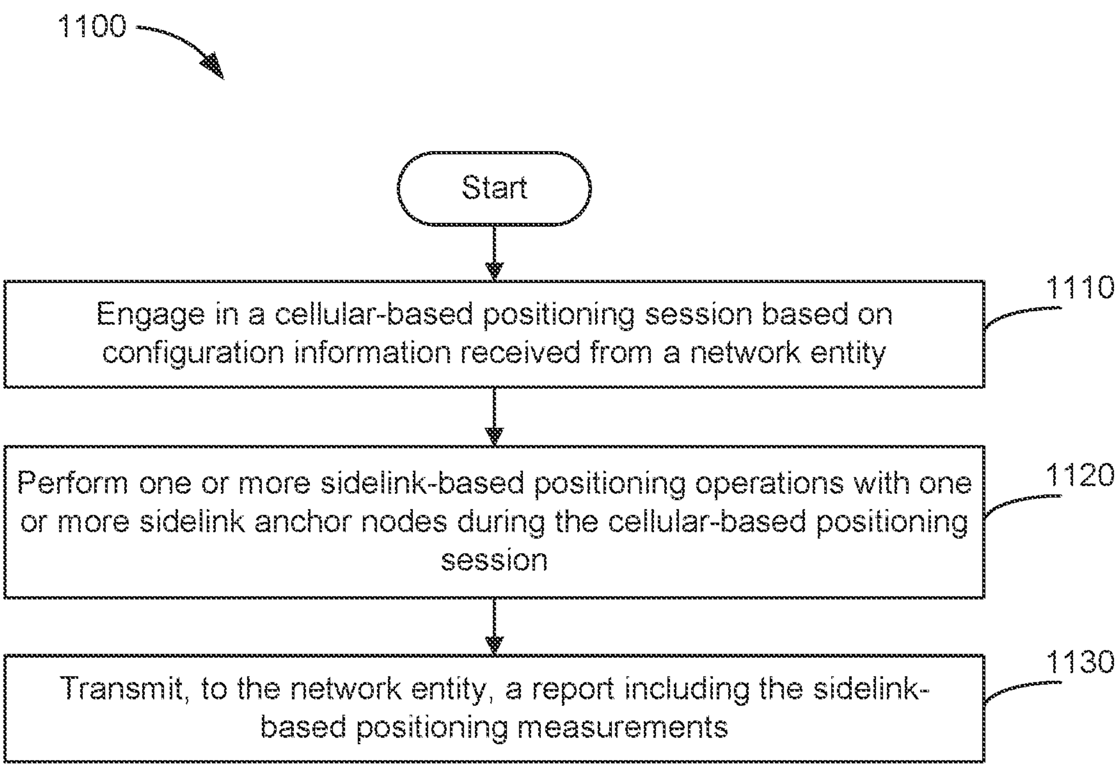
1100
Start
Engage in a cellular-based positioning session based on configuration information received from a network entity
1110
Perform one or more sidelink-based positioning operations with one or more sidelink anchor nodes during the cellular-based positioning session
1120
Transmit, to the network entity, a report including the sidelink-based positioning measurements
1130

FIG. 11

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2024/010257

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W64/00 H04W72/25 H04W72/40 H04W92/18
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04W

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	MODERATOR (QUALCOMM): "Moderator Summary #2 on potential solutions for SL positioning", 3GPP DRAFT; R1-2207974, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Toulouse, France; 20220822 - 20220826 28 August 2022 (2022-08-28), XP052275903, Retrieved from the Internet: URL:https://ftp.3gpp.org/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2207974.zip R1-2207974.docx [retrieved on 2022-08-28]	1-15, 30-33
A	clause 4.1.3 on page 28 - 33, clause 5.3.2 on page 59	16-29, 34-40

-/--

[x] Further documents are listed in the continuation of Box C. [x] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 July 2024	12/07/2024

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Böhmert, Jörg

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Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	WO 2022/221792 A1 (QUALCOMM INC [US]) 20 October 2022 (2022-10-20) Figures 4B, 10A, 10B, 11; paragraphs [0091]-[0093],[0102]-[0125]	16-24, 34-37 1-15, 25-33, 38-40
X A	ZHIHUA SHI ET AL: "Discussion on potential solutions for SL positioning", 3GPP DRAFT; R1-2211447; TYPE DISCUSSION; FS_NR_POS_ENH2, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. 3GPP RAN 1, no. Toulouse, FR; 20221114 - 20221118 7 November 2022 (2022-11-07), XP052222011, Retrieved from the Internet: URL:https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_111/Docs/R1-2211447.zip R1-2211447_OPPO_solution for SL Pos.docx [retrieved on 2022-11-07] e.g. Proposals 19 and 20 on page 9	16-24, 34-37 1-15, 25-33, 38-40
X A	FUMIHIRO HASEGAWA ET AL: "Resource allocation for SL positioning reference signal", 3GPP DRAFT; R1-2301118; TYPE DISCUSSION; NR_POS_ENH2-CORE, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. 3GPP RAN 1, no. Athens, GR; 20230227 - 20230303 17 February 2023 (2023-02-17), XP052248257, Retrieved from the Internet: URL:https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112/Docs/R1-2301118.zip R1-2301118_112_POS_AI9513_SLSolns.docx [retrieved on 2023-02-17] Proposal 24 on pages 11 and 12	16-24, 34-37 1-15, 25-33, 38-40

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PARDHASARATHY JYOTHI ET AL: "View on SL positioning methods, measurements and reporting for SL positioning", 3GPP DRAFT; R1-2301696; TYPE DISCUSSION; NR_POS_ENH2-CORE, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. 3GPP RAN 1, no. Athens, GR; 20230227 - 20230303 17 February 2023 (2023-02-17), XP052248826, Retrieved from the Internet: URL:https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112/Docs/R1-2301696.zip R1-2301696-View on SL positioning methods, measurements and reporting for SL positioning.docx [retrieved on 2023-02-17]	25-29, 38-40
A	page 3 - page 7	1-24, 30-37
X	ROBIN THOMAS ET AL: "Discussion on SL Positioning Measurement and Reporting", 3GPP DRAFT; R1-2301212; TYPE DISCUSSION; NR_POS_ENH2-CORE, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. 3GPP RAN 1, no. Athens, GR; 20230227 - 20230303 17 February 2023 (2023-02-17), XP052248350, Retrieved from the Internet: URL:https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112/Docs/R1-2301212.zip R1-2301212_SLPos_MeasReport_Lenovo.docx [retrieved on 2023-02-17]	25-29, 38-40
A	the whole document	1-24, 30-37

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2024/010257

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

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

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

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

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

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims;; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

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

1. claims: 1-15, 30-33

   Activate sidelink positioning

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2. claims: 16-24, 34-37

   Improve OTA resources utilization

   ---

3. claims: 25-29, 38-40

   Indicate the results of the sidelink positioning measurements

   ---

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2024/010257

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2022221792 A1	20-10-2022	BR 112023020606 A2	05-12-2023
		CN 117158069 A	01-12-2023
		EP 4324261 A1	21-02-2024
		JP 2024513931 A	27-03-2024
		KR 20230169126 A	15-12-2023
		TW 202241153 A	16-10-2022
		US 2024163955 A1	16-05-2024
		WO 2022221792 A1	20-10-2022