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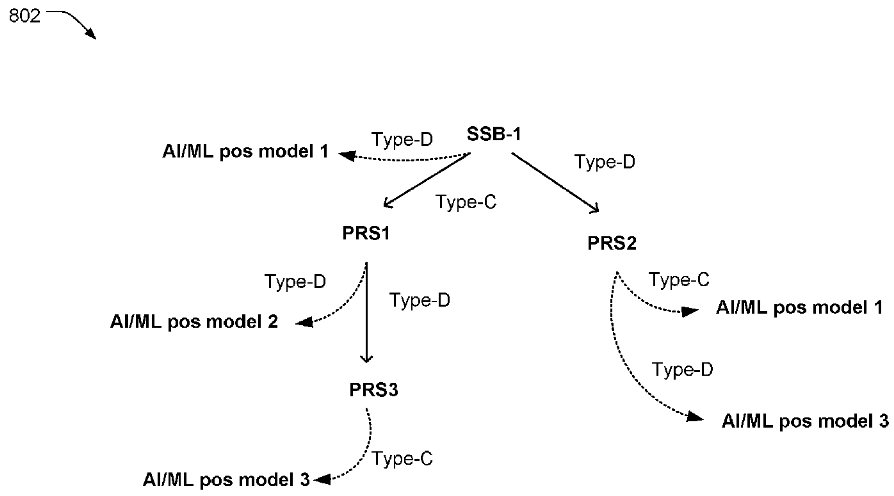

FIG. 8

(57) **Abstract:** Techniques are provided for utilizing QCL relationships with AI/ML models and reference signals. An example method for providing positioning reference signal configuration information includes receiving, from a wireless node, an indication of a quasi co-location (QCL) relationship between an AI/ML model and a reference signal, configuring one or more positioning reference signal resources based at least in part on the indication of the QCL relationship, and providing configuration information for the one or more positioning reference signal resources to the wireless node.

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INDICATION OF QUASI CO-LOCATION RELATION FOR ARTIFICIAL INTELLIGENCE – MACHINE LEARNING BASED POSITIONING

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Application No. 18/502,250, filed November 6, 2023, entitled "INDICATION OF QUASI CO-LOCATION RELATION FOR ARTIFICIAL INTELLIGENCE - MACHINE LEARNING BASED POSITIONING," which is assigned to the assignee hereof, and the entire contents of which are hereby incorporated herein by reference for all purposes.

BACKGROUND

[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, a fourth-generation (4G) service (e.g., Long Term Evolution (LTE) or WiMax®), a fifth-generation (5G) service (e.g., 5G New Radio (NR)), etc. 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), Orthogonal Frequency Division Multiple Access (OFDMA), Time Division Multiple Access (TDMA), the Global System for Mobile access (GSM) variation of TDMA, etc.

[0003] A fifth generation (5G) mobile standard calls for higher data transfer speeds, greater numbers of connections, and better coverage, among other improvements. The 5G standard, according to the Next Generation Mobile Networks Alliance, is designed to provide data rates of several tens of megabits per second to each of tens of thousands of users, with 1 gigabit per second to tens of workers on an office floor. Several hundreds of thousands of simultaneous connections should be supported in order to support large sensor deployments. Consequently, the spectral efficiency of 5G mobile communications should be significantly enhanced compared to the current 4G standard.

Furthermore, signaling efficiencies should be enhanced and latency should be substantially reduced compared to current standards.

[0004] It is often desirable to know the location of a user equipment (UE), e.g., a cellular phone, with the terms "location" and "position" being synonymous and used interchangeably herein. A location services (LCS) client may desire to know the location of the UE and may communicate with a location center in order to request the location of the UE. The location center and the UE may exchange messages, as appropriate, to obtain a location estimate for the UE. The location center may return the location estimate to the LCS client, e.g., for use in one or more applications.

[0005] Obtaining the location of a mobile device that is accessing a wireless network may be useful for many applications including, for example, emergency calls, personal navigation, asset tracking, locating a friend or family member, etc. In industrial applications, the location of a mobile device may be necessary for asset tracking, robotic control, and other kinematic operations which may require a precise location of an end effector. Existing positioning methods include methods based on measuring radio signals transmitted from a variety of devices including satellite vehicles and terrestrial radio sources in a wireless network such as base stations and access points. Stations in a wireless network may be configured to transmit reference signals to enable mobile device to perform positioning measurements.

SUMMARY

[0006] An example method for obtaining an output of an AI/ML model according to the disclosure includes receiving an indication of a quasi co-location (QCL) relationship between the AI/ML model and a reference signal, obtaining one or more measurement values associated with the reference signal, and computing the output of the AI/ML model based at least in part on the one or more measurement values.

[0007] An example method for providing positioning reference signal configuration information according to the disclosure includes receiving, from a wireless node, an indication of a quasi co-location (QCL) relationship between an AI/ML model and a reference signal, configuring one or more positioning reference signal resources based at least in part on the indication of the QCL relationship, and providing configuration information for the one or more positioning reference signal resources to the wireless node.

[0008] Items and/or techniques described herein may provide one or more of the following capabilities, as well as other capabilities not mentioned. A wireless node or a network server may be configured to indicate quasi co-location (QCL) relations between an artificial intelligence/machine learning (AI/ML) positioning model and a reference signal. The AI/ML model may be trained and/or provided by the wireless node or the network server. Wireless nodes may be configured to prioritize and select reference signal resources to measure and report based at least in part on the QCL relations with the AI/ML models. The accuracy of position estimates for mobile devices may be increased. Other capabilities may be provided and not every implementation according to the disclosure must provide any, let alone all, of the capabilities discussed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 is a simplified diagram of an example wireless communications system.

[0010] FIG. 2 is a block diagram of components of an example user equipment shown in FIG. 1.

[0011] FIG. 3 is a block diagram of components of an example transmission/reception point.

[0012] FIG. 4 is a block diagram of components of a server, various examples of which are shown in FIG. 1.

[0013] FIGS. 5A and 5B are block diagrams of example Artificial Intelligence / Machine Learning (AI/ML) models for positioning applications.

[0014] FIG 6A includes block diagrams of example UE-based and UE-assisted positioning techniques with AI/ML models.

[0015] FIG. 6B includes block diagrams of example node assisted positioning techniques with AI/ML models.

[0016] FIG. 7 is an illustration of example legacy QCL relationships between reference signals.

[0017] FIG. 8 is an example illustration of QCL relationships between reference signals and AI/ML models.

[0018] FIGS. 9A and 9B are example message flow diagrams for indicating QCL AI/ML positioning models.

[0019] FIG. 10 is a process flow diagram of an example method for obtaining an output of an AI/ML model.

[0020] FIG. 11 is a process flow diagram of an example method for providing positioning reference signal configuration information.

DETAILED DESCRIPTION

[0021] Techniques are discussed herein for utilizing QCL relationships with AI/ML models and reference signals. AI/ML positioning models may be configured to learn solutions to map specific reference signal characteristics and site-specific features. For example, an AI/ML model may be specific to certain radio characteristics (e.g., delay spread, Doppler, spatial relation, spatial relations, etc.). The techniques provided herein enable network nodes, such as UEs and network servers (e.g., Location Management Function (LMF)) to indicate applicable radio characteristics for AI/ML positioning models. The indications allow a UE and a network server (e.g., LMF) to quickly and efficiently signal the applicability of AI/ML models to one another to enable the selection and prioritization of reference signal measurements and reporting. The indications may also allow applying control (e.g., model life cycle control) to AI/ML models, including selection of models, switching between models, monitoring models, or falling back to non-AI/ML positioning approaches

[0022] In operation, a UE or a LMF may be configured to indicate QCL relations between an AI/ML positioning model and a reference signal. The AI/ML model may be trained and/or provided by the UE or the LMF. UE-side AI/ML positioning models may be trained and/or provided by a UE, and the UE may indicate QCL relationship information for the model to an LMF. In an example, the UE-side AI/ML positioning models may be trained and/or provided by an LMF, and the LMF may be configured to provide QCL relationship information for the model to a UE. In an example, LMF-side AI/ML positioning models may be trained and/or provided by the LMF, and the LMF may be configured to provide QCL relationship information for the models to a UE and the UE may be configured to prioritize and select reference signal resources to measure and report. In an example, the indicated QCL relation may be utilized to apply model control, including selection, switching, monitoring to UE-side AI/ML positioning models. In an example, the indicated QCL relation can be used to apply model control, including selection, switching, monitoring to LMF-side AI/ML positioning model. In general, the AI/ML models described herein provide AI/ML positioning functionality include AI/ML positioning physical models and/or AI/ML positioning logical models.

[0023] Particular aspects of the subject matter described in this disclosure may be implemented to realize one or more of the following potential advantages. AI/ML positioning models may be utilized for multiple reference signals and/or antenna ports. Network messaging protocols may be used to provide QCL relations between positioning reference signals (PRS) and other reference signals (e.g., synchronization signal blocks (SSBs) and/or other PRSs). AI/ML positioning model lifecycle management may be simplified. The prioritization and selection of PRS resource measuring and reporting may be improved. The accuracy of position estimates for mobile devices may be increased. Other advantages may also be realized.

[0024] Obtaining the locations of mobile devices that are accessing a wireless network may be useful for many applications including, for example, emergency calls, personal navigation, consumer asset tracking, locating a friend or family member, etc. Existing positioning methods include methods based on measuring radio signals transmitted from a variety of devices or entities including satellite vehicles (SVs) and terrestrial radio sources in a wireless network such as base stations and access points. It is expected that standardization for the 5G wireless networks will include support for various positioning methods, which may utilize reference signals transmitted by base stations in a manner similar to which LTE wireless networks currently utilize Positioning Reference Signals (PRS) and/or Cell-specific Reference Signals (CRS) for position determination.

[0025] The description herein may refer to sequences of actions to be performed, for example, by elements of a computing device. Various actions described herein can be performed by specific circuits (e.g., an application specific integrated circuit (ASIC)), by program instructions being executed by one or more processors, or by a combination of both. Sequences of actions described herein may be embodied within a non-transitory computer-readable medium having stored thereon a corresponding set of computer instructions that upon execution would cause an associated processor to perform the functionality described herein. Thus, the various examples described herein may be embodied in a number of different forms, all of which are within the scope of the disclosure, including claimed subject matter.

[0026] As used herein, the terms "user equipment" (UE) and "base station" are not specific to or otherwise limited to any particular Radio Access Technology (RAT), unless otherwise noted. In general, a UE may be any wireless communication device (e.g., a mobile phone, router, tablet computer, laptop computer, consumer asset tracking device, Internet of Things (IoT) device, automobile, etc.) used to communicate over a wireless communications network. A UE may be mobile or may (e.g., at certain times) be stationary, and may communicate with a Radio Access Network (RAN). As used herein, the term "UE" may be referred to interchangeably as an "access terminal" or "AT," a "client device," a "wireless device," a "wireless node," a "subscriber device," a "subscriber terminal," a "subscriber station," a "user terminal" or UT, a "mobile terminal," a "mobile station," a "mobile device," or variations thereof. Generally, UEs can communicate with a core network via a RAN, and through the core network the UEs can be connected with external networks such as the Internet and with other UEs. Of course, other mechanisms of connecting to the core network and/or the Internet are also possible for the UEs, such as over wired access networks, WiFi® networks (e.g., based on IEEE (Institute of Electrical and Electronics Engineers) 802.11, etc.) and so on. Two or more UEs may communicate directly in addition to or instead of passing information to each other through a network.

[0027] A base station may operate according to one of several RATs in communication with UEs depending on the network in which it is deployed. Examples of a base station include an Access Point (AP), a Network Node, a NodeB, an evolved NodeB (eNB), or a general Node B (gNodeB, gNB). In addition, 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.

[0028] UEs may be embodied by any of a number of types of devices including but not limited to printed circuit (PC) cards, compact flash devices, external or internal modems, wireless or wireline phones, smartphones, tablets, consumer asset tracking devices, asset tags, and so on. A communication link through which UEs can send signals to a RAN is called an uplink channel (e.g., a reverse traffic channel, a reverse control channel, an access channel, etc.). A communication link through which the RAN can send signals to UEs is called a downlink or forward link channel (e.g., a paging channel, a control channel, a broadcast channel, a forward traffic channel, etc.).

As used herein the term traffic channel (TCH) can refer to either an uplink / reverse or downlink / forward traffic channel.

[0029] As used herein, the term "cell" or "sector" may correspond to one of a plurality of cells of a base station, or to the base station itself, depending on the context. The term "cell" may refer to a logical communication entity used for communication with a base station (for example, over a carrier), and may be associated with an identifier for distinguishing neighboring cells (for example, a physical cell identifier (PCID), a virtual cell identifier (VCID)) operating via the same or a different carrier. In some examples, a carrier may support multiple cells, and different cells may be configured according to different protocol types (for example, machine-type communication (MTC), narrowband Internet-of-Things (NB-IoT), enhanced mobile broadband (eMBB), or others) that may provide access for different types of devices. In some examples, the term "cell" may refer to a portion of a geographic coverage area (for example, a sector) over which the logical entity operates.

[0030] Referring to FIG. 1, an example of a communication system 100 includes a UE 105, a UE 106, a Radio Access Network (RAN), here a Fifth Generation (5G) Next Generation (NG) RAN (NG-RAN) 135, a 5G Core Network (5GC) 140, and a server 150. The UE 105 and/or the UE 106 may be, e.g., an IoT device, a location tracker device, a cellular telephone, a vehicle (e.g., a car, a truck, a bus, a boat, etc.), or another device. A 5G network may also be referred to as a New Radio (NR) network; NG-RAN 135 may be referred to as a 5G RAN or as an NR RAN; and 5GC 140 may be referred to as an NG Core network (NGC). Standardization of an NG-RAN and 5GC is ongoing in the 3rd Generation Partnership Project (3GPP). Accordingly, the NG-RAN 135 and the 5GC 140 may conform to current or future standards for 5G support from 3GPP. The NG-RAN 135 may be another type of RAN, e.g., a 3G RAN, a 4G Long Term Evolution (LTE) RAN, etc. The UE 106 may be configured and coupled similarly to the UE 105 to send and/or receive signals to/from similar other entities in the system 100, but such signaling is not indicated in FIG. 1 for the sake of simplicity of the figure. Similarly, the discussion focuses on the UE 105 for the sake of simplicity. The communication system 100 may utilize information from a constellation 185 of satellite vehicles (SVs) 190, 191, 192, 193 for a Satellite Positioning System (SPS) (e.g., a Global Navigation Satellite System (GNSS)) like the Global Positioning System (GPS), the Global Navigation Satellite System (GLONASS), Galileo, or Beidou or some other local or regional SPS such as the Indian Regional Navigational Satellite System (IRNSS), the European Geostationary Navigation Overlay Service (EGNOS), or the Wide Area Augmentation System (WAAS). Additional components of the communication system 100 are described below. The communication system 100 may include additional or alternative components.

[0031] As shown in FIG. 1, the NG-RAN 135 includes NR nodeBs (gNBs) 110a, 110b, and a next generation eNodeB (ng-eNB) 114, and the 5GC 140 includes an Access and Mobility Management Function (AMF) 115, a Session Management Function (SMF) 117, a Location Management Function (LMF) 120, and a Gateway Mobile Location Center (GMLC) 125. The gNBs 110a, 110b and the ng-eNB 114 are communicatively coupled to each other, are each configured to bi-directionally wirelessly communicate with the UE 105, and are each communicatively coupled to, and configured to bi-directionally communicate with, the AMF 115. The gNBs 110a, 110b, and the ng-eNB 114 may be referred to as base stations (BSs). The AMF 115, the SMF 117, the LMF 120, and the GMLC 125 are communicatively coupled to each other, and the GMLC is communicatively coupled to an external client 130. The SMF 117 may serve as an initial contact point of a Service Control Function (SCF) (not shown) to create, control, and delete media sessions. Base stations such as the gNBs 110a, 110b and/or the ng-eNB 114 may be a macro cell (e.g., a high-power cellular base station), or a small cell (e.g., a low-power cellular base station), or an access point (e.g., a short-range base station configured to communicate with short-range technology such as WiFi®, WiFi®-Direct (WiFi®-D), Bluetooth®, Bluetooth®-low energy (BLE), Zigbee®, etc. One or more base stations, e.g., one or more of the gNBs 110a, 110b and/or the ng-eNB 114 may be configured to communicate with the UE 105 via multiple carriers. Each of the gNBs 110a, 110b and/or the ng-eNB 114 may provide communication coverage for a respective geographic region, e.g., a cell. Each cell may be partitioned into multiple sectors as a function of the base station antennas.

[0032] FIG. 1 provides a generalized illustration of various components, any or all of which may be utilized as appropriate, and each of which may be duplicated or omitted as necessary. Specifically, although one UE 105 is illustrated, many UEs (e.g., hundreds, thousands, millions, etc.) may be utilized in the communication system 100. Similarly, the communication system 100 may include a larger (or smaller) number of SVs (i.e., more or fewer than the four SVs 190-193 shown), gNBs 110a, 110b, ng-eNBs

114, AMFs 115, external clients 130, and/or other components. The illustrated connections that connect the various components in the communication system 100 include data and signaling connections which may include additional (intermediary) components, direct or indirect physical and/or wireless connections, and/or additional networks. Furthermore, components may be rearranged, combined, separated, substituted, and/or omitted, depending on desired functionality.

[0033] While FIG. 1 illustrates a 5G-based network, similar network implementations and configurations may be used for other communication technologies, such as 3G, Long Term Evolution (LTE), etc. Implementations described herein (be they for 5G technology and/or for one or more other communication technologies and/or protocols) may be used to transmit (or broadcast) directional synchronization signals, receive and measure directional signals at UEs (e.g., the UE 105) and/or provide location assistance to the UE 105 (via the GMLC 125 or other location server) and/or compute a location for the UE 105 at a location-capable device such as the UE 105, the gNB 110a, 110b, or the LMF 120 based on measurement quantities received at the UE 105 for such directionally-transmitted signals. The gateway mobile location center (GMLC) 125, the location management function (LMF) 120, the access and mobility management function (AMF) 115, the SMF 117, the ng-eNB (eNodeB) 114 and the gNBs (gNodeBs) 110a, 110b are examples and may be replaced by or include various other location server functionality and/or base station functionality respectively.

[0034] The system 100 is capable of wireless communication in that components of the system 100 can communicate with one another (at least some times using wireless connections) directly or indirectly, e.g., via the gNBs 110a, 110b, the ng-eNB 114, and/or the 5GC 140 (and/or one or more other devices not shown, such as one or more other base transceiver stations). For indirect communications, the communications may be altered during transmission from one entity to another, e.g., to alter header information of data packets, to change format, etc. The UE 105 may include multiple UEs and may be a mobile wireless communication device, but may communicate wirelessly and via wired connections. The UE 105 may be any of a variety of devices, e.g., a smartphone, a tablet computer, a vehicle-based device, etc., but these are examples as the UE 105 is not required to be any of these configurations, and other configurations of UEs may be used. Other UEs may include wearable devices (e.g., smart watches, smart jewelry, smart glasses or headsets, etc.). Still other UEs may be used, whether currently existing or developed in the future. Further, other wireless devices (whether mobile or not) may be implemented within the system 100 and may communicate with each other and/or with the UE 105, the gNBs 110a, 110b, the ng-eNB 114, the 5GC 140, and/or the external client 130. For example, such other devices may include internet of thing (IoT) devices, medical devices, home entertainment and/or automation devices, etc. The 5GC 140 may communicate with the external client 130 (e.g., a computer system), e.g., to allow the external client 130 to request and/or receive location information regarding the UE 105 (e.g., via the GMLC 125).

[0035] The UE 105 or other devices may be configured to communicate in various networks and/or for various purposes and/or using various technologies (e.g., 5G, Wi-Fi® communication, multiple frequencies of Wi-Fi® communication, satellite positioning, one or more types of communications (e.g., GSM (Global System for Mobiles), CDMA (Code Division Multiple Access), LTE (Long Term Evolution), V2X (Vehicle-to-Everything, e.g., V2P (Vehicle-to-Pedestrian), V2I (Vehicle-to-Infrastructure), V2V (Vehicle-to-Vehicle), etc.), IEEE 802.11p, etc.). V2X communications may be cellular (Cellular-V2X (C-V2X)) and/or WiFi® (e.g., DSRC (Dedicated Short-Range Connection)). The system 100 may support operation on multiple carriers (waveform signals of different frequencies). Multi-carrier transmitters can transmit modulated signals simultaneously on the multiple carriers. Each modulated signal may be a Code Division Multiple Access (CDMA) signal, a Time Division Multiple Access (TDMA) signal, an Orthogonal Frequency Division Multiple Access (OFDMA) signal, a Single-Carrier Frequency Division Multiple Access (SC-FDMA) signal, etc. Each modulated signal may be sent on a different carrier and may carry pilot, overhead information, data, etc. The UEs 105, 106 may communicate with each other through UE-to-UE sidelink (SL) communications by transmitting over one or more sidelink channels such as a physical sidelink synchronization channel (PSSCH), a physical sidelink broadcast channel (PSBCH), or a physical sidelink control channel (PSCCH). Direct wireless-device-to-wireless-device communications without going through a network may be referred to generally as sidelink communications without limiting the communications to a particular protocol.

[0036] The UE 105 may comprise and/or may be referred to as a device, a mobile device, a wireless device, a mobile terminal, a terminal, a mobile station (MS), a Secure User Plane Location (SUPL) Enabled Terminal (SET), or by some other name.

Moreover, the UE 105 may correspond to a cellphone, smartphone, laptop, tablet, PDA, consumer asset tracking device, navigation device, Internet of Things (IoT) device, health monitors, security systems, smart city sensors, smart meters, wearable trackers, or some other portable or moveable device. Typically, though not necessarily, the UE 105 may support wireless communication using one or more Radio Access Technologies (RATs) such as Global System for Mobile communication (GSM), Code Division Multiple Access (CDMA), Wideband CDMA (WCDMA), LTE, High Rate Packet Data (HRPD), IEEE 802.11 WiFi® (also referred to as Wi-Fi®), Bluetooth® (BT), Worldwide Interoperability for Microwave Access (WiMax®), 5G new radio (NR) (e.g., using the NG-RAN 135 and the 5GC 140), etc. The UE 105 may support wireless communication using a Wireless Local Area Network (WLAN) which may connect to other networks (e.g., the Internet) using a Digital Subscriber Line (DSL) or packet cable, for example. The use of one or more of these RATs may allow the UE 105 to communicate with the external client 130 (e.g., via elements of the 5GC 140 not shown in FIG. 1, or possibly via the GMLC 125) and/or allow the external client 130 to receive location information regarding the UE 105 (e.g., via the GMLC 125).

[0037] The UE 105 may include a single entity or may include multiple entities such as in a personal area network where a user may employ audio, video and/or data I/O (input/output) devices and/or body sensors and a separate wireline or wireless modem. An estimate of a location of the UE 105 may be referred to as a location, location estimate, location fix, fix, position, position estimate, or position fix, and may be geographic, thus providing location coordinates for the UE 105 (e.g., latitude and longitude) which may or may not include an altitude component (e.g., height above sea level, height above or depth below ground level, floor level, or basement level). Alternatively, a location of the UE 105 may be expressed as a civic location (e.g., as a postal address or the designation of some point or small area in a building such as a particular room or floor). A location of the UE 105 may be expressed as an area or volume (defined either geographically or in civic form) within which the UE 105 is expected to be located with some probability or confidence level (e.g., 67%, 95%, etc.). A location of the UE 105 may be expressed as a relative location comprising, for example, a distance and direction from a known location. The relative location may be expressed as relative coordinates (e.g., X, Y (and Z) coordinates) defined relative to some origin at a known location which may be defined, e.g., geographically, in civic terms, or by reference to a point, area, or volume, e.g., indicated on a map, floor plan, or building plan. In the description contained herein, the use of the term location may comprise any of these variants unless indicated otherwise. When computing the location of a UE, it is common to solve for local x, y, and possibly z coordinates and then, if desired, convert the local coordinates into absolute coordinates (e.g., for latitude, longitude, and altitude above or below mean sea level).

[0038] The UE 105 may be configured to communicate with other entities using one or more of a variety of technologies. The UE 105 may be configured to connect indirectly to one or more communication networks via one or more device-to-device (D2D) peer-to-peer (P2P) links. The D2D P2P links may be supported with any appropriate D2D radio access technology (RAT), such as LTE Direct (LTE-D), WiFi® Direct (WiFi®-D), Bluetooth®, and so on. One or more of a group of UEs utilizing D2D communications may be within a geographic coverage area of a Transmission/Reception Point (TRP) such as one or more of the gNBs 110a, 110b, and/or the ng-eNB 114. Other UEs in such a group may be outside such geographic coverage areas, or may be otherwise unable to receive transmissions from a base station. Groups of UEs communicating via D2D communications may utilize a one-to-many (1:M) system in which each UE may transmit to other UEs in the group. A TRP may facilitate scheduling of resources for D2D communications. In other cases, D2D communications may be carried out between UEs without the involvement of a TRP. One or more of a group of UEs utilizing D2D communications may be within a geographic coverage area of a TRP. Other UEs in such a group may be outside such geographic coverage areas, or be otherwise unable to receive transmissions from a base station. Groups of UEs communicating via D2D communications may utilize a one-to-many (1:M) system in which each UE may transmit to other UEs in the group. A TRP may facilitate scheduling of resources for D2D communications. In other cases, D2D communications may be carried out between UEs without the involvement of a TRP.

[0039] Base stations (BSs) in the NG-RAN 135 shown in FIG. 1 include NR Node Bs, referred to as the gNBs 110a and 110b. Pairs of the gNBs 110a, 110b in the NG-RAN 135 may be connected to one another via one or more other gNBs. Access to the 5G network is provided to the UE 105 via wireless communication between the UE 105 and one or more of the gNBs 110a, 110b, which may provide wireless communications access to the 5GC 140 on behalf of the UE 105 using 5G. In FIG. 1, the serving gNB for the UE 105 is assumed to be the gNB 110a, although another gNB (e.g., the gNB 110b) may act as a serving gNB if the UE 105 moves to another location or may act as a secondary gNB to provide additional throughput and bandwidth to the UE 105.

[0040] Base stations (BSs) in the NG-RAN 135 shown in FIG. 1 may include the ng-eNB 114, also referred to as a next generation evolved Node B. The ng-eNB 114 may be connected to one or more of the gNBs 110a, 110b in the NG-RAN 135, possibly via one or more other gNBs and/or one or more other ng-eNBs. The ng-eNB 114 may provide LTE wireless access and/or evolved LTE (eLTE) wireless access to the UE 105. One or more of the gNBs 110a, 110b and/or the ng-eNB 114 may be configured to function as positioning-only beacons which may transmit signals to assist with determining the position of the UE 105 but may not receive signals from the UE 105 or from other UEs.

[0041] The gNBs 110a, 110b and/or the ng-eNB 114 may each comprise one or more TRPs. For example, each sector within a cell of a BS may comprise a TRP, although multiple TRPs may share one or more components (e.g., share a processor but have separate antennas). The system 100 may include macro TRPs exclusively or the system 100 may have TRPs of different types, e.g., macro, pico, and/or femto TRPs, etc. A macro TRP may cover a relatively large geographic area (e.g., several kilometers in radius) and may allow unrestricted access by terminals with service subscription. A pico TRP may cover a relatively small geographic area (e.g., a pico cell) and may allow unrestricted access by terminals with service subscription. A femto or home TRP may cover a relatively small geographic area (e.g., a femto cell) and may allow restricted access by terminals having association with the femto cell (e.g., terminals for users in a home).

[0042] Each of the gNBs 110a, 110b and/or the ng-eNB 114 may include a radio unit (RU), a distributed unit (DU), and a central unit (CU). For example, the gNB 110b includes an RU 111, a DU 112, and a CU 113. The RU 111, DU 112, and CU 113 divide functionality of the gNB 110b. While the gNB 110b is shown with a single RU, a single DU, and a single CU, a gNB may include one or more RUs, one or more DUs, and/or one or more CUs. An interface between the CU 113 and the DU 112 is referred to as an F1 interface. The RU 111 is configured to perform digital front end (DFE) functions (e.g., analog-to-digital conversion, filtering, power amplification, transmission/reception) and digital beamforming, and includes a portion of the physical

(PHY) layer. The RU 111 may perform the DFE using massive multiple input/multiple output (MIMO) and may be integrated with one or more antennas of the gNB 110b. The DU 112 hosts the Radio Link Control (RLC), Medium Access Control (MAC), and physical layers of the gNB 110b. One DU can support one or more cells, and each cell is supported by a single DU. The operation of the DU 112 is controlled by the CU 113. The CU 113 is configured to perform functions for transferring user data, mobility control, radio access network sharing, positioning, session management, etc. although some functions are allocated exclusively to the DU 112. The CU 113 hosts the Radio Resource Control (RRC), Service Data Adaptation Protocol (SDAP), and Packet Data Convergence Protocol (PDCP) protocols of the gNB 110b. The UE 105 may communicate with the CU 113 via RRC, SDAP, and PDCP layers, with the DU 112 via the RLC, MAC, and PHY layers, and with the RU 111 via the PHY layer.

[0043] As noted, while FIG. 1 depicts nodes configured to communicate according to 5G communication protocols, nodes configured to communicate according to other communication protocols, such as, for example, an LTE protocol or IEEE 802.11x protocol, may be used. For example, in an Evolved Packet System (EPS) providing LTE wireless access to the UE 105, a RAN may comprise an Evolved Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (E-UTRAN) which may comprise base stations comprising evolved Node Bs (eNBs). A core network for EPS may comprise an Evolved Packet Core (EPC). An EPS may comprise an E-UTRAN plus EPC, where the E-UTRAN corresponds to the NG-RAN 135 and the EPC corresponds to the 5GC 140 in FIG. 1.

[0044] The gNBs 110a, 110b and the ng-eNB 114 may communicate with the AMF 115, which, for positioning functionality, communicates with the LMF 120. The AMF 115 may support mobility of the UE 105, including cell change and handover and may participate in supporting a signaling connection to the UE 105 and possibly data and voice bearers for the UE 105. The LMF 120 may communicate directly with the UE 105, e.g., through wireless communications, or directly with the gNBs 110a, 110b and/or the ng-eNB 114. The LMF 120 may support positioning of the UE 105 when the UE 105 accesses the NG-RAN 135 and may support position procedures / methods such as Assisted GNSS (A-GNSS), Observed Time Difference of Arrival (OTDOA) (e.g., Downlink (DL) OTDOA or Uplink (UL) OTDOA), Round Trip Time (RTT), Multi-Cell RTT, Real Time Kinematic (RTK), Precise Point Positioning (PPP), Differential

GNSS (DGNSS), Enhanced Cell ID (E-CID), angle of arrival (AoA), angle of departure (AoD), and/or other position methods. The LMF 120 may process location services requests for the UE 105, e.g., received from the AMF 115 or from the GMLC 125. The LMF 120 may be connected to the AMF 115 and/or to the GMLC 125. The LMF 120 may be referred to by other names such as a Location Manager (LM), Location Function (LF), commercial LMF (CLMF), or value added LMF (VLMF). A node / system that implements the LMF 120 may additionally or alternatively implement other types of location-support modules, such as an Enhanced Serving Mobile Location Center (E-SMLC) or a Secure User Plane Location (SUPL) Location Platform (SLP). At least part of the positioning functionality (including derivation of the location of the UE 105) may be performed at the UE 105 (e.g., using signal measurements obtained by the UE 105 for signals transmitted by wireless nodes such as the gNBs 110a, 110b and/or the ng-eNB 114, and/or assistance data provided to the UE 105, e.g., by the LMF 120). The AMF 115 may serve as a control node that processes signaling between the UE 105 and the 5GC 140, and may provide QoS (Quality of Service) flow and session management. The AMF 115 may support mobility of the UE 105 including cell change and handover and may participate in supporting signaling connection to the UE 105.

[0045] The server 150, e.g., a cloud server, is configured to obtain and provide location estimates of the UE 105 to the external client 130. The server 150 may, for example, be configured to run a microservice/service that obtains the location estimate of the UE 105. The server 150 may, for example, pull the location estimate from (e.g., by sending a location request to) the UE 105, one or more of the gNBs 110a, 110b (e.g., via the RU 111, the DU 112, and the CU 113) and/or the ng-eNB 114, and/or the LMF 120. As another example, the UE 105, one or more of the gNBs 110a, 110b (e.g., via the RU 111, the DU 112, and the CU 113), and/or the LMF 120 may push the location estimate of the UE 105 to the server 150.

[0046] The GMLC 125 may support a location request for the UE 105 received from the external client 130 via the server 150 and may forward such a location request to the AMF 115 for forwarding by the AMF 115 to the LMF 120 or may forward the location request directly to the LMF 120. A location response from the LMF 120 (e.g., containing a location estimate for the UE 105) may be returned to the GMLC 125 either directly or via the AMF 115 and the GMLC 125 may then return the location response (e.g., containing the location estimate) to the external client 130 via the server 150. The

GMLC 125 is shown connected to both the AMF 115 and LMF 120, though may not be connected to the AMF 115 or the LMF 120 in some implementations.

[0047] As further illustrated in FIG. 1, the LMF 120 may communicate with the gNBs 110a, 110b and/or the ng-eNB 114 using a New Radio Position Protocol A (which may be referred to as NPPa or NRPPa), which may be defined in 3GPP Technical Specification (TS) 38.455. NRPPa may be the same as, similar to, or an extension of the LTE Positioning Protocol A (LPPa) defined in 3GPP TS 36.455, with NRPPa messages being transferred between the gNB 110a (or the gNB 110b) and the LMF 120, and/or between the ng-eNB 114 and the LMF 120, via the AMF 115. As further illustrated in FIG. 1, the LMF 120 and the UE 105 may communicate using an LTE Positioning Protocol (LPP), which may be defined in 3GPP TS 36.355. The LMF 120 and the UE 105 may also or instead communicate using a New Radio Positioning Protocol (which may be referred to as NPP or NRPP), which may be the same as, similar to, or an extension of LPP. Here, LPP and/or NPP messages may be transferred between the UE 105 and the LMF 120 via the AMF 115 and the serving gNB 110a, 110b or the serving ng-eNB 114 for the UE 105. For example, LPP and/or NPP messages may be transferred between the LMF 120 and the AMF 115 using a 5G Location Services Application Protocol (LCS AP) and may be transferred between the AMF 115 and the UE 105 using a 5G Non-Access Stratum (NAS) protocol. The LPP and/or NPP protocol may be used to support positioning of the UE 105 using UE-assisted and/or UE-based position methods such as A-GNSS, RTK, OTDOA and/or E-CID. The NRPPa protocol may be used to support positioning of the UE 105 using network-based position methods such as E-CID (e.g., when used with measurements obtained by the gNB 110a, 110b or the ng-eNB 114) and/or may be used by the LMF 120 to obtain location related information from the gNBs 110a, 110b and/or the ng-eNB 114, such as parameters defining directional SS or PRS transmissions from the gNBs 110a, 110b, and/or the ng-eNB 114. The LMF 120 may be co-located or integrated with a gNB or a TRP, or may be disposed remote from the gNB and/or the TRP and configured to communicate directly or indirectly with the gNB and/or the TRP.

[0048] With a UE-assisted position method, the UE 105 may obtain location measurements and send the measurements to a location server (e.g., the LMF 120) for computation of a location estimate for the UE 105. For example, the location measurements may include one or more of a Received Signal Strength Indication

(RSSI), Round Trip signal propagation Time (RTT), Reference Signal Time Difference (RSTD), Reference Signal Received Power (RSRP) and/or Reference Signal Received Quality (RSRQ) for the gNBs 110a, 110b, the ng-eNB 114, and/or a WLAN AP. The location measurements may also or instead include measurements of GNSS pseudorange, code phase, and/or carrier phase for the SVs 190-193.

[0049] With a UE-based position method, the UE 105 may obtain location measurements (e.g., which may be the same as or similar to location measurements for a UE-assisted position method) and may compute a location of the UE 105 (e.g., with the help of assistance data received from a location server such as the LMF 120 or broadcast by the gNBs 110a, 110b, the ng-eNB 114, or other base stations or APs).

[0050] With a network-based position method, one or more base stations (e.g., the gNBs 110a, 110b, and/or the ng-eNB 114) or APs may obtain location measurements (e.g., measurements of RSSI, RTT, RSRP, RSRQ or time information such as Time of Arrival (ToA) for signals transmitted by the UE 105) and/or may receive measurements obtained by the UE 105. The one or more base stations or APs may send the measurements to a location server (e.g., the LMF 120) for computation of a location estimate for the UE 105.

[0051] Information provided by the gNBs 110a, 110b, and/or the ng-eNB 114 to the LMF 120 using NRPPa may include timing and configuration information for directional SS or PRS transmissions and location coordinates. The LMF 120 may provide some or all of this information to the UE 105 as assistance data in an LPP and/or NPP message via the NG-RAN 135 and the 5GC 140.

[0052] An LPP or NPP message sent from the LMF 120 to the UE 105 may instruct the UE 105 to do any of a variety of things depending on desired functionality. For example, the LPP or NPP message could contain an instruction for the UE 105 to obtain measurements for GNSS (or A-GNSS), WLAN, E-CID, and/or OTDOA (or some other position method). In the case of E-CID, the LPP or NPP message may instruct the UE 105 to obtain one or more measurement quantities (e.g., beam ID, beam width, mean angle, RSRP, RSRQ measurements) of directional signals transmitted within particular cells supported by one or more of the gNBs 110a, 110b, and/or the ng-eNB 114 (or supported by some other type of base station such as an eNB or WiFi® AP). The UE 105 may send the measurement quantities back to the LMF 120 in an LPP or NPP message (e.g., inside a 5G NAS message) via the serving gNB 110a (or the serving ng-eNB 114) and the AMF 115.

[0053] As noted, while the communication system 100 is described in relation to 5G technology, the communication system 100 may be implemented to support other communication technologies, such as GSM, WCDMA, LTE, etc., that are used for supporting and interacting with mobile devices such as the UE 105 (e.g., to implement voice, data, positioning, and other functionalities). In some such implementations, the 5GC 140 may be configured to control different air interfaces. For example, the 5GC 140 may be connected to a WLAN using a Non-3GPP InterWorking Function (N3IWF, not shown FIG. 1) in the 5GC 140. For example, the WLAN may support IEEE 802.11 WiFi® access for the UE 105 and may comprise one or more WiFi® APs. Here, the N3IWF may connect to the WLAN and to other elements in the 5GC 140 such as the AMF 115. In some examples, both the NG-RAN 135 and the 5GC 140 may be replaced by one or more other RANs and one or more other core networks. For example, in an EPS, the NG-RAN 135 may be replaced by an E-UTRAN containing eNBs and the 5GC 140 may be replaced by an EPC containing a Mobility Management Entity (MME) in place of the AMF 115, an E-SMLC in place of the LMF 120, and a GMLC that may be similar to the GMLC 125. In such an EPS, the E-SMLC may use LPPa in place of NRPPa to send and receive location information to and from the eNBs in the E-UTRAN and may use LPP to support positioning of the UE 105. In these other examples, positioning of the UE 105 using directional PRSs may be supported in an analogous manner to that described herein for a 5G network with the difference that functions and procedures described herein for the gNBs 110a, 110b, the ng-eNB 114, the AMF 115, and the LMF 120 may, in some cases, apply instead to other network elements such eNBs, WiFi® APs, an MME, and an E-SMLC.

[0054] As noted, in some examples, positioning functionality may be implemented, at least in part, using the directional SS or PRS beams, sent by base stations (such as the gNBs 110a, 110b, and/or the ng-eNB 114) that are within range of the UE whose position is to be determined (e.g., the UE 105 of FIG. 1). The UE may, in some instances, use the directional SS or PRS beams from a plurality of base stations (such as the gNBs 110a, 110b, the ng-eNB 114, etc.) to compute the position of the UE.

[0055] Referring also to FIG. 2, a UE 200 may be an example of one of the UEs 105, 106 and may comprise a computing platform including a processor 210, memory 211 including software (SW) 212, one or more sensors 213, a transceiver interface 214 for a transceiver 215 (that includes a wireless transceiver 240 and a wired transceiver 250), a user interface 216, a Satellite Positioning System (SPS) receiver 217, a camera 218, and a position device (PD) 219. The processor 210, the memory 211, the sensor(s) 213, the transceiver interface 214, the user interface 216, the SPS receiver 217, the camera 218, and the position device 219 may be communicatively coupled to each other by a bus 220 (which may be configured, e.g., for optical and/or electrical communication). One or more of the shown apparatus (e.g., the camera 218, the position device 219, and/or one or more of the sensor(s) 213, etc.) may be omitted from the UE 200. The processor 210 may include one or more hardware devices, e.g., a central processing unit (CPU), a microcontroller, an application specific integrated circuit (ASIC), etc. The processor 210 may comprise multiple processors including a general-purpose/application processor 230, a Digital Signal Processor (DSP) 231, a modem processor 232, a video processor 233, and/or a sensor processor 234. One or more of the processors 230-234 may comprise multiple devices (e.g., multiple processors). For example, the sensor processor 234 may comprise, e.g., processors for RF (radio frequency) sensing (with one or more (cellular) wireless signals transmitted and reflection(s) used to identify, map, and/or track an object), and/or ultrasound, etc. The modem processor 232 may support dual SIM/dual connectivity (or even more SIMs). For example, a SIM (Subscriber Identity Module or Subscriber Identification Module) may be used by an Original Equipment Manufacturer (OEM), and another SIM may be used by an end user of the UE 200 for connectivity. The memory 211 may be a non-transitory storage medium that may include random access memory (RAM), flash memory, disc memory, and/or read-only memory (ROM), etc. The memory 211 may store the software 212 which may be processor-readable, processor-executable software code containing instructions that may be configured to, when executed, cause the processor 210 to perform various functions described herein. Alternatively, the software 212 may not be directly executable by the processor 210 but may be configured to cause the processor 210, e.g., when compiled and executed, to perform the functions. The description herein may refer to the processor 210 performing a function, but this includes other implementations such as where the processor 210 executes software and/or firmware. The description herein may refer to the processor 210 performing a function as shorthand for one or more of the processors 230-234 performing the function. The description herein may refer to the UE 200 performing a function as shorthand for one or more appropriate components of the UE 200 performing the function. The processor 210 may include a memory with stored instructions in addition to and/or instead of the memory 211. Functionality of the processor 210 is discussed more fully below.

[0056] The configuration of the UE 200 shown in FIG. 2 is an example and not limiting of the disclosure, including the claims, and other configurations may be used. For example, an example configuration of the UE may include one or more of the processors 230-234 of the processor 210, the memory 211, and the wireless transceiver 240. Other example configurations may include one or more of the processors 230-234 of the processor 210, the memory 211, a wireless transceiver, and one or more of the sensor(s) 213, the user interface 216, the SPS receiver 217, the camera 218, the PD 219, and/or a wired transceiver.

[0057] The UE 200 may comprise the modem processor 232 that may be capable of performing baseband processing of signals received and down-converted by the transceiver 215 and/or the SPS receiver 217. The modem processor 232 may perform baseband processing of signals to be upconverted for transmission by the transceiver 215. Also or alternatively, baseband processing may be performed by the general-purpose/application processor 230 and/or the DSP 231. Other configurations, however, may be used to perform baseband processing.

[0058] The UE 200 may include the sensor(s) 213 that may include, for example, an Inertial Measurement Unit (IMU) 270, one or more magnetometers 271, and/or one or more environment sensors 272. The IMU 270 may comprise, for example, one or more accelerometers 273 (e.g., collectively responding to acceleration of the UE 200 in three dimensions) and/or one or more gyroscopes 274 (e.g., three-dimensional gyroscope(s)). The sensor(s) 213 may include the one or more magnetometers 271 (e.g., three-dimensional magnetometer(s)) to determine orientation (e.g., relative to magnetic north and/or true north) that may be used for any of a variety of purposes, e.g., to support one or more compass applications. The environment sensor(s) 272 may comprise, for example, one or more temperature sensors, one or more barometric pressure sensors, one or more ambient light sensors, one or more camera imagers, and/or one or more microphones, etc. The sensor(s) 213 may generate analog and/or digital signals indications of which may be stored in the memory 211 and processed by the DSP 231 and/or the general-purpose/application processor 230 in support of one or more applications such as, for example, applications directed to positioning and/or navigation operations. The sensor(s) 213 may comprise one or more of other various types of sensors such as one or more optical sensors, one or more weight sensors, and/or one or more radio frequency (RF) sensors, etc.

[0059] The sensor(s) 213 may be used in relative location measurements, relative location determination, motion determination, etc. Information detected by the sensor(s) 213 may be used for motion detection, relative displacement, dead reckoning, sensor-based location determination, and/or sensor-assisted location determination. The sensor(s) 213 may be useful to determine whether the UE 200 is fixed (stationary) or mobile and/or whether to report certain useful information to the LMF 120 regarding the mobility of the UE 200. For example, based on the information obtained/measured by the sensor(s) 213, the UE 200 may notify/report to the LMF 120 that the UE 200 has detected movements or that the UE 200 has moved, and may report the relative displacement/distance (e.g., via dead reckoning, or sensor-based location determination, or sensor-assisted location determination enabled by the sensor(s) 213). In another example, for relative positioning information, the sensors/IMU may be used to determine the angle and/or orientation of the other device with respect to the UE 200, etc.

[0060] The IMU 270 may be configured to provide measurements about a direction of motion and/or a speed of motion of the UE 200, which may be used in relative location determination. For example, the one or more accelerometers 273 and/or the one or more gyroscopes 274 of the IMU 270 may detect, respectively, a linear acceleration and a speed of rotation of the UE 200. The linear acceleration and speed of rotation measurements of the UE 200 may be integrated over time to determine an instantaneous direction of motion as well as a displacement of the UE 200. The instantaneous direction of motion and the displacement may be integrated to track a location of the UE 200. For example, a reference location of the UE 200 may be determined, e.g., using the SPS receiver 217 (and/or by some other means) for a moment in time and measurements from the accelerometer(s) 273 and the gyroscope(s) 274 taken after this moment in time may be used in dead reckoning to determine present location of the UE 200 based on movement (direction and distance) of the UE 200 relative to the reference location.

[0061] The magnetometer(s) 271 may determine magnetic field strengths in different directions which may be used to determine orientation of the UE 200. For example, the orientation may be used to provide a digital compass for the UE 200. The magnetometer(s) may include a two-dimensional magnetometer configured to detect and provide indications of magnetic field strength in two orthogonal dimensions. The magnetometer(s) 271 may include a three-dimensional magnetometer configured to detect and provide indications of magnetic field strength in three orthogonal dimensions. The magnetometer(s) 271 may provide means for sensing a magnetic field and providing indications of the magnetic field, e.g., to the processor 210.

[0062] The transceiver 215 may include a wireless transceiver 240 and a wired transceiver 250 configured to communicate with other devices through wireless connections and wired connections, respectively. For example, the wireless transceiver 240 may include a wireless transmitter 242 and a wireless receiver 244 coupled to an antenna 246 for transmitting (e.g., on one or more uplink channels and/or one or more sidelink channels) and/or receiving (e.g., on one or more downlink channels and/or one or more sidelink channels) wireless signals 248 and transducing signals from the wireless signals 248 to wired (e.g., electrical and/or optical) signals and from wired (e.g., electrical and/or optical) signals to the wireless signals 248. The wireless transmitter 242 includes appropriate components (e.g., a power amplifier and a digital-to-analog converter). The wireless receiver 244 includes appropriate components (e.g., one or more amplifiers, one or more frequency filters, and an analog-to-digital converter). The wireless transmitter 242 may include multiple transmitters that may be discrete components or combined/integrated components, and/or the wireless receiver 244 may include multiple receivers that may be discrete components or combined/integrated components. The wireless transceiver 240 may be configured to communicate signals (e.g., with TRPs and/or one or more other devices) according to a variety of radio access technologies (RATs) such as 5G New Radio (NR), GSM (Global System for Mobiles), UMTS (Universal Mobile Telecommunications System), AMPS (Advanced Mobile Phone System), CDMA (Code Division Multiple Access), WCDMA (Wideband CDMA), LTE (Long Term Evolution), LTE Direct (LTE-D), 3GPP LTE-V2X (PC5), IEEE 802.11 (including IEEE 802.11p), WiFi®, WiFi® Direct (WiFi®-D), Bluetooth®, Zigbee®, etc. New Radio may use mm-wave frequencies and/or sub-6GHz frequencies. The wired transceiver 250 may include a wired transmitter 252 and a wired receiver 254 configured for wired communication, e.g., a network interface that may be utilized to communicate with the NG-RAN 135 to send communications to, and receive communications from, the NG-RAN 135. The wired transmitter 252 may include multiple transmitters that may be discrete components or combined/integrated components, and/or the wired receiver 254 may include multiple receivers that may be discrete components or combined/integrated components. The wired transceiver 250 may be configured, e.g., for optical communication and/or electrical communication. The transceiver 215 may be communicatively coupled to the transceiver interface 214, e.g., by optical and/or electrical connection. The transceiver interface 214 may be at least partially integrated with the transceiver 215. The wireless transmitter 242, the wireless receiver 244, and/or the antenna 246 may include multiple transmitters, multiple receivers, and/or multiple antennas, respectively, for sending and/or receiving, respectively, appropriate signals.

[0063] The user interface 216 may comprise one or more of several devices such as, for example, a speaker, microphone, display device, vibration device, keyboard, touch screen, etc. The user interface 216 may include more than one of any of these devices. The user interface 216 may be configured to enable a user to interact with one or more applications hosted by the UE 200. For example, the user interface 216 may store indications of analog and/or digital signals in the memory 211 to be processed by DSP 231 and/or the general-purpose/application processor 230 in response to action from a user. Similarly, applications hosted on the UE 200 may store indications of analog and/or digital signals in the memory 211 to present an output signal to a user. The user interface 216 may include an audio input/output (I/O) device comprising, for example, a speaker, a microphone, digital-to-analog circuitry, analog-to-digital circuitry, an amplifier and/or gain control circuitry (including more than one of any of these devices). Other configurations of an audio I/O device may be used. Also or alternatively, the user interface 216 may comprise one or more touch sensors responsive to touching and/or pressure, e.g., on a keyboard and/or touch screen of the user interface 216.

[0064] The SPS receiver 217 (e.g., a Global Positioning System (GPS) receiver) may be capable of receiving and acquiring SPS signals 260 via an SPS antenna 262. The SPS antenna 262 is configured to transduce the SPS signals 260 from wireless signals to wired signals, e.g., electrical or optical signals, and may be integrated with the antenna

246. The SPS receiver 217 may be configured to process, in whole or in part, the acquired SPS signals 260 for estimating a location of the UE 200. For example, the SPS receiver 217 may be configured to determine location of the UE 200 by trilateration using the SPS signals 260. The general-purpose/application processor 230, the memory 211, the DSP 231 and/or one or more specialized processors (not shown) may be utilized to process acquired SPS signals, in whole or in part, and/or to calculate an estimated location of the UE 200, in conjunction with the SPS receiver 217. The memory 211 may store indications (e.g., measurements) of the SPS signals 260 and/or other signals (e.g., signals acquired from the wireless transceiver 240) for use in performing positioning operations. The general-purpose/application processor 230, the DSP 231, and/or one or more specialized processors, and/or the memory 211 may provide or support a location engine for use in processing measurements to estimate a location of the UE 200.

[0065] The UE 200 may include the camera 218 for capturing still or moving imagery. The camera 218 may comprise, for example, an imaging sensor (e.g., a charge coupled device or a CMOS (Complementary Metal-Oxide Semiconductor) imager), a lens, analog-to-digital circuitry, frame buffers, etc. Additional processing, conditioning, encoding, and/or compression of signals representing captured images may be performed by the general-purpose/application processor 230 and/or the DSP 231. Also or alternatively, the video processor 233 may perform conditioning, encoding, compression, and/or manipulation of signals representing captured images. The video processor 233 may decode/decompress stored image data for presentation on a display device (not shown), e.g., of the user interface 216.

[0066] The position device (PD) 219 may be configured to determine a position of the UE 200, motion of the UE 200, and/or relative position of the UE 200, and/or time. For example, the PD 219 may communicate with, and/or include some or all of, the SPS receiver 217. The PD 219 may work in conjunction with the processor 210 and the memory 211 as appropriate to perform at least a portion of one or more positioning methods, although the description herein may refer to the PD 219 being configured to perform, or performing, in accordance with the positioning method(s). The PD 219 may also or alternatively be configured to determine location of the UE 200 using terrestrial-based signals (e.g., at least some of the wireless signals 248) for trilateration, for assistance with obtaining and using the SPS signals 260, or both. The PD 219 may be configured to determine location of the UE 200 based on a cell of a serving base station (e.g., a cell center) and/or another technique such as E-CID. The PD 219 may be configured to use one or more images from the camera 218 and image recognition combined with known locations of landmarks (e.g., natural landmarks such as mountains and/or artificial landmarks such as buildings, bridges, streets, etc.) to determine location of the UE 200. The PD 219 may be configured to use one or more other techniques (e.g., relying on the UE's self-reported location (e.g., part of the UE's position beacon)) for determining the location of the UE 200, and may use a combination of techniques (e.g., SPS and terrestrial positioning signals) to determine the location of the UE 200. The PD 219 may include one or more of the sensors 213 (e.g., gyroscope(s), accelerometer(s), magnetometer(s), etc.) that may sense orientation and/or motion of the UE 200 and provide indications thereof that the processor 210 (e.g., the general-purpose/application processor 230 and/or the DSP 231) may be configured to use to determine motion (e.g., a velocity vector and/or an acceleration vector) of the UE 200. The PD 219 may be configured to provide indications of uncertainty and/or error in the determined position and/or motion. Functionality of the PD 219 may be provided in a variety of manners and/or configurations, e.g., by the general-purpose/application processor 230, the transceiver 215, the SPS receiver 217, and/or another component of the UE 200, and may be provided by hardware, software, firmware, or various combinations thereof.

[0067] Referring also to FIG. 3, an example of a TRP 300 of the gNBs 110a, 110b and/or the ng-eNB 114 may comprise a computing platform including a processor 310, memory 311 including software (SW) 312, and a transceiver 315. The processor 310, the memory 311, and the transceiver 315 may be communicatively coupled to each other by a bus 320 (which may be configured, e.g., for optical and/or electrical communication). One or more of the shown apparatus may be omitted from the TRP 300. The processor 310 may include one or more hardware devices, e.g., a central processing unit (CPU), a microcontroller, an application specific integrated circuit (ASIC), etc. The processor 310 may comprise multiple processors (e.g., including a general-purpose/application processor, a DSP, a modem processor, a video processor, and/or a sensor processor as shown in FIG. 2). The memory 311 may be a non-transitory storage medium that may include random access memory (RAM)), flash memory, disc memory, and/or read-only memory (ROM), etc. The memory 311 may store the software 312 which may be processor-readable, processor-executable software code containing instructions that are configured to, when executed, cause the processor 310 to perform various functions described herein. Alternatively, the software 312 may not be directly executable by the processor 310 but may be configured to cause the processor 310, e.g., when compiled and executed, to perform the functions.

[0068] The description herein may refer to the processor 310 performing a function, but this includes other implementations such as where the processor 310 executes software and/or firmware. The description herein may refer to the processor 310 performing a function as shorthand for one or more of the processors contained in the processor 310 performing the function. The description herein may refer to the TRP 300 performing a function as shorthand for one or more appropriate components (e.g., the processor 310 and the memory 311) of the TRP 300 (and thus of one of the gNBs 110a, 110b and/or the ng-eNB 114) performing the function. The processor 310 may include a memory with stored instructions in addition to and/or instead of the memory 311. Functionality of the processor 310 is discussed more fully below.

[0069] The transceiver 315 may include a wireless transceiver 340 and/or a wired transceiver 350 configured to communicate with other devices through wireless connections and wired connections, respectively. For example, the wireless transceiver 340 may include a wireless transmitter 342 and a wireless receiver 344 coupled to one or more antennas 346 for transmitting (e.g., on one or more uplink channels and/or one or more downlink channels) and/or receiving (e.g., on one or more downlink channels and/or one or more uplink channels) wireless signals 348 and transducing signals from the wireless signals 348 to wired (e.g., electrical and/or optical) signals and from wired (e.g., electrical and/or optical) signals to the wireless signals 348. Thus, the wireless transmitter 342 may include multiple transmitters that may be discrete components or combined/integrated components, and/or the wireless receiver 344 may include multiple receivers that may be discrete components or combined/integrated components. The wireless transceiver 340 may be configured to communicate signals (e.g., with the UE 200, one or more other UEs, and/or one or more other devices) according to a variety of radio access technologies (RATs) such as 5G New Radio (NR), GSM (Global System for Mobiles), UMTS (Universal Mobile Telecommunications System), AMPS (Advanced Mobile Phone System), CDMA (Code Division Multiple Access), WCDMA (Wideband CDMA), LTE (Long Term Evolution), LTE Direct (LTE-D), 3GPP LTE-

V2X (PC5), IEEE 802.11 (including IEEE 802.11p), WiFi®, WiFi® Direct (WiFi®-D), Bluetooth®, Zigbee®, etc. The wired transceiver 350 may include a wired transmitter 352 and a wired receiver 354 configured for wired communication, e.g., a network interface that may be utilized to communicate with the NG-RAN 135 to send communications to, and receive communications from, the LMF 120, for example, and/or one or more other network entities. The wired transmitter 352 may include multiple transmitters that may be discrete components or combined/integrated components, and/or the wired receiver 354 may include multiple receivers that may be discrete components or combined/integrated components. The wired transceiver 350 may be configured, e.g., for optical communication and/or electrical communication.

[0070] The configuration of the TRP 300 shown in FIG. 3 is an example and not limiting of the disclosure, including the claims, and other configurations may be used. For example, the description herein discusses that the TRP 300 may be configured to perform or performs several functions, but one or more of these functions may be performed by the LMF 120 and/or the UE 200 (i.e., the LMF 120 and/or the UE 200 may be configured to perform one or more of these functions).

[0071] Referring also to FIG. 4, a server 400, of which the LMF 120 may be an example, may comprise a computing platform including a processor 410, memory 411 including software (SW) 412, and a transceiver 415. The processor 410, the memory 411, and the transceiver 415 may be communicatively coupled to each other by a bus 420 (which may be configured, e.g., for optical and/or electrical communication). One or more of the shown apparatus (e.g., a wireless transceiver) may be omitted from the server 400. The processor 410 may include one or more hardware devices, e.g., a central processing unit (CPU), a microcontroller, an application specific integrated circuit (ASIC), etc. The processor 410 may comprise multiple processors (e.g., including a general-purpose/application processor, a DSP, a modem processor, a video processor, and/or a sensor processor as shown in FIG. 2). The memory 411 may be a non-transitory storage medium that may include random access memory (RAM)), flash memory, disc memory, and/or read-only memory (ROM), etc. The memory 411 may store the software 412 which may be processor-readable, processor-executable software code containing instructions that are configured to, when executed, cause the processor 410 to perform various functions described herein. Alternatively, the software 412 may not be directly executable by the processor 410 but may be configured to cause the processor 410, e.g., when compiled and executed, to perform the functions. The description herein may refer to the processor 410 performing a function, but this includes other implementations such as where the processor 410 executes software and/or firmware. The description herein may refer to the processor 410 performing a function as shorthand for one or more of the processors contained in the processor 410 performing the function. The description herein may refer to the server 400 performing a function as shorthand for one or more appropriate components of the server 400 performing the function. The processor 410 may include a memory with stored instructions in addition to and/or instead of the memory 411. Functionality of the processor 410 is discussed more fully below.

[0072] The transceiver 415 may include a wireless transceiver 440 and/or a wired transceiver 450 configured to communicate with other devices through wireless connections and wired connections, respectively. For example, the wireless transceiver 440 may include a wireless transmitter 442 and a wireless receiver 444 coupled to one or more antennas 446 for transmitting (e.g., on one or more downlink channels) and/or receiving (e.g., on one or more uplink channels) wireless signals 448 and transducing signals from the wireless signals 448 to wired (e.g., electrical and/or optical) signals and from wired (e.g., electrical and/or optical) signals to the wireless signals 448. Thus, the wireless transmitter 442 may include multiple transmitters that may be discrete components or combined/integrated components, and/or the wireless receiver 444 may include multiple receivers that may be discrete components or combined/integrated components. The wireless transceiver 440 may be configured to communicate signals (e.g., with the UE 200, one or more other UEs, and/or one or more other devices) according to a variety of radio access technologies (RATs) such as 5G New Radio (NR), GSM (Global System for Mobiles), UMTS (Universal Mobile Telecommunications System), AMPS (Advanced Mobile Phone System), CDMA (Code Division Multiple Access), WCDMA (Wideband CDMA), LTE (Long Term Evolution), LTE Direct (LTE-D), 3GPP LTE-V2X (PC5), IEEE 802.11 (including IEEE 802.11p), WiFi®, WiFi® Direct (WiFi®-D), Bluetooth®, Zigbee®, etc. The wired transceiver 450 may include a wired transmitter 452 and a wired receiver 454 configured for wired communication, e.g., a network interface that may be utilized to communicate with the NG-RAN 135 to send communications to, and receive communications from, the TRP 300, for example, and/or one or more other network entities. The wired transmitter 452 may include multiple transmitters that may be discrete components or combined/integrated components, and/or the wired receiver 454 may include multiple receivers that may be discrete components or combined/integrated components. The wired transceiver 450 may be configured, e.g., for optical communication and/or electrical communication.

[0073] The description herein may refer to the processor 410 performing a function, but this includes other implementations such as where the processor 410 executes software (stored in the memory 411) and/or firmware. The description herein may refer to the server 400 performing a function as shorthand for one or more appropriate components (e.g., the processor 410 and the memory 411) of the server 400 performing the function.

[0074] The configuration of the server 400 shown in FIG. 4 is an example and not limiting of the disclosure, including the claims, and other configurations may be used. For example, the wireless transceiver 440 may be omitted. Also or alternatively, the description herein discusses that the server 400 is configured to perform or performs several functions, but one or more of these functions may be performed by the TRP 300 and/or the UE 200 (i.e., the TRP 300 and/or the UE 200 may be configured to perform one or more of these functions).

[0075] For terrestrial positioning of a UE in cellular networks, techniques such as Advanced Forward Link Trilateration (AFLT) and Observed Time Difference Of Arrival (OTDOA) often operate in “UE-assisted” mode in which measurements of reference signals (e.g., PRS, CRS, etc.) transmitted by base stations are taken by the UE and then provided to a location server. The location server calculates the position of the UE based on the measurements and known locations of the base stations. Because these techniques use the location server to calculate the position of the UE, rather than the UE itself, these positioning techniques are not frequently used in applications such as car or cell-phone navigation, which instead typically rely on satellite-based positioning.

[0076] A UE may use a Satellite Positioning System (SPS) (a Global Navigation Satellite System (GNSS)) for high-accuracy positioning using precise point positioning (PPP) or real time kinematic (RTK) technology. These technologies use assistance data such as measurements from ground-based stations. LTE Release 15 allows the data to be encrypted so that the UEs subscribed to the service exclusively can read the information. Such assistance data varies with time. Thus, a UE subscribed to the service may not easily “break encryption” for other UEs by passing on the data to other

UEs that have not paid for the subscription. The passing on would need to be repeated every time the assistance data changes.

[0077] In UE-assisted positioning, the UE sends measurements (e.g., TDOA, Angle of Arrival (AoA), etc.) to the positioning server (e.g., LMF/eSMLC). The positioning server has the base station almanac (BSA) that contains multiple 'entries' or 'records', one record per cell, where each record contains geographical cell location but also may include other data. An identifier of the 'record' among the multiple 'records' in the BSA may be referenced. The BSA and the measurements from the UE may be used to compute the position of the UE.

[0078] In conventional UE-based positioning, a UE computes its own position, thus avoiding sending measurements to the network (e.g., location server), which in turn improves latency and scalability. The UE uses relevant BSA record information (e.g., locations of gNBs (more broadly base stations)) from the network. The BSA information may be encrypted. But since the BSA information varies much less often than, for example, the PPP or RTK assistance data described earlier, it may be easier to make the BSA information (compared to the PPP or RTK information) available to UEs that did not subscribe and pay for decryption keys. Transmissions of reference signals by the gNBs make BSA information potentially accessible to crowd-sourcing or war-driving, essentially enabling BSA information to be generated based on in-the-field and/or over-the-top observations.

[0079] Positioning techniques may be characterized and/or assessed based on one or more criteria such as position determination accuracy and/or latency. Latency is a time elapsed between an event that triggers determination of position-related data and the availability of that data at a positioning system interface, e.g., an interface of the LMF 120. At initialization of a positioning system, the latency for the availability of position-related data is called time to first fix (TTFF), and is larger than latencies after the TTFF. An inverse of a time elapsed between two consecutive position-related data availabilities is called an update rate, i.e., the rate at which position-related data are generated after the first fix. Latency may depend on processing capability, e.g., of the UE. For example, a UE may report a processing capability of the UE as a duration of DL PRS symbols in units of time (e.g., milliseconds) that the UE can process every T amount of time (e.g., T ms) assuming 272 PRB (Physical Resource Block) allocation. Other examples of capabilities that may affect latency are a number of TRPs from which the UE can process PRS, a number of PRS that the UE can process, and a bandwidth of the UE.

[0080] One or more of many different positioning techniques (also called positioning methods) may be used to determine position of an entity such as one of the UEs 105, 106. For example, known position-determination techniques include RTT, multi-RTT, OTDOA (also called TDOA and including UL-TDOA and DL-TDOA), Enhanced Cell Identification (E-CID), DL-AoD, UL-AoA, etc. RTT uses a time for a signal to travel from one entity to another and back to determine a range between the two entities. The range, plus a known location of a first one of the entities and an angle between the two entities (e.g., an azimuth angle) can be used to determine a location of the second of the entities. In multi-RTT (also called multi-cell RTT), multiple ranges from one entity (e.g., a UE) to other entities (e.g., TRPs) and known locations of the other entities may be used to determine the location of the one entity. In TDOA techniques, the difference in travel times between one entity and other entities may be used to determine relative ranges from the other entities and those, combined with known locations of the other entities may be used to determine the location of the one entity. Angles of arrival and/or departure may be used to help determine location of an entity. For example, an angle of arrival or an angle of departure of a signal combined with a range between devices (determined using signal, e.g., a travel time of the signal, a received power of the signal, etc.) and a known location of one of the devices may be used to determine a location of the other device. The angle of arrival or departure may be an azimuth angle relative to a reference direction such as true north. The angle of arrival or departure may be a zenith angle relative to directly upward from an entity (i.e., relative to radially outward from a center of Earth). E-CID uses the identity of a serving cell, the timing advance (i.e., the difference between receive and transmit times at the UE), estimated timing and power of detected neighbor cell signals, and possibly angle of arrival (e.g., of a signal at the UE from the base station or vice versa) to determine location of the UE. In TDOA, the difference in arrival times at a receiving device of signals from different sources along with known locations of the sources and known offset of transmission times from the sources are used to determine the location of the receiving device.

[0081] In a network-centric RTT estimation, the serving base station instructs the UE to scan for / receive RTT measurement signals (e.g., PRS) on serving cells of two or more neighboring base stations (and typically the serving base station, as at least three base stations are needed). The one of more base stations transmit RTT measurement signals on low reuse resources (e.g., resources used by the base station to transmit system information) allocated by the network (e.g., a location server such as the LMF 120). The UE records the arrival time (also referred to as time information, a receive time, a reception time, a time of reception, or a time of arrival (ToA)) of each RTT measurement signal relative to the UE's current downlink timing (e.g., as derived by the UE from a DL signal received from its serving base station), and transmits a common or individual RTT response message (e.g., SRS (sounding reference signal) for positioning, i.e., UL-PRS) to the one or more base stations (e.g., when instructed by its serving base station) and may include the time difference $T_{Rx \to Tx}$ (i.e., UE T_{Rx-Tx} or UE_{Rx-Tx}) between the ToA of the RTT measurement signal and the transmission time of the RTT response message in a payload of each RTT response message. The RTT response message would include a reference signal from which the base station can deduce the ToA of the RTT response. By comparing the difference $T_{Tx \to Rx}$ between the transmission time of the RTT measurement signal from the base station and the ToA of the RTT response at the base station to the UE-reported time difference $T_{Rx \to Tx}$, and subtracting the UE_{Rx-Tx}, the base station can deduce the propagation time between the base station and the UE, from which the base station can determine the distance between the UE and the base station by assuming the speed of light during this propagation time.

[0082] A UE-centric RTT estimation is similar to the network-based method, except that the UE transmits uplink RTT measurement signal(s) (e.g., when instructed by a serving base station), which are received by multiple base stations in the neighborhood of the UE. Each involved base station responds with a downlink RTT response message, which may include the time difference between the ToA of the RTT measurement signal at the base station and the transmission time of the RTT response message from the base station in the RTT response message payload.

[0083] For both network-centric and UE-centric procedures, the side (network or UE) that performs the RTT calculation typically (though not always) transmits the first message(s) or signal(s) (e.g., RTT measurement signal(s)), while the other side responds with one or more RTT response message(s) or signal(s) that may include the difference between the ToA of the first message(s) or signal(s) and the transmission time of the RTT response message(s) or signal(s).

[0084] A multi-RTT technique may be used to determine position. For example, a first entity (e.g., a UE) may send out one or more signals (e.g., unicast, multicast, or broadcast from the base station) and multiple second entities (e.g., other TSPs such as base station(s) and/or UE(s)) may receive a signal from the first entity and respond to this received signal. The first entity receives the responses from the multiple second entities. The first entity (or another entity such as an LMF) may use the responses from the second entities to determine ranges to the second entities and may use the multiple ranges and known locations of the second entities to determine the location of the first entity by trilateration.

[0085] In some instances, additional information may be obtained in the form of an angle of arrival (AoA) or angle of departure (AoD) that defines a straight-line direction (e.g., which may be in a horizontal plane or in three dimensions) or possibly a range of directions (e.g., for the UE from the locations of base stations). The intersection of two directions can provide another estimate of the location for the UE.

[0086] For positioning techniques using PRS (Positioning Reference Signal) signals (e.g., TDOA and RTT), PRS signals sent by multiple TRPs are measured and the arrival times of the signals, known transmission times, and known locations of the TRPs used to determine ranges from a UE to the TRPs. For example, an RSTD (Reference Signal Time Difference) may be determined for PRS signals received from multiple TRPs and used in a TDOA technique to determine position (location) of the UE. A positioning reference signal may be referred to as a PRS or a PRS signal. The PRS signals are typically sent using the same power and PRS signals with the same signal characteristics (e.g., same frequency shift) may interfere with each other such that a PRS signal from a more distant TRP may be overwhelmed by a PRS signal from a closer TRP such that the signal from the more distant TRP may not be detected. PRS muting may be used to help reduce interference by muting some PRS signals (reducing the power of the PRS signal, e.g., to zero and thus not transmitting the PRS signal). In this way, a weaker (at the UE) PRS signal may be more easily detected by the UE without a stronger PRS signal interfering with the weaker PRS signal. The term RS, and variations thereof (e.g., PRS, SRS, CSI-RS (Channel State Information – Reference Signal)), may refer to one reference signal or more than one reference signal.

[0087] Positioning reference signals (PRS) include downlink PRS (DL PRS, often referred to simply as PRS) and uplink PRS (UL PRS) (which may be called SRS (Sounding Reference Signal) for positioning). A PRS may comprise a PN code (pseudorandom number code) or be generated using a PN code (e.g., by modulating a carrier signal with the PN code) such that a source of the PRS may serve as a pseudo-satellite (a pseudolite). The PN code may be unique to the PRS source (at least within a specified area such that identical PRS from different PRS sources do not overlap). PRS may comprise PRS resources and/or PRS resource sets of a frequency layer. A DL PRS positioning frequency layer (or simply a frequency layer) is a collection of DL PRS resource sets, from one or more TRPs, with PRS resource(s) that have common parameters configured by higher-layer parameters *DL-PRS-PositioningFrequencyLayer*, *DL-PRS-ResourceSet*, and *DL-PRS-Resource*. Each frequency layer has a DL PRS subcarrier spacing (SCS) for the DL PRS resource sets and the DL PRS resources in the frequency layer. Each frequency layer has a DL PRS cyclic prefix (CP) for the DL PRS resource sets and the DL PRS resources in the frequency layer. In 5G, a resource block occupies 12 consecutive subcarriers and a specified number of symbols. Common resource blocks are the set of resource blocks that occupy a channel bandwidth. A bandwidth part (BWP) is a set of contiguous common resource blocks and may include all the common resource blocks within a channel bandwidth or a subset of the common resource blocks. Also, a DL PRS Point A parameter defines a frequency of a reference resource block (and the lowest subcarrier of the resource block), with DL PRS resources belonging to the same DL PRS resource set having the same Point A and all DL PRS resource sets belonging to the same frequency layer having the same Point A. A frequency layer also has the same DL PRS bandwidth, the same start PRB (and center frequency), and the same value of comb size (i.e., a frequency of PRS resource elements per symbol such that for comb-N, every N$^{\underline{th}}$ resource element is a PRS resource element). A PRS resource set is identified by a PRS resource set ID and may be associated with a particular TRP (identified by a cell ID) transmitted by an antenna panel of a base station. A PRS resource ID in a PRS resource set may be associated with an omnidirectional signal, and/or with a single beam (and/or beam ID) transmitted from a single base station (where a base station may transmit one or more beams). Each PRS resource of a PRS resource set may be transmitted on a different beam and as such, a PRS resource (or simply resource) can also be referred to as a beam. This does not have any implications on whether the base stations and the beams on which PRS are transmitted are known to the UE.

[0088] A TRP may be configured, e.g., by instructions received from a server and/or by software in the TRP, to send DL PRS per a schedule. According to the schedule, the TRP may send the DL PRS intermittently, e.g., periodically at a consistent interval from an initial transmission. The TRP may be configured to send one or more PRS resource sets. A resource set is a collection of PRS resources across one TRP, with the resources having the same periodicity, a common muting pattern configuration (if any), and the same repetition factor across slots. Each of the PRS resource sets comprises multiple PRS resources, with each PRS resource comprising multiple OFDM (Orthogonal Frequency Division Multiplexing) Resource Elements (REs) that may be in multiple Resource Blocks (RBs) within N (one or more) consecutive symbol(s) within a slot. PRS resources (or reference signal (RS) resources generally) may be referred to as OFDM PRS resources (or OFDM RS resources). An RB is a collection of REs spanning a quantity of one or more consecutive symbols in the time domain and a quantity (12 for a 5G RB) of consecutive sub-carriers in the frequency domain. Each PRS resource is configured with an RE offset, slot offset, a symbol offset within a slot, and a number of consecutive symbols that the PRS resource may occupy within a slot. The RE offset defines the starting RE offset of the first symbol within a DL PRS resource in frequency. The relative RE offsets of the remaining symbols within a DL PRS resource are defined based on the initial offset. The slot offset is the starting slot of the DL PRS resource with respect to a corresponding resource set slot offset. The symbol offset determines the starting symbol of the DL PRS resource within the starting slot. Transmitted REs may repeat across slots, with each transmission being called a repetition such that there may be multiple repetitions in a PRS resource. The DL PRS resources in a DL PRS resource set are associated with the same TRP and each DL PRS resource has a DL PRS resource ID. A DL PRS resource ID in a DL PRS resource set is associated with a single beam transmitted from a single TRP (although a TRP may transmit one or more beams).

[0089] A PRS resource may also be defined by quasi-co-location and start PRB parameters. A quasi-co-location (QCL) parameter may define any quasi-co-location information of the DL PRS resource with other reference signals. The DL PRS may be configured to be QCL type D with a DL PRS or SS/PBCH (Synchronization

Signal/Physical Broadcast Channel) Block from a serving cell or a non-serving cell. The DL PRS may be configured to be QCL type C with an SS/PBCH Block from a serving cell or a non-serving cell. The start PRB parameter defines the starting PRB index of the DL PRS resource with respect to reference Point A. The starting PRB index has a granularity of one PRB and may have a minimum value of 0 and a maximum value of 2176 PRBs.

[0090] A PRS resource set is a collection of PRS resources with the same periodicity, same muting pattern configuration (if any), and the same repetition factor across slots. Every time all repetitions of all PRS resources of the PRS resource set are configured to be transmitted is referred as an “instance”. Therefore, an “instance” of a PRS resource set is a specified number of repetitions for each PRS resource and a specified number of PRS resources within the PRS resource set such that once the specified number of repetitions are transmitted for each of the specified number of PRS resources, the instance is complete. An instance may also be referred to as an “occasion.” A DL PRS configuration including a DL PRS transmission schedule may be provided to a UE to facilitate (or even enable) the UE to measure the DL PRS.

[0091] Multiple frequency layers of PRS may be aggregated to provide an effective bandwidth that is larger than any of the bandwidths of the layers individually. Multiple frequency layers of component carriers (which may be consecutive and/or separate) and meeting criteria such as being quasi co-located (QCLed), and having the same antenna port, may be stitched to provide a larger effective PRS bandwidth (for DL PRS and UL PRS) resulting in increased time information (e.g., time of arrival) measurement accuracy. Stitching comprises combining PRS measurements over individual bandwidth fragments into a unified piece such that the stitched PRS may be treated as having been taken from a single measurement. Being QCLed, the different frequency layers behave similarly, enabling stitching of the PRS to yield the larger effective bandwidth. The larger effective bandwidth, which may be referred to as the bandwidth of an aggregated PRS or the frequency bandwidth of an aggregated PRS, provides for better time-domain resolution (e.g., of TDOA). An aggregated PRS includes a collection of PRS resources and each PRS resource of an aggregated PRS may be called a PRS component, and each PRS component may be transmitted on different component carriers, bands, or frequency layers, or on different portions of the same band.

[0092] RTT positioning is an active positioning technique in that RTT uses positioning signals sent by TRPs to UEs and by UEs (that are participating in RTT positioning) to TRPs. The TRPs may send DL-PRS signals that are received by the UEs and the UEs may send SRS (Sounding Reference Signal) signals that are received by multiple TRPs. A sounding reference signal may be referred to as an SRS or an SRS signal. In 5G multi-RTT, coordinated positioning may be used with the UE sending a single UL-SRS for positioning that is received by multiple TRPs instead of sending a separate UL-SRS for positioning for each TRP. A TRP that participates in multi-RTT will typically search for UEs that are currently camped on that TRP (served UEs, with the TRP being a serving TRP) and also UEs that are camped on neighboring TRPs (neighbor UEs). Neighbor TRPs may be TRPs of a single BTS (Base Transceiver Station) (e.g., gNB), or may be a TRP of one BTS and a TRP of a separate BTS. For RTT positioning, including multi-RTT positioning, the DL-PRS signal and the UL-SRS for positioning signal in a PRS/SRS for positioning signal pair used to determine RTT (and thus used to determine range between the UE and the TRP) may occur close in time to each other such that errors due to UE motion and/or UE clock drift and/or TRP clock drift are within acceptable limits. For example, signals in a PRS/SRS for positioning signal pair may be transmitted from the TRP and the UE, respectively, within about 10 ms of each other. With SRS for positioning being sent by UEs, and with PRS and SRS for positioning being conveyed close in time to each other, it has been found that radio-frequency (RF) signal congestion may result (which may cause excessive noise, etc.) especially if many UEs attempt positioning concurrently and/or that computational congestion may result at the TRPs that are trying to measure many UEs concurrently.

[0093] RTT positioning may be UE-based or UE-assisted. In UE-based RTT, the UE 200 determines the RTT and corresponding range to each of the TRPs 300 and the position of the UE 200 based on the ranges to the TRPs 300 and known locations of the TRPs 300. In UE-assisted RTT, the UE 200 measures positioning signals and provides measurement information to the TRP 300, and the TRP 300 determines the RTT and range. The TRP 300 provides ranges to a location server, e.g., the server 400, and the server determines the location of the UE 200, e.g., based on ranges to different TRPs 300. The RTT and/or range may be determined by the TRP 300 that received the signal(s) from the UE 200, by this TRP 300 in combination with one or more other devices, e.g., one or more other TRPs 300 and/or the server 400, or by one or more devices other than the TRP 300 that received the signal(s) from the UE 200.

[0094] Various positioning techniques are supported in 5G NR. The NR native positioning methods supported in 5G NR include DL-only positioning methods, UL-only positioning methods, and DL+UL positioning methods. Downlink-based positioning methods include DL-TDOA and DL-AoD. Uplink-based positioning methods include UL-TDOA and UL-AoA. Combined DL+UL-based positioning methods include RTT with one base station and RTT with multiple base stations (multi-RTT).

[0095] A position estimate (e.g., for a UE) may be referred to by other names, such as a location estimate, location, position, position fix, fix, or the like. A position 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 position 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 position 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). Position information may include one or more positioning signal measurements (e.g., of one or more satellite signals, of PRS, and/or one or more other signals), and/or one or more values (e.g., one or more ranges (possibly including one or more pseudoranges), and/or one or more position estimates, etc.) based on one or more positioning signal measurements.

[0096] Referring to FIGS. 5A and 5B, block diagrams of example AI/ML models for positioning applications are shown. A AI/ML positioning model 502 may be trained to learn relationships between reference signal measurements (e.g., channel impulse response (CIR), power delay profile (PDP), delay profile (DP) etc.) and positioning based labels such as a location or other intermediate messages. FIG. 5A depicts a direct AI/ML positioning use case with an AI/ML positioning model 502 configured to receive reference signal measurements and output a target location (e.g., a direct label). FIG. 5B depicts a AI/ML assisted positioning use case with a AI/ML positioning model 502 configured to receive reference signal measurements and output one or more intermediate labels such as time information (e.g., time of arrival), LOS identification, AoA, etc. The intermediate measurements may be provided to a second positioning model 504 configured to output a target location. The second positioning model 504 may be another AI/ML model or other non-AI models (e.g., Chans algorithm, Kalman Filter, etc.). In an example, the size of the AI/ML positioning model 502 may be very large, and it may not be feasible to share the entire dataset with a mobile device, such as the UE 200, or other network stations (e.g., TRP 300). In some cases, a practical approach may be to train the AI/ML positioning model 502 as a neural network (NN) and then share the neural network model and the parameters (e.g., weights and the like) for the trained model with a mobile device or network station. In an example, the AI/ML positioning models may be communicated via the Open Neural Network Exchange (ONNX) format. Other formats may also be used (e.g., flat files, binary files, etc.). The mobile device or network station may then use the trained NN to predict target locations and/or intermediate measurements based on the reference signal measurements.

[0097] In an example, the AI/ML positioning model 502 may be trained using supervised learning techniques in which an input data set including reference signal measurements, location information, and other parameters. Other training techniques may also be used. For example, supervised learning algorithms, semi-supervised learning algorithm, unsupervised learning algorithms, reinforcement learning algorithms, deep learning algorithms, artificial neural network algorithms, or other type of machine learning algorithms may be used. For example, the machine learning may be performed using a deep convolutional network (DCN). DCNs are networks of convolutional networks, configured with additional pooling and normalization layers. DCNs have achieved state-of-the-art performance on many tasks. DCNs may be trained using supervised learning in which both the input and output targets are known for many examples and are used to modify the weights of the network by use of gradient descent methods. DCNs may be feed-forward networks. In addition, as described above, the connections from a neuron in a first layer of a DCN to a group of neurons in the next higher layer are shared across the neurons in the first layer. The feed-forward and shared connections of DCNs may be exploited for fast processing. The computational burden of a DCN may be much less, for example, than that of a similarly sized neural network that comprises recurrent or feedback connections.

[0098] Referring to FIG. 6A, block diagram examples of UE based and UE assisted positioning techniques with AI/ML models are shown. A first use case 620 (Case 1), a second use case 622 (Case 2a), and a third use case 624 (Case 2b) include a LMF 602, a gNB 604 and a UE 606 configured to communicate with one another via LPP, RRC or other signaling techniques as known in the art. The first use case 620 includes an example UE-side model such that the UE 606 is configured with a first AI/ML positioning model 608. The first AI/ML positioning model 608 may be configured as a direct AI/ML model (i.e., D-AIML) as described in FIG. 5A, or as an assisted AI/ML model (i.e., A-AIML) as described in FIG. 5B. The UE 606 may measure reference signal transmissions from the gNB 604 (and possibly other network nodes) and provide the corresponding measurements as an input to the AI/ML model 608. For example, the UE 606 may measure PRS transmissions to determine a RSRP, ToA, AoA, or other measurements such as the CIR, power delay profile, delay profile, or channel frequency response, based on the input requirements for the AI/ML model 608. In an example, the UE 606 may be configured to determine a target location based on the output of the AI/ML model 608 (and a second positioning model for the A-AIML use case) and provide the target location to the LMF 602 (e.g., via LPP messaging).

[0099] In the second use case 622, the UE 606 may be configured with a second AI/ML model 610 configured as an assisted AI/ML model. The UE 606 may obtain reference signal measurements and utilize the second AI/ML model 610 to compute intermediate labels. The UE 606 may provide the intermediate measurement values (e.g., labels) to the LMF 602, and the LMF 602 may be configured with a positioning model to compute a target location for the UE 606 based on the intermediate measurement values. In the third use case 624, the LMF 602 may include a third AI/ML model 612 configured to receive reference signal measurement values from the UE 606 and compute a target location for the UE 606. For example, the UE 606 may obtain measurements based on the PRS transmitted by the gNB 604 and provide the PRS based measurement values to the LMF 602.

[00100] Referring to FIG. 6B, with further reference to FIG. 6A, block diagrams of example node assisted positioning techniques with AI/ML models are shown. A fourth use case 626 (Case 3a) and a fifth use case 628 (Case 3b) include the LMF 602, the gNB 604 and the UE 606. In these use cases, the UE 606 is configured to transmit an uplink reference signal, such as SRS, which are received and measured by the gNB 604. In the fourth use case 626, the gNB 604 is configured with a fourth AI/ML model 614 and the gNB 604 may provide the measurement values based on the SRS transmitted from the UE 606. The fourth AI/ML model 614 may be configured as an A-AIML and the gNB 604 may provide the intermediate measurements (i.e., the output of the fourth AI/ML model 614) to the LMF 602. The LMF 602 may compute the target location based on intermediate measurements provided by the gNB 604 (and potentially other gNBs or wireless nodes in the network). In the fifth use case 628, the LMF 602 may be configured with a fifth AI/ML model 616 configured to receive SRS based measurements obtained by the gNB 604 (and other nodes) and compute the target location. The use cases in FIGS. 6A and 6B are examples, and not limitations, as other configurations and AI/ML models may be used in the communication system 100. For example, other servers 150 and/or external clients 130 may be configured to receive PRS and/or SRS measurement values and to compute a target location based on an output of one or more AI/ML models.

[00101] Referring to FIG. 7, an illustration of example legacy QCL relationships between reference signals is shown. In general, antenna ports are considered to have a QCL relationship where transmissions using different antenna ports experience radio channels which share some common characteristics. The radio channel characteristics which may be common across the different antenna ports may include Doppler shift, Doppler spread, average delay, delay spread, and spatial receiver parameters (e.g., AoA at the UE). QLC relationship concepts were introduced in 3GPP to assist a UE with channel estimation, frequency offset estimation and synchronization procedures. For example, if two antenna ports are categorized as being QCL in terms of delay spread, then the UE can determine the delay spread for a first antenna port and then apply the result to both antenna ports. Thus, the UE will not have to separately determine the delay spread for each of the antenna ports. A list 702 indicates four types of QCL relationships specified by 3GPP to indicate which large scale channel characteristics are common across the set of QCL antenna ports. The four types of QCLs are: Type A (Doppler shift, Doppler spread, average delay, delay spread), Type B (Doppler shift, Doppler spread), Type C (Doppler shift, average delay), and Type D (spatial receiver parameters).

[00102] In operation, referring to an example association diagram 704, network stations may be configured to provide indications of QCL relationships for different reference signals. For example, a UE may indicate to a network server (e.g., LMF) what QCL source the UE is configured to support (e.g., SSB of serving/neighboring cells, PRS of serving/neighboring cells, etc.). The network server may utilize the QCL information to determine how to indicate future QCL relationships as part of reference signal configurations (e.g., PRS configurations). A UE may request PRS resources, including QCL relationship information, from a network resource (e.g., the LMF). When the network resource provides the PRS configuration information, the QCL relationship information may indicate the QCL relations between PRS and SSB signals and/or between PRS and other PRS. For example, referring to the association diagram 704, the QCL relationship information indicates that a SSB signal (i.e., SSB-1) has a Type C relationship with a first PRS (i.e., PRS1), and a Type D relationship with a second PRS (i.e., PRS2). The QCL relationship information may also indicate that the first PRS has a Type D relationship with a third PRS (i.e., PRS3). The QCL information may be provided via existing signaling techniques such as LPP and RRC. The relationships depicted in the association diagram 704 are examples, and not limitations, as other reference signals and other QCL relationships may be included in the QCL information provided to a mobile device.

[00103] Referring to FIG. 8, with further reference to FIGS. 6A-7, an example association diagram 802 including QCL relationships between reference signals and AI/ML models is shown. In an example, the AI/ML models 608, 610 may be provided to the UE 606 with indications of QCL relationships to inform the UE 606 on the recommended reference signals (e.g., PRS resources) to consider for model input (e.g.. the first use case 620 and the second use case 622). The UE may also be configured to autonomously run model Life Cycle Management (LCM) operations on the received AI/ML models. The LCM operations may include model training, model deployment, model inference, model monitoring, and model updating. Other LCM operations may also be performed (e.g., see 3GPP TR 38.843 V0.1.0, May 2023). In the third use case 624 (e.g., when the AI/ML positioning model runs on the LMF 602), the QCL relationship information may assist the UE 606 in determining the prioritization and/or selection of PRS resources to measure and report to the LMF. This use case may be implemented when the UE 606 has limited capabilities for measuring and reporting measurements to the LMF 602 (e.g., a reduced capability UE (RedCap UE), or a bandwidth limited UE).

[00104] In operation, the UE 606 may receive one or more indicators from the LMF that indicate relationships between AI/ML positioning models and reference signals (e.g., SSB of serving/neighboring cells, PRS of serving/neighboring cells). The indicators may indicate QCL relations which show an equivalency/similarity types between AI/ML positioning models and one of the characteristics of a reference signal as described in the list 702. For example, referring to the association diagram 802, the indicators may include a Type D QCL relationship between SSB-1 and AI/ML positioning model 1, a Type D QCL relationship between PRS1 and AI/ML positioning model 2, and a Type C QCL relationship between PRS3 and AI/ML positioning model 3. Multiple positioning models may be associated with a reference signal. For example, the indicators may include a Type C QCL relationship between PRS2 and AI/ML positioning model 1 and a Type D QCL relationship between PRS2 and AI/ML positioning model 3. The UE 606 may be configured to utilize such QCL relationship indications to apply model life cycle management (e.g., activation, deactivation, selection, switching, falling back) for the AI/ML positioning model (e.g., in use cases 620, 622 when the AI/ML model is stored locally). In other use cases, the UE 606 may be configured to prioritize and/or select PRS resources to measure and report back to the LMF 602 (e.g., when the AI/ML models are not stored locally). The one or more indications of QCL relationships between reference signals and AI/ML models may be signal via existing network protocols. For example, the indications may be signaled as part of LPP location request messaging, LPP assistance data exchange messaging, and LPP broadcast positioning (e.g., posSIB). Other signaling may also be used.

[00105] In an example, the UE 606 may be configured to provide one or more indications to the LMF 602 to indicate relations between AI/ML positioning models (e.g., models 608, 610) and one or more reference signals (e.g., SSB of serving/neighboring cells, PRS of serving/neighboring cells). The LMF 602 may be configured to utilize the indication information received from the UE 606 to configure PRS resources for the indicated AI/ML positioning models. The LMF 602 may also be configured to apply model LCM (e.g., activation, deactivation, selection, switching, falling back) for the AI/ML positioning models. In an example, the UE 606 may be configured to signal the indication information as part of an LPP capability exchange (e.g., component/condition part of AI/ML feature or feature group for AI/ML positioning). The LMF 602 may be configured to send a request to UE 606 to provide the indication information. In an example, the UE 606 may request additional PRS resources based on indicated QCL relations of the AI/ML positioning models in which the UE 606 indicates the recommended QCL relations for running the AI/ML positioning model (e.g., on-demand PRS for AI/ML positioning model). The AI/ML positioning models may be trained and supported by the UE-side and multiple UEs may be configured to provide AI/ML models and QCL indications to the LMF.

[00106] Referring to FIGS. 9A and 9B, example message flow diagrams for indicating QCL AI/ML models is shown. The example message flows include a wireless node and a network resource, such as a UE 902 and a LMF 904. Other wireless nodes, such as a gNB may also utilize the message flows. In a first example message flow 900, the LMF 904 may be configured to provide AI/ML indicators 906 including indications of relations between an AI/LM positioning model and a reference signal (e.g., SSB of serving / neighboring cells, PRS of serving / neighboring cells). The AI/ML indicators 906 may be signaled as part of LPP location request messaging, LPP assistance data exchange messaging, LPP broadcast positioning (e.g., posSIB), or combinations of such messaging. Other signaling may also be used. The AI/ML indicators 906 may include QCL relation information which shows an equivalency/similarity type between the AI/ML positioning model and one of the characteristics of the reference signal. For example, the QCL relations may include QCL Type A (Average delay, delay spread, Doppler shift, Doppler spread), QCL Type B (Doppler shift, Doppler spread), QCL Type C (Average delay, Doppler shift), and QCL Type D (Spatial RX relation). The UE 902 may be configured to optionally provide measurement report messages 908 to the LMF 904. In an example, the UE 902 may prioritize and measure PRS resources based at least in part on the AI/ML model and provide the one or more measurement report messages 908 including the measurement results.

[00107] In a second example message flow 910, the UE 902 may be configured to provide AI/ML indicators 912 to the LMF 904 including indications of relations between an AI/LM positioning model and a reference signal (e.g., SSB of serving / neighboring cells, PRS of serving / neighboring cells). The AI/ML indications may be signaled in a LPP capability exchange (e.g., component/condition part of AI/ML feature or feature group for AI/ML positioning). Other signaling may also be used. The LMF 904 may be configured to send a request to UE 902 to provide the AI/ML indicators 912. In an example, the LMF 904 may configure PRS resources based on the AI/ML positioning models and the associated QCL indications received from the UE 902, and then provide one or more PRS configurations 914 to the UE 902. The UE 902 may obtain PRS measurements based at least in part on the received PRS configurations 914. The LMF 904 may configure PRS resources based on the AI/ML indications and provide one or more PRS configurations 914 to the UE 902, and the UE 902 be configured to apply AI/ML model life cycle management in response to receiving the PRS configurations 914.

[00108] Referring to FIG. 10, with further reference to FIGS. 1-9B, a method 1000 for obtaining an output of a AI/ML model includes the stages shown. The method 1000 is, however, an example only and not limiting. The method 1000 may be altered, e.g., by having one or more stages added, removed, rearranged, combined, performed concurrently, and/or by having one or more single stages split into multiple stages. For example, transmitting an output of an AI/ML model to a location server at stage 1008 is optional.

[00109] At stage 1002, the method includes receiving an indication of a quasi co-location (QCL) relationship between an AI/ML model and a reference signal. A UE 200, including processors 210 and a transceiver 215, is a means for receiving the indication of a QCL relationship. In an example, a UE 200 (such as the UE 902) may receive AI/ML indicators 906 from a network entity, such as the LMF 904. LPP protocols, or other signaling techniques (e.g., RRC SIBs) may also be used to provide the AI/ML indicators. The AI/ML indicators 906 may include QCL relation information which shows an equivalency/similarity type between the AI/ML positioning model and one of the characteristics of the reference signal, such as depicted in FIG. 8. The reference signals may include SSB, PRS, or other signals used for channel measurements. For example, the QCL relations may include QCL Type A (Average delay, delay spread, Doppler shift, Doppler spread), QCL Type B (Doppler shift, Doppler spread), QCL Type C (Average delay, Doppler shift), and QCL Type D (Spatial RX relation). Other QCL relationships may also be defined.

[00110] At stage 1004, the method includes obtaining one or more measurement values associated with the reference signal. The UE 200, including the processors 210 and the transceiver 215, is a means for obtaining measurement values. The selection of the reference signal to be measured may be based on the QCL relationships to the AI/ML models on the UE 200 and the indication received at stage 1002. In an example, the one or more measurement values may be based on UE-based or UE-assisted positioning methods and may include RSSI, RTT, RSTD, RSRP, and/or RSRQ. Other measurements, such as AoA, TDOA, E-CID, CIR, power delay profile, delay profile, CFR values may be obtained and/or computed based on the received reference signals. The measurement values obtained may be based on the AI/ML training and the desired output labels.

[00111] At stage 1006, the method includes computing an output of the AI/ML model based at least in part on the one or more measurement values. The UE 200, including the processors 210 and the transceiver 215, is a means for computing the output of the AI/ML model. The AI/ML model may be configured as a direct AI/ML model (i.e., D-AIML), or as an assisted AI/ML model (i.e., A-AIML). The AI/ML model may be trained to learn relationships between reference signal measurements obtained at stage 1004 (e.g., channel impulse response (CIR), etc.) and positioning based labels such as a location or other intermediate messages (e.g., as described in FIGS. 5A, 5B). The intermediate measurements may be provided to a second positioning model configured to output a target location. In an example, the second positioning model may be located on a network resource (e.g., the LMF 120) and may be another AI/ML model or other non-AI models (e.g., Chans algorithm, Kalman Filter, etc.).

[00112] At stage 1008, the method may optionally include transmitting the output of the AI/ML model to a location server. The UE 200, including the processors 210 and the transceiver 215, is a means for transmitting the output of the AI/ML model. The UE 200 may be configured to utilize the communication system 100 to provide direct and/or intermediate labels to a location server, such as the LMF 120. For example, the UE 200 may provide the computed target location and/or intermediate measurements via LPP messages or other signaling techniques.

[00113] While the method 1000 may be performed on the UE 200, other wireless nodes such as the TRP 300 may be configured to perform the method 1000. For example, referring to FIG. 6B, the gNB 604 may receive the QCL indications associated with the AI/ML model 614 (and other such models) and SRS signals. The gNB 604 may be configured to measure the SRS and compute the output of the AI/ML model 614. The output may be provided to the LMF 602 as described in FIG. 6B.

[00114] Referring to FIG. 11, with further reference to FIGS. 1-9B, a method 1100 for providing positioning reference signal configuration information includes the stages shown. The method 1100 is, however, an example only and not limiting. The method 1100 may be altered, e.g., by having one or more stages added, removed, rearranged, combined, performed concurrently, and/or by having one or more single stages split into multiple stages.

[00115] At stage 1102, the method includes receiving, from a wireless node, an indication of a quasi co-location (QCL) relationship between an AI/ML model and a reference signal. A server 400, such as the LMF 120, including a processor 410 and transceiver 415, is a means for receiving the indication of the QCL relationship. In an example, referring to FIG. 9B, a wireless node such as a UE and the gNB may be configured to provide AI/ML indicators to a network resource, such as an LMF, including indications of relations between an AI/LM positioning model and a reference signal (e.g., SSB of serving / neighboring cells, PRS of serving / neighboring cells). The AI/ML indicators may include QCL relation information which shows an equivalency/similarity type between the AI/ML positioning model and one of the characteristics of the reference signal. For example, the QCL relations may include QCL Type A (Average delay, delay spread, Doppler shift, Doppler spread), QCL Type B (Doppler shift, Doppler spread), QCL Type C (Average delay, Doppler shift), and QCL Type D (Spatial RX relation). The AI/ML indications may be signaled in a LPP capability exchange (e.g., component/condition part of AI/ML feature or feature group for AI/ML positioning). Other signaling may also be used.

[00116] At stage 1104, the method includes configuring one or more positioning reference signal resources based at least in part on the indication of the QCL relationship. The server 400, including a processor 410 and transceiver 415, is a means for configuring one or more PRS. The LMF may utilize the QCL relationship characteristics to configure PRS resources and then disseminate the PRS resources to the wireless nodes (e.g., gNBs, UEs). The characteristics may be based on the QCL relationship types described in FIG. 7 (e.g., average delay, delay spread, Doppler shift, Doppler spread, spatial relation, etc.).

[00117] At stage 1106, the method includes providing configuration information for the one or more positioning reference signal resources to the wireless node. The server 400, including a processor 410 and transceiver 415, is a means for providing the configuration information. In an example, the PRS resource configuration may be provided in one or more LPP messages, such as NR-DL-PRS-Resource messages. Other signaling techniques, such as RRC and SIBs, may be used to provide the configuration information.

[00118] Other examples and implementations are within the scope of the disclosure and appended claims. For example, due to the nature of software and computers, functions described above can be implemented using software executed by a processor, hardware, firmware, hardwiring, or a combination of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations.

[00119] As used herein, the singular forms "a," "an," and "the" include the plural forms as well, unless the context clearly indicates otherwise. Thus, reference to a device in the singular (e.g., "a device," "the device"), including in the claims, includes at least one, i.e., one or more, of such devices (e.g., "a processor" includes at least one processor (e.g., one processor, two processors, etc.), "the processor" includes at least one processor, "a memory" includes at least one memory, "the memory" includes at least one memory, etc.). The phrases "at least one" and "one or more" are used interchangeably and such that "at least one" referred-to object and "one or more" referred-to objects include implementations that have one referred-to object and implementations that have multiple referred-to objects. For example, "at least one processor" and "one or more processors" each includes implementations that have one processor and implementations that have multiple processors.

[00120] The terms "comprises," "comprising," "includes," and/or "including," as used herein, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[00121] Also, as used herein, "or" as used in a list of items (possibly prefaced by "at least one of" or prefaced by "one or more of") indicates a disjunctive list such that, for example, a list of "at least one of A, B, or C," or a list of "one or more of A, B, or C" or a list of "A or B or C" means A, or B, or C, or AB (A and B), or AC (A and C), or BC (B and C), or ABC (i.e., A and B and C), or combinations with more than one feature (e.g., AA, AAB, ABBC, etc.). Thus, a recitation that an item, e.g., a processor, is configured to perform a function regarding at least one of A or B, or a recitation that an item is configured to perform a function A or a function B, means that the item may be configured to perform the function regarding A, or may be configured to perform the function regarding B, or may be configured to perform the function regarding A and B.

For example, a phrase of "a processor configured to measure at least one of A or B" or "a processor configured to measure A or measure B" means that the processor may be configured to measure A (and may or may not be configured to measure B), or may be configured to measure B (and may or may not be configured to measure A), or may be configured to measure A and measure B (and may be configured to select which, or both, of A and B to measure). Similarly, a recitation of a means for measuring at least one of A or B includes means for measuring A (which may or may not be able to measure B), or means for measuring B (and may or may not be configured to measure A), or means for measuring A and B (which may be able to select which, or both, of A and B to measure). As another example, a recitation that an item, e.g., a processor, is configured to at least one of perform function X or perform function Y means that the item may be configured to perform the function X, or may be configured to perform the function Y, or may be configured to perform the function X and to perform the function Y. For example, a phrase of "a processor configured to at least one of measure X or measure Y" means that the processor may be configured to measure X (and may or may not be configured to measure Y), or may be configured to measure Y (and may or may not be configured to measure X), or may be configured to measure X and to measure Y (and may be configured to select which, or both, of X and Y to measure).

[00122] As used herein, unless otherwise stated, a statement that a function or operation is "based on" an item or condition means that the function or operation is based on the stated item or condition and may be based on one or more items and/or conditions in addition to the stated item or condition.

[00123] Substantial variations may be made in accordance with specific requirements. For example, customized hardware might also be used, and/or particular elements might be implemented in hardware, software (including portable software, such as applets, etc.) executed by a processor, or both. Further, connection to other computing devices such as network input/output devices may be employed. Components, functional or otherwise, shown in the figures and/or discussed herein as being connected or communicating with each other are communicatively coupled unless otherwise noted. That is, they may be directly or indirectly connected to enable communication between them.

[00124] The systems and devices discussed above are examples. Various configurations may omit, substitute, or add various procedures or components as appropriate. For instance, features described with respect to certain configurations may be combined in various other configurations. Different aspects and elements of the configurations may be combined in a similar manner. Also, technology evolves and, thus, many of the elements are examples and do not limit the scope of the disclosure or claims.

[00125] A wireless communication system is one in which communications are conveyed wirelessly, i.e., by electromagnetic and/or acoustic waves propagating through atmospheric space rather than through a wire or other physical connection, between wireless communication devices. A wireless communication system (also called a wireless communications system, a wireless communication network, or a wireless communications network) may not have all communications transmitted wirelessly, but is configured to have at least some communications transmitted wirelessly. Further, the term “wireless communication device,” or similar term, does not require that the functionality of the device is exclusively, or even primarily, for communication, or that communication using the wireless communication device is exclusively, or even primarily, wireless, or that the device be a mobile device, but indicates that the device includes wireless communication capability (one-way or two-way), e.g., includes at least one radio (each radio being part of a transmitter, receiver, or transceiver) for wireless communication.

[00126] Specific details are given in the description herein to provide a thorough understanding of example configurations (including implementations). However, configurations may be practiced without these specific details. For example, well-known circuits, processes, algorithms, structures, and techniques have been shown without unnecessary detail in order to avoid obscuring the configurations. The description herein provides example configurations, and does not limit the scope, applicability, or configurations of the claims. Rather, the preceding description of the configurations provides a description for implementing described techniques. Various changes may be made in the function and arrangement of elements.

[00127] The terms “processor-readable medium,” “machine-readable medium,” and “computer-readable medium,” as used herein, refer to any medium that participates in providing data that causes a machine to operate in a specific fashion. Using a computing platform, various processor-readable media might be involved in providing instructions/code to processor(s) for execution and/or might be used to store and/or carry such instructions/code (e.g., as signals). In many implementations, a processor-readable medium is a physical and/or tangible storage medium. Such a medium may take many forms, including but not limited to, non-volatile media and volatile media. Non-volatile media include, for example, optical and/or magnetic disks. Volatile media include, without limitation, dynamic memory.

[00128] Having described several example configurations, various modifications, alternative constructions, and equivalents may be used. For example, the above elements may be components of a larger system, wherein other rules may take precedence over or otherwise modify the application of the disclosure. Also, a number of operations may be undertaken before, during, or after the above elements are considered. Accordingly, the above description does not bound the scope of the claims.

[00129] Unless otherwise indicated, “about” and/or “approximately” as used herein when referring to a measurable value such as an amount, a temporal duration, and the like, encompasses variations of ±20% or ±10%, ±5%, or ±0.1% from the specified value, as appropriate in the context of the systems, devices, circuits, methods, and other implementations described herein. Unless otherwise indicated, “substantially” as used herein when referring to a measurable value such as an amount, a temporal duration, a physical attribute (such as frequency), and the like, also encompasses variations of ±20% or ±10%, ±5%, or ±0.1% from the specified value, as appropriate in the context of the systems, devices, circuits, methods, and other implementations described herein.

[00130] A statement that a value exceeds (or is more than or above) a first threshold value is equivalent to a statement that the value meets or exceeds a second threshold value that is slightly greater than the first threshold value, e.g., the second threshold value being one value higher than the first threshold value in the resolution of a computing system. A statement that a value is less than (or is within or below) a first threshold value is equivalent to a statement that the value is less than or equal to a second threshold value that is slightly lower than the first threshold value, e.g., the second threshold value being one value lower than the first threshold value in the resolution of a computing system.

[00131] Implementation examples are described in the following numbered clauses:

[00132] Clause 1. A method for obtaining an output of an AI/ML model, comprising: receiving an indication of a quasi co-location (QCL) relationship between the AI/ML model and a reference signal; obtaining one or more measurement values associated with the reference signal; and computing the output of the AI/ML model based at least in part on the one or more measurement values.

[00133] Clause 2. The method of clause 1, wherein the output of the AI/ML model is a target location.

[00134] Clause 3. The method of clause 2, further comprising transmitting the target location to a location server.

[00135] Clause 4. The method of clause 1, wherein the output of the AI/ML model is an intermediate measurement comprising at least one of a time information, an angle of arrival, and line-of-sight path information.

[00136] Clause 5. The method of clause 4, further comprising transmitting the intermediate measurement to a location server.

[00137] Clause 6. The method of clause 1, wherein the one or more measurement values include a channel impulse response, power delay profile, delay profile, or channel frequency response.

[00138] Clause 7. The method of clause 1, wherein the indication of the QCL relationship is received via a LPP message.

[00139] Clause 8. The method of clause 7, wherein the indication of the QCL relationship is received from a location management function.

[00140] Clause 9. The method of clause 1, wherein the reference signal is a positioning reference signal.

[00141] Clause 10. The method of clause 1, wherein the reference signal is a sounding reference signal.

[00142] Clause 11. The method of clause 1, further comprising applying model life cycle management operations on the AI/ML model in response to receiving the indication of the QCL relationship.

[00143] Clause 12. A method for providing positioning reference signal configuration information, comprising: receiving, from a wireless node, an indication of a quasi co-location (QCL) relationship between an AI/ML model and a reference signal; configuring one or more positioning reference signal resources based at least in part on the indication of the QCL relationship; and providing configuration information for the one or more positioning reference signal resources to the wireless node.

[00144] Clause 13. The method of clause 12, wherein the indication of the QCL relationship includes at least one of an average delay, a delay spread, a Doppler shift, a Doppler spread, and a spatial relationship.

[00145] Clause 14. The method of clause 12, wherein the indication of the QCL relationship is received via a LPP message or a NRPPa message.

[00146] Clause 15. The method of clause 12, wherein the wireless node is a user equipment.

[00147] Clause 16. The method of clause 15, further comprising requesting the indication of the QCL relationship from the user equipment.

[00148] Clause 17. The method of clause 15, further comprising receiving a request for additional positioning reference signal resources from the user equipment.

[00149] Clause 18. The method of clause 12, wherein the wireless node is gNode B.

[00150] Clause 19. The method of clause 12, further comprising applying model life cycle management operations on at least one AI/ML model in response to receiving the indication of the QCL relationship.

[00151] Clause 20. An apparatus, comprising: at least one memory; at least one transceiver; at least one processor communicatively coupled to the at least one memory and the at least one transceiver, and configured to: receive an indication of a quasi co-location (QCL) relationship between an AI/ML model and a reference signal; obtain one or more measurement values associated with the reference signal; and compute an output of the AI/ML model based at least in part on the one or more measurement values.

[00152] Clause 21. The apparatus of clause 20, wherein the output of the AI/ML model is a target location.

[00153] Clause 22. The apparatus of clause 21, wherein the at least one processor is further configured to transmit the target location to a location server.

[00154] Clause 23. The apparatus of clause 20, wherein the output of the AI/ML model is an intermediate measurement comprising at least one of a time information, an angle of arrival, and line-of-sight path information.

[00155] Clause 24. The apparatus of clause 23, wherein the at least one processor is further configured to transmit the intermediate measurement to a location server.

[00156] Clause 25. The apparatus of clause 20, wherein the one or more measurement values include a channel impulse response, power delay profile, delay profile, or channel frequency response.

[00157] Clause 26. The apparatus of clause 20, wherein the indication of the QCL relationship is received via a LPP message.

[00158] Clause 27. The apparatus of clause 26, wherein the indication of the QCL relationship is received from a location management function.

[00159] Clause 28. The apparatus of clause 20, wherein the reference signal is a positioning reference signal.

[00160] Clause 29. The apparatus of clause 20, wherein the reference signal is a sounding reference signal.

[00161] Clause 30. The apparatus of clause 20, wherein the at least one processor is further configured to apply model life cycle management operations on the AI/ML model in response to receiving the indication of the QCL relationship.

[00162] Clause 31. An apparatus, comprising: at least one memory; at least one transceiver; at least one processor communicatively coupled to the at least one memory and the at least one transceiver, and configured to: receive, from a wireless node, an indication of a quasi co-location (QCL) relationship between an AI/ML model and a reference signal; configure one or more positioning reference signal resources based at least in part on the indication of the QCL relationship; and provide configuration information for the one or more positioning reference signal resources to the wireless node.

[00163] Clause 32. The apparatus of clause 31, wherein the indication of the QCL relationship includes at least one of an average delay, a delay spread, a Doppler shift, a Doppler spread, and a spatial relationship.

[00164] Clause 33. The apparatus of clause 31, wherein the indication of the QCL relationship is received via a LPP message or a NRPPa message.

[00165] Clause 34. The apparatus of clause 31, wherein the wireless node is a user equipment.

[00166] Clause 35. The apparatus of clause 34, wherein the at least one processor is further configured to request the indication of the QCL relationship from the user equipment.

[00167] Clause 36. The apparatus of clause 34, wherein the at least one processor is further configured to receive a request for additional positioning reference signal resources from the user equipment.

[00168] Clause 37. The apparatus of clause 31, wherein the wireless node is gNode B.

[00169] Clause 38. The apparatus of clause 31, wherein the at least one processor is further configured to apply model life cycle management operations on at least one AI/ML model in response to receiving the indication of the QCL relationship.

[00170] Clause 39. An apparatus for obtaining an output of an AI/ML model, comprising: means for receiving an indication of a quasi co-location (QCL) relationship between the AI/ML model and a reference signal; means for obtaining one or more measurement values associated with the reference signal; and means for computing the output of the AI/ML model based at least in part on the one or more measurement values.

[00171] Clause 40. An apparatus for providing positioning reference signal configuration information, comprising: means for receiving, from a wireless node, an indication of a quasi co-location (QCL) relationship between an AI/ML model and a reference signal; means for configuring one or more positioning reference signal resources based at least in part on the indication of the QCL relationship; and means for providing configuration information for the one or more positioning reference signal resources to the wireless node.

[00172] Clause 41. A non-transitory processor-readable storage medium comprising processor-readable instructions configured to cause one or more processors to obtain an output of an AI/ML model, comprising code for: receiving an indication of a quasi co-location (QCL) relationship between the AI/ML model and a reference signal; obtaining one or more measurement values associated with the reference signal; and computing the output of the AI/ML model based at least in part on the one or more measurement values.

[00173] Clause 42. A non-transitory processor-readable storage medium comprising processor-readable instructions configured to cause one or more processors to provide positioning reference signal configuration information, comprising code for: receiving, from a wireless node, an indication of a quasi co-location (QCL) relationship between an AI/ML model and a reference signal; configuring one or more positioning reference signal resources based at least in part on the indication of the QCL relationship; and providing configuration information for the one or more positioning reference signal resources to the wireless node.

CLAIMS:

1. A method for obtaining an output of an AI/ML model, comprising:

receiving an indication of a quasi co-location (QCL) relationship between the AI/ML model and a reference signal;

obtaining one or more measurement values associated with the reference signal; and

computing the output of the AI/ML model based at least in part on the one or more measurement values.

2. The method of claim 1, wherein the output of the AI/ML model is a target location.

3. The method of claim 2, further comprising transmitting the target location to a location server.

4. The method of claim 1, wherein the output of the AI/ML model is an intermediate measurement comprising at least one of a time information, an angle of arrival, and line-of-sight path information.

5. The method of claim 4, further comprising transmitting the intermediate measurement to a location server.

6. The method of claim 1, wherein the one or more measurement values include a channel impulse response, power delay profile, delay profile, or channel frequency response.

7. The method of claim 1, wherein the indication of the QCL relationship is received via a LPP message.

8. The method of claim 7, wherein the indication of the QCL relationship is received from a location management function.

9. The method of claim 1, wherein the reference signal is a positioning reference signal.

10. The method of claim 1, wherein the reference signal is a sounding reference signal.

11. The method of claim 1, further comprising applying model life cycle management operations on the AI/ML model in response to receiving the indication of the QCL relationship.

12. A method for providing positioning reference signal configuration information, comprising:

receiving, from a wireless node, an indication of a quasi co-location (QCL) relationship between an AI/ML model and a reference signal;

configuring one or more positioning reference signal resources based at least in part on the indication of the QCL relationship; and

providing configuration information for the one or more positioning reference signal resources to the wireless node.

13. The method of claim 12, wherein the indication of the QCL relationship includes at least one of an average delay, a delay spread, a Doppler shift, a Doppler spread, and a spatial relationship.

14. The method of claim 12, wherein the indication of the QCL relationship is received via a LPP message or a NRPPa message.

15. The method of claim 12, wherein the wireless node is a user equipment.

16. The method of claim 15, further comprising requesting the indication of the QCL relationship from the user equipment.

17. The method of claim 15, further comprising receiving a request for additional positioning reference signal resources from the user equipment.

18. The method of claim 12, wherein the wireless node is gNode B.

19. The method of claim 12, further comprising applying model life cycle management operations on at least one AI/ML model in response to receiving the indication of the QCL relationship.

20. An apparatus, comprising:

at least one memory;

at least one transceiver;

at least one processor communicatively coupled to the at least one memory and the at least one transceiver, and configured to:

receive an indication of a quasi co-location (QCL) relationship between an AI/ML model and a reference signal;

obtain one or more measurement values associated with the reference signal; and

compute an output of the AI/ML model based at least in part on the one or more measurement values.

21. The apparatus of claim 20, wherein the output of the AI/ML model is a target location, and the at least one processor is further configured to transmit the target location to a location server.

22. The apparatus of claim 20, wherein the output of the AI/ML model is an intermediate measurement comprising at least one of a time information, an angle of arrival, and line-of-sight path information, and the at least one processor is further configured to transmit the intermediate measurement to a location server.

23. The apparatus of claim 20, wherein the at least one processor is further configured to apply model life cycle management operations on the AI/ML model in response to receiving the indication of the QCL relationship.

24. An apparatus, comprising:

at least one memory;

at least one transceiver;

at least one processor communicatively coupled to the at least one memory and the at least one transceiver, and configured to:

receive, from a wireless node, an indication of a quasi co-location (QCL) relationship between an AI/ML model and a reference signal;

configure one or more positioning reference signal resources based at least in part on the indication of the QCL relationship; and

provide configuration information for the one or more positioning reference signal resources to the wireless node.

25. The apparatus of claim 24, wherein the indication of the QCL relationship includes at least one of an average delay, a delay spread, a Doppler shift, a Doppler spread, and a spatial relationship.

26. The apparatus of claim 24, wherein the wireless node is a user equipment.

27. The apparatus of claim 26, wherein the at least one processor is further configured to request the indication of the QCL relationship from the user equipment.

28. The apparatus of claim 26, wherein the at least one processor is further configured to receive a request for additional positioning reference signal resources from the user equipment.

29. The apparatus of claim 24, wherein the wireless node is gNode B.

30. The apparatus of claim 24, wherein the at least one processor is further configured to apply model life cycle management operations on at least one AI/ML model in response to receiving the indication of the QCL relationship.

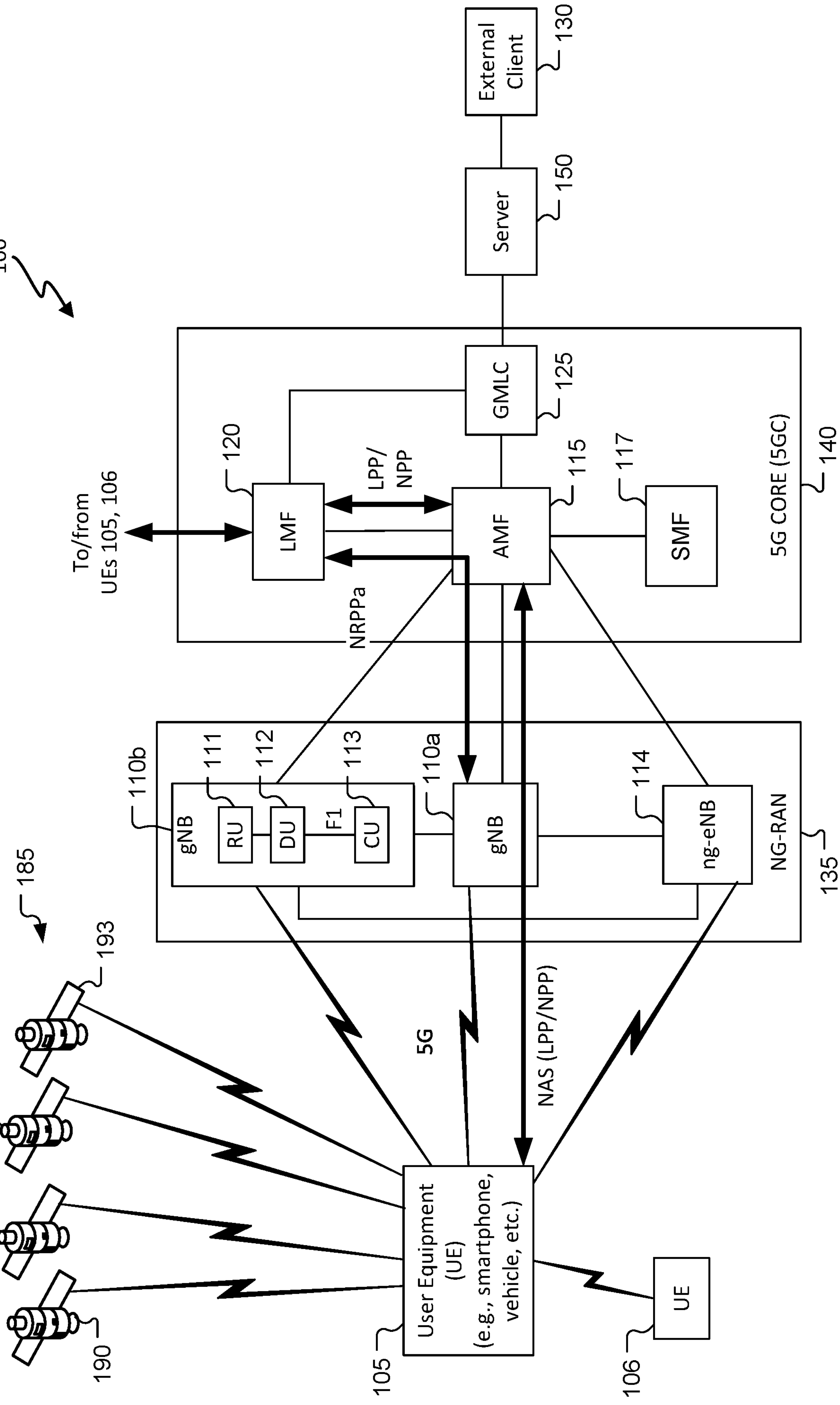
100
185
190
191
192
193
User Equipment (UE) (e.g., smartphone, vehicle, etc.)
105
UE
106
5G
NAS (LPP/NPP)
gNB
110b
RU
111
DU
112
F1
CU
113
gNB
110a
ng-eNB
114
NG-RAN
135
NRPPa
To/from UEs 105, 106
LMF
120
LPP/ NPP
AMF
115
SMF
117
GMLC
125
5G CORE (5GC)
140
Server
150
External Client
130

FIG. 1

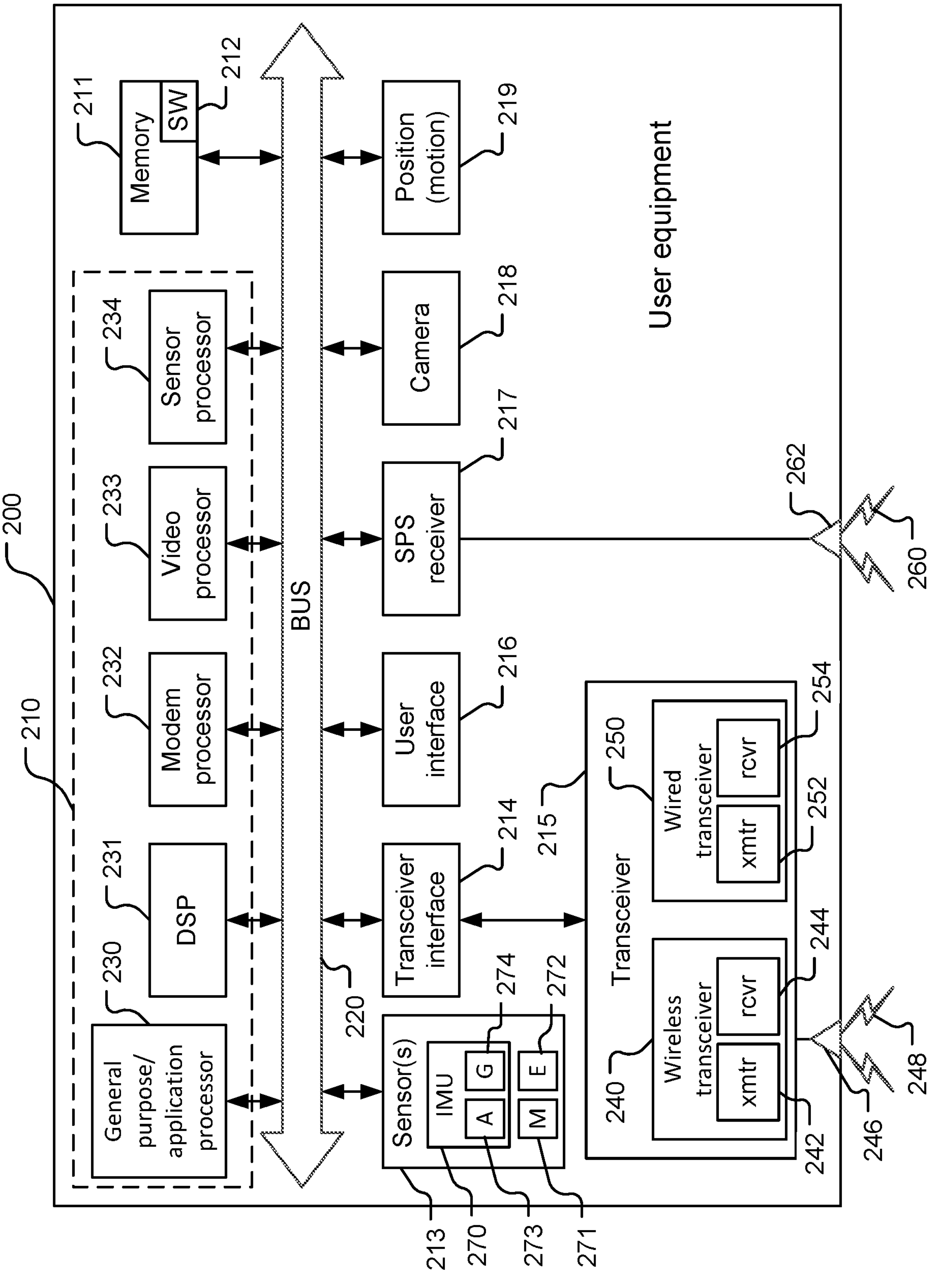
200
210
General purpose/ application processor
230
DSP
231
Modem processor
232
Video processor
233
Sensor processor
234
Memory
211
SW
212
BUS
220
Sensor(s)
213
IMU
270
A
273
G
274
M
271
E
272
Transceiver interface
214
User interface
216
SPS receiver
217
Camera
218
Position (motion)
219
User equipment
Transceiver
215
Wireless transceiver
240
xmtr
242
rcvr
244
246
248
Wired transceiver
250
xmtr
252
rcvr
254
260
262

FIG. 2

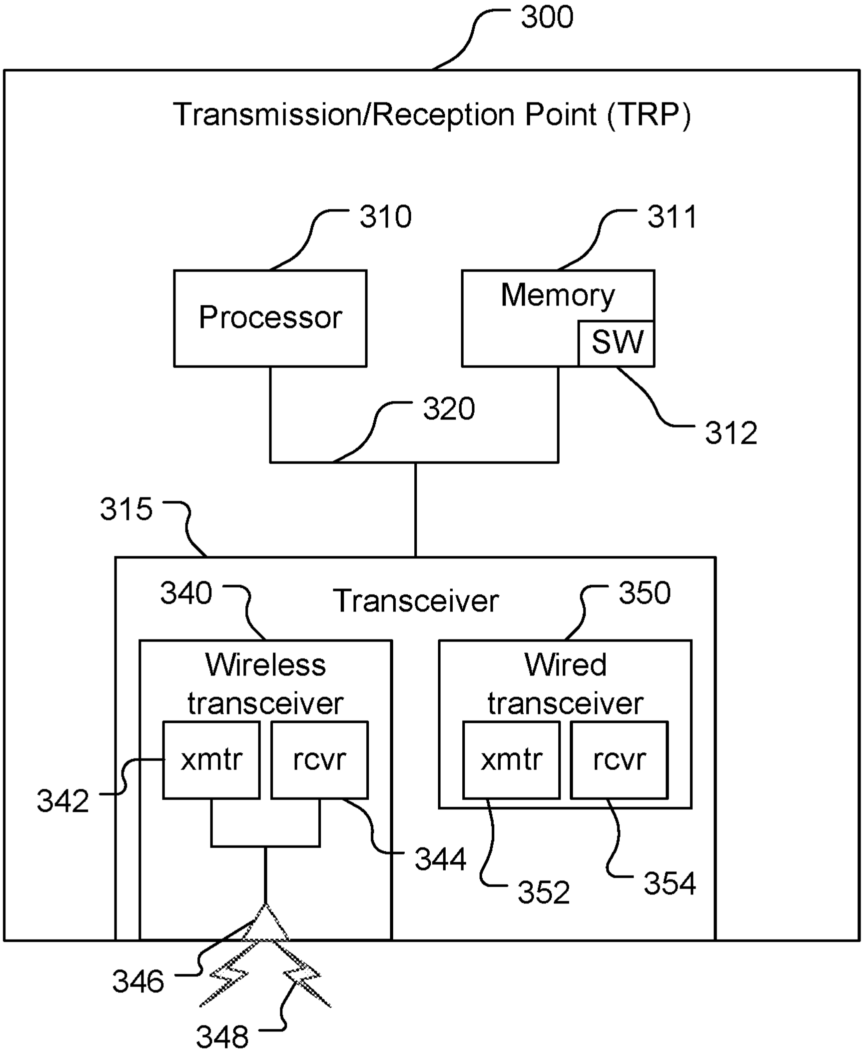
300
Transmission/Reception Point (TRP)
310
311
Processor
Memory
SW
320
312
315
340
Transceiver
350
Wireless transceiver
Wired transceiver
xmtr
rcvr
xmtr
rcvr
342
344
352
354
346
348

FIG. 3

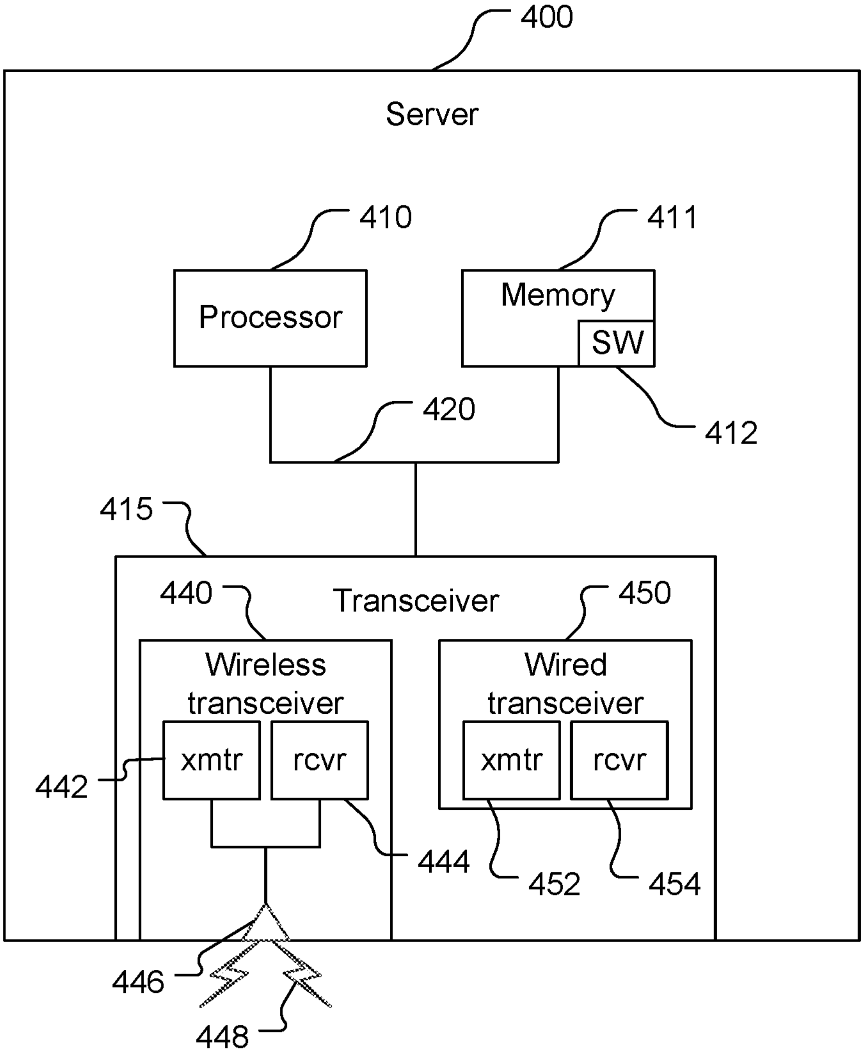
400
Server
410
Processor
411
Memory
SW
412
420
415
Transceiver
440
Wireless transceiver
xmtr
rcvr
442
444
446
448
450
Wired transceiver
xmtr
rcvr
452
454

FIG. 4

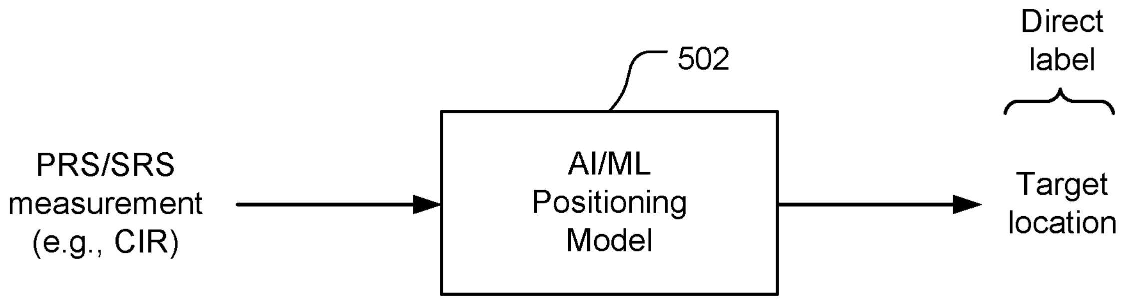
PRS/SRS
measurement
(e.g., CIR)
502
AI/ML
Positioning
Model
Direct
label
Target
location

FIG. 5A

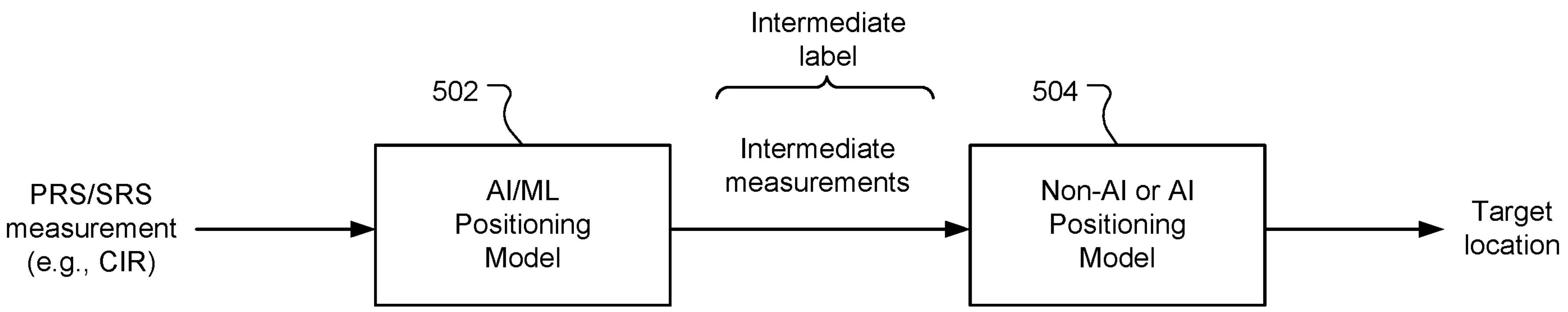
PRS/SRS
measurement
(e.g., CIR)
502
AI/ML
Positioning
Model
Intermediate
label
Intermediate
measurements
504
Non-AI or AI
Positioning
Model
Target
location

FIG. 5B

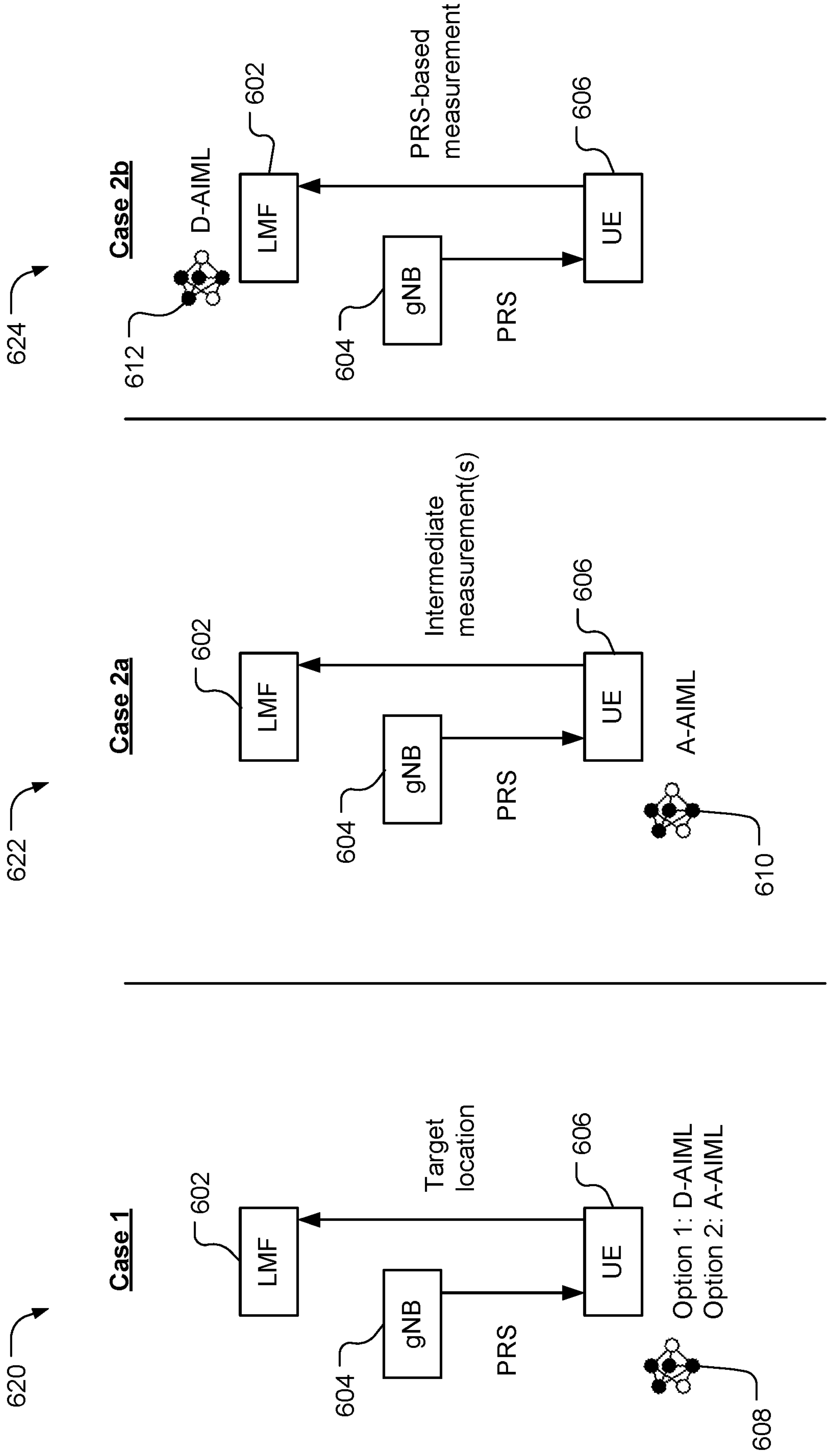
620
Case 1
602
LMF
604
gNB
PRS
606
UE
Target location
Option 1: D-AIML
Option 2: A-AIML
608
622
Case 2a
602
LMF
604
gNB
PRS
606
UE
Intermediate measurement(s)
A-AIML
610
624
Case 2b
612
D-AIML
602
LMF
604
gNB
PRS
606
UE
PRS-based measurement

FIG. 6A

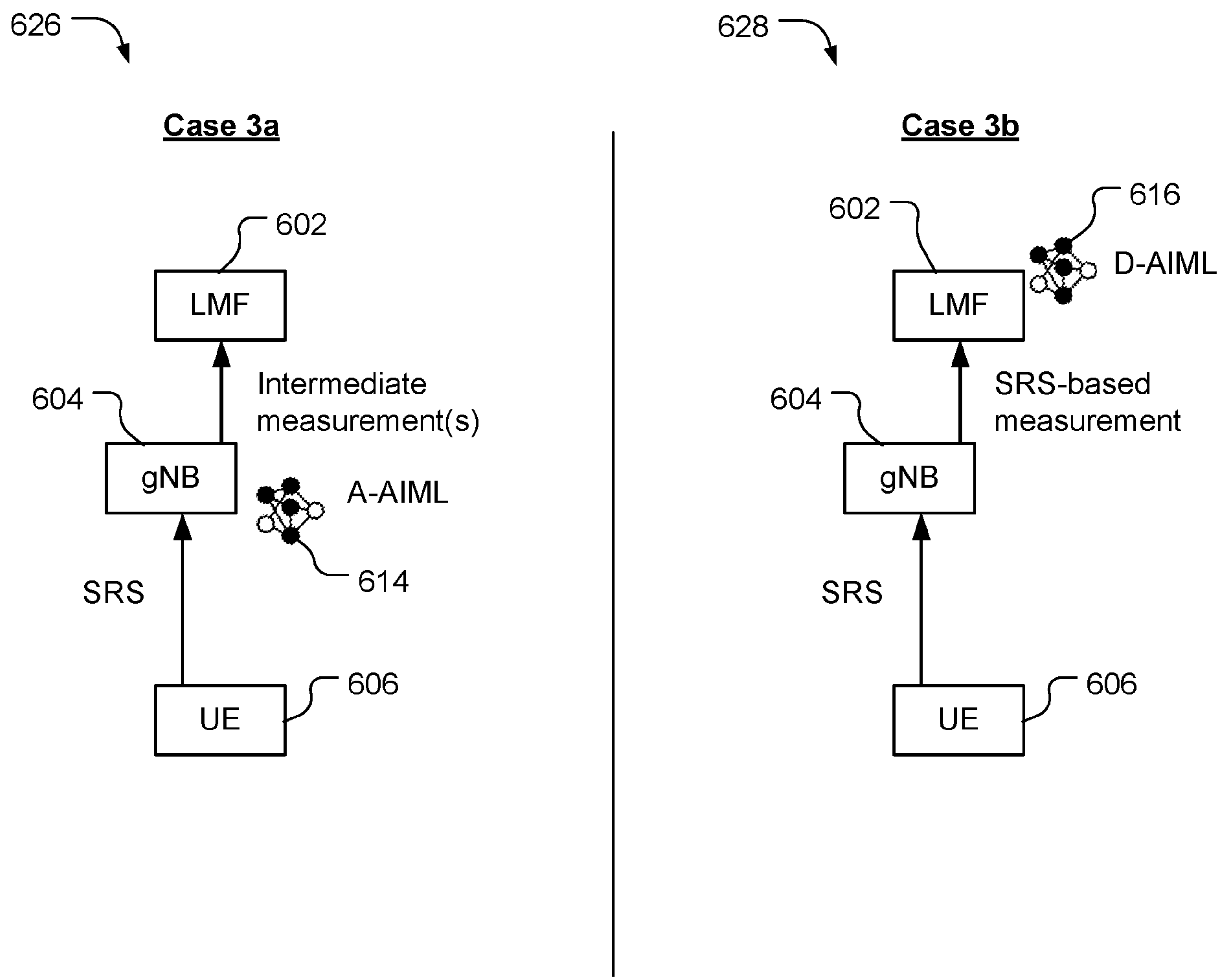
626
Case 3a
602
LMF
604
gNB
Intermediate measurement(s)
A-AIML
614
SRS
UE
606
628
Case 3b
602
LMF
616
D-AIML
604
gNB
SRS-based measurement
SRS
UE
606

FIG. 6B

702

QCL Types supported in 3GPP specs:

- QCL Type A: {Avg. delay, delay spread, Doppler shift, Doppler spread}
- QCL Type B: {Doppler shift, Doppler spread}
- QCL Type C: {Avg. delay, Doppler shift}
- QCL Type D: {Spatial Receiver Parameters}

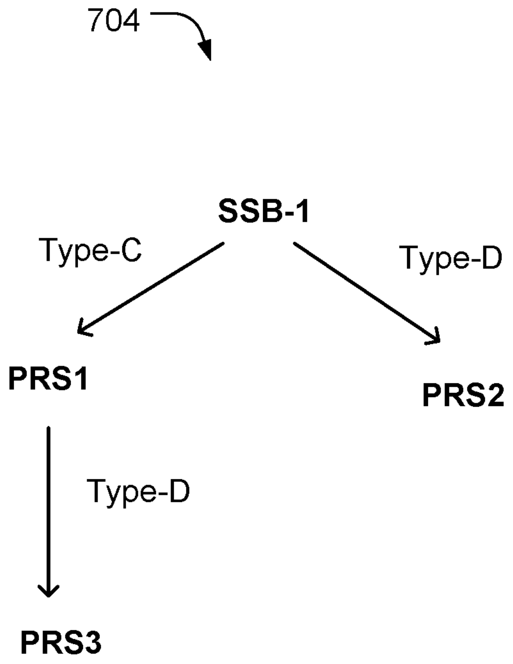

FIG. 7

Prior Art

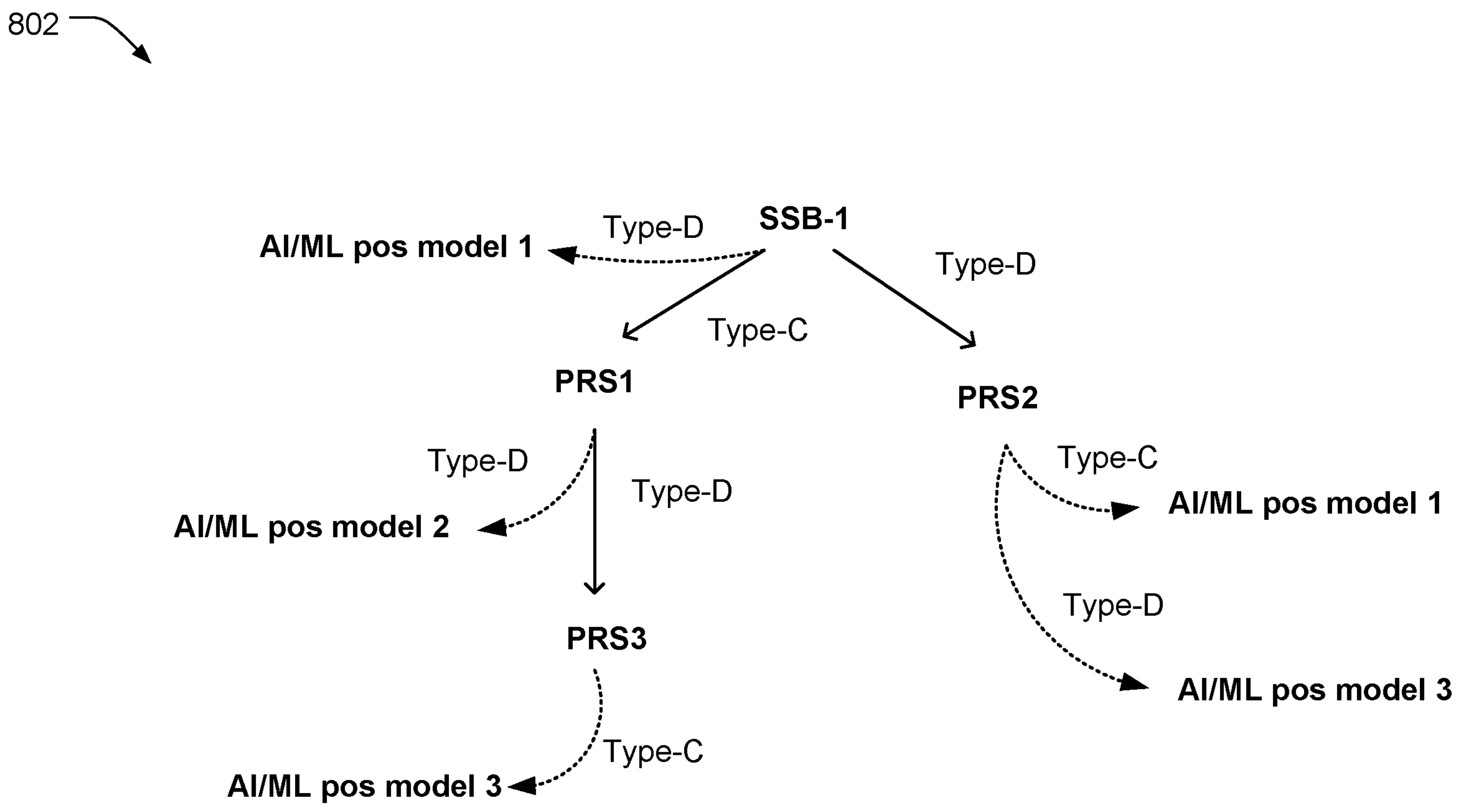
802
SSB-1
Type-D
AI/ML pos model 1
Type-C
Type-D
PRS1
PRS2
Type-D
Type-D
AI/ML pos model 2
PRS3
Type-C
AI/ML pos model 3
Type-C
AI/ML pos model 1
Type-D
AI/ML pos model 3

FIG. 8

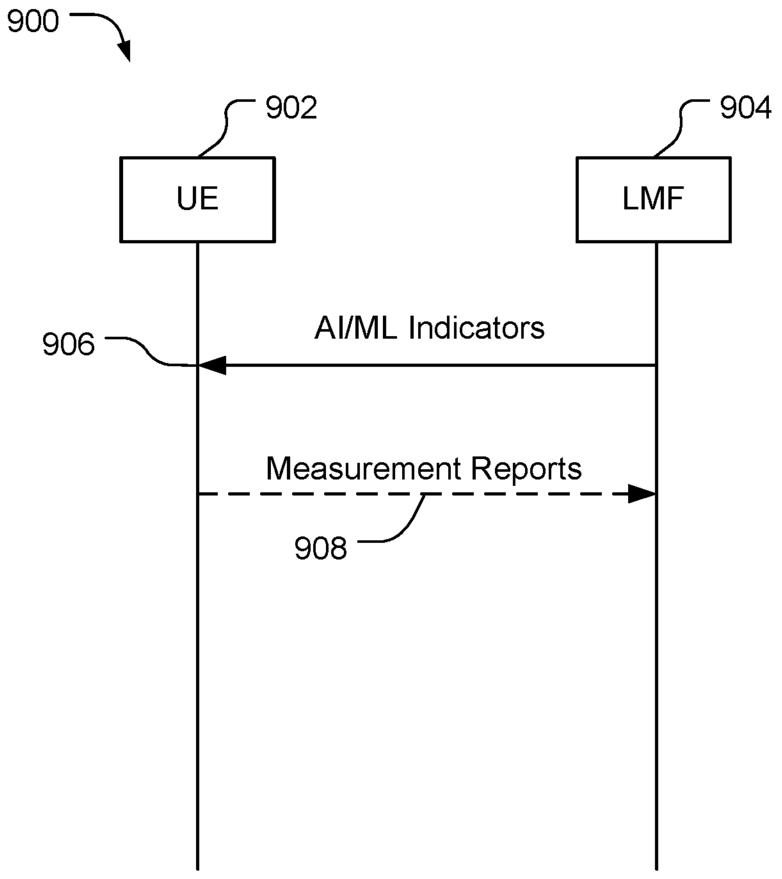
900
902
904
UE
LMF
AI/ML Indicators
906
Measurement Reports
908

FIG. 9A

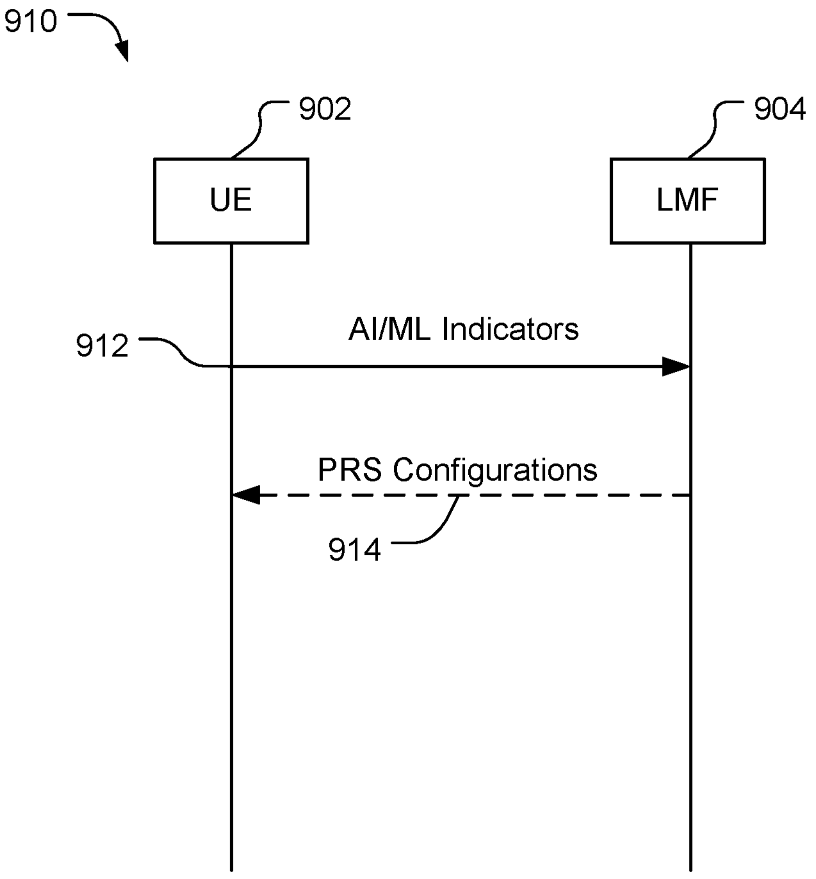
910
902
904
UE
LMF
AI/ML Indicators
912
PRS Configurations
914

FIG. 9B

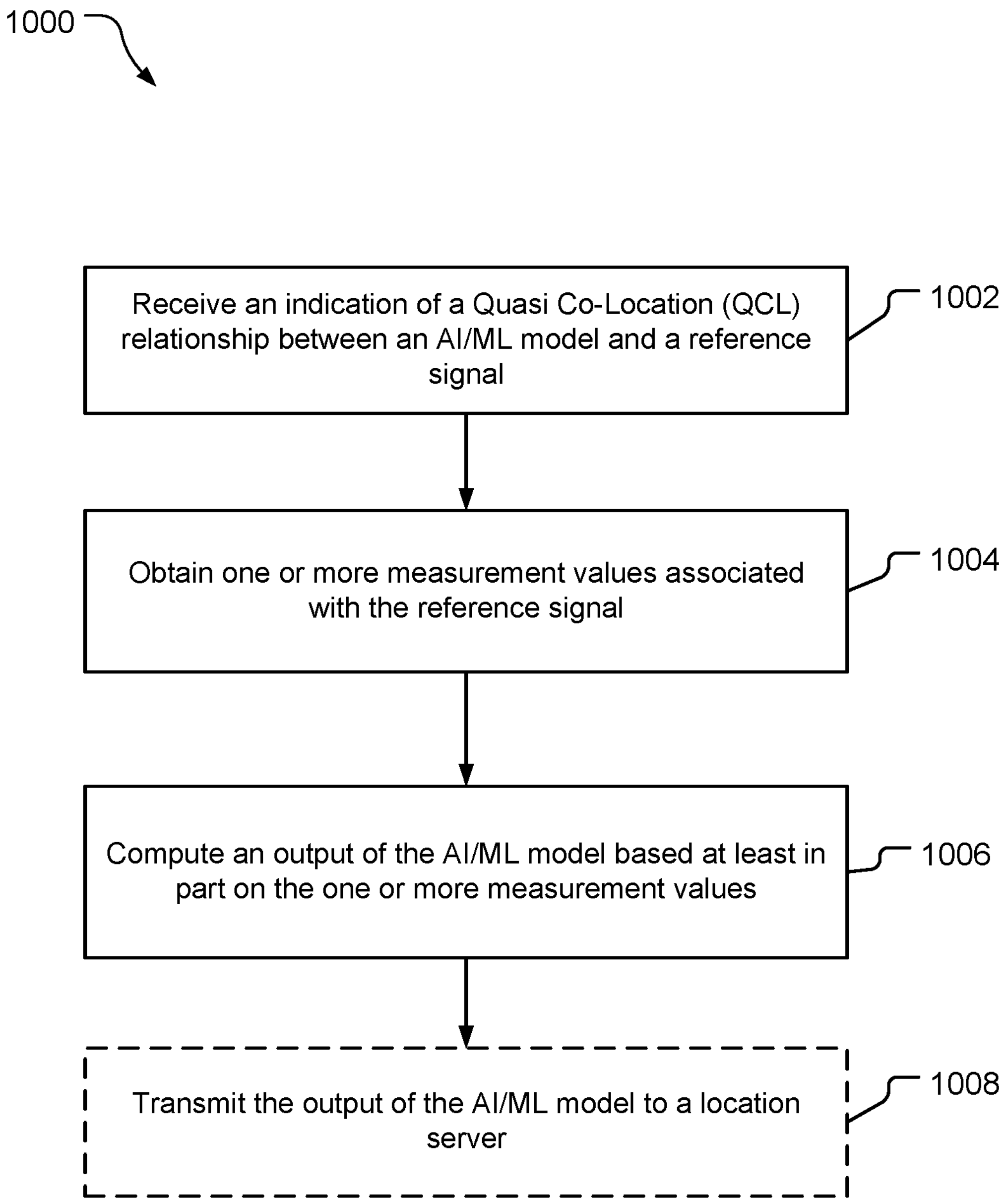
1000
Receive an indication of a Quasi Co-Location (QCL) relationship between an AI/ML model and a reference signal
1002
Obtain one or more measurement values associated with the reference signal
1004
Compute an output of the AI/ML model based at least in part on the one or more measurement values
1006
Transmit the output of the AI/ML model to a location server
1008

FIG. 10

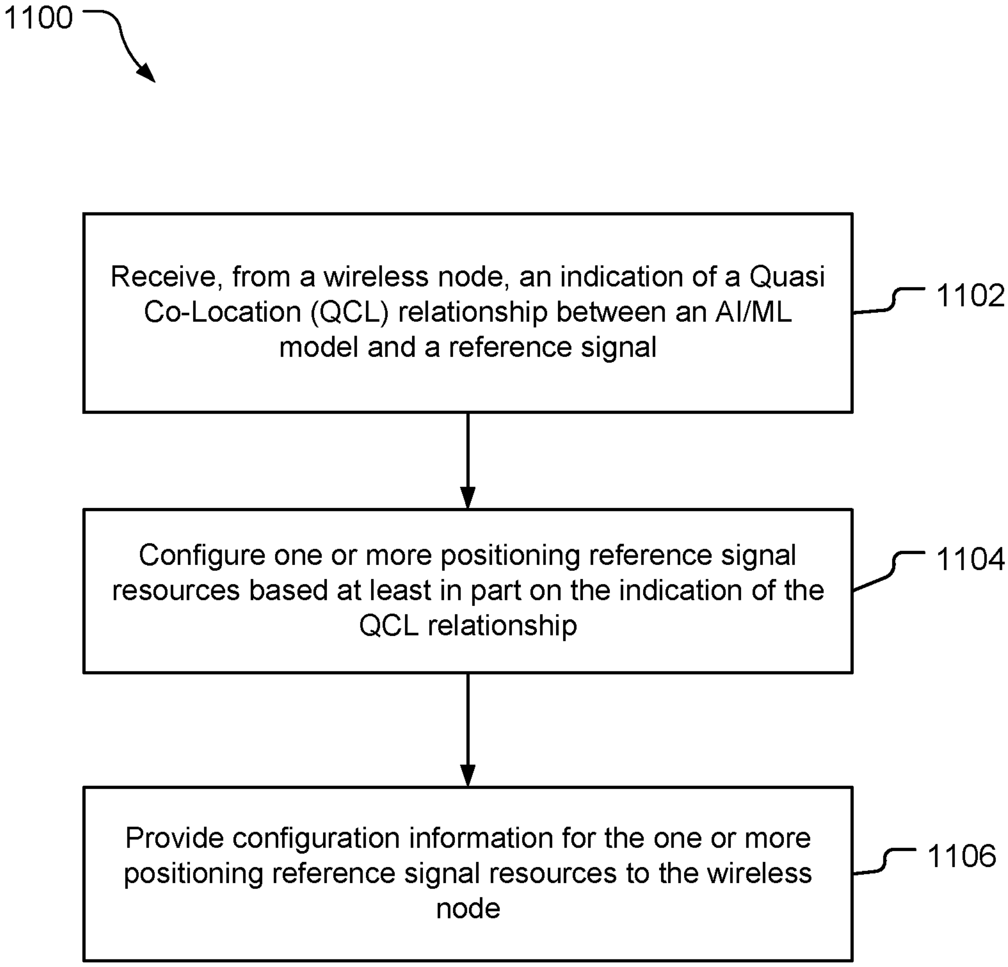
1100
Receive, from a wireless node, an indication of a Quasi Co-Location (QCL) relationship between an AI/ML model and a reference signal
1102
Configure one or more positioning reference signal resources based at least in part on the indication of the QCL relationship
1104
Provide configuration information for the one or more positioning reference signal resources to the wireless node
1106

FIG. 11

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2024/051563

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W64/00
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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	PETER GAAL ET AL: "Other aspects on AI/ML for positioning accuracy enhancement", 3GPP DRAFT; R1-2301409; TYPE DISCUSSION; FS_NR_AIML_AIR, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Athens, GR; 20230227 - 20230303 17 February 2023 (2023-02-17), XP052248541, Retrieved from the Internet: URL:https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112/Docs/R1-2301409.zip R1-2301409/R1-2301409 Other aspects on AI-ML for positioning accuracy enhancement-ran1-112_QCOM.docx [retrieved on 2023-02-17] -/--	1-30

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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

INTERNATIONAL SEARCH REPORT

International application No	PCT/US2024/051563

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	paragraph [0003] - paragraph [0005] -----	
Y	WO 2023/148665 A1 (LENOVO SINGAPORE PTE LTD [SG]) 10 August 2023 (2023-08-10) paragraph [0043] - paragraph [0069] paragraph [0113] - paragraph [0158] -----	1-30
Y	WO 2023/154710 A1 (INTERDIGITAL PATENT HOLDINGS INC [US]) 17 August 2023 (2023-08-17) paragraph [0079] - paragraph [0179] -----	1-30
Y	US 2022/256315 A1 (LEI JING [US] ET AL) 11 August 2022 (2022-08-11) paragraph [0016] - paragraph [0084] paragraph [0153] - paragraph [0223] -----	1-30

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2024/051563

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		EP 4473751 A1	11-12-2024
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US 2022256315 A1	11-08-2022	NONE	