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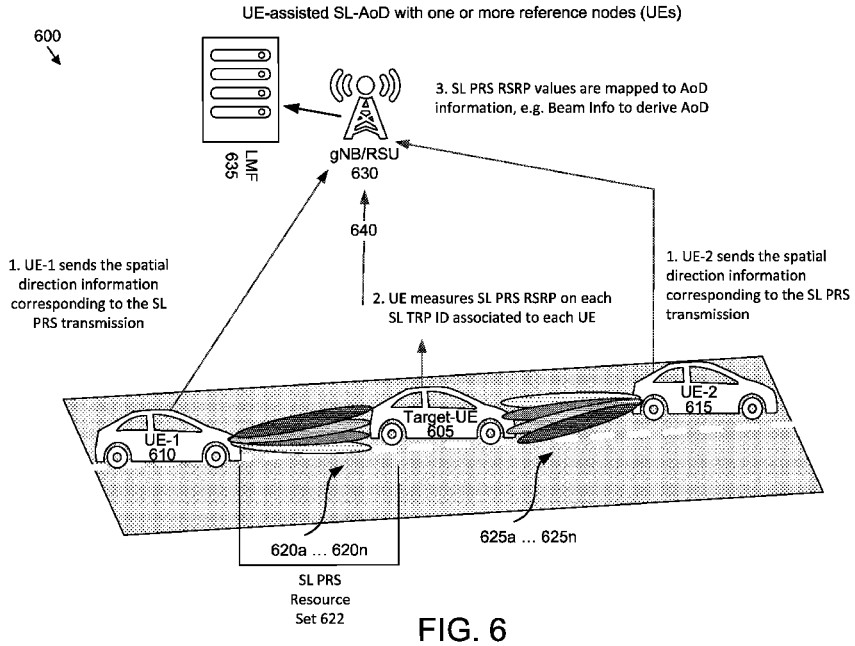


FIG. 6

(57) Abstract: An apparatus 1100 for localizing a target UE (605,805) sidelink ("SL") positioning includes a processor 1105 configured to cause the target UE (605,805) to receive from a sidelink configuration source (610 or 635) SL PRS assistance data associated with SL reference signal transmissions e.g., beam transmissions (620a-620b), transmitted from one or more SL signal transmitting devices (e.g., 610, 615, 630). The target UE (605,805) receives transmitted SL signal information from the one or more SL signal transmitting devices (610, 615, 630) and performs SL signal angle of arrival ("AoA") measurements or reference signal received power ("RSRP") measurements for deriving angle of departure (AoD) mapped to the received SL RSRP measurements or performs SL radio resource management measurements ("SL-RMM") for determining an estimated location of the target UE (605,805) using SL-AoD, SL-AoA, SL-RMM positioning techniques or combinations thereof.

WO 2022/034484 A3

[Continued on next page]

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SIDELINK ANGULAR-BASED AND SL RRM-BASED POSITIONING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application Number 63/063,854 titled "Sidelink Angular-Based And SL RRM-Based Positioning" filed on August 10, 2020, U.S. Provisional Patent Application Number 63/063,836 titled "Sidelink Timing-Based Positioning Methods" filed on August 10, 2020, and U.S. Provisional Patent Application Number 63/063,824 titled "Apparatuses, Methods, And System For SL PRS Transmission Methodology" filed on August 10, 2020, which applications are incorporated herein by reference to the extent permissible under relevant patent laws and rules.

FIELD

[0002] The subject matter disclosed herein relates generally to wireless communications and more particularly relates to sidelink ("SL") angular-based and SL radio resource management ("RRM")-based positioning.

BACKGROUND

[0003] In certain wireless communication systems, Radio Access Technology ("RAT") dependent positioning using 3GPP New Radio ("NR") technology has been recently supported in Release 16 of the 3GPP specifications. The positioning features include Fifth Generation ("5C") network core architectural and interface enhancements, as well as Radio Access Node ("RAN") functionality that support physical layer and Layer-2/Layer-3 signaling procedures to enable RAT-dependent positioning methods for the Uu interface in LTE and NR. However, various existing systems lack adequate positioning features for sidelink interfaces.

BRIEF SUMMARY

[0004] Disclosed are a signaling and measurement framework for configuring and performing angular/range-based and SL-RRM NR sidelink (SL) methods, which enable sidelink angular-based and SL RRM-based positioning. This disclosure provides multiple features to enable sidelink angular-based and SL RRM-based positioning.

[0005] An apparatus is disclosed for localizing a target UE in a communication network using sidelink ("SL") positioning, the apparatus including a target UE that includes a processor, memory, and program code executable by the processor to cause the target UE to: receive from a sidelink

configuration source multiple SL PRS assistance data associated with multiple SL signal transmissions that serve as reference signal transmissions such as beam transmissions, antenna panel transmissions, or combinations thereof, transmitted from one or more SL signal transmitting devices. The apparatus may receive the SL reference signal transmissions from the one or more SL signal transmitting devices and may perform SL signal angle of arrival ("AoA") measurements of the received SL reference signal transmissions and may perform SL reference signal reference signal received power ("RSRP") measurements for deriving angle of departure (AoD) calculations mapped to the received SL RSRP measurements for determining an estimated location of the target UE using SL AoD or SL AoA positioning techniques or combinations thereof.

[0006] A further apparatus for a communication network for localizing a target UE includes a target UE that includes a processor, memory, and program code executable by the processor to cause the target UE to perform one or more sidelink ("SL") radio resource management ("RRM") measurements such as measurements of: physical sidelink broadcast channel ("PSBCH") reference signal received power ("RSRP"), physical sidelink shared channel ("PSSCH") RSRP, physical sidelink control channel ("PSCCH") RSRP, SL channel-state reference signals ("CSI-RS"), SL synchronization signals ("SLSS"), and combinations thereof. In various embodiments, in response to being configured for UE-based SL range-based positioning, the target UE determines its estimated location based on the selected RRM measurements. In some embodiments, in response to being configured for UE-assisted SL range-based positioning, report the selected RRM measurements to an LMF configured to estimate the location of the target UE based on the reported RRM measurements.

[0007] A method for sidelink based positioning of a target UE in a communication network, is disclosed. In some examples, the method includes sidelink angular-based positioning techniques that may include SL AoA positioning, SL AoD positioning, or combinations thereof, and a second set of sidelink positioning techniques based on SL-Radio Resource Management ('RRM") measurements, where the first sidelink positioning technique that is SL angular-based includes: receiving a plurality of SL PRS assistance data associated with a plurality of SL signal transmissions that serve as reference signal transmissions and are selected from beam transmissions, and antenna panel transmissions, or combinations thereof, transmitted from one or more SL signal transmitting devices; receiving the SL reference signal transmissions from the one or more SL signal transmitting devices; and performing configured measurements selected from: SL angle of arrival ("AoA") measurements of the received SL reference signal transmissions for determining an estimated location of the target UE using SL AoA positioning techniques; SL reference signal received power ("RSRP") measurements for deriving

angle of departure (AoD) calculations mapped to the received SL reference signal transmissions for determining an estimated location of the target UE using SL AoD positioning techniques; and combinations thereof.

[0008] The present disclosure addresses various deficiencies of existing solutions and lack of functionality in C-V2X positioning by providing angular/range-based SL positioning. The disclosed SL positioning techniques also provide high accuracy depending on the scenario and radio environment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] A more particular description of the embodiments briefly described above will be rendered by reference to specific embodiments that are illustrated in the appended drawings. Understanding that these drawings depict only some embodiments and are not therefore to be considered to be limiting of scope, the embodiments will be described and explained with additional specificity and detail through the use of the accompanying drawings, in which:

[0010] Figure 1 is a schematic block diagram illustrating a wireless communication system for sidelink ("SL") angular-based and SL RRM-based positioning, , in accordance with one or more embodiments of the disclosure;

[0011] Figure 2 is a block diagram of a 5G New Radio ("NR") protocol stack, in accordance with one or more embodiments of the disclosure;

[0012] Figure 3 is a block diagram illustrating an example of NR beam-based positioning, in accordance with one or more embodiments of the disclosure;

[0013] Figure 4 is a diagram illustrating downlink ("DL") time-difference-of-arrival ("TDOA") assistance data in accordance with one or more embodiments of the disclosure;

[0014] Figure 5 is a diagram illustrating a DL-TDOA measurement report, in accordance with one or more embodiments of the disclosure;

[0015] Figure 6 is a diagram illustrating an example procedure for user equipment ("UE")-assisted SL-AoD and/or AoA positioning with one or more UEs serving as reference nodes, in accordance with one or more embodiments of the disclosure;

[0016] Figure 7 is a diagram illustrating an example scenario of UE-based SL-AoD and/or AoA positioning with one or more UEs serving as reference nodes, in accordance with one or more embodiments of the disclosure;

[0017] Figure 8 is a diagram illustrating user equipment ("UE")-assisted SL radio resource management ("RRM")-based positioning with one or more UEs serving as reference nodes, in accordance with one or more embodiments of the disclosure;

[0018] Figure 9 is a diagram illustrating an example of a capability signaling exchange for SL-AoD and/or AoA positioning, in accordance with one or more embodiments of the disclosure;

[0019] Figure 10 is a diagram illustrating an example of an assistance data signaling exchange for SL-TDOA and/or SL-RTT, in accordance with one or more embodiments of the disclosure;

[0020] Figure 11 is a block diagram illustrating a user equipment apparatus that may be used for sidelink angular-based and SL RRM-based positioning, in accordance with one or more embodiments of the disclosure;

[0021] Figure 12 is a block diagram a network equipment apparatus that may be used for sidelink angular-based and SL RRM-based positioning, in accordance with one or more embodiments of the disclosure;

[0022] Figure 13 is a block diagram illustrating an example of a method for sidelink angular-based positioning using AoD and/or AoA in accordance with one or more embodiments of the disclosure; and

[0023] Figure 14 is a block diagram illustrating an example of a method for SL RRM-based positioning in accordance with one or more embodiments of the disclosure.

DETAILED DESCRIPTION

[0024] As will be appreciated by one skilled in the art, aspects of the embodiments may be embodied as a system, apparatus, method, or program product. Accordingly, embodiments may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, etc.) or an embodiment combining software and hardware aspects.

[0025] For example, the disclosed embodiments may be implemented as a hardware circuit comprising custom very-large-scale integration ("VLSI") circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. The disclosed embodiments may also be implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices, or the like. As another example, the disclosed embodiments may include one or more physical or logical blocks of executable code which may, for instance, be organized as an object, procedure, or function.

[0026] Furthermore, embodiments may take the form of a program product embodied in one or more computer readable storage devices storing machine readable code, computer readable code, and/or program code, referred hereafter as code. The storage devices may be tangible, non-transitory, and/or non-transmission. The storage devices may not embody signals. In a certain embodiment, the storage devices only employ signals for accessing code.

[0027] Any combination of one or more computer readable medium may be utilized. The computer readable medium may be a computer readable storage medium. The computer readable storage medium may be a storage device storing the code. The storage device may be, for example, but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, holographic, micromechanical, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing.

[0028] More specific examples (a non-exhaustive list) of the storage device would include the following: an electrical connection having one or more wires, a portable computer diskette, a hard disk, a random-access memory ("RAM"), a read-only memory ("ROM"), an erasable programmable read-only memory ("EPROM" or Flash memory), a portable compact disc read-only memory ("CD-ROM"), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing. In the context of this document, a computer readable storage medium may be any tangible medium that can contain or store a program for use by or in connection with an instruction execution system, apparatus, or device.

[0029] Code for carrying out operations for embodiments may be any number of lines and may be written in any combination of one or more programming languages including an object-oriented programming language such as Python, Ruby, Java, Smalltalk, C++, or the like, and conventional procedural programming languages, such as the "C" programming language, or the like, and/or machine languages such as assembly languages. The code may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the user's computer through any type of network, including a local area network ("LAN") or a wide area network ("WAN"), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider).

[0030] Furthermore, the described features, structures, or characteristics of the embodiments may be combined in any suitable manner. In the following description, numerous specific details are provided, such as examples of programming, software modules, user selections, network transactions,

database queries, database structures, hardware modules, hardware circuits, hardware chips, etc., to provide a thorough understanding of embodiments. One skilled in the relevant art will recognize, however, that embodiments may be practiced without one or more of the specific details, or with other methods, components, materials, and so forth. In other instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of an embodiment.

[0031] Reference throughout this specification to "one embodiment," "an embodiment," or similar language means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, appearances of the phrases "in one embodiment," "in an embodiment," and similar language throughout this specification may, but do not necessarily, all refer to the same embodiment, but mean "one or more but not all embodiments" unless expressly specified otherwise. The terms "including," "comprising," "having," and variations thereof mean "including but not limited to," unless expressly specified otherwise. An enumerated listing of items does not imply that any or all of the items are mutually exclusive, unless expressly specified otherwise. The terms "a," "an," and "the" also refer to "one or more" unless expressly specified otherwise.

[0032] As used herein, a list with a conjunction of "and/or" includes any single item in the list or a combination of items in the list. For example, a list of A, B, and/or C includes only A, only B, only C, a combination of A and B, a combination of B and C, a combination of A and C or a combination of A, B and C. As used herein, a list using the terminology "one or more of" includes any single item in the list or a combination of items in the list. For example, one or more of A, B and C includes only A, only B, only C, a combination of A and B, a combination of B and C, a combination of A and C or a combination of A, B and C. As used herein, a list using the terminology "one of" includes one and only one of any single item in the list. For example, "one of A, B, and C" includes only A, only B or only C and excludes combinations of A, B and C. As used herein, "a member selected from the group consisting of A, B, and C," includes one and only one of A, B, or C, and excludes combinations of A, B, and C." As used herein, "a member selected from the group consisting of A, B, and C and combinations thereof" includes only A, only B, only C, a combination of A and B, a combination of B and C, a combination of A and C or a combination of A, B, and C.

[0033] Aspects of the embodiments are described below with reference to schematic flowchart diagrams and/or schematic block diagrams of methods, apparatuses, systems, and program products according to embodiments. It will be understood that each block of the schematic flowchart diagrams and/or schematic block diagrams, and combinations of blocks in the schematic flowchart diagrams

and/or schematic block diagrams, can be implemented by code. This code may be provided to a processor of a general-purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart diagrams and/or block diagrams.

[0034] The code may also be stored in a storage device that can direct a computer, other programmable data processing apparatus, or other devices to function in a particular manner, such that the instructions stored in the storage device produce an article of manufacture including instructions which implement the function/act specified in the flowchart diagrams and/or block diagrams.

[0035] The code may also be loaded onto a computer, other programmable data processing apparatus, or other devices to cause a series of operational steps to be performed on the computer, other programmable apparatuses, or other devices to produce a computer implemented process such that the code which execute on the computer or other programmable apparatus provide processes for implementing the functions/acts specified in the flowchart diagrams and/or block diagrams.

[0036] The flowchart diagrams and/or block diagrams in the Figures illustrate the architecture, functionality, and operation of possible implementations of apparatuses, systems, methods, and program products according to various embodiments. In this regard, each block in the flowchart diagrams and/or block diagrams may represent a module, segment, or portion of code, which includes one or more executable instructions of the code for implementing the specified logical function(s).

[0037] It should also be noted that, in some alternative implementations, the functions noted in the block may occur out of the order noted in the Figures. For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. Other steps and methods may be conceived that are equivalent in function, logic, or effect to one or more blocks, or portions thereof, of the illustrated Figures.

[0038] Although various arrow types and line types may be employed in the flowchart and/or block diagrams, they are understood not to limit the scope of the corresponding embodiments. Indeed, some arrows or other connectors may be used to indicate only the logical flow of the depicted embodiment. For instance, an arrow may indicate a waiting or monitoring period of unspecified duration between enumerated steps of the depicted embodiment. It will also be noted that each block of the block diagrams and/or flowchart diagrams, and combinations of blocks in the block diagrams

and/or flowchart diagrams, can be implemented by special purpose hardware-based systems that perform the specified functions or acts, or combinations of special purpose hardware and code.

[0039] The description of elements in each figure may refer to elements of proceeding figures. Like numbers refer to like elements in all figures, including alternate embodiments of like elements.

General Overview

[0040] Generally, the present disclosure describes systems, methods, and apparatuses for sidelink angular-based and SL RRM-based positioning. More specifically, the present disclosure discloses an improved signaling and measurement framework, e.g., for NR, for enabling sidelink positioning using angular (e.g., AoD, AoA) and/or range-based SL-RRM-based NR sidelink (SL) RAT-dependent and RAT-independent positioning techniques.

[0041] Radio Access Technology ("RAT")-dependent positioning methods such as TDOA, RTT, angle of departure ("AoD") and cell identifier ("CID"), and U-UTRAN cell identifier ("E-CID") have been specified for the Uu interface in Long-Term Evolution ("LTE") and Third Generation Partnership Project ("3GPP") New Radio ("NR"). Similarly, these positioning techniques show high potential for application in sidelink, although there currently exists no specified methods to realize such implementations in 3GPP. Furthermore, aspects of sidelink positioning which beneficially should be addressed may include determining use cases and requirements for sidelink positioning which in existing systems may not be adapted for sidelink, e.g., in vehicle-to-everything ("V2X"), public safety, commercial services as well as potential operation scenarios and design considerations in the topics of network coverage, including in-coverage and out-of-coverage conditions; Candidate frequency bands; Usage scenario and deployment of UEs, RAT-dependent and RAT-independent positioning, and hybrids; mobile-based (performed by UE) and mobile-assisted (performed at least partial by LMF) sidelink positioning; absolute and relative positioning; and architecture.

[0042] Another feature of SL positioning is that it enables relative positioning, which may be beneficial for location estimation in mobile vehicular scenarios. For example, relative positioning is a performance requirement in the horizontal accuracy of devices in industrial internet of things ("IIoT") environments where flexible and modular assembly areas are required in a smart factory setting.

[0043] The present disclosure aims to tackle this problem and lack of functionality in cellular V2X ("C-V2X") positioning by developing angular-based and/or SL-RRM based mechanisms to perform SL positioning. The proposed SL positioning techniques aim to provide high accuracy depending on the scenario and radio environment.

[0044] Figure 1 depicts a wireless communication system 100 supporting sidelink angular-based and SL RRM-based positioning, according to one or more embodiments of the disclosure. In one embodiment, the wireless communication system 100 includes at least one remote unit 105, a radio access network ("RAN") 120, and a mobile core network 140. The RAN 120 and the mobile core network 140 form a mobile communication network. The RAN 120 may be composed of a base unit 121 with which the remote unit 105 communicates using wireless communication links 115. Even though a specific number of remote units 105, base unit 121, wireless communication links 115, RANs 120, and mobile core networks 140 are depicted in Figure 1, one of skill in the art will recognize that any number of remote units 105, base unit 121, wireless communication links 115, RANs 120, and mobile core networks 140 may be included in the wireless communication system 100.

[0045] In one implementation, the RAN 120 is compliant with the 5G system specified in the 3GPP specifications. In another implementation, the RAN 120 is compliant with the LTE system specified in the 3GPP specifications. More generally, however, the wireless communication system 100 may implement some other open or proprietary communication network, for example WiMAX, among other networks. The present disclosure is not intended to be limited to the implementation of any particular wireless communication system architecture or protocol.

[0046] In one embodiment, the remote units 105 may include computing devices, such as desktop computers, laptop computers, personal digital assistants ("PDAs"), tablet computers, smart phones, smart televisions (e.g., televisions connected to the Internet), smart appliances (e.g., appliances connected to the Internet), set-top boxes, game consoles, security systems (including security cameras), vehicle on-board computers, network devices (e.g., routers, switches, modems), or the like. In some embodiments, the remote units 105 include wearable devices, such as smart watches, fitness bands, optical head-mounted displays, or the like. Moreover, the remote units 105 may be referred to as the UEs, subscriber units, mobiles, mobile stations, users, terminals, mobile terminals, fixed terminals, subscriber stations, user terminals, wireless transmit/receive unit ("WTRU"), a device, or by other terminology used in the art. In various embodiments, the remote unit 105 includes a subscriber identity and/or identification module ("SIM") and the mobile equipment ("ME") providing mobile termination functions (e.g., radio transmission, handover, speech encoding and decoding, error detection and correction, signaling and access to the SIM). In certain embodiments, the remote unit 105 may include a terminal equipment ("TE") and/or be embedded in an appliance or device (e.g., a computing device, as described above).

[0047] The remote units 105 may communicate directly with one or more of the base units 121 in the RAN 120 via uplink ("UL") and downlink ("DL") communication signals. Furthermore, the UL and DL communication signals may be carried over the wireless communication links 115. Here, the RAN 120 is an intermediate network that provides the remote units 105 with access to the mobile core network 140. As described in greater detail below, the base unit(s) 121 may provide a cell operating using a first frequency range and/or a cell operating using a second frequency range.

[0048] In some embodiments, the remote units 105 communicate with an application server 151 via a network connection with the mobile core network 140. For example, an application 107 (e.g., web browser, media client, telephone and/or Voice-over-Internet-Protocol ("VoIP") application) in a remote unit 105 may trigger the remote unit 105 to establish a protocol data unit ("PDU") session (or other data connection) with the mobile core network 140 via the RAN 120. The mobile core network 140 then relays traffic between the remote unit 105 and the application server 151 in the packet data network 150 using the PDU session. The PDU session represents a logical connection between the remote unit 105 and the User Plane Function ("UPF") 141.

[0049] In order to establish the PDU session (or PDN connection), the remote unit 105 must be registered with the mobile core network 140, also referred to as "attached to the mobile core network" in the context of a Fourth Generation ("4G") system. Note that the remote unit 105 may establish one or more PDU sessions (or other data connections) with the mobile core network 140. As such, the remote unit 105 may have at least one PDU session for communicating with the packet data network 150. The remote unit 105 may establish additional PDU sessions for communicating with other data networks and/or other communication peers.

[0050] In the context of a 5G system ("5GS"), the term "PDU Session" refers to a data connection that provides end-to-end ("E2E") user plane ("UP") connectivity between the remote unit 105 and a specific Data Network ("DN") through the UPF 141. A PDU Session supports one or more Quality of Service ("QoS") Flows. In certain embodiments, there may be a one-to-one mapping between a QoS Flow and a QoS profile, such that all packets belonging to a specific QoS Flow have the same 5G QoS Identifier ("5QI").

[0051] In the context of a 4G/LTE system, such as the Evolved Packet System ("EPS"), a Packet Data Network ("PDN") connection (also referred to as EPS session) provides E2E UP connectivity between the remote unit and a PDN. The PDN connectivity procedure establishes an EPS Bearer, i.e., a tunnel between the remote unit 105 and a Packet Gateway ("PGW", not shown) in the mobile core network 140. In certain embodiments, there is a one-to-one mapping between an EPS

Bearer and a QoS profile, such that all packets belonging to a specific EPS Bearer have the same QoS Class Identifier ("QCI").

[0052] The base units 121 may be distributed over a geographic region. In certain embodiments, a base unit 121 may also be referred to as an access terminal, an access point, a base, a base station, a Node-B ("NB"), an Evolved Node B (abbreviated as eNodeB or "eNB," also known as Evolved Universal Terrestrial Radio Access Network ("E-UTRAN") Node B), a 5G/NR Node B ("gNB"), a Home Node-B, a relay node, a RAN node, or by any other terminology used in the art. The base units 121 are generally part of a RAN, such as the RAN 120, that may include one or more controllers communicably coupled to one or more corresponding base units 121. These and other elements of radio access network are not illustrated but are well known generally by those having ordinary skill in the art. The base units 121 connect to the mobile core network 140 via the RAN 120.

[0053] The base units 121 may serve a number of remote units 105 within a serving area, for example, a cell or a cell sector, via a wireless communication link 115. The base units 121 may communicate directly with one or more of the remote units 105 via communication signals. Generally, the base units 121 transmit DL communication signals to serve the remote units 105 in the time, frequency, and/or spatial domain. Furthermore, the DL communication signals may be carried over the wireless communication links 115. The wireless communication links 115 may be any suitable carrier in licensed or unlicensed radio spectrum. The wireless communication links 115 facilitate communication between one or more of the remote units 105 and/or one or more of the base units 121. Note that during NR operation on unlicensed spectrum (referred to as "NR-U"), the base unit 121 and the remote unit 105 communicate over unlicensed (i.e., shared) radio spectrum.

[0054] In one embodiment, the mobile core network 140 is a 5GC or an Evolved Packet Core ("EPC"), which may be coupled to a packet data network 150, like the Internet and private data networks, among other data networks. A remote unit 105 may have a subscription or other account with the mobile core network 140. In various embodiments, each mobile core network 140 belongs to a single mobile network operator ("MNO"). The present disclosure is not intended to be limited to the implementation of any particular wireless communication system architecture or protocol.

[0055] In certain embodiments, the mobile core network 140 also includes multiple control plane ("CP") functions including, but not limited to, one or more User Plane Functions ("UPF") 141, an Access and Mobility Management Function ("AMF") 143 that serves the RAN 120, a Session Management Function ("SMF") 145, a Location Management Function ("LMF") 147, a Unified Data Management function ("UDM"") and a User Data Repository ("UDR"). Although specific numbers

and types of network functions are depicted in Figure 1, one of skill in the art may recognize that any number and type of network functions may be included in the mobile core network 140.

[0056] The UPF(s) 141 is/are responsible for packet routing and forwarding, packet inspection, QoS handling, and external PDU session for interconnecting Data Network ("DN"), in the 5G architecture. The AMF 143 is responsible for termination of NAS signaling, NAS ciphering & integrity protection, registration management, connection management, mobility management, access authentication and authorization, security context management. The SMF 145 is responsible for session management (i.e., session establishment, modification, release), remote unit (i.e., UE) IP address allocation & management, DL data notification, and traffic steering configuration of the UPF 141 for proper traffic routing.

[0057] The LMF 147 receives measurements from RAN 120 and the remote unit 105 (e.g., via the AMF 143) and computes the position of the remote unit 105. The UDM is responsible for generation of Authentication and Key Agreement ("AKA") credentials, user identification handling, access authorization, subscription management. The UDR is a repository of subscriber information and may be used to service a number of network functions. For example, the UDR may store subscription data, policy-related data, subscriber-related data that is permitted to be exposed to third party applications, and the like. In some embodiments, the UDM is co-located with the UDR, depicted as combined entity "UDM/UDR" 149.

[0058] In various embodiments, the mobile core network 140 may also include a Policy Control Function ("PCF") 144 (which provides policy rules to CP functions), a Network Repository Function ("NRF") (which provides Network Function ("NF") service registration and discovery, enabling NFs to identify appropriate services in one another and communicate with each other over Application Programming Interfaces ("APIs")), a Network Exposure Function ("NEF") (which is responsible for making network data and resources easily accessible to customers and network partners), an Authentication Server Function ("AUSF"), or other NFs defined for the 5GC. When present, the AUSF may act as an authentication server and/or authentication proxy, thereby allowing the AMF 143 to authenticate a remote unit 105. In certain embodiments, the mobile core network 140 may include an authentication, authorization, and accounting ("AAA") server.

[0059] In various embodiments, the mobile core network 140 supports different types of mobile data connections and different types of network slices, wherein each mobile data connection utilizes a specific network slice. Here, a "network slice" refers to a portion of the mobile core network 140 optimized for a certain traffic type or communication service. For example, one or more network

slices may be optimized for enhanced mobile broadband ("eMBB") service. As another example, one or more network slices may be optimized for ultra-reliable low-latency communication ("URLLC") service. In other examples, a network slice may be optimized for machine-type communication ("MTC") service, massive MTC ("mMTC") service, Internet-of-Things ("IoT") service. In yet other examples, a network slice may be deployed for a specific application service, a vertical service, a specific use case, etc.

[0060] A network slice instance may be identified by a single-network slice selection assistance information ("S-NSSAI") while a set of network slices for which the remote unit 105 is authorized to use is identified by network slice selection assistance information ("NSSAI"). Here, "NSSAI" refers to a vector value including one or more S-NSSAI values. In certain embodiments, the various network slices may include separate instances of network functions, such as the SMF 145 and UPF 141. In some embodiments, the different network slices may share some common network functions, such as the AMF 143. The different network slices are not shown in Figure 1 for ease of illustration, but their support is assumed.

[0061] As discussed in greater detail below, the remote unit 105 receives a measurement configuration 125 from the network (e.g., from the LMF 147 via RAN 120). The remote unit 105 performs positioning measurement, as described in greater detail below, and sends a positioning report 127 to the LMF 147. In certain embodiments, the LMF 147 is implemented as a standalone network core function. In some embodiments, the LMF is implemented in a location server.

[0062] While Figure 1 depicts components of a 5G RAN and a 5G core network, the described embodiments for performing sidelink angular-based and/or SL-RRM based positioning apply to other types of communication networks and RATs, including IEEE 802.11 variants, Global System for Mobile Communications ("GSM", i.e., a 2G digital cellular network), General Packet Radio Service ("GPRS"), Universal Mobile Telecommunications System ("UMTS"), LTE variants, CDMA 2000, Bluetooth®, ZigBee®, Sigfox®, and the like.

[0063] Moreover, in an LTE variant where the mobile core network 140 is an EPC, the depicted network functions may be replaced with appropriate EPC entities, such as a Mobility Management Entity ("MME"), a Serving Gateway ("SGW"), a PGW, a Home Subscriber Server ("HSS"), and the like. For example, the AMF 143 may be mapped to an MME, the SMF 145 may be mapped to a control plane portion of a PGW and/or to an MME, the UPF 141 may be mapped to an SGW and a user plane portion of the PGW, the UDM/UDR 149 may be mapped to an HSS, etc.

[0064] In the following descriptions, the term "RAN node" is used for the base station but it is replaceable by any other radio access node, e.g., gNB, ng-eNB, eNB, Base Station ("BS"), Access Point ("AP"), etc. Further, the operations are described mainly in the context of 5G NR. However, the proposed solutions/methods are also equally applicable to other mobile communication systems supporting performing sidelink angular-based positioning and/or RRM based positioning.

[0065] Figure 2 depicts a NR protocol stack 200, in accordance with one or more embodiments of the disclosure. While Figure 2 shows the UE 205, the RAN node 210 and an AMF 215 in a 5G core network ("5GC"), these are representative of a set of remote units 105 interacting with a base unit 121 and a mobile core network 140. As depicted, the protocol stack 200 comprises a User Plane protocol stack 201 and a Control Plane protocol stack 203. The User Plane protocol stack 201 includes a physical ("PHY") layer 220, a Medium Access Control ("MAC") sublayer 225, the Radio Link Control ("RLC") sublayer 230, a Packet Data Convergence Protocol ("PDCP") sublayer 235, and Service Data Adaptation Protocol ("SDAP") layer 240. The Control Plane protocol stack 203 includes a physical layer 220, a MAC sublayer 225, a RLC sublayer 230, and a PDCP sublayer 235. The Control Plane protocol stack 203 also includes a Radio Resource Control ("RRC") layer 245 and a Non-Access Stratum ("NAS") layer 250.

[0066] The AS layer (also referred to as "AS protocol stack") for the User Plane protocol stack 201 consists of at least SDAP, PDCP, RLC and MAC sublayers, and the physical layer. The AS layer for the Control Plane protocol stack 203 consists of at least RRC, PDCP, RLC and MAC sublayers, and the physical layer. The Layer-2 ("L2") is split into the SDAP, PDCP, RLC and MAC sublayers. The Layer-3 ("L3") includes the RRC layer 245 and the NAS layer 250 for the control plane and includes, e.g., an Internet Protocol ("IP") layer and/or PDU Layer (not depicted) for the user plane. L1 and L2 are referred to as "lower layers," while L3 and above (e.g., transport layer, application layer) are referred to as "higher layers" or "upper layers."

[0067] The physical layer 220 offers transport channels to the MAC sublayer 225. The physical layer 220 may perform a Clear Channel Assessment and/or Listen-Before-Talk ("CCA/LBT") procedure. In certain embodiments, the physical layer 220 may send a notification of UL Listen-Before-Talk ("LBT") failure to a MAC entity at the MAC sublayer 225. The MAC sublayer 225 offers logical channels to the RLC sublayer 230. The RLC sublayer 230 offers RLC channels to the PDCP sublayer 235. The PDCP sublayer 235 offers radio bearers to the SDAP layer 240 and/or RRC layer 245. The SDAP layer 240 offers QoS flows to the core network (e.g., 5GC). The RRC layer 245 provides for the addition, modification, and release of Carrier Aggregation and/or Dual Connectivity.

The RRC layer 245 also manages the establishment, configuration, maintenance, and release of Signaling Radio Bearers ("SRBs") and Data Radio Bearers ("DRBs").

[0068] The NAS layer 250 is between the UE 205 and the AMF 215 of the core network (e.g., 5GC). NAS messages are passed transparently through the RAN. The NAS layer 250 is used to manage the establishment of communication sessions and for maintaining continuous communications with the UE 205 as it moves between different cells of the RAN. In contrast, the AS layer is between the UE 205 and the RAN (i.e., RAN node 210) and carries information over the wireless portion of the network.

RAT-dependent Positioning Techniques

[0069] The following RAT-dependent positioning techniques may be supported by the system 100:

[0070] DL-TDoA: The DL-TDOA positioning method makes use of the DL RSTD (and optionally DL PRS RSRP) of downlink signals received from multiple TPs, at the UE. The UE measures the DL RSTD (and optionally DL PRS RSRP) of the received signals using assistance data received from the positioning server, and the resulting measurements are used along with other configuration information to locate the UE in relation to the neighboring TPs.

[0071] DL-AoD: The DL AoD positioning method makes use of the measured DL PRS RSRP of downlink signals received from multiple TPs, at the UE. The UE measures the DL PRS RSRP of the received signals using assistance data received from the positioning server, and the resulting measurements are used along with other configuration information to locate the UE in relation to the neighboring TPs.

[0072] Multi-RTT: The Multi-RTT positioning method makes use of the UE Rx-Tx measurements and DL PRS RSRP of downlink signals received from multiple TRPs, measured by the UE and the measured gNB Rx-Tx measurements and UL SRS-RSRP at multiple TRPs of uplink signals transmitted from UE.

[0073] The UE measures the UE Rx-Tx measurements (and optionally DL PRS RSRP of the received signals) using assistance data received from the positioning server, and the TRPs measure the gNB Rx-Tx measurements (and optionally UL SRS-RSRP of the received signals) using assistance data received from the positioning server. The measurements are used to determine the RTT at the positioning server which are used to estimate the location of the UE.

[0074] E-CID/ NR E-CID: Enhanced Cell ID (CID) positioning method, the position of a UE is estimated with the knowledge of its serving ng-eNB, gNB and cell and is based on LTE signals. The information about the serving ng-eNB, gNB and cell may be obtained by paging, registration, or other methods. NR Enhanced Cell ID (NR E CID) positioning refers to techniques which use additional UE measurements and/or NR radio resource and other measurements to improve the UE location estimate using NR signals.

[0075] Although NR E-CID positioning may utilize some of the same measurements as the measurement control system in the RRC protocol, the UE generally is not expected to make additional measurements for the sole purpose of positioning; i.e., the positioning procedures do not supply a measurement configuration or measurement control message, and the UE reports the measurements that it has available rather than being required to take additional measurement actions.

[0076] UL-TDoA: The UL TDOA positioning method makes use of the UL TDOA (and optionally UL SRS-RSRP) at multiple RPs of uplink signals transmitted from UE. The RPs measure the UL TDOA (and optionally UL SRS-RSRP) of the received signals using assistance data received from the positioning server, and the resulting measurements are used along with other configuration information to estimate the location of the UE.

[0077] UL-AoA: The UL AoA positioning method makes use of the measured azimuth and the zenith of arrival at multiple RPs of uplink signals transmitted from UE. The RPs measure A-AoA and Z-AoA of the received signals using assistance data received from the positioning server, and the resulting measurements are used along with other configuration information to estimate the location of the UE.

[0078] Table 1 lists various positioning performance requirements for different scenarios in an IIoT or indoor factory setting. For IIoT in Release 17 ("Rel-17"), certain positioning requirements are especially stringent with respect to accuracy, latency, and reliability.

[0079] The apparatuses, methods, and systems disclosed herein facilitate implementation of sidelink angular-based and SL-RRM-based positioning with high accuracy, low latency, and high reliability.

Table 1: IIoT Positioning Performance Requirements

Scenario	Horizontal accuracy	Vertical accuracy	Availability	Latency for position estimation of UE	UE Speed	Corresponding Positioning Service Level

Mobile control panels with safety functions (non-danger zones)	< 5 m	< 3 m	90 %	< 5 s	N/A	Service Level 2
Process automation – plant asset management	< 1 m	< 3 m	90 %	< 2 s	< 30 km/h	Service Level 3
Flexible, modular assembly area in smart factories (for tracking of tools at the work-place location)	< 1 m (relative positioning)	N/A	99 %	1 s	< 30 km/h	Service Level 3
Augmented reality in smart factories	< 1 m	< 3 m	99 %	< 15 ms	< 10 km/h	Service Level 4
Mobile control panels with safety functions in smart factories (within factory danger zones)	< 1 m	< 3 m	99.9 %	< 1 s	N/A	Service Level 4
Flexible, modular assembly area in smart factories (for autonomous vehicles, only for monitoring proposes)	< 50 cm	< 3 m	99 %	1 s	< 30 km/h	Service Level 5
Inbound logistics for manufacturing (for driving trajectories (if supported by further sensors like camera, GNSS, IMU) of indoor autonomous driving systems))	< 30 cm (if supported by further sensors like camera, GNSS, IMU)	< 3 m	99.9 %	10 ms	< 30 km/h	Service Level 6
Inbound logistics for manufacturing (for storage of goods)	< 20 cm	< 20 cm	99 %	< 1 s	< 30 km/h	Service Level 7

[0080] The present disclosure describes mechanisms to perform sidelink positioning of a term UE. Beneficially, angular-based measurements and location estimation facilitate high resolution in terms of accuracy for a target UE. Furthermore, enabling SL AoD/AOA and/or SL RMM based measurements and locations estimation for both anchor UE and non-anchor UE configurations facilitates high accuracy positioning in out-of-coverage scenarios may be especially beneficial for public safety and V2X scenarios.

[0081] Other technologies disclosed herein may be used to enable a target UE to autonomously perform round trip time (RTT) measurements for TX-RX distance/range computation using multiple beams between multiple pairs of UEs in sidelink. The disclosed RTT measurements for TX-RX distance computation may be readily configured, require no network assistance, and be applied for Mode 2 SL operations. Moreover, multiple SL beams can be exploited to perform accurate RTT measurements in a unicast scenario, while RTT measurements from multiple UEs can also enable mapping of a target UE's immediate surroundings.

[0082] Figure 1 depicts a wireless communication system 100 for performing sidelink angular/range-based positioning, according to various embodiments of the disclosure. In one embodiment, the wireless communication system 100 includes at least one remote unit 105, a radio access network ("RAN") 120, and a mobile core network 140. The RAN 120 and the mobile core network 140 form a mobile communication network. The RAN 120 may be composed of a base unit 121 with which the remote unit 105 communicates using wireless communication links 115. Even though a specific number of remote units 105, base units 121, wireless communication links 115, RANs 120, and mobile core networks 140 are depicted in Figure 1, one of skill in the art will recognize that any number of remote units 105, base units 121, wireless communication links 115, RANs 120, and mobile core networks 140 may be included in the wireless communication system 100.

[0083] In one implementation, the RAN 120 is compliant with the 5G system specified in the Third Generation Partnership Project ("3GPP") specifications. For example, the RAN 120 may be a Next Generation Radio Access Network ("NG-RAN"), implementing New Radio ("NR") Radio Access Technology ("RAT") and/or Long-Term Evolution ("LTE") RAT. In another example, the RAN 120 may include non-3GPP RAT (e.g., Wi-Fi® or Institute of Electrical and Electronics Engineers ("IEEE") 802.11-family compliant WLAN). In another implementation, the RAN 120 is compliant with the LTE system specified in the 3GPP specifications. More generally, however, the wireless communication system 100 may implement some other open or proprietary communication network, for example Worldwide Interoperability for Microwave Access ("WiMAX") or IEEE

802.16-family standards, among other networks. The present disclosure is not intended to be limited to the implementation of any particular wireless communication system architecture or protocol.

[0084] In one embodiment, the remote units 105 may include computing devices, such as desktop computers, laptop computers, personal digital assistants ("PDAs"), tablet computers, smart phones, smart televisions (e.g., televisions connected to the Internet), smart appliances (e.g., appliances connected to the Internet), set-top boxes, game consoles, security systems (including security cameras), vehicle on-board computers, network devices (e.g., routers, switches, modems), or the like. In some embodiments, the remote units 105 include wearable devices, such as smart watches, fitness bands, optical head-mounted displays, or the like. Moreover, the remote units 105 may be referred to as the UEs, subscriber units, mobiles, mobile stations, users, terminals, mobile terminals, fixed terminals, subscriber stations, user terminals, wireless transmit/receive unit ("WTRU"), a device, or by other terminology used in the art. In various embodiments, the remote unit 105 includes a subscriber identity and/or identification module ("SIM") and the mobile equipment ("ME") providing mobile termination functions (e.g., radio transmission, handover, speech encoding and decoding, error detection and correction, signaling and access to the SIM). In certain embodiments, the remote unit 105 may include a terminal equipment ("TE") and/or be embedded in an appliance or device (e.g., a computing device, as described above).

[0085] The remote units 105 may communicate directly with one or more of the base units 121 in the RAN 120 via uplink ("UL") and downlink ("DL") communication signals. Furthermore, the UL and DL communication signals may be carried over the wireless communication links 115. Here, the RAN 120 is an intermediate network that provides the remote units 105 with access to the mobile core network 140. As described in greater detail below, the base unit(s) 121 may provide a cell operating using a first frequency range and/or a cell operating using a second frequency range.

[0086] In some embodiments, the remote units 105 communicate with an application server 151 via a network connection with the mobile core network 140. For example, an application 107 (e.g., web browser, media client, telephone and/or Voice-over-Internet-Protocol ("VoIP") application) in a remote unit 105 may trigger the remote unit 105 to establish a protocol data unit ("PDU") session (or other data connection) with the mobile core network 140 via the RAN 120. The mobile core network 140 then relays traffic between the remote unit 105 and the application server 151 in the packet data network 150 using the PDU session. The PDU session represents a logical connection between the remote unit 105 and the User Plane Function ("UPF") 141.

[0087] In order to establish the PDU session (or PDN connection), the remote unit 105 must be registered with the mobile core network 140 (also referred to as "attached to the mobile core network" in the context of a Fourth Generation ("4G") system). Note that the remote unit 105 may establish one or more PDU sessions (or other data connections) with the mobile core network 140. As such, the remote unit 105 may have at least one PDU session for communicating with the packet data network 150. The remote unit 105 may establish additional PDU sessions for communicating with other data networks and/or other communication peers.

[0088] In the context of a 5G system ("5GS"), the term "PDU Session" refers to a data connection that provides end-to-end ("E2E") user plane ("UP") connectivity between the remote unit 105 and a specific Data Network ("DN") through the UPF 141. A PDU Session supports one or more Quality of Service ("QoS") Flows. In certain embodiments, there may be a one-to-one mapping between a QoS Flow and a QoS profile, such that all packets belonging to a specific QoS Flow have the same 5G QoS Identifier ("5QI").

[0089] In the context of a 4G/LTE system, such as the Evolved Packet System ("EPS"), a Packet Data Network ("PDN") connection (also referred to as EPS session) provides E2E UP connectivity between the remote unit and a PDN. The PDN connectivity procedure establishes an EPS Bearer, i.e., a tunnel between the remote unit 105 and a Packet Gateway ("PGW", not shown) in the mobile core network 140. In certain embodiments, there is a one-to-one mapping between an EPS Bearer and a QoS profile, such that all packets belonging to a specific EPS Bearer have the same QoS Class Identifier ("QCI").

[0090] The base units 121 may be distributed over a geographic region. In certain embodiments, a base unit 121 may also be referred to as an access terminal, an access point, a base, a base station, a Node-B ("NB"), an Evolved Node B (abbreviated as eNodeB or "eNB," also known as Evolved Universal Terrestrial Radio Access Network ("E-UTRAN") Node B), a 5G/NR Node B ("gNB"), a Home Node-B, a relay node, a RAN node, or by any other terminology used in the art. The base units 121 are generally part of a RAN, such as the RAN 120, that may include one or more controllers communicably coupled to one or more corresponding base units 121. These and other elements of radio access network are not illustrated but are well known generally by those having ordinary skill in the art. The base units 121 connect to the mobile core network 140 via the RAN 120.

[0091] The base units 121 may serve a number of remote units 105 within a serving area, for example, a cell or a cell sector, via a wireless communication link 115. The base units 121 may communicate directly with one or more of the remote units 105 via communication signals. Generally,

the base units 121 transmit DL communication signals to serve the remote units 105 in the time, frequency, and/or spatial domain. Furthermore, the DL communication signals may be carried over the wireless communication links 115. The wireless communication links 115 may be any suitable carrier in licensed or unlicensed radio spectrum. The wireless communication links 115 facilitate communication between one or more of the remote units 105 and/or one or more of the base units 121. Note that during NR operation on unlicensed spectrum (referred to as "NR-U"), the base unit 121 and the remote unit 105 communicate over unlicensed (i.e., shared) radio spectrum.

[0092] In one embodiment, the mobile core network 140 is a 5GC or an Evolved Packet Core ("EPC"), which may be coupled to a packet data network 150, like the Internet and private data networks, among other data networks. A remote unit 105 may have a subscription or other account with the mobile core network 140. In various embodiments, each mobile core network 140 belongs to a single mobile network operator ("MNO"). The present disclosure is not intended to be limited to the implementation of any particular wireless communication system architecture or protocol.

[0093] The mobile core network 140 includes several network functions ("NFs"). As depicted, the mobile core network 140 includes at least one UPF 141. The mobile core network 140 also includes multiple control plane ("CP") functions including, but not limited to, an Access and Mobility Management Function ("AMF") 143 that serves the RAN 120, a Session Management Function ("SMF") 145, a Location Management Function ("LMF") 147, a Unified Data Management function ("UDM"") and a User Data Repository ("UDR"). Although specific numbers and types of network functions are depicted in Figure 1, one of skill in the art will recognize that any number and type of network functions may be included in the mobile core network 140.

[0094] The UPF(s) 141 is/are responsible for packet routing and forwarding, packet inspection, QoS handling, and external PDU session for interconnecting Data Network (DN), in the 5G architecture. The AMF 143 is responsible for termination of NAS signaling, NAS ciphering & integrity protection, registration management, connection management, mobility management, access authentication and authorization, security context management. The SMF 145 is responsible for session management (i.e., session establishment, modification, release), remote unit (i.e., UE) IP address allocation & management, DL data notification, and traffic steering configuration of the UPF 141 for proper traffic routing.

[0095] The LMF 147 receives measurements from RAN 120 and the remote unit 105 (e.g., via the AMF 143) and computes the position of the remote unit 105. The UDM is responsible for generation of Authentication and Key Agreement ("AKA") credentials, user identification handling,

access authorization, subscription management. The UDR is a repository of subscriber information and may be used to service a number of network functions. For example, the UDR may store subscription data, policy-related data, subscriber-related data that is permitted to be exposed to third party applications, and the like. In some embodiments, the UDM is co-located with the UDR, depicted as combined entity "UDM/UDR" 149.

[0096] In various embodiments, the mobile core network 140 may also include a Policy Control Function ("PCF") (which provides policy rules to CP functions), a Network Repository Function ("NRF") (which provides Network Function ("NF") service registration and discovery, enabling NFs to identify appropriate services in one another and communicate with each other over Application Programming Interfaces ("APIs")), a Network Exposure Function ("NEF") (which is responsible for making network data and resources easily accessible to customers and network partners), an Authentication Server Function ("AUSF"), or other NFs defined for the 5GC. When present, the AUSF may act as an authentication server and/or authentication proxy, thereby allowing the AMF 143 to authenticate a remote unit 105. In certain embodiments, the mobile core network 140 may include an authentication, authorization, and accounting ("AAA") server.

[0097] In various embodiments, the mobile core network 140 supports different types of mobile data connections and different types of network slices, wherein each mobile data connection utilizes a specific network slice. Here, a "network slice" refers to a portion of the mobile core network 140 optimized for a certain traffic type or communication service. For example, one or more network slices may be optimized for enhanced mobile broadband ("eMBB") service. As another example, one or more network slices may be optimized for ultra-reliable low-latency communication ("URLLC") service. In other examples, a network slice may be optimized for machine-type communication ("MTC") service, massive MTC ("mMTC") service, Internet-of-Things ("IoT") service. In yet other examples, a network slice may be deployed for a specific application service, a vertical service, a specific use case, etc.

[0098] A network slice instance may be identified by a single-network slice selection assistance information ("S-NSSAI") while a set of network slices for which the remote unit 105 is authorized to use is identified by network slice selection assistance information ("NSSAI"). Here, "NSSAI" refers to a vector value including one or more S-NSSAI values. In certain embodiments, the various network slices may include separate instances of network functions, such as the SMF 145 and UPF 141. In some embodiments, the different network slices may share some common network

functions, such as the AMF 143. The different network slices are not shown in Figure 1 for ease of illustration, but their support is assumed.

[0099] As discussed in greater detail below, the remote unit 105 receives a measurement configuration 125 from the network (e.g., from the LMF 147 via RAN 120). In various embodiments, the remote unit 105 performs positioning measurement, as described in greater detail below, and sends a positioning report 127 to the LMF 147 for performing certain steps of the positioning calculations. In some embodiments, (e.g., in scenarios where a location server is not immediately available, the target UE is configured to perform the sidelink positioning techniques locally.

[0100] Some UE positioning methods supported in Rel-16 are listed in Table 2. The separate positioning techniques as indicated in Table 2 may be currently configured and performed based on the requirements of the LMF and/or UE capabilities. Note that Table 2 includes TBS positioning based on PRS signals, but only OTDOA based on LTE signals is supported. The E-CID includes Cell-ID for NR method. The Terrestrial Beacon System ("TBS") method refers to TBS positioning based on Metropolitan Beacon System ("MBS") signals.

[0101] The transmission of Positioning Reference Signals ("PRS") enables the UE 205 to perform UE positioning-related measurements to enable the computation of a UE's location estimate and are configured per Transmission Reception Point ("TRP"), where a TRP may transmit one or more beams.

[0102] Figure 3 is a block diagram illustrating an example 300 of NR beam-based positioning, in accordance with one or more embodiments of the disclosure. According to Rel-16, the PRS can be transmitted by different base stations (serving and neighboring) using narrow beams over Frequency Range #1 Between ("FR1", i.e., frequencies from 410 MHz to 7125 MHz) and Frequency Range #2 ("FR2", i.e., frequencies from 24.25 GHz to 52.6 GHz), which is relatively different when compared to LTE where the PRS was transmitted across the whole cell. As illustrated in Figure 3, a UE 205 may receive PRS from a first gNB ("gNB #1) 310 which is a serving gNB, and also from a neighboring second gNB ("gNB #2) 315, and a neighboring third gNB ("gNB #3) 320. Here, the PRS can be locally associated with a PRS Resource ID and Resource Set ID for a base station (i.e., TRP). In the depicted embodiments, each gNB 310, 315, 320 is configured with a first Resource Set ID 325 and a second Resource Set ID 330. As depicted, the UE 205 receives PRS on transmission beams; here, receiving PRS from the gNB #1 310 on PRS Resource ID #1 from the second Resource Set ID 330, receiving PRS from the gNB #2 315 on PSR Resource ID #3 from the second Resource Set ID 330, and receiving PRS from the gNB #3 320 on PRS Resource ID #3 from the first Resource Set ID 325. Within 5G

RAN, an NRPPa protocol uses the services provided by a NGAP protocol. An NRPPa message 335 is carried inside an NGAP message. The LMF 305 is connected to the NG-RAN node through the AMF 143. The NG-RAN node as a base unit 121 may control several TRPs. Both split NG-RAN architectures (i.e., CU/DU) and non-split NG-RAN architectures are supported. A full Description of an NRPPa can be found in 3GPP TS 38.455.

[0103] Some UE positioning methods supported in Rel-16 are listed in Table 2. The separate positioning techniques as indicated in Table 2 may be currently configured and performed based on the requirements of the LMF and/or UE capabilities. Note that Table 2 includes TBS positioning based on PRS signals, but only OTDOA based on LTE signals is supported. The E-CID includes Cell-ID for NR method. The Terrestrial Beacon System ("TBS") method refers to TBS positioning based on Metropolitan Beacon System ("MBS") signals.

Table 2: Supported Rel-16 UE positioning methods

Method	UE-based	UE-assisted, LMF-based	NG-RAN node assisted	Secure User Plane Location ("SUPL")
A-GNSS	Yes	Yes	No	Yes (UE-based and UE-assisted)
OTDOA	No	Yes	No	Yes (UE-assisted)
E-CID	No	Yes	Yes	Yes, for E-UTRA (UE-assisted)
Sensor	Yes	Yes	No	No
WLAN	Yes	Yes	No	Yes
Bluetooth	No	Yes	No	No
TBS	Yes	Yes	No	Yes (MBS)
DL-TDOA	Yes	Yes	No	No
DL-AoD	Yes	Yes	No	No
Multi-RTT	No	Yes	Yes	No
NR E-CID	No	Yes	FFS	No
UL-TDOA	No	No	Yes	No
UL-AoA	No	No	Yes	No

[0104] Separate positioning techniques as indicated in Table 2 can be currently configured and performed based on the requirements of the LMF and UE capabilities. The transmission of Positioning Reference Signals (PRS) enable the UE to perform UE positioning-related measurements to enable the computation of a UE's location estimate and are configured per Transmission Reception Point (TRP), where a TRP may transmit one or more beams.

[0105] Table 3 lists RS-to-measurements mapping for each of the supported RAT-dependent positioning techniques at the UE. UE positioning measurements such as Reference Signal Time Difference ("RSTD") and PRS RSRP measurements are made between beams as opposed to different cells as was the case in LTE. In addition, there are additional UL positioning methods for the network to exploit in order to compute the target UE's location. Table 3 lists the RS-to-measurements mapping required for each of the supported RAT-dependent positioning techniques at the UE, and Table 4 (below) lists the RS-to-measurements mapping required for each of the supported RAT-dependent positioning techniques at the gNB.

Table 3: UE Measurements to enable RAT-dependent positioning techniques

DL/UL Reference Signals	UE Measurements	To facilitate support of the following positioning techniques
Rel-16 DL PRS	DL RSTD	DL-TDOA
Rel-16 DL PRS	DL PRS RSRP	DL-TDOA, DL-AoD, Multi-RTT
Rel-16 DL PRS / Rel-16 SRS for positioning	UE Rx-Tx time difference	Multi-RTT
Rel. 15 SSB / CSI-RS for RRM	SS-RSRP(RSRP for RRM), SS-RSRQ(for RRM), CSI-RSRP (for RRM), CSI-RSRQ (for RRM), SS-RSRPB (for RRM)	E-CID

[0106] RAT-dependent positioning techniques involve the 3GPP RAT and core network entities to perform the position estimation of the UE, which are differentiated from RAT-independent positioning techniques which rely on Global Navigation Satellite System ("GNSS"), Inertial Measurement Unit ("IMU") sensor, WLAN and Bluetooth technologies for performing target device (i.e., UE) positioning.

[0107] Table 4 lists RS-to-measurements mapping for each of the supported RAT-dependent positioning techniques at the gNB. RAT-dependent positioning techniques involve the 3GPP RAT and core network entities to perform the position estimation of the UE, which are differentiated from RAT-independent positioning techniques which rely on GNSS, IMU sensor, WLAN and Bluetooth technologies for performing target device (UE) positioning.

Table 4: gNB Measurements to enable RAT-dependent positioning techniques

DL/UL Reference Signals	gNB Measurements	To facilitate support of the following positioning techniques
Rel-16 SRS for positioning	UL RTOA	UL-TDOA
Rel-16 SRS for positioning	UL SRS-RSRP	UL-TDOA, UL-AoA, Multi-RTT
Rel-16 SRS for positioning, Rel-16 DL PRS	gNB Rx-Tx time difference	Multi-RTT
Rel-16 SRS for positioning,	A-AoA and Z-AoA	UL-AoA, Multi-RTT

PRS Design

[0108] For 3GPP Rel-16, a DL PRS Resource ID in a DL PRS Resource set is associated with a single beam transmitted from a single TRP (a TRP may transmit one or more beams). A DL PRS occasion is one instance of periodically repeated time windows (consecutive slot(s)) where DL PRS is expected to be transmitted. With regards to QCL relations beyond Type-D of a DL PRS resource, support one or more of the following options:

[0109] Option 1: QCL-TypeC from an SSB from a TRP.

[0110] Option 2: QCL-TypeC from a DL PRS resource from a TRP.

[0111] Option 3: QCL-TypeA from a DL PRS resource from TRP.

[0112] Option 4: QCL-TypeC from a CSI-RS resource from a TRP.

[0113] Option 5: QCL-TypeA from a CSI-RS resource from a TRP.

[0114] Option 6: No QCL relation beyond Type-D is supported.

[0115] Note that QCL-TypeA refers to Doppler shift, Doppler spread, average delay, delay spread; QCL-TypeB refers to Doppler shift, Doppler spread'; QCL-TypeC refers to Average delay, Doppler shift; and QCL-TypeD refers to Spatial Rx parameter.

[0116] For a DL PRS resource, QCL-TypeC from an SSB from a TRP (Option 1) is supported. An ID is defined that can be associated with multiple DL PRS Resource Sets associated with a single TRP. An ID is defined that can be associated with multiple DL PRS Resource Sets associated with a single TRP. This ID can be used along with a DL PRS Resource Set ID and a DL PRS Resources ID to uniquely identify a DL PRS Resource. Each TRP should only be associated with one such ID.

[0117] DL PRS Resource IDs are locally defined within DL PRS Resource Set. DL PRS Resource Set IDs are locally defined within TRP. The time duration spanned by one DL PRS Resource set containing repeated DL PRS Resources should not exceed DL-PRS-Periodicity. Parameter DL-*PRS-ResourceRepetitionFactor* is configured for a DL PRS Resource Set and controls how many

times each DL-PRS Resource is repeated for a single instance of the DL-PRS Resource Set. Supported values may include: 1, 2, 4, 6, 8, 16, 32.

[0118] In some implementations, signaling may be defined to support any RAT dependent positioning technique including hybrid RAT dependent positioning solutions.

[0119] As related to NR positioning, the term "positioning frequency layer" refers to a collection of DL PRS Resource Sets across one or more TRPs which have: the same SCS and CP type; the same center frequency; the same point-A; all DL PRS Resources of the DL PRS Resource Set have the same bandwidth; and/or all DL PRS Resource Sets belonging to the same Positioning Frequency Layer have the same value of DL PRS Bandwidth and Start PRB.

[0120] A duration of DL PRS symbols in units of ms may be defined such that a UE can process every T ms assuming 272 PRB allocation is a UE capability. Duration of DL PRS symbols in units of ms a UE can process every T ms assuming 272 PRB allocation is a UE capability.

Measurement and Report Configuration

[0121] UE measurements which are applicable to DL-based positioning techniques are discussed below. For a conceptual overview, the assistance data configurations (see Figure 9) and measurement information (see Figure 10) are provided for each of the supported positioning techniques.

[0122] Figure 4 depicts an example of DL-TDOA assistance data 400 including a *NR-DL-TDOA-ProvideAssistanceData* information element ("IE") that may be used by the location server to provide assistance data to enable UE-assisted and UE-based NR downlink TDOA. It may also be used to provide NR DL TDOA positioning specific error reason. However, as depicted, the *NR-DL-TDOA-ProvideAssistanceData* IE does not provide assistance data specific to SL angular-based positioning such as the SL-AoD/AoA or SL-RRM positioning techniques disclosed herein. Accordingly, to implement the various embodiments of SL angular and/or SL-RRM-based positioning disclosed herein, it may be useful to use a provide assistance data IE that includes information specific to SL angular-based positioning such as SL-AoD/AoA or SL-RRM based positioning.

[0123] Figure 5 depicts an example of a DL-TDOA measurement report 500 including a *NR-DL-TDOA-SignalMeasurementInformation* IE that may be used by the target device to provide NR-DL TDOA measurements to the location server. The measurements are provided as a list of TRPs, where the first TRP in the list is used as reference TRP in case RSTD measurements are reported. The first TRP in the list may or may not be the reference TRP indicated in the *NR-DL-PRS-AssistanceData*.

Furthermore, the target device selects a reference resource per TRP, and compiles the measurements per TRP based on the selected reference resource. However, as depicted, the *NR-DL-TDOA-SignalMeasurementInformation* IE does not provide angle of departure and/or angle or arrival measurement information specific to SL angular-based or range-based positioning such as SL-AoD and/or SL-AoA disclosed herein. Accordingly, to implement the various embodiments of SL angular-based positioning disclosed herein, it may be useful to use an information element that includes information specific to SL angular-based positioning such as such as SL-AoD and/or SL-AoA or SL-RRM based positioning.

[0124] Further details about the the types of information that may be beneficially included are described below with respect to tables 6 and 7 for SL-TDOA based positioning and table 9 for SL-RRM based positioning.

RAT-dependent Positioning Measurements

[0125] Table 5 lists various DL Measurements used for DL-based positioning methods. The different DL measurements include DL PRS-RSRP, DL RSTD and UE Rx-Tx Time Difference required for the supported RAT-dependent positioning techniques are shown in Table 5.

Table 5: DL Measurements required for DL-based positioning methods

DL PRS reference signal received power (DL PRS-RSRP)	
Definition	DL PRS reference signal received power (DL PRS-RSRP), is defined as the linear average over the power contributions (in [W]) of the resource elements that carry DL PRS reference signals configured for RSRP measurements within the considered measurement frequency bandwidth. For frequency range 1, the reference point for the DL PRS-RSRP shall be the antenna connector of the UE. For frequency range 2, DL PRS-RSRP shall be measured based on the combined signal from antenna elements corresponding to a given receiver branch. For frequency range 1 and 2, if receiver diversity is in use by the UE, the reported DL PRS-RSRP value shall not be lower than the corresponding DL PRS-RSRP of any of the individual receiver branches.
Applicable for	RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency
DL reference signal time difference (DL RSTD)	

Definition	DL reference signal time difference (DL RSTD) is the DL relative timing difference between the positioning node *j* and the reference positioning node *i*, defined as $T_{SubframeRxj} - T_{SubframeRxi}$, Where: $T_{SubframeRxj}$ is the time when the UE receives the start of one subframe from positioning node *j*; and $T_{SubframeRxi}$ is the time when the UE receives the corresponding start of one subframe from positioning node *i* that is closest in time to the subframe received from positioning node *j*. Multiple DL PRS resources can be used to determine the start of one subframe from a positioning node. For frequency range 1, the reference point for the DL RSTD shall be the antenna connector of the UE. For frequency range 2, the reference point for the DL RSTD shall be the antenna of the UE.
Applicable for	RRC_CONNECTED intra-frequency RRC_CONNECTED inter-frequency
UE Rx – Tx time difference	
Definition	The UE Rx – Tx time difference is defined as $T_{UE-RX} - T_{UE-TX}$ Where: T_{UE-RX} is the UE received timing of downlink subframe #*i* from a positioning node, defined by the first detected path in time; and T_{UE-TX} is the UE transmit timing of uplink subframe #*j* that is closest in time to the subframe #i received from the positioning node. Multiple DL PRS resources can be used to determine the start of one subframe of the first arrival path of the positioning node. For frequency range 1, the reference point for T_{UE-RX} measurement shall be the Rx antenna connector of the UE and the reference point for T_{UE-TX} measurement shall be the Tx antenna connector of the UE. For frequency range 2, the reference point for T_{UE-RX} measurement shall be the Rx antenna of the UE and the reference point for T_{UE-TX} measurement shall be the Tx antenna of the UE.
Applicable for	RRC_CONNECTED intra-frequency RRC_CONNECTED inter-frequency

[0126] The following measurement configurations are specified:

[0127] Four pairs of DL RSTD measurements can be performed per pair of cells. Each measurement is performed between a different pair of DL PRS Resources/Resource Sets with a single reference timing.

[0128] Eight DL PRS RSRP measurements can be performed on different DL PRS resources from the same cell.

Sidelink angular-based and SL RRM-based positioning

[0129] The present disclosure provides various solutions for SL RAT-dependent positioning techniques related to angular-based and SL RRM-based methods: One or more embodiments disclose a method for a target UE to estimate the TX-RX distance between itself and other proximal UEs based on angular characteristics of the SL PRS signal, e.g., Angle-of-Departure, Angle-of-Arrival and/or using the SL PRS measurement metrics.

[0130] Beneficially, such embodiments enable multiple SL TRPs/beams from different UEs to be exploited to perform accurate angular measurements. Furthermore, certain embodiments require only one anchor node with a known location and in the case of a non-anchor node, location assistance information can be exchanged with the anchor node or with the gNB/LMF (e.g., using Mode 1 operations). Moreover, in one or more embodiments, a method is disclosed for a target UE and/or LMF to estimate the distance between the target UE and one or more UEs as well as absolute or relative location using SL RRM measurements.

[0131] In such embodiments, beneficially, the target UE does not require SL-specific positioning related reference signals for location or distance estimation, which reduces signaling overhead and complexity at the cost of location accuracy. Furthermore, such embodiments may be suited for Mode 2 operations for obtaining the course accuracy of a target UE and does not depend on network coverage (RAT-independent positioning).

[0132] Multi-antenna systems have enabled the implementation of positioning methods, which exploit angular measurements at the transmitter (AoD) and receiver (AoA) to compute the TX-RX distance. The use of angular-based positioning techniques in SL can greatly benefit distributed nodes and the lack of synchronization between nodes can simplify the overall implementation of such positioning schemes. The use of SL RRM measurement can lower the complexity of positioning methods at the cost of accuracy and therefore can be applied in scenarios/applications, where course accuracy is required.

[0133] Various examples of the disclosed subject matter are disclosed below and referred to herein as Embodiments 1, 2, and 3. Many aspects of embodiments 1-3 may be implemented in combination with each other for certain reasons, such as for example, to achieve an improved location accuracy estimate. Moreover, various aspects of embodiments disclosed in U.S. Provisional Patent Application Number 63/063,836 titled "Sidelink Timing-Based Positioning Methods and/or U.S. Provisional Patent Application Number 63/063,824 titled "Apparatuses, Methods, And System For SL PRS Transmission Methodology which are incorporated herein by reference may be implemented in combination with the embodiments in this disclosure.

Embodiment 1: SL-AoD/AoA positioning

[0134] The SL AoD/AoA may also be used to determine the absolute and relative location of a SL UE with respect to another reference UE. The advantage of this technique is that the distance/range can be computed using only one anchor node and a target UE. This embodiment describes additional enhancements for SL angular-based positioning methods including SL-AoA and SL-AoD to enhance to the overall location estimation accuracy at the target UE.

Embodiment 1a): SL-AoD/AoA positioning UE-assisted procedures

[0135] Embodiment 1a discloses certain scenarios where SL-AoD/AoA positioning can be performed over multiple SL TRPs originating from multiple UEs. This is mainly applicable for UE-assisted positioning and includes signaling mechanisms for the AoD/AoA measurements to be reported to the LMF in addition to the SL-PRS RSRP measurements.

[0136] Figure 6 illustrates an example implementation of a SL-AoD procedure 600 for UE-assisted positioning, which can also be extended to be configured using multiple TRPs or multiple beams 620a...620n, 625a... 625n from multiple anchor nodes 610, 615.

[0137] It can be observed that UE-1 610 and UE-2 615 act as reference nodes with respect to the target UE 605 for the SL-AoD procedure 600.

[0138] According to Figure 6, it can be noted that the target UE 605 performs at least two sets of SL-RSRP measurements with respect to UE-1 610 and UE-2 615. The target UE 605 then transmits a measurement report 640 to the LMF 635 (Step 2), where the SL-AoD is derived based on the mapping between the SL-RSRP of the SL TRP IDs/SL PRS IDs/SL PRS resource set ID and SL transmit beam information (Step 3). The SL TRP ID or SL PRS ID or SL PRS resource set ID describes the unique SL-PRS resource/resource set 622 that has been transmitted. The SL-AoD is obtained from the SL TRP ID/ SL beam ID/ SL PRS ID/SL PRS resource set ID with the best SL-PRS RSRP and the

AoD may correspond to the azimuth (A-AoD) or zenith (Z-AoD). Prior to the initiation of the SL-AoD procedure, UE-1 610 and UE-2 615 may transmit their spatial direction information (e.g., beam information and/or antenna pattern configurations) to the LMF as indicated in Step 1 of Figure 6.

[0139] The beam information from the associated TRP corresponding to the SL TRP ID/ SL beam ID/ SL PRS ID may be defined with respect to Global Coordinate System (GCS) (e.g., PRS azimuth angle measured counter-clockwise from geographical North, PRS elevation angle measured relative to zenith and positive to the horizontal direction (elevation 0 deg. points to zenith, 90 deg to the horizon)) or Local Coordinate System (LCS) (e.g., azimuth angle is measured counter-clockwise from the x-axis of the LCS, elevation angle is measured relative to the z-axis of the LCS (elevation 0 deg. points to the z-axis, 90 deg to the x-y plane) together with a LCS to GCS translation information (e.g., using angles α (bearing angle), β (downtilt angle) and γ (slant angle) for the translation of a Local Coordinate System (LCS) to a Global Coordinate System (GCS) as defined in TR 38.901).

[0140] In certain implementations, the mapping procedure may be performed at the gNB/ RSU and shared with the LMF via a dedicated interface, e.g., NRPPa. In some implementations gNB TRPs may also be measured at the target UE 605 and in combination with the SL TRPs may be reported to the LMF 635 for an improved accuracy estimate.

[0141] In various implementations, the target UE 605 measures the received phase difference at each antenna element, which phase differences may be translated into AoA measurements and the target UE may use these AoA measurements or report the AoA measurements to the LMF 635 per SL TRP ID/SL PRS ID/SL PRS resource set ID per UE. In some embodiments, the target UE 605 signals both AoA measurements and SL-PRS RSRP measurements to the LMF 625 or gNB 630 and a mapping between these two parameters per SL TRP ID/SL PRS ID/SL PRS resource set ID can be configured at the LMF or gNB side.

Embodiment 1b): SL-AoD/AoA UE-based procedures

[0142] Embodiment, 1b discloses SL-AoD/AoA positioning in the context of UE-based positioning, where the target UE performs the angular-based measurements and computes the location estimate at the target UE as opposed to the LMF (as in Embodiment 1a).

[0143] Figure 7 illustrates an example embodiment of an SL-AoD procedure 700 for UE-based positioning, where the target UE 705 exploits the measured angles of departure or angles of arrival or both to compute its own location estimate. This can also be extended to be configured using multiple beams 720a...720n and multiple reference anchor nodes 710, 715 or both. In various embodiments,

the UE-1 710 and the UE-2 715 act as reference nodes with respect to the target UE 705 for the SL-AoD procedure 700.

[0144] Similar to Embodiment 1a), the target UE 705 measures the SL PRS of each of the SL TRPs/beams 720a...720n, 725a...725n from different UEs (UE-1 710) and (UE-2 715). In such embodiments, the UE-1 710 and the UE-2 715 signal the respective AoD beam information corresponding to its SL PRS transmission with the target UE 705 so that the location estimate may be computed at the target UE 705. It can be noted that this positioning procedure can also operate in a RAT-independent fashion, i.e., in out-of-coverage scenarios. The target UE 705 derives the SL-AoD using the SL TRP ID/ SL beam ID/SL PRS ID mapping with the best SL-PRS RSRP and the derived SL-AoD may correspond to the azimuth (A-AoD) or zenith (Z-AoD) planes.

[0145] In some implementations, the target UE 705 measures the received phase differences at each antenna element and translate these into a AoA measurements to utilize these AoA measurements to compute the TX-RX distance and subsequently its absolute location (for anchor nodes) or relative location (for non-anchor nodes). Alternatively, the target UE 705 may signal both AoA measurements and SL-PRS RSRP measurements to an LMF 635 or gNB 630 or to both and a mapping between the AoA and SL-PRS RSRP parameters per SL TRP ID can be configured at the LMF 635 or gNB 630 side.

Embodiment 1c): SL-AoD configuration and reporting

[0146] Embodiment 1c discloses selected SL configuration parameters that may be utilized to implement Embodiments 1a and 1b.

[0147] Table 6 illustrates various SL-AoD/AoA configuration parameters transmitted by the LMF 635 required at the target UE 605,705. These parameters are further differentiated based on the whether these parameters are required for the LMF 635 (UE-assisted) or SL target UE 605,705 (UE-based) to perform the location estimation.

Table 6: SL-AoD/AoA Configuration parameters from LMF to UE

Configuration Parameter	SL UE-assisted	SL UE-based
PCI, GCI, RSU ID, Source UE-ID, Destination UE-ID, Zone ID, SL TRP ID/SL-PRS ID of candidate NR SL-TRPs from gNBs/RSUs/SL-UEs/VRUs	Yes	Yes
Timing relative to the serving (reference) TRP of candidate NR TRPs/RSUs/SL-UEs/VRUs	Yes	Yes

SL-PRS configuration (e.g., consisting of SL-PRS resource set comprising at least one SL-PRS resource; quasi-collocation relation information (QCL reference RS, QCL type/property of SL-PRS resource) of candidate NR TRPs	Yes	Yes
SL-SSB information of the TRPs (the time/frequency occupancy of SSBs)	Yes	Yes
Spatial direction information (e.g., azimuth, elevation, zenith, etc.,) of the SL-PRS Resources of the SL TRPs served by the gNB/RSU/ RSUs/SL-UEs/VRUs	No	Yes
Geographical coordinates of the TRPs served by the gNBs/RSUs/SL-UEs/VRUs (include a transmission reference location for each SL-PRS Resource/Resource Set ID, reference location for the transmitting antenna of the reference TRP, relative locations for transmitting antennas of other TRPs)	No	Yes

[0148] An RSU ID will provide additional information in terms of identifying which RSU would be transmitting SL, while the Zone ID provides complimentary assistance information for localizing the target UE 605, 705 using the V2X zone concept where a cell is partitioned into rectangular grids based on a geographic reference.

[0149] Table 7 illustrates various SL-AoD/AoA measurement report parameters from UE to LMF. Table shows the exemplary reporting parameters for the SL-AoD/AoA positioning procedure by the target UE 605, 705. If the target UE 605, 705 is out-of-coverage, it may signal this report to the LMF 635 as soon as it enters a network coverage area.

Table 7: SL-AoD and/or SL-AoA measurement report parameters from UE to LMF

Configuration Parameter	SL UE-assisted	SL UE-based
Latitude/Longitude/Altitude, together with uncertainty shape	Yes	Yes
PCI, GCI, Source UE-ID, Destination UE-ID, SL TRP ID/SL-PRS ID, and Zone ID for each measurement	Yes	Yes
SL PRS-RSRP measurement	Yes	Yes
Time stamp of the measurements	Yes	Yes
Time stamp of location estimate	No	Yes
SL-PRS receive beam index	No	Yes

AoD /AoA measurement	Yes	Yes

[0150] When the SL positioning configuration (or SL positioning request) is transmitted by the LMF 635, it may also include the Source L2 ID of the target UE 605, 705 and then the Destination L2 ID is transmitted for anchor UEs to transmit the PRS. The SL PRS resource set 622,722 is configured per Destination L2 ID. The target UE's report to LMF 635 includes the Source L2 ID and the Destination L2 ID for which the positioning request was transmitted. Furthermore, the report 640 from the target UE 605, 705 may multiplex multiple reports from multiple source/destination L2 IDs.

Embodiment 2: SL-RRM-based positioning

[0151] Figure 8 is a diagram illustrating an example procedure 800 for user equipment ("UE")-assisted SL radio resource management ("RRM")-based positioning with one or more UEs serving as reference nodes, in accordance with one or more embodiments of the disclosure.

[0152] Embodiment 2 describes a positioning procedure using the SL interface, which exploits SL-RRM measurements to compute the estimated location of the target UE 805. The disclosed procedure may also be referred to as SL-Enhanced Cell-Zone ID (SL-ECZID) positioning. Beneficially, various implementations of this SL positioning technique are low in complexity and require no transmission of SL-PRS but rather utilize SL RRM measurements of sidelink signals from one or more anchor or non-anchor UEs 810, 815. In certain implementations, the SL-RRM measurement are reported to the LMF 835 (in the case of UE-assisted positioning) or computed at the target UE 805 (in case of UE-based positioning). For certain V2X/positioning applications requiring low-latency and course accuracy, SL positioning using RRM could be employed and configured by the LMF 835 or target UE 805.

[0153] In some implementations, the target UE 805 may use existing SL-RRM measurements from a unicast session, a groupcast session, or a broadcast session as illustrated in Figure 8 or combinations thereof. The target UE 805 may be localized using cell identifiers on a cell level, and beneficially in the case of SL positioning, further granularity may be added using the Zone ID, which can supplement the cell of origin technique employed in the Uu interface. In various examples, the SL-RRM measurements may be used to estimate the TX-RX distance between the reference nodes, i.e., UE-1 810 and UE-2 815 and thus derive the absolute location (for anchor nodes) and relative location (non-anchor) with respect to each of these UEs.

[0154] In some embodiments, the LMF 835 may trigger the reporting of the SL-RRM measurements 820 from the target UE 805. In one or more implementations, the LMF 835 may also request the SL-RRM measurements 820 from the serving gNB/RSU 830 if the target UE 805 has reported this information to the serving gNB/RSU 830.

[0155] In various embodiments, the LMF 835 may also configure the reporting of multiple SL-RRM measurements from multiple anchor/non-anchor nodes.

[0156] Table 8 depicts various SL-RRM measurements 820 (also referred to as metrics) for location estimation, such as for example, certain SL-RRM measurements to be reported. Other SL metrics or measurements such as SL Reference Signal Received Quality ("RSRQ") and Signal-to-Interference-and-Noise Ratio ("SINR") may also be utilized in certain implementations. Certain SL RRM measurements 820 are shown in the Table 8 which may be used by the LMF 835 or the target UE 805 or both to implement TX-RX distance estimation algorithms that rely on the received signal strength, which may not offer the best accuracy when compared to timing-based positioning techniques but which are lower in complexity. In some implementations, the SL RRM measurements 820 are reported per SL TRP ID/SL PRS ID/SL PRS resource set ID per Source-UE in order to associate the correct measurements to the correct source.

Table 8: SL-RRM metrics for location estimation

SL-RRM Metric	Description
PSBCH-RSRP (PSBCH reference signal received power)	PSBCH Reference Signal Received Power (PSBCH-RSRP) is defined as the linear average over the power contributions (in [W]) of the resource elements that carry demodulation reference signals associated with physical sidelink broadcast channel (PSBCH).
PSSCH-RSRP (PSSCH reference signal received power)	PSSCH Reference Signal Received Power (PSSCH-RSRP) is defined as the linear average over the power contributions (in [W]) of the resource elements that carry demodulation reference signals associated with physical sidelink shared channel (PSSCH).
PSCCH-RSRP (PSCCH reference signal received power)	PSCCH Reference Signal Received Power (PSCCH-RSRP) is defined as the linear average over the power contributions (in [W]) of the resource

	elements that carry demodulation reference signals associated with physical sidelink control channel (PSCCH).
SL RSSI (Sidelink received signal strength indicator)	Sidelink Received Signal Strength Indicator (SL RSSI) is defined as the linear average of the total received power (in [W]) observed in the configured sub-channel in OFDM symbols of a slot configured for PSCCH and PSSCH, starting from the 2nd OFDM symbol

[0157] Various implementations of Embodiment 2 disclose a low complexity SL-ECZID (SL-RRM-based) positioning technique that rely on existing SL measurements to localize the target UE 805. In certain implementations, the SL-RRM measurements 820 to be reported may originate from multiple SL TRPs from multiple anchor UE or non-anchor UEs for the absolute and/or relative location estimation.

Embodiment 3: SL Positioning Capability Exchange Signaling

[0158] Figure 9 depicts an example of a signaling procedure 900 between a target UE 905 and a location server (LMF) 910. Prior to performing SL positioning, the LMF 910 may exchange capability signaling with the target UE 905 enquiring whether the target UE 905 to be localized has the required UE features necessary to perform SL-AoD/AoA or SL-ECZID positioning. For example, in some implementations the target UE 905 receives 915 a request from a sidelink configuration source such as the LMF 910 to provide capability information related to the SL AoD and/or SL AoA positioning and in response, the target UE 905 transmits 920 the requested capability information related to the SL AoD, and or SL AoA, angular-based positioning to the sidelink configuration source; and

[0159] Figure 10 depicts an example of a signaling procedure 1000 between the target UE 1005 and the LMF 1010. The target UE 1005 may also request positioning assistance data information for performing SL-AoD/AoA or SL-ECZID positioning. For example, in certain implementations, the target UE 1005 transmits 1015 to the sidelink configuration source such as LMF 1010 a request for assistance data information related to the SL AoD and/or SL AoA positioning and the target UE 1005 receives 1020 the requested assistance data information related to the SL AoD, and or SL AoA, angular-based positioning from the sidelink configuration source e.g., the LMF 1010. In some

embodiments, entities other than the LMF such as UEs, RSUs, gNBs, and the like may serve as sidelink configuration sources.

[0160] As one example illustration of improvements over existing systems, the various implementations of Embodiment 3 include the necessary capability and assistance data information exchange for the respective SL-AoD/AoA and SL-ECZID (SL-RRM-based) positioning techniques.

[0161] Figure 11 depicts a user equipment apparatus 1100 that may be used for sidelink angular-based and SL RRM-based positioning, according to embodiments of the disclosure. In various embodiments, the user equipment apparatus 1100 is used to implement one or more of the solutions described above. The user equipment apparatus 1100 may be one embodiment of the remote unit 105 and/or the UE, described above. Furthermore, the user equipment apparatus 1100 may include a processor 1105, a memory 1110, an input device 1115, an output device 1120, and a transceiver 1125.

[0162] In some embodiments, the input device 1115 and the output device 1120 are combined into a single device, such as a touchscreen. In certain embodiments, the user equipment apparatus 1100 may not include any input device 1115 and/or output device 1120. In various embodiments, the user equipment apparatus 1100 may include one or more of: the processor 1105, the memory 1110, and the transceiver 1125, and may not include the input device 1115 and/or the output device 1120.

[0163] The processor 1105, in one embodiment, may include any known controller capable of executing computer-readable instructions and/or capable of performing logical operations. For example, the processor 1105 may be a microcontroller, a microprocessor, a central processing unit ("CPU"), a graphics processing unit ("GPU"), an auxiliary processing unit, a field programmable gate array ("FPGA"), or similar programmable controller. In some embodiments, the processor 1105 executes instructions stored in the memory 1110 to perform the methods and routines described herein. The processor 1105 is communicatively coupled to the memory 1110, the input device 1115, the output device 1120, and the transceiver 1125.

[0164] In various embodiments, the processor 1105 controls the user equipment apparatus 1100 to implement UE behavior according to one or more of the above described embodiments.

[0165] The memory 1110, in one embodiment, is a computer readable storage medium. In some embodiments, the memory 1110 includes volatile computer storage media. For example, the memory 1110 may include a RAM, including dynamic RAM ("DRAM"), synchronous dynamic RAM ("SDRAM"), and/or static RAM ("SRAM"). In some embodiments, the memory 1110 includes non-volatile computer storage media. For example, the memory 1110 may include a hard disk drive, a flash

memory, or any other suitable non-volatile computer storage device. In some embodiments, the memory 1110 includes both volatile and non-volatile computer storage media.

[0166] In some embodiments, the memory 1110 stores data related to sidelink angular-based and SL RRM-based positioning. For example, the memory 1110 may store various parameters, configurations, policies, and the like as described above. In certain embodiments, the memory 1110 also stores program code and related data, such as an operating system or other controller algorithms operating on the apparatus 1100.

[0167] The input device 1115, in one embodiment, may include any known computer input device including a touch panel, a button, a keyboard, a stylus, a microphone, or the like. In some embodiments, the input device 1115 may be integrated with the output device 1120, for example, as a touchscreen or similar touch-sensitive display. In some embodiments, the input device 1115 includes a touchscreen such that text may be input using a virtual keyboard displayed on the touchscreen and/or by handwriting on the touchscreen. In some embodiments, the input device 1115 includes two or more different devices, such as a keyboard and a touch panel.

[0168] The output device 1120, in one embodiment, is designed to output visual, audible, and/or haptic signals. In some embodiments, the output device 1120 includes an electronically controllable display or display device capable of outputting visual data to a user. For example, the output device 1120 may include, but is not limited to, an LCD display, an LED display, an OLED display, a projector, or similar display device capable of outputting images, text, or the like to a user. As another, non-limiting, example, the output device 1120 may include a wearable display separate from, but communicatively coupled to, the rest of the user equipment apparatus 1100, such as a smart watch, smart glasses, a heads-up display, or the like. Further, the output device 1120 may be a component of a smart phone, a personal digital assistant, a television, a table computer, a notebook (laptop) computer, a personal computer, a vehicle dashboard, or the like.

[0169] In certain embodiments, the output device 1120 includes one or more speakers for producing sound. For example, the output device 1120 may produce an audible alert or notification (e.g., a beep or chime). In some embodiments, the output device 1120 includes one or more haptic devices for producing vibrations, motion, or other haptic feedback. In some embodiments, all, or portions of the output device 1120 may be integrated with the input device 1115. For example, the input device 1115 and output device 1120 may form a touchscreen or similar touch-sensitive display. In other embodiments, the output device 1120 may be located near the input device 1115.

[0170] The transceiver 1125 communicates with one or more network functions of a mobile communication network via one or more access networks. The transceiver 1125 operates under the control of the processor 1105 to transmit messages, data, and other signals and also to receive messages, data, and other signals. For example, the processor 1105 may selectively activate the transceiver 1125 (or portions thereof) at particular times in order to send and receive messages.

[0171] The transceiver 1125 includes at least transmitter 1130 and at least one receiver 1135. One or more transmitters 1130 may be used to provide UL communication signals to a base unit 121, such as the UL transmissions described herein. Similarly, one or more receivers 1135 may be used to receive DL communication signals from the base unit 121, as described herein. Although only one transmitter 1130 and one receiver 1135 are illustrated, the user equipment apparatus 1100 may have any suitable number of transmitters 1130 and receivers 1135. Further, the transmitter(s) 1130 and the receiver(s) 1135 may be any suitable type of transmitters and receivers.

[0172] In one embodiment, the transceiver 1125 includes a first transmitter/receiver pair used to communicate with a mobile communication network over licensed radio spectrum and a second transmitter/receiver pair used to communicate with a mobile communication network over unlicensed radio spectrum. In certain embodiments, the first transmitter/receiver pair used to communicate with a mobile communication network over licensed radio spectrum and the second transmitter/receiver pair used to communicate with a mobile communication network over unlicensed radio spectrum may be combined into a single transceiver unit, for example a single chip performing functions for use with both licensed and unlicensed radio spectrum. In some embodiments, the first transmitter/receiver pair and the second transmitter/receiver pair may share one or more hardware components. For example, certain transceivers 1125, transmitters 1130, and receivers 1135 may be implemented as physically separate components that access a shared hardware resource and/or software resource, such as for example, the network interface 1140.

[0173] In various embodiments, one or more transmitters 1130 and/or one or more receivers 1135 may be implemented and/or integrated into a single hardware component, such as a multi-transceiver chip, a system-on-a-chip, an ASIC, or other type of hardware component. In certain embodiments, one or more transmitters 1130 and/or one or more receivers 1135 may be implemented and/or integrated into a multi-chip module. In some embodiments, other components such as the network interface 1140 or other hardware components/circuits may be integrated with any number of transmitters 1130 and/or receivers 1135 into a single chip. In such embodiment, the transmitters 1130 and receivers 1135 may be logically configured as a transceiver 1125 that uses one more common

control signals or as modular transmitters 1130 and receivers 1135 implemented in the same hardware chip or in a multi-chip module.

[0174] Figure 12 depicts a network equipment apparatus 1200 that may be used for sidelink angular-based and SL RRM-based positioning, according to embodiments of the disclosure. The network equipment apparatus 1200 may be one embodiment of the base unit 121, RAN node, AMF and/or location server, described above. Furthermore, the base network equipment apparatus 1200 may include a processor 1205, a memory 1210, an input device 1215, an output device 1220, and a transceiver 1225. In some embodiments, the input device 1215 and the output device 1220 are combined into a single device, such as a touchscreen. In certain embodiments, the network equipment apparatus 1200 may not include any input device 1215 and/or output device 1220. In various embodiments, the network equipment apparatus 1200 may include one or more of: the processor 1205, the memory 1210, and the transceiver 1225, and may not include the input device 1215 and/or the output device 1220.

[0175] The processor 1205, in one embodiment, may include any known controller capable of executing computer-readable instructions and/or capable of performing logical operations. For example, the processor 1205 may be a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or similar programmable controller. In some embodiments, the processor 1205 executes instructions stored in the memory 1210 to perform the methods and routines described herein. The processor 1205 is communicatively coupled to the memory 1210, the input device 1215, the output device 1220, and the transceiver 1225.

[0176] In various embodiments, the network equipment apparatus 1200 is a RAN node. Here, the processor 1205 controls the network equipment apparatus 1200 to perform the gNB/RAN behaviors described herein.

[0177] In various embodiments, the network equipment apparatus 1200 is an AMF. Here, the processor 1205 controls the network equipment apparatus 1200 to perform the AMF behaviors described herein.

[0178] In various embodiments, the network equipment apparatus 1200 is a location server. Here, the processor 1205 controls the network equipment apparatus 1200 to perform the location server behaviors described herein.

[0179] The memory 1210, in one embodiment, is a computer readable storage medium. In some embodiments, the memory 1210 includes volatile computer storage media. For example, the memory 1210 may include a RAM, including dynamic RAM ("DRAM"), synchronous dynamic RAM

("SDRAM"), and/or static RAM ("SRAM"). In some embodiments, the memory 1210 includes non-volatile computer storage media. For example, the memory 1210 may include a hard disk drive, a flash memory, or any other suitable non-volatile computer storage device. In some embodiments, the memory 1210 includes both volatile and non-volatile computer storage media.

[0180] In some embodiments, the memory 1210 stores data related to sidelink angular-based and SL RRM-based positioning. For example, the memory 1210 may store various parameters, configurations, policies, and the like as described above. In certain embodiments, the memory 1210 also stores program code and related data, such as an operating system or other controller algorithms operating on the network equipment apparatus 1200.

[0181] The input device 1215, in one embodiment, may include any known computer input device including a touch panel, a button, a keyboard, a stylus, a microphone, or the like. In some embodiments, the input device 1215 may be integrated with the output device 1220, for example, as a touchscreen or similar touch-sensitive display. In some embodiments, the input device 1215 includes a touchscreen such that text may be input using a virtual keyboard displayed on the touchscreen and/or by handwriting on the touchscreen. In some embodiments, the input device 1215 includes two or more different devices, such as a keyboard and a touch panel.

[0182] The output device 1220, in one embodiment, is designed to output visual, audible, and/or haptic signals. In some embodiments, the output device 1220 includes an electronically controllable display or display device capable of outputting visual data to a user. For example, the output device 1220 may include, but is not limited to, an LCD display, an LED display, an OLED display, a projector, or similar display device capable of outputting images, text, or the like to a user. As another, non-limiting, example, the output device 1220 may include a wearable display separate from, but communicatively coupled to, the rest of the network equipment apparatus 1200, such as a smart watch, smart glasses, a heads-up display, or the like. Further, the output device 1220 may be a component of a smart phone, a personal digital assistant, a television, a table computer, a notebook (laptop) computer, a personal computer, a vehicle dashboard, or the like.

[0183] In certain embodiments, the output device 1220 includes one or more speakers for producing sound. For example, the output device 1220 may produce an audible alert or notification (e.g., a beep or chime). In some embodiments, the output device 1220 includes one or more haptic devices for producing vibrations, motion, or other haptic feedback. In some embodiments, all, or portions of the output device 1220 may be integrated with the input device 1215. For example, the

input device 1215 and output device 1220 may form a touchscreen or similar touch-sensitive display. In other embodiments, the output device 1220 may be located near the input device 1215.

[0184] The transceiver 1225 includes at least one transmitter 1230 and at least one receiver 1235. One or more transmitters 1230 may be used to communicate with the UE, as described herein. Similarly, one or more receivers 1235 may be used to communicate with network functions in the PLMN and/or RAN, as described herein. Although only one transmitter 1230 and one receiver 1235 are illustrated, the network equipment apparatus 1200 may have any suitable number of transmitters 1230 and receivers 1235. Further, the transmitter(s) 1230 and the receiver(s) 1235 may be any suitable type of transmitters and receivers.

[0185] In various embodiments, one or more transmitters 1230 and/or one or more receivers 1235 may be implemented and/or integrated into a single hardware component, such as a multi-transceiver chip, a system-on-a-chip, an ASIC, or other type of hardware component. In certain embodiments, one or more transmitters 1230 and/or one or more receivers 1235 may be implemented and/or integrated into a multi-chip module. In some embodiments, other components such as the network interface 1240 or other hardware components/circuits may be integrated with any number of transmitters 1230 and/or receivers 1235 into a single chip. In such embodiment, the transmitters 1230 and receivers 1235 may be logically configured as a transceiver 1225 that uses one more common control signals or as modular transmitters 1230 and receivers 1235 implemented in the same hardware chip or in a multi-chip module.

[0186] Figure 13 depicts one embodiment of a method 1300 for sidelink angular-based, according to one or more embodiments of the disclosure. In various embodiments, the method 1300 is performed by at least one target UE in a communication network that includes a base station, the target User Equipment (UE), at least one reference node, and a LMF that may be implemented in a location server . In some embodiments, the one or more reference nodes and the one target UE are configured to transmit SL PRS or other SL signals over multiple SL TRPs.

[0187] In one or more examples, the method 1300 includes receiving 1305 from a sidelink configuration source, SL PRS assistance data associated with multiple SL signal transmissions that serve as reference signal transmissions such as beam transmissions, antenna panel transmissions, or combinations of both, transmitted from one or more SL signal transmitting devices such as UEs, RSU, and the like. The method 1300 continues and includes receiving 1310 the multiple SL signal transmissions that server as reference signals from the one or more SL signal transmitting devices. The method 1300 continues and includes, in some embodiments, performing 1315 SL signal angle of

arrival ("AoA") measurements of the received SL reference signal transmissions and in various embodiments performing SL reference signal reference signal received power ("RSRP") measurements for deriving angle of departure (AoD) calculations which are then mapped to the received SL RSRP measurements for determining an estimated location of the target UE using SL AoD or SL AoA positioning techniques or combinations thereof.

[0188] Although the method 1300 is depicted from a UE perspective, corresponding steps may be performed by other entities in the communications network such as location servers, LMFs, gNB, RSUs, and so forth. In some embodiments, the method 1300 is performed by one or more processors, such as a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or the like.

[0189] Figure 14 depicts an example of a method 1400 for SL RRM-based positioning, according to one or more embodiments of the disclosure. In some embodiments, the method is for a location server in a communication network comprising at least a base station, at least one anchor/non-anchor reference node, a least one target UE to be localized, and the location server, wherein the anchor reference node and/or the non-anchor reference node transmit a SL beam-based unicast signal and/or a groupcast signal and/or a broadcast signal via the PSBCH, PSCCH, and/or PSSCH for the purposes of providing control and/or data and/or positioning.

[0190] For example, in various embodiments, method 1400 includes performing 1405 one or more sidelink ("SL") radio resource management ("RRM") measurements such as measurements of: physical sidelink broadcast channel ("PSBCH") reference signal received power ("RSRP"), physical sidelink shared channel ("PSSCH") RSRP, physical sidelink control channel("PSCCH") RSRP, SL channel-state reference signals ("CSI-RS"), SL synchronization signals ("SLSS"), and combinations thereof. The method 1400 may include performing 1405 measurements of other SL parameters such as for example, SL Channel Occupancy Ratio, SL Channel Busy Ratio, or other SL measurements. The method 1400 continues and includes determining 1410 an estimated location of the target UE based on selected SL-RRM measurements. In certain implementations, in response to being configured for UE-assisted SL range-based positioning, the method includes reporting the selected RRM measurements to an LMF configured to estimate the location of the target UE based on the reported RRM measurements.

[0191] The method 1400 begins the location server configures 1405 the target UE to report the SL-RRM metrics if configured with the SL-RRM-based (SL-ECZID) positioning technique. The method 1400 continues and the location server processes 1410 the SL-RRM measurements from the

target UE to calculate the absolute location and/or relative location with respect to other anchor and/or non-anchor UEs. The method 1400 ends. Although the method 1400 is depicted from a UE perspective, corresponding steps may be performed by other entities in the communications network such as location servers, LMFs, gNB, RSUs, and so forth. In various embodiments, the method 1400 is performed by a processor, such as a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or the like.

[0192] Various actions of the method 1300 and the method 1400 may be performed by one or more apparatuses similar to those shown or described in one or more examples of the disclosure.

[0193] An apparatus for localizing a target UE in a communication network using sidelink ("SL") positioning, the apparatus including a target UE that includes a processor, memory, and program code executable by the processor to cause the target UE to: receive from a sidelink configuration source multiple SL PRS assistance data associated with multiple SL signal transmissions that serve as reference signal transmissions such as beam transmissions, antenna panel transmissions, or combinations thereof, transmitted from one or more SL signal transmitting devices. The apparatus may receive the SL reference signal transmissions from the one or more SL signal transmitting devices and may perform SL signal angle of arrival ("AoA") measurements of the received SL reference signal transmissions and may perform SL reference signal reference signal received power ("RSRP") measurements for deriving angle of departure (AoD) calculations mapped to the received SL RSRP measurements for determining an estimated location of the target UE using SL AoD or SL AoA positioning techniques or combinations thereof.

[0194] In certain embodiments, the sidelink configuration source is selected from a Roadside Unit ("RSU"), a Location Management Function ("LMF"), or a UE other than the target UE and the one or more sidelink transmitting devices are selected from RSUs and UEs other than the target UE.

[0195] In some embodiments, in response to being configured for UE-based SL angular-based positioning, the target UE determines its estimated location based on the configured SL AoA measurements and/or the derived SL AoD calculations mapped to the SL RSRP measurements. In one or more embodiments, in response to being configured for UE-assisted SL angular-based positioning, the target UE reports the SL AoA measurements and/or the SL RSRP measurements to an LMF configured to estimate the location of the target UE based on the SL AoA measurements or based on derived SL AoD calculations mapped to the reported SL RSRP measurements or combinations thereof.

[0196] In various embodiments, the received SL signal transmissions include SL signals such as SL synchronization signals ("SLSS"), SL channel-state information reference signals (SL CSI-RS),

SL positioning reference signals ("SL PRS), and combinations thereof. In some embodiments, the target-UE is configured with a set of IDs selected from: RSU ID, Source UE-ID, Destination UE-ID; Zone ID; SL TRP ID; SL PRS ID; and combinations thereof configured to uniquely identify SL reference signal resources to be measured and/or reported by the target-UE.

[0197] In certain embodiments, the estimated location of the target UE is based on the derived AoD calculations using further spatial direction information selected from azimuth, elevation, zenith, and combinations thereof, corresponding to the received SL signal transmissions. In some embodiments, the estimated location of the target UE is determined for a configured SL AoA based positioning technique using measured phase differences of the SL signal transmissions received at a plurality of receive antenna elements of the target UE.

[0198] In various embodiments, the SL signal transmissions received by the target UE are configured and measured at a plurality of time instances corresponding to points along a trajectory of the target UE. In one or more embodiments, in response to being configured for UE-assisted angular-based positioning, the target UE reports to the LMF, an SL beam index corresponding to a plurality of SL-PRS resource sets.

[0199] A further apparatus for a communication network for localizing a target UE includes a target UE that includes a processor, memory, and program code executable by the processor to cause the target UE to perform one or more sidelink ("SL") radio resource management ("RRM") measurements such as measurements of: physical sidelink broadcast channel ("PSBCH") reference signal received power ("RSRP"), physical sidelink shared channel ("PSSCH") RSRP, physical sidelink control channel ("PSCCH") RSRP, SL channel-state reference signals ("CSI-RS"), SL synchronization signals ("SLSS"), and combinations thereof. In various embodiments, in response to being configured for UE-based SL range-based positioning, the target UE determines its estimated location based on the selected RRM measurements. In some embodiments, in response to being configured for UE-assisted SL range-based positioning, report the selected RRM measurements to an LMF configured to estimate the location of the target UE based on the reported RRM measurements.

[0200] In some embodiments, the target UE differentiates the selected RRM measurements based on identification such as RSU ID, source UE ID, destination UE ID, or combinations thereof. In one or more embodiments, granularity of the estimated location calculation of the target UE is enhanced by using a zone ID corresponding to the target UE at receipt of the SL reference signal transmissions.

[0201] In various embodiments, the target UE performs of or more of the following actions: receiving a request from the sidelink configuration source to provide capability information related to the SL AoD and/or SL AoA positioning and in response, transmitting the requested capability information related to the SL AoD, and or SL AoA, angular-based positioning to the sidelink configuration source; and transmitting to the sidelink configuration source a request for assistance data information related to the SL AoD and/or SL AoA positioning and receiving the requested assistance data information related to the SL AoD, and or SL AoA, angular-based positioning from the sidelink configuration source.

[0202] In certain embodiments, the target UE performs of or more of the following actions: receiving a request from the sidelink configuration source to provide capability information related to the SL RRM range-based positioning and in response, transmitting the requested capability information related to the SL RRM-based positioning to the sidelink configuration source; and transmitting to the sidelink configuration source a request for assistance data information related to the SL RRM range-based positioning and receiving the requested assistance data information related to the SL RRM range-based positioning from the sidelink configuration source.

[0203] A method for sidelink based positioning of a target UE in a communication network, the method selected from a first set of sidelink angular-based positioning techniques that may be selected from SL AoA positioning, SL AoD positioning, or combinations thereof, and a second set of sidelink positioning techniques based on SL-Radio Resource Management ('RRM") measurements, where the first sidelink positioning technique that is SL angular-based includes: receiving a plurality of SL PRS assistance data associated with a plurality of SL signal transmissions that serve as reference signal transmissions and are selected from beam transmissions, and antenna panel transmissions, or combinations thereof, transmitted from one or more SL signal transmitting devices; receiving the SL reference signal transmissions from the one or more SL signal transmitting devices; and performing configured measurements selected from: SL angle of arrival ("AoA") measurements of the received SL reference signal transmissions for determining an estimated location of the target UE using SL AoA positioning techniques; SL reference signal received power ("RSRP") measurements for deriving angle of departure (AoD) calculations mapped to the received SL reference signal transmissions for determining an estimated location of the target UE using SL AoD positioning techniques; and combinations thereof.

[0204] In certain embodiments, the second sidelink positioning technique that is SL RRM-based includes: performing one or more sidelink ("SL") radio resource management ("RRM")

measurement such as measurements of: physical sidelink broadcast channel ("PSBCH") reference signal received power ("RSRP"), physical sidelink shared channel ("PSSCH") RSPR, physical sidelink control channel ("PSCCH") RSRP, SL channel-state reference signals ("CSI-RS"), SL synchronization signals ("SLSS"), and combinations thereof. The method further includes determining the estimated location of the target UE based on the selected RRM measurements.

[0205] Embodiments may be practiced in other specific forms. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

CLAIMS

What is claimed is:

1. A UE apparatus for localizing a target UE in a communication network using sidelink ("SL") positioning, the apparatus comprising a target UE that includes a processor, memory, and program code executable by the processor to cause the target UE to:

receive from a sidelink configuration source a plurality of SL PRS assistance data associated with a plurality of SL signal transmissions that serve as reference signal transmissions and are selected from beam transmissions, antenna panel transmissions, or combinations thereof, transmitted from one or more SL signal transmitting devices;

receive the SL reference signal transmissions from the one or more SL signal transmitting devices; and

perform SL signal angle of arrival ("AoA") measurements of the received SL reference signal transmissions or perform SL reference signal reference signal received power ("RSRP") measurements for deriving angle of departure (AoD) calculations mapped to the received SL RSRP measurements for determining an estimated location of the target UE using SL AoD or SL AoA positioning techniques or combinations thereof.

2. The apparatus of claim 1, wherein :

the sidelink configuration source is selected from a Roadside Unit ("RSU"), a Location Management Function ("LMF"), or a UE other than the target UE;

the one or more sidelink transmitting devices are selected from RSUs and UEs other

than the target UE, wherein:

in response to being configured for UE-based SL angular-based positioning, the target UE determines its estimated location based on the configured SL AoA measurements and/or the derived SL AoD calculations mapped to the SL RSRP measurements; and

in response to being configured for UE-assisted SL angular-based positioning, the target UE reports the SL AoA measurements and/or the SL RSRP measurements to an LMF configured to estimate the location of the target UE based on the SL AoA measurements or based on derived SL AoD calculations mapped to the reported SL RSRP measurements or combinations thereof.

3. The apparatus of claim 2, wherein the received SL signal transmissions comprise SL signals selected from SL synchronization signals ("SLSS"), SL channel-state information reference signals (SL CSI-RS), SL positioning reference signals ("SL PRS), and combinations thereof.

4. The apparatus of claim 2, wherein the target-UE is configured with a set of IDs selected from: RSU ID, Source UE-ID, Destination UE-ID; Zone ID; SL TRP ID; SL PRS ID; and combinations thereof configured to uniquely identify SL reference signal resources to be measured and/or reported by the target-UE.

5. The apparatus of claim 2, wherein the estimated location of the target UE is based on the derived AoD calculations using further spatial direction information selected from azimuth, elevation, zenith, and combinations thereof, corresponding to the received SL signal transmissions.

6. The apparatus of claim 1, wherein the estimated location of the target UE is determined for a configured SL AoA based positioning technique using measured phase differences of the SL signal transmissions received at a plurality of receive antenna elements of the target UE.

7. The apparatus of claim 1, wherein the SL signal transmissions received by the target UE are configured and measured at a plurality of time instances corresponding to points along a trajectory of the target UE.

8. The apparatus of claim 1, wherein in response to being configured for UE-assisted angular-based positioning, the target UE reports to the LMF, an SL beam index corresponding to a plurality of SL-PRS resource sets.

9. An apparatus for a communication network for localizing a target UE, the apparatus comprising a target UE that includes a processor, memory, and program code executable by the processor to cause the target UE to:

perform one or more sidelink ("SL") radio resource management ("RRM") measurements selected from measurements of: physical sidelink broadcast channel ("PSBCH") reference signal received power ("RSRP"), physical sidelink shared channel ("PSSCH") RSRP, physical sidelink control channel ("PSCCH") RSRP, SL channel-state reference signals ("CSI-RS"), SL synchronization signals ("SLSS"), and combinations thereof; and

in response to being configured for UE-based SL range-based positioning, determine its estimated location based on the selected RRM measurements; and

in response to being configured for UE-assisted SL range-based positioning, report

the selected RRM measurements to an LMF configured to estimate the location of the target UE based on the reported RRM measurements.

10. The apparatus according to claim 9, wherein the target UE differentiates the selected RRM measurements based on identification selected from RSU ID, source UE ID, destination UE ID, or combinations thereof.

11. The apparatus of claim 10, wherein granularity of the estimated location calculation of the target UE is enhanced by using a zone ID corresponding to the target UE at receipt of the SL reference signal transmissions.

12. The apparatus of claim **Error! Reference source not found.**, wherein the target UE performs of or more of the following actions:

receiving a request from the sidelink configuration source to provide capability information related to the SL AoD and/or SL AoA positioning and in response, transmitting the requested capability information related to the SL AoD, and or SL AoA, angular-based positioning to the sidelink configuration source; and

transmitting to the sidelink configuration source a request for assistance data information related to the SL AoD and/or SL AoA positioning and receiving the requested assistance data information related to the SL AoD, and or SL AoA, angular-based positioning from the sidelink configuration source.

13. The apparatus of claim **Error! Reference source not found.**, wherein the target UE performs of or more of the following actions:

receiving a request from the sidelink configuration source to provide capability information related to the SL RRM range-based positioning and in response, transmitting the requested capability information related to the SL RRM-based positioning to the sidelink configuration source; and

transmitting to the sidelink configuration source a request for assistance data information related to the SL RRM range-based positioning and receiving the requested assistance data information related to the SL RRM range-based positioning from the sidelink configuration source.

14. A method for sidelink based positioning of a target UE in a communication network, the method selected from a first set of sidelink angular-based positioning techniques selected from SL AoA positioning, SL AoD positioning, or combinations thereof, and a second set of sidelink positioning techniques based on SL-Radio Resource Management ('RRM") measurements, wherein:

the first sidelink positioning technique that is SL angular-based comprises:

receiving a plurality of SL PRS assistance data associated with a plurality of SL signal transmissions that serve as reference signal transmissions and are selected from beam transmissions, and antenna panel transmissions, or combinations thereof, transmitted from one or more SL signal transmitting devices;

receiving the SL reference signal transmissions from the one or more SL signal transmitting devices;

performing configured measurements selected from:

SL angle of arrival ("AoA") measurements of the received SL

reference signal transmissions for determining an estimated location of the target UE using SL AoA positioning techniques;

SL reference signal received power ("RSRP") measurements for deriving angle of departure (AoD) calculations mapped to the received SL reference signal transmissions for determining an estimated location of the target UE using SL AoD positioning techniques; and

combinations thereof.

15. The method of claim 14, wherein the second sidelink positioning technique that is SL RRM-based comprises:

performing one or more sidelink ("SL") radio resource management ("RRM") measurement selected from measurements of: physical sidelink broadcast channel ("PSBCH") reference signal received power ("RSRP"), physical sidelink shared channel ("PSSCH") RSPR, physical sidelink control channel ("PSCCH") RSRP, SL channel-state reference signals ("CSI-RS"), SL synchronization signals ("SLSS"), and combinations thereof; and

determining the estimated location of the target UE based on the selected RRM measurements.

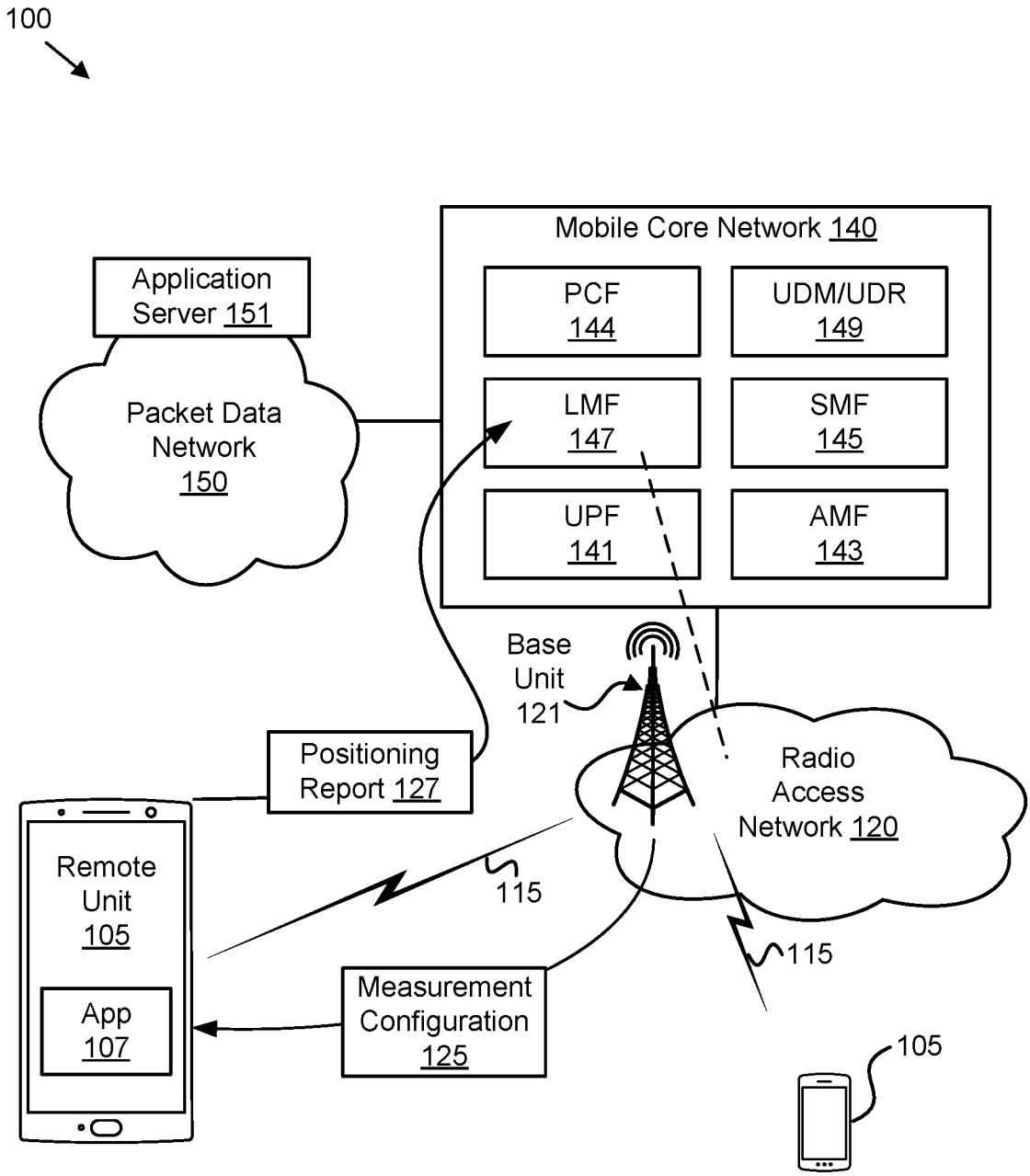

100
Mobile Core Network 140
PCF 144
UDM/UDR 149
LMF 147
SMF 145
UPF 141
AMF 143
Application Server 151
Packet Data Network 150
Base Unit 121
Positioning Report 127
Radio Access Network 120
Remote Unit 105
App 107
115
115
Measurement Configuration 125
105

FIG. 1

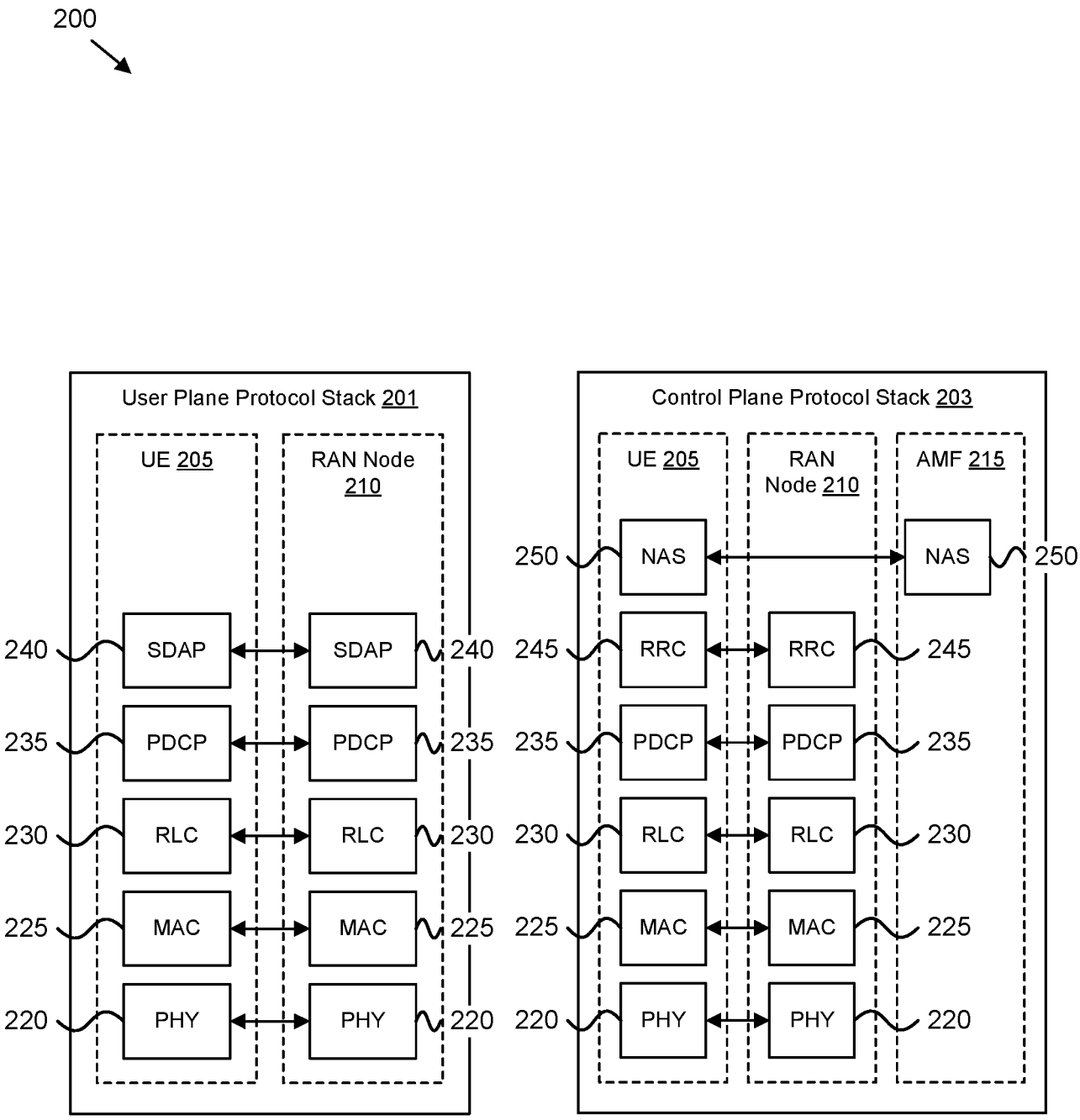

200
User Plane Protocol Stack 201
UE 205
RAN Node 210
SDAP
PDCP
RLC
MAC
PHY
240
235
230
225
220
Control Plane Protocol Stack 203
UE 205
RAN Node 210
AMF 215
NAS
RRC
PDCP
RLC
MAC
PHY
250
245
235
230
225
220

FIG. 2

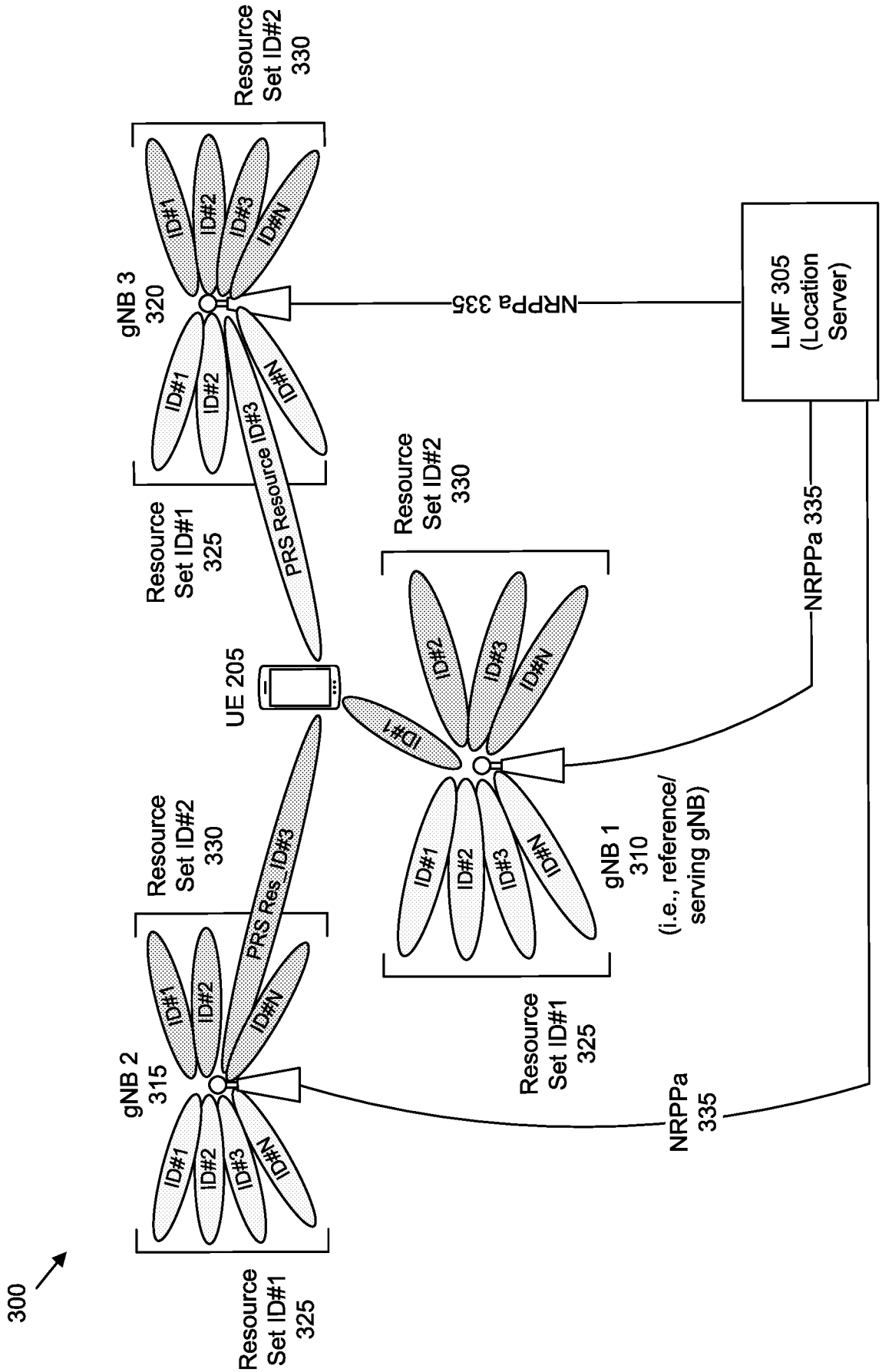

300
gNB 2
315
gNB 3
320
gNB 1
310
(i.e., reference/
serving gNB)
UE 205
LMF 305
(Location
Server)
NRPPa 335
NRPPa
335
NRPPa 335
PRS Resource ID#3
PRS Res_ID#3
Resource
Set ID#1
325
Resource
Set ID#2
330
ID#1
ID#2
ID#3
ID#N

FIG. 3

DL-TDOA Assistance Data 400

```
-- ASN1START

NR-DL-TDOA-ProvideAssistanceData-r16 ::= SEQUENCE {
    nr-DL-PRS-AssistanceData-r16     NR-DL-PRS-AssistanceData-r16                OPTIONAL,  -- Need ON
    nr-SelectedDL-PRS-IndexList-r16  NR-SelectedDL-PRS-IndexList-r16             OPTIONAL,  -- Need ON
    nr-PositionCalculationAssistance-r16  NR-PositionCalculationAssistance-r16   OPTIONAL, -- Cond UEB
    nr-DL-TDOA-Error-r16             NR-DL-TDOA-Error-r16                        OPTIONAL, -- Need ON
    ...
}
-- ASN1STOP
```

FIG. 4

DL-TDOA Measurement Report 500

```
-- ASN1START

NR-DL-TDOA-SignalMeasurementInformation-r16 ::= SEQUENCE {
    dl-PRS-ReferenceInfo-r16     DL-PRS-IdInfo-r16,
    nr-DL-TDOA-MeasList-r16          NR-DL-TDOA-MeasList-r16,
    ...
}

NR-DL-TDOA-MeasList-r16 ::= SEQUENCE (SIZE(1..nrMaxTRPs-r16)) OF
                            NR-DL-TDOA-MeasElement-r16

NR-DL-TDOA-MeasElemnt-r16 ::= SEQUENCE {
    trp-ID-r16                  TRP-ID-r16,
    nr-DL-PRS-ResourceId-r16    NR-DL-PRS-ResourceId-r16                    OPTIONAL,
    nr-DL-PRS-ResourceSetId-r16     NR-DL-PRS-ResourceSetId-r16             OPTIONAL,
    nr-TimeStamp-r16            NR-TimeStamp-r16,
    nr-RSTD-r16                     CHOICE {
           k0-r16                   INTEGER (0..1970049),
           k1-r16                   INTEGER (0..985025),
           k2-r16                   INTEGER (0..492513),
           k3-r16                   INTEGER (0..246257),
           k4-r16                   INTEGER (0..123129),
           k5-r16                   INTEGER (0..61565),
           ...
    },
    nr-AdditionalPathList-r16       NR-AdditionalPathList-r16               OPTIONAL,
    nr-TimingQuality-r16        NR-TimingQuality-r16,
    nr-DL-PRS-RSRP-Result-r16       INTEGER (0..126)                        OPTIONAL,
    nr-DL-TDOA-AdditionalMeasurements-r16
                                NR-DL-TDOA-AdditionalMeasurements-r16       OPTIONAL,
    ...
}

NR-DL-TDOA-AdditionalMeasurements-r16 ::= SEQUENCE (SIZE (1..3)) OF
                                          NR-DL-TDOA-AdditionalMeasurementElement-r16


NR-DL-TDOA-AdditionalMeasurementElement-r16 ::= SEQUENCE {
    nr-DL-PRS-ResourceId-r16    NR-DL-PRS-ResourceId-r16                    OPTIONAL,
    nr-DL-PRS-ResourceSetId-r16     NR-DL-PRS-ResourceSetId-r16             OPTIONAL,
    nr-TimeStamp-r16            NR-TimeStamp-r16,
    nr-RSTD-ResultDiff-r16          CHOICE {
           k0-r16                   INTEGER (0..8191),
           k1-r16                   INTEGER (0..4095),
           k2-r16                   INTEGER (0..2047),
           k3-r16                   INTEGER (0..1023),
           k4-r16                   INTEGER (0..511),
           k5-r16                   INTEGER (0..255),
           ...
    },
    nr-TimingQuality-r16        NR-TimingQuality-r16,
    nr-DL-PRS-RSRP-ResultDiff-r16   INTEGER (0..61)                         OPTIONAL,
    nr-AdditionalPathList-r16       NR-AdditionalPathList-r16               OPTIONAL,
    ...
}

-- ASN1STOP
```

FIG. 5

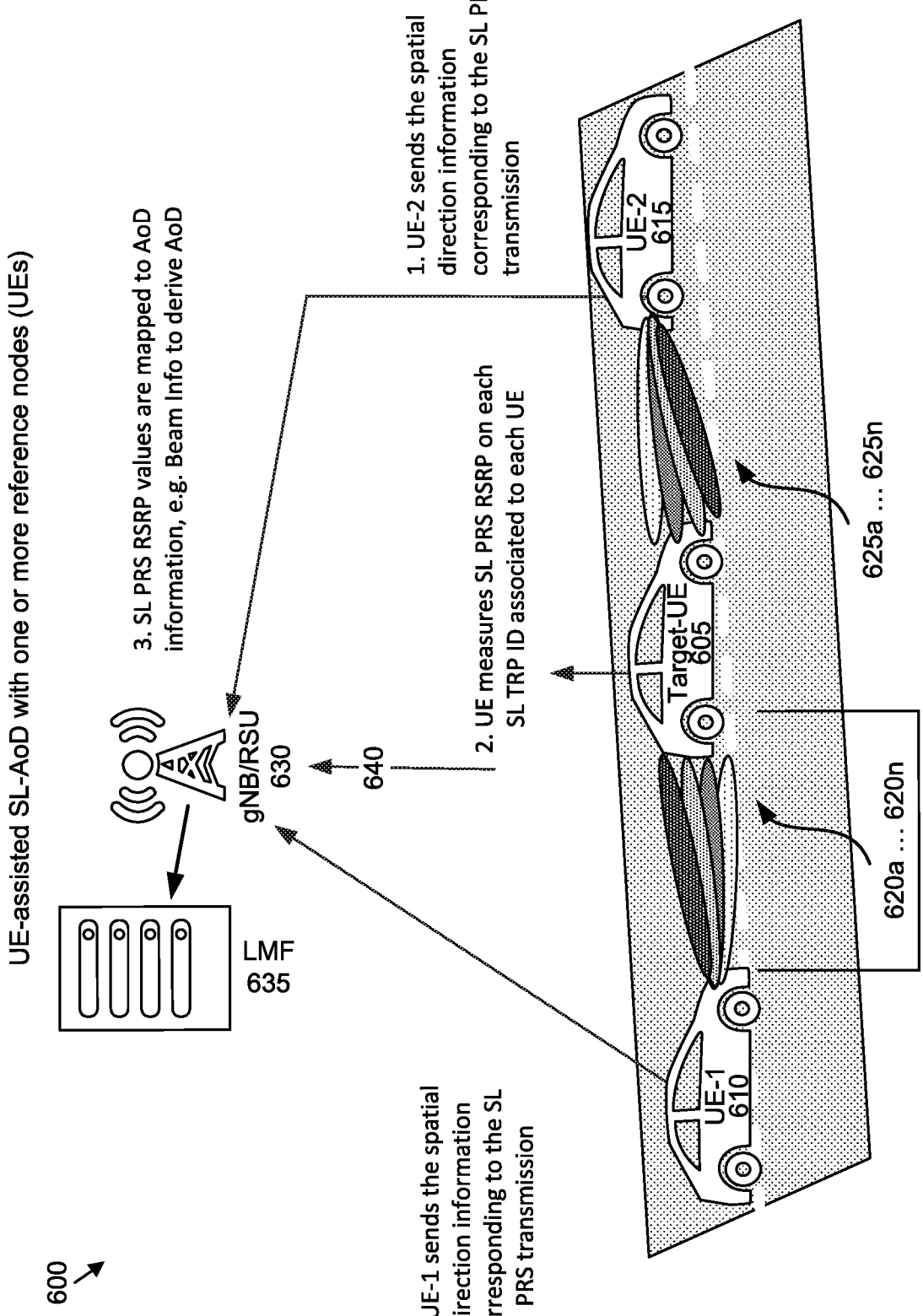

600
UE-assisted SL-AoD with one or more reference nodes (UEs)
LMF
635
gNB/RSU
630
640
3. SL PRS RSRP values are mapped to AoD information, e.g. Beam Info to derive AoD
1. UE-2 sends the spatial direction information corresponding to the SL PRS transmission
2. UE measures SL PRS RSRP on each SL TRP ID associated to each UE
1. UE-1 sends the spatial direction information corresponding to the SL PRS transmission
UE-2
615
Target-UE
605
UE-1
610
625a ... 625n
620a 620n
SL PRS Resource Set 622

FIG. 6

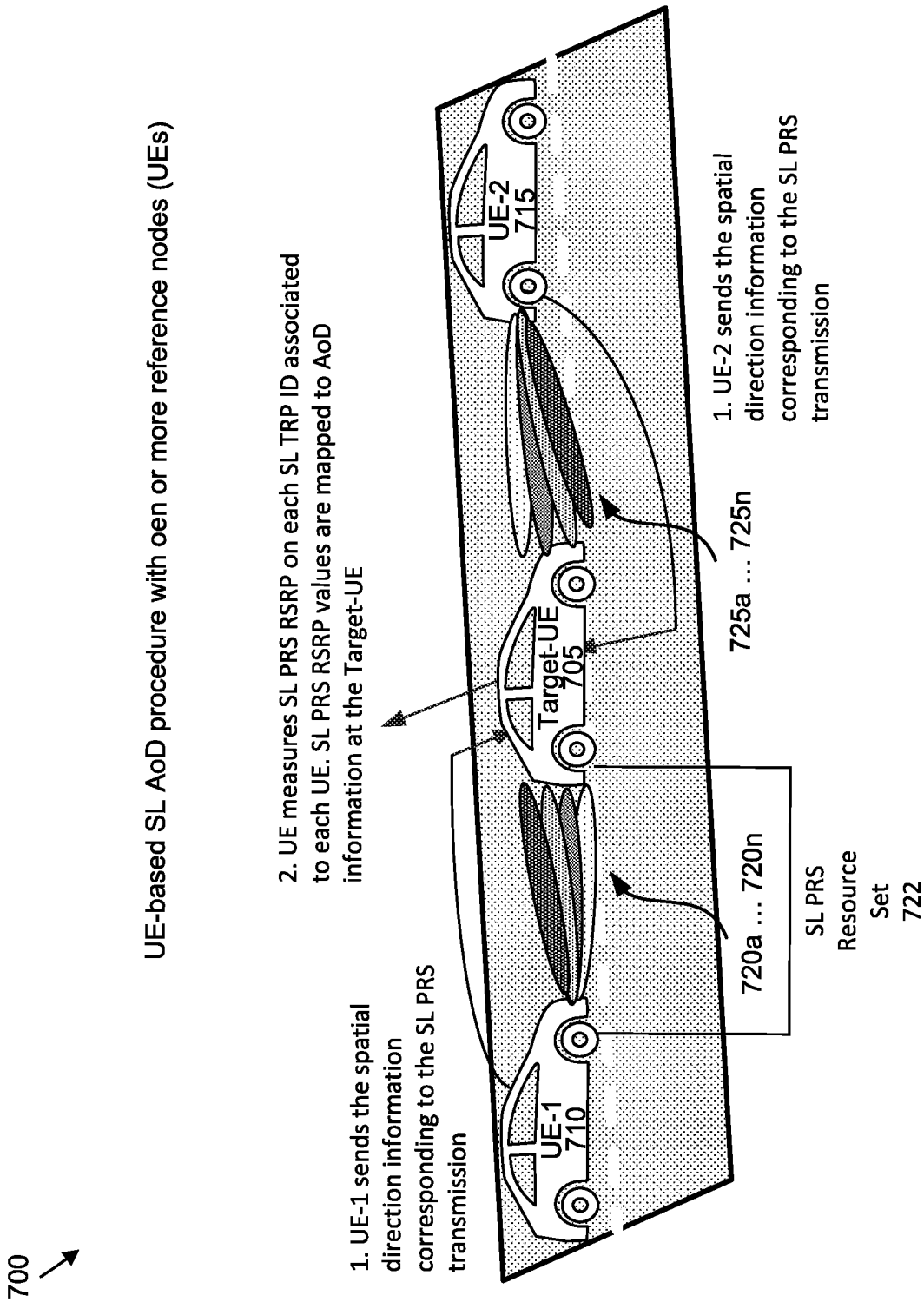

700
UE-based SL AoD procedure with oen or more reference nodes (UEs)
1. UE-1 sends the spatial direction information corresponding to the SL PRS transmission
2. UE measures SL PRS RSRP on each SL TRP ID associated to each UE. SL PRS RSRP values are mapped to AoD information at the Target-UE
1. UE-2 sends the spatial direction information corresponding to the SL PRS transmission
UE-1 710
Target-UE 705
UE-2 715
720a ... 720n
725a ... 725n
SL PRS Resource Set 722

FIG. 7

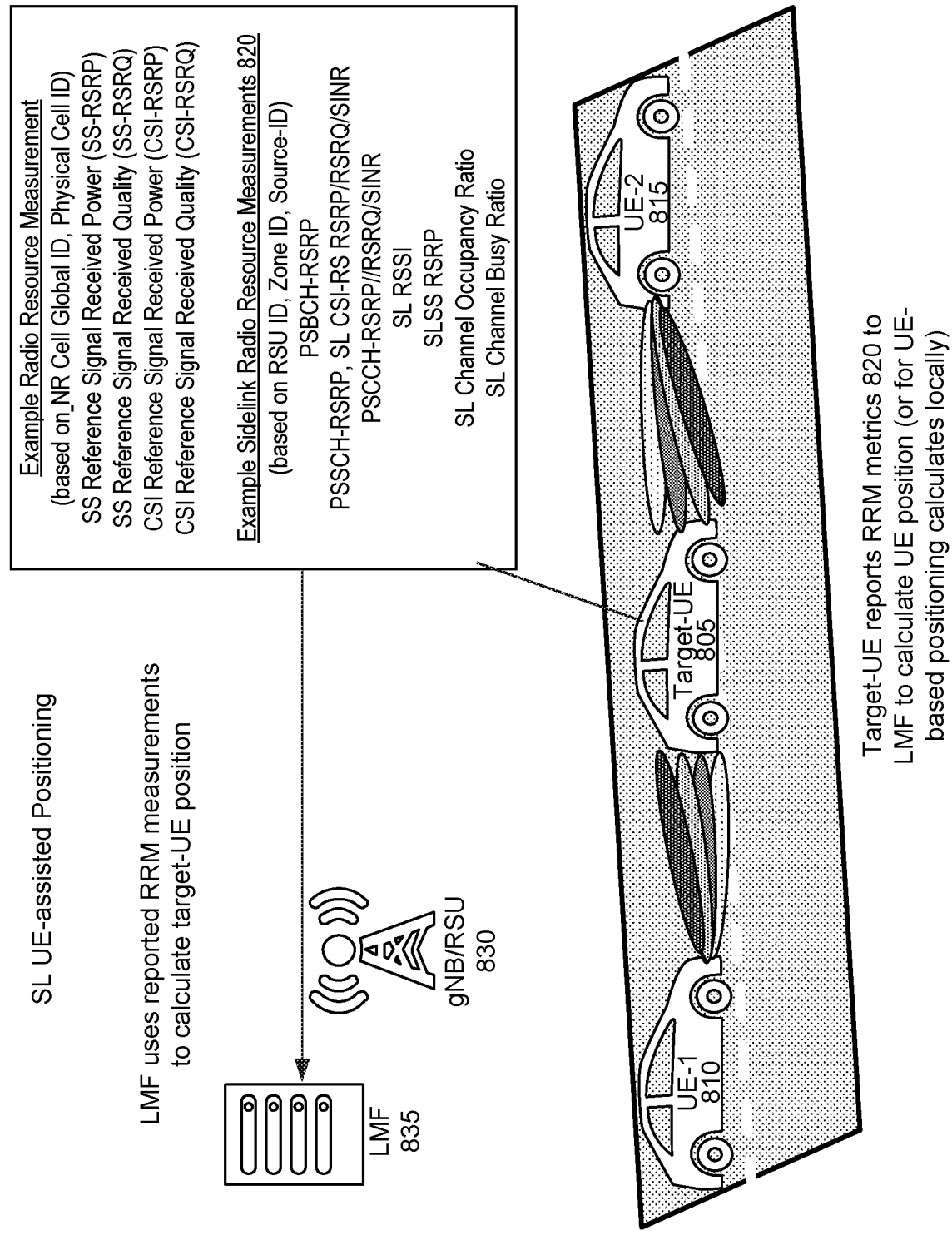

800
SL UE-assisted Positioning
LMF uses reported RRM measurements to calculate target-UE position
Example Radio Resource Measurement
(based on_NR Cell Global ID, Physical Cell ID)
SS Reference Signal Received Power (SS-RSRP)
SS Reference Signal Received Quality (SS-RSRQ)
CSI Reference Signal Received Power (CSI-RSRP)
CSI Reference Signal Received Quality (CSI-RSRQ)
Example Sidelink Radio Resource Measurements 820
(based on RSU ID, Zone ID, Source-ID)
PSBCH-RSRP
PSSCH-RSRP, SL CSI-RS RSRP/RSRQ/SINR
PSCCH-RSRP//RSRQ/SINR
SL RSSI
SLSS RSRP
SL Channel Occupancy Ratio
SL Channel Busy Ratio
LMF 835
gNB/RSU 830
UE-1 810
Target-UE 805
UE-2 815
Target-UE reports RRM metrics 820 to LMF to calculate UE position (or for UE-based positioning calculates locally)

FIG. 8

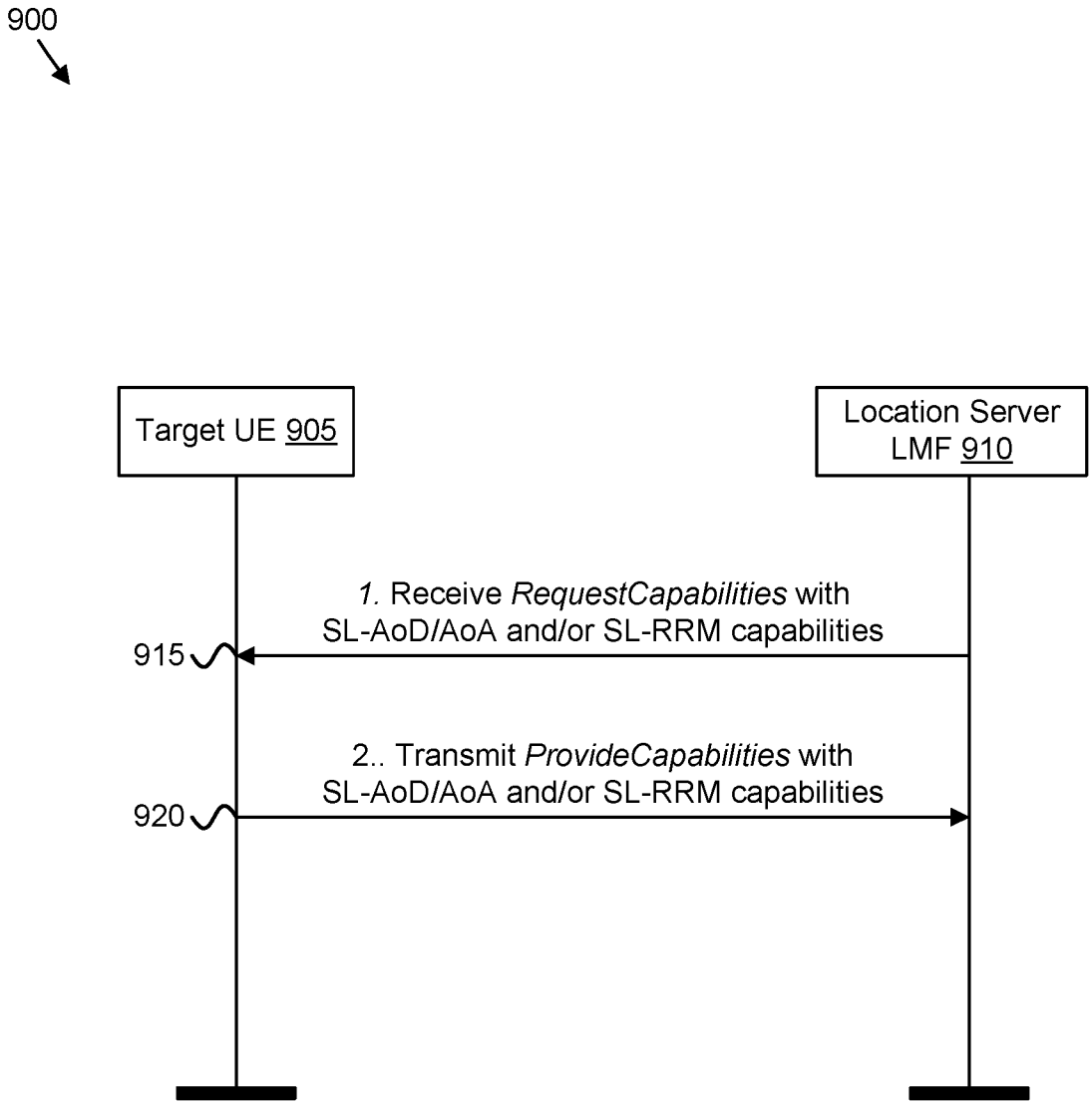

900
Target UE 905
Location Server
LMF 910
1. Receive RequestCapabilities with
SL-AoD/AoA and/or SL-RRM capabilities
915
2.. Transmit ProvideCapabilities with
SL-AoD/AoA and/or SL-RRM capabilities
920

FIG. 9

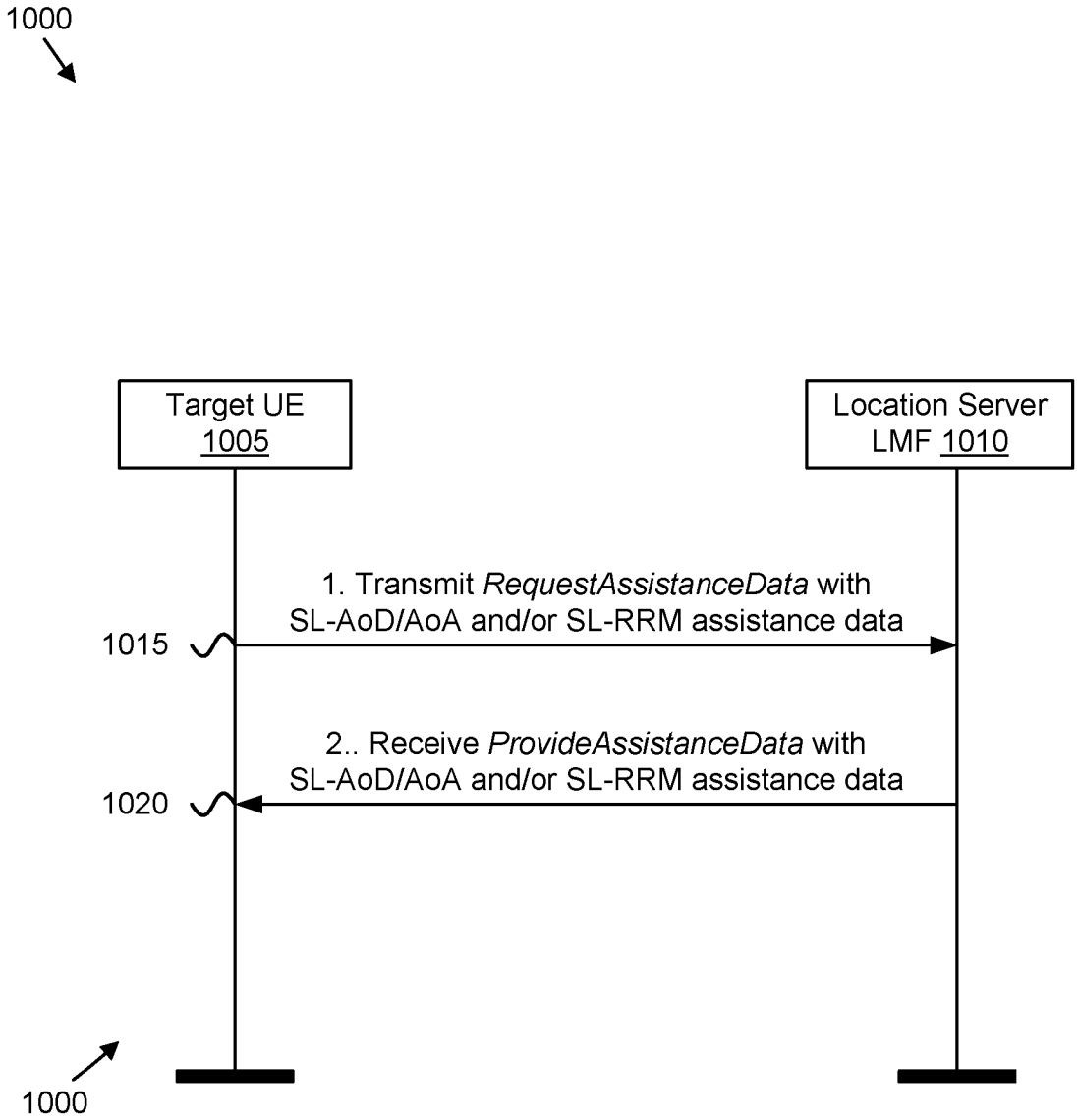

1000
Target UE
1005
Location Server
LMF 1010
1. Transmit *RequestAssistanceData* with
SL-AoD/AoA and/or SL-RRM assistance data
1015
2.. Receive *ProvideAssistanceData* with
SL-AoD/AoA and/or SL-RRM assistance data
1020
1000

FIG. 10

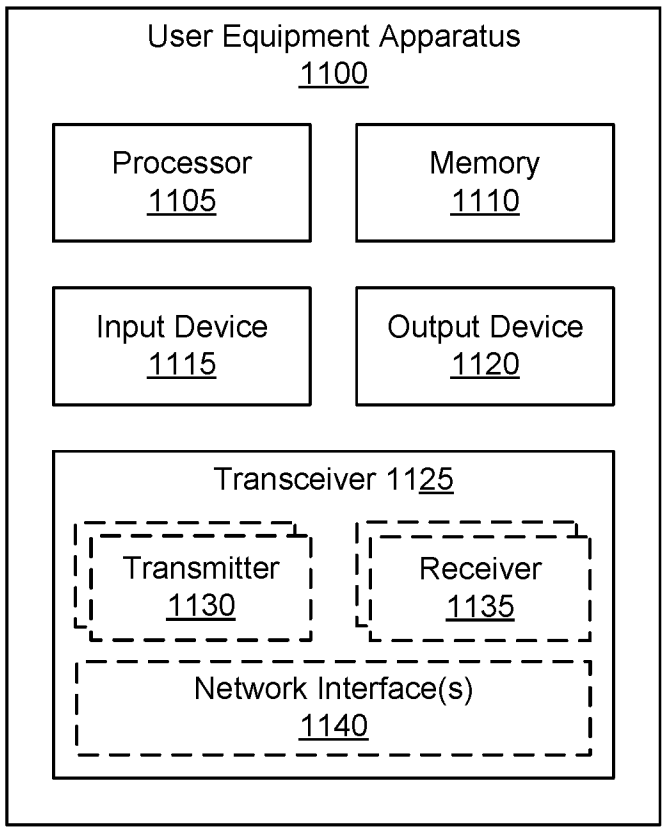

User Equipment Apparatus
1100
Processor
1105
Memory
1110
Input Device
1115
Output Device
1120
Transceiver 1125
Transmitter
1130
Receiver
1135
Network Interface(s)
1140

FIG. 11

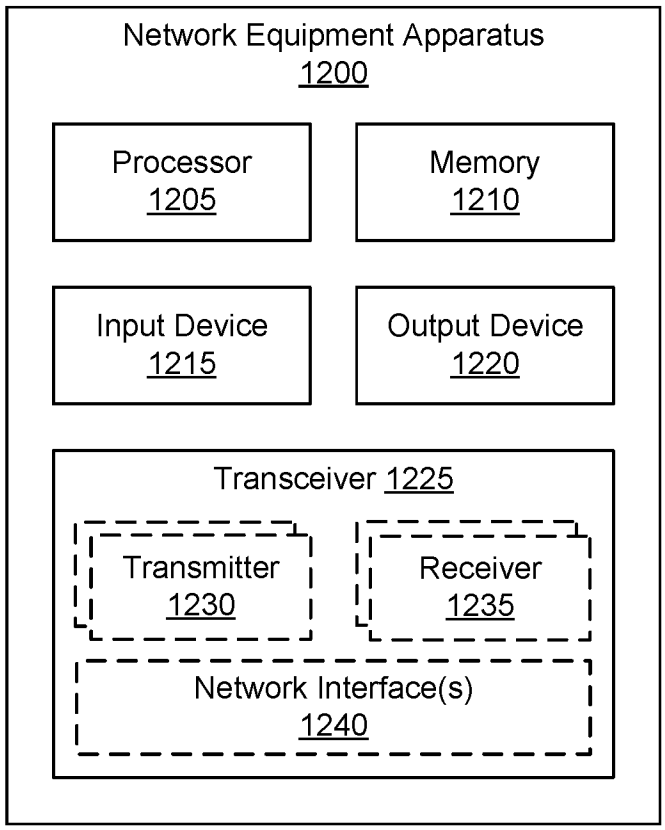

Network Equipment Apparatus
1200
Processor
1205
Memory
1210
Input Device
1215
Output Device
1220
Transceiver 1225
Transmitter
1230
Receiver
1235
Network Interface(s)
1240

FIG. 12

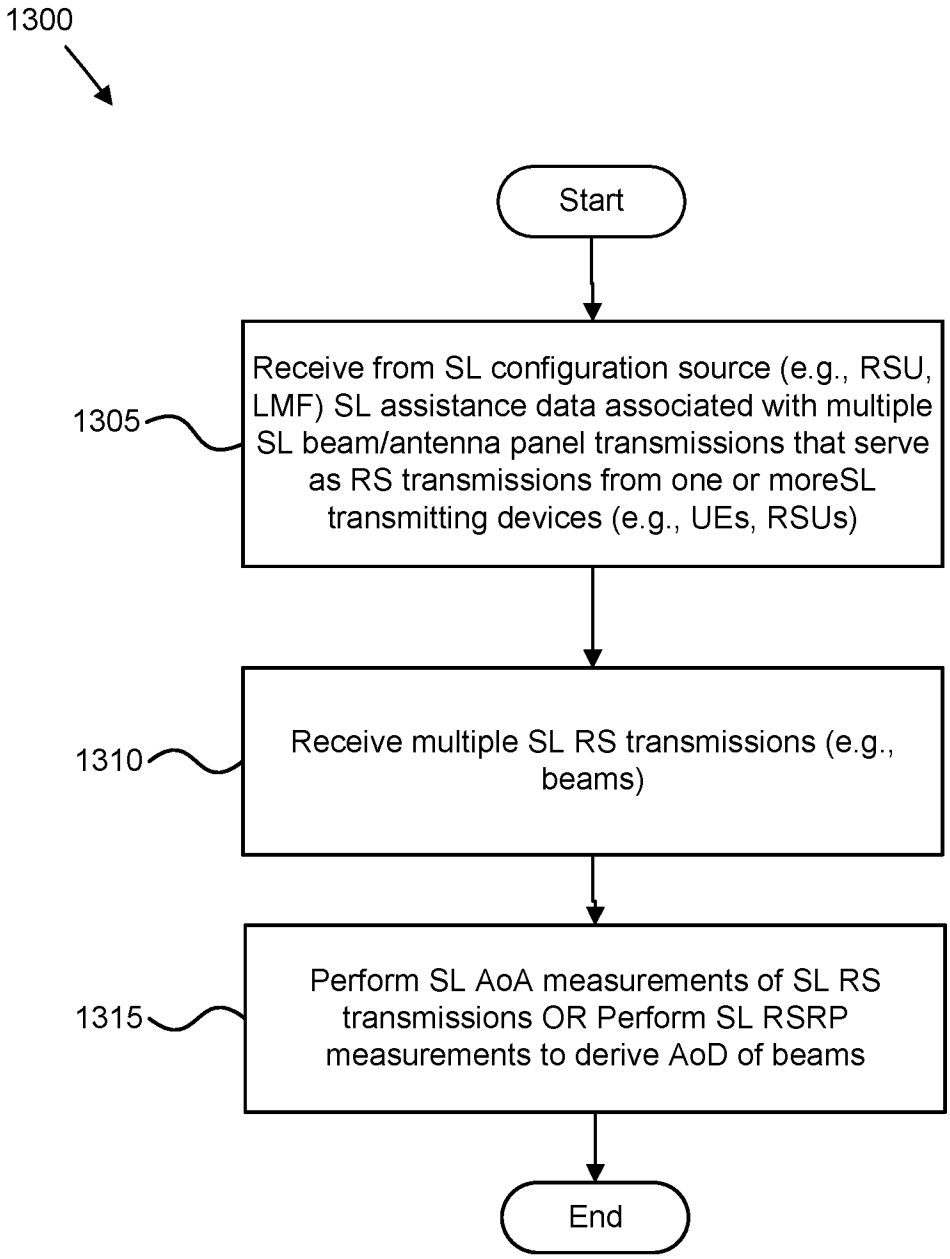

1300
Start
Receive from SL configuration source (e.g., RSU, LMF) SL assistance data associated with multiple SL beam/antenna panel transmissions that serve as RS transmissions from one or moreSL transmitting devices (e.g., UEs, RSUs)
1305
Receive multiple SL RS transmissions (e.g., beams)
1310
Perform SL AoA measurements of SL RS transmissions OR Perform SL RSRP measurements to derive AoD of beams
1315
End

FIG. 13

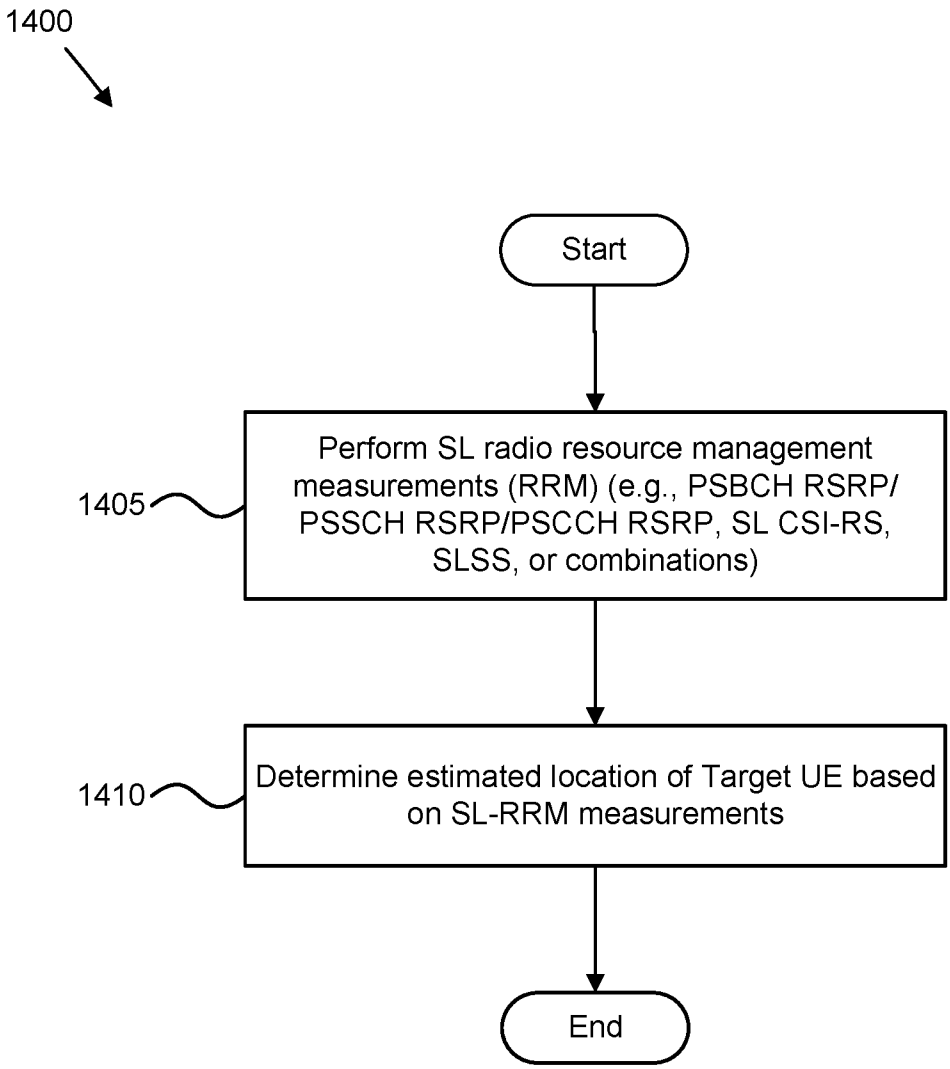

1400
Start
Perform SL radio resource management measurements (RRM) (e.g., PSBCH RSRP/ PSSCH RSRP/PSCCH RSRP, SL CSI-RS, SLSS, or combinations)
1405
Determine estimated location of Target UE based on SL-RRM measurements
1410
End

FIG. 14