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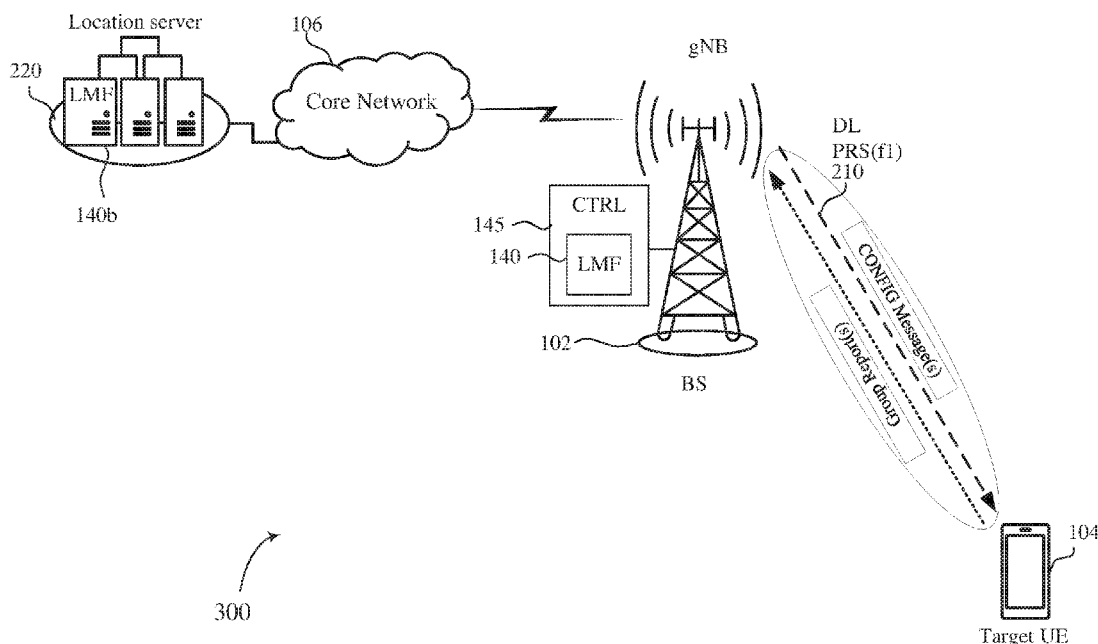


FIG. 3

(57) Abstract: Disclosed are techniques for integer ambiguity (IA) resolution in communication devices. A method includes receiving, from a network apparatus, a configuration message comprising one or more carrier phase positioning measurement configurations for performing downlink (DL) Positioning Reference Signals (PLS) phase measurements used for IA resolution. The method includes receiving, from the network apparatus, one or more downlink (DL) positioning reference signals (PRS). The method also includes performing, based on the one or more carrier phase positioning measurement configurations, carrier phase measurements on at least one frequency characteristic provided by the one or more DL PRS to generate measurement results for resolving integer ambiguity. The method also includes, in response to receiving a measurement reporting configuration message, generating and transmitting, to the network apparatus, a report comprising the measurement results for IA resolution to enable the network apparatus to accurately



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determine a location of the apparatus.

## **CARRIER PHASE POSITIONING MEASUREMENT CONFIGURATION ENHANCEMENTS FOR INTEGER AMBIGUITY RESOLUTION**

### **PRIORITY APPLICATION**

**[0001]** This application claims priority to U.S. Provisional Application No. 63/483,525, filed February 6, 2023, the entire contents of which is incorporated herein by reference.

### **TECHNICAL FIELD**

**[0001]** The present disclosure relates to wireless communications, and more specifically to carrier phase-based positioning of user equipment in wireless communication.

### **BACKGROUND**

**[0002]** A wireless communications system may include one or multiple network communication devices, such as base stations, which may be otherwise known as an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. Each network communication devices, such as a base station may support wireless communications for one or multiple user communication devices, which may be otherwise known as user equipment (UE), or other suitable terminology. The wireless communications system may support wireless communications with one or multiple user communication devices by utilizing resources of the wireless communication system (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers). Additionally, the wireless communications system may support wireless communications across various radio access technologies including third generation (3G) radio access technology, fourth generation (4G) radio access technology, fifth generation (5G) radio access technology, among other suitable radio access technologies beyond 5G (e.g., sixth generation (6G)).

**[0003]** Carrier phase measurement-based positioning is a positioning technique that has been widely used in GNSS (e.g., GPS, GLONASS) for centimeter-level accuracy. Positioning horizontal and vertical stringent accuracy requirements could be met using carrier phase-based positioning, depending on the type of environmental scenario. Although there exists a GPS/GNSS carrier phase positioning framework, there is currently a lack of support

for RAT-dependent carrier phase-based positioning procedures in mobile telecommunication specifications, such as utilized with 4G and 5G technology.

## SUMMARY

**[0004]** The present disclosure relates to methods, apparatuses, and systems that support and provides measurement and reporting configuration related to resolution of integer ambiguity in carrier-phase based positioning of a target device, such as a target user equipment (UE), by configuring the UE to locally perform downlink (DL) Positioning Reference Signals (PRS) phase measurements and provide measurements reports to a network location measurement function (LMF) for integer ambiguity (IA) resolution. By configuring the UE to perform specific types of phase measurements and provide a specific set of reports, the LMF can determine a much more accurate position of the target UE.

**[0005]** Various aspects of the present disclosure relate to an apparatuses and methods for wireless communication. According to a first aspect, some implementations of the method and apparatuses described herein may include a method for wireless communication at a network device. In one or more embodiments, the method includes receiving, from a network apparatus, a configuration message comprising one or more carrier phase positioning measurement configurations for resolving integer ambiguity using frequency-based or timing-based methods. The method includes in response to receiving the configuration message, receiving, from the network apparatus, one or more downlink (DL) positioning reference signals (PRS). The method also includes performing, based on the one or more carrier phase positioning measurement configurations, carrier phase measurements on at least one frequency characteristic provided by the one or more DL PRS to generate measurement results for resolving integer ambiguity. The method also includes, in response to receiving a measurement reporting configuration message, generating and transmitting, to the network apparatus, a report comprising the measurement results for IA resolution to enable the network apparatus to accurately determine a location of the apparatus.

**[0006]** In some implementations of the method and apparatuses described herein, the method further includes receiving a second configuration message comprising a measurement reporting configuration that configures the apparatus to provide a report to the

LMF with IA resolution related measurement results. The method further includes in response to receiving the second configuration message, generating and transmitting, to the network apparatus, a report comprising the measurement results for IA resolution to enable the network apparatus to accurately determine a location of the apparatus.

**[0007]** According to one or more embodiments, some implementations of the method further include grouping phase measurements associated with each transmission reception point and performed over different DL PRS carrier frequencies or different subcarriers, and transmitting the groups of phase measurements within a same report by differentiating each group via a group ID. The transmitted report includes phase measurements performed over the same DL PRS (same in terms of DL PRS configuration and carrier frequency) received at different time instances.

**[0008]** According to one or more embodiments, some implementations of the method further include generating reports comprising different measurements of different DL PRS resource sets in one of a cluster or individually and transmitting different measurements of different positioning frequency layers (PFLs) in different measurement reports.

**[0009]** According to a second aspect, some implementations of the methods and apparatuses described herein may further include a method performed by a network apparatus for wireless communication. In one or more embodiments, the method includes determining which of one or more carrier phase measurements configurations to include in a configuration message for IA resolution. The determining is based on one or more parameters from a group comprising IA search range, IA uncertainty level, positioning target requirements, target apparatus capabilities, and measurement reporting overhead. The method also includes transmitting, to the target apparatus, a first configuration message comprising a selected one or more carrier phase measurement configurations, the selected one or more carrier phase measurement configurations configuring the target apparatus to perform DL PRS phase measurements related to one or both of frequency-based and timing-based integer ambiguity resolution methods.

**[0010]** In some implementations of the methods and apparatuses described herein, the method further includes incorporating, within the second configuration message, second

configuration assistance data that configures the target apparatus to report phase measurements of certain predefined subcarriers, which are indicated by the LMF. The method includes assigning with the configuration assistance data, a subcarrier ID to differentiate between each subcarrier, wherein the subcarrier ID is incorporated within a corresponding measurement report generated at and received from the target apparatus.

[0011] In some implementations of the methods and apparatuses described herein, the method includes selecting a fifth configuration, which is one or more consecutive time windows for DL PRS measurements. The method includes identifying the one or more consecutive time windows to define within the fifth configuration, where the DL PRS carrier frequency and configuration are the same during each of the one or more consecutive time windows. The method includes incorporating/including the fifth configuration within the first configuration message sent to the target apparatus.

### BRIEF DESCRIPTION OF THE DRAWINGS

[0012] **FIG. 1** illustrates an example of a wireless communications system that supports resolution of integer ambiguity by configuring a target UT to perform downlink (DL) positioning reference signals (PRS) phase measurements and report the measurements to a location management function (LMF), in accordance with aspects of the present disclosure.

[0013] **FIG. 2** illustrates an example of beam-based positioning of a UE using a location server communicatively coupled to multiple base stations, according to prior art.

[0014] **FIG. 3** illustrates an example communication system with a LMF of a base station providing a DL PRS communicated at a first frequency from the base station to a target UE over a unique user (Uu) interface, with the target UE transmitting reports of carrier phase measurements for use in integer ambiguity resolution, in accordance with aspects of the present disclosure.

[0015] **FIG. 4** illustrates an example DL PRS configuration message presented as LTE Positioning Protocol (LPP) message utilized to transmit the one or more carrier phase

positioning measurement configurations to the target UE, in accordance with aspects of the present disclosure.

[0016] **FIG. 5A** illustrates an example target UE LPP configuration message with multiple carrier frequency phase measurements, in accordance with one or more embodiments of the present disclosure.

[0017] **FIG. 5B** illustrates an example target UE LPP configuration message with multiple subcarrier phase measurements, in accordance with one or more embodiments of the present disclosure.

[0018] **FIG. 6** illustrates an example of relative carrier phase determination by a UE receiving a DL PRS at two different times to enable a time-difference carrier phase (TDCP) technique for time-based integer ambiguity resolution, according to one or more aspects of the disclosure.

[0019] **FIG. 7** illustrates an example target UE LPP configuration message with TDCP, in accordance with aspects of the present disclosure.

[0020] **FIG. 8** illustrates an example second LLP message with IAR information to configure the target UE to generate and transmit measurement reports, in accordance with aspects of the present disclosure.

[0021] **FIG. 9** illustrates an example of DL-TDOA Assistance data configurations presented within the second configuration message to enable UE-assisted and UE-based NR downlink TDOA.

[0022] **FIG. 10 (10A-10B)** illustrates an example measurement report generated by the target UE.

[0023] **FIG. 11** illustrates a block diagram of an example apparatus for wireless communication that can be configured by an LMF to complete DL PRS phase measurements and report measurements for use in IA resolution, in accordance with aspects of the present disclosure.

[0024] **FIG. 12** illustrates a block diagram of an example network apparatus for wireless communication that provides an LMF, which generates configuration messages for configuring a target UE to perform DL PRS phase measurements based on selected configurations, in accordance with aspects of the present disclosure.

[0025] **FIG. 13** illustrates a flowchart of a method by which a target UE is configured to perform and report DL PRS phase measurements based on received configuration messages from an LMF, in accordance with aspects of the present disclosure.

[0026] **FIG. 14** illustrates a flowchart of a method by which an LMF selects specific configuration parameters and generates configuration messages to provide to a target UE to configure the target UE to perform a corresponding DL PRS phase measurement and report the measurements for use in IA resolution, in accordance with aspects of the present disclosure.

## DETAILED DESCRIPTION

[0027] Current timing-based and angle-based radio access technology (RAT)-dependent positioning methods benefit from the current positioning reference signal (PRS) design in order to enable flexible and high positioning accuracies. Standardized timing-based and angle-based positioning techniques allow for sub-meter level accuracy only.

[0028] In the context of positioning, a variety of Positioning techniques may be utilized to obtain good positioning performance (e.g., good accuracy and/or low latency positioning). Examples of Uu and SL positioning techniques include AoA, RTT, TDoA, and so forth. However, CPP promises to achieve the tight accuracy requirements in certain Uu and SL scenarios including IIoT and other indoor scenarios. High accuracies enabled by CPP are only possible if the integer ambiguity (which is the unknown integer number of cycles between the transmitter and the receiver) is resolved. This disclosure provides novel methods to realize the support of CPP between devices and nodes within a network via configuration enhancements mainly related to integer ambiguity resolution (IAR) to enable the accurate and timely DL carrier phase in different scenarios and deployments.

[0029] In theory, centimeter-level accuracy for certain scenarios can be met using a carrier phase-based positioning technique; However, this is possible only if all error sources (e.g., initial phase offset, time and frequency synchronization errors, carrier frequency offset (CFO), Antenna reference points (ARPs), Doppler velocity, etc.) are correctly mitigated. Several techniques have been proposed to mitigate these errors that hugely impact the carrier phase measurement performance. The use of the double differential method has been presented as a potential technique to mitigate part of the error sources, especially phase related errors. In order to mitigate errors, resolve integer ambiguity, and achieve centimeter-level accuracy, measurement reporting can include many measurements other than the carrier phase measurement associated with each carrier frequency and TRP.

[0030] NR positioning based on NR Uu signals and SA architecture (e.g., beam-based transmissions) have been specified for wireless communication systems, including for commercial and regulatory (emergency services) scenarios. The performance requirements are the following:

| Positioning Error      | Indoor               | Outdoor               |
|------------------------|----------------------|-----------------------|
| Horizontal Positioning | < 3m for 80 % of UEs | < 10m for 80 % of UEs |
| Vertical Positioning   | < 3m for 80 % of UEs | < 3m for 80 % of UEs  |

**Table I**

[0031] Current positioning performance requirements for Commercial and IIoT use cases are defined as follows:

| Positioning Error                                    | Commercial              | IIoT                       |
|------------------------------------------------------|-------------------------|----------------------------|
| Horizontal Positioning                               | (< 1 m) for 90 % of UEs | (< 0.2 m) for 90 % of UEs; |
| Vertical Positioning                                 | (< 3 m) for 90 % of UEs | (< 1 m) for 90 % of UEs    |
| Physical layer latency for position estimation of UE | (< 10 ms)               | (< 10 ms)                  |

|                                                        |           |                                                 |
|--------------------------------------------------------|-----------|-------------------------------------------------|
| End-to-End Latency<br>for position estimation<br>of UE | (<100 ms) | (< 100 ms, in the order of<br>10 ms is desired) |
|--------------------------------------------------------|-----------|-------------------------------------------------|

Table II

[0032] Additionally, several RAT-dependent positioning techniques have been proposed. Among these techniques are the following:

[0033] **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.

[0034] **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.

[0035] **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.

[0036] 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. Multi-RTT is only supported for UE-assisted/NG-RAN assisted positioning techniques as noted in **Error! Reference source not found.** above.

[0037] **Carrier Phase Based Positioning (CPP):** The NR carrier-phase based positioning technique refers to the positioning method, where the transmitter (either the gNB or the UE)

transmits the positioning reference signals at the pre-configured carrier frequency, and the receiver (either the UE or the gNB) obtains the carrier phase measurements by tracking reference signals. The phase measurements are derived from the complex correlations at the receiver side. The measurements combined with TDOA are used to estimate user position.

**[0038] E-CID/ NR E-CID:** With Enhanced Cell ID (CID) positioning method, the position of the UE is estimated with the knowledge of the UE's 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 that use additional UE measurements and/or NR radio resource and other measurements to improve the UE location estimate using NR signals.

**[0039]** 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. That is, the positioning procedures do not supply a measurement configuration or measurement control message, and the UE reports the measurements that the UE has available rather than being required to take additional measurement actions.

**[0040] 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.

**[0041] 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 the UE. **FIG. 2** illustrates an example of NR beam-based positioning of a UE using a location server communicatively coupled to multiple base stations, as provided by the uplink (UL) AoA positioning method, according to prior art. 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.

[0042] With this approach the PRS can be transmitted by different base stations (serving and neighboring) using narrow beams over FR1 and FR2 as illustrated in Error! Reference source not found.. This use of narrow beams is relatively different when compared to LTE, where the PRS was transmitted across the whole cell. The PRS can be locally associated with a PRS Resource ID and Resource Set ID for a base station (TRP). Similarly, UE positioning measurements such as Reference Signal Time Difference (RSTD) and PRS RSRP measurements are made between beams (e.g., between a different pair of DL PRS resources or DL PRS resource sets), 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 1 and Table 2 below show the reference signal to measurements mapping required for each of the supported RAT-dependent positioning techniques at the UE and gNB, respectively.

| 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                                                         |

**Table 1: UE 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, | AoA and ZoA | UL-AoA, Multi-RTT |
|-----------------------------|-------------|-------------------|

**Table 2: gNB Measurements to enable RAT-dependent positioning techniques**

**[0043]** 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.

**[0044]** An additional method provided for coarse position determination of a mobile terminal includes the double differential techniques in GNSS. In differential GNSS, the position of a fixed GNSS receiver, referred to as a base station, is determined to a high degree of accuracy using conventional surveying techniques. Then, the base station determines ranges to the GNSS satellites in view using (i) the code-based positioning technique and (ii) the location of the satellites determined from the precisely known orbit ephemerides and satellite time. The base station compares the surveyed position to the position calculated from the satellite ranges. Differences between the positions can be attributed to satellite ephemeris and clock errors, but mostly to errors associated with atmospheric delay. The base station sends these errors to other receivers (rovers), which incorporate the corrections into their position calculations. Differential positioning requires a data link between the base station and rovers, if corrections need to be applied in real-time, and at least four GNSS satellites in view at both the base station and the rovers. The absolute accuracy of the rover's computed position will depend on the absolute accuracy of the base station's position.

**[0045]** The present disclosure provides a solution to the above problems encountered with providing accurate UE device positioning with the existing technologies/methods. Generally, the present disclosure provides solutions to the various shortfalls in existing methods by identifying that, depending on the chosen method used to resolve integer ambiguity, different configurations for multi-frequency carrier phase measurements or single frequency carrier phase measurements could be signaled by the LMF to the target UE. Specifically, the disclosure provides three different methods that collectively enable a target UE to locally perform DL PRS phase measurements for use in either frequency-based or

timing-based IA resolution and to provide/report the measurements to the LMF that then performs the particular type of IA resolution that uses those measurements.

**[0046]** The present disclosure provides a set of solutions to support reporting of carrier phase measurement related to integer ambiguity resolution through appropriate reporting and measurements configurations. A component of the solution includes the measurement configuration related to integer ambiguity resolution for both frequency-based IAR methods and timing-based IAR methods. A further aspect of the solution involves the efficient reporting of DL carrier phase measurements including the reporting of phase measurements of different carrier frequencies and/or different subcarriers within the DL PRS bandwidth. Furthermore, the solution includes phase measurements over DL PRS received at different time instances.

**[0047]** According to one aspect, a method includes receiving, from a network apparatus, a configuration message comprising one or more carrier phase positioning measurement configurations for performing downlink (DL) Positioning Reference Signals (PLS) phase measurements used for IA resolution. The method includes receiving, from the network apparatus, one or more downlink (DL) positioning reference signals (PRS). The method also includes performing, based on the one or more carrier phase positioning measurement configurations, carrier phase measurements on at least one frequency characteristic provided by the one or more DL PRS to generate measurement results for resolving integer ambiguity. The method also includes, in response to receiving a measurement reporting configuration message, generating and transmitting, to the network apparatus, a report comprising the measurement results for IA resolution to enable the network apparatus to accurately determine a location of the apparatus.

**[0048]** As presented herein, integer ambiguity refers to the unknown number,  $N$ , of cycles in a reference signal between the base station or network node (e.g., gNB) and target network device (e.g., target UE). Resolving the integer ambiguity allows for an accurate distance estimation and eventually accurate absolute/relative position of the target UE. Within the description, a target UE may be referred to as an apparatus or target apparatus and the terms are utilized interchangeably to refer to the same device. Similarly, the base station may be referred to as a network apparatus/device/entity, without limitation. The LMF may

exist within the base station or be separate from the base station and communicatively connected to the base station.

**[0049]** Within the described embodiments, a positioning-related reference signal may be referred to as a reference signal used for positioning procedures/purposes in order to estimate the location of a target UE. The positioning-related reference signal is generated by the base station (or LMF) and can be a PRS. In various embodiments, the term ‘PRS’ may refer to any signal, such as a reference signal, which may or may not be used primarily for positioning. In different embodiments, the positioning-related reference signal can be based on existing reference signals such as channel state information reference signal (CSI-RS) or sounding reference signal (SRS) or can be a new reference signal for carrier phase positioning.

**[0050]** The novel aspects of the disclosure provide several different advantages over the existing technology. By implementing the processes of the disclosure, the integer ambiguity resolution is performed with actual measurements of the carrier phase by the target UE, based on specific configuration data selected by the LMF, which results in the elimination of many of the aforementioned errors in the other methods described above. The disclosure provides accurate integer ambiguity resolution, which enables an accurate carrier phase estimation and thus a high positioning accuracy for the target UE.

**[0051]** Aspects of the present disclosure are described in the context of a wireless communications system. Aspects of the present disclosure are further illustrated and described with reference to device diagrams, configuration and report message, and flowcharts.

**[0052]** **FIG. 1** illustrates an example of a wireless communications system that supports resolution of integer ambiguity by configuring a target UT to perform downlink (DL) positioning reference signals (PRS) phase measurements and report the measurements to a location management function (LMF), in accordance with aspects of the present disclosure. The wireless communications system 100 may include one or more network entities 102, one or more UEs 104, a core network 106, and a packet data network 108. The wireless communications system 100 may support various radio access technologies. In some

implementations, the wireless communications system 100 may be a 4G network, such as an LTE network or an LTE-Advanced (LTE-A) network. In some other implementations, the wireless communications system 100 may be a 5G network, such as an NR network. In other implementations, the wireless communications system 100 may be a combination of a 4G network and a 5G network, or other suitable radio access technology including Institute of Electrical and Electronics Engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20. The wireless communications system 100 may support radio access technologies beyond 5G. Additionally, the wireless communications system 100 may support technologies, such as time division multiple access (TDMA), frequency division multiple access (FDMA), or code division multiple access (CDMA), etc.

**[0053]** The one or more network entities 102 may be dispersed throughout a geographic region to form the wireless communications system 100. One or more of the network entities 102 described herein may be or include or may be referred to as a network apparatus, a network node, a base station, a network element, a radio access network (RAN), a base transceiver station, an access point, a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. A network entity 102 and a UE 104 may communicate via a communication link 110, which may be a wireless or wired connection. For example, a network entity 102 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface. A network entity can also communicate via a different communication link 111 to a global positioning system (GPS) satellite 120, which can assist with location positioning of UE 104 and other mobile devices within communication network.

**[0054]** A network entity 102 may provide a geographic coverage area 112 for which the network entity 102 may support services (e.g., voice, video, packet data, messaging, broadcast, etc.) for one or more UEs 104 within the geographic coverage area 112. For example, a network entity 102 and a UE 104 may support wireless communication of signals related to services (e.g., voice, video, packet data, messaging, broadcast, etc.) according to one or multiple radio access technologies. According to one aspect of the disclosure, at least one network entity 102 (e.g., positioned on right in the figure) has an associated location management function 140, which supports location management services for one or more

target UE 104. An example target UE 104 is shown as the rightmost UE in the figure, indicated in dashed outline. In some implementations, a network entity 102 may be moveable, for example, a satellite associated with a non-terrestrial network. In some implementations, different geographic coverage areas 112 associated with the same or different radio access technologies may overlap, but the different geographic coverage areas 112 may be associated with different network entities 102. Information and signals described herein may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

**[0055]** The one or more UEs 104 may be dispersed throughout a geographic region of the wireless communications system 100. A UE 104 may include or may be referred to as a mobile device, a wireless device, a remote device, a remote unit, a handheld device, or a subscriber device, or some other suitable terminology. In some implementations, the UE 104 may be referred to as an apparatus, a user apparatus, a unit, a station, a terminal, or a client, among other examples. Additionally, or alternatively, the UE 104 may be referred to as an Internet-of-Things (IoT) device, an Internet-of-Everything (IoE) device, or machine-type communication (MTC) device, among other examples. In some implementations, a UE 104 may be stationary in the wireless communications system 100. In some other implementations, a UE 104 may be mobile in the wireless communications system 100.

**[0056]** The one or more UEs 104 may be communication devices or devices in different forms or having different capabilities. Some examples of UEs 104 are illustrated in FIG. 1. A UE 104 may be capable of communicating with various types of devices, such as the network entities 102, other UEs 104, or network equipment (e.g., the core network 106, the packet data network 108, a relay device, an integrated access and backhaul (IAB) node, or another network equipment), as shown in FIG. 1. Additionally, or alternatively, a UE 104 may support communication with other network entities 102 or UEs 104, which may act as relays in the wireless communications system 100.

**[0057]** A UE 104 may also be able to support wireless communication directly with other UEs 104 over a communication link 114. For example, a UE 104 may support wireless communication directly with another UE 104 over a device-to-device (D2D) communication link. In some implementations, such as vehicle-to-vehicle (V2V) deployments, vehicle-to-everything (V2X) deployments, or cellular-V2X deployments, the communication link 114 may be referred to as a sidelink. For example, a UE 104 may support wireless communication directly with another UE 104 over a PC5 interface. When the UE is the intended end point of a communication or signal, the UE can be referred to herein as a target UE or target apparatus, according to one or more embodiments. An example target UE 104 is shown as the rightmost UE in the figure, indicated in dashed outline.

**[0058]** A network entity 102 may support communications with the core network 106, or with another network entity 102, or both. For example, a network entity 102 may interface with the core network 106 through one or more backhaul links 116 (e.g., via an S1, N2, N2, or another network interface). The network entities 102 may communicate with each other over the backhaul links 116 (e.g., via an X2, Xn, or another network interface). In some implementations, the network entities 102 may communicate with each other directly (e.g., between the network entities 102). In some other implementations, the network entities 102 may communicate with each other or indirectly (e.g., via the core network 106). In some implementations, one or more network entities 102 may include subcomponents, such as an access network entity, which may be an example of an access node controller (ANC). An ANC may communicate with the one or more UEs 104 through one or more other access network transmission entities, which may be referred to as a radio heads, smart radio heads, or transmission-reception points (TRPs).

**[0059]** In some implementations, a network entity 102 may be configured in a disaggregated architecture, which may be configured to utilize a protocol stack physically or logically distributed among two or more network entities 102, such as an integrated access backhaul (IAB) network, an open RAN (O-RAN) (e.g., a network configuration sponsored by the O-RAN Alliance), or a virtualized RAN (vRAN) (e.g., a cloud RAN (C-RAN)). For example, a network entity 102 may include one or more of a central unit (CU), a distributed unit (DU), a radio unit (RU), a RAN Intelligent Controller (RIC) (e.g., a Near-Real Time RIC

(Near-RT RIC), a Non-Real Time RIC (Non-RT RIC)), a Service Management and Orchestration (SMO) system, or any combination thereof.

**[0060]** An RU may also be referred to as a radio head, a smart radio head, a remote radio head (RRH), a remote radio unit (RRU), or a transmission reception point (TRP). One or more components of the network entities 102 in a disaggregated RAN architecture may be co-located, or one or more components of the network entities 102 may be located in distributed locations (e.g., separate physical locations). In some implementations, one or more network entities 102 of a disaggregated RAN architecture may be implemented as virtual units (e.g., a virtual CU (VCU), a virtual DU (VDU), a virtual RU (VRU)).

**[0061]** Split of functionality between a CU, a DU, and an RU may be flexible and may support different functionalities depending upon which functions (e.g., network layer functions, protocol layer functions, baseband functions, radio frequency functions, and any combinations thereof) are performed at a CU, a DU, or an RU. For example, a functional split of a protocol stack may be employed between a CU and a DU such that the CU may support one or more layers of the protocol stack and the DU may support one or more different layers of the protocol stack. In some implementations, the CU may host upper protocol layer (e.g., a layer 3 (L3), a layer 2 (L2)) functionality and signaling (e.g., Radio Resource Control (RRC), service data adaptation protocol (SDAP), Packet Data Convergence Protocol (PDCP)). The CU may be connected to one or more DUs or RUs, and the one or more DUs or RUs may host lower protocol layers, such as a layer 1 (L1) (e.g., physical (PHY) layer) or an L2 (e.g., radio link control (RLC) layer, medium access control (MAC) layer) functionality and signaling, and the one or more DUs or RUs may each be at least partially controlled by the CU 160.

**[0062]** Additionally, or alternatively, a functional split of the protocol stack may be employed between a DU and an RU such that the DU may support one or more layers of the protocol stack and the RU may support one or more different layers of the protocol stack. The DU may support one or multiple different cells (e.g., via one or more RUs). In some implementations, a functional split between a CU and a DU, or between a DU and an RU may be within a protocol layer (e.g., some functions for a protocol layer may be performed

by one of a CU, a DU, or an RU, while other functions of the protocol layer are performed by a different one of the CU, the DU, or the RU).

**[0063]** A CU may be functionally split further into CU control plane (CU-CP) and CU user plane (CU-UP) functions. A CU may be connected to one or more DUs via a midhaul communication link (e.g., F1, F1-c, F1-u), and a DU may be connected to one or more RUs via a fronthaul communication link (e.g., open fronthaul (FH) interface). In some implementations, a midhaul communication link or a fronthaul communication link may be implemented in accordance with an interface (e.g., a channel) between layers of a protocol stack supported by respective network entities 102 that are in communication via such communication links.

**[0064]** The core network 106 may support user authentication, access authorization, tracking, connectivity, and other access, routing, or mobility functions. The core network 106 may be an evolved packet core (EPC), or a 5G core (5GC), which may include a control plane entity that manages access and mobility (e.g., a mobility management entity (MME), an access and mobility management functions (AMF)) and a user plane entity that routes packets or interconnects to external networks (e.g., a serving gateway (S-GW), a Packet Data Network (PDN) gateway (P-GW), or a user plane function (UPF)). In some implementations, the control plane entity may manage non-access stratum (NAS) functions, such as mobility, authentication, and bearer management (e.g., data bearers, signal bearers, etc.) for the one or more UEs 104 served by the one or more network entities 102 associated with the core network 106.

**[0065]** The core network 106 may communicate with the packet data network 108 over one or more backhaul links 116 (e.g., via an S1, N2, N2, or another network interface). The packet data network 108 may include an application server 118. In some implementations, one or more UEs 104 may communicate with the application server 118. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or the like) with the core network 106 via a network entity 102. The core network 106 may route traffic (e.g., control information, data, and the like) between the UE 104 and the application server 118 using the established session (e.g., the established PDU session). The PDU session may be an example

of a logical connection between the UE 104 and the core network 106 (e.g., one or more network functions of the core network 106).

**[0066]** In the wireless communications system 100, the network entities 102 and the UEs 104 may use resources of the wireless communication system 100 (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers)) to perform various operations (e.g., wireless communications). In some implementations, the network entities 102 and the UEs 104 may support different resource structures. For example, the network entities 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the network entities 102 and the UEs 104 may support a single frame structure. In some other implementations, such as in 5G and among other suitable radio access technologies, the network entities 102 and the UEs 104 may support various frame structures (i.e., single and multiple frame structures). The network entities 102 and the UEs 104 may support various frame structures based on one or more numerologies.

**[0067]** One or more numerologies may be supported in the wireless communications system 100, and a numerology may include a subcarrier spacing and a cyclic prefix. A first numerology (e.g.,  $\mu=0$ ) may be associated with a first subcarrier spacing (e.g., 15 kHz) and a normal cyclic prefix. In some implementations, the first numerology (e.g.,  $\mu=0$ ) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe. A second numerology (e.g.,  $\mu=1$ ) may be associated with a second subcarrier spacing (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g.,  $\mu=2$ ) may be associated with a third subcarrier spacing (e.g., 60 kHz) and a normal cyclic prefix or an extended cyclic prefix. A fourth numerology (e.g.,  $\mu=3$ ) may be associated with a fourth subcarrier spacing (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g.,  $\mu=4$ ) may be associated with a fifth subcarrier spacing (e.g., 240 kHz) and a normal cyclic prefix.

**[0068]** A time interval of a resource (e.g., a communication resource) may be organized according to frames (also referred to as radio frames). Each frame may have a duration, for example, a 10 millisecond (ms) duration. In some implementations, each frame may include multiple subframes. For example, each frame may include 10 subframes, and each subframe may have a duration, for example, a 1 ms duration. In some implementations, each frame

may have the same duration. In some implementations, each subframe of a frame may have the same duration.

**[0069]** Additionally, or alternatively, a time interval of a resource (e.g., a communication resource) may be organized according to slots. For example, a subframe may include a number (e.g., quantity) of slots. The number of slots in each subframe may also depend on the one or more numerologies supported in the wireless communications system 100. For instance, the first, second, third, fourth, and fifth numerologies (i.e.,  $\mu=0$ ,  $\mu=1$ ,  $\mu=2$ ,  $\mu=3$ ,  $\mu=4$ ) associated with respective subcarrier spacings of 15 kHz, 30 kHz, 60 kHz, 120 kHz, and 240 kHz may utilize a single slot per subframe, two slots per subframe, four slots per subframe, eight slots per subframe, and 16 slots per subframe, respectively. Each slot may include a number (e.g., quantity) of symbols (e.g., OFDM symbols). In some implementations, the number (e.g., quantity) of slots for a subframe may depend on a numerology. For a normal cyclic prefix, a slot may include 14 symbols. For an extended cyclic prefix (e.g., applicable for 60 kHz subcarrier spacing), a slot may include 12 symbols. The relationship between the number of symbols per slot, the number of slots per subframe, and the number of slots per frame for a normal cyclic prefix and an extended cyclic prefix may depend on a numerology. It should be understood that reference to a first numerology (e.g.,  $\mu=0$ ) associated with a first subcarrier spacing (e.g., 15 kHz) may be used interchangeably between subframes and slots.

**[0070]** In the wireless communications system 100, an electromagnetic (EM) spectrum may be split, based on frequency or wavelength, into various classes, frequency bands, frequency channels, etc. By way of example, the wireless communications system 100 may support one or multiple operating frequency bands, such as frequency range designations FR1 (410 MHz – 7.125 GHz), FR2 (24.25 GHz – 52.6 GHz), FR3 (7.125 GHz – 24.25 GHz), FR4 (52.6 GHz – 114.25 GHz), FR4a or FR4-1 (52.6 GHz – 71 GHz), and FR5 (114.25 GHz – 300 GHz). In some implementations, the network entities 102 and the UEs 104 may perform wireless communications over one or more of the operating frequency bands. In some implementations, FR1 may be used by the network entities 102 and the UEs 104, among other equipment or devices for cellular communications traffic (e.g., control information,

data). In some implementations, FR2 may be used by the network entities 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

**[0071]** FR1 may be associated with one or multiple numerologies (e.g., at least three numerologies). For example, FR1 may be associated with a first numerology (e.g.,  $\mu=0$ ), which includes 15 kHz subcarrier spacing; a second numerology (e.g.,  $\mu=1$ ), which includes 30 kHz subcarrier spacing; and a third numerology (e.g.,  $\mu=2$ ), which includes 60 kHz subcarrier spacing. FR2 may be associated with one or multiple numerologies (e.g., at least 2 numerologies). For example, FR2 may be associated with a third numerology (e.g.,  $\mu=2$ ), which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g.,  $\mu=3$ ), which includes 120 kHz subcarrier spacing.

**[0072]** According to one aspect of the disclosure, the wireless communications system 100 also includes a plurality of PRUs 130 that are in fixed locations at a known distance away from one or more base stations 102. The PRUs, which are generally referred to as network apparatuses herein, can be in a same cell as a target UE 104 and can receive a same transmission (Tx) beam as the target UE 104, in one embodiment. Aspects of the disclosure refers to neighboring network apparatuses or PRUs to indicate PRUs that are geographically close to the target UE 104 to enable reception of the same Tx beam, in some embodiments.

**[0073]** **FIG. 3** illustrates an example communication system with LMF 140 of a base station (e.g., eNodeB) 102 providing a DL PRS 210 via a unique user (Uu) interface with a target UE 104. The DL PRS 210 is communicated from the base station 102 to a target UE 104 within a beam signal at a first frequency ( $f_1$ ). The LMF 140 also transmits a configuration message to the target UE 104 via the Uu interface. As also shown by the figure, target UE 104 transmits one or more measurement report back to the LMF 140, which uses the received report(s) to perform an corresponding IA resolution processes. As illustrated by the figure, a remote LMF 140b can also be provided by a location server 220 communicatively coupled to the core network 106, to which the base station 102 is also communicatively coupled.

**[0074]** According to one or more embodiments, as further presented by FIG. 10, LMF 140 is a program block (or code) executed by/within a controller/processor 145 of a computing apparatus (1000) at base station 102. The communication system 300, and in

particular the LMF and target UE, collectively provide the processes of the disclosure. The LMF 140 transmits configuration messages to configure the target UE 104 to perform specific types of DL RPS phase measurements. The target UE generates and transmits, to the LMF 140, reports of carrier phase measurements for use in integer ambiguity resolution at the LMF 140, in accordance with aspects of the present disclosure.

**[0075]** It is appreciated that both of the above devices (i.e., the LMF 140 and target UE 104) are configured with the required hardware and software code/programming to support the various functions required by each device/apparatus. The disclosure thus utilized these devices to provide solutions for enabling configuration of the target UE by the LMF related to carrier phase positioning measurements utilized for integer ambiguity resolution. Generally, the disclosure includes/provides the following three aspects, presented as method processes:

- (i) A method to configure the one or more responder/target UE devices to perform carrier phase measurements over (a) different subcarriers from the same DL PRS bandwidth and/or (b) different DL PRS carrier frequencies from the same TRP/target UE Uu interface, based on a received DL PRS configuration.
- (ii) A method to configure the one or more responder/target UE devices to perform carrier phase measurements over different consecutive time instances associated with one carrier frequency from the same TRP/target UE Uu interface, based on a received DL PRS configuration.
- (iii) A method to report all above measurements to a location server or LMF as part of the measurement report. Based on these measurements, the LMF can then determine accurate target UE position.

**[0076]** According to a first aspect, which involves measurement configuration for frequency-based IA resolution methods, the target UE is configured by the LMF or location server to perform measurements that would assist the LMF with frequency-based integer ambiguity resolution. The target UE would thus be configured to perform carrier phase measurements over DL PRS received on different carrier frequencies at the same time. The

embodiments also include configuring the target UE to perform and report phase measurements over different subcarriers from the DL PRS bandwidth.

[0077] In one implementation, LMF, or any configuration entity, could decide the appropriate method for integer ambiguity resolution based on some parameters, e.g., the IA search range (which is determined beforehand based on a coarse location or based on assistance data from PRUs), IA uncertainty level, positioning target requirements, target UE capabilities, measurement reporting overhead, etc. The LMF then signals the corresponding configuration to the target UE via a “*ProvideAssistanceData*” LPP message. The LMF also signals the measurement reporting configuration to the target UE via a “*RequestLocationInformation*” LPP message.

[0078] Thus, from the LMF or LPP or location entity standpoint, the disclosure provides a network apparatus supporting wireless communication. The network apparatus includes at least one network interface that enables the network apparatus to communicate with at least one target apparatus in a communication network. The network apparatus includes a memory that has program code stored thereon for a location management function (LMF). The program code includes code for generating configuration messages that can configure a target apparatus (e.g., target UE) to perform measurements to enable frequency-based integer ambiguity (IA) resolution and timing-based IA resolution methods. The controller is communicatively coupled to the memory and to the at least one network interface. The controller determines which of one or more carrier phase measurements configurations to include in the configuration message for IA resolution processing by the target apparatus. The controller transmits, to the target apparatus, a first configuration message that includes a selected one or more carrier phase measurement configurations. The selected one or more carrier phase measurement configurations configure the target apparatus to perform DL PRS measurements related to IA resolution. FIG. 11 provides an illustration of the main components of an example network apparatus.

[0079] In one or more embodiments, the first configuration message includes different multi-frequency and multi-PFL configurations of a downlink (DL) positioning reference signal (PRS). The target apparatus is accordingly configured to perform a multi-frequency carrier phase measurement enabling multi-frequency linear combination providing (i) IA

resolution by a lower DL PRS carrier frequency to reduce an IA search space and (ii) IA resolution via higher DL PRS carrier frequencies for accuracy.

**[0080]** In one or more embodiments, the one or more carrier phase positioning measurement configurations include one or more of: (i) a first configuration of different DL PRS carrier frequencies within a same position frequency layer (PFL); (ii) a second configuration of different DL PRS carrier frequencies, with the DL PRS received at a same time within different PFLs; (iii) a third configuration of different DL PRS subcarriers within a same DL PRS bandwidth; (iv) a fourth configuration of different DL PRS subcarriers within different DL PRS bandwidths; and (v) a fifth configuration of one or more consecutive time windows for DL PRS measurement. The controller selects one or more of the selected one or more carrier phase positioning measurement configurations from among the first, second, third, fourth, and fifth configurations and incorporates the selected one or more carrier phase positioning measurement configurations within the first configuration message sent to the target apparatus.

**[0081]** As an example, in one or more embodiments, the controller selects the third configuration providing a multiple frequency scheme based on phase measurements performed over different subcarriers within a same DL PRS bandwidth, and the controller includes the third configuration within the first configuration message sent to the target apparatus.

**[0082]** In another example, in one or more embodiments, the controller selects the fourth configuration providing a multiple frequency scheme based on phase measurements performed over different subcarriers within different DL PRS bandwidths, and the controller includes the fourth configuration within the first configuration message sent to the target apparatus.

**[0083]** In one or more embodiments, the first configuration message includes configuration assistance data. In one or more embodiments, the configuration assistance data comprises a set of subcarriers over which the phases are to be measured, the set of subcarriers defined via a separate group ID. In one or more embodiments, the configuration assistance data includes a frequency granularity, wherein the target apparatus is configured to

determine, based on the frequency granularity, DL PRS subcarriers on which to perform and report measurements for integer ambiguity resolution.

**[0084]** From the target UE operational standpoint, the disclosure provides an apparatus for wireless communication. The apparatus includes a memory comprising program code for performing downlink (DL) Positioning Reference Signals (PLS) measurements. The apparatus includes at least one transceiver that enables the apparatus to communicate with other network components, including a network apparatus providing a location management function. The apparatus includes a controller communicatively coupled to the memory and to the at least one transceiver and which: receives, from the network apparatus, a configuration message comprising one or more carrier phase positioning measurement configurations for performing DL PRS phase measurements used for integer ambiguity (IA) resolution. The controller also receives, from the network apparatus, at least one downlink (DL) positioning reference signals (PRS). The controller performs, based on the one or more carrier phase positioning measurement configurations, carrier phase measurements on at least one frequency characteristic provided by the DL PRS to generate measurement results for resolving integer ambiguity.

**[0085]** According to one or more embodiments, the one or more carrier phase positioning measurement configurations comprise one or more of (i) a first configuration of different DL PRS carrier frequencies within a same position frequency layer (PFL); (ii) a second configuration of different DL PRS carrier frequencies, with the DL PRS received at a same time within different PFLs; (iii) a third configuration of different DL PRS subcarriers within a same DL PRS bandwidth; (iv) a fourth configuration of different DL PRS subcarriers within different DL PRS bandwidths; and (v) a fifth configuration of one or more consecutive time windows for DL PRS measurements.

**[0086]** In one or more embodiments, based on the one or more carrier phase positioning measurement configurations being the first configuration, the controller performs carrier phase measurements over different subcarriers from a same DL PRS bandwidth. In one or more embodiments, based on the one or more carrier phase positioning measurement configurations being the second configuration, the controller performs carrier phase measurements over different subcarriers, within the DL PRS bandwidths, where DL PRS is being received from a same transmission reception point over a unique user (Uu) interface of

the apparatus. In one or more embodiments, based on the one or more carrier phase positioning measurement configurations being the third configuration, the controller performs phase measurements over different subcarriers within a same DL PRS bandwidth.

[0087] In one or more embodiments, based on the one or more carrier phase positioning measurement configurations being the fourth configuration, the controller performs phase measurements over different subcarriers within different DL PRS bandwidths.

[0088] In one implementation, the DL or one directional carrier phase measurements may be performed per positioning frequency layer associated with the following PRS parameters and illustrated in FIG. 4:

- (i) Subcarrier spacing: Defines the subcarrier spacing of the DL-PRS Resource, e.g., 15, 30, 60 kHz for FR1; 60, 120 kHz, 240 kHz, 480 kHz, 960 kHz for FR2. All DL-PRS Resources and DL-PRS Resource Sets in the same Positioning Frequency layer have the same value;
- (ii) Resource bandwidth: Defines the number of PRBs allocated for the DL SL PRS Resource (allocated DL or SL PRS bandwidth) in multiples of X PRBs, where X can be configured. All PRS Resources of a PRS Resource Set within a same resource pool have the same bandwidth. All PRS Resource Sets belonging to the same Positioning Frequency Layer have the same value of PRS Bandwidth and Start PRB;
- (iii) Start PRB: Defines the start PRB index defined as an offset with respect to reference PRS Point A for the Positioning Frequency Layer;
- (iv) PRS Point A: Defines the absolute frequency of the reference resource block for the PRS. Its lowest subcarrier is also known as DL-PRS Point A;
- (v) PRS comb size N: Defines the Resource Element spacing in each symbol of a PRS Resource. All PRS Resource Sets belonging to the same Positioning Frequency Layer or resource pool have the same value of comb size N; and
- (vi) PRS Cyclic Prefix: Defines the Cyclic Prefix (CP) length of the PRS Resource. All PRS Resources Sets belonging to the same Positioning Frequency Layer have the same CP.

[0089] In an extended implementation, the above parameters may also apply to carrier phase measurements performed on the UL by the gNB using, for example, SRS for positioning and MIMO SRS. In one or more embodiments, the “*ProvideAssistanceData*” LPP message can also reference different multi-frequency and multi-PFL configurations of the DL PRS.

[0090] FIG. 4 illustrates an example DL PRS configuration message 400 presented as LTE Positioning Protocol (LPP) message utilized to transmit the one or more carrier phase positioning measurement configurations to the target UE, in accordance with aspects of the present disclosure. Multi-frequency carrier phase measurements enable IA resolution by choosing lower DL PRS carrier frequencies to reduce the IA search space and choosing higher DL PRS carrier frequencies to ensure good accuracy. This selection process is one of the IAR methods, which is referred to as multi-frequency linear combination. A virtual carrier for carrier phase measurement, which has a significantly low frequency, can be obtained by assigning the different sets of integer coefficients to multiple carriers. Carrier phase measurements at a relatively low virtual frequency can benefit the integer ambiguity resolution. Using virtual frequency with a longer wavelength reduces the computational burden on the device side by reducing the number of possible candidates for ambiguity resolution, thus reducing the search time. Consequently, the choice of the multiple carrier frequencies enables a trade-off between reduced IA search space and high positioning accuracies. According to one or more embodiments, the multiple frequency schemes can also be based on phase measurements performed over different subcarriers within same or different DL PRS bandwidths.

[0091] According to the first embodiment, the LMF could configure a target UE with different DL PRS carrier frequencies/resources transmitted from same or different TRPs. These DL PRS carrier frequencies can belong to the same positioning frequency layer (PFL). In another implementation, DL PRS carrier frequencies/resources can be chosen from different PFLs. This implementation is possible if PFL hopping is utilized to get multiple carrier phase measurement from multiple PFLs. In this case, the UE does not need to measure more than one PRS resource from multiple PFLs simultaneously, but the length of the required measurement gap would be increased to accommodate not only the time for measuring multiple PFL resources but also the gap between PFL measurements.

[0092] According to one or more embodiments, the LMF could also configure the target UE to perform carrier phase measurements over different subcarriers within a same DL PRS bandwidth or different DL PRS bandwidths. In these embodiments, important UE capabilities and reporting resources are pre-programmed into the device to perform phase measurements over all subcarriers, especially when DL PRS bandwidth is large. Alternatively, in one or

more embodiments, the target UE could be configured by the LMF to report phase measurements of certain predefined subcarriers that are determined and signaled (to the UE) by the LMF. In order to differentiate between each of the subcarriers, a subcarrier ID could be used and signaled to the target UE within the configuration assistance data. This subcarrier ID can then additionally be included in the corresponding measurement reported by the UE. In an alternate embodiment, the report can consist of the different measurements, which can be ordered based on the increasing (or decreasing) ID value or frequency of the respective measured subcarriers. In another embodiment, the location server, e.g., the LMF, may configure a set of subcarriers over which the phases are to be measured. In one embodiment, the set of subcarriers can be realized via a grouping mechanism, including a separate group ID and type of subcarriers to be measured.

[0093] In an extended implementation, the target UE could be configured with a start subcarrier and/or carrier component and subcarrier granularity and/or carrier component granularity. The selected frequency granularity could be adjusted based on several parameters to better estimate the integer ambiguity. Alternatively, the target UE could also be configured with a frequency granularity and, based on this granularity, the UE could be programmed to determine or select the DL PRS subcarriers on which to perform and report measurements for integer ambiguity resolution.

[0094] According to another implementation of this embodiment, the LMF could configure a target UE to perform measurements over both different DL PRS carrier components and different DL PRS subcarriers among the same DL PRS bandwidth or different DL PRS bandwidths. In an extended implementation of this embodiment, different DL PRSs transmitted over different carrier frequencies and/or positioning frequency layers PFLs could be received from different TRPs.

[0095] The different “*ProvideAssistanceData*” message bodies including configuration related to IA resolution are presented in **FIGs. 5A** and **5B**. **FIG. 5** illustrates an example target UE LPP configuration message 500 with multiple carrier frequency phase measurements, in accordance with one or more embodiments of the present disclosure. The field descriptions of the configuration message of **FIG. 5A** are presented in the following table.

| <b>NR-DL-CPP-ProvideAssistanceData field descriptions</b>                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>nr-DL-PRS-AssistanceData</b>                                                                                                                                                                                                                                                                            | <p>This field specifies the assistance data reference and neighbour TRPs and provides the DL-PRS configuration for the TRPs.</p> <p>Note, if this field is absent but the <i>nr-SelectedDL-PRS-IndexList</i> field is present, the <i>nr-DL-PRS-AssistanceData</i> may be provided in IE <i>NR-Multi-RTT-ProvideAssistanceData</i> or <i>NR-DL-AoD-ProvideAssistanceData</i> or <i>NR-TDoA-ProvideAssistanceData</i></p> |
| <b>nr-SelectedDL-PRS-IndexList</b>                                                                                                                                                                                                                                                                         | <p>This field specifies the DL-PRS Resources which are applicable for this <i>NR-DL-CPP-ProvideAssistanceData</i> message.</p>                                                                                                                                                                                                                                                                                           |
| <b>nr-SelectedDL-PRS-IA-IndexList</b>                                                                                                                                                                                                                                                                      | <p>This field specifies the DL-PRS Resources which are applicable for this <i>NR-DL-CPP-ProvideAssistanceData</i> message. These DL PRS resources/carrier frequencies are associated with the same TRP and measurements will be used to resolve integer ambiguity</p>                                                                                                                                                    |
| <b>nr-SelectedDL-PRS-IA-PFLs-r18</b>                                                                                                                                                                                                                                                                       | <p>This field specifies the DL positioning frequency layers used for measuring the phase of the DL PRS and reported to LMF to estimate integer ambiguity</p>                                                                                                                                                                                                                                                             |
| <b>nr-SelectedDL-PRS-IA-grouping-r18</b>                                                                                                                                                                                                                                                                   | <p>This field indicates if measurement over different carriers/subcarriers could be grouped</p>                                                                                                                                                                                                                                                                                                                          |
| <b>nr-SelectedDL-PRS-IA-groupingID-r18</b>                                                                                                                                                                                                                                                                 | <p>This field specifies the group IDs for reporting if <i>nr-SelectedDL-PRS-IA-grouping-r18</i> is configured.</p>                                                                                                                                                                                                                                                                                                       |
| <b>nr-PositionCalculationAssistance</b>                                                                                                                                                                                                                                                                    | <p>This field provides position calculation assistance data for UE-based mode.</p>                                                                                                                                                                                                                                                                                                                                       |
| <b>nr-DL-TDOA-Error</b>                                                                                                                                                                                                                                                                                    | <p>This field provides DL-TDOA error reasons.</p>                                                                                                                                                                                                                                                                                                                                                                        |
| <b>nr-On-Demand-DL-PRS-Configurations</b>                                                                                                                                                                                                                                                                  | <p>This field provides a set of available DL-PRS configurations which can be requested by the target device on-demand.</p>                                                                                                                                                                                                                                                                                               |
| <p>NOTE 1:       Void</p> <p>NOTE 2: If this field is absent but the <i>nr-On-Demand-DL-PRS-Configurations-Selected-IndexList</i> is present, the <i>nr-On-Demand-DL-PRS-Configurations</i> may be provided in IE <i>NR-Multi-RTT-ProvideAssistanceData</i> or <i>NR-DL-AoD-ProvideAssistanceData</i>.</p> |                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>nr-On-Demand-DL-PRS-Configurations-Selected-IndexList</b>                                                                                                                                                                                                                                               | <p>This field specifies the selected available on-demand DL-PRS configurations which are applicable for this <i>NR-DL-TDOA-ProvideAssistanceData</i> message.</p>                                                                                                                                                                                                                                                        |

***assistanceDataValidityArea***

This field specifies the network area for which this *NR-DL-TDOA-ProvideAssistanceData* is valid.

**Table III**

[0096] FIG. 5B illustrates an example target UE LPP configuration message 510 with multiple subcarrier phase measurements, in accordance with one or more embodiments of the present disclosure. The field descriptions of the configuration message of FIG. 5B are presented in the following table.

| <b><i>NR-DL-CPP-ProvideAssistanceData</i> field descriptions</b> |                                                                                                                                                                                                                                                                                                                                                                                                               |
|------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b><i>nr-DL-PRS-AssistanceData</i></b>                           | This field specifies the assistance data reference and neighbour TRPs and provides the DL-PRS configuration for the TRPs.<br>Note, if this field is absent but the <i>nr-SelectedDL-PRS-IndexList</i> field is present, the <i>nr-DL-PRS-AssistanceData</i> may be provided in IE <i>NR-Multi-RTT-ProvideAssistanceData</i> or <i>NR-DL-AoD-ProvideAssistanceData</i> or <i>NR-TDoA-ProvideAssistanceData</i> |
| <b><i>nr-SelectedDL-PRS-IndexList</i></b>                        | This field specifies the DL-PRS Resources which are applicable for this <i>NR-DL-CPP-ProvideAssistanceData</i> message.                                                                                                                                                                                                                                                                                       |
| <b><i>nr-SelectedDL-PRS-IA-subcarrierID-r18</i></b>              | This field specifies the subcarriers IDs within the DL PRS bandwidth on which phase measurements should be performed and reported.                                                                                                                                                                                                                                                                            |
| <b><i>nr-SelectedDL-PRS-IA-subca1-r18</i></b>                    | This field specifies one start subcarrier within the DL PRS bandwidth on which phase measurements should be performed and reported.                                                                                                                                                                                                                                                                           |
| <b><i>nr-SelectedDL-PRS-IA-subcagranularity-r18</i></b>          | This field specifies the frequency or subcarrier granularity                                                                                                                                                                                                                                                                                                                                                  |
| <b><i>nr-SelectedDL-PRS-IA-grouping-r18</i></b>                  | This field indicates if measurement over different carriers/subcarriers could be grouped                                                                                                                                                                                                                                                                                                                      |
| <b><i>nr-SelectedDL-PRS-IA-groupingID-r18</i></b>                | This field specifies the group IDs for reporting if <i>nr-SelectedDL-PRS-IA-grouping-r18</i> is configured.                                                                                                                                                                                                                                                                                                   |
| <b><i>nr-PositionCalculationAssistance</i></b>                   | This field provides position calculation assistance data for UE-based mode.                                                                                                                                                                                                                                                                                                                                   |
| <b><i>nr-DL-TDOA-Error</i></b>                                   | This field provides DL-TDOA error reasons.                                                                                                                                                                                                                                                                                                                                                                    |

***nr-On-Demand-DL-PRS-Configurations***

This field provides a set of available DL-PRS configurations which can be requested by the target device on-demand.

NOTE 1: Void

NOTE 2: If this field is absent but the *nr-On-Demand-DL-PRS-Configurations-Selected-IndexList* is present, the *nr-On-Demand-DL-PRS-Configurations* may be provided in IE *NR-Multi-RTT-ProvideAssistanceData* or *NR-DL-AoD-ProvideAssistanceData*.

***nr-On-Demand-DL-PRS-Configurations-Selected-IndexList***

This field specifies the selected available on-demand DL-PRS configurations which are applicable for this *NR-DL-TDOA-ProvideAssistanceData* message.

***assistanceDataValidityArea***

This field specifies the network area for which this *NR-DL-TDOA-ProvideAssistanceData* is valid.

**Table IV**

[0097] According to the second aspect of the disclosure, the LMF configures the target UE with a measurement configuration for performing specific types of measurements that support time-based IA resolution. According to the second embodiment, the LMF or any configuration entity (also generally referred to as an LMF for simplicity) could determine to configure target UE with configuration data to support time-based integer ambiguity resolution methods. In one or more embodiments, the determination is based on one or more parameters, such as UE mobility, UE capability, positioning target requirements, IA uncertainty levels, IA range, etc.

[0098] The time-based integer ambiguity resolution method is based on the time-differenced carrier phase (TDCP) technique, which is also called relative carrier phase. TDCP is based on the differences between consecutive carrier-phase measurements which enables the exploitation of the high precision of a carrier-phase observable, without having the ambiguity issue. With the TDCP technique, the time-correlated errors can be eliminated or largely reduced if the sampling interval is short. More importantly, the biggest impediment of the carrier phases, the integer ambiguities, can also be eliminated, as long as there is no cycle slip between the two consecutive time instances.

[0099] Accordingly, returning to the description of the processes performed by the network apparatus, in one or more embodiments, the controller selects the fifth configuration of one or more consecutive time windows for DL PRS measurement. The controller identifies the one or more consecutive time windows to define within the fifth configuration. According to one control aspect, the DL PRS carrier frequency and configuration are the same during each of the one or more consecutive time windows. The controller includes the fifth configuration within the first configuration message sent to the target apparatus.

[0100] In one or more embodiments, the first configuration message includes configuration assistance data to configure the target apparatus to provide time-based integer ambiguity resolution related measurements by performing carrier phase measurements for DL PRS received at consecutive time instances. In one or more embodiments, the controller identifies and incorporates into the first configuration message at least two consecutive time windows over which the target apparatus is to perform carrier phase measurements associated with each time instance based on a same DL PRS configuration. In one or more embodiments, the configuration assistance data comprises consecutive carrier-phase measurements to enable the target apparatus to perform time-based integer ambiguity resolution based on a time-differenced carrier phase (TDCP) determination.

[0101] In one or more embodiments, the time windows include a time period during which all time-varying parameters are unchanged and each time window includes a respective start time and a respective one of a length, an end time, or a periodicity.

[0102] With respect to the processes performed by the target apparatus, in one or more embodiments, based on the one or more carrier phase positioning measurement configurations being the fifth configuration, the controller performs carrier phase measurements over different time instances associated with one carrier frequency from a same transmission reception point over a Uu interface of the apparatus. In one or more embodiments, the controller performs the phase measurements on PRS time-frequency resources that can span one or more consecutive time instances. In one or more embodiments, the configuration message is a long-term evolution (LTE) positioning protocol (LPP) message.

[0103] FIG. 6 illustrates an example of relative carrier phase determination by a UE receiving a DL PRS at two different times to enable a time-difference carrier phase (TDCP) technique for time-based integer ambiguity resolution, according to one or more aspects of the disclosure. According to the figure, target UE begins at location A at time  $t_1$  and moves a distance,  $d_1$ , from location A to location B, arriving at time  $t_2$ . At both location A and B, TRP provides UE with first DL PRS on Uu interface, with similar DL PRS configuration. The side diagram shows the relative carrier phase between the two signals transmitted at different times,  $t_1$  and  $t_2$ . Evaluating the relative phases involves the following two equations:

$$\varphi_1(t_1) = \frac{2\pi d_1}{\lambda_1} + 2\pi N \quad (1)$$

$$\varphi_2(t_2) = \frac{2\pi(d_1 + \Delta d_1)}{\lambda_1} + 2\pi N \quad (2)$$

[0104] In the above equations,  $\varphi_1$ ,  $d_1$  are the corresponding received carrier phase and TRP/target UE distance at  $t_1$  and  $\varphi_2$  and  $d_1 + \Delta d_1$  are the corresponding received carrier phase and the TRP/target UE distance at  $t_2$ ,  $\lambda_1$  is the wavelength and  $N$  is the unknown integer number of cycles.

[0105] According to the second embodiment, the LMF (or any configuration entity) would configure the target UE with at least two consecutive time windows,  $A$  and  $B$ , over which the target UE will perform carrier phase measurements associated with each time instance, based on the same DL PRS configuration. According to one embodiment, the time windows  $A$  and  $B$  are defined by a start time  $t_1$  and  $t_2$ , but can also be defined by the windows lengths and/or end times and/or periodicities, or a combination of two or more of these parameters. Different time window lengths could be signaled to target UE to measure the same DL PRS. When used to define the windows, the time window lengths should be configured such that channel conditions between the corresponding DL PRS measurements remain stable with regards to Doppler effects. In one implementation, a threshold could be configured over the consecutive time windows' lengths.

[0106] Similar to a GNSS epoch, a time window would define the time period during which all time-varying parameters are unchanged and referenced. According to a first

implementation, the time window signaled by the LMF to target UE could span a part of the DL PRS period. In another implementation, the time window could span part of the DL PRS positioning occasion. As described below, the measurement reports generated by the target UE will include timestamps associated with each of the phase measurements.

[0107] According to the processes performed by the target apparatus, in one or more embodiments, the controller receives a second configuration message that includes a measurement reporting configuration that configures the apparatus to provide a report to the LMF with IA resolution related measurement results. In response to receiving the second configuration message, the controller generates and transmits, to the network apparatus, a report that includes the measurement results for IA resolution to enable the network apparatus to accurately determine a location of the apparatus.

[0108] In one or more embodiments, the controller groups phase measurements associated with each transmission reception point and performed over different DL PRS carrier frequencies or different subcarriers, and the controller transmits the groups of phase measurements within a same report by differentiating each group via a group ID. Accordingly, the controller reports phase measurements over DL PRS received at different time instances.

[0109] In one or more embodiments, the controller generates reports comprising different measurements of different DL PRS resource sets in one of a cluster or individually. The controller signals different measurements of different positioning frequency layers (PFLs) in different measurement reports.

[0110] **FIG. 8** illustrates an example target UE LPP configuration message 800 with TDCP, in accordance with aspects of the present disclosure. The field descriptions of the content of configuration message 800 are provided in the Table 5 below.

| <b>NR-DL-CPP-ProvideAssistanceData field descriptions</b>           |                                                                                                                                                                                                                                                                                                                                                                                                               |
|---------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b><i>nr-DL-PRS-CPP-AssistanceData</i></b>                          | This field specifies the assistance data reference and neighbour TRPs and provides the DL-PRS configuration for the TRPs.<br>Note, if this field is absent but the <i>nr-SelectedDL-PRS-IndexList</i> field is present, the <i>nr-DL-PRS-AssistanceData</i> may be provided in IE <i>NR-Multi-RTT-ProvideAssistanceData</i> or <i>NR-DL-AoD-ProvideAssistanceData</i> or <i>NR-TDoA-ProvideAssistanceData</i> |
| <b><i>nr-SelectedDL-PRS-IndexList</i></b>                           | This field specifies the DL-PRS Resources which are applicable for this <i>NR-DL-CPP-ProvideAssistanceData</i> message.                                                                                                                                                                                                                                                                                       |
| <b><i>nr-TimeWindow-IA-IndexList-r18</i></b>                        | This field specifies measurements should be performed over two (or more) consecutive time instances over received DL PRS transmitted from same TRP                                                                                                                                                                                                                                                            |
| <b><i>nr-SelectedDL-PRS-IA-windstart-r18</i></b>                    | This field specifies the windows start time                                                                                                                                                                                                                                                                                                                                                                   |
| <b><i>nr-SelectedDL-PRS-IA-windlength-r18</i></b>                   | This field indicates the windows lengths                                                                                                                                                                                                                                                                                                                                                                      |
| <b><i>nr-SelectedDL-PRS-IA-windend-r18</i></b>                      | This field specifies the windows end time                                                                                                                                                                                                                                                                                                                                                                     |
| <b><i>nr-SelectedDL-PRS-IA-windperio-r18</i></b>                    | This field specifies the windows periodicity.                                                                                                                                                                                                                                                                                                                                                                 |
| <b><i>nr-PositionCalculationAssistance</i></b>                      | This field provides position calculation assistance data for UE-based mode.                                                                                                                                                                                                                                                                                                                                   |
| <b><i>nr-DL-TDOA-Error</i></b>                                      | This field provides DL-TDOA error reasons.                                                                                                                                                                                                                                                                                                                                                                    |
| <b><i>nr-On-Demand-DL-PRS-Configurations</i></b>                    | This field provides a set of available DL-PRS configurations which can be requested by the target device on-demand.                                                                                                                                                                                                                                                                                           |
| NOTE 1:                                                             | Void                                                                                                                                                                                                                                                                                                                                                                                                          |
| NOTE 2:                                                             | If this field is absent but the <i>nr-On-Demand-DL-PRS-Configurations-Selected-IndexList</i> is present, the <i>nr-On-Demand-DL-PRS-Configurations</i> may be provided in IE <i>NR-Multi-RTT-ProvideAssistanceData</i> or <i>NR-DL-AoD-ProvideAssistanceData</i> .                                                                                                                                            |
| <b><i>nr-On-Demand-DL-PRS-Configurations-Selected-IndexList</i></b> |                                                                                                                                                                                                                                                                                                                                                                                                               |

|                                                                                                                                                            |
|------------------------------------------------------------------------------------------------------------------------------------------------------------|
| This field specifies the selected available on-demand DL-PRS configurations which are applicable for this <i>NR-DL-TDOA-ProvideAssistanceData</i> message. |
| <b><i>assistanceDataValidityArea</i></b>                                                                                                                   |
| This field specifies the network area for which this <i>NR-DL-TDOA-ProvideAssistanceData</i> is valid.                                                     |

**Table V**

[0111] In an alternate implementation of this embodiment, the target UE could be configured to perform carrier phase measurements over DL PRS transmitted from different co-located antenna elements PRS#1 received at time  $t_1$  and PRS#2 received at time  $t_2$  using the same carrier frequency.

[0112] The third aspect of the disclosure includes the LMF configuring the target UE to generate and provides measurement reports that include IA resolution associated measurements. According to a first implementation of this embodiment, a “*ProvideLocationInformation*” LPP message that includes the IAR methods related measurements are signaled to the target UE to configure the UE to perform the program functions indicated. **FIG. 8** illustrates an example second LLP message **800** with IAR information to configure the target UE to generate and transmit measurement reports, in accordance with aspects of the present disclosure.

[0113] In one or more embodiment, the “*RequestLocationInformation*” LPP message includes a measurement report configuration associated with each of the carrier frequencies and/or with each of the subcarriers identified by a subcarrier ID or frequency granularity. According to the first implementation, the phase measurements associated with each TRP and performed over different DL PRS carrier frequencies are grouped and transmitted/signaled within the same report by differentiating such groups via a group ID and type of subcarriers to be measured. Different measurements of different DL PRS resource sets can also be reported in a clustered manner or reported individually. Different measurements of different positioning frequency layers (PFLs) are provided in different measurement reports.

[0114] According to the processes performed by the network apparatus, in one or more embodiments, the controller also transmits a second configuration message comprising a measurement reporting configuration which configures the target apparatus to provide a

response message with IA resolution related measurements. The measurement report configuration corresponds with carrier frequencies and subcarriers identified by a subcarrier ID or frequency granularity. The controller: incorporates, within the second configuration message, second configuration assistance data that configures the target apparatus to report phase measurements of certain predefined subcarriers, which are indicated by the LMF. The controller assigns, with the configuration assistance data, a subcarrier ID to differentiate between each subcarrier, where the subcarrier ID is incorporated within a corresponding measurement report generated at and received from the target apparatus. In one or more embodiments, the second configuration assistance data configures the target apparatus to provide measurement results comprising multiple different measurements with corresponding report IDs or frequency of corresponding respective measured subcarriers.

[0115] The disclosure utilizes defined UE measurements that are defined and are applicable to DL-based positioning techniques. **FIG. 9** illustrates an example of DL-TDOA Assistance data configurations 900 presented within the second configuration message to enable UE-assisted and UE-based NR downlink TDOA. The IE *NR-DL-TDOA-ProvideAssistanceData* is used by the location server (or LMF) to provide assistance data to enable the UE-assisted and UE-based NR downlink TDOA. According to one embodiment, the UE-based NR downlink TDOA may also be used to provide NR DL TDOA positioning specific error reason.

[0116] The IE *NR-DL-TDOA-SignalMeasurementInformation* configuration message is used by the target UE 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 when 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. **FIG. 10 (10A-10B)** illustrates an example measurement report 1000 generated by the target UE.

[0117] **FIG. 11** illustrates a block diagram 1100 of an example an apparatus 1102 for wireless communication that can be configured by an LMF/LS to complete DL PRS phase measurements and report measurements for use in IA resolution, in accordance with aspects

of the present disclosure. The apparatus 1102 may be an example of a target UE 104 as illustrated in the preceding figures and described herein. As a UE 104, performing the functions attributable to a UE, the apparatus 1102 can be interchangeably referred to as a device 1102 or UE 104 that supports wireless communication with one or more network entities 102 (e.g., eNB), other UEs 104, other network devices, such as a location server 220, or any combination thereof. The device 1102 may include components for bi-directional communications including components for transmitting and receiving communications, such as a processor (or controller) 1104, a memory 1106, a transceiver 1108, and an I/O controller 1110. These components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

**[0118]** The processor 1104, the memory 1106, the transceiver 1108, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. For example, the processor 1104, the memory 1106, the transceiver 1108, or various combinations or components thereof may support a method for performing one or more of the operations described herein.

**[0119]** In some implementations, the processor 1104, the memory 1106, the transceiver 1108, or various combinations or components thereof may be implemented in hardware (e.g., in communications management circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA) or other programmable logic device, a discrete gate or transistor logic, discrete hardware components, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure. In some implementations, the processor 1104 and the memory 1106 coupled with the processor 1104 may be configured to perform one or more of the functions described herein (e.g., executing, by the processor 1104, instructions stored in the memory 1106).

**[0120]** The processor 1104 can be interchangeably referred to as a controller. However, it is appreciated that the term controller applies more generally to a combination of one or

more components that performs the various functions of the device 1102, including processing of program code, digital signal processing, wireless communication, and so on.

**[0121]** For example, the controller 1104 may support wireless communication at the device 1102 in accordance with examples as disclosed herein. The controller 1104 may be configured as or otherwise support the process steps illustrated within the flow chart of method 1300 and as described herein throughout the specification. Accordingly, in one embodiment, the controller 1104 receives, from the network apparatus, at least one downlink (DL) positioning reference signals (PRS). The controller 1104 performs, based on the one or more carrier phase positioning measurement configurations, carrier phase measurements on at least one frequency characteristic provided by the DL PRS to generate measurement results for resolving integer ambiguity. The controller 1104 receives a second configuration message that includes a measurement reporting configuration that configures the apparatus to provide a report to the LMF with IA resolution related measurement results. In response to receiving the second configuration message, the controller 1104 generates and transmits, to the network apparatus, a report that includes the measurement results for IA resolution to enable the network apparatus to accurately determine a location of the apparatus.

**[0122]** The controller 1104 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, a microcontroller, an ASIC, an FPGA, a programmable logic device, a discrete gate or transistor logic component, a discrete hardware component, or any combination thereof). In some implementations, the controller 1104 may be configured to operate a memory array using a memory controller. In some other implementations, a memory controller may be integrated into the processor 1104. The controller 1104 may be configured (as a processor) to execute computer-readable instructions stored in a memory (e.g., the memory 1106) to cause the device 1102 to perform various functions of the present disclosure.

**[0123]** The memory 1106 may include random access memory (RAM) and read-only memory (ROM). The memory 1106 may store computer-readable, computer-executable code including instructions that, when executed by the processor 1104 cause the device 1102 to perform various functions described herein. In the illustrative embodiment, the code includes target UE DL PRS phase measurement and reporting code 1120 that enables the various

functions described herein attributable to the target UE. The memory 1106 may also store reports 1125 with data generated from the measurements. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. In some implementations, the code may not be directly executable by the processor 1104 but may cause a computer (e.g., when compiled and executed) to perform functions described herein. In some implementations, the memory 1106 may include, among other things, a basic I/O system (BIOS) which may control basic hardware or software operation such as the interaction with peripheral components or devices.

**[0124]** The I/O controller 1110 may manage input and output signals for the device 1102. The I/O controller 1110 may also manage peripherals not integrated into the device M02. In some implementations, the I/O controller 1110 may represent a physical connection or port to an external peripheral. In some implementations, the I/O controller 1110 may utilize an operating system such as iOS®, ANDROID®, MS-DOS®, MS-WINDOWS®, OS/2®, UNIX®, LINUX®, or another known operating system. In some implementations, the I/O controller 1110 may be implemented as part of a processor, such as the processor M06. In some implementations, a user may interact with the device 1102 via the I/O controller 1110 or via hardware components controlled by the I/O controller 1110.

**[0125]** In some implementations, the device 1102 may include a single antenna 1112. However, in some other implementations, the device 1102 may have more than one antenna 1112 (i.e., multiple antennas), including multiple antenna panels or antenna arrays, which may be capable of concurrently transmitting or receiving multiple wireless transmissions. The transceiver 1108 may communicate bi-directionally, via the one or more antennas 1112, wired, or wireless links as described herein. For example, the transceiver 1108 may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver 1108 may also include a modem to modulate the packets, to provide the modulated packets to one or more antennas 1112 for transmission, and to demodulate packets received from the one or more antennas 1112.

**[0126]** **FIG. 12** illustrates a block diagram of an example network apparatus for wireless communication that includes an LMF, which generates configuration messages for configuring a target UE to perform DL RPS phase measurements based on selected

configurations, in accordance with aspects of the present disclosure. Network apparatus 1202 can be location server 220 that includes LMF via LMF code 1220. The component makeup of **FIG. 12** can be similar to that of **FIG. 11**, and both figures are presented with the same primary components of the processor/controller 1104/1204, memory 1106/1206, transceiver 1108/1208, and other components introduced in **FIG. 11** and described within the **FIG. 11** description. Given the similarity in the component makeup across these figures, no expanded description is provided of these physical structures within **FIGs. 12** for those features of **FIG. 11** that are duplicated within **FIGs. 12** and **8**. With the exception of the different blocks of code within memory 1206 (from memory 1106), the description of these components in **FIG. 11** apply also to the similar components in **FIGs. 12**.

[0127] In the illustrative embodiment of **FIG. 12**, the memory 706 includes LMF code 1220, IA Resolution code 1225, and Configuration Message Generation code 1230. The various code may be stored in a non-transitory computer-readable medium, such as system memory or another type of memory. In some implementations, the code may not be directly executable by the processor 604 but may cause a computer (e.g., when compiled and executed) to perform the associated functions described herein.

[0128] The processor/controller 1104 may be configured to support the process steps illustrated within the flow chart of method 1400 and as described herein throughout the specification. Accordingly, in one embodiment, the controller 1104 determines which of one or more carrier phase measurements configurations to include in the configuration message for IA resolution processing by the target apparatus. The controller transmits, to the target apparatus, a first configuration message that includes a selected one or more carrier phase measurement configurations. The selected one or more carrier phase measurement configurations configure the target apparatus to perform DL PRS measurements related to IA resolution.

[0129] **FIG. 13** illustrates a flowchart of a method by which an apparatus 1100, such as a target UE 104, is configured to perform and report DL PRS phase measurements based on received configuration messages from an LMF, in accordance with aspects of the present disclosure. The operations of the method 1300 may be implemented by an apparatus or its components, as described herein. For example, the operations of the method 1300 may be

performed by apparatus 1100 or target UE 104, as described with reference to the preceding **FIGs. 1 and 3-12**. In some implementations, the apparatus 1100 may execute a set of instructions to control the function elements of the apparatus 1100 to perform the described functions. Additionally, or alternatively, the apparatus 1100 may perform aspects of the described functions using special-purpose hardware. The terms apparatus and device are used interchangeably herein.

**[0130]** At 1305, the method 1300 may include receiving, from a network apparatus, a configuration message comprising one or more carrier phase positioning measurement configurations for performing downlink (DL) Positioning Reference Signals (PLS) phase measurements used for integer ambiguity (IA) resolution. The operations of 1305 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1305 may be performed by a device as described with reference to **1 and 3-12**.

**[0131]** At 1310, the method 1300 may include receiving, from the network apparatus, one or more downlink (DL) positioning reference signals (PRS). The operations of 1310 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1310 may be performed by a device as described with reference to **FIGs. 1 and 3-12**.

**[0132]** At 1315, the method 1300 may include performing, based on the one or more carrier phase positioning measurement configurations, carrier phase measurements on at least one frequency characteristic provided by the one or more DL PRS to generate measurement results for resolving integer ambiguity. The operations of 1315 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of **1315** may be performed by a device as described with reference to **FIGs. 1 and 3-12**.

**[0133]** At 1320, the method 1300 may include receiving a second configuration message comprising a measurement reporting configuration that configures the apparatus to provide a report to the LMF with IA resolution related measurement results. The operations of 1315 may be performed in accordance with examples as described herein. In some

implementations, aspects of the operations of **1315** may be performed by a device as described with reference to **FIGs. 1** and **3-12**.

[0134] At 1325, the method 1300 may include in response to receiving the second configuration message, generating and transmitting, to the network apparatus, a report comprising the measurement results for IA resolution to enable the network apparatus to accurately determine a location of the apparatus. The operations of 1315 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of **1315** may be performed by a device as described with reference to **1** and **3-12**.

[0135] According to one or more embodiments, the one or more carrier phase positioning measurement configurations comprise one or more of (i) a first configuration of different DL PRS carrier frequencies within a same position frequency layer (PFL); (ii) a second configuration of different DL PRS carrier frequencies, with the DL PRS received at a same time within different PFLs; (iii) a third configuration of different DL PRS subcarriers within a same DL PRS bandwidth; (iv) a fourth configuration of different DL PRS subcarriers within different DL PRS bandwidths; and (v) a fifth configuration of one or more consecutive time windows for DL PRS measurements.

[0136] In one or more embodiments, the method 1300 includes one or more of: based on the one or more carrier phase positioning measurement configurations being the first configuration, performing carrier phase measurements over different subcarriers within the same DL PRS bandwidth; based on the one or more carrier phase positioning measurement configurations being the second configuration, performing carrier phase measurements over different subcarriers, within the DL PRS bandwidths where DL PRS is being received from a same transmission reception point over a unique user (Uu) interface of the apparatus; based on the one or more carrier phase positioning measurement configurations being the third configuration, performing phase measurements over different subcarriers within a same DL PRS bandwidth; based on the one or more carrier phase positioning measurement configurations being the fourth configuration, performing phase measurements over different subcarriers within different DL PRS bandwidths; and based on the one or more carrier phase positioning measurement configurations being the fifth configuration, performing carrier

phase measurements over different time instances associated with one carrier frequency from a same transmission reception point over the Uu interface of the apparatus 1100.

[0137] In one or more embodiments, the method 1300 includes grouping phase measurements associated with each transmission reception point and performed over different DL PRS carrier frequencies or different subcarriers. The method 1300 includes transmitting the groups of phase measurements within a same report by differentiating each group via a group ID. The report includes phase measurements over DL PRS received at different time instances.

[0138] In one or more embodiments, the method 1300 includes generating reports comprising different measurements of different DL PRS resource sets in one of a cluster or individually. The method 1300 includes transmitting different measurements of different positioning frequency layers (PFLs) in different measurement reports.

[0139] **FIG. 14** illustrates a flowchart of a method by which an LMF selects specific configuration parameters and generates configuration messages to provide to a target UE to configure the target UE to perform a corresponding DL PRS phase measurement and report the measurements for use in IA resolution, in accordance with aspects of the present disclosure. The operations of the method 1400 may be implemented by a network apparatus 1200 or its components as described herein. For example, the operations of the method 1400 may be performed by a network device, such as an eNodeB 102 or a location server 220, as described with reference to **FIGs. 1 and 3-12**. In some implementations, the network apparatus 1200 (or device) may execute a set of instructions to control the function elements of the device to perform the described functions. Additionally, or alternatively, the network apparatus 1200 device may perform aspects of the described functions using special-purpose hardware.

[0140] At 1405, the method 1400 may include determining which of one or more carrier phase measurements configurations to include in a configuration message for IA resolution processing by a target apparatus, the determining based on one or more parameters from a group comprising IA search range, IA uncertainty level, positioning target requirements, target apparatus capabilities, and measurement reporting overhead. The operations of 1405

may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1405 may be performed by a device as described with reference to **FIG. 1** and **3-12**.

**[0141]** At 1410, the method 1400 may include transmitting, to the target apparatus, a first configuration message comprising a selected one or more carrier phase measurement configurations, the selected one or more carrier phase measurement configurations configuring the target apparatus to perform DL PRS phase measurements related to one or both of frequency-based and timing-based integer ambiguity resolution methods. The operations of 1410 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1410 may be performed by a device as described with reference to **FIG. 1** and **3-12**.

**[0142]** At 1415, the method 1400 may include transmitting a second configuration message comprising a measurement reporting configuration which configures the target apparatus to provide a response message with IA resolution related measurement results. The operations of 1415 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1415 may be performed by a device as described with reference to **FIG. 1** and **3-12**.

**[0143]** In one or more embodiments, the method 1400 for transmitting the first configuration includes selecting one or more carrier phase positioning measurement configurations from among the first, second, third, fourth, and fifth configurations. The method 1400 includes incorporating the selected one or more carrier phase positioning measurement configurations within the first configuration message sent to the target apparatus.

**[0144]** In one or more embodiments, the method 1400 includes incorporating, within the second configuration message, second configuration assistance data that configures the target apparatus to report phase measurements of certain predefined subcarriers, which are indicated by the LMF. The method 1400 includes assigning with the configuration assistance data, a subcarrier ID to differentiate between each subcarrier. The subcarrier ID is

incorporated within a corresponding measurement report generated at and received from the target apparatus.

**[0145]** In one or more embodiments, the method 1400 for selecting includes selecting the fifth configuration of one or more consecutive time windows. The method includes identifying the one or more consecutive time windows to define within the fifth configuration. The DL PRS carrier frequency and configuration are the same during each of the one or more consecutive time windows. The method includes incorporating/including the fifth configuration within the first configuration message sent to the target apparatus.

**[0146]** According to one or more of the described embodiments, the disclosure provides a method by a target-UE in a wireless communication network. The method includes receiving from a network entity a plurality of carrier phase positioning measurement configurations to perform carrier phase measurements and resolve the integer ambiguity. The carrier phase positioning measurement configuration further includes configuration of different DL PRS carrier frequencies within same or different positioning frequency layers (PFLs), configuration of different DL PRS subcarriers within same or different DL PRS bandwidth, and/or configuration of one or more time windows, or a combination thereof. The method includes receiving a plurality of positioning reference signals in response to the plurality of carrier phase configurations and performing phase measurements over different DL PRS carrier frequencies and/or subcarriers or time instances based on the signaled configuration. The method also includes reporting the integer ambiguity related measurements to a network entity.

**[0147]** In accordance with the above method, in one or more embodiments, the carrier phase measurements configurations are associated to phase measurements performed on PRS time-frequency resources that may span one or more carrier frequencies within same or different positioning frequency layers, or measurements performed on subcarriers within a same or a different DL PRS bandwidth, or a combination thereof.

**[0148]** In accordance with the above method, in one or more embodiments, the carrier phase measurements configurations are associated to phase measurements performed on PRS time-frequency resources that may span one or more consecutive time instances given by the

configuration of one or more time windows. The time windows configuration comprises of a starting time, a window length, or a periodicity, or a combination thereof.

**[0149]** In accordance with the above method, in one or more embodiments, carrier components or subcarriers phase measurements are grouped and reported to a network entity within the same measurement report, tagged with an associated group ID that is configured and signaled to the target UE by the network entity. The signaled subcarriers or carriers frequencies can be associated with a subcarrier or carrier ID and/or a frequency or a subcarrier granularity.

**[0150]** It should be noted that the methods described herein describes possible implementations, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible. Further, aspects from two or more of the methods may be combined.

**[0151]** The various illustrative blocks and components described in connection with the disclosure herein may be implemented or performed with a general-purpose processor, a DSP, an ASIC, a CPU, an FPGA or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices (e.g., a combination of a DSP and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration).

**[0152]** The functions described herein may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Other examples and implementations are within the scope of the disclosure and appended claims. For example, due to the nature of software, functions described herein may be implemented using software executed by a processor, hardware, firmware, hardwiring, or combinations of any of these. Features

implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations.

**[0153]** Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer. By way of example, and not limitation, non-transitory computer-readable media may include RAM, ROM, electrically erasable programmable ROM (EEPROM), flash memory, compact disk (CD) ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other non-transitory medium that may be used to carry or store desired program code means in the form of instructions or data structures and that may be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor.

**[0154]** Any connection may be properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of computer-readable medium. Disk and disc, as used herein, include CD, laser disc, optical disc, digital versatile disc (DVD), floppy disk and Blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above are also included within the scope of computer-readable media.

**[0155]** As used herein, including in the claims, “or” as used in a list of items (e.g., a list of items prefaced by a phrase such as “at least one of” or “one or more of” or “one or both of”) indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase “based on” shall not be construed as a reference to a closed set of conditions. For example, an example step that is described as “based on condition A” may be based on both a condition A and a condition B without departing from the scope of the present disclosure.

In other words, as used herein, the phrase “based on” shall be construed in the same manner as the phrase “based at least in part on. Further, as used herein, including in the claims, a “set” may include one or more elements.

**[0156]** The terms “transmitting,” “receiving,” or “communicating,” when referring to a network entity, may refer to any portion of a network entity (e.g., a base station, a CU, a DU, a RU) of a RAN communicating with another device (e.g., directly or via one or more other network entities).

**[0157]** The description set forth herein, in connection with the appended drawings, describes example configurations and does not represent all the examples that may be implemented or that are within the scope of the claims. The term “example” used herein means “serving as an example, instance, or illustration,” and not “preferred” or “advantageous over other examples.” The detailed description includes specific details for the purpose of providing an understanding of the described techniques. These techniques, however, may be practiced without these specific details. In some instances, known structures and devices are shown in block diagram form to avoid obscuring the concepts of the described example.

**[0158]** The description herein is provided to enable a person having ordinary skill in the art to make or use the disclosure. Various modifications to the disclosure will be apparent to a person having ordinary skill in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not limited to the examples and designs described herein but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.

## CLAIMS

What is claimed is:

1. A user equipment (UE) for wireless communication, the UE comprising:
  - a memory comprising program code for performing downlink (DL) Positioning Reference Signals (PLS) measurements; and
  - at least one transceiver that enables the UE to communicate with other network components, including a network apparatus providing a location management function (LMF); and
  - a controller communicatively coupled to the memory and to the at least one transceiver and which:
    - receives, from the network apparatus, a configuration message comprising one or more carrier phase positioning measurement configurations for performing DL PRS phase measurements used for integer ambiguity (IA) resolution;
    - receives, from the network apparatus, at least one downlink (DL) positioning reference signals (PRS); and
    - performs, based on the one or more carrier phase positioning measurement configurations, carrier phase measurements on at least one frequency characteristic provided by the DL PRS to generate measurement results for resolving integer ambiguity.
2. The UE of claim 1, wherein:
  - the one or more carrier phase positioning measurement configurations comprise one or more of (i) a first configuration of different DL PRS carrier frequencies within a same position frequency layer (PFL); (ii) a second configuration of different DL PRS carrier frequencies, with the DL PRS received at a same time within different PFLs; (iii) a third configuration of different DL PRS subcarriers within a same DL PRS bandwidth; (iv) a fourth configuration of different DL PRS subcarriers within different DL PRS bandwidths; and (v) a fifth configuration of one or more consecutive time windows for DL PRS measurements.

3. The UE of claim 2, wherein based on the one or more carrier phase positioning measurement configurations being the first configuration, the controller performs carrier phase measurements over different subcarriers from a same DL PRS bandwidth.

4. The UE of claim 2, wherein based on the one or more carrier phase positioning measurement configurations being the second configuration, the controller performs carrier phase measurements over different subcarriers, within the DL PRS bandwidths, where DL PRS is being received from a same transmission reception point over a unique user (Uu) interface of the UE.

5. The UE of claim 2, wherein based on the one or more carrier phase positioning measurement configurations being the third configuration, the controller performs phase measurements over different subcarriers within a same DL PRS bandwidth.

6. The UE of claim 2, wherein based on the one or more carrier phase positioning measurement configurations being the fourth configuration, the controller performs phase measurements over different subcarriers within different DL PRS bandwidths.

7. The UE of claim 2, wherein based on the one or more carrier phase positioning measurement configurations being the fifth configuration, the controller performs carrier phase measurements over different time instances associated with one carrier frequency from a same transmission reception point over a unique user (Uu) interface of the UE, wherein the controller performs the phase measurements on PRS time-frequency resources that can span one or more consecutive time instances.

8. The UE of claim 1, wherein the configuration message is a long-term evolution (LTE) positioning protocol (LPP) message, and the controller:

receives a second configuration message comprising a measurement reporting configuration that configures the UE to provide a report to the LMF with IA resolution related measurement results; and

based on receiving the second configuration message, generates and transmits, to the network apparatus, a report comprising the measurement results for IA resolution to enable the network apparatus to accurately determine a location of the UE.

9. The UE of claim 8, wherein the controller:

groups phase measurements associated with each transmission reception point and performed over different DL PRS carrier frequencies or different subcarriers; and

transmits the groups of phase measurements within a same report by differentiating each group via a group ID;

wherein the controller reports phase measurements over DL PRS received at different time instances;

generates reports comprising different measurements of different DL PRS resource sets in one of a cluster or individually; and

signals different measurements of different positioning frequency layers (PFLs) in different measurement reports.

10. A method performed by a user equipment (UE), the method comprising:

receiving, from a network apparatus that provides a location management function (LMF), a configuration message comprising one or more carrier phase positioning measurement configurations for performing downlink (DL) Positioning Reference Signals (PLS) phase measurements used for integer ambiguity (IA) resolution;

receiving, from the network apparatus, one or more downlink (DL) positioning reference signals (PRS); and

performing, based on the one or more carrier phase positioning measurement configurations, carrier phase measurements on at least one frequency characteristic provided by the one or more DL PRS to generate measurement results for resolving integer ambiguity.

11. The method of claim 10, wherein:

the one or more carrier phase positioning measurement configurations comprise one or more of (i) a first configuration of different DL PRS carrier frequencies within a same position frequency layer (PFL); (ii) a second configuration of different DL PRS carrier

frequencies, with the DL PRS received at a same time within different PFLs; (iii) a third configuration of different DL PRS subcarriers within a same DL PRS bandwidth; (iv) a fourth configuration of different DL PRS subcarriers within different DL PRS bandwidths; and (v) a fifth configuration of one or more consecutive time windows for DL PRS measurements;

based on the one or more carrier phase positioning measurement configurations being the first configuration, the method comprises performing carrier phase measurements over different subcarriers within the same DL PRS bandwidth;

based on the one or more carrier phase positioning measurement configurations being the second configuration, the method comprises performing carrier phase measurements over different subcarriers, within the DL PRS bandwidths where DL PRS is being received from a same transmission reception point over a unique user (Uu) interface of the apparatus;

based on the one or more carrier phase positioning measurement configurations being the third configuration, the method comprises performing phase measurements over different subcarriers within a same DL PRS bandwidth;

based on the one or more carrier phase positioning measurement configurations being the fourth configuration, the method comprises performing phase measurements over different subcarriers within different DL PRS bandwidths; and

based on the one or more carrier phase positioning measurement configurations being the fifth configuration, the method comprises performing carrier phase measurements over different time instances associated with one carrier frequency from a same transmission reception point over the Uu interface of the apparatus.

12. The method of claim 10, further comprising:

receiving a second configuration message comprising a measurement reporting configuration that configures the apparatus to provide a report to the LMF with IA resolution related measurements; and

in response to receiving the second configuration message, generating and transmitting, to the network apparatus, a report comprising the measurements for IA resolution to enable the network apparatus to accurately determine a location of the apparatus.

13. A network apparatus supporting wireless communication, the network apparatus comprising:

at least one network interface that enables the network apparatus to communicate with at least one target user equipment (UE) in a communication network;

a memory comprising program code for a location management function (LMF), the program code comprising code for generating configuration messages that can configure a target UE to perform measurements to enable frequency-based integer ambiguity (IA) resolution and timing-based IA resolution methods; and

a controller communicatively coupled to the memory and to the at least one network interface and which:

determines which of one or more carrier phase measurements configurations to include in the configuration message for IA resolution processing by the target apparatus; and

transmits, to the target apparatus, a first configuration message comprising a selected one or more carrier phase measurement configurations, the selected one or more carrier phase measurement configurations configuring the target apparatus to perform DL PRS measurements related to IA resolution.

14. The network apparatus of claim 13, wherein the first configuration message comprises different multi-frequency and multi-PFL configurations of a downlink (DL) positioning reference signal (PRS), the target apparatus configured to perform a multi-frequency carrier phase measurement enabling multi-frequency linear combination providing IA resolution by a lower DL PRS carrier frequency to reduce an IA search space and IA resolution via higher DL PRS carrier frequencies for accuracy.

15. The network apparatus of claim 13, wherein:

the one or more carrier phase positioning measurement configurations comprise one or more of (i) a first configuration of different DL PRS carrier frequencies within a same position frequency layer (PFL); (ii) a second configuration of different DL PRS carrier frequencies, with the DL PRS received at a same time within different PFLs; (iii) a third configuration of different DL PRS subcarriers within a same DL PRS bandwidth; (iv) a fourth

configuration of different DL PRS subcarriers within different DL PRS bandwidths; and (v) a fifth configuration of one or more time windows for DL PRS measurement; and

the controller:

selects one or more of the selected one or more carrier phase positioning measurement configurations from among the first, second, third, fourth, and fifth configurations; and

incorporates the selected one or more carrier phase positioning measurement configurations within the first configuration message sent to the target UE.

16. The network apparatus of claim 13, wherein the controller:

selects the third configuration providing a multiple frequency scheme based on phase measurements performed over different subcarriers within a same DL PRS bandwidth; and

includes the third configuration within the first configuration message sent to the target apparatus.

17. The network apparatus of claim 13, wherein the controller:

selects the fourth configuration providing a multiple frequency scheme based on phase measurements performed over different subcarriers within different DL PRS bandwidths; and

includes the fourth configuration within the first configuration message sent to the target apparatus.

18. The network apparatus of claim 13, wherein the controller:

selects the fifth configuration;

identifies the one or more consecutive time windows to define within the fifth configuration, wherein a DL PRS carrier frequency and configuration are the same during each of the one or more consecutive time windows; and

includes the fifth configuration within the first configuration message sent to the target apparatus.

19. The network apparatus of claim 13, wherein the first configuration message comprises configuration assistance data to configure the target apparatus to provide time-based integer ambiguity resolution related measurements by performing carrier phase measurements for DL PRS received at consecutive time instances,

wherein the configuration assistance data comprises at least one of:

consecutive carrier-phase measurements to enable the target apparatus to perform time-based integer ambiguity resolution based on a time-differenced carrier phase (TDCP) determination;

a set of subcarriers over which the phases are to be measured, the set of subcarriers defined via a separate group ID; and

a frequency granularity, wherein the target UE is configured to determine, based on the frequency granularity, DL PRS subcarriers on which to perform and report measurements for integer ambiguity resolution.

20. The network apparatus of claim 13, wherein the controller:

transmits a second configuration message comprising a measurement reporting configuration which configures the target apparatus to provide a response message with IA resolution related measurements, the measurement report configuration corresponds with carrier frequencies and subcarriers identified by a subcarrier ID or frequency granularity; and

incorporates, within the second configuration message, second configuration assistance data that configures the target apparatus to report phase measurements of certain predefined subcarriers, which are indicated by the LMF; and

assigns with the configuration assistance data, a subcarrier ID to differentiate between each subcarrier, wherein the subcarrier ID is incorporated within a corresponding measurement report generated at and received from the target UE;

wherein the second configuration assistance data configures the target UE to provide measurement results comprising multiple different measurements with corresponding report IDs or frequency of corresponding respective measured subcarriers.

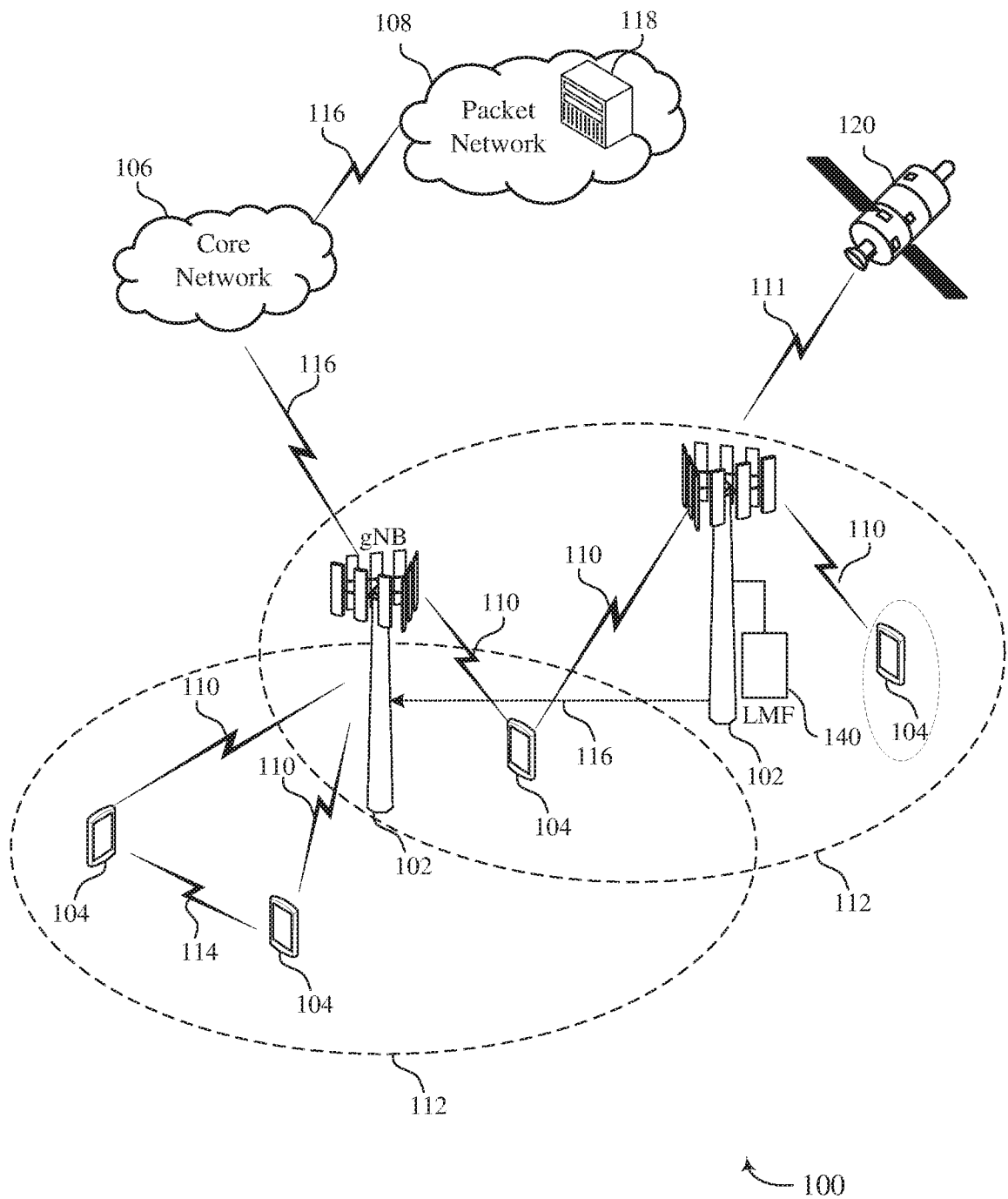


FIG. 1

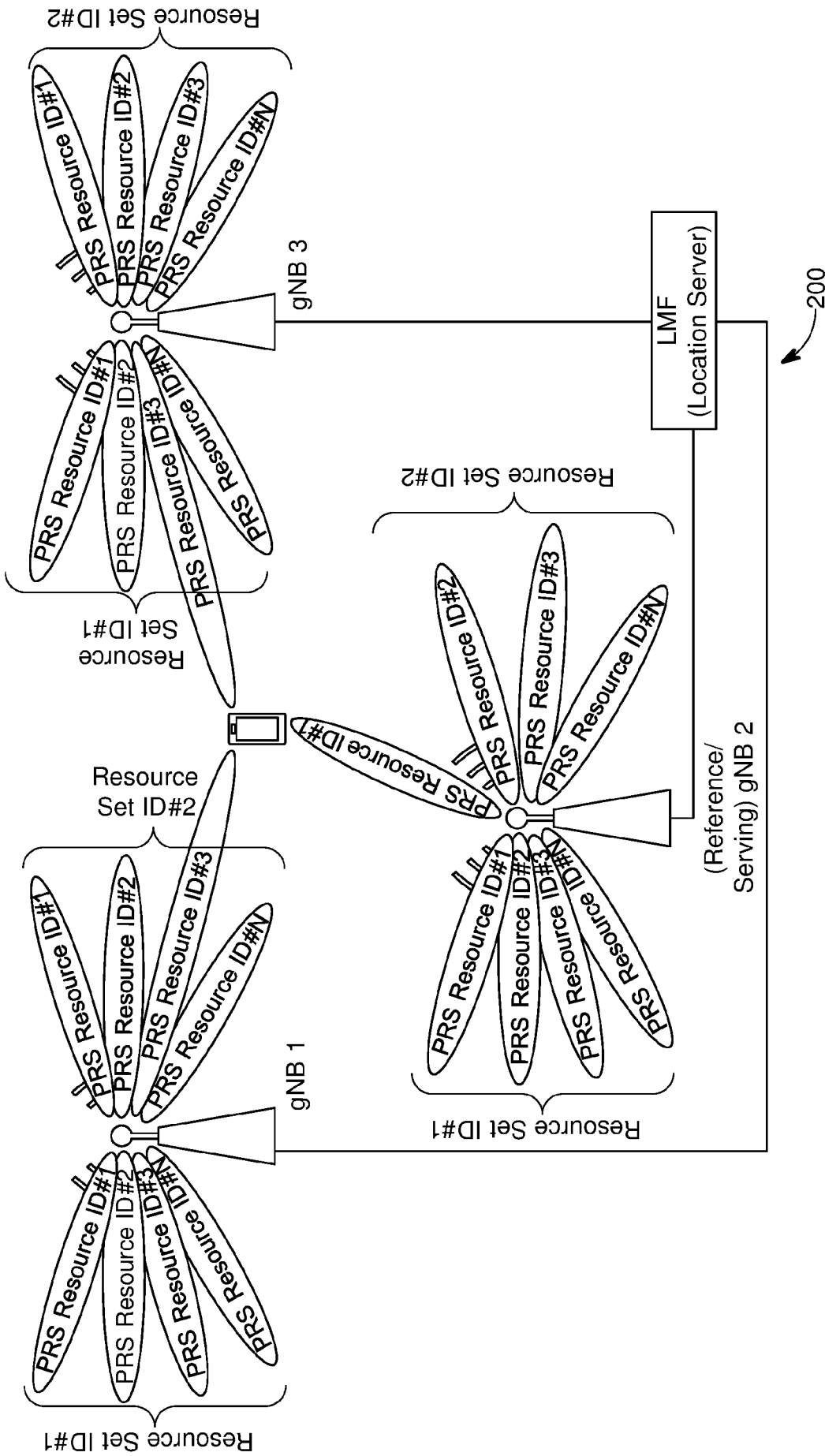


**FIG. 2 (Prior Art)**

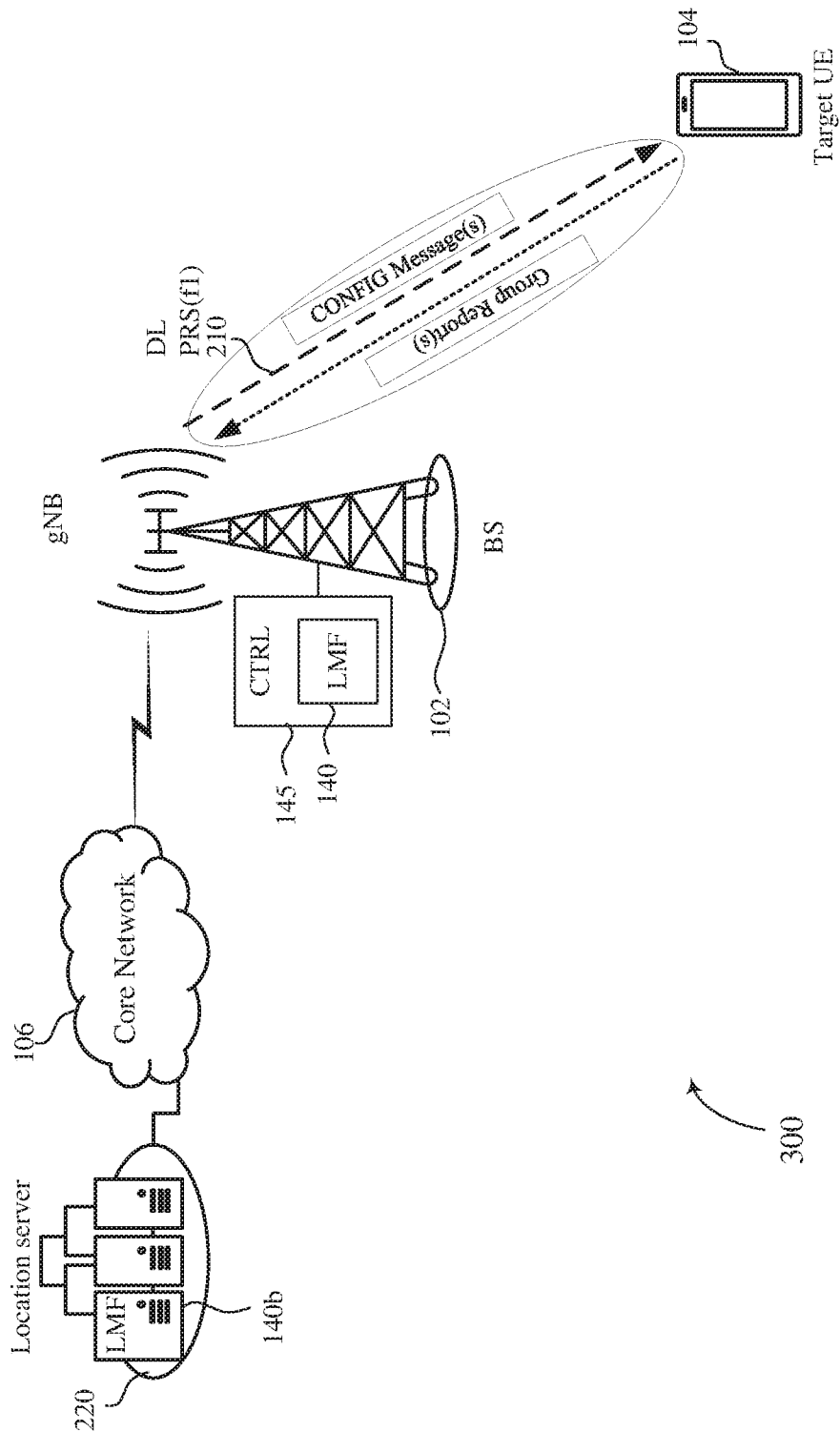


FIG. 3

400 }

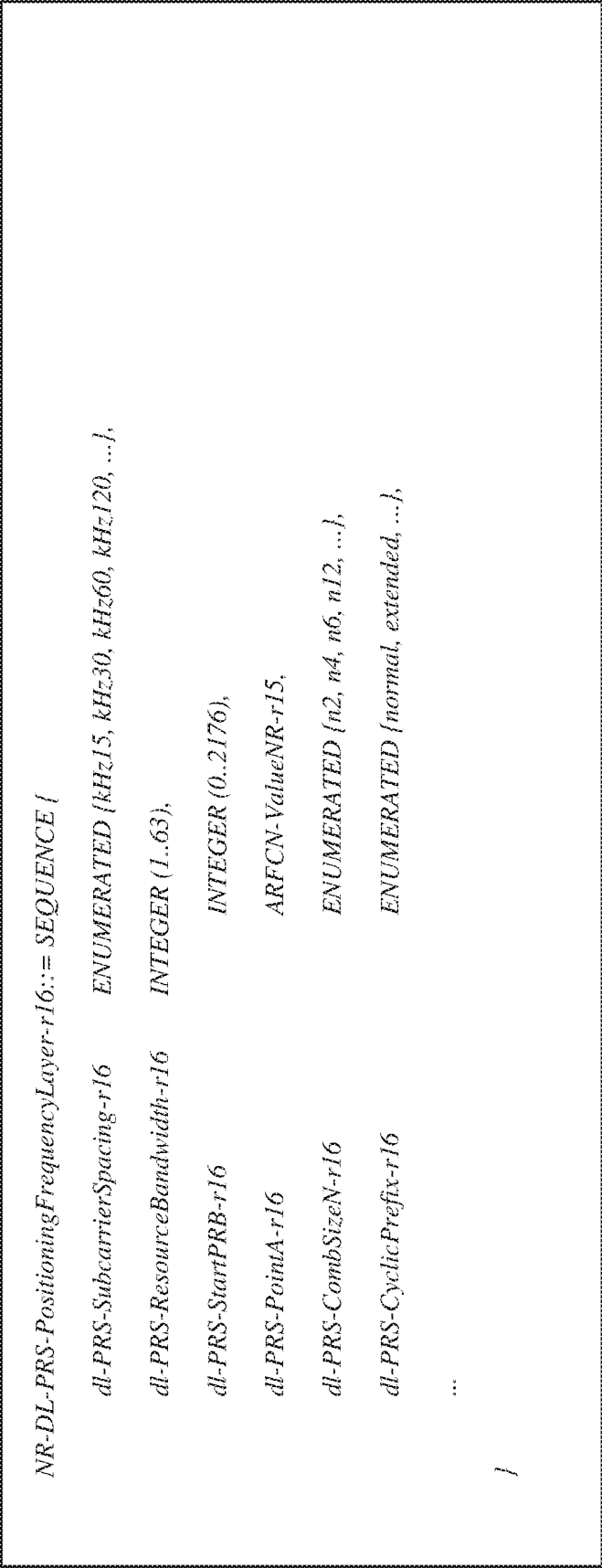


FIG. 4

500

```

-- ASN1START
NR-DL-CPP-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-SelectedDL-PRS-IA-IndexList-r18     NR-SelectedDL-PRS-IA-IndexList-r18     OPTIONAL, -- Need ON
    nr-SelectedDL-PRS-IA-PFLs-r18         NR-SelectedDL-PRS-IA-PFLs-r18         OPTIONAL, -- Need ON
    nr-SelectedDL-PRS-IA-grouping-r18      NR-SelectedDL-PRS-IA-grouping-r18      OPTIONAL, -- Need ON
    nr-SelectedDL-PRS-IA-groupingID-r18    NR-SelectedDL-PRS-IA-groupingID-r18    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
    ...,
    [{
        nr-On-Demand-DL-PRS-Configurations-r17
            NR-On-Demand-DL-PRS-Configurations-r17
            OPTIONAL, -- Need ON

        nr-On-Demand-DL-PRS-Configurations-Selected-IndexList-r17
            NR-On-Demand-DL-PRS-Configurations-Selected-IndexList-r17
            OPTIONAL, -- Need ON

        assistanceDataValidityArea-r17     AreaID-CellList-r17
            OPTIONAL -- Need ON
    ]
}

-- ASN1STOP

```

FIG. 5A

```

-- ASN1START
NR-DL-CPP-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-SelectedDL-PRS-IA-subcarrierID-r18 NR-SelectedDL-PRS-IA-subcarrierID-r18 OPTIONAL, --Need ON
    nr-SelectedDL-PRS-IA-subcal-r18      NR-SelectedDL-PRS-IA-sbcal-r18      OPTIONAL, --Need ON
    nr-SelectedDL-PRS-IA-subcagranularity-r18
        NR-SelectedDL-PRS-IA-grouping-r18
        OPTIONAL, ---Need ON
    nr-SelectedDL-PRS-IA-grouping-r18    NR-SelectedDL-PRS-IA-grouping-r18    OPTIONAL, --Need ON
    nr-SelectedDL-PRS-IA-groupingID-r18  NR-SelectedDL-PRS-IA-groupingID-r18  OPTIONAL, --Need ON
    nr-DL-CPP-Error-r16                  NR-DL-TDOA-Error-r16                  OPTIONAL, --- Need ON
    ...,
    [{
        nr-On-Demand-DL-PRS-Configurations-r17
            NR-On-Demand-DL-PRS-Configurations-r17
            OPTIONAL, -- Need ON
        nr-On-Demand-DL-PRS-Configurations-Selected-IndexList-r17
            NR-On-Demand-DL-PRS-Configurations-Selected-IndexList-r17
            OPTIONAL, -- Need ON
        assistanceDataValidityArea-r17    AreaID-CellList-r17
        OPTIONAL, -- Need ON
    ]
}
-- ASN1STOP

```

FIG. 5B

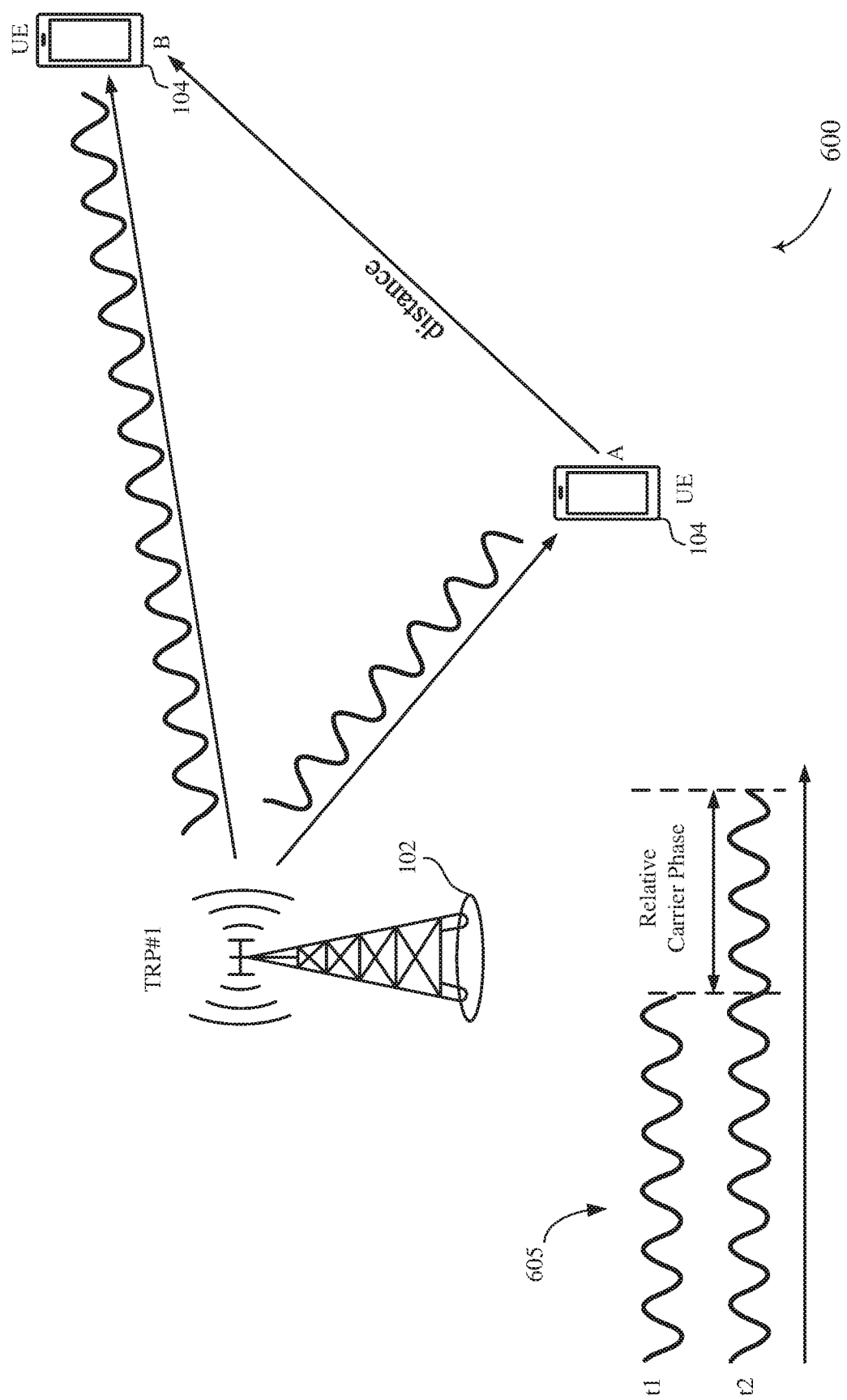


FIG. 6

```
--- ASN1START
NR-DL-CPP-ProvideAssistanceData ::= 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-TimeWindow-IA-IndexList-r18     NR-TimeWindow-IA-IndexList-r18     OPTIONAL, -- Need ON
  nr-SelectedDL-PRS-IA-windstart-r18  NR-SelectedDL-PRS-IA-windstart-r18  OPTIONAL, -- Need ON
  nr-SelectedDL-PRS-IA-windlength-r18 NR-SelectedDL-PRS-IA-windlength-r18 OPTIONAL, -- Need ON
  nr-SelectedDL-PRS-IA-windend-r18   NR-SelectedDL-PRS-IA-windend-r18   OPTIONAL, -- Need ON
  nr-SelectedDL-PRS-IA-windperio-r18 NR-SelectedDL-PRS-IA-windperio-r18 OPTIONAL, -- Need ON

  nr-PositionCalculationAssistance-r16
    NR-PositionCalculationAssistance-r16
    OPTIONAL, -- Cond UEB
    OPTIONAL, -- Need ON
  ...,
  [ [
    nr-On-Demand-DL-PRS-Configurations-r17
      NR-On-Demand-DL-PRS-Configurations-r17
      OPTIONAL, -- Need ON
    nr-On-Demand-DL-PRS-Configurations-Selected-IndexList-r17
      NR-On-Demand-DL-PRS-Configurations-Selected-IndexList-r17
      OPTIONAL, -- Need ON
    assistanceDataValidityArea-r17
      AreaID-CellList-r17
      OPTIONAL, -- Need ON
  ] ]
}
--- ASN1STOP
```

FIG. 7

700

```
-- ASN1START
NR-DL-CPP-ProvideLocationInformation ::= SEQUENCE {
  nr-DL-CPP-SignalMeasurementInformation-r16
    NR-DL-CPP-SignalMeasurementInformation-r16
    OPTIONAL,
  nr-dl-cpp-LocationInformation-r16
    NR-DL-CPP-LocationInformation-r16
    OPTIONAL,
  nr-DL-CPP-Error-r16
    NR-DL-CPP-Error-r16
    OPTIONAL,
  ...,
  [[
    nr-DL-CPP-SignalMeasurementInstances-r17
      SEQUENCE (SIZE (1..maxMeasInstances-r17)) OF
        NR-DL-CPP-SignalMeasurementInformation-r16
        OPTIONAL, -- Cond batchUEA

    nr-DL-CPP-SignalMeasurement-IA-PRSIndexID
      OPTIONAL,
    nr-DL-CPP-SignalMeasurement-IA-SubcarrierID
      OPTIONAL,
    nr-DL-CPP-SignalMeasurement-IA-timeWindow
      OPTIONAL,
    nr-DL-CPP-SignalMeasurement-IA-Timestamp
      OPTIONAL,
    nr-DL-CPP-SignalMeasurement-IA-groupID
      OPTIONAL,

    nr-DL-CPP-LocationInformationInstances-r17
      SEQUENCE (SIZE (1..maxMeasInstances-r17)) OF
        NR-DL-CPP-LocationInformation-r16
        OPTIONAL -- Cond batchUEB
  ]]
}
-- ASN1STOP
```

FIG. 8

800

```
-- 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
```

900

FIG. 9

```
-- 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-MeasElement-r16 ::= SEQUENCE {
    dl-PRS-ID-r16                INTEGER (0..255),
    nr-PhysCellID-r16            NR-PhysCellID-r16
    OPTIONAL,
    nr-CellGlobalID-r16          NCGI-r15
    OPTIONAL,
    nr-ARFCN-r16                 ARFCN-ValueNR-r15
    OPTIONAL,
    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),
        ...
    },
}
```

1000

FIG. 10A

```

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. 10B

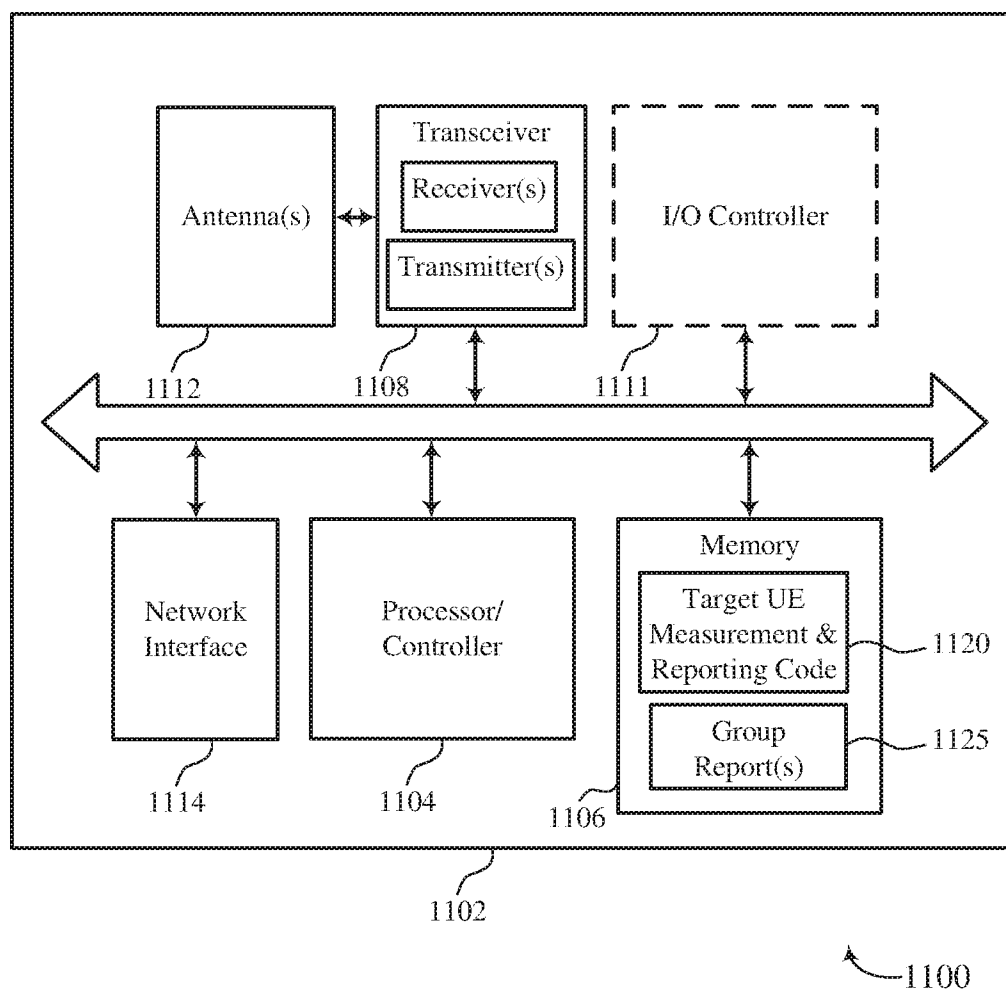


FIG. 11

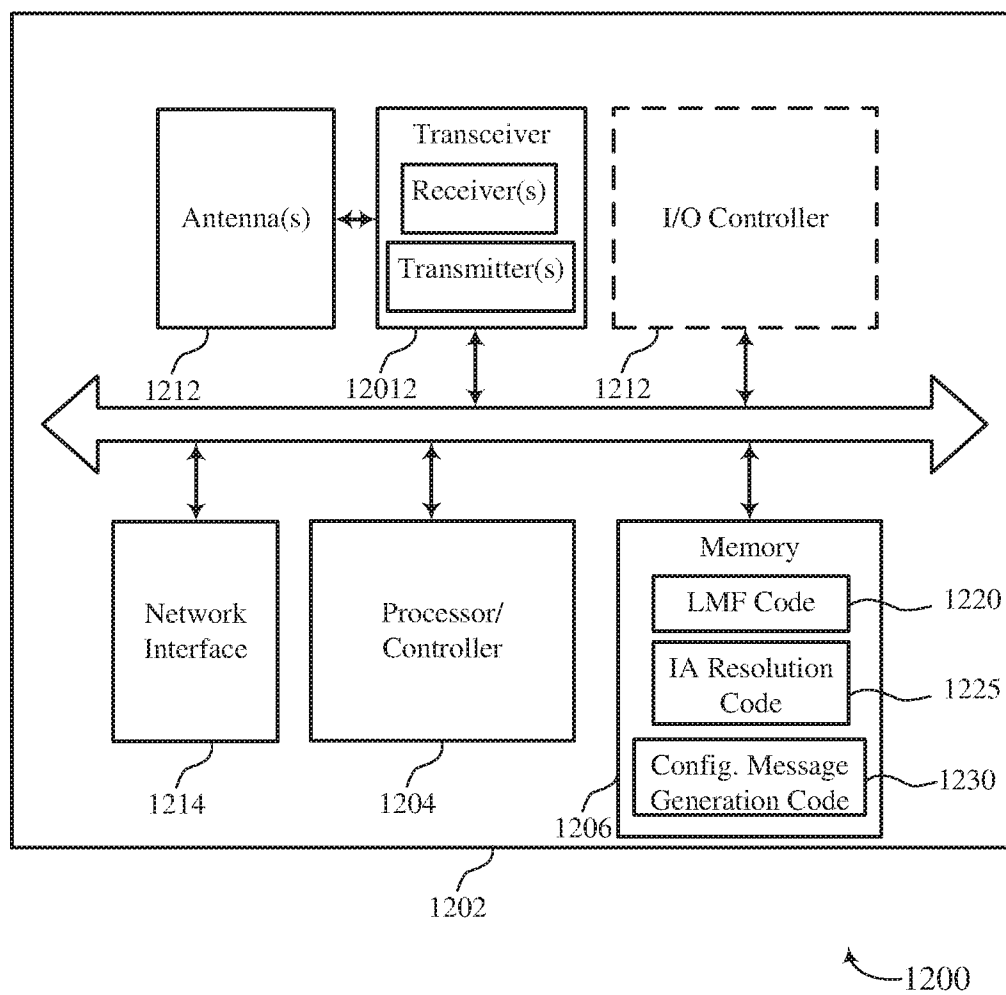


FIG. 12

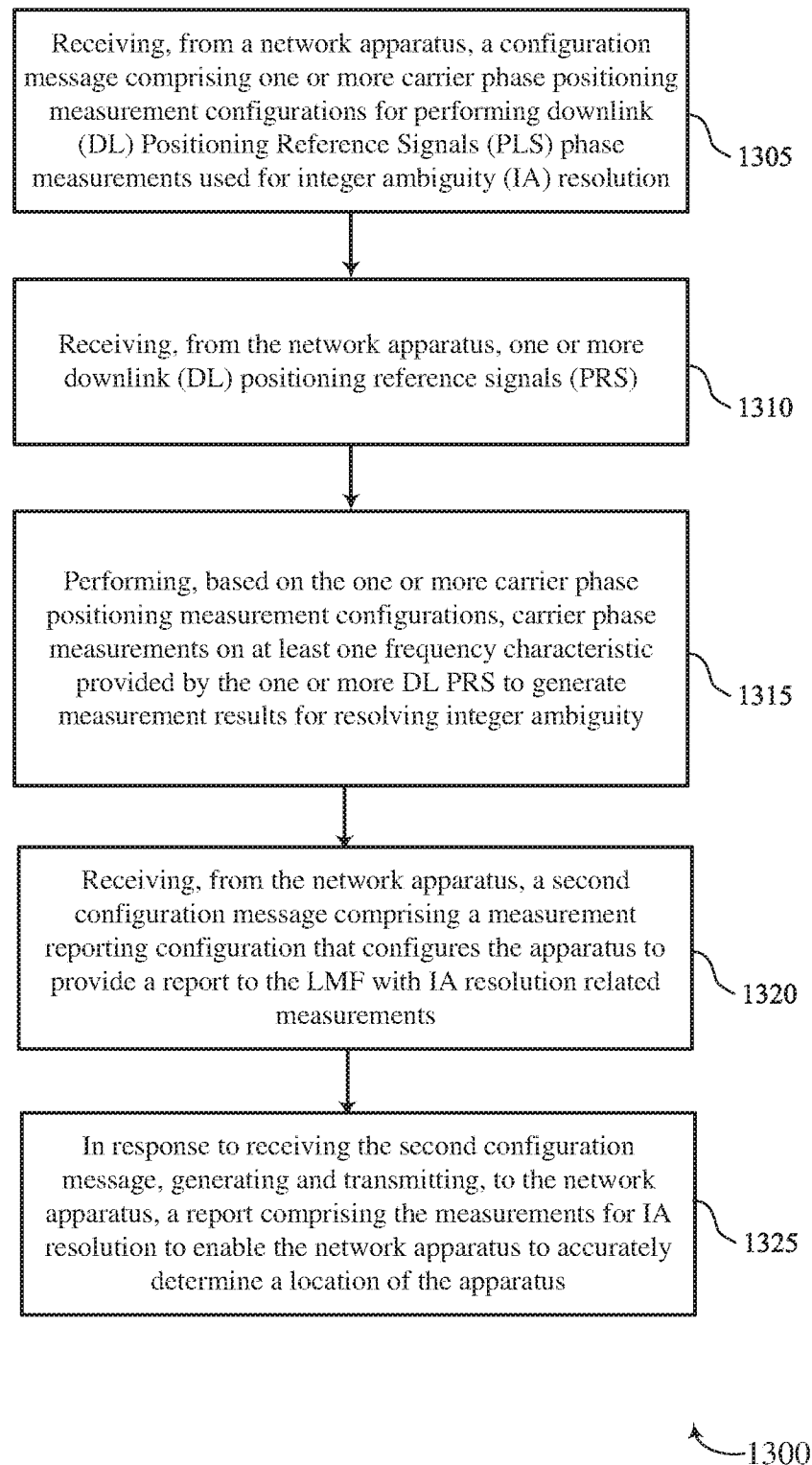


FIG. 13

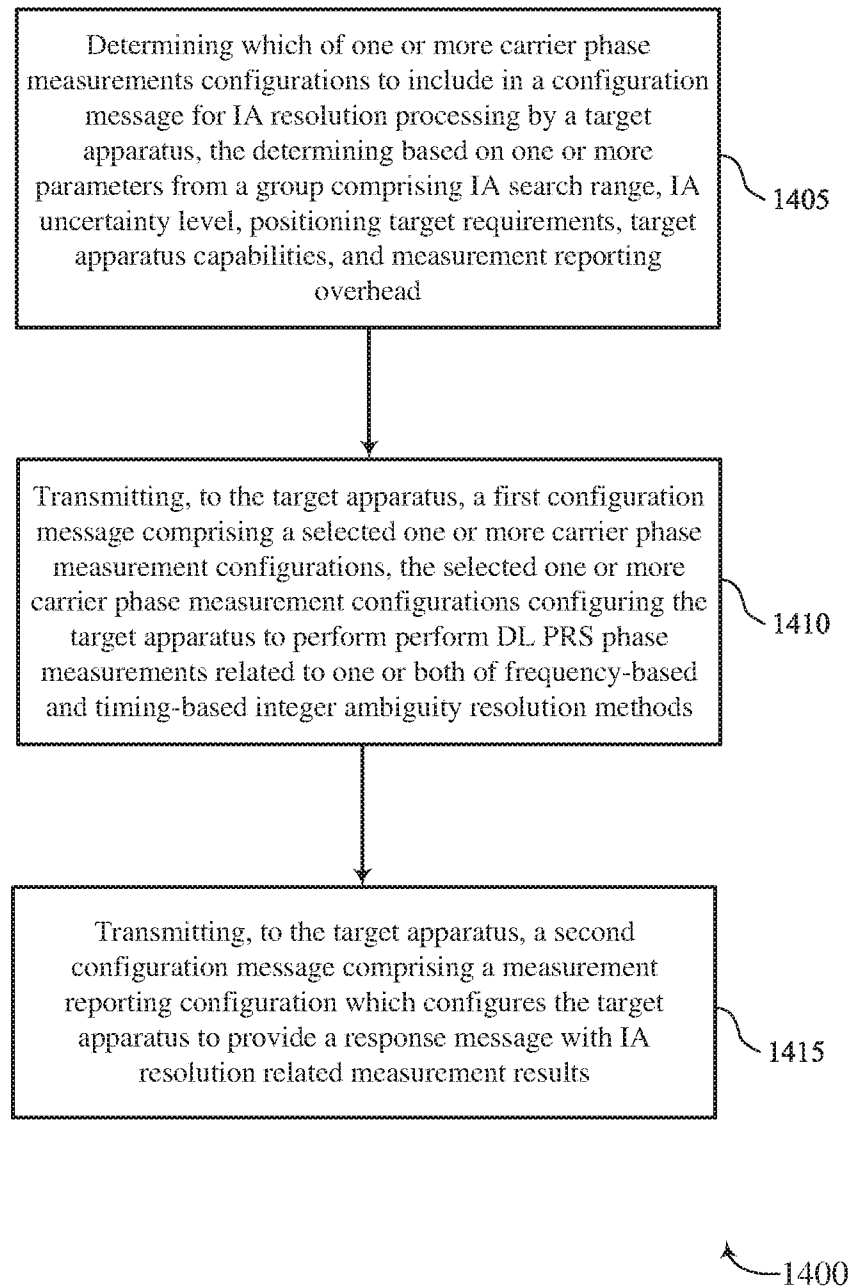


FIG. 14

## INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2024/051077

## A. CLASSIFICATION OF SUBJECT MATTER

INV. G01S5/00 G01S5/02 H04W64/00  
ADD.

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

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G01S H04W

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

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

EPO-Internal, WPI Data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                                                                              | Relevant to claim No. |
|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| X         | WO 2022/116857 A1 (DATANG MOBILE COMMUNICATIONS EQUIPMENT CO LTD [CN])<br>9 June 2022 (2022-06-09)<br>figures 2, 3<br>page 13, line 18 - page 15, line 1<br>page 17, lines 2-9, 25-27<br>page 18, lines 15-16<br>-----                                                                                          | 1-20                  |
| X         | WO 2021/227821 A1 (DATANG MOBILE COMMUNICATIONS EQUIPMENT CO LTD [CN])<br>18 November 2021 (2021-11-18)<br>claim 7; figures 6, 2<br>page 7, line 22 - page 8, line 2<br>page 12, lines 13-23<br>page 19, lines 4-6<br>page 19, line 12 - page 20, line 12<br>page 23, line 8 - page 24, line 13<br>-----<br>-/- | 1-20                  |



Further documents are listed in the continuation of Box C.



See patent family annex.

\* Special categories of cited documents :

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&amp;" document member of the same patent family

Date of the actual completion of the international search

17 April 2024

Date of mailing of the international search report

30/04/2024

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Authorized officer

Krummenacker, Benoît

# INTERNATIONAL SEARCH REPORT

International application No  
PCT/IB2024/051077

| C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                       |
|------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Category*                                            | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Relevant to claim No. |
| X                                                    | <p>WO 2021/259318 A1 (DATANG MOBILE COMMUNICATIONS EQUIPMENT CO LTD [CN])<br/>30 December 2021 (2021-12-30)<br/>claims 1-11, 49-59, 61-71; figures 7, 8<br/>page 2, lines 18-21<br/>page 10, lines 26-30, 29-30<br/>page 18, lines 15-20<br/>page 21, lines 9-14</p> <p>-----</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 1-20                  |
| A                                                    | <p>MCC SUPPORT: "Draft Report of 3GPP TSG RAN WG1 #111 v0.1.0 (Toulouse, France, 14th - 18th November 2022)",<br/>3GPP DRAFT;<br/>DRAFT_MINUTES_REPORT_RAN1#111_V010, 3RD GENERATION PARTNERSHIP PROJECT (3GPP),<br/>MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE<br/>/<br/>vol. RAN WG1, no. Athens, Greece; 20230227 - 20230303<br/>27 November 2022 (2022-11-27),<br/>XP052260295,<br/>Retrieved from the Internet:<br/>URL:https://ftp.3gpp.org/tsg_ran/WG1_RL1/TSGR1_111/Report/Archive/Draft_Minutes_report_RAN1%23111_v010.zip<br/>Draft_Minutes_report_RAN1#111_v010.docx<br/>[retrieved on 2022-11-27]<br/>pages 57-58; section: R1-2212819 Moderator Summary#3 on Rel-18 CSI enhancements:<br/>Round 2<br/>pages 118-122; section: R1-2212546 FL Summary #2 for improved accuracy based on NR carrier phase measurements<br/>page 123; penultimate row of the table</p> <p>-----</p> | 2-7,11,<br>15-19      |

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No  
PCT/IB2024/051077

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s)                                                                | Publication<br>date                                                |
|-------------------------------------------|---------------------|-------------------------------------------------------------------------------------------|--------------------------------------------------------------------|
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| WO 2021227821 A1                          | 18-11-2021          | CN 113691929 A<br>EP 4152774 A1<br>TW 202145814 A<br>US 2023180172 A1<br>WO 2021227821 A1 | 23-11-2021<br>22-03-2023<br>01-12-2021<br>08-06-2023<br>18-11-2021 |
| WO 2021259318 A1                          | 30-12-2021          | CN 113840227 A<br>EP 4175327 A1<br>US 2023262646 A1<br>WO 2021259318 A1                   | 24-12-2021<br>03-05-2023<br>17-08-2023<br>30-12-2021               |