TECHNIQUES FOR CARRIER PHASE MEASUREMENT REPORTING WITHIN A MEASUREMENT TIME WINDOW

TECHNICAL FIELD

[0001] The present disclosure relates to wireless communications, and more specifically to techniques for carrier phase measurement reporting within a measurement time window.

BACKGROUND

[0002] A wireless communications system may include one or multiple network communication devices, otherwise known as network equipment (NE), supporting 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, or the like)). 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)).

SUMMARY

[0003] An article "a" before an element is unrestricted and understood to refer to "at least one" of those elements or "one or more" of those elements. The terms "a," "at least one," "one or more," and "at least one of one or more" may be interchangeable. 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.

[0004] An NE for wireless communication is described. The NE may be configured to, capable of, or operable to perform one or more operations as described herein. For example, the NE may be configured to, capable of, or operable to transmit, to one or more UE, a request to perform carrier phase measurements with respect to a reference time within a time window and receive, from the one or more UE, the carrier phase measurements performed with respect to the reference time within the time window.

[0005] A method performed or performable by an NE for wireless communication is described. The method may include transmitting, to one or more UE, a request to perform carrier phase measurements with respect to a reference time within a time window and receiving, from the one or more UE, the carrier phase measurements performed with respect to the reference time within the time window.

[0006] A processor for wireless communication is described. The processor may be configured to, capable of, or operable to perform one or more operations as described herein. For example, the processor may be configured to, capable of, or operable to transmit, to one or more UE, a request to perform carrier phase measurements with respect to a reference time within a time window and receive, from the one or more UE, the carrier phase measurements performed with respect to the reference time within the time window.

[0007] A UE for wireless communication is described. The UE may be configured to, capable of, or operable to perform one or more operations as described herein. For example, the UE may be configured to, capable of, or operable to receive a request to perform carrier phase measurements with respect to a reference time within a time window, perform the carrier phase measurements, and transmit the carrier phase measurements performed with respect to the reference time within the time window.

[0008] A processor for wireless communication is described. The processor may be configured to, capable of, or operable to perform one or more operations as described herein. For example, the processor may be configured to, capable of, or operable to receive a request to perform carrier phase measurements with respect to a reference time within a time window, perform the carrier phase measurements, and transmit the carrier

phase measurements performed with respect to the reference time within the time window.

[0009] A method performed or performable by a UE for wireless communication is described. The method may include receiving a request to perform carrier phase measurements with respect to a reference time within a time window, performing the carrier phase measurements, and transmitting the carrier phase measurements performed with respect to the reference time within the time window.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Figure 1 illustrates an example of a wireless communications system in accordance with aspects of the present disclosure.

[0011] Figure 2 illustrates an example of an architecture for new radio (NR) downlink (DL)-based positioning measurements and reference signals (RSs), in accordance with aspects of the present disclosure.

[0012] Figure 3A illustrates a graph that charts the maximum phase error vs. time between positioning RS (PRS) symbols from different transmission reception points (TRPs) (in symbols), in accordance with aspects of the present disclosure.

[0013] Figure 3B illustrates a graph that charts the maximum phase error vs. the number of slots separating positioning reference unit (PRU) and UE measurements, in accordance with aspects of the present disclosure.

[0014] Figure 4A illustrates an example measurement window for performing carrier phase measurements in different subframes, in accordance with aspects of the present disclosure.

[0015] Figure 4B illustrates an example measurement window for performing carrier phase measurements with reference to a measurement time window configuration, in accordance with aspects of the present disclosure.

[0016] Figure 4C illustrates an example measurement window for performing carrier phase measurements with reference to a measurement time window configuration in different slots, in accordance with aspects of the present disclosure.

[0017] Figure 5 illustrates a procedure for UE-assisted positioning, in accordance with aspects of the present disclosure.

[0018] Figure 6 illustrates an example of a procedure for UE-based positioning, in accordance with aspects of the present disclosure.

[0019] Figure 7 illustrates an example of a UE in accordance with aspects of the present disclosure.

[0020] Figure 8 illustrates an example of a processor in accordance with aspects of the present disclosure.

[0021] Figure 9 illustrates an example of a NE in accordance with aspects of the present disclosure.

[0022] Figure 10 illustrate a flowchart of a method performed by a UE in accordance with aspects of the present disclosure.

[0023] Figure 11 illustrate a flowchart of a method performed by a NE in accordance with aspects of the present disclosure.

DETAILED DESCRIPTION

[0024] Carrier phase positioning is a high precision positioning method employed in Global Navigation Satellite Systems such as GPS, Galileo, etc. This positioning technique involves measuring the phase of the satellite transmissions and comparing it with the reception phase at the receiver's antenna. In certain embodiments, specification of carrier phase positioning is carried out to complement existing radio access technology (RAT)-dependent measurements such as DL reference signal time different (DL-RSTD), uplink relative time of arrival (UL-RTOA), gNB reception (Rx)-transmission (Tx) time difference measurements, UE Rx-Tx time difference measurements, UL-angle of arrival (AoA), and DL-angle of departure (AoD).

[0025] The problem addressed herein is how to correct for carrier frequency offsets between the TRPs and the receivers of the UEs and the PRUs. Even frequency errors within the allowed tolerance will result in large carrier phase measurement errors because the transmitter phase difference measured by the PRU on one symbol will not be corrected when applied to a later (different) symbol, which will result in large phase measurement errors. This problem needs to be addressed for carrier phase positioning to work. In order for the UE and PRU to perform joint measurement of RAT-dependent positioning measurements in time, including DL and UL Reference Signal Carrier Phase (RSCP) and

Reference Signal Carrier Phase Difference (RSCPD), it is proposed to define a time window to perform simultaneous measurements.

[0026] This disclosure presents solutions for an enhanced configuration and reporting mechanism to enable mitigation of carrier frequency offsets of the configured carrier phase measurement by referring RSCP and RSCPD measurements to a common reference time for both the target UE and PRU.

[0027] Aspects of the present disclosure are described in the context of a wireless communications system.

[0028] Figure 1 illustrates an example of a wireless communications system 100 in accordance with aspects of the present disclosure. The wireless communications system 100 may include one or more NE 102, one or more UE 104, and a core network (CN) 106. 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 NR network, such as a 5G network, a 5G-Advanced (5G-A) network, or a 5G ultrawideband (5G-UWB) 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, for example, 6G. 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.

[0029] The one or more NE 102 may be dispersed throughout a geographic region to form the wireless communications system 100. One or more of the NE 102 described herein may be or include or may be referred to as a network node, a base station, a network element, a network function, a network entity, a radio access network (RAN), a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. An NE 102 and a UE 104 may communicate via a communication link, which may be a wireless or wired connection. For example, an NE 102 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface.

[0030] An NE 102 may provide a geographic coverage area for which the NE 102 may support services for one or more UEs 104 within the geographic coverage area. For example, an NE 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. In some implementations, an NE 102 may be moveable, for example, a satellite associated with a non-terrestrial network (NTN). 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 may be associated with different NE 102.

[0031] The one or more UE 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 remote unit, a mobile device, a wireless device, a remote device, a subscriber device, a transmitter device, a receiver device, or some other suitable terminology. In some implementations, the UE 104 may be referred to as 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.

[0032] A UE 104 may be able to support wireless communication directly with other UEs 104 over a communication link. 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.

[0033] An NE 102 may support communications with the CN 106, or with another NE 102, or both. For example, an NE 102 may interface with other NE 102 or the CN 106 through one or more backhaul links (e.g., S1, N2, N3, or network interface). In some implementations, the NE 102 may communicate with each other directly. In some other implementations, the NE 102 may communicate with each other indirectly (e.g., via the CN 106). In some implementations, one or more NE 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 TRPs.

[0034] The CN 106 may support user authentication, access authorization, tracking, connectivity, and other access, routing, or mobility functions. The CN 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 NE 102 associated with the CN 106.

[0035] The CN 106 may communicate with a packet data network over one or more backhaul links (e.g., via an S1, N2, N3, or another network interface). The packet data network may include an application server. In some implementations, one or more UEs 104 may communicate with the application server. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or the like) with the CN 106 via an NE 102. The CN 106 may route traffic (e.g., control information, data, and the like) between the UE 104 and the application server 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 CN 106 (e.g., one or more network functions of the CN 106).

[0036] In the wireless communications system 100, the NEs 102 and the UEs 104 may use resources of the wireless communications 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 NEs 102 and the UEs 104 may support different resource structures. For example, the NEs 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the NEs 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 NEs 102 and the UEs 104 may support various frame

structures (i.e., multiple frame structures). The NEs 102 and the UEs 104 may support various frame structures based on one or more numerologies.

[0037] 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., μ=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., μ=0) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe. A second numerology (e.g., μ=1) may be associated with a second subcarrier spacing (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., μ=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., μ=3) may be associated with a fourth subcarrier spacing (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g., μ=4) may be associated with a fifth subcarrier spacing (e.g., 240 kHz) and a normal cyclic prefix.

[0038] 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.

[0039] 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., μ=0, μ=1, μ=2, μ=3, μ=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., μ=0) associated with a first subcarrier spacing (e.g., 15 kHz) may be used interchangeably between subframes and slots.

[0040] 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 NEs 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 NEs 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 NEs 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

[0041] 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., μ=0), which includes 15 kHz subcarrier spacing; a second numerology (e.g., μ=1), which includes 30 kHz subcarrier spacing; and a third numerology (e.g., μ=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., μ=2), which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g., μ=3), which includes 120 kHz subcarrier spacing.

[0042] NR positioning based on NR Uu signals and standalone (SA) architecture (e.g., beam-based transmissions) is discussed in Rel-16. The targeted use cases include commercial and regulatory (emergency services) scenarios, as in Rel-15. The performance requirements are shown in the table below, e.g., from TR 38.855 (incorporated herein by reference).

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

[0043] 3GPP Rel-17 Positioning defines the positioning performance requirements for Commercial and industrial Internet of Things (IIoT) use cases, shown in the table below, e.g., as in TR 38.857 (incorporated herein by reference).

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 for position estimation of UE	(<100 ms)	(< 100 ms, in the order of 10 ms is desired)

[0044] Various positioning techniques are supported in Rel-16, which are listed below in the table below:

Method	UE-based	UE-assisted, LMF-based	NG-RAN node assisted	SUPL
A-GNSS	Yes	Yes	No	Yes (UE-based and UE-assisted)
OTDOA Note1, Note 2	No	Yes	No	Yes (UE-assisted)
E-CID Note 4	No	Yes	Yes	Yes for E-UTRA (UE-assisted)
Sensor	Yes	Yes	No	No
WLAN	Yes	Yes	No	Yes
Bluetooth	No	Yes	No	No
TBS Note 5	Yes	Yes	No	Yes (MBS)
DL-TDOA	Yes	Yes	No	No
DL-AoD	Yes	Yes	No	No
Multi-RTT	No	Yes	Yes	No
NR E-CID	No	Yes	FFS	No
UL-TDOA	No	No	Yes	No
UL-AoA	No	No	Yes	No
NOTE 1: This includes TBS positioning based on PRS signals. NOTE 2: In this version of the specification only OTDOA based on LTE signals is supported. NOTE 4: This includes Cell-ID for NR method. NOTE 5: In this version of the specification only for TBS positioning based on MBS signals.				

[0045] Separate positioning techniques as indicated above can be currently configured and performed based on the requirements of the location management function (LMF) and UE capabilities. The transmission of Uu (uplink and downlink) PRSs enable the UE to perform UE positioning-related measurements to enable the computation of a UE's absolute location estimate and are configured per TRP, where a TRP may include a set of one or more beams. A conceptual overview is illustrated in Figure 2.

[0046] Figure 2 illustrates an example of an architecture 200 for NR DL-based positioning measurements and RSs, in accordance with aspects of the present disclosure. Figure 2 shows the UE 202, the gNBs 204-208, and a LMF 210. In various embodiments, the UE 202 is representative of a set of UEs 104 interacting with a set of NEs 102 (e.g., gNBs 204-208) and the LMF 210 is representative of a network function (NF) in the CN 106.

[0047] As depicted, the architecture 200 for NR DL-based positioning includes a UE 202 which may receive a DL PRS from a neighboring first gNB/TRP (denoted "gNB1–TRP1") 204, from a neighboring second gNB (denoted "gNB2–TRP1") 206, and also from a third gNB/TRP (denoted "gNB3–TRP1") 208, which is a reference or serving gNB. The DL PRS can be transmitted by different base stations (e.g., serving gNB and

neighboring gNB(s)) using narrow beams over Frequency Range #1 ("FR1") (i.e., frequencies from 410 MHz to 7125 MHz) and Frequency Range #2 ("FR2") (i.e., frequencies from 24.25 GHz to 52.6 GHz), which is relatively different in NR when compared to LTE where the PRS was transmitted across the whole cell.

[0048] Here, the DL PRS can be locally associated with a DL PRS Resource Identifier ("ID") and Resource Set ID for a base station (i.e., TRP). In the depicted embodiments, each gNB 204, 206, 208 is configured with a first Resource Set ID (depicted as "Resource Set ID#0") 212 and a second Resource Set ID (depicted as "Resource Set ID#1") 214. As depicted, the UE 202 receives DL PRS on transmission beams; here, receiving DL PRS from the gNB1–TRP1 204 on DL PRS Resource ID #3 from the second Resource Set ID ("Resource Set ID#1") 214, receiving DL PRS from the gNB2–TRP1 206 on DL PRS Resource ID #3 from the first Resource Set ID ("Resource Set ID#0") 212, and receiving DL PRS from the gNB3–TRP1 208 on DL PRS Resource ID #1 from the second Resource Set ID ("Resource Set ID#1") 214.

[0049] UE positioning measurements, such as Reference Signal Time Difference (RSTD) and PRS Reference Signal Received Power (RSRP) measurements, may be made between different beams (e.g., between a different pair of DL PRS resources or DL PRS resource sets). The LMF 210 uses the UE positioning measurements to determine the location (e.g., absolute position) of the UE 202. In addition, there are additional uplink (UL) positioning methods for the network to exploit in order to compute the location of the target UE 202.

[0050] 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.

[0051] There are various RAT-dependent positioning techniques supported in Rel-16 and Rel-17. 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.

[0052] 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.

[0053] 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. 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 may only be supported for UE-assisted/NG-RAN assisted positioning techniques as noted above.

[0054] Enhanced Cell ID (E-CID) positioning method - the position of a UE is estimated with the knowledge of its serving ng-eNB, gNB and cell and is based on LTE signals. The information about the serving ng-eNB, gNB and cell may be obtained by paging, registration, or other methods. NR Enhanced Cell ID (NR E CID) positioning refers to techniques which use additional UE measurements and/or NR radio resource and other measurements to improve the UE location estimate using NR signals. Although NR E-CID positioning may utilize some of the same measurements as the measurement control system in the RRC protocol, the UE generally is not expected to make additional measurements for the sole purpose of positioning; i.e., the positioning procedures do not supply a measurement configuration or measurement control message, and the UE reports the measurements that it has available rather than being required to take additional measurement actions.

[0055] The UL TDOA positioning method makes use of the UL RTOA (and optionally UL SRS-RSRP) at multiple RPs of uplink signals transmitted from UE. The RPs measure the UL RTOA (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.

[0056] The UL AoA positioning method makes use of the measured azimuth and the zenith of arrival at multiple RPs of uplink signals transmitted from UE. The RPs measure A-AoA and Z-AoA of the received signals using assistance data received from the positioning server, and the resulting measurements are used along with other configuration information to estimate the location of the UE.

[0057] Further, there are different RAT-dependent positioning measurements, including DL PRS-RSRP, DL RSTD and UE Rx-Tx Time Difference, which are described in more detail in the table below:

DL PRS reference signal received power (DL PRS-RSRP)	
Definition	DL PRS reference signal received power (DL PRS-RSRP), is defined as the linear average over the power contributions (in 8) of the resource elements that carry DL PRS reference signals configured for RSRP measurements within the considered measurement frequency bandwidth. For frequency range 1, the reference point for the DL PRS-RSRP shall be the antenna connector of the UE. For frequency range 2, DL PRS-RSRP shall be measured based on the combined signal from antenna elements corresponding to a given receiver branch. For frequency range 1 and 2, if receiver diversity is in use by the UE, the reported DL PRS-RSRP value shall not be lower than the corresponding DL PRS-RSRP of any of the individual receiver branches.
Applicable for	RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency
DL reference signal time difference (DL RSTD)	
Definition	DL reference signal time difference (DL RSTD) is the DL relative timing difference between the positioning node *j* and the reference positioning node *i*, defined as $T_{SubframeRxj} - T_{SubframeRxi}$, Where: $T_{SubframeRxj}$ is the time when the UE receives the start of one subframe from positioning node *j*. $T_{SubframeRxi}$ is the time when the UE receives the corresponding start of one subframe from positioning node *i* that is closest in time to the subframe received from positioning node *j*. Multiple DL PRS resources can be used to determine the start of one subframe from a positioning node. For frequency range 1, the reference point for the DL RSTD shall be the antenna connector of the UE. For frequency range 2, the reference point for the DL RSTD shall be the antenna of the UE.
Applicable for	RRC_CONNECTED intra-frequency

	RRC_CONNECTED inter-frequency
UE Rx – Tx time difference	
Definition	The UE Rx – Tx time difference is defined as $T_{UE-RX} - T_{UE-TX}$ Where: T_{UE-RX} is the UE received timing of downlink subframe #*i* from a positioning node, defined by the first detected path in time. T_{UE-TX} is the UE transmit timing of uplink subframe #*j* that is closest in time to the subframe #i received from the positioning node. Multiple DL PRS resources can be used to determine the start of one subframe of the first arrival path of the positioning node. For frequency range 1, the reference point for T_{UE-RX} measurement shall be the Rx antenna connector of the UE and the reference point for T_{UE-TX} measurement shall be the Tx antenna connector of the UE. For frequency range 2, the reference point for T_{UE-RX} measurement shall be the Rx antenna of the UE and the reference point for T_{UE-TX} measurement shall be the Tx antenna of the UE.
Applicable for	RRC_CONNECTED intra-frequency RRC_CONNECTED inter-frequency
DL PRS RSRPP (Reference Signal Received Path Power)	
Definition	DL PRS reference signal received path power (DL PRS-RSRPP), is defined as the power of the linear average of the channel response at the i-th path delay of the resource elements that carry DL PRS signal configured for the measurement, where DL PRS-RSRPP for the 1st path delay is the power contribution corresponding to the first detected path in time. For frequency range 1, the reference point for the DL PRS-RSRPP shall be the antenna connector of the UE. For frequency range 2, DL PRS-RSRPP shall be measured based on the combined signal from antenna elements corresponding to a given receiver branch.
Applicable for	RRC_CONNECTED, RRC_INACTIVE

[0058] The solutions described herein are directed to carrier phase positioning including reference symbol carrier phase and reference symbol carrier phase difference positioning. The problem that is addressed is how to correct for carrier frequency offsets between the TRPs and the receivers of the UEs and the PRUs.

[0059] The carrier frequency tolerance for the base station, e.g., as defined in TS 38.104 (incorporated herein by reference) is given in the following tables:

BS class	Accuracy
Wide Area BS	±0.05 ppm
Medium Range BS	±0.1 ppm
Local Area BS	±0.1 ppm

Frequency error minimum requirement

BS class	Accuracy
Wide Area BS	±0.05 ppm
Medium Range BS	±0.1 ppm
Local Area BS	±0.1 ppm

OTA frequency error minimum requirement

[0060] In one embodiment, the carrier frequency tolerance for the UE is defined in TS 38.101-1 (incorporated herein by reference) for FR1. Section 6.4.1 of TS 38.101-1 states that the UE basic measurement interval of modulated carrier frequency is 1 UL slot. The mean value of basic measurements of UE modulated carrier frequency shall be accurate to within ± 0.1 PPM observed over a period of 1 ms of cumulated measurement intervals compared to the carrier frequency received from the NR Node B.

[0061] In one embodiment, the expected value of the carrier phase measurement error can be computed as

$$n\left(\Delta\varphi_{m,UE}^{TX} - \Delta\varphi_{m,PRU}^{TX}\right)$$

[0062] here $\Delta\varphi_{m,UE}^{TX}$ and $\Delta\varphi_{m,UE}^{TX}$ denote the phase rotation over one symbol of the carrier of the m-th TRP relative to the UE and the PRU, respectively, and n is the difference in the symbol indices of the two DL-PRS symbols. The maximum phase error vs. time between DL-PRS symbol from different TRP's (in symbols) is shown in Figure 3A.

[0063] Figure 3A illustrates a graph 300 that charts the maximum phase error vs. time between PRS symbols from different TRPs (in symbols), in accordance with aspects of the present disclosure. From Figure 3A, it is apparent that carrier frequency offsets between the TRP transmitters and the UE and PRS receivers can result in very large measurement errors, which depend on both the time and distance between the PRS symbols and the carrier frequency.

[0064] Figure 3B illustrates a graph 350 that charts the maximum phase error vs. the number of slots separating PRU and UE measurements, in accordance with aspects of the

present disclosure. In Figure 3A, it is assumed that the PRU and UE take measurements on the same DL-PRS slot so that $N = 0$. Conversely, in Figure 3B, it is assumed that the symbol separation within the time slot so that n = 1, and the number of slots separating the PRU and UE DL-PRS measurements is varied from N = 0 to N = 5. Figures 3A and 3B show that the maximum value of the mean error will be very large if the UE and the PRU take measurements on different slots and these errors are not corrected.

[0065] In one embodiment, to enable the LMF to correct carrier phase difference measurement errors due to carrier frequency offsets, the carrier frequency offset should be measured by both the UE and the PRU for each TRP for which measurements are taken, and these carrier frequency offsets should be reported to the LMF. Additionally, if either carrier phase measurements or carrier phase difference measurements are reported by the UE and the PRU, the number of symbols separating the measured DL-PRS for any two TRP's may be reported to the LMF (see R4-2311991, incorporated herein by reference).

[0066] In one embodiment, errors due to the carrier frequency offsets can be removed by referring the carrier phase measurements at the UE and the PRU to a common reference time (see R4-2313577, incorporated herein by reference). In one embodiment, removing errors due to carrier frequency offsets can be achieved by defining a common reference time and referring the DL-PRS carrier phase measurements to this reference time by subtracting the phase rotation due to the carrier frequency offset in the time interval between the DL-PRS and the reference time for the carrier phase measurement.

[0067] Figure 4A illustrates an example measurement window 400 for performing carrier phase measurements in different subframes, in accordance with aspects of the present disclosure. In certain embodiments, the UE and the PRU may not be able to take measurements on the same DL-PRS subframes. In Figure 4A, the PRU takes phase measurements on DL-PRS from *l*-th 402 and *m*-th 404 TRP's in the first slot 406, while the UE takes measurements on these same DL-PRS in the N+1-th slot 408. In one embodiment, the mean error in the carrier phase difference measurement between two TRP's, *l* 402 and *m* 404 (on the same subcarrier), due to carrier frequency offsets is given by

$$N\ L\ \Delta\varphi_{m,l}^{TX} + n\left(\Delta\varphi_{m,UE}^{TX} - \Delta\varphi_{m,PRU}^{TX}\right)$$

[0068] where N is the number of slots separating the measurements, L is the number of symbols per slot, and n is the number of symbols separating the PRS symbols within the slot.

[0069] Given that the frequency error of the TRP, the UE, and the PRU are all limited to ± 0.1 ppm, the maximum frequency difference between the TRP and the UE and between the TRP and the PRU are both limited to 0.2 ppm. In the case that the UE receiver carrier frequency is at the range minimum and the PRU receiver carrier frequency is at the range maximum, this mean error term can be expressed in degrees as

$$n\left(\Delta\varphi_{m,UE}^{TX} - \Delta\varphi_{m,PRS}^{TX}\right) \leq n\,T_s \cdot 2 \cdot 10^{-7}\,f_c \cdot 360$$

[0070] If additionally, it is assumed the transmitter frequency of the m-th TRP is at the range maximum and the transmitter frequency of the l-th TRP is at the range minimum, then it follows that

$$N\,L\,\Delta\varphi_{m,l}^{TX} \leq N\,L\,T_s \cdot 2 \cdot 10^{-7}\,f_c \cdot 360$$

[0071] so that

$$N\,L\,\Delta\varphi_{m,l}^{TX} + n\left(\Delta\varphi_{m,UE}^{TX} - \Delta\varphi_{m,PRU}^{TX}\right) \leq (N\,L + n)\,T_s \cdot 2 \cdot 10^{-7}\,f_c \cdot 360$$

[0072] where N is the number of slots separating the measurements by the PRU and the UE, L is the number of symbols per slot, and n is the number of symbols separating the PRS symbols from the l-th and m-th TRP (within the same time slot).

[0073] The solutions herein are directed to mapping the common reference time to the configured time windows defined for positioning measurements. These time windows can include single time slots, multiple time slots, or periodic time slots.

[0074] According to one embodiment, a UE may be configured to perform downlink carrier phase measurements including RSCP and RSCPD measurements with reference to a common time associated to a received time window configuration. This measurement time window configured by the location server/LMF to the target-UE indicates the specific DL-PRS resources, e.g., in terms of DL-PRS resource IDs, DL-PRS resource sets, TRP IDs, Positioning frequency layers (PFLs) from which to perform the RSCP and RSCPD measurements jointly at the target UE and PRU UE. In addition, this time window may be associated with various configuration parameters that may be signaled to the target-UE.

[0075] The aim of the measurement time windows is to enable the UE and PRU to perform the configured measurements at exactly the same time duration as specified by the measurement time window. It can be noted that this measurement time window is a best effort configuration and there may exist case where the UE or PRU may be unable to perform the requested measurements within the measurement time due to other reasons, e.g., scheduling delays, prioritized data transmissions, RRM measurements, etc.

[0076] In one embodiment, the configuration parameters include an indicated DL-PRS resource set(s)/resources from which to perform the RSCP and RSCPD measurements, a start system frame number (SFN) reference time that indicates the initial start time of the measurement time window, a periodicity parameter that indicates the periodicity of the time window in slots configured per DL-PRS Resource Set, a DL-PRS slot offset that indicates with respect to SFN #0 slot #0 for a TRP where the DL-PRS Resource Set is configured, a time window duration that indicates the overall duration of a configured time window that can be specified in terms of a number of slots and/or a number of orthogonal frequency division multiplexing (OFDM) symbols, a number of time windows that may be configured to the target UE depending on its UE capability (each time window may be associated with above configuration parameters, which may be the same or different across different number of configured time windows), and/or a combination of the foregoing.

[0077] In one aspect of the embodiment, in the case of UE-assisted positioning wherein the location server/LMF computes the target-UE's position, the location server/LMF may utilize the LPP *RequestLocationInformation* message or LPP *ProvideAssistanceData* message to request the target UE and PRU UE to perform RSCP and/or RSCPD measurements with respect to a time window reference time, which may be implicitly or explicitly indicated by the time window. Since carrier frequency offsets (CFOs) can typically degrade the RSCP/RSCPD measurement accuracy, it is proposed to mitigate the carrier phase offsets effect by establishing a common reference time with respect to a given measurement window configuration. By defining a common reference time with respect to a given measurement time window configuration for the carrier phase measurements, the carrier phase offsets due to the carrier frequency offsets in the time interval between the common reference time with respect to a given measurement time window configuration and the DL-PRS measurement are removed from the carrier phase measurements.

[0078] Figure 4B illustrates an example measurement window 450 for performing carrier phase measurements with reference to a measurement time window configuration, in accordance with aspects of the present disclosure. In Figure 4B, the common reference time is the first symbol of the time slot (symbol 0) 452. The phase measurements of the positioning reference symbols are referred to the reference time by removing the phase rotation that occurs due to the carrier frequency offset of the TRP transmitting the reference symbol relative to the UE during the time interval between the reference time and the time at which the reference symbol is received. The PRU may also perform the same measurement behavior as the UE, with respect to common reference time, e.g., in case with reference to symbol 0. The reference time may be defined by default, or the reference time may be signaled by the LMF or may be part of a pre-configuration in the UE and PRU. In some instances, the reference time may be defined as a symbol near, at, or proximate to the center of the time slot to minimize errors in the referred phase measurements due to any error in the estimation of the carrier frequency offset. In general, it is beneficial to minimize the distance, measured in symbols, between the positioning reference symbol for which the phase is measured and the reference time.

[0079] In the case that the time window includes multiple consecutive slots, the reference time can be defined as the first symbol of the first slot. Alternatively, the reference time can be defined as a symbol near, at, or proximate to the middle of the multiple consecutive slots. For example, if there are N consecutive slots in the time window, then the reference time can be chosen as a symbol within slot (N+1)/2 if N is odd, or within slots N/2 or N/2+1 in the case that N is even. Again, selection of a symbol near, at, or proximate to the middle of the multiple consecutive slots will minimize errors in the referred phase measurements due to any error in the estimation of the carrier frequency offset.

[0080] Figure 4C illustrates an example measurement window for performing carrier phase measurements with reference to a measurement time window configuration in different slots, in accordance with aspects of the present disclosure. As discussed above, in the general case the UE and the PRU may not be able to take measurements on the same DL-PRS subframes. Figure 4C illustrates the symbol indices k 477 and k' 479 can be any integer and are not limited to the number of symbols per slot and are used to number the symbols consecutively across slot boundaries.

[0081] In Figure 4C, the carrier phase measurements will be referred to a symbol within a slot between slot 1 481 and slot N+1 483. Let k_{ref} 485 denote the symbol index to which the measurements are to be referred. Typically, k_{ref} will be the first symbol of a slot.

[0082] As discussed previously, where the UE and the PRU take measurements in the same slot, let $\theta_{i,k,l}$ denote the UE's carrier phase measurement for the DL-PRS received from the l-th TRP in subcarrier i with symbol index k. The referred carrier phase measurement for the UE is then given by

$$\tilde{\theta}_{i,k,l} = \text{mod}\left(\theta_{i,k,l} - (k - k_{\text{ref}})\,\Delta\varphi_{l,UE}^{TX}, 2\pi\right).$$

[0083] Similarly, let $\Omega_{i,k,l}$ denote the PRU's carrier phase measurement for the DL-PRS received from the l-th TRP in subcarrier i with symbol index k. The *referred carrier phase measurement* for the PRU is then given by

$$\tilde{\Omega}_{i,k,l} = \text{mod}\left(\Omega_{i,k,l} - (k - k_{\text{ref}})\,\Delta\varphi_{l,PRU}^{TX}, 2\pi\right).$$

[0084] By using the referred carrier phase measurements rather than the carrier phase measurements, the carrier phase difference measurements errors due to carrier frequency offsets are removed. As a result, the same proposal to define a common reference time can be used to remove the errors due to carrier frequency offsets.

[0085] In particular, a common reference time is defined and the DL-PRS carrier phase measurements are referred to this reference time by subtracting the phase rotation due to the carrier frequency offset in the time interval between the DL-PRS and the reference time for the carrier phase measurement. The referred carrier phase difference is defined as the difference between the referred carrier phase measurements. The same common reference time is defined for the UE and the PRU. The UE and the PRU report either the referred carrier phase measurements or the carrier phase difference measurements computed using the referred carrier phase measurements.

[0086] As used herein, $\Delta\omega_{l,UE}^{TX}$ denotes the frequency offset of the carrier of the l-th TRP relative to that of the UE receiver and $\Delta\omega_{l,PRU}^{TX}$ denotes the frequency offset of the carrier of the l-th TRP relative to that of the PRU receiver. The phase increment $\Delta\varphi_{l,UE}^{TX}$ denotes the change in the phase of the carrier of the l-th TRP relative to that of the UE carrier over the period of one symbol given by $\Delta\varphi_{l,UE}^{TX} = \Delta\omega_{l,UE}^{TX}\,T_s$, where T_s is the symbol period.

[0087] The phase increment $\Delta\varphi_{l,PRU}^{TX}$ denotes the change in the phase of the carrier of the l-th TRP relative to that of the PRU carrier over the period of one symbol given by $\Delta\varphi_{m,l}^{TX} = \Delta\omega_{m,l}^{TX} T_s$, where T_s is the symbol period and $\Delta\omega_{m,l}^{TX}$ denotes the frequency offset of the carrier of the m-th TRP relative to that of the l-th TRP. The phase increment $\Delta\varphi_{m,l}^{TX}$ can also be expressed as $\Delta\varphi_{m,l}^{TX} = \Delta\varphi_{m,UE}^{TX} - \Delta\varphi_{l,UE}^{TX}$ or equivalently as $\Delta\varphi_{m,l}^{TX} = \Delta\varphi_{m,PRU}^{TX} - \Delta\varphi_{l,PRU}^{TX}$.

[0088] In the case of periodic DL-PRS, a reference time is defined for each time window of the periodic time windows. In general, the reference time definition relative to the time window will be the same for each of the periodic time windows. Because each of the periodic time windows has its own reference time, carrier phase measurements or carrier phase difference measurements taken by the UE on one of the periodic time windows should only be combined with PRU measurements taken on the same periodic time window. Otherwise, combining UE and PRS carrier phase measurements or carrier phase difference measurements taken on different periodic time windows can result in large measurement errors.

[0089] In the case that the DL-PRS carrier phase (RSCP) or carrier phase different (RSCPD) measurements are performed outside the time window, the measurements can still be referred to the reference time within the time window. However, in this case, the quality of the measurement will be degraded due to the longer time interval between the DL-PRS measurement and the reference time for which carrier phase rotation due to carrier frequency offset must be extrapolated. In this case, the UE or PRU taking the referred measurement can signal reduced quality of the measurement, or alternatively, may indicate (with some granularity) the number of symbols or slots between the carrier phase measurement and the time window or the reference time within the time window.

[0090] In another implementation, due to the effect of the large measurement errors, DL-PRS symbols measured outside the measurement time window may be dropped, subsequently resulting in the dropping of requested (in the case of UE-assisted positioning) or desired (in the case of UE-based positioning) RSCP or RSCPD measurements at the UE and/or PRU. The UE and/or PRU may notify or provide an indication to the LMF via e.g., LPP *Error* messages that the RSCP/RSCPD measurements have been dropped or were unable to be performed. In other instances, such error

messages may be signaled along with the DL-TDOA Error cause messages or Multi-RTT Error Cause messages that originate from the target UE or PRU.

[0091] Figure 5 illustrates a procedure 500 for UE-assisted positioning, in accordance with aspects of the present disclosure. At 1 (see messaging 502), in one embodiment, the location server/LMF 505 requests the target UE 503 and PRU UE 501 to perform RSCP/RSCPD measurements with a time window reference time (can also be referred to as common reference time with respect to the measurement time window).

[0092] At 2 (see messaging 504), in one embodiment, the target UE 503 and PRU UE 501 each perform RSCP/RSCPD measurements with respect to a time window reference time and reports these measurements according to the time window reference time to the location server. The target UE 503 will have already determined and mitigated the carrier frequency offset error of the RSCP and/or RSCPD measurements prior to the reporting these measurements to the LMF 505.

[0093] In one aspect of the embodiment, in the case of UE-based carrier phase positioning, wherein the target-UE computes its own position, the target-UE may utilize the LPP *RequestAssistanceData* message to request the location server to indicate to the target UE and PRU UE to perform RSCP and/or RSCPD measurements with respect to a time window reference time, which may be implicitly or explicitly indicated by the time window. In the case of UE-based positioning, the LPP *RequestLocationInformation* described earlier to carry the time window information and time window reference time indication is an optional message by the location server/LMF and hence it would be more suitable to utilize the LPP *ProvideAssistanceData* message to signal the time window information and time window reference time indication for the RSCP/RSCPD measurements. In other implementations, the same procedure may be used to provide the measurement time window to both UE and PRU for the correction of timing -related errors, e.g., timing offsets, timing bias, Tx/Rx timing error groups associated to one or more DL-RSTD, UE Rx-Tx time difference measurements or DL-AoD measurements, where supported by the appropriate UE capability.

[0094] Figure 6 illustrates an example of a procedure 600 for UE-based positioning, in accordance with aspects of the present disclosure. At 1 (see messaging 602), in one embodiment, the target UE 603 requests the location server/LMF 605 for DL-PRS configuration information. In one embodiment, the configuration information may

include an indication to perform 1) DL-TDOA positioning based DL-RSTD measurements; 2) DL-TDOA positioning based on DL-RSTD measurements and carrier phase positioning using RSCPD measurements; or 3) carrier phase positioning using RSCPD measurements. In other implementations, RSCP measurements may also be supported provided that the UE is capable of performing such measurements, e.g., to be signaled along with Multi-RTT measurements when supported for UE-based operation. In one embodiment, the configuration information may include an indication to provide an implicit/explicit time window reference time wherein each RSCPD measurement may be referred to this time window reference time. In one embodiment, the configuration information may include an indication that the same DL-PRS assistance data, i.e. same DL-PRS configuration in terms of positioning frequency layer ID, resource set ID, DL-PRS resources, combsize, resource element (RE) offset, number of symbols, DL-PRS periodicity may be provisioned to the PRU UE for performing simultaneous RAT-dependent positioning measurements including e.g., DL-RSTD and DL RSCPD.

[0095] At 2 (see messaging 604), in one embodiment, the location server/LMF 605 provisions the target UE 603 and PRU UE 601 to each perform RSCP/RSCPD measurements with respect to a time window reference time, e.g., using the LPP *ProvideAssistanceData* message. The LPP *ProvideAssistanceData* message to the target UE 603 may further indicate if the PRU UE 601 is to perform 1) only DL-RSTD measurements; 2) DL RSPD measurements only; or 3) both DL-RSTD and DL RSCPD measurements. In other instances, the LMF may provide a set of pre-configured assistance data comprising these measurement time window configurations and associated time window reference time configurations to be used at a future time. The LMF may then activate/deactivate these measurement time windows explicitly on-demand or implicitly via the validity of the pre-configured assistance data based on the area validity comprising a list of cells, wherein a UE or PRU entering the validity assumes activation of the measurement time window and a UE or PRU leaving the validity assumes deactivation of the measurement time window. This pre-configured assistance data behavior may be applied to both UE-assisted and UE-based positioning.

[0096] In one embodiment, the same recommended DL-PRS assistance data may be applied to the PRU UE 601 as indicated in the request in 1 or in other implementations a different set of DL-PRS assistance data may be provisioned to the target UE 603. In the case that the same DL-PRS assistance data is applied to the target UE 603 and PRU UE

601, the same simultaneous measurement time window configuration and measurement time window reference time should be applied to both target UE 603 and PRU UE 601. It should be further specified that the same DL-PRS assistance data, same simultaneous measurement time window configuration and measurement time window reference time should be applied to both target UE 603 and PRU UE 601.

[0097] In the case that the different DL-PRS assistance data is applied to the target UE 603 and PRU UE 601, the same different measurement time window configuration and different measurement time window reference times may be provisioned to the target UE 603 and PRU UE 601. Thereafter, implementation should strive to ensure that the measurement time window configurations and different measurement time window reference times are aligned as close as possible to avoid reduction in measurement accuracy of the timing-based and carrier phase-based measurements.

[0098] At 3 (see messaging 606), in one embodiment, since the target UE 603 processes the measurements internally for UE-based positioning, there is no need to report it to the LMF 605. However, the location server/LMF 605 may receive the PRU reference measurements from the PRU UE 601 including 1) Both DL-RSTD and RSCPD measurements; 2) Only DL-RSTD measurements; or 3) only RSCPD measurements. In other implementations, the location server may also receive gNB Rx-Tx time difference measurements and/or UE Rx-Tx time difference measurements, provided that the UE supports UE-based Multi-RTT positioning and has the associated capability.

[0099] At 4 (see messaging 608), in one embodiment, the location server/LMF 605 transmits the DL-RSTD and/or RSCP/RSCPD measurements with respect to the time window reference time using *ProvideAssistanceData* message. In the case of PRU measurements made from multiple PRUs, the location server/LMF 605 may associate each of the provided measurements using a measurement ID, temporary UE identifier, or any related unique identification sequence whereby a target UE 603 can distinguish different sets of DL-RSTD and/or RSCP/RSCPD measurements from different PRU UEs 601. It is important that the reference measurements provided by a particular PRU are aligned based on the same measurements performed across the same set of DL-PRS resources or DL-PRS resource sets.

[0100] In other implementations, the described measurement time window for performing simultaneous measurements by both the target UE 603 and PRU UE 601 may

be further associated with an identifier to further distinguish multiple measurements that may be aligned based on the same measurement time window identifier. Examples of measurement time window identifier may include a measurement time window ID, a temporary ID for a given measurement window, and/or the like.

[0101] For example, PRU UE 1 601 and target UE 603 may be configured with a measurement time window ID 1, while PRU UE 2 (not shown) and target UE 603 may be configured with a measurement time window ID 2, and so forth. Additionally, such measurement windows may be activated/deactivated based on the appropriated measurement time window ID. This will assist in keeping track of multiple measurements performed using multiple measurement windows. In another implementation, the target UE 603 may receive a temporary PRU UE identifier along with the performed PRU measurement forwarded or provisioned by the LMF 605. This also enables association of measurements performed with respect to multiple measurement time windows at the multiple PRUs based on a (temporary) PRU UE identifier. The (temporary) PRU identifier may be self-assigned by a PRU or generated at the AMF or LMF 605 and also be provided along with the DL-PRS assistance data to the target UE 603. Therefore, the LMF 605 may provide PRU measurements from multiple PRUs to a target UE 603, which are distinguished based on a PRU UE identifier, which may be a temporary or long-term/permanent ID.

[0102] In other implementations, the described measurement time window for performing simultaneous measurements by both the target UE 603 and PRU UE 601 may be applicable to legacy positioning such as DL-RSTD, UE Rx-Tx time difference measurements, DL-AoD and other NR DL E-CID measurements such as channel state information (CSI)-RS and synchronization signal block (SSB) RSRPs.

[0103] Figure 7 illustrates an example of a UE 700 in accordance with aspects of the present disclosure. The UE 700 may include a processor 702, a memory 704, a controller 706, and a transceiver 708. The processor 702, the memory 704, the controller 706, or the transceiver 708, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. These components may be coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

[0104] The processor 702, the memory 704, the controller 706, or the transceiver 708, or various combinations or components thereof may be implemented in hardware (e.g., circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

[0105] The processor 702 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, or any combination thereof). In some implementations, the processor 702 may be configured to operate the memory 704. In some other implementations, the memory 704 may be integrated into the processor 702. The processor 702 may be configured to execute computer-readable instructions stored in the memory 704 to cause the UE 700 to perform various functions of the present disclosure.

[0106] The memory 704 may include volatile or non-volatile memory. The memory 704 may store computer-readable, computer-executable code including instructions when executed by the processor 702 cause the UE 700 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as the memory 704 or another type of memory. 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.

[0107] In some implementations, the processor 702 and the memory 704 coupled with the processor 702 may be configured to cause the UE 700 to perform one or more of the functions described herein (e.g., executing, by the processor 702, instructions stored in the memory 704). For example, the processor 702 may support wireless communication at the UE 700 in accordance with examples as disclosed herein. The UE 700 may be configured to support a means to receive a request to perform carrier phase measurements with respect to a reference time within a time window, perform the carrier phase measurements, and transmit the carrier phase measurements performed with respect to the reference time within the time window.

[0108] In one embodiment, the UE 700 may be configured to support a means to transmit a request for a positioning configuration indicating the carrier phase measurements to be performed and the reference time within the time window. In one embodiment, carrier phase measurements performed outside the time window are dropped.

[0109] The controller 706 may manage input and output signals for the UE 700. The controller 706 may also manage peripherals not integrated into the UE 700. In some implementations, the controller 706 may utilize an operating system such as iOS®, ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 706 may be implemented as part of the processor 702.

[0110] In some implementations, the UE 700 may include at least one transceiver 708. In some other implementations, the UE 700 may have more than one transceiver 708. The transceiver 708 may represent a wireless transceiver. The transceiver 708 may include one or more receiver chains 710, one or more transmitter chains 712, or a combination thereof.

[0111] A receiver chain 710 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 710 may include one or more antennas for receiving the signal over the air or wireless medium. The receiver chain 710 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 710 may include at least one demodulator configured to demodulate the received signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receiver chain 710 may include at least one decoder for decoding and/or processing the demodulated signal to receive the transmitted data.

[0112] A transmitter chain 712 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 712 may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmitter chain 712 may also include at least one power amplifier configured to amplify the modulated signal to an appropriate

power level suitable for transmission over the wireless medium. The transmitter chain 712 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0113] Figure 8 illustrates an example of a processor 800 in accordance with aspects of the present disclosure. The processor 800 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 800 may include a controller 802 configured to perform various operations in accordance with examples as described herein. The processor 800 may optionally include at least one memory 804, which may be, for example, an L1/L2/L3 cache. Additionally, or alternatively, the processor 800 may optionally include one or more arithmetic-logic units (ALUs) 806. One or more of 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).

[0114] The processor 800 may be a processor chipset and include a protocol stack (e.g., a software stack) executed by the processor chipset to perform various operations (e.g., receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) in accordance with examples as described herein. The processor chipset may include one or more cores, one or more caches (e.g., memory local to or included in the processor chipset (e.g., the processor 800)) or other memory (e.g., random access memory (RAM), read-only memory (ROM), dynamic RAM (DRAM), synchronous dynamic RAM (SDRAM), static RAM (SRAM), ferroelectric RAM (FeRAM), magnetic RAM (MRAM), resistive RAM (RRAM), flash memory, phase change memory (PCM), and others).

[0115] The controller 802 may be configured to manage and coordinate various operations (e.g., signaling, receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) of the processor 800 to cause the processor 800 to support various operations in accordance with examples as described herein. For example, the controller 802 may operate as a control unit of the processor 800, generating control signals that manage the operation of various components of the processor 800. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[0116] The controller 802 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 804 and determine subsequent instruction(s) to be executed to cause the processor 800 to support various operations in accordance with examples as described herein. The controller 802 may be configured to track memory address of instructions associated with the memory 804. The controller 802 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 802 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 800 to cause the processor 800 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 802 may be configured to manage flow of data within the processor 800. The controller 802 may be configured to control transfer of data between registers, arithmetic logic units (ALUs), and other functional units of the processor 800.

[0117] The memory 804 may include one or more caches (e.g., memory local to or included in the processor 800) or other memory, such as RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementations, the memory 804 may reside within or on a processor chipset (e.g., local to the processor 800). In some other implementations, the memory 804 may reside external to the processor chipset (e.g., remote to the processor 800).

[0118] The memory 804 may store computer-readable, computer-executable code including instructions that, when executed by the processor 800, cause the processor 800 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. The controller 802 and/or the processor 800 may be configured to execute computer-readable instructions stored in the memory 804 to cause the processor 800 to perform various functions. For example, the processor 800 and/or the controller 802 may be coupled with or to the memory 804, the processor 800, the controller 802, and the memory 804 may be configured to perform various functions described herein. In some examples, the processor 800 may include multiple processors and the memory 804 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may, individually or collectively, be configured to perform various functions herein.

[0119] The one or more ALUs 806 may be configured to support various operations in accordance with examples as described herein. In some implementations, the one or more ALUs 806 may reside within or on a processor chipset (e.g., the processor 800). In some other implementations, the one or more ALUs 806 may reside external to the processor chipset (e.g., the processor 800). One or more ALUs 806 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 806 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 806 may be configured with a variety of logical and arithmetic circuits, including adders, subtractors, shifters, and logic gates, to process and manipulate the data according to the operation. Additionally, or alternatively, the one or more ALUs 806 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 806 to handle conditional operations, comparisons, and bitwise operations.

[0120] The processor 800 may support wireless communication in accordance with examples as disclosed herein. The processor 800 may be configured to or operable to support a means to transmit, to one or more UE, a request to perform carrier phase measurements with respect to a reference time within a time window and receive, from the one or more UE, the carrier phase measurements performed with respect to the reference time within the time window.

[0121] In one embodiment, the at least one UE comprises a target UE, or a PRU UE, or both. In one embodiment, the processor 800 may be configured to or operable to support a means to request from the target UE for a positioning configuration that indicates the carrier phase measurements to be performed and the reference time within the time window.

[0122] In one embodiment, the processor 800 may be configured to or operable to support a means to receive the carrier phase measurements with respect to the reference time within the time window from the PRU UE. In one embodiment, the processor 800 may be configured to or operable to support a means to transmit the received carrier phase measurements with respect to the reference time within the time window to the target UE.

[0123] In one embodiment, the carrier phase measurements include an RSCP measurement, an RSCPD measurement, or a combination thereof. In one embodiment,

the time window comprises a slot. In one embodiment, the reference time comprises a first symbol of the slot. In one embodiment, the time window comprises a plurality of consecutive slots. In one embodiment, the reference time comprises a symbol at a middle of the plurality of consecutive slots.

[0124] In one embodiment, the reference time is a default reference time. In one embodiment, the reference time is defined as a symbol at a center of a slot. In one embodiment, the time window comprises one of a plurality of periodic time windows. In one embodiment, each of the plurality of periodic time windows comprises a reference time.

[0125] In one embodiment, the processor 800 may be configured to or operable to support a means to provide a set of preconfigured assistance data, wherein the preconfigured assistance data comprises a carrier phase measurement time window configuration and an associated time window reference time configuration.

[0126] In one embodiment, the time window is associated with an identifier for distinguishing multiple different measurements that are aligned based on a same measurement time window identifier. In one embodiment, the processor 800 may be configured to or operable to support a means to provide PRU measurements from multiple PRUs to a target UE, the different PRU measurements distinguished based on a PRU identifier.

[0127] In one embodiment, the processor 800 may be configured to or operable to support a means to receive a request to perform carrier phase measurements with respect to a reference time within a time window, perform the carrier phase measurements, and transmit the carrier phase measurements performed with respect to the reference time within the time window. In one embodiment, carrier phase measurements performed outside the time window are dropped.

[0128] Figure 9 illustrates an example of a NE 900 in accordance with aspects of the present disclosure. The NE 900 may include a processor 902, a memory 904, a controller 906, and a transceiver 908. The processor 902, the memory 904, the controller 906, or the transceiver 908, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. These components may be coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

[0129] The processor 902, the memory 904, the controller 906, or the transceiver 908, or various combinations or components thereof may be implemented in hardware (e.g., circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

[0130] The processor 902 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, or any combination thereof). In some implementations, the processor 902 may be configured to operate the memory 904. In some other implementations, the memory 904 may be integrated into the processor 902. The processor 902 may be configured to execute computer-readable instructions stored in the memory 904 to cause the NE 900 to perform various functions of the present disclosure.

[0131] The memory 904 may include volatile or non-volatile memory. The memory 904 may store computer-readable, computer-executable code including instructions when executed by the processor 902 cause the NE 900 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as the memory 904 or another type of memory. 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.

[0132] In some implementations, the processor 902 and the memory 904 coupled with the processor 902 may be configured to cause the NE 900 to perform one or more of the functions described herein (e.g., executing, by the processor 902, instructions stored in the memory 904). For example, the processor 902 may support wireless communication at the NE 900 in accordance with examples as disclosed herein. The NE 900 may be configured to support a means to transmit, to one or more UE, a request to perform carrier phase measurements with respect to a reference time within a time window and receive, from the one or more UE, the carrier phase measurements performed with respect to the reference time within the time window.

[0133] In one embodiment, the one or more UE comprises a target UE, or a PRU UE, or both. In one embodiment, the NE 900 may be configured to support a means to request from the target UE for a positioning configuration that indicates the carrier phase measurements to be performed and the reference time within the time window.

[0134] In one embodiment, the NE 900 may be configured to support a means to receive the carrier phase measurements with respect to the reference time within the time window from the PRU UE. In one embodiment, the NE 900 may be configured to support a means to transmit the received carrier phase measurements with respect to the reference time within the time window to the target UE.

[0135] In one embodiment, the carrier phase measurements include an RSCP measurement, or an RSCPD measurement, or a combination thereof. In one embodiment, the time window comprises a slot. In one embodiment, the reference time comprises a first symbol of the slot. In one embodiment, the time window comprises a plurality of consecutive slots. In one embodiment, the reference time comprises a symbol at a middle of the plurality of consecutive slots.

[0136] In one embodiment, the reference time is a default reference time. In one embodiment, the reference time is defined as a symbol at a center of a slot. In one embodiment, the time window comprises one of a plurality of periodic time windows. In one embodiment, each of the plurality of periodic time windows comprises a reference time.

[0137] In one embodiment, the NE 900 may be configured to support a means to provide a set of preconfigured assistance data, wherein the preconfigured assistance data comprises a carrier phase measurement time window configuration and an associated time window reference time configuration.

[0138] In one embodiment, the time window is associated with an identifier for distinguishing multiple different measurements that are aligned based on a same measurement time window identifier. In one embodiment, the NE 900 may be configured to support a means to provide PRU measurements from multiple PRUs to a target UE, the different PRU measurements distinguished based on a PRU identifier.

[0139] The controller 906 may manage input and output signals for the NE 900. The controller 906 may also manage peripherals not integrated into the NE 900. In some

implementations, the controller 906 may utilize an operating system such as iOS®, ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 906 may be implemented as part of the processor 902.

[0140] In some implementations, the NE 900 may include at least one transceiver 908. In some other implementations, the NE 900 may have more than one transceiver 908. The transceiver 908 may represent a wireless transceiver. The transceiver 908 may include one or more receiver chains 910, one or more transmitter chains 912, or a combination thereof.

[0141] A receiver chain 910 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 910 may include one or more antennas for receiving the signal over the air or wireless medium. The receiver chain 910 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 910 may include at least one demodulator configured to demodulate the received signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receiver chain 910 may include at least one decoder for decoding and processing the demodulated signal to receive the transmitted data.

[0142] A transmitter chain 912 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 912 may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmitter chain 912 may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmitter chain 912 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0143] Figure 10 illustrates a flowchart of a method in accordance with aspects of the present disclosure. The operations of the method may be implemented by a UE as described herein. In some implementations, the UE may execute a set of instructions to control the function elements of the UE to perform the described functions.

[0144] At 1002, the method may transmit, to one or more UE, a request to perform carrier phase measurements with respect to a reference time within a time window. The operations of 1002 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1002 may be performed by a UE as described with reference to Figure 10.

[0145] At 1004, the method may receive, from the one or more UE, the carrier phase measurements performed with respect to the reference time within the time window. The operations of 1004 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1004 may be performed by a UE as described with reference to Figure 10.

[0146] It should be noted that the method described herein describes a possible implementation, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible.

[0147] Figure 11 illustrates a flowchart of a method in accordance with aspects of the present disclosure. The operations of the method may be implemented by a NE as described herein. In some implementations, the NE may execute a set of instructions to control the function elements of the NE to perform the described functions.

[0148] At 1102, the method may receive a request to perform carrier phase measurements with respect to a reference time within a time window. The operations of 1102 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1102 may be performed by a NE as described with reference to Figure 11.

[0149] At 1104, the method may perform the carrier phase measurements. The operations of 1104 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1104 may be performed by a NE as described with reference to Figure 11.

[0150] At 1106, the method may transmit the carrier phase measurements performed with respect to the reference time within the time window. The operations of 1106 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1106 may be performed a NE as described with reference to Figure 11.

[0151] It should be noted that the method described herein describes a possible implementation, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible.

[0152] 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

1. A network equipment (NE) for wireless communication, comprising:
at least one memory; and
at least one processor coupled with the at least one memory and
configured to cause the NE to:
transmit, to one or more user equipment (UE), a request to perform carrier phase measurements with respect to a reference time within a time window; and
receive, from the one or more UE, the carrier phase measurements performed with respect to the reference time within the time window.

2. The NE of claim 1, wherein the one or more UE comprise a target UE, or a position reference unit (PRU) UE, or both.

3. The NE of claim 2, wherein the at least one processor is configured to cause the NE to receive a request from the target UE for a positioning configuration that indicates the carrier phase measurements to be performed and the reference time within the time window.

4. The NE of claim 3, wherein the at least one processor is configured to cause the NE to receive the carrier phase measurements with respect to the reference time within the time window from the PRU UE; and
to transmit the received carrier phase measurements with respect to the reference time within the time window to the target UE.

5. The NE of claim 1, wherein the carrier phase measurements comprise a reference signal carrier phase (RSCP) measurement, or an RSCP difference (RSCPD) measurement, or a combination thereof.

6. The NE of claim 1, wherein the time window comprises a slot, and wherein the reference time comprises a first symbol of the slot.

7. The NE of claim 1, wherein the time window comprises a plurality of consecutive slots, and wherein the reference time comprises a symbol located at a middle of the plurality of consecutive slots.

8. The NE of claim 1, wherein the reference time is a default reference time, or wherein the reference time is defined as a symbol at a center of a slot.

9. The NE of claim 1, wherein the time window comprises one of a plurality of periodic time windows, and wherein each of the plurality of periodic time windows comprises a reference time.

10. The NE of claim 1, wherein the at least one processor is configured to cause the NE to provide a set of preconfigured assistance data, wherein the preconfigured assistance data comprises a carrier phase measurement time window configuration and an associated time window reference time configuration.

11. The NE of claim 1, wherein the time window is associated with an identifier for distinguishing multiple different measurements that are aligned based on a same measurement time window identifier.

12. A method performed by a network equipment (NE), the method comprising:
transmitting, to at least one user equipment (UE), a request to perform carrier phase measurements with respect to a reference time within a time window; and
receiving, from the at least one UE, the carrier phase measurements performed with respect to the reference time within the time window.

13. A user equipment (UE) for wireless communication, comprising:
at least one memory; and
at least one processor coupled with the at least one memory and configured to cause the UE to:
receive a request to perform carrier phase measurements with respect to a reference time within a time window;
perform the carrier phase measurements; and

transmit the carrier phase measurements performed with respect to the reference time within the time window.

14. The UE of claim 13, wherein carrier phase measurements performed outside the time window are dropped.

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

receiving a request to perform carrier phase measurements with respect to a reference time within a time window;

performing the carrier phase measurements; and

transmitting the carrier phase measurements performed with respect to the reference time within the time window.