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Method And Reporting Of The Carrier Phase Measurement Reporting

Abstract

An apparatus includes at least one processor; and at least one memory storing instructions that, when executed by the processor, cause the apparatus at least to: receive a request to report a carrier phase measurement for a first detected arrival signal path of a reference signal; detect multiple arrival signal paths from the reference signal including the first detected arrival signal path; determine line of sight indicator values for the detected multiple arrival signal paths including the first detected arrival signal path; and transmit, based on the determined line of sight indicator value for the first detected arrival signal path not being greater than at least one other line of sight indicator value for at least one other detected arrival signal path of the multiple arrival signal paths, a report comprising at least one carrier phase measurement for at least one arrival signal path of the multiple arrival signal paths.

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Background/Summary

TECHNICAL FIELD

[0001] The examples and non-limiting example embodiments relate generally to communications and, more particularly, to a method and reporting of the carrier phase measurement reporting. Some example embodiments may generally relate to mobile or wireless telecommunication systems, such as 3.sup.rd Generation Partnership Project (3GPP) Long Term Evolution (LTE), 5.sup.th generation (5G) radio access technology (RAT), new radio (NR) access technology, 6.sup.th generation (6G), and/or other communications systems. For example, certain example embodiments may relate to systems and/or methods for providing carrier phase positioning.

BACKGROUND

[0002] It is known for a communication device to gain access to a communication network via an access network node.

SUMMARY

[0003] In accordance with an aspect, an apparatus includes at least one processor; and at least one non-transitory memory storing instructions that, when executed by the at least one processor, cause the apparatus at least to: receive a request to report a carrier phase measurement for a first detected arrival signal path of a reference signal; detect multiple arrival signal paths from the reference signal including the first detected arrival signal path; determine line of sight indicator values for the detected multiple arrival signal paths including the first detected arrival signal path; and transmit, based on the determined line of sight indicator value for the first detected arrival signal path not being greater than at least one other line of sight indicator value for at least one other detected arrival signal path of the multiple arrival signal paths, a report comprising at least one carrier phase measurement for at least one arrival signal path of the multiple arrival signal paths.

[0004] In accordance with an aspect, an apparatus includes at least one processor; and at least one non-transitory memory storing instructions that, when executed by the at least one processor, cause the apparatus at least to: transmit a request to report a carrier phase measurement for a first detected arrival signal path of a reference signal; receive, based on a line of sight indicator value for the first detected arrival signal path not being greater than at least one other line of sight indicator value for at least one other arrival signal path of multiple arrival signal paths of the reference signal, a report comprising at least one carrier phase measurement for at least one arrival signal path of the multiple arrival signal paths; and estimate a location of a user equipment, based on the at least one carrier phase measurement for the least one arrival signal path of the multiple arrival signal paths.

[0005] In accordance with an aspect, an apparatus includes at least one processor; and at least one non-transitory memory storing instructions that, when executed by the at least one processor, cause the apparatus at least to: receive a request to report a carrier phase measurement for a first detected arrival signal path of a reference signal; detect multiple arrival signal paths from the reference signal including the first detected arrival signal path; determine a line of sight indicator value for the detected multiple arrival signal paths including the first detected arrival signal path; and transmit, based on the determined line of sight indicator value for the first detected arrival signal path not being greater than at least one of the line of sight indicator values for the other arrival signal paths, a report comprising one of: a carrier phase measurement for the first detected arrival signal path, when the line of sight indicator value for the first detected arrival signal path is greater than a threshold value, or a carrier phase measurement for one arrival signal path of the detected multiple arrival signal paths, wherein the one arrival signal path has the largest line of sight indicator value among the determined line of sight indicator values for the multiple arrival signal paths, or an average carrier phase measurement for at least one arrival signal path of the multiple arrival signal paths.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The foregoing aspects and other features are explained in the following description, taken in connection with the accompanying drawings.

[0007] FIG. **1** is a block diagram of one possible and non-limiting system in which the example embodiments may be practiced.

[0008] FIG. **2** is a flow chart for DL-based CP positioning.

[0009] FIG. **3** is a flow chart for UL-based CP positioning.

[0010] FIG. **4** is an example apparatus configured to implement the examples described herein.

[0011] FIG. **5** shows a representation of an example of non-volatile memory media used to store instructions that implement the examples described herein.

[0012] FIG. **6** is an example method, based on the examples described herein.

[0013] FIG. **7** is an example method, based on the examples described herein.

[0014] FIG. **8** is an example method, based on the examples described herein.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

[0015] Turning to FIG. **1**, this figure shows a block diagram of one possible and non-limiting example in which the examples may be practiced. A user equipment (UE) **110**, radio access network (RAN) node **170**, and network element(s) **190** are illustrated. In the example of FIG. **1**, the user equipment (UE) **110** is in wireless communication with a wireless network **100**. A UE is a wireless device that can access the wireless network **100**. The UE **110** includes one or more processors **120**, one or more memories **125**, and one or more transceivers **130** interconnected through one or more buses **127**. Each of the one or more transceivers **130** includes a receiver, Rx, **132** and a transmitter, Tx, **133**. The one or more buses **127** may be address, data, or control buses, and may include any interconnection mechanism, such as a series of lines on a motherboard or integrated circuit, fiber optics or other optical communication equipment, and the like. The one or more transceivers **130** are connected to one or more antennas **128**. The one or more memories **125** include computer program code **123**. The UE **110** includes a module **140**, comprising one of or both parts **140-1** and/or **140-2**, which may be implemented in a number of ways. The module **140** may be implemented in hardware as module **140-1**, such as being implemented as part of the one or more processors **120**. The module **140-1** may be implemented also as an integrated circuit or through other hardware such as a programmable gate array. In another example, the module **140** may be implemented as module **140-2**, which is implemented as computer program code **123** and is executed by the one or more processors **120**. For instance, the one or more memories **125** and the computer program code **123** may be configured to, with the one or more processors **120**, cause the user equipment **110** to perform one or more of the operations as described herein. The UE **110** communicates with RAN node **170** via a wireless link **111**.

[0016] The RAN node **170** in this example is a base station that provides access for wireless devices such as the UE **110** to the wireless network **100**. The RAN node **170** may be, for example, a base station for 5G, also called New Radio (NR). In 5G, the RAN node **170** may be a NG-RAN node, which is defined as either a gNB or an ng-eNB. A gNB is a node providing NR user plane and control plane protocol terminations towards the UE, and connected via the NG interface (such as connection **131**) to a 5GC (such as, for example, the network element(s) **190**). The ng-eNB is a node providing E-UTRA user plane and control plane protocol terminations towards the UE, and connected via the NG interface (such as connection **131**) to the 5GC. The NG-RAN node may include multiple gNBs, which may also include a central unit (CU) (gNB-CU) **196** and distributed unit(s) (DUs) (gNB-DUs), of which DU **195** is shown. Note that the DU **195** may include or be coupled to and control a radio unit (RU). The gNB-CU **196** is a logical node hosting radio resource control (RRC), SDAP and PDCP protocols of the gNB or RRC and PDCP protocols of the en-gNB that control the operation of one or more gNB-DUs. The gNB-CU **196** terminates the F1 interface connected with the gNB-DU **195**. The F1 interface is illustrated as reference **198**, although reference **198** also illustrates a link between remote elements of the RAN node **170** and centralized elements of the RAN node **170**, such as between the gNB-CU **196** and the gNB-DU **195**. The gNB-DU **195** is a logical node hosting RLC, MAC and PHY layers of the gNB or en-gNB, and its operation is partly controlled by gNB-CU **196**. One gNB-CU **196** supports one or multiple cells. One cell may be supported with one gNB-DU **195**, or one cell may be supported/shared with multiple DUs under RAN sharing. The gNB-DU **195** terminates the F1 interface **198** connected with the gNB-CU **196**. Note that the DU **195** is considered to include the transceiver **160**, e.g., as part of a RU, but some examples of this may have the transceiver **160** as part of a separate RU, e.g., under control of and connected to the DU **195**. The RAN node **170** may also be an eNB (evolved NodeB) base station, for LTE (long term evolution), or any other suitable base station or node.

[0017] The RAN node **170** includes one or more processors **152**, one or more memories **155**, one or more network interfaces (N/W I/F(s)) **161**, and one or more transceivers **160** interconnected through one or more buses **157**. Each of the one or more transceivers **160** includes a receiver, Rx, **162** and a transmitter, Tx, **163**. The one or more transceivers **160** are connected to one or more antennas **158**. The one or more memories **155** include computer program code **153**. The CU **196** may include the processor(s) **152**, one or more memories **155**, and network interfaces **161**. Note that the DU **195** may also contain its own memory/memories and processor(s), and/or other hardware, but these are not shown.

[0018] The RAN node **170** includes a module **150**, comprising one of or both parts **150-1** and/or **150-2**, which may be implemented in a number of ways. The module **150** may be implemented in hardware as module **150-1**, such as being implemented as part of the one or more processors **152**. The module **150-1** may be implemented also as an integrated circuit or through other hardware such as a programmable gate array. In another example, the module **150** may be implemented as module **150-2**, which is implemented as computer program code **153** and is executed by the one or more processors **152**. For instance, the one or more memories **155** and the computer program code **153** are configured to, with the one or more processors **152**, cause the RAN node **170** to perform one or more of the operations as described herein. Note that the functionality of the module **150** may be distributed, such as being distributed between the DU **195** and the CU **196**, or be implemented solely in the DU **195**.

[0019] The one or more network interfaces **161** communicate over a network such as via the links **176** and **131**. Two or more gNBs **170** may communicate using, e.g., link **176**. The link **176** may be wired or wireless or both and may implement, for example, an Xn interface for 5G, an X2 interface for LTE, or other suitable interface for other standards.

[0020] The one or more buses **157** may be address, data, or control buses, and may include any interconnection mechanism, such as a series of lines on a motherboard or integrated circuit, fiber optics or other optical communication equipment, wireless channels, and the like. For example, the one or more transceivers **160** may be implemented as a remote radio head (RRH) **195** for LTE or a distributed unit (DU) **195** for gNB implementation for 5G, with the other elements of the RAN node **170** possibly being physically in a different location from the RRH/DU **195**, and the one or more buses **157** could be implemented in part as, for example, fiber optic cable or other suitable network connection to connect the other elements (e.g., a central unit (CU), gNB-CU **196**) of the RAN node **170** to the RRH/DU **195**. Reference **198** also indicates those suitable network link(s).

[0021] A RAN node/gNB can comprise one or more TRPs to which the methods described herein may be applied. FIG. **1** shows that the RAN node **170** comprises TRP **51** and TRP **52**, in addition to the TRP represented by transceiver **160**. Similar to transceiver **160**, TRP **51** and TRP **52** may each include a transmitter and a receiver. The RAN node **170** may host or comprise other TRPs not shown in FIG. **1**.

[0022] A relay node in NR is called an integrated access and backhaul node. A mobile termination part of the IAB node facilitates the backhaul (parent link) connection. In other words, the mobile termination part comprises the functionality which carries UE functionalities. The distributed unit part of the IAB node facilitates the so called access link (child link) connections (i.e. for access link UEs, and backhaul for other IAB nodes, in the case of multi-hop IAB). In other words, the distributed unit part is responsible for certain base station functionalities. The IAB scenario may follow the so called split architecture, where the central unit hosts the higher layer protocols to the UE and terminates the control plane and user plane interfaces to the 5G core network.

[0023] It is noted that the description herein indicates that "cells" perform functions, but it should be clear that equipment which forms the cell may perform the functions. The cell makes up part of a base station. That is, there can be multiple cells per base station. For example, there could be three cells for a single carrier frequency and associated bandwidth, each cell covering one-third of a 360 degree area so that the single base station's coverage area covers an approximate oval or circle. Furthermore, each cell can correspond to a single carrier and a base station may use multiple carriers. So if there are three 120 degree cells per carrier and two carriers, then the base station has a total of 6 cells.

[0024] The wireless network **100** may include a network element or elements **190** that may include core network functionality, and which provides connectivity via a link or links **181** with a further network, such as a telephone network and/or a data communications network (e.g., the Internet). Such core network functionality for 5G may include location management functions (LMF(s)) and/or access and mobility management function(s) (AMF(S)) and/or user plane functions (UPF(s)) and/or session management function(s) (SMF(s)). Such core network functionality for LTE may include MME (mobility management entity)/SGW (serving gateway) functionality. Such core network functionality may include SON (self-organizing/optimizing network) functionality. These are merely example functions that may be supported by the network element(s) **190**, and note that both 5G and LTE functions might be supported. The RAN node **170** is coupled via a link **131** to the network element **190**. The link **131** may be implemented as, e.g., an NG interface for 5G, or an S1 interface for LTE, or other suitable interface for other standards. The network element **190** includes one or more processors **175**, one or more memories **171**, and one or more network interfaces (N/W I/F(s)) **180**, interconnected through one or more buses **185**. The one or more memories **171** include computer program code **173**. Computer program code **173** may include SON and/or MRO functionality **172**.

[0025] The wireless network **100** may implement network virtualization, which is the process of combining hardware and software network resources and network functionality into a single, software-based administrative entity, or a virtual network. Network virtualization involves platform virtualization, often combined with resource virtualization. Network virtualization is categorized as either external, combining many networks, or parts of networks, into a virtual unit, or internal, providing network-like functionality to software containers on a single system. Note that the virtualized entities that result from the network virtualization are still implemented, at some level, using hardware such as processors **152** or **175** and memories **155** and **171**, and also such virtualized entities create technical effects.

[0026] The computer readable memories **125**, **155**, and **171** may be of any type suitable to the local technical environment and may be implemented using any suitable data storage technology, such as semiconductor based memory devices, flash memory, magnetic memory devices and systems, optical memory devices and systems, non-transitory memory, transitory memory, fixed memory and removable memory. The computer readable memories **125**, **155**, and **171** may be means for performing storage functions. The processors **120**, **152**, and **175** may be of any type suitable to the local technical environment, and may include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and processors based on a multi-core processor architecture, as non-limiting examples. The processors **120**, **152**, and **175** may be means for performing functions, such as controlling the UE **110**, RAN node **170**, network element(s) **190**, and other functions as described herein.

[0027] In general, the various example embodiments of the user equipment **110** can include, but are not limited to, cellular telephones such as smart phones, tablets, personal digital assistants (PDAs) having wireless communication capabilities, portable computers having wireless communication capabilities, image capture devices such as digital cameras having wireless communication capabilities, gaming devices having wireless communication capabilities, music storage and playback devices having wireless communication capabilities, internet appliances including those permitting wireless internet access and browsing, tablets with wireless communication capabilities, head mounted displays such as those that implement virtual/augmented/mixed reality, as well as portable units or terminals that incorporate combinations of such functions. The UE **110** can also be a vehicle such as a car, or a UE mounted in a vehicle, a UAV such as e.g. a drone, or a UE mounted in a UAV. The user equipment **110** may be terminal device, such as mobile phone, mobile device, sensor device etc., the terminal device being a device used by the user or not used by the user.

[0028] UE **110**, RAN node **170**, and/or network element(s) **190**, (and associated memories, computer program code and modules) may be configured to implement (e.g. in part) the methods described herein. Thus, computer program code **123**, module **140-1**, module **140-2**, and other elements/features shown in FIG. **1** of UE **110** may implement user equipment related aspects of the examples described herein. Similarly, computer program code **153**, module **150-1**, module **150-2**, and other elements/features shown in FIG. **1** of RAN node **170** may implement gNB/TRP related aspects of the examples described herein. Computer program code **173** and other elements/features shown in FIG. **1** of network element(s) **190** may be configured to implement network element related aspects of the examples described herein.

[0029] Having thus introduced a suitable but non-limiting technical context for the practice of the example embodiments, the example embodiments are now described with greater specificity.

[0030] A Rel-18 work item [RP-223549, "New WID on Expanded and Improved NR Positioning"] was agreed for further enhancement of NR positioning. One of the main topics is to support carrier phase (CP) positioning on top of the currently supported positioning technique.

[0031] The work item included work to: specify physical layer measurements and signaling to support NR DL and UL carrier phase positioning for UE-based, UE-assisted, and NG-RAN node assisted positioning. Existing DL PRS and UL SRS for positioning are used for NR carrier phase measurements, specify measurements that are limited to a single carrier and/or DL PRS positioning frequency layer (PFL), specify corresponding new core requirements, as well as identifying and specifying the impact on the existing specification, including RRM measurements without measurement gaps in connected and inactive mode (including PRS measurement period/reporting) and procedures.

[0032] Provided next is brief background information on measurements and a procedure for a carrier phase (CP) positioning method assuming UL (uplink)-based CP. Fundamentally, in the carrier phase positioning technique, the target UE transmits uplink reference signals, and multiple TRPs (Transmission and Reception Point) measure phase measurements, which are used to estimate the location of target UEs. For the transmitted SRS resource from the k-th UE, the phase measurement at the i-th TRP can be denoted by

[00001] $\varphi_{ik} = d_{ik} + c(\delta_k - \delta_i) + \lambda N_{ik}$ InEquation(1), $\varphi_{\mathrm{ik}} = \frac{1}{2\pi}\phi_{\mathrm{ik}}$ Equation(1)

denotes the phase measurement in cycles and to leave out repeated use of 2π, and d.sub.ik, c, δ.sub.k, δ.sub.i, and N.sub.ik represent respectively actual geographical distance between the k-th UE and the i-th TRP, speed of light, internal clock bias at the k-th UE, internal clock bias at the i-th TRP, and integer ambiguity of the propagated wavelength. Similar to (1), the same equation is derived for the j-th TRP such that φ.sub.jk=d.sub.jk+c(δ.sub.k−δ.sub.j)+λN.sub.jk, and the single difference measurement between two TRPs is described as the following equation.

[00002] $\Delta\varphi_{ij}^{k} = \Delta d_k + c\Delta\delta_{ij} + \Delta N_{ij}^{k}\lambda$ InEquation(2), $\Delta\varphi_{ij}^{k} = \varphi_{\mathrm{ik}} - \varphi_{jk}$, $\Delta d_k = d_{\mathrm{ik}} - d_{jk}$, $\Delta\delta_{ij} = \delta_i - \delta_j$, and $\Delta N_{ij}^{k} = N_i - N_j$. (2)

[0033] From this single differential operation, the UE clock bias is cancelled, which is similar to RTOA (Relative Time of Arrival) measurement of UL-TDOA. The clock error between TRPs is remaining but it is cancelled by double differential operation using measurements from reference device.

[0034] Let us assume that the K-th UE is a positioning reference Unit (PRU). For the transmitted SRS from the PRU, the single difference measurement between the i-th TRP and j-th TRP is

[00003]
$\Delta\varphi_{ij}^{K} = \Delta d_{K} \times \frac{1}{\lambda} + f\Delta\delta_{ij} + \Delta N_{ij}^{K}$. $\Delta\Delta\varphi_{ij}^{kK} = \Delta\Delta d_{kK} + \Delta\Delta N_{ij}^{kK}\lambda$ InEquation(3), $\Delta\Delta\varphi_{ij}^{kK} = \Delta\varphi_{ij}^{k} - \Delta\varphi_{ij}^{K}$, $\Delta\Delta d_{kK} = \Delta d_{k} - \Delta d_{K}$, and $\Delta\Delta N_{ij}^{kK} = \Delta N$
In the end, the clock error between TRPs is cancelled out. We considered clock bias at the UE and the TRP, which are the main errors to explain single difference and double difference method of carrier phase method.
[0035] A LoS (Line of Sight)/NLoS (Non-Line of Sight) indicator was introduced in the specification TS 37.355.
[0036] Described herein is the way to report carrier phase measurement for the first arrival path of received reference signals. the following progress was achieved.
TABLE-US-00001 Agreement Only the carrier phase measurements (i.e., DL/UL RSCP, DL RSCPD) of the first path are supported in Rel-18.
[0037] The current agreement only allows the UE to report RSCP (Reference Signal Carrier Phase) or RSCPD (Reference Signal Carrier Phase Difference) measurement only for the arrival 1.sup.st path. It should be noted that the legacy RSTD or UE Rx-Tx time difference measurement can be reported also for additional paths. In addition, when the UE reports CP measurements, it should include timing measurements. The LoS/NLoS indicator field is shared between the timing measurement and CP measurement, as the detection capability of the path is not tied with the positioning techniques.
[0038] Issue: the following example case is feasible, as the first path could be a peak from interference or noise. The UE can report a timing measurement for the 1.sup.st detected path with an LoS indicator value of 0.4. The UE can report a timing measurement for the 2.sup.nd detected path with an LoS indicator value of 0.6.
[0039] Based on the current agreement, the UE is not able to report CP measurement for the 2nd detected path, but the first detected path may not be the actual 1.sup.st path as the LoS indicator value is not greater than the 2.sup.nd detected path. Based on the current specification, there is ambiguity of UE behavior. The examples described herein address this issue.
[0040] Described herein is UE behavior to address the ambiguous UE behavior on the RSCP or RSCPD measurement reporting.
[0041] A first arrival path is the first detected path from the device, but the UE cannot guarantee if it is a real/actual first arrival path as it could be noise/interference signal. Also, the signal strength of the first path could be very weak if there is a strong blockage between the UE and the TRP. For example, the UE can detect three arrival paths like path1 (t1), path2 (t2), path3 (t3), for times t1, t2, and t3, where t1 is less than t2, and t2 is less than t3, then the detected first path is path1 (t1). However, if for example the LoS/NLoS factors are 0.1 for path1, 0.1 for path2, and 0.8 for path 3, the path3 (t3) would be likely to be the actual first arrival path. Thus, “detected arrival path” and “actual/true arrival path” are not the same.
DL-Based CP Positioning
[0042] The LMF provides the UE with assistance data including PRS configuration information.
[0043] For DL (Downlink)-based CP positioning, the LMF initiates CP technique. The LMF requests UE to report CP measurements for the specific TRPs.
[0044] The UE detects multiple arrival signal paths from a specific PRS transmitted from a TRP. For a specific DL PRS resource, the UE detects a high LoS indication value other than the 1.sup.st detected path. For example, the UE determines that the LoS indication value of the 2.sup.nd detected path is greater than that of the 1.sup.st detected path.
[0045] Option 1) The UE reports a RSCP or RSCPD measurement for the 1.sup.st detected path even though LoS probability is lower than the LoS probability of the additional paths such as 2.sup.nd detected path, but it also informs to the LMF that the 1.sup.st path LoS indicator is not greater than that of additional paths.
[0046] The following example is provided for a better understanding of Option 1. Reporting contents #1: (LoS indicator=0.4, RSTD measurement, RSCPD measurement). Reporting contents #2: (LoS indicator=0.6, RSTD measurement). In addition, the UE reports the reported measurements associated with LoS indicator of 0.4 is corresponding to the “first path”.
[0047] Option 2) The UE reports or is indicated by the LMF to report a RSCP or RSCPD measurement for a signal path showing the largest LoS indication value. In this option, even if the UE does not report the LoS indicator (as it is optional parameter), the LMF assumes the set of reporting contents containing RSCP or RSCPD is associated with the largest LoS path.
[0048] Option 2-1) The UE can additionally provide which signal path (N-th detected path) was selected to obtain a CP measurement.
[0049] Option 2-2) The UE does not additionally provide any information. The LMF will consider the reported CP measurement for the first detected path, even though the CP measurement was not made from the first detected path.
[0050] For example, for option 2-2, the LMF may determine that the carrier phase measurement for the arrival signal path having the largest line of sight indicator value is for the arrival signal path having a line of sight indicator value that is not greater than at least one line of sight indicator for another arrival signal path, in response to the report having the carrier phase difference measurement not comprising the arrival signal path having the largest line of sight indicator value, and the report comprising the carrier phase measurement for the arrival signal path having the largest line of sight indicator value, when the report does not comprise the arrival signal path having the largest line of sight indicator value, and the report comprises the carrier phase measurement for the arrival signal path having the largest line of sight indicator value.
[0051] Option 3) The UE reports an average of RSCP or RSCPD measurements for the first N detected paths (for a number N). In this case, the UE acknowledge that anyone of the first N detected paths could be an actual first path. For the necessity of this option, we can consider the following cases. The LoS indicator value is the maximum at the N-th detected path. The LoS indicator value is almost same of the N detected path. For example, the 1.sup.st and the 2.sup.nd detected path can have LoS indicator value of 0.5
[0052] The above options are for a specific DL PRS resource. The LMF may indicate the UE to perform measurement for a specific DL PRS resource set that includes multiple DL PRS resources. In this case, For the CP measurement reporting, the UE prioritizes a DL PRS resource which shows the largest LoS indicator value at the first detected path of all the detected paths from the DL PRS resource. In one embodiment, the UE prioritizes a specific DL PRS resource within the DL PRS resource set such that the line-of-sight indicator value of a first detected path obtained from the DL PRS resource is the largest value among line-of-sight indicators of a first detected path from other DL PRS resources within the DL PRS resource set.
[0053] The LMF estimates the UE location based on the provided measurements.
[0054] Similar to the DL CP positioning, we also propose the gNB behavior for the UL CP positioning.
UL-Based CP Positioning
[0055] The gNB provides the UE with assistance data including SRS configuration information.
[0056] For UL (uplink)-based CP positioning, the UE transmits SRS so that multiple TRPs measure the signals in different paths.
[0057] When each TRP detects the arrival signal from UE, multiple signals from different paths can be measured. Therefore, TRP could detect a high LoS indication value for a specific arrival path(s) other than the 1.sup.st detected path of the received signals from a specific SRS resource. For example, the LoS indication value of the 2.sup.nd detected path is greater than that of the 1.sup.st detected path. Then, when the gNB sends a report to LMF on the measurement and its LoS indication value, the following options can be used.
[0058] Option 1) The gNB reports a UL RSCP measurement for the 1.sup.st detected path even though LoS probability is lower than the LoS probability of the additional paths such as 2.sup.nd detected path, but it also informs to the LMF that the 1.sup.st path LoS indicator is not greater than that of additional paths.
[0059] Similar to the DL case, the following example is provided. Reporting contents #1: (LoS indicator=0.4, RTOA measurement, RSCP measurement). Reporting contents #2: (LoS indicator=0.6, RTOA measurement). In addition, the gNB reports the reported measurements associated

with LoS indicator of 0.4 is corresponding to the “first path”.
[0060] Option 2) The gNB reports or is requested by the LMF to report a RSCP or RTOA measurement for a signal path showing the largest LoS indication value. In this option, even if the gNB does not report the LoS indicator, the LMF assumes the set of reporting contents containing RSCP is associated with the largest LoS path.
[0061] Option 2-1) The gNB can additionally provide which signal path (n-th detected path, where n>=2) was selected for CP measurement.
[0062] Option 2-2) The gNB does not additionally provide any information. The LMF will consider the reported CP measurement for the first path, even though the CP measurement was not made from the first “detected” path.
[0063] For example, for option 2-2, the LMF may determine that the carrier phase measurement for the arrival signal path having the largest line of sight indicator value is for the arrival signal path having a line of sight indicator value that is not greater than at least one line of sight indicator for another arrival signal path, in response to the report having the carrier phase difference measurement not comprising the arrival signal path having the largest line of sight indicator value, and the report comprising the carrier phase measurement for the arrival signal path having the largest line of sight indicator value, when the report does not comprise the arrival signal path having the largest line of sight indicator value, and the report comprises the carrier phase measurement for the arrival signal path having the largest line of sight indicator value.
[0064] Option 3) The gNB reports an average of RSCP measurements for the first N detected paths (for a number N).
[0065] The above options are for a specific UL SRS resource. The LMF may request the gNB to perform measurement for a specific UL PRS resource set SL PRS resources (prior art). The gNB may prioritize specific UL SRS resource(s) which shows the largest LoS indicator value at the first detected path of all the detected paths from the UL SRS resources.
[0066] The LMF estimates the UE location based on the provided measurements.
[0067] Additional details and the flow chart of the proposed method both for DL-based CP and UL-based CP techniques are provided in FIG. **2** and FIG. **3**.
[0068] FIG. **2** is the flow chart for DL-based CP positioning, based on the examples described herein. At **202**, the LMF **190** provides assistance data to the UE **110**, where the assistance data may include PRS configuration information. At **204**, the LMF initiates the CP technique. At **206**, the LMF **190** requests from the UE **110** CP measurements for specific TRPs. At **208**, the UE detects multiple arrival signal paths from at least one DL PRS.
[0069] At **210** (Option 1), the UE **110** reports to the LMF **190** a CP measurement in the first detected path. At **212** (Option 2), the UE **110** reports to the LMF **190** a CP measurement in a signal path with the largest LoS indication value. At **214** (Option 2-1), the UE **110** provides to the LMF **190** information on the selected arrival signal path. At **216** (Option 2-2) performed with the LMF **190**, if no information on the signal path is provided, it is assumed that the reported CP measurement is from the first detected path.
[0070] At **218** (Option 3), the UE **110** reports to the LMF **190** the average CP measurement of the first N detected paths. At **220** (alternatively), the UE **110** measures the DL PRS resource with the largest LoS indicator as the first detected path.
[0071] FIG. **3** is the flow chart for UL-based CP positioning, based on the examples described herein. At **302**, the gNB **170** transmits to the UE **110** assistance data, such as SRS configuration information. At **304**, the LMF **190** initiates the CP technique. At **306**, the LMF **190** requests from the gNB **170** CP measurements. At **308**, the UE **110** transmits SRS to the gNB **170**. At **310**, the gNB **170** measures arrival SRS signals in multiple paths.
[0072] At **312** (Option 1) the gNB **170** reports to the LMF **190** a CP measurement in a first detected path. At **314** (Option 2), the gNB **170** reports to the LMF **190** the CP measurement in a signal path with the largest LoS indication value. At **316** (Option 2-1), the gNB **170** provides to the LMF **190** information on the selected arrival signal path. At **318** (Option 2-2), performed with the LMF **190**, if no information on the signal path is provided, it is assumed that the reported CP measurement is from the first detected path.
[0073] At **320**, the gNB **170** reports to the LMF **190** the average CP measurement of the first N detected paths. At **322** (alternatively), the gNB **170** measures the UL SRS resource with the largest LoS indicator as the first detected path.
[0074] In some examples, when a first line of sight indicator value for a first arrival signal path of a reference signal has a value that is the same as a value of a second line of sight indicator value for a second arrival signal path of the reference signal, both the first line of sight indicator value and the second line of sight indicator value are considered to be the largest line of sight indicator value.
[0075] For Option 1, Option 2, and Option 3, for both DL-based CP positioning and UL-based CP positioning, reported carrier phase measurement may be a reference signal carrier phase difference (RSCPD) measurement. For example, the carrier phase measurement for the arrival signal path having a determined line of sight indicator value that is not greater than at least one of the line of sight indicator values for other detected arrival signal paths may be a reference signal carrier phase difference (RSCPD) measurement. The carrier phase measurement for the arrival signal path that has the largest line of sight indicator value among the determined line of sight indicator values for the detected arrival signal paths may be a reference signal carrier phase difference (RSCPD) measurement. The average carrier phase measurement for at least one arrival signal path of the detected arrival signal paths may be a reference signal carrier phase difference (RSCPD) measurement.
[0076] Advantages and technical effects of the examples described herein include accuracy enhancement, and that the examples described herein address the UE ambiguous behavior for the carrier phase measurement reporting.
[0077] FIG. **4** is an example apparatus **400**, which may be implemented in hardware, configured to implement the examples described herein. The apparatus **400** comprises at least one processor **402** (e.g. an FPGA and/or CPU), one or more memories **404** including computer program code **405**, the computer program code **405** having instructions to carry out the methods described herein, wherein the at least one memory **404** and the computer program code **405** are configured to, with the at least one processor **402**, cause the apparatus **400** to implement circuitry, a process, component, module, or function (implemented with control module **406**) to implement the examples described herein. The memory **404** may be a non-transitory memory, a transitory memory, a volatile memory (e.g. RAM), or a non-volatile memory (e.g. ROM).
[0078] CP measurement reporting **430** may implement the examples described herein related to a method and reporting of carrier phase measurement reporting.
[0079] The apparatus **400** includes a display and/or I/O interface **408**, which includes user interface (UI) circuitry and elements, that may be used to display aspects or a status of the methods described herein (e.g., as one of the methods is being performed or at a subsequent time), or to receive input from a user such as with using a keypad, camera, touchscreen, touch area, microphone, biometric recognition, one or more sensors, etc. The apparatus **400** includes one or more communication e.g. network (N/W) interfaces (I/F(s)) **410**. The communication I/F(s) **410** may be wired and/or wireless and communicate over the Internet/other network(s) via any communication technique including via one or more links **424**. The link(s) **424** may be the link(s) **131** and/or **176** from FIG. **1**. The link(s) **131** and/or **176** from FIG. **1** may also be implemented using transceiver(s) **416** and corresponding wireless link(s) **426**. The communication I/F(s) **410** may comprise one or more transmitters or one or more receivers.
[0080] The transceiver **416** comprises one or more transmitters **418** and one or more receivers **420**. The transceiver **416** and/or communication I/F(s) **410** may comprise standard well-known components such as an amplifier, filter, frequency-converter, (de)modulator, and encoder/decoder circuitries and one or more antennas, such as antennas **414** used for communication over wireless link **426**.
[0081] The control module **406** of the apparatus **400** comprises one of or both parts **406-1** and/or **406-2**, which may be implemented in a number of ways. The control module **406** may be implemented in hardware as control module **406-1**, such as being implemented as part of the one or more processors **402**. The control module **406-1** may be implemented also as an integrated circuit or through other hardware such as a programmable gate array. In another example, the control module **406** may be implemented as control module **406-2**, which is implemented as computer program code (having corresponding instructions) **405** and is executed by the one or more processors **402**. For instance, the one or more memories **404** store instructions that, when executed by the one or more processors **402**, cause the apparatus **400** to perform one or more of the operations as described herein. Furthermore, the one or more processors **402**, the one or more memories **404**, and example algorithms (e.g., as flowcharts and/or signaling

diagrams), encoded as instructions, programs, or code, are means for causing performance of the operations described herein.

[0082] The apparatus **400** to implement the functionality of control **406** may be UE **110**, RAN node **170** (e.g. gNB), or network element(s) **190** (e.g. LMF **190**). Thus, processor **402** may correspond to processor(s) **120**, processor(s) **152** and/or processor(s) **175**, memory **404** may correspond to one or more memories **125**, one or more memories **155** and/or one or more memories **171**, computer program code **405** may correspond to computer program code **123**, computer program code **153**, and/or computer program code **173**, control module **406** may correspond to module **140-1**, module **140-2**, module **150-1**, and/or module **150-2**, and communication I/F(s) **410** and/or transceiver **416** may correspond to transceiver **130**, antenna(s) **128**, transceiver **160**, antenna(s) **158**, N/W I/F(s) **161**, and/or N/W I/F(s) **180**. Alternatively, apparatus **400** and its elements may not correspond to either of UE **110**, RAN node **170**, or network element(s) **190** and their respective elements, as apparatus **400** may be part of a self-organizing/optimizing network (SON) node or other node, such as a node in a cloud.

[0083] The apparatus **400** may also be distributed throughout the network (e.g. **100**) including within and between apparatus **400** and any network element (such as a network control element (NCE) **190** and/or the RAN node **170** and/or UE **110**).

[0084] Interface **412** enables data communication and signaling between the various items of apparatus **400**, as shown in FIG. **4**. For example, the interface **412** may be one or more buses such as address, data, or control buses, and may include any interconnection mechanism, such as a series of lines on a motherboard or integrated circuit, fiber optics or other optical communication equipment, and the like. Computer program code (e.g. instructions) **405**, including control **406** may comprise object-oriented software configured to pass data or messages between objects within computer program code **405**, or computer program code (e.g. instructions) **405**, including control **406** may include functional, scripting, or procedural code. The apparatus **400** need not comprise each of the features mentioned, or may comprise other features as well. The various components of apparatus **400** may at least partially reside in a common housing **428**, or a subset of the various components of apparatus **400** may at least partially be located in different housings, which different housings may include housing **428**.

[0085] FIG. **5** shows a schematic representation of non-volatile memory media **500***a* (e.g. computer/compact disc (CD) or digital versatile disc (DVD)) and **500***b* (e.g. universal serial bus (USB) memory stick) and **500***c* (e.g. cloud storage for downloading instructions and/or parameters **502** or receiving emailed instructions and/or parameters **502**) storing instructions and/or parameters **502** which when executed by a processor allows the processor to perform one or more of the steps of the methods described herein. Instructions and/or parameters **502** may represent a non-transitory computer readable medium.

[0086] FIG. **6** is an example method **600** based on the examples described herein. At **610**, the method includes receiving a request to report a carrier phase measurement for a first detected arrival signal path of a reference signal. At **620**, the method includes detecting multiple arrival signal paths from the reference signal including the first detected arrival signal path. At **630**, the method includes determining line of sight indicator values for the detected multiple arrival signal paths including the first detected arrival signal path. At **640**, the method includes transmitting, based on the determined line of sight indicator value for the first detected arrival signal path not being greater than at least one other line of sight indicator value for at least one other detected arrival signal path of the multiple arrival signal paths, a report comprising at least one carrier phase measurement for at least one arrival signal path of the multiple arrival signal paths. Method **600** may be performed with UE **110**, RAN node **170** (e.g. gNB **170**), or apparatus **400**.

[0087] FIG. **7** is an example method **700** based on the examples described herein. At **710**, the method includes transmitting a request to report a carrier phase measurement for a first detected arrival signal path of a reference signal. At **720**, the method includes receiving, based on a line of sight indicator value for the first detected arrival signal path not being greater than at least one other line of sight indicator value for at least one other arrival signal path of multiple arrival signal paths of the reference signal, a report comprising at least one carrier phase measurement for at least one arrival signal path of the multiple arrival signal paths. At **730**, the method includes estimating a location of a user equipment, based on the at least one carrier phase measurement for the least one arrival signal path of the multiple arrival signal paths. Method **700** may be performed with one or more network elements **190** (e.g. LMF **190**), or apparatus **400**.

[0088] FIG. **8** is an example method **800** based on the examples described herein. At **810**, the method includes receiving a request to report a carrier phase measurement for a first detected arrival signal path of a reference signal. At **820**, the method includes detecting multiple arrival signal paths from the reference signal including the first detected arrival signal path. At **830**, the method includes determining a line of sight indicator value for the detected multiple arrival signal paths including the first detected arrival signal path. At **840**, the method includes transmitting, based on the determined line of sight indicator value for the first detected arrival signal path not being greater than at least one of the line of sight indicator values for the other arrival signal paths, a report comprising one of: a carrier phase measurement for the first detected arrival signal path, when the line of sight indicator value for the first detected arrival signal path is greater than a threshold value, or a carrier phase measurement for one arrival signal path of the detected multiple arrival signal paths, wherein the one arrival signal path has the largest line of sight indicator value among the determined line of sight indicator values for the multiple arrival signal paths, or an average carrier phase measurement for at least one arrival signal path of the multiple arrival signal paths. Method **800** may be performed with UE **110**, RAN node **170** (e.g. gNB **170**), or apparatus **400**.

[0089] The following examples are provided and described herein.

[0090] Example 1. An apparatus including: at least one processor; and at least one non-transitory memory storing instructions that, when executed by the at least one processor, cause the apparatus at least to: receive a request to report a carrier phase measurement for a first detected arrival signal path of a reference signal; detect multiple arrival signal paths from the reference signal including the first detected arrival signal path; determine line of sight indicator values for the detected multiple arrival signal paths including the first detected arrival signal path; and transmit, based on the determined line of sight indicator value for the first detected arrival signal path not being greater than at least one other line of sight indicator value for at least one other detected arrival signal path of the multiple arrival signal paths, a report comprising at least one carrier phase measurement for at least one arrival signal path of the multiple arrival signal paths.

[0091] Example 2. The apparatus of example 1, wherein the instructions, when executed by the at least one processor, cause the apparatus at least to: transmit, to a network entity, an indication that the line of sight indicator value for the first detected arrival signal path is not greater than the at least one other line of sight indicator value for the at least one other detected arrival signal path of the multiple arrival signal paths.

[0092] Example 3. The apparatus of any of examples 1 to 2, wherein the instructions, when executed by the at least one processor, cause the apparatus at least to: determine that the line of sight indicator value for the first detected arrival signal path is greater than a threshold value; determine a carrier phase measurement for the first detected arrival signal path; and determine to include, within the report, the carrier phase measurement for the first detected arrival signal path, in response to the determining that the line of sight indicator value for the first detected arrival signal path is greater than the threshold value.

[0093] Example 4. The apparatus of any of examples 1 to 3, wherein the instructions, when executed by the at least one processor, cause the apparatus at least to: determine a carrier phase measurement for one arrival signal path of the detected multiple arrival signal paths, wherein the one arrival signal path has the largest line of sight indicator value among the determined line of sight indicator values for the multiple arrival signal paths; and determine to include, within the report, the carrier phase measurement for the one arrival signal path having the largest line of sight indicator value among the determined line of sight indicator values for the multiple arrival signal paths.

[0094] Example 5. The apparatus of example 4, wherein the instructions, when executed by the at least one processor, cause the apparatus at least to: determine to include, within the report, an indication of the one arrival signal path having the largest line of sight indicator value.

[0095] Example 6. The apparatus of any of examples 1 to 5, wherein the instructions, when executed by the at least one processor, cause the apparatus at least to: determine an average carrier phase measurement for one or more arrival signal paths of the multiple arrival signal paths; and determine to include, within the report, the average carrier phase measurement for the one or more arrival signal paths of the multiple arrival signal

paths.
[0096] Example 7. The apparatus of example 6, wherein the instructions, when executed by the at least one processor, cause the apparatus at least to: determine a set of the multiple arrival signal paths, wherein the line of sight indicator values for arrival signal paths within the set are the same, or differences between the line of sight indicator values for arrival signal paths within the set are less than a threshold value; wherein determining the average carrier phase measurement for the one or more arrival signal paths of the multiple arrival signal paths comprises determining an average carrier phase measurement for the arrival signal paths within the set of the multiple arrival signal paths.
[0097] Example 8. The apparatus of any of examples 6 to 7, wherein the instructions, when executed by the at least one processor, cause the apparatus at least to: determine one arrival signal path that has the largest line of sight indicator value among the determined line of sight indicator values for the multiple arrival signal paths; and wherein determining the average carrier phase measurement for the one or more arrival signal paths of the multiple arrival signal paths comprises determining an average carrier phase measurement for the one arrival signal path that has the largest line of sight indicator value among the determined line of sight indicator values for the multiple arrival signal paths.
[0098] Example 9. The apparatus of any of examples 1 to 8, wherein the at least one carrier phase measurement for the at least one arrival signal path of the multiple arrival signal paths comprises a reference signal carrier phase measurement.
[0099] Example 10. The apparatus of any of examples 1 to 9, wherein the instructions, when executed by the at least one processor, cause the apparatus at least to: prioritize, for carrier phase measurement reporting, a downlink positioning reference signal resource associated with the largest line of sight indicator value among the determined line of sight indicator values for the multiple arrival signal paths.
[0100] Example 11. The apparatus of any of examples 1 to 10, wherein the instructions, when executed by the at least one processor, cause the apparatus at least to: prioritize, for carrier phase measurement reporting, an uplink sounding reference signal resource associated with the largest line of sight indicator value among the determined line of sight indicator values for the multiple arrival signal paths.
[0101] Example 12. The apparatus of any of examples 1 to 11, wherein: the first detected arrival signal path of the multiple arrival signal paths is detected by the apparatus at a first time, and other arrival signal paths of the multiple arrival signal paths other than the first detected arrival signal path are detected by the apparatus at times later than the first time; and the line of sight indicator value for the first detected arrival signal path is not greater than at least one of the line of sight indicator values for the other arrival signal paths. The first detected arrival signal path may be associated with a first noise signal, a first interference signal, or a first received signal power, and another arrival signal path of the multiple arrival signal paths different from the first detected arrival signal path may not comprise a noise signal or an interference signal, or may be associated with a second noise signal that is less strong than the first noise signal, a second interference signal that is less strong than the first interference signal, or a second received signal power that is greater than the first received signal power, wherein the another arrival signal path is detected with the apparatus at another time later than the first time.
[0102] Example 13. The apparatus of any of examples 1 to 12, wherein: the reference signal comprises a positioning reference signal; and the apparatus comprises a user equipment, or the user equipment comprises the apparatus.
[0103] Example 14. The apparatus of any of examples 1 to 13, wherein: the reference signal comprises a sounding reference signal; and the apparatus comprises a transmission reception point, or the transmission reception point comprises the apparatus.
[0104] Example 15. The apparatus of any of examples 1 to 14, wherein: the request to report the carrier phase measurement for the first detected arrival signal path of the reference signal is received from a network entity; and the report comprising the at least one carrier phase measurement for the at least one arrival signal path is transmitted to the network entity; wherein the network entity comprises a location management function.
[0105] Example 16. An apparatus including: at least one processor; and at least one non-transitory memory storing instructions that, when executed by the at least one processor, cause the apparatus at least to: transmit a request to report a carrier phase measurement for a first detected arrival signal path of a reference signal; receive, based on a line of sight indicator value for the first detected arrival signal path not being greater than at least one other line of sight indicator value for at least one other arrival signal path of multiple arrival signal paths of the reference signal, a report comprising at least one carrier phase measurement for at least one arrival signal path of the multiple arrival signal paths; and estimate a location of a user equipment, based on the at least one carrier phase measurement for the least one arrival signal path of the multiple arrival signal paths.
[0106] Example 17. The apparatus of example 16, wherein the instructions, when executed by the at least one processor, cause the apparatus at least to: receive, from the user equipment or a transmission reception point, an indication that the line of sight indicator value for the first detected arrival signal path is not greater than the at least one other line of sight indicator value for the at least one other arrival signal path of the multiple arrival signal paths.
[0107] Example 18. The apparatus of any of examples 16 to 17, wherein the at least one carrier phase measurement received within the report comprises a carrier phase measurement for the first detected arrival signal path, when the line of sight indicator value for the first detected arrival signal path is greater than a threshold value.
[0108] Example 19. The apparatus of any of examples 16 to 18, wherein the at least one carrier phase measurement received within the report comprises a carrier phase measurement for one arrival signal path having the largest line of sight indicator value among line of sight indicator values for the multiple arrival signal paths.
[0109] Example 20. The apparatus of example 19, wherein the report comprises an indication of the one arrival signal path having the largest line of sight indicator value.
[0110] Example 21. The apparatus of any of examples 16 to 20, wherein the report comprises an average carrier phase measurement for one or more arrival signal paths of the multiple arrival signal paths.
[0111] Example 22. The apparatus of example 21, wherein: the average carrier phase measurement for the one or more arrival signal paths of the multiple arrival signal paths within the report comprises an average carrier phase measurement for arrival signal paths within a set of the multiple arrival signal paths; and line of sight indicator values for the arrival signal paths within the set are the same, or differences between line of sight indicator values for the arrival signal paths within the set are less than a threshold value. The threshold value can be configured by the LMF or predefined as a fixed value.
[0112] Example 23. The apparatus of any of examples 21 to 22, wherein the average carrier phase measurement for the one or more arrival signal paths of the multiple arrival signal paths within the report comprises an average carrier phase measurement for one arrival signal path having the largest line of sight indicator value among line of sight indicator values for the multiple arrival signal paths.
[0113] Example 24. The apparatus of any of examples 16 to 23, wherein the at least one carrier phase measurement for the at least one arrival signal path of the multiple arrival signal paths comprises a reference signal carrier phase measurement.
[0114] Example 25. The apparatus of any of examples 16 to 24, wherein the instructions, when executed by the at least one processor, cause the apparatus at least to: transmit, to the user equipment, an indication to prioritize, for carrier phase measurement reporting, a downlink positioning reference signal resource associated with the largest line of sight indicator value among line of sight indicator values for the multiple arrival signal paths.
[0115] Example 26. The apparatus of any of examples 16 to 25, wherein the instructions, when executed by the at least one processor, cause the apparatus at least to: transmit, to a transmission reception point, an indication to prioritize, for carrier phase measurement reporting, an uplink sounding reference signal resource associated with the largest line of sight indicator value among line of sight indicator values for the multiple arrival signal paths.
[0116] Example 27. The apparatus of any of examples 16 to 26, wherein: the first detected arrival signal path of the multiple arrival signal paths is associated with a first time, and other arrival signal paths of the multiple arrival signal paths other than the first detected arrival signal path are

associated with times later than the first time; and the line of sight indicator value for the first detected arrival signal path is not greater than at least one of the line of sight indicator values for the other arrival signal paths. The first detected arrival signal path may be associated with a first noise signal, a first interference signal, or a first received signal power, and another arrival signal path of the multiple arrival signal paths different from the first detected arrival signal path may not comprise a noise signal or an interference signal, or may be associated with a second noise signal that is less strong than the first noise signal, a second interference signal that is less strong than the first interference signal, or a second received signal power that is greater than the first received signal power, wherein the another arrival signal path is detected at another time later than the first time.

[0117] Example 28. The apparatus of any of examples 16 to 27, wherein: the reference signal comprises a positioning reference signal; the request to report the carrier phase measurement for the first detected arrival signal path of the reference signal is transmitted to the user equipment; and the report comprising the at least one carrier phase measurement for the at least one arrival signal path is received from the user equipment.

[0118] Example 29. The apparatus of any of examples 16 to 28, wherein: the reference signal comprises a sounding reference signal; the request to report the carrier phase measurement for the first detected arrival signal path of the reference signal is transmitted to a transmission reception point; and the report comprising the at least one carrier phase measurement for the at least one arrival signal path is received from the transmission reception point.

[0119] Example 30. The apparatus of any of examples 16 to 29, wherein the apparatus comprises a location management function.

[0120] Example 31. An apparatus including: at least one processor; and at least one non-transitory memory storing instructions that, when executed by the at least one processor, cause the apparatus at least to: receive a request to report a carrier phase measurement for a first detected arrival signal path of a reference signal; detect multiple arrival signal paths from the reference signal including the first detected arrival signal path; determine a line of sight indicator value for the detected multiple arrival signal paths including the first detected arrival signal path; and transmit, based on the determined line of sight indicator value for the first detected arrival signal path not being greater than at least one of the line of sight indicator values for the other arrival signal paths, a report comprising one of: a carrier phase measurement for the first detected arrival signal path, when the line of sight indicator value for the first detected arrival signal path is greater than a threshold value, or a carrier phase measurement for one arrival signal path of the detected multiple arrival signal paths, wherein the one arrival signal path has the largest line of sight indicator value among the determined line of sight indicator values for the multiple arrival signal paths, or an average carrier phase measurement for at least one arrival signal path of the multiple arrival signal paths.

[0121] Example 32. A method including: receiving a request to report a carrier phase measurement for a first detected arrival signal path of a reference signal; detecting multiple arrival signal paths from the reference signal including the first detected arrival signal path; determining line of sight indicator values for the detected multiple arrival signal paths including the first detected arrival signal path; and transmitting, based on the determined line of sight indicator value for the first detected arrival signal path not being greater than at least one other line of sight indicator value for at least one other detected arrival signal path of the multiple arrival signal paths, a report comprising at least one carrier phase measurement for at least one arrival signal path of the multiple arrival signal paths.

[0122] Example 33. A method including: transmitting a request to report a carrier phase measurement for a first detected arrival signal path of a reference signal; receiving, based on a line of sight indicator value for the first detected arrival signal path not being greater than at least one other line of sight indicator value for at least one other arrival signal path of multiple arrival signal paths of the reference signal, a report comprising at least one carrier phase measurement for at least one arrival signal path of the multiple arrival signal paths; and estimating a location of a user equipment, based on the at least one carrier phase measurement for the least one arrival signal path of the multiple arrival signal paths.

[0123] Example 34. A method including: receiving a request to report a carrier phase measurement for a first detected arrival signal path of a reference signal; detecting multiple arrival signal paths from the reference signal including the first detected arrival signal path; determining a line of sight indicator value for the detected multiple arrival signal paths including the first detected arrival signal path; and transmitting, based on the determined line of sight indicator value for the first detected arrival signal path not being greater than at least one of the line of sight indicator values for the other arrival signal paths, a report comprising one of: a carrier phase measurement for the first detected arrival signal path, when the line of sight indicator value for the first detected arrival signal path is greater than a threshold value, or a carrier phase measurement for one arrival signal path of the detected multiple arrival signal paths, wherein the one arrival signal path has the largest line of sight indicator value among the determined line of sight indicator values for the multiple arrival signal paths, or an average carrier phase measurement for at least one arrival signal path of the multiple arrival signal paths.

[0124] Example 35. An apparatus including: means for receiving a request to report a carrier phase measurement for a first detected arrival signal path of a reference signal; means for detecting multiple arrival signal paths from the reference signal including the first detected arrival signal path; means for determining line of sight indicator values for the detected multiple arrival signal paths including the first detected arrival signal path; and means for transmitting, based on the determined line of sight indicator value for the first detected arrival signal path not being greater than at least one other line of sight indicator value for at least one other detected arrival signal path of the multiple arrival signal paths, a report comprising at least one carrier phase measurement for at least one arrival signal path of the multiple arrival signal paths.

[0125] Example 36. An apparatus including: means for transmitting a request to report a carrier phase measurement for a first detected arrival signal path of a reference signal; means for receiving, based on a line of sight indicator value for the first detected arrival signal path not being greater than at least one other line of sight indicator value for at least one other arrival signal path of multiple arrival signal paths of the reference signal, a report comprising at least one carrier phase measurement for at least one arrival signal path of the multiple arrival signal paths; and means for estimating a location of a user equipment, based on the at least one carrier phase measurement for the least one arrival signal path of the multiple arrival signal paths.

[0126] Example 37. An apparatus including: means for receiving a request to report a carrier phase measurement for a first detected arrival signal path of a reference signal; means for detecting multiple arrival signal paths from the reference signal including the first detected arrival signal path; means for determining a line of sight indicator value for the detected multiple arrival signal paths including the first detected arrival signal path; and means for transmitting, based on the determined line of sight indicator value for the first detected arrival signal path not being greater than at least one of the line of sight indicator values for the other arrival signal paths, a report comprising one of: a carrier phase measurement for the first detected arrival signal path, when the line of sight indicator value for the first detected arrival signal path is greater than a threshold value, or a carrier phase measurement for one arrival signal path of the detected multiple arrival signal paths, wherein the one arrival signal path has the largest line of sight indicator value among the determined line of sight indicator values for the multiple arrival signal paths, or an average carrier phase measurement for at least one arrival signal path of the multiple arrival signal paths.

[0127] Example 38. A computer readable medium including instructions stored thereon for performing at least the following: receiving a request to report a carrier phase measurement for a first detected arrival signal path of a reference signal; detecting multiple arrival signal paths from the reference signal including the first detected arrival signal path; determining line of sight indicator values for the detected multiple arrival signal paths including the first detected arrival signal path; and transmitting, based on the determined line of sight indicator value for the first detected arrival signal path not being greater than at least one other line of sight indicator value for at least one other detected arrival signal path of the multiple arrival signal paths, a report comprising at least one carrier phase measurement for at least one arrival signal path of the multiple arrival signal paths.

[0128] Example 39. A computer readable medium including instructions stored thereon for performing at least the following: transmitting a request to report a carrier phase measurement for a first detected arrival signal path of a reference signal; receiving, based on a line of sight indicator value for the first detected arrival signal path not being greater than at least one other line of sight indicator value for at least one other arrival signal path of multiple arrival signal paths of the reference signal, a report comprising at least one carrier phase measurement for at least one arrival signal path of

the multiple arrival signal paths; and estimating a location of a user equipment, based on the at least one carrier phase measurement for the least one arrival signal path of the multiple arrival signal paths.
[0129] Example 40. A computer readable medium including instructions stored thereon for performing at least the following: receiving a request to report a carrier phase measurement for a first detected arrival signal path of a reference signal; detecting multiple arrival signal paths from the reference signal including the first detected arrival signal path; determining a line of sight indicator value for the detected multiple arrival signal paths including the first detected arrival signal path; and transmitting, based on the determined line of sight indicator value for the first detected arrival signal path not being greater than at least one of the line of sight indicator values for the other arrival signal paths, a report comprising one of: a carrier phase measurement for the first detected arrival signal path, when the line of sight indicator value for the first detected arrival signal path is greater than a threshold value, or a carrier phase measurement for one arrival signal path of the detected multiple arrival signal paths, wherein the one arrival signal path has the largest line of sight indicator value among the determined line of sight indicator values for the multiple arrival signal paths, or an average carrier phase measurement for at least one arrival signal path of the multiple arrival signal paths. The carrier phase measurement includes an RSCP (Reference Signal Carrier Phase) measurement and an RSCPD (Reference Signal Carrier Phase Difference) measurement. The RSCPD is a difference of two different RSCP measurements, where the RSCP measurements could be measured from a single or two different TRPs. In addition, the carrier phase measurement includes a difference value of two different RSCPD measurements, which may be also called (for example referred to as) a double differential measurement.
[0130] References to a ‘computer’, ‘processor’, etc. should be understood to encompass not only computers having different architectures such as single/multi-processor architectures and sequential or parallel architectures but also specialized circuits such as field-programmable gate arrays (FPGAs), application specific circuits (ASICs), signal processing devices and other processing circuitry. References to computer program, instructions, code etc. should be understood to encompass software for a programmable processor or firmware such as, for example, the programmable content of a hardware device whether instructions for a processor, or configuration settings for a fixed-function device, gate array or programmable logic device etc.
[0131] The memories as described herein may be implemented using any suitable data storage technology, such as semiconductor based memory devices, flash memory, magnetic memory devices and systems, optical memory devices and systems, non-transitory memory, transitory memory, fixed memory and removable memory. The memories may comprise a database for storing data.
[0132] As used herein, the term ‘circuitry’ may refer to the following: (a) hardware circuit implementations, such as implementations in analog and/or digital circuitry, and (b) combinations of circuits and software (and/or firmware), such as (as applicable): (i) a combination of processor(s) or (ii) portions of processor(s)/software including digital signal processor(s), software, and memories that work together to cause an apparatus to perform various functions, and (c) circuits, such as a microprocessor(s) or a portion of a microprocessor(s), that require software or firmware for operation, even if the software or firmware is not physically present. As a further example, as used herein, the term ‘circuitry’ would also cover an implementation of merely a processor (or multiple processors) or a portion of a processor and its (or their) accompanying software and/or firmware. The term ‘circuitry’ would also cover, for example and if applicable to the particular element, a baseband integrated circuit or applications processor integrated circuit for a mobile phone or a similar integrated circuit in a server, a cellular network device, or another network device.
[0133] It should be understood that the foregoing description is only illustrative. Various alternatives and modifications may be devised by those skilled in the art. For example, features recited in the various dependent claims could be combined with each other in any suitable combination(s). In addition, features from different example embodiments described above could be selectively combined into a new example embodiment. Accordingly, this description is intended to embrace all such alternatives, modifications and variances which fall within the scope of the appended claims.
[0134] The following acronyms and abbreviations that may be found in the specification and/or the drawing figures are given as follows (the abbreviations and acronyms may be appended/combined with each other or with other characters using e.g. a dash, hyphen, slash, letter, or number, and may be case insensitive): [0135] 3GPP third generation partnership project [0136] 4G fourth generation [0137] 5G fifth generation [0138] 5GC 5G core network [0139] 6G sixth generation [0140] AMF access and mobility management function [0141] ASIC application-specific integrated circuit [0142] CD compact/computer disc [0143] CP carrier phase [0144] CPU central processing unit [0145] CU central unit or centralized unit [0146] DL downlink [0147] DSP digital signal processor [0148] DU distributed unit [0149] DVD digital versatile disc [0150] eNB evolved Node B (e.g., an LTE base station) [0151] EN-DC E-UTRAN new radio-dual connectivity [0152] en-gNB node providing NR user plane and control plane protocol terminations towards the UE, and acting as a secondary node in EN-DC [0153] E-UTRA evolved UMTS terrestrial radio access, i.e., the LTE radio access technology [0154] E-UTRAN E-UTRA network [0155] F1 interface between the CU and the DU [0156] FPGA field-programmable gate array [0157] gNB base station for 5G/NR, i.e., a node providing NR user plane and control plane protocol terminations towards the UE, and connected via the NG interface to the 5GC [0158] IAB integrated access and backhaul [0159] I/F interface [0160] I/O input/output [0161] LMF location management function [0162] LoS line of sight [0163] LTE long term evolution (4G) [0164] MAC medium access control [0165] MME mobility management entity [0166] MRO mobility robustness optimization [0167] N indication of a number for variable number N [0168] NCE network control element [0169] ng or NG new generation [0170] ng-eNB new generation eNB [0171] NG-RAN new generation radio access network [0172] NLoS non line of sight [0173] NR new radio [0174] N/W network [0175] PDA personal digital assistant [0176] PDCP packet data convergence protocol [0177] PFL positioning frequency layer [0178] PHY physical layer [0179] PRS positioning reference signal [0180] PRU positioning reference unit [0181] RAM random access memory [0182] RAN radio access network [0183] RAT radio access technology [0184] Rel release [0185] RLC radio link control [0186] ROM read-only memory [0187] RP RAN plenary [0188] RRC radio resource control [0189] RRM radio resource management [0190] RSCP reference signal carrier phase [0191] RSCPD reference signal carrier phase difference [0192] RSTD reference signal time difference [0193] RTOA relative time of arrival [0194] RU radio unit [0195] Rx, RX receive, or receiver, or reception [0196] SDAP service data adaptation protocol [0197] SGW serving gateway [0198] SMF session management function [0199] SON self-organizing/optimizing network [0200] SRS sounding reference signal [0201] TDOA time difference of arrival [0202] TRP transmission reception point [0203] TS technical specification [0204] Tx, TX transmit, or transmitter, or transmission [0205] UAV unmanned aerial vehicle [0206] UE user equipment (e.g., a wireless, typically mobile device) [0207] UI user interface [0208] UL uplink [0209] UMTS Universal Mobile Telecommunications System [0210] UPF user plane function [0211] USB universal serial bus [0212] UTRAN UMTS terrestrial radio access network [0213] WID work item description [0214] X2 network interface between RAN nodes and between RAN and the core network [0215] Xn network interface between NG-RAN nodes

Claims

1. An apparatus comprising: at least one processor; and at least one non-transitory memory storing instructions that, when executed by the at least one processor, cause the apparatus at least to: receive a request to report a carrier phase measurement for a first detected arrival signal path of a reference signal; detect multiple arrival signal paths from the reference signal including the first detected arrival signal path; determine line of sight indicator values for the detected multiple arrival signal paths including the first detected arrival signal path; and transmit, based on the determined line of sight indicator value for the first detected arrival signal path not being greater than at least one other line of sight indicator value for at least one other detected arrival signal path of the multiple arrival signal paths, a report comprising at least one carrier phase measurement for at least one arrival signal path of the multiple arrival signal paths.
2. The apparatus of claim 1, wherein the instructions, when executed by the at least one processor, cause the apparatus at least to: transmit, to a

network entity, an indication that the line of sight indicator value for the first detected arrival signal path is not greater than the at least one other line of sight indicator value for the at least one other detected arrival signal path of the multiple arrival signal paths.

3. The apparatus of claim 1, wherein the instructions, when executed by the at least one processor, cause the apparatus at least to: determine that the line of sight indicator value for the first detected arrival signal path is greater than a threshold value; determine a carrier phase measurement for the first detected arrival signal path; and determine to include, within the report, the carrier phase measurement for the first detected arrival signal path, in response to the determining that the line of sight indicator value for the first detected arrival signal path is greater than the threshold value.

4. The apparatus of claim 1, wherein the instructions, when executed by the at least one processor, cause the apparatus at least to: determine a carrier phase measurement for one arrival signal path of the detected multiple arrival signal paths, wherein the one arrival signal path has the largest line of sight indicator value among the determined line of sight indicator values for the multiple arrival signal paths; and determine to include, within the report, the carrier phase measurement for the one arrival signal path having the largest line of sight indicator value among the determined line of sight indicator values for the multiple arrival signal paths.

5. The apparatus of claim 4, wherein the instructions, when executed by the at least one processor, cause the apparatus at least to: determine to include, within the report, an indication of the one arrival signal path having the largest line of sight indicator value.

6. The apparatus of claim 1, wherein the instructions, when executed by the at least one processor, cause the apparatus at least to: determine an average carrier phase measurement for one or more arrival signal paths of the multiple arrival signal paths; and determine to include, within the report, the average carrier phase measurement for the one or more arrival signal paths of the multiple arrival signal paths.

7. The apparatus of claim 6, wherein the instructions, when executed by the at least one processor, cause the apparatus at least to: determine a set of the multiple arrival signal paths, wherein the line of sight indicator values for arrival signal paths within the set are the same, or differences between the line of sight indicator values for arrival signal paths within the set are less than a threshold value; wherein determining the average carrier phase measurement for the one or more arrival signal paths of the multiple arrival signal paths comprises determining an average carrier phase measurement for the arrival signal paths within the set of the multiple arrival signal paths.

8. The apparatus of claim 6, wherein the instructions, when executed by the at least one processor, cause the apparatus at least to: determine one arrival signal path that has the largest line of sight indicator value among the determined line of sight indicator values for the multiple arrival signal paths; and wherein determining the average carrier phase measurement for the one or more arrival signal paths of the multiple arrival signal paths comprises determining an average carrier phase measurement for the one arrival signal path that has the largest line of sight indicator value among the determined line of sight indicator values for the multiple arrival signal paths.

9. The apparatus of claim 1, wherein the at least one carrier phase measurement for the at least one arrival signal path of the multiple arrival signal paths comprises a reference signal carrier phase measurement.

10. The apparatus of claim 1, wherein the instructions, when executed by the at least one processor, cause the apparatus at least to: prioritize, for carrier phase measurement reporting, a downlink positioning reference signal resource associated with the largest line of sight indicator value among the determined line of sight indicator values for the multiple arrival signal paths.

11. The apparatus of claim 1, wherein the instructions, when executed by the at least one processor, cause the apparatus at least to: prioritize, for carrier phase measurement reporting, an uplink sounding reference signal resource associated with the largest line of sight indicator value among the determined line of sight indicator values for the multiple arrival signal paths.

12. The apparatus of claim 1, wherein: the first detected arrival signal path of the multiple arrival signal paths is detected by the apparatus at a first time, and other arrival signal paths of the multiple arrival signal paths other than the first detected arrival signal path are detected by the apparatus at times later than the first time; and the line of sight indicator value for the first detected arrival signal path is not greater than at least one of the line of sight indicator values for the other arrival signal paths.

13. The apparatus of claim 1, wherein: the reference signal comprises a positioning reference signal; and the apparatus comprises a user equipment, or the user equipment comprises the apparatus.

14. The apparatus of claim 1, wherein: the reference signal comprises a sounding reference signal; and the apparatus comprises a transmission reception point, or the transmission reception point comprises the apparatus.

15. The apparatus of claim 1, wherein: the request to report the carrier phase measurement for the first detected arrival signal path of the reference signal is received from a network entity; and the report comprising the at least one carrier phase measurement for the at least one arrival signal path is transmitted to the network entity; wherein the network entity comprises a location management function.

16. An apparatus comprising: at least one processor; and at least one non-transitory memory storing instructions that, when executed by the at least one processor, cause the apparatus at least to: transmit a request to report a carrier phase measurement for a first detected arrival signal path of a reference signal; receive, based on a line of sight indicator value for the first detected arrival signal path not being greater than at least one other line of sight indicator value for at least one other arrival signal path of multiple arrival signal paths of the reference signal, a report comprising at least one carrier phase measurement for at least one arrival signal path of the multiple arrival signal paths; and estimate a location of a user equipment, based on the at least one carrier phase measurement for the least one arrival signal path of the multiple arrival signal paths.

17. The apparatus of claim 16, wherein the at least one carrier phase measurement received within the report comprises a carrier phase measurement for the first detected arrival signal path, when the line of sight indicator value for the first detected arrival signal path is greater than a threshold value.

18. The apparatus of claim 16, wherein the at least one carrier phase measurement received within the report comprises a carrier phase measurement for one arrival signal path having the largest line of sight indicator value among line of sight indicator values for the multiple arrival signal paths.

19. The apparatus of claim 16, wherein the instructions, when executed by the at least one processor, cause the apparatus at least to: transmit, to the user equipment, an indication to prioritize, for carrier phase measurement reporting, a downlink positioning reference signal resource associated with the largest line of sight indicator value among line of sight indicator values for the multiple arrival signal paths.

20. The apparatus of claim 16, wherein the instructions, when executed by the at least one processor, cause the apparatus at least to: transmit, to a transmission reception point, an indication to prioritize, for carrier phase measurement reporting, an uplink sounding reference signal resource associated with the largest line of sight indicator value among line of sight indicator values for the multiple arrival signal paths.

21. An apparatus comprising: at least one processor; and at least one non-transitory memory storing instructions that, when executed by the at least one processor, cause the apparatus at least to: receive a request to report a carrier phase measurement for a first detected arrival signal path of a reference signal; detect multiple arrival signal paths from the reference signal including the first detected arrival signal path; determine line of sight indicator values for the detected multiple arrival signal paths including the first detected arrival signal path; and transmit, based on the determined line of sight indicator value for the first detected arrival signal path not being greater than at least one of the line of sight indicator values for the other arrival signal paths, a report comprising one of: a carrier phase measurement for the first detected arrival signal path, when the line of sight indicator value for the first detected arrival signal path is greater than a threshold value, or a carrier phase measurement for one arrival signal path of the detected multiple arrival signal paths, wherein the one arrival signal path has the largest line of sight indicator value among the determined line of sight indicator values for the multiple arrival signal paths, or an average carrier phase measurement for at least one arrival signal path of the multiple arrival signal paths.