

UPLINK CHANNEL PROFILE MEASUREMENT FOR MACHINE LEARNING POSITIONING

RELATED APPLICATION

[0001] This application claims priority to U.S. Provisional Application Serial No. 63/554,764 filed February 16, 2024 entitled “Uplink Channel Profile Measurement for Machine Learning Positioning,” the disclosure of which is incorporated by reference herein in its entirety.

TECHNICAL FIELD

[0002] The present disclosure relates to wireless communications, and more specifically to machine learning techniques for wireless device positioning.

BACKGROUND

[0003] A wireless communications system may include one or multiple network communication devices, which may be otherwise known as network equipment (NE), supporting wireless communications for one or multiple user communication devices, which may be otherwise known as user equipment (UE), or other suitable terminology. The wireless communications system may support wireless communications with one or multiple user communication devices by utilizing resources of the wireless communication system (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like)) or frequency resources (e.g., subcarriers, carriers, or the like). Additionally, the wireless communications system may support wireless communications across various radio access technologies including third generation (3G) radio access technology, fourth generation (4G) radio access technology, fifth generation (5G) radio access technology, among other suitable radio access technologies beyond 5G (e.g., sixth generation (6G)).

[0004] The wireless communications system may support wireless device positioning and location, such as to estimate positioning and determine a location of a UE in the wireless communications system. The wireless communications system may also include one or more wireless devices, such as UEs and/or network equipment (NE), among other devices, that transmit and/or receive signaling. Location services that enable positioning estimations may be supported in

the wireless communications system, such as to determine the location of a UE to receive transmitted signals in the wireless communications system.

SUMMARY

[0005] An article “a” before an element is unrestricted and understood to refer to “at least one” of those elements or “one or more” of those elements. The terms “a,” “at least one,” “one or more,” and “at least one of one or more” may be interchangeable. As used herein, including in the claims, “or” as used in a list of items (e.g., a list of items prefaced by a phrase such as “at least one of” or “one or more of” or “one or both of”) indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase “based on” shall not be construed as a reference to a closed set of conditions. For example, an example step that is described as “based on condition A” may be based on both a condition A and a condition B without departing from the scope of the present disclosure. In other words, as used herein, the phrase “based on” shall be construed in the same manner as the phrase “based at least in part on.” Further, as used herein, including in the claims, a “set” may include one or more elements.

[0006] An NE for wireless communication is described. The NE may be configured to, capable of, or operable to perform one or more operations as described herein. For example, the NE may be configured to, capable of, or operable to receive, from a positioning equipment, a measurement configuration to conduct one or more uplink channel sample-based measurement profile measurements on a reference signal; and transmit, to the positioning equipment for a positioning estimation, the one or more uplink channel sample-based measurement profile measurements performed on the reference signal based at least in part on the measurement configuration.

[0007] A processor (e.g., a standalone processor chipset, or a component of a NE) for wireless communication is described. The processor may be configured to, capable of, or operable to perform one or more operations as described herein. For example, the processor may be configured to, capable of, or operable to receive, from a positioning equipment, a measurement configuration to conduct one or more uplink channel sample-based measurement profile measurements on a reference signal; and transmit, to the positioning equipment for a positioning estimation, the one or

more uplink channel sample-based measurement profile measurements performed on the reference signal based at least in part on the measurement configuration.

[0008] A method performed or performable by an NE for wireless communication is described. The method may include receiving, from a positioning equipment, a measurement configuration to conduct one or more uplink channel sample-based measurement profile measurements on a reference signal; and transmitting, to the positioning equipment for a positioning estimation, the one or more uplink channel sample-based measurement profile measurements performed on the reference signal based at least in part on the measurement configuration.

[0009] In some implementations of the NE, the processor, and the method described herein, the measurement configuration indicates one or more types of uplink channel sample-based measurement profiles to be measured. In some implementations of the NE, the processor, and the method described herein, the one or more uplink channel sample-based measurement profile measurements are associated with one or more channel profiles comprising one or more of a power delay profile (PDP), an angular delay profile (ADP), an angle spectrum function (ASF), or a delay profile (DP). In some implementations of the NE, the processor, and the method described herein, the one or more uplink channel sample-based measurement profile measurements are input data to a machine learning model that determines the positioning estimation. In some implementations of the NE, the processor, and the method described herein, the input data is usable to train the machine learning model to determine the positioning estimation. In some implementations of the NE, the processor, and the method described herein, the NE has a known location and is configured as at least one of a gNB, a transmission-reception point (TRP), a positioning reference unit (PRU) TRP, or a reference TRP. In some implementations of the NE, the processor, and the method described herein, the positioning equipment is at least one of a location server, a location management function (LMF), a UE, or a PRU UE. In some implementations of the NE, the processor, and the method described herein, the reference signal is at least one of a sounding reference signal (SRS), a SRS for positioning, a multiple-input multiple-output (MIMO) SRS, a physical uplink shared channel (PUSCH) demodulation reference signal (DM-RS), or a phase tracking reference signal (PT-RS). In some implementations of the NE, the processor, and the method described herein, the configuration parameters of the measurement configuration to conduct the one or more uplink channel sample-based measurement profile measurements comprises one or more of power-delay

parameters, a start sample, a length of samples, a number of samples, a sampling resolution, an end sample, or time of arrival of multiple received signal paths.

[0010] In some implementations of the NE, the processor, and the method described herein, the NE, the processor, and the method may be configured to, capable of, or operable to maintain the one or more uplink channel sample-based measurement profile measurements as one or more of a one-dimensional (1D), a two-dimensional (2D), a three-dimensional (3D), or a multi-dimensional signature or fingerprint vector that represents a known location of a TRP. In some implementations of the NE, the processor, and the method described herein, the one or more uplink channel sample-based measurement profile measurements include channel profile measurement information determined over a configured bandwidth of the reference signal. In some implementations of the NE, the processor, and the method described herein, the one or more uplink channel sample-based measurement profile measurements are performed within a defined measurement time duration that includes one or more of a start time, a periodicity, an end time, a start sample, a length of samples, an end sample, a power threshold, a power threshold interval, or a time duration length. In some implementations of the NE, the processor, and the method described herein, the NE, the processor, and the method may be configured to, capable of, or operable to report the one or more uplink channel sample-based measurement profile measurements as a configuration of at least one of a power threshold or a power interval. In some implementations of the NE, the processor, and the method described herein, a number of the one or more uplink channel sample-based measurement profile measurements to be conducted is reduced based at least in part on one or more of a prioritization of transmission-reception points (TRPs) to be measured, one or more quality metrics of a channel profile, or a number of additional UEs reporting the one or more uplink channel sample-based measurement profile measurements. In some implementations of the NE, the processor, and the method described herein, the NE, the processor, and the method may be configured to, capable of, or operable to transmit at least one of the one or more uplink channel sample-based measurement profile measurements and associated one or more measurement quality metrics.

[0011] A positioning equipment for wireless communication is described. The positioning equipment may be configured to, capable of, or operable to perform one or more operations as described herein. For example, the positioning equipment may be configured to, capable of, or

operable to transmit, to a NE, a measurement configuration to conduct one or more uplink channel sample-based measurement profile measurements on a reference signal; receive, from the NE, the one or more uplink channel sample-based measurement profile measurements performed on the reference signal based at least in part on the measurement configuration; perform a positioning estimation based at least in part on the one or more uplink channel sample-based measurement profile measurements; and determine a location of a UE based at least in part on the positioning estimation.

[0012] A processor (e.g., a standalone processor chipset, or a component of a positioning equipment) for wireless communication is described. The processor may be configured to, capable of, or operable to transmit, to a NE, a measurement configuration to conduct one or more uplink channel sample-based measurement profile measurements on a reference signal; receive, from the NE, the one or more uplink channel sample-based measurement profile measurements performed on the reference signal based at least in part on the measurement configuration; perform a positioning estimation based at least in part on the one or more uplink channel sample-based measurement profile measurements; and determine a location of a UE based at least in part on the positioning estimation.

[0013] A method performed or performable by a positioning equipment for wireless communication is described. The method may include transmitting, to a NE, a measurement configuration to conduct one or more uplink channel sample-based measurement profile measurements on a reference signal; receiving, from the NE, the one or more uplink channel sample-based measurement profile measurements performed on the reference signal based at least in part on the measurement configuration; performing a positioning estimation based at least in part on the one or more uplink channel sample-based measurement profile measurements; and determining a location of a UE based at least in part on the positioning estimation.

[0014] In some implementations of the positioning equipment, the processor, and the method described herein, the measurement configuration indicates one or more types of uplink channel sample-based measurement profiles to be measured. In some implementations of the positioning equipment, the processor, and the method described herein, the one or more uplink channel sample-based measurement profile measurements are associated with one or more channel profiles comprising one or more of a PDP, an ADP, an ASF, or a DP. In some implementations of the

positioning equipment, the processor, and the method described herein, the positioning equipment, the processor, and the method may be configured to, capable of, or operable to use the one or more uplink channel sample-based measurement profile measurements as input data to a machine learning model that determines the positioning estimation. In some implementations of the positioning equipment, the processor, and the method described herein, the positioning equipment, the processor, and the method may be configured to, capable of, or operable to use the input data to train the machine learning model to determine the positioning estimation.

[0015] In some implementations of the positioning equipment, the processor, and the method described herein, the positioning equipment is at least one of a location server, a LMF, the UE, or a PRU UE. In some implementations of the positioning equipment, the processor, and the method described herein, the reference signal is at least one of a SRS, a SRS for positioning, a MIMO SRS, a PUSCH DM-RS, or a PT-RS. In some implementations of the positioning equipment, the processor, and the method described herein, the configuration parameters of the measurement configuration to conduct the one or more uplink channel sample-based measurement profile measurements comprises one or more of power-delay parameters, angle-delay parameters, power-angle parameters, or time of arrival of multiple received signal paths. In some implementations of the positioning equipment, the processor, and the method described herein, the one or more uplink channel sample-based measurement profile measurements include channel profile measurement information determined over a configured bandwidth of the reference signal. In some implementations of the positioning equipment, the processor, and the method described herein, the one or more uplink channel sample-based measurement profile measurements are performed within a defined measurement time duration that includes one or more of a start time, a periodicity, an end time, or a time duration length.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Figure 1 illustrates an example of a wireless communications system in accordance with aspects of the present disclosure.

[0017] Figure 2 illustrates an example of a system for NR beam-based positioning, in accordance with aspects of the present disclosure.

[0018] Figure 3 illustrates an example of a multi-cell round trip time (RTT) signaling procedure, in accordance with aspects of the present disclosure.

[0019] Figure 4 illustrates an example system of a functional framework for a machine learning model and NR air interface, in accordance with aspects of the present disclosure.

[0020] Figure 5 illustrates an example of a machine learning model functional framework for RAN intelligence, in accordance with aspects of the present disclosure.

[0021] Figure 6 illustrates an example procedure diagram for using uplink (UL)-based PDP, ADP, ASF, DP measurements by a machine learning model to determine and output a location of a UE, in accordance with aspects of the present disclosure.

[0022] Figure 7 illustrates an example SRS or SRS for positioning received power delay profile, in accordance with aspects of the present disclosure.

[0023] Figure 8 illustrates an example SRS or SRS for positioning received power-angle profile and angle-delay profile as a signature, in accordance with aspects of the present disclosure.

[0024] Figure 9 illustrates an example SRS or SRS for positioning transmitted AoD profile as a signature, in accordance with aspects of the present disclosure.

[0025] Figure 10 illustrates an example SRS or SRS for positioning received delay profile, in accordance with aspects of the present disclosure.

[0026] Figure 11 illustrates an example of a UE in accordance with aspects of the present disclosure.

[0027] Figure 12 illustrates an example of a processor in accordance with aspects of the present disclosure.

[0028] Figure 13 illustrates an example of a network equipment (NE) in accordance with aspects of the present disclosure.

[0029] Figure 14 illustrates an example of a positioning equipment in accordance with aspects of the present disclosure.

[0030] Figure 15 illustrates a flowchart of a method performed by a NE in accordance with aspects of the present disclosure.

[0031] Figure 16 illustrates a flowchart of a method performed by a positioning equipment in accordance with aspects of the present disclosure.

DETAILED DESCRIPTION

[0032] A wireless communications system may support location services that enable positioning estimations (e.g., determining, tracking, identifying, monitoring, estimating) of wireless device locations in the wireless communications system. The wireless communications system includes one or more wireless devices, such as UEs and/or NEs, among other devices, that transmit and/or receive signaling. For example, a UE may establish a wireless connection with a NE for transmitting and/or receiving control signaling, data signaling, or both. Reference is made herein to communicating data or information, such as signaling communication resources and/or communications that are transmitted or received between devices. It is to be appreciated that other terms may be used interchangeably with communicating, such as signaling, transmitting, receiving, outputting, forwarding, retrieving, obtaining, and so forth.

[0033] Features and characteristics of a transmitted signal in the wireless communications system may include a received signal strength, a delay profile, a power delay profile (e.g., reference signal received power (RSRP), reference signal received path power (RSRPP), a received signal strength indicator (RSSI) of a particular reference signal), and/or a channel impulse response (CIR) of a received signal. A CIR of a received signal is a measure of how a wireless channel affects a transmitted signal over time, and can be used to characterize the multipath propagation, delay spread, and frequency selectivity of the channel. The CIR can support time domain characterization of the signal power and angular components of a received signal, and therefore may be considered more accurate representation of the signal, rather than considering only the received signal strength characteristics of the signal. A radio frequency signature, or fingerprint, may include any one or more of these features and characteristics of a transmitted signal, and therefore, an identifying signature or fingerprint of the signal may be detectable.

[0034] Aspects of the present disclosure support using artificial intelligence (AI) and/or machine learning (ML), and are directed to ascertaining the measurements, signaling, and features

that support location management component (LCM) operations for direct and/or assisted AI and/or ML positioning. In a context of positioning estimations, a location estimation of a wireless device in the wireless communications system may be performed using AI and/or ML for NR air interface based at least in part on the identifying signature or fingerprint of a received signal that has been transmitted by the wireless device, such as a UE. The location of the UE may be determined based on the radio frequency signature and other features associated with the signal at the particular location. The location may be characterized and represented by the unique channel observations that are measured and/or determined as the signature or fingerprint of a transmitted signal from a wireless device at the particular location. This also supports positioning estimations of wireless device locations in indoor environments.

[0035] Aspects of the present disclosure support using a ML model or algorithm (e.g., a neural network, artificial intelligence (AI) algorithms). For example, a positioning equipment (e.g., a location management function (LMF)) implemented at least in part with a machine learning model may include AI, a ML model or algorithm, a neural network, and/or any other type of machine learning model to implement the described techniques. As used herein, a machine learning model refers to a computer representation that is trainable based on inputs to approximate unknown functions. For example, a machine learning model can utilize algorithms to learn from, and make predictions on, inputs of known data (e.g., training and/or reference data) by analyzing the known data to learn to generate outputs. In aspects of the present disclosure, a machine learning model may receive input data as one or more channel profile measurements and determine positioning estimations, such as a location of a UE in a wireless communications system. A channel profile may be based on signal characteristics, such as an uplink-based PDP, an ADP, ASF, and/or a DP of a reference signal (e.g., DL positioning reference signal (PRS), channel state information reference signal (CSI RS), etc.).

[0036] Additional aspects of the present disclosure are directed to establishing a channel profile that can be derived for a uplink transmission at a particular location based on the signature or fingerprint of a received signal. A channel profile may depend on the signal characteristics of a captured signal and the link to be measured, such as separate UL CIR measurements that are defined based on the type of reference signal (e.g., a sounding reference signal (SRS)). These channel profile measurements of a signal may be provided as input data to a machine learning

model (e.g., an AI and/or ML model) that can train on the input data, as well as infer or determine the location of a wireless device in the wireless communications system based on positioning estimation.

[0037] As training data for the machine learning model, the input data (e.g., as one or more channel profile measurements) are configurable, such as depending on the application or scenario in which an AI and/or ML process (e.g., for training or inference) manages processing and resources overhead for training and/or performing positioning estimation, while maintaining accuracy of the measurements and estimations. The channel profile measurements support the AI and/or ML positioning techniques, such as based on a signal signature or fingerprinting of the signal. In addition to providing support for AI and/or ML positioning, the described techniques support managing signaling overhead, such as by allowing a signal measurement vector that represents the channel profile measurements to be configurable depending on aspects such as the number of samples, the sampling resolution, as well as the power, time, angle, and domain characteristics.

[0038] Aspects of the present disclosure are described in the context of a wireless communications system.

[0039] **Figure 1** illustrates an example of a wireless communications system 100 in accordance with aspects of the present disclosure. The wireless communications system 100 may include one or more NE 102, one or more UE 104, and a core network (CN) 106. The wireless communications system 100 may support various radio access technologies. In some implementations, the wireless communications system 100 may be a 4G network, such as an LTE network or an LTE-Advanced (LTE-A) network. In some other implementations, the wireless communications system 100 may be a NR network, such as a 5G network, a 5G-Advanced (5G-A) network, or a 5G ultrawideband (5G-UWB) network. In other implementations, the wireless communications system 100 may be a combination of a 4G network and a 5G network, or other suitable radio access technology including Institute of Electrical and Electronics Engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20. The wireless communications system 100 may support radio access technologies beyond 5G, for example, 6G. Additionally, the wireless communications system 100 may support technologies, such as time division multiple access (TDMA), frequency division multiple access (FDMA), or code division multiple access (CDMA), etc.

[0040] The one or more NE 102 may be dispersed throughout a geographic region to form the wireless communications system 100. One or more of the NE 102 described herein may be or include or may be referred to as a network node, a base station, a network element, a network function, a network entity, network infrastructure (or infrastructure), a radio access network (RAN), a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. An NE 102 and a UE 104 may communicate via a communication link, which may be a wireless or wired connection. For example, an NE 102 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface.

[0041] An NE 102 may provide a geographic coverage area for which the NE 102 may support services for one or more UEs 104 within the geographic coverage area. For example, an NE 102 and a UE 104 may support wireless communication of signals related to services (e.g., voice, video, packet data, messaging, broadcast, etc.) according to one or multiple radio access technologies. In some implementations, an NE 102 may be moveable, for example, a satellite associated with a non-terrestrial network (NTN). In some implementations, different geographic coverage areas associated with the same or different radio access technologies may overlap, but the different geographic coverage areas may be associated with different NE 102.

[0042] The one or more UEs 104 may be dispersed throughout a geographic region of the wireless communications system 100. A UE 104 may include or may be referred to as a remote unit, a mobile device, a wireless device, a remote device, a subscriber device, a transmitter device, a receiver device, or some other suitable terminology. In some implementations, the UE 104 may be referred to as a unit, a station, a terminal, or a client, among other examples. Additionally, or alternatively, the UE 104 may be referred to as an Internet-of-Things (IoT) device, an Internet-of-Everything (IoE) device, or machine-type communication (MTC) device, among other examples.

[0043] A UE 104 may be able to support wireless communication directly with other UEs 104 over a communication link. For example, a UE 104 may support wireless communication directly with another UE 104 over a device-to-device (D2D) communication link. In some implementations, such as vehicle-to-vehicle (V2V) deployments, vehicle-to-everything (V2X) deployments, or cellular-V2X deployments, the communication link may be referred to as a sidelink. For example, a UE 104 may support wireless communication directly with another UE 104 over a PC5 interface.

[0044] An NE 102 may support communications with the CN 106, or with another NE 102, or both. For example, an NE 102 may interface with other NE 102 or the CN 106 through one or more backhaul links (e.g., S1, N2, N6, or other network interface). In some implementations, the NE 102 may communicate with each other directly. In some other implementations, the NE 102 may communicate with each other indirectly (e.g., via the CN 106). In some implementations, one or more NE 102 may include subcomponents, such as an access network entity, which may be an example of an access node controller (ANC). An ANC may communicate with the one or more UEs 104 through one or more other access network transmission entities, which may be referred to as a radio heads, smart radio heads, or transmission-reception points (TRPs).

[0045] The CN 106 may support user authentication, access authorization, tracking, connectivity, and other access, routing, or mobility functions. The CN 106 may be an evolved packet core (EPC), or a 5G core (5GC), which may include a control plane entity that manages access and mobility (e.g., a mobility management entity (MME), an access and mobility management functions (AMF)) and a user plane entity that routes packets or interconnects to external networks (e.g., a serving gateway (S-GW), a packet data network (PDN) gateway (P-GW), or a user plane function (UPF)). In some implementations, the control plane entity may manage non-access stratum (NAS) functions, such as mobility, authentication, and bearer management (e.g., data bearers, signal bearers, etc.) for the one or more UEs 104 served by the one or more NE 102 associated with the CN 106.

[0046] The CN 106 may communicate with a packet data network over one or more backhaul links (e.g., via an S1, N2, N6, or other network interface). The packet data network may include an application server. In some implementations, one or more UEs 104 may communicate with the application server. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or the like) with the CN 106 via an NE 102. The CN 106 may route traffic (e.g., control information, data, and the like) between the UE 104 and the application server using the established session (e.g., the established PDU session). The PDU session may be an example of a logical connection between the UE 104 and the CN 106 (e.g., one or more network functions of the CN 106).

[0047] In the wireless communications system 100, the NEs 102 and the UEs 104 may use resources of the wireless communications system 100 (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers)) to perform

various operations (e.g., wireless communications). In some implementations, the NEs 102 and the UEs 104 may support different resource structures. For example, the NEs 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the NEs 102 and the UEs 104 may support a single frame structure. In some other implementations, such as in 5G and among other suitable radio access technologies, the NEs 102 and the UEs 104 may support various frame structures (i.e., multiple frame structures). The NEs 102 and the UEs 104 may support various frame structures based on one or more numerologies.

[0048] One or more numerologies may be supported in the wireless communications system 100, and a numerology may include a subcarrier spacing and a cyclic prefix. A first numerology (e.g., $\mu=0$) may be associated with a first subcarrier spacing (e.g., 15 kHz) and a normal cyclic prefix. In some implementations, the first numerology (e.g., $\mu=0$) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe. A second numerology (e.g., $\mu=1$) may be associated with a second subcarrier spacing (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., $\mu=2$) may be associated with a third subcarrier spacing (e.g., 60 kHz) and a normal cyclic prefix or an extended cyclic prefix. A fourth numerology (e.g., $\mu=3$) may be associated with a fourth subcarrier spacing (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g., $\mu=4$) may be associated with a fifth subcarrier spacing (e.g., 240 kHz) and a normal cyclic prefix.

[0049] A time interval of a resource (e.g., a communication resource) may be organized according to frames (also referred to as radio frames). Each frame may have a duration, for example, a 10 millisecond (ms) duration. In some implementations, each frame may include multiple subframes. For example, each frame may include 10 subframes, and each subframe may have a duration, for example, a 1 ms duration. In some implementations, each frame may have the same duration. In some implementations, each subframe of a frame may have the same duration.

[0050] Additionally, or alternatively, a time interval of a resource (e.g., a communication resource) may be organized according to slots. For example, a subframe may include a number (e.g., quantity) of slots. The number of slots in each subframe may also depend on the one or more numerologies supported in the wireless communications system 100. For instance, the first, second, third, fourth, and fifth numerologies (i.e., $\mu=0$, $\mu=1$, $\mu=2$, $\mu=3$, $\mu=4$) associated with respective subcarrier spacings of 15 kHz, 30 kHz, 60 kHz, 120 kHz, and 240 kHz may utilize a single slot per

subframe, two slots per subframe, four slots per subframe, eight slots per subframe, and 16 slots per subframe, respectively. Each slot may include a number (e.g., quantity) of symbols (e.g., OFDM symbols). In some implementations, the number (e.g., quantity) of slots for a subframe may depend on a numerology. For a normal cyclic prefix, a slot may include 14 symbols. For an extended cyclic prefix (e.g., applicable for 60 kHz subcarrier spacing), a slot may include 12 symbols. The relationship between the number of symbols per slot, the number of slots per subframe, and the number of slots per frame for a normal cyclic prefix and an extended cyclic prefix may depend on a numerology. It should be understood that reference to a first numerology (e.g., $\mu=0$) associated with a first subcarrier spacing (e.g., 15 kHz) may be used interchangeably between subframes and slots.

[0051] In the wireless communications system 100, an electromagnetic (EM) spectrum may be split, based on frequency or wavelength, into various classes, frequency bands, frequency channels, etc. By way of example, the wireless communications system 100 may support one or multiple operating frequency bands, such as frequency range designations FR1 (410 MHz – 7.125 GHz), FR2 (24.25 GHz – 52.6 GHz), FR3 (7.125 GHz – 24.25 GHz), FR4 (52.6 GHz – 114.25 GHz), FR4a or FR4-1 (52.6 GHz – 71 GHz), and FR5 (114.25 GHz – 300 GHz). In some implementations, the NEs 102 and the UEs 104 may perform wireless communications over one or more of the operating frequency bands. In some implementations, FR1 may be used by the NEs 102 and the UEs 104, among other equipment or devices for cellular communications traffic (e.g., control information, data). In some implementations, FR2 may be used by the NEs 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

[0052] FR1 may be associated with one or multiple numerologies (e.g., at least three numerologies). For example, FR1 may be associated with a first numerology (e.g., $\mu=0$), which includes 15 kHz subcarrier spacing; a second numerology (e.g., $\mu=1$), which includes 30 kHz subcarrier spacing; and a third numerology (e.g., $\mu=2$), which includes 60 kHz subcarrier spacing. FR2 may be associated with one or multiple numerologies (e.g., at least 2 numerologies). For example, FR2 may be associated with a third numerology (e.g., $\mu=2$), which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g., $\mu=3$), which includes 120 kHz subcarrier spacing.

[0053] According to implementations, one or more of the NEs 102 and the UEs 104 are operable to implement various aspects of the techniques described with reference to the present

disclosure. In one or more implementations, a NE 102, receives from a positioning equipment (e.g., another NE 102 implemented as a positioning equipment), a measurement configuration to conduct one or more uplink channel sample-based measurement profile measurements on a reference signal. The NE 102 transmits, to the positioning equipment for a positioning estimation, the uplink channel profile measurements performed on the reference signal based on the measurement configuration. In one or more implementations, a positioning equipment (e.g., a NE 102 implemented as a positioning equipment) transmits, to a NE 102, a measurement configuration to conduct one or more uplink channel sample-based measurement profile measurements on a reference signal. The positioning equipment receives, from the NE 102, the uplink channel profile measurements performed on the reference signal based on the measurement configuration. The positioning equipment performs a positioning estimation based on the uplink channel profile measurements, and determines a location of a UE 104 based on the positioning estimation. In one or more implementations, the NE 102 has a known location and is configured as at least one of a gNB, a TRP, a PRU TRP, or a reference TRP. In further one or more implementations, the positioning equipment is at least one of a location server, a LMF, a UE 104, or a PRU UE. In further one or more implementations, the one or more uplink channel sample-based measurement profile measurements are input data to a machine learning model that determines the positioning estimation. The input data is also usable to train the machine learning model to determine the positioning estimation.

[0054] Separate positioning techniques, as indicated in Table (1) below, can be currently configured and performed based on the requirements of the LMF and UE capabilities. The transmission of PRSs enable a UE to perform UE positioning-related measurements, enable computation of a UE's location estimate, and are configured per TRP, where a TRP may transmit one or more beams.

Method	UE-based	UE-assisted, LMF-based	NG-RAN node assisted	SUPL
A-GNSS	Yes	Yes	No	Yes (UE-based and UE-assisted)
OTDOA ^{Notes 1,2}	No	Yes	No	Yes (UE-assisted)
E-CID ^{Note 4}	No	Yes	Yes	Yes for E-UTRA (UE-assisted)
Sensor	Yes	Yes	No	No
WLAN	Yes	Yes	No	Yes
Bluetooth	No	Yes	No	No
TBS ^{Note 5}	Yes	Yes	No	Yes (MBS)
DL-TDOA	Yes	Yes	No	No
DL-AoD	Yes	Yes	No	No
Multi-RTT	No	Yes	Yes	No
NR E-CID	No	Yes	FFS	No
UL-TDOA	No	No	Yes	No
UL-AoA	No	No	Yes	No
NOTE 1: This includes TBS positioning based on PRS signals. NOTE 2: In this version of the specification, only observed time difference of arrival (OTDOA) based on LTE signals is supported. NOTE 3: Void NOTE 4: This includes Cell-ID for NR method. NOTE 5: This version of the specification is for TBS positioning based on metropolitan beacon system (MBS) signals. NOTE 6: Void				

Table (1): Supported Rel-16 UE Positioning Methods

[0055] **Figure 2** illustrates an example of system 200 for NR beam-based positioning in accordance with aspects of the present disclosure. The system 200 illustrates a UE 104 and NEs 102 (e.g., gNBs). The PRS can be transmitted by different base stations (serving and neighboring) using narrow beams over FR1 and FR2 as illustrated in the example system 200, which is relatively different when compared to LTE where the PRS was transmitted across the whole cell. The PRS can be locally associated with a PRS resource identifier (ID) and resource set ID for a base station (e.g., a TRP). Similarly, UE positioning measurements, such as reference signal time difference (RSTD) and PRS RSRP measurements are performed on a per beam basis (e.g., based on downlink (DL) PRS resources, or DL PRS resource sets) as opposed to different cells, as was the case in LTE. In addition, there are additional UL positioning methods that the network can use to compute the location of a target UE.

[0056] A reference signal (RS) to measurements mapping is shown below in Table (2) and in Table (3), which indicate the RS to measurements mapping for each of the supported RAT-

dependent positioning techniques at a UE and at a gNB, respectively. RAT-dependent positioning techniques involve the 3GPP RAT and core network entities to perform a position estimation of a UE, which are differentiated from RAT-independent positioning techniques that rely on the global navigation satellite system (GNSS), inertial measurement unit (IMU) sensor, wireless local area network (WLAN), and Bluetooth technologies for performing target device (UE) positioning.

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

Table (2): UE Measurements for RAT-dependent Positioning Techniques

DL/UL Reference Signals	gNB Measurements	To facilitate support of the positioning techniques
Rel.16 SRS for positioning	UL RTOA	UL-TDOA
Rel.16 SRS for positioning	UL SRS-reference signal received power (RSRP)	UL-TDOA, UL-AoA, Multi-RTT
Rel.16 SRS for positioning, Rel.16 DL PRS	gNB Rx-Tx time difference	Multi-RTT
Rel.16 SRS for positioning	AoA and ZoA	UL-AoA, Multi-RTT

Table (3): gNB Measurements for RAT-dependent Positioning Techniques.

[0057] Various RAT-dependent positioning techniques are supported in Rel-16, such as downlink time difference of arrival (DL-TDoA), DL-angle of departure (AoD), multi-RTT, enhanced cell-ID (E-CID)/ NR E-CID, UL-TDoA, and UL-AoA. The DL-TDoA positioning method makes use of the measured DL PRS RSRP of downlink signals received from multiple transmission points (TPs), at the UE. The UE measures the DL PRS RSRP of the received signals using assistance data received from the positioning server, and the resulting measurements are used along with other configuration information to locate the UE in relation to the neighboring TPs.

[0058] The DL AoD positioning method makes use of the measured DL PRS RSRP of downlink signals received from multiple TPs, at the UE. The UE measures the DL PRS RSRP of the received signals using assistance data received from the positioning server, and the resulting measurements are used along with other configuration information to locate the UE in relation to the neighboring TPs.

[0059] **Figure 3** illustrates an example 300 of a multi-cell RTT signaling procedure in accordance with aspects of the present disclosure. The multi-RTT positioning technique makes use of the UE Rx-Tx measurements and DL PRS RSRP of downlink signals received from multiple TRPs, as measured by the UE, as well as the measured gNB Rx-Tx measurements and uplink sounding reference signal (SRS) RSRP (UL SRS-RSRP) at multiple TRPs of uplink signals transmitted from a UE. The UE measures the UE Rx-Tx measurements (and optionally DL PRS RSRP of the received signals) using assistance data received from the positioning server (also referred to herein as a location server, or positioning equipment), and the TRPs the gNB Rx-Tx measurements (and optionally UL SRS-RSRP of the received signals) using assistance data received from the positioning server. The measurements are used to determine the RTT at the positioning server, which are used to estimate the location of the UE. The multi-RTT is only supported for UE-assisted and NG-RAN assisted positioning techniques as noted in Table (1).

[0060] For the E-CID positioning technique, the position of a UE is estimated with the knowledge of its serving ng-eNB, gNB, and cell, and is based on LTE signals. The information about the serving ng-eNB, gNB, and cell may be obtained by paging, registration, or other methods. The NR E-CID positioning refers to techniques which use additional UE measurements and/or NR radio resources and other measurements to improve the UE location estimate using NR signals. Although NR E-CID positioning may utilize some of the same measurements as the measurement

control system in the RRC protocol, the UE may not (or is not expected to) make additional measurements for the sole purpose of positioning (e.g., the positioning procedures do not supply a measurement configuration or measurement control message, and the UE reports the measurements that it has available rather than being required to take additional measurement actions).

[0061] The UL-TDoA positioning technique makes use of the UL RTOA (and optionally UL SRS-RSRP) at multiple reception points (RPs) of uplink signals transmitted from UE. The RPs measure the UL-RTOA (and optionally UL SRS-RSRP) of the received signals using assistance data received from the positioning server, and the resulting measurements are used along with other configuration information to estimate the location of the UE.

[0062] The UL-AoA positioning technique makes use of the measured azimuth and the zenith of arrival at multiple RPs of uplink signals transmitted from UE. The RPs measure azimuth-AoA (A-AoA) and zenith-AoA (Z-AoA) of the received signals using assistance data received from the positioning server (also referred to herein as the location server, or positioning equipment), and the resulting measurements are used along with other configuration information to estimate the location of the UE.

[0063] Various RAT-independent positioning techniques may also be used, such as network-assisted GNSS techniques, barometric pressure sensor positioning, WLAN positioning, Bluetooth positioning, terrestrial beacon system (TBS) positioning, and motion sensor positioning. The network-assisted GNSS techniques make use of UEs that are equipped with radio receivers capable of receiving GNSS signals. In 3GPP specifications, the term GNSS encompasses both global and regional/augmentation navigation satellite systems. Examples of global navigation satellite systems include Global Positioning System (GPS), Modernized GPS, Galileo, Global Navigation Satellite System (GLONASS), and BeiDou Navigation Satellite System (BDS). Regional navigation satellite systems include Quasi Zenith Satellite System (QZSS), while the many augmentation systems are classified under the generic term of Space Based Augmentation Systems (SBAS) and provide regional augmentation services. The network-assisted GNSS techniques may use different GNSSs (e.g., GPS, Galileo, etc.) separately or in combination to determine the location of a UE.

[0064] The barometric pressure sensor positioning technique makes use of barometric sensors to determine the vertical component of the position of the UE. The UE measures barometric pressure,

optionally aided by assistance data, to calculate the vertical component of its location or to send measurements to the positioning server for position calculation. This technique can be combined with other positioning techniques to determine the 3D position of a UE.

[0065] The WLAN positioning technique makes use of the WLAN measurements (access point (AP) identifiers and optionally other measurements) and databases to determine the location of the UE. The UE measures received signals from WLAN access points, optionally aided by assistance data, to send measurements to the positioning server for position calculation. Using the measurement results and a references database, the location of a UE can be calculated. Additionally, or alternatively, a UE makes use of WLAN measurements, and optionally WLAN AP assistance data provided by the positioning server to determine its location.

[0066] The Bluetooth positioning technique makes use of Bluetooth measurements (beacon identifiers and optionally other measurements) to determine the location of a UE. The UE measures received signals from Bluetooth beacons, and using the measurement results and a references database, the location of the UE can be calculated. The Bluetooth technique may be combined with other positioning techniques (e.g., WLAN) to improve positioning accuracy of a UE.

[0067] The TBS positioning technique includes a network of ground-based transmitters that broadcast signals for positioning purposes. Examples of types of TBS positioning signals are Metropolitan Beacon System (MBS) signals and PRSs. A UE measures received TBS signals, optionally aided by assistance data, to calculate its location and/or to send measurements to a positioning server for position calculation.

[0068] The motion sensor positioning techniques make use of different sensors, such as accelerometers, gyros, magnetometers, and so forth to calculate the displacement of a UE. The UE can estimate a relative displacement based on a reference position and/or a reference time. The UE can send a report that includes the determined relative displacement, which can be used to determine the absolute position of the UE. This technique can be used with other positioning techniques for hybrid positioning.

[0069] Different downlink measurements, such as used for RAT-dependent positioning measurements and techniques, include DL PRS-RSRP, DL RSTD, and UE Rx-Tx time difference, such as the supported RAT-dependent positioning techniques shown below in Table (4).

Measurement configurations that may be used include four (4) pair of DL RSTD measurements, which may be performed per pair of cells, and each measurement is performed between a different pair of DL PRS resources and/or resource sets with a single reference timing. Additionally, eight (8) DL PRS RSRP measurements can be performed on different DL PRS resources from the same cell.

DL PRS reference signal received power (DL PRS-RSRP)	
Definition	DL PRS-RSRP is the linear average over the power contributions (in 8) of the resource elements that carry DL PRS reference signals configured for RSRP measurements within the considered measurement frequency bandwidth. For FR1, the reference point for the DL PRS-RSRP shall be the antenna connector of the UE. For FR2, DL PRS-RSRP shall be measured based on the combined signal from antenna elements corresponding to a given receiver branch. For FR1 and FR2, if receiver diversity is in use by the UE, the reported DL PRS-RSRP value shall not be lower than the corresponding DL PRS-RSRP of any of the individual receiver branches.
Applicable for	RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency
DL reference signal time difference (DL RSTD)	
Definition	DL RSTD is the DL relative timing difference between the positioning node j and the reference positioning node i, defined as $T_{\text{SubframeRx}j} - T_{\text{SubframeRx}i}$, Where: $T_{\text{SubframeRx}j}$ is the time when the UE receives the start of one subframe from positioning node j. $T_{\text{SubframeRx}i}$ is the time when the UE receives the corresponding start of one subframe from positioning node i that is closest in time to the subframe received from positioning node j. Multiple DL PRS resources can be used to determine the start of one subframe from a positioning node. For FR1, the reference point for the DL RSTD shall be the antenna connector of the UE. For FR2, the reference point for the DL RSTD shall be the antenna of the UE.
Applicable for	RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency
UE Rx – Tx time difference	
Definition	The UE Rx – Tx time difference is defined as $T_{\text{UE-RX}} - T_{\text{UE-TX}}$ Where:

	T_{UE-RX} is the UE received timing of downlink subframe #i from a positioning node, defined by the first detected path in time. T_{UE-TX} is the UE transmit timing of uplink subframe #j that is closest in time to the subframe #i received from the positioning node. Multiple DL PRS resources can be used to determine the start of one subframe of the first arrival path of the positioning node. For FR1, the reference point for T_{UE-RX} measurement shall be the Rx antenna connector of the UE and the reference point for T_{UE-TX} measurement shall be the Tx antenna connector of the UE. For FR2, the reference point for T_{UE-RX} measurement shall be the Rx antenna of the UE and the reference point for T_{UE-TX} measurement shall be the Tx antenna of the UE.
Applicable for	RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency
DL PRS RSRPP (Reference Signal Received Path Power)	
Definition	DL PRS reference signal received path power (DL PRS-RSRPP), is the power of the linear average of the channel response at the i-th path delay of the resource elements that carry a DL PRS signal configured for the measurement, where DL PRS-RSRPP for the 1st path delay is the power contribution corresponding to the first detected path in time. For FR1, the reference point for the DL PRS-RSRPP shall be the antenna connector of the UE. For FR2, DL PRS-RSRPP shall be measured based on the combined signal from antenna elements corresponding to a given receiver branch.
Applicable for	RRC_CONNECTED, RRC_INACTIVE
UL Angle of Arrival (UL AoA)	
Definition	UL AoA is the estimated azimuth angle (A-AoA) and vertical angle (Z-AoA) of a UE with respect to a reference direction, where the reference direction is: - In the global coordinate system (GCS), where estimated azimuth angle is measured relative to geographical North and is positive in a counter-clockwise direction, and estimated vertical angle is measured relative to zenith and positive to horizontal direction; - In the local coordinate system (LCS), where estimated azimuth angle is measured relative to the x-axis of LCS and is positive in a counter-clockwise direction, and estimated vertical angle is measured relative to z-axis of LCS and positive to x-y plane direction. The bearing, downtilt, and slant angles of LCS are defined. The UL-AoA is determined at the gNB antenna for an UL channel corresponding to this UE.
UL Relative Time of Arrival ($T_{UL-RTOA}$)	

Definition	The UL $T_{UL-RTOA}$ is the beginning of subframe i containing SRS received in Reception Point (RP) j, relative to the RTOA Reference Time. The UL RTOA reference time is defined as $T_0 + t_{SRS}$, where - T_0 is the nominal beginning time of SFN 0 provided by SFN Initialization Time - $t_{SRS} = (10n_f + n_{sf}) \times 10^{-3}$, where n_f and n_{sf} are the system frame number and the subframe number of the SRS, respectively. Multiple SRS resources can be used to determine the beginning of one subframe containing SRS received at a RP. The reference point for $T_{UL-RTOA}$ shall be: - for type 1-C base station TS 38.104: the Rx antenna connector, - for type 1-O or 2-O base station TS 38.104: the Rx antenna (i.e. the center location of the radiating region of the Rx antenna), - for type 1-H base station TS 38.104: the Rx Transceiver Array Boundary connector.
gNB Rx – Tx time difference	
Definition	The gNB Rx – Tx time difference is defined as $T_{gNB-RX} - T_{gNB-TX}$ Where: T_{gNB-RX} is the transmission-reception point (TRP) received timing of uplink subframe $\#i$ containing SRS associated with UE, defined by the first detected path in time. T_{gNB-TX} is the TRP transmit timing of downlink subframe $\#j$ that is closest in time to the subframe $\#i$ received from the UE. Multiple SRS resources can be used to determine the start of one subframe containing SRS. The reference point for T_{gNB-RX} shall be: - for type 1-C base station: the Rx antenna connector, - for type 1-O or 2-O base station: the Rx antenna (i.e. the center location of the radiating region of the Rx antenna), - for type 1-H base station: the Rx transceiver array boundary connector. The reference point for T_{gNB-TX} shall be: - for type 1-C base station TS 38.104]: the Tx antenna connector, - for type 1-O or 2-O base station TS 38.104]: the Tx antenna (i.e. the center location of the radiating region of the Tx antenna), - for type 1-H base station TS 38.104: the Tx transceiver array boundary connector.

Table (4): Positioning Measurement Definitions for DL-based and UL-based positioning

[0070] **Figure 4** illustrates an example system 400 of a functional framework for a machine learning model and NR air interface, in accordance with aspects of the present disclosure. In this example system 400, the functional framework includes multiple processes that enable AI/ML functionality over the air interface. Data collection 402 is a function that provides input data to model training 404, management 406, and inference 408 functions. Training data 410 is a data input to the AI/ML model training 404, and monitoring data 412 is a data input to the management 406 of the AI/ML model or for AI/ML functionalities. Similarly, inference data 414 is a data input to the AI/ML function for inference 408.

[0071] The model training 404 is a function that performs AI/ML model training, validation, and testing, which may generate model performance metrics that can be used as part of the model testing procedure. The model training 404 is also responsible for data preparation (e.g., data pre-processing and cleaning, formatting, and transformation) based on the training data 410 that is received from data collection 402, if required. A model storage 416 can be used to deliver trained, validated, and tested AI/ML models (e.g., a trained and/or updated model 418), or can receive an updated version of a model at the model storage.

[0072] The management 406 is a function that oversees the operation (e.g., selection, (de)activation, switching, and/or fallback) and monitoring (e.g., performance) of AI/ML models and/or AI/ML functionalities. This function is also implemented to make decisions to ensure the proper inference operation based on data received from the functions for data collection 402 and inference 408. A management instruction 420 from management 406 to inference 408 is information provided as an input to manage the inference function. This information may include selection, (de)activation and/or switching of AI/ML models and/or AI/ML-based functionalities, or as a fallback to non-AI/ML operations (i.e., not relying on an inference process), etc. A model transfer and/or delivery request 422 from management 406 to the model storage 416 is used to request model(s) from the model storage. A performance feedback and/or retraining request 424 from management 406 to model training 404 is information used as an input for the model training function (e.g., for model (re)training or updating purposes).

[0073] The function for inference 408 provides outputs from the process of applying AI/ML models and/or AI/ML functionalities, using the data that is provided by data collection 402 (i.e., the inference data 414 from data collection 402 as a data input to inference 408). The function of inference 408 is also responsible for data preparation (e.g., data pre-processing and cleaning, formatting, and transformation) based on the inference data 414 delivered by data collection 402, if required. An inference output 426 is data used by the function of management 406 to monitor the performance of AI/ML models and/or AI/ML functionalities.

[0074] The model storage 416 is a function responsible for storing the trained and/or updated models 418 that can be used to perform the inference function. The function of model storage 416 is representative of a reference point (if any) when applicable for protocol terminations, model transfer and/or delivery, and related processes. It should be noted that its purpose does not encompass restricting the actual storage locations of models, and all data, information, and instruction input and outputs to/from the model storage are case by case, as needed. The model transfer and/or delivery 428 is used to deliver an AI/ML model to the inference function.

[0075] With reference to positioning accuracy enhancements, some selected representative sub-use cases may include direct AI/ML positioning, with an AI/ML model output indicating a UE location (e.g., fingerprinting or signature based on channel observation as the input of the AI/ML model). An AI/ML assisted positioning, with an AI/ML model output indicating a new measurement and/or enhancement of an existing measurement (e.g., a line of sight (LOS) or NLOS identification, timing, and/or angle of measurement, likelihood of measurement). More specifically, additional use cases may include a case 1 for UE-based positioning with a UE-side model, direct AI/ML, or AI/ML assisted positioning; a case 2a for UE-assisted and/or LMF-based positioning with a UE-side model, or AI/ML assisted positioning; a case 2b for UE-assisted and/or LMF-based positioning with a LMF-side model, or direct AI/ML positioning; a case 3a for NG-RAN node assisted positioning with a gNB-side model, or AI/ML assisted positioning; and a case 3b for NG-RAN node assisted positioning with a LMF-side model, or direct AI/ML positioning. Additionally, a one-sided model with inference may be performed entirely at a UE, or at the network (e.g., as prioritized in Rel-18 SI).

[0076] **Figure 5** illustrates an example of a machine learning model functional framework 500 for RAN intelligence, in accordance with aspects of the present disclosure. In this example, the

functional framework 500 includes data collection 502 as a function that provides input data to model training 504 and model inference 506 functions. The AI/ML algorithm specific data preparation (e.g., data pre-processing and cleaning, formatting, and transformation) may not be implemented in the function for data collection 502. Examples of input data may include measurements from UEs or different network entities, feedback from an actor 508, and/or output from an AI/ML model. Training data 510 is a data input to the AI/ML model training 504, and inference data 512 is a data input to the AI/ML function for model inference 506. The model training 504 may provide a model deployment and/or update 514 to the function for model inference 506.

[0077] The function for model inference 506 provides AI/ML model inference output 516 (e.g. predictions or decisions), and in implementations, may provide model performance feedback 518 to the model training 504. The function for model inference 506 may also implemented for data preparation (e.g. data pre-processing and cleaning, formatting, and transformation) based on the inference data 512 delivered from data collection 502, if required. The inference output 516 of the AI/ML model is generated or determined by the model inference function, and details of the inference output are specific for various use cases. Additionally, the model performance feedback 518 from model inference 506 may be used to monitor the performance of the AI/ML model, when available. The actor 508 is a function that receives the output 516 from the model inference 506 and triggers or performs corresponding actions. The actor 508 may trigger actions directed to other entities, or to itself. The feedback 520 back to data collection 502 is information that may be needed to derive the training data 510, the inference data 512, or to monitor the performance of the AI/ML model and its impact to the network through updating of KPIs and performance counters.

[0078] The following are some non-limiting examples of entities and terminologies that may be referred to in this disclosure. A transmission point (TP) is a set of geographically co-located transmit antennas (e.g. an antenna array, such as with one or more antenna elements) for one cell, part of one cell, or one PRS-only TP. Transmission points can include base station (eNodeB) antennas, remote radio heads, a remote antenna of a base station, an antenna of a PRS-only TP, etc. One cell can be formed by one or multiple transmission points. For a homogeneous deployment, each transmission point may correspond to one cell.

[0079] A reception point (RP) is a set of geographically co-located receive antennas (e.g. an antenna array, such as with one or more antenna elements) for one cell, part of one cell, or one UL-SRS-only RP. Reception points can include base station (ng-eNB or gNB) antennas, remote radio heads, a remote antenna of a base station, an antenna of a UL-SRS-only RP, etc. One cell can include one or multiple reception points. For a homogeneous deployment, each reception point may correspond to one cell. A transmission-reception point (TRP) is a set of geographically co-located antennas (e.g. an antenna array, such as with one or more antenna elements) supporting TP and/or RP functionality. A PRS-only TP is a TP that only transmits PRS signals or DL-PRS for PRS-based TBS positioning and is not associated with a cell.

[0080] A positioning reference unit (PRU) at a known location can perform positioning measurements (e.g., RSTD, RSRP, UE Rx-Tx time difference measurements, etc.) and report these measurements to a location server. In addition, the PRU can transmit SRS to enable TRPs to measure and report UL positioning measurements (e.g., RTOA, UL-AoA, gNB Rx-Tx time difference, etc.) from a PRU at a known location. The PRU measurements can be compared by a location server with the measurements expected at the known PRU location to determine correction terms for other nearby target devices. The DL and/or UL location measurements for other target devices can then be corrected based on the previously determined correction terms. A PRU may also comprise of a TRP with a known location.

[0081] Additionally, a target-UE may be referred to as a UE of interest, having a position or location (absolute or relative) that is to be obtained or determined by the network or by the UE itself. Further, any reference made to a device or UE position or location information may refer to a 2D or 3D absolute position, a 2D or 3D relative position, a distance, a relative direction with respect to another node or network entity, ranging in terms of distance, ranging in terms of direction, and/or any combination thereof. As described in the present disclosure, the terms AI and ML may be used interchangeably to refer to an intelligent software component or system, such as a machine learning model.

[0082] In aspects of this disclosure, an UL-based PDP, ADP, ASF, and/or DP measurement is an aspect to enable direct AI/ML-based positioning. For direct AI/ML positioning, techniques such as fingerprinting can be leveraged by AI/ML models to obtain enhanced location estimates based on the type of RF signatures associated with a given location. The present disclosure provides for UL-

based PDP, ADP, ASF, and/or DP measurements that support implementations of direct AI/ML positioning, and provides for configurability to manage the CIR measurement overhead. In aspects of the described techniques, a first technique supports defining a multi-dimensional UL-based raw PDP vector signature or fingerprint for supporting UE-based positioning with a UE-side model, as well as UE-assisted and/or LMF-based positioning with a LMF-side model.

[0083] A second technique is described to define a multi-dimensional UL-based PDP, ADP, ASF, and/or DP vector signature or fingerprint on a sample level. It is noted that, in defining channel observations, they are a function of a number of samples and are performed over a time period and over a certain frequency, which could result in higher overhead measurements that may affect air interface resources. A third technique is described to define a multi-dimensional UL-based DP on a system-level (e.g., reduced TRPs to be measured and quality of the PDPs to be measured). A fourth technique is described to reduce the overhead that may occur for multi-dimensional UL-based PDP, ADP, ASF, and/or DP measurements, particularly on the system level (e.g., based on reducing the number of TRPs to be measured and a quality of the PDPs to be measured).

[0084] With reference to the first described technique for SRS or SRS for positioning fingerprint measurement and power delay profile, a fingerprint measurement is generated based on a power delay profile measurement of a received UL-PRS, SRS or SRS for positioning signal at a gNB, TRP, PRU TRP, and/or reference TRP. In other implementations, other reference signals may be used to derive a fingerprint measurement including MIMO SRS, PUSCH DM-RS, etc. In an example implementation, the SRS or SRS for positioning fingerprint may be derived based on multiple transmitted SRS or SRS for positioning resources that include one or more of uplink carriers, TRPs, SRS resource sets, SRS or SRS for positioning resources, or a combination thereof. This RF fingerprint represents a unique RF signature of the received SRS or SRS for positioning at a given location.

[0085] According to a current positioning framework, it is possible to obtain the first arrival path of the time-of-arrival (ToA) measurement, including up to eight (8) additional paths (as of Rel-17), which may be reported to the LMF. This implies that a total of nine (9) paths (including first path) of a supported positioning measurement (e.g., UL-RTOA, UL-AoA and gNB Rx-Tx time difference measurement) may be reported to the LMF. This effectively constitutes a delay profile of the received SRS or SRS for positioning, which can serve as one type of input data. Additionally, a

SRS or SRS for positioning RSRPP measurement is defined, which is the power of the linear average of the channel response at the i^{th} path delay of the resource elements that carry the SRS or SRS for positioning signal configured for the measurement, which together with the additional paths, may implicitly constitute a PDP of the received SRS or SRS for positioning. Aside from the limited number of paths, the responsibility is on the data collection entity to piece together a type of measurement profile associated to a certain measurement data (e.g., UL-RTOA, UL-AoA, RTT measurements). Furthermore, a consolidated measurement capturing all of the power delay profile or delay profile characteristics has not yet been defined.

[0086] **Figure 6** illustrates an example procedure diagram 600 for using UL-based PDP, ADP, ASF, and/or DP measurements by a machine learning model to determine and output a location of a UE, in accordance with aspects of the present disclosure. This example procedure diagram 600 represents an overview of the process from the perspective of receiver 602 (e.g., a gNB, TRP, PRU TRP, and/or reference TRP). An advantage of a PRU is that it can perform multiple measurements at a known location of the UE, store the captured data associated with the known location, which may then be used to train a machine learning model based on the stored and captured data.

[0087] At 604 (step 1), a gNB, TRP, PRU TRP, and/or reference TRP performs a UL-based PDP, ADP, ASF, and/or DP measurement per location per TRP based on received SRS or SRS for positioning and sample size. The receiver 602 may be configured for a type of PDP, ADP, ASF, and/or DP measurement to be performed (e.g., raw PDP, ADP, ASF, and/or DP measurements, or overhead reduced measurements). At 606 (step 2), the gNB, TRP, PRU TRP, and/or reference TRP performs associated receiver processing on the UL-based PDP, ADP, ASF, and/or DP measurements to remove any hardware and/or software imperfections of the measurement, or to assist in reducing the overall PDP.

[0088] At 608 (step 3), a data collection entity 610, which may include a UE, a PRU UE, or a network entity (e.g., a LMF, a network data analytics function (NWDAF)) may pre-process the DL PDP, ADP, ASF, and/or DP measurement inputs based on the techniques described for overhead reduction with pre-processing techniques, or remove outliers or add labels (e.g., reference location, timestamp information, PDP or DP quality metrics, etc.) to filter the measurement data. At 612 (step 4) the raw measurements (e.g., the unfiltered measurements from receiver processing at 606), or the processed input data (e.g., the filtered measurements for overhead reduction at 608), is provided as

input data to an AI/ML model 614. At 616 (steps 5a, 5b), classification or regression techniques, or unsupervised learning techniques, are performed with a trained AI/ML model (also referred to herein as a machine learning model) with the goal of determining an output 618 as the location of a UE based on the UL-based PDP, ADP, ASF, and/or DP measurements. At 620 (step 6), the configured AI/ML model 614 outputs 2D and/or 3D location information of a target UE based on the trained, multi-dimensional PDP, ADP, ASF, and/or DP signatures or vectors.

[0089] **Figure 7** illustrates an example SRS or SRS for positioning received power delay profile 700, in accordance with aspects of the present disclosure. A power delay profile measurement is generated based on a received SRS or SRS for positioning signal at a gNB, TRP, PRU TRP, and/or reference TRP, which has been transmitted from a UE or PRU UE. It indicates the relative amplitude of multipath components arriving at different times and/or delays. It is normally computed by performing a spatial average of the complex valued CIR, which is shown at 702 in Figure 7 for a reference signal received with L paths or cluster paths, where P_t (at 704) is the transmit power, $P_{r0}, P_{r1}, \dots, P_{rL}$ is received average power at each time instance with a delay $t + \tau_L$, where the number of signal paths = $[0, \dots, L]$.

[0090] The power delay profile is then defined by equation(1):

$$S(\tau) = E[|h(t, \tau)|^2] \quad (1)$$

[0091] Based on the discrete PDP shown in Figure 7, the root mean square (RMS) delay spread may be given as equation(2):

$$\tau_{rms} = \sqrt{\frac{\sum_{l=1}^L P_{r(l)} (\tau_l - \bar{\tau})^2}{\sum_{l=1}^L P_{r(l)}}}, \quad (2)$$

where $P_{r(l)}$ is the average received power of the l^{th} path, τ_l is the delay of the l^{th} path, while the mean delay is given by $\bar{\tau} = \frac{\sum_{l=1}^L P_{r(l)} \tau_l}{\sum_{l=1}^L P_{r(l)}}$. The equation(2) is normally compared with the symbol duration to determine the effect of inter-symbol interference, but can also be used as a characteristic of a unique fingerprint for a particular location.

[0092] According to another aspect of the techniques, a consolidated power delay profile comprising of the received reference signal (RS) power and/or amplitude and delay may be

extracted from a received signal, which may serve as input data for an AI/ML model or algorithm. For example, the SRS or SRS for positioning power delay profile may be expressed as a 2D vector comprising of $[P_{r(l)}, \tau_l]$ where l paths or cluster path may range from $[0 \dots L]$.

[0093] According to an aspect of the techniques, the SRS or SRS for positioning PDP may comprise of the raw SRS or SRS for positioning PDP, which is generated using equation(1) and equation(2). This resulting SRS or SRS for positioning provides an insight on the power-delay over a certain bandwidth and period of time. However, a full wideband PDP has significant data overhead for transferring such information (e.g., in the case of NG-RAN-assisted positioning with a gNB-side model, direct AI/ML positioning), where a gNB, TRP, PRU TRP, and/or reference TRP may need to transfer such information to the LMF via NRPPa. In an implementation, SRS or SRS for positioning aggregation may also be applied to receive a wideband PDP. This is considering that the SRS or SRS for positioning PDP can be generated based on various factors.

[0094] The factors include a number of PDP profiles for each SRS or SRS for positioning symbol r (resource element transmission), which depends on the SRS or SRS for positioning configuration, including comb-size, number of symbols, RE offset, slot offset, and/or bandwidth in terms of PRB allocations. The PDP may also be generated based on multiple uplink subcarriers and multiple uplink symbols within a slot, subframe, and/or frame. The PRB allocations defines the bandwidth for which the PDP is measured (e.g., up to 100 MHz for FR1 and up to 400 MHz for FR2). Other factors consider over N_{Tx-Rx} antenna pairs. Other factors include based on a total number of N_{RP} RPs (reception points) given by a vector $\mathbf{n}_{RP} = [RP(1), RP(2), \dots, RP(N_{RP})]$, where a UE or PRU UE traverses each location q and transmits SRS for positioning which is received by a total N_{RP} reception points.

[0095] Additionally, or alternatively, factors can include a vector of reference locations or ground truth locations given by $\mathbf{Q} = [1, \dots, q]$. In such an implementation, for simplicity, a 2D location (x_1, y_1) is given a label 1, a 2D location (x_2, y_2) is given a label 2, a 2D location (x_q, y_q) is given a label q , and so on. In other implementations, a 3D location may also be utilized within a given environment. In the case of UL-based direct AI/ML positioning, the gNB, TRP, PRU TRP, and/or reference TRP location information is normally static and is pre-defined during deployment, therefore one or more combinations of locations may result in a unique UL-based fingerprint, given

a location of the gNB, TRP, PRU TRP, and/or reference TRP; a location of the UE at the time of SRS for positioning transmission; or a combination of location of the gNB, TRP, PRU TRP, and/or reference TRP and location of a UE at the time of SRS for positioning transmission, which may be termed or labeled as a unique location pair, and may still be mapped to the ground truth location pairs given by $\mathbf{Q} = [1, \dots, q]$.

[0096] An UL power delay profile is indicated below in Table (5) as a function of the various parameters detailed above. In different implementations one or more combinations of the parameters may be used to define the UL PDP, ADP, ASF, and/or DP measurements.

UL-based (SRS for positioning) PDP based on a single Tx-Rx antenna element pair	
Definition	The SRS power delay profile is defined as the discretized two-dimensional vector PDP measurement for every l^{th} path delay, τ_L of each resource element carrying SRS received at Reception Point (RP) i at a given reference location q . This discretized PDP measurement is given by: $S(\tau) = E[h(t, \tau) ^2]$ where $ h(t, \tau) $ is the complex-valued received channel impulse response or represents the power of the linear average of the channel response at the l^{th} path delay measured at resource elements that carry SRS received in Reception Point (RP) i . Multiple SRS resources can be used to determine a PDP measurement.
Applicable for the following RRC states	RRC_CONNECTED, RRC_INACTIVE, RRC_IDLE
UL-based (SRS for positioning) PDP based on a multiple Tx-Rx antenna element pair	
Definition	The SRS power delay profile is defined as the discretized two-dimensional vector PDP measurement for every l^{th} path delay, τ_L of each resource element carrying SRS received at Reception Point (RP) i at a given reference location q. This discretized PDP measurement is given by: $S(\tau) = E[h(t, \tau) ^2]$ where $h(t, \tau)$ is the complex-valued received channel impulse response or represents the power of the linear average of the channel response at the l^{th} path delay measured at resource elements that carry SRS received in a receiver branch (Rx0 ... Rxn). Multiple SRS resources can be used to determine a PDP measurement. For FR1 and FR2, if receiver diversity is in use by the gNB for UL-based PDP measurements: - The reported UL-based PDP for the first and additional paths shall be provided for the same receiver branch(es) as applied for UL CIR measurements, or - The reported UL-based PDP value for the first path shall not be lower than the corresponding UL-based PDP for the first path of any of the individual receiver branches (Rx0 ... Rxn) and the reported UL-based PDP for the additional paths shall

	be provided for the same receiver branch(es) (Rx0 ... Rxn) as applied UL-based PDP for the first path.
Applicable for the following RRC states	RRC_CONNECTED, RRC_INACTIVE, RRC_IDLE

Table (5): UL Power Delay Profile

[0097] With reference to the second described technique for SRS or SRS for positioning fingerprint measurement and angular profile, a fingerprint measurement is generated based on an angular delay profile (angle-delay domain) measurement or an angle spectrum function (power-angle domain) of a received SRS or SRS for positioning signal at a gNB, TRP, PRU TRP, and/or reference TRP. In other implementations, other reference signals may be used to derive a fingerprint measurement including MIMO SRS, PUSCH DM-RS, etc. In an example implementation, the SRS or SRS for positioning fingerprint may be derived based on multiple transmitted SRS or SRS for positioning resources, including uplink carriers, TRPs, a SRS or SRS for positioning resource set, SRS or SRS for positioning resources, or a combination thereof. This RF fingerprint represents a unique RF signature of the received SRS or SRS for positioning at a given location.

[0098] **Figure 8** illustrates an example 800 of a SRS or SRS for positioning received power-angle profile and angle-delay profile as a signature, in accordance with aspects of the present disclosure. According to an aspect of the techniques, an ADP or an angle spectrum function (power-angle domain) measurement is generated based on a received SRS or SRS for positioning signal at a gNB, TRP, PRU TRP, and/or reference TRP, which has been transmitted from a UE or a PRU UE. It indicates the relative power (at 802) of different angle of arrivals of each multipath component, or relative angle-of-arrival (AoAs) of the multipath components (at 804) arriving at different times and/or delays. These angles of arrivals may include azimuth angle of arrivals, or zenith and/or elevation angles at the gNB, TRP, PRU TRP, and/or reference TRP. It is normally computed by determining the phase and angle of the complex valued CIR, which is shown for a reference signal received with L paths or cluster paths received at each antenna element, where φ_L is the SRS or SRS for positioning azimuth angle of arrival or elevation angle of arrival, and $P_{r0}, P_{r1}, \dots, P_{rL}$ is received average power at each angle of arrival, where the number of signal paths = $[0, \dots, L]$.

[0099] The angular spectrum function Figure 8(a) is then defined by equation(3):

$$S(\varphi) = E[|h(t, \varphi)|^2] \quad (3)$$

[0100] Based on the discrete PDP in Figure 7, the root mean square (RMS) delay spread may be given as equation(4):

$$\varphi_{rms} = \sqrt{\frac{\sum_{l=1} P_{r(l)} (\varphi_l - \bar{\varphi})^2}{\sum_{l=1} P_{r(l)}}}, \quad (4)$$

where $P_{r(l)}$ is the average received power of the l^{th} path, φ_l is the AoA of the l^{th} path, while the mean AoA is given by $\bar{\varphi} = \frac{\sum_{l=1} P_{r(l)} \varphi_l}{\sum_{l=1} P_{r(l)}}$. The equation(3) could be used as characteristic of a unique fingerprint for a particular location, while equation(4) could be further used as a fingerprint characteristic to determine the mean angular spread.

[0101] According to another aspect of the techniques, a consolidated power delay profile comprising of the received reference signal (RS) power and/or amplitude and delay may be extracted from a received signal, which may serve as input data for an AI/ML model or algorithm. For example, the SRS or SRS for positioning angular spectrum function may be expressed as a 2D vector comprising of $[P_{r(l)}, \varphi_l]$, where l paths or cluster path may range from $[0 \dots L]$ at each Rx antenna element.

[0102] According to an implementation, the SRS or SRS for positioning ADP (angle-delay domain) or an angle spectrum function (ASF) (power-angle domain) measurement may include the raw SRS or SRS for positioning ADP or ASF, which is generated using equation(3) and equation(4). This resulting received SRS or SRS for positioning angular profile provides an insight on the angle-delay or power-angle spread over a certain bandwidth and period of time. However, a full wideband angle-delay or power-angle spread has significant data overhead for transferring such information (e.g., in the case of NG-RAN-assisted positioning with gNB-side model, direct AI/ML positioning), where a gNB, TRP, PRU TRP, and/or reference TRP may need to transfer such information to the LMF via NRPPa signaling. This is considering that the SRS or SRS for positioning ADP and/or ASF is generated based on various factors.

[0103] The factors include a number of angle-delay or power-angle spread profiles for each SRS or SRS for positioning symbol r (resource element transmission), which depends on the SRS or SRS for positioning configuration, including comb-size, number of symbols, RE offset, slot

offset, and/or bandwidth in terms of PRB allocations. The PRB allocations defines the bandwidth for which the ADP and/or ASF is measured (e.g., up to 100 MHz for FR1 and up to 400 MHz for FR2). The factors consider over N_{Tx-Rx} antenna pairs. Other factors include based on a total number of N_{RP} RPs (reception points) given by a vector $\mathbf{n}_{RP} = [RP(1), RP(2), \dots, RP(N_{RP})]$, where a UE or PRU UE traverses each location q and transmits SRS for positioning, which is received by a total N_{RP} reception points.

[0104] Additionally, or alternatively, the factors include a vector of reference locations or ground truth locations given by $\mathbf{Q} = [1, \dots, q]$. In such an implementation, for simplicity, a 2D location (x_1, y_1) is given a label 1, a 2D location (x_2, y_2) is given a label 2, a 2D location (x_q, y_q) is given a label q and so on. In other implementations, a 3D location may also be utilized within a given environment. In the case of UL-based direct AI/ML positioning, the gNB, TRP, PRU TRP, and/or reference TRP location information is normally static and is pre-defined during deployment, therefore one or more combinations of locations may result in a unique UL-based fingerprint, such as for a location of the gNB, TRP, PRU TRP, and/or reference TRP; a location of the UE at the time of SRS for positioning transmission; and/or a combination of location of the gNB, TRP, PRU TRP, and/or reference TRP and location of a UE at the time of SRS for positioning transmission, which may be termed or labeled as a unique location pair, and may still be mapped to the ground truth location pairs given by $\mathbf{Q} = [1, \dots, q]$.

[0105] An UL-based angular delay profile is indicated below in Table (6) as a function of the various parameters detailed above.

UL-based (SRS for positioning) Angular Delay Profile (ADP)	
Definition	The SRS angular delay profile is defined as the discretized two-dimensional vector ADP measurement for every l^{th} AoA, φ_L of each resource element carrying SRS received at Reception Point (RP) i at a given reference location q. This discretized ADP measurement is given by the AoAs of complex-valued received channel impulse response at each l^{th} path delay measured at resource elements that carry SRS received in Reception Point (RP) j or measured at resource elements that carry SRS received in a receiver branch (Rx0 ... Rxn). Multiple SRS resources can be used to determine an ADP measurement. For FR1 and FR2, if receiver diversity is in use by the gNB for UL-based ADP measurements:

	- The reported UL-based ADP for the first and additional paths shall be provided for the same receiver branch(es) as applied for UL PDP measurements, or - The reported UL-based ADP value for the first path shall not be lower than the corresponding UL-based ADP for the first path of any of the individual receiver branches (Rx0 ... Rxn) and the reported UL-based ADP for the additional paths shall be provided for the same receiver branch(es) (Rx0 ... Rxn) as applied UL-based PDP for the first path.
Applicable for the following RRC states	RRC_CONNECTED, RRC_INACTIVE, RRC_IDLE
UL-based (SRS for positioning) Angular Spectrum Function (ASF)	
Definition	The SRS angular spectrum function is defined as the discretized two-dimensional vector ASF measurement for every l^{th} path delay, φ_L of each resource element carrying SRS received at Reception Point (RP) i at a given reference location q. This discretized ASF measurement is given by: $S(\tau) = E[h(t, \tau) ^2]$ where $h(t, \tau)$ is the complex-valued received channel impulse response or represents the power of the linear average of the channel response at the l^{th} path AoA measured at resource elements that carry SRS received in a receiver branch (Rx0 ... Rxn). Multiple SRS resources can be used to determine a ASF measurement. For FR1 and FR2, if receiver diversity is in use by the gNB for UL-based ASF measurements: - The reported UL-based ASF for the first and additional paths shall be provided for the same receiver branch(es) as applied for UL PDP measurements, or - The reported UL-based ADP value for the first path shall not be lower than the corresponding UL-based ASF for the first path of any of the individual receiver branches (Rx0 ... Rxn) and the reported UL-based ASF for the additional paths shall be provided for the same receiver branch(es) (Rx0 ... Rxn) as applied for UL-based PDP for the first path.
Applicable for the following RRC states	RRC_CONNECTED, RRC_INACTIVE, RRC_IDLE

Table (6): UL Angular Delay Profile

[0106] **Figure 9** illustrates an example 900 of a SRS or SRS for positioning transmitted AoD profile as a signature, in accordance with aspects of the present disclosure. According to an aspect of the techniques, an angular delay profile (ADP) or an angle spectrum function (power-angle domain) measurement is generated based on a transmitted SRS or SRS for positioning at a UE or PRU UE, which indicates the relative power of different angle of departures of each transmitted SRS resource or relative angle-of-departure (AoDs) of the multipath components arriving at

different times and/or delays. These angles of departures may include azimuth angle of departures, or zenith and/or elevation angles at the UE or PRU UE.

[0107] With reference to the third described technique for SRS or SRS for positioning fingerprint measurement and delay profile, a fingerprint measurement is generated based on a DP of the received SRS or SRS for positioning at a gNB, TRP, PRU TRP, and/or reference TRP. In other implementations, other reference signals may be used to derive a fingerprint measurement including MIMO SRS, PUSCH DM-RS, etc. In an example implementation, the SRS or SRS for positioning fingerprint may be derived based on multiple transmitted SRS or SRS for positioning resources, including one or more of UL carriers, carrier IDs, TRPs, a SRS or SRS for positioning resource set, SRS or SRS for positioning resources, or a combination thereof. This RF fingerprint represents a unique RF signature of the received SRS or SRS for positioning at a given location.

[0108] **Figure 10** illustrates an example SRS or SRS for positioning received delay profile 1000, in accordance with aspects of the present disclosure. According to an aspect of the implementation, a DP measurement is generated based on a received SRS or SRS for positioning at a gNB, TRP, PRU TRP, and/or reference TRP, which has been transmitted from a UE or PRU UE. It indicates the relative time-of-arrival (ToA) of each multipath component, or describes the multipath components arriving at different times and/or delays. It is normally computed by determining the ToA of the complex valued CIR, which is shown in the figure for a reference signal received with L paths or cluster paths at each Rx antenna element.

[0109] According to another aspect of the techniques, a consolidated delay profile measurement that includes the received reference signal (RS) multipath delay may be extracted from a received signal, which may serve as input data for an AI/ML model or algorithm. For example, the received SRS or SRS for positioning delay profile may be expressed as a 1D vector of ToAs of the received signal (τ_l), where l paths or cluster path may range from $[0 \dots L]$ at each Rx antenna element.

[0110] In an implementation, the SRS or SRS for positioning delay may include the raw SRS or SRS for positioning delay profile. This resulting SRS or SRS for positioning provides an insight on the delay of multipath over a certain bandwidth and period of time. However, a full wideband DP may incur overhead data for transferring such information (e.g., in the case of NG-RAN-assisted positioning with a gNB-side or LMF-side model, direct AI/ML positioning), where a gNB, TRP,

PRU TRP, and/or reference TRP may need to transfer such information to the LMF via NRPPa. This overhead is comparably less than that of the CIR and PDP, ADP, and ASF. This takes into consideration that the SRS or SRS for positioning DP is generated based on various factors.

[0111] The various factors include a number of DP profiles for each SRS or SRS for positioning symbol r (resource element transmission), which depends on the SRS or SRS for positioning configuration, including a comb-size, a number of symbols, a RE offset, a slot offset, and/or a bandwidth in terms of PRB allocations. The PRB allocations defines the bandwidth for which the CIR is measured (e.g., up to 100 MHz for FR1 and up to 400 MHz for FR2). The factors consider over N_{Tx-Rx} antenna pairs. Other factors are based on a total number of N_{TP} RPs (reception points) given by a vector $\mathbf{n}_{RP} = [RP(1), RP(2), \dots, RP(N_{RP})]$.

[0112] Additionally, or alternatively, the factors can include a vector of reference locations or ground truth locations given by $\mathbf{Q} = [1, \dots, q]$. In such an implementation, for simplicity, a 2D location (x_1, y_1) is given a label 1, a 2D location (x_2, y_2) is given a label 2, a 2D location (x_q, y_q) is given a label q , and so on. In other implementations, a 3D location may also be utilized within a given environment. In the case of UL-based direct AI/ML positioning, the gNB, TRP, PRU TRP, and/or reference TRP location information is normally static and is pre-defined during deployment, therefore one or more combinations of locations may result in a unique UL-based fingerprint, such as for a location of the gNB, TRP, PRU TRP, and/or reference TRP; a location of the UE at the time of SRS for positioning transmission; and/or a combination of location of the gNB, TRP, PRU TRP, and/or reference TRP and location of a UE at the time of SRS for positioning transmission, which may be termed or labeled as a unique location pair, and may still be mapped to the ground truth location pairs given by $\mathbf{Q} = [1, \dots, q]$.

[0113] An UL-based delay profile is indicated below in Table (7) as a function of the various parameters detailed above.

UL-based (SRS for positioning) DP based on a single Tx-Rx antenna element pair	
Definition	The SRS delay profile is defined as the discretized one-dimensional vector DP measurement for every l^{th} path ToA of each resource element carrying SRS received at Reception Point (RP) i at a given reference location q defined as $T_{SubframeRxj}$. The SRS may be received in different receiver branches (Rx0 ... Rxn).

	Where: $T_{\text{SubframeRxj}}$ is the time when the RP i receives a (SRS or other UL RS) at the start of one subframe/slot/symbol index from a UE. Multiple SRS resources can be used to determine a DP measurement. For FR1, the reference point for the UL ToA shall be the antenna connector of the UE. For FR2, the reference point for the UL ToA shall be the antenna of the UE.
Applicable for the following RRC states	RRC_CONNECTED, RRC_INACTIVE, RRC_IDLE

Table (7): UL Delay Profile

[0114] Aspects of the described techniques are directed to solutions for UL-based PDP, ADP, ASF, and/or DP measurement overhead reduction. Given that a SRS for positioning resource configuration may include at least a comb size of {2, 4 and 8} and at least a number of symbols including {1, 2, 4, 8, and 12} in a given PRB, the UL-based channel profile reporting overhead may significantly scale up considering the bandwidth requirements. In one or more implementations, an UL post-processing window can be defined where PDP, ADP, ASF, and/or DP samples falling within the window duration are reported. In an implementation, the window may be static window, while in another implementation the window may be a rolling window over the total number of samples. The UL-based PDP, ADP, ASF, and/or DP window configuration may include a start sample, a length of samples, an end sample, or any combination thereof. The UL-based PDP, ADP, ASF, and/or DP window configuration may be periodic over a total sample length (i.e., multiple windows with a fixed sample spacing between each window). In other implementations, the UL-based PDP, ADP, ASF, and/or DP measurement window may be aperiodic with multiple windows configured with a variable sample apart from each other. The UL-based PDP, ADP, ASF, and/or DP window configuration, including a start sample, a length of samples, and an end sample may be provided to the gNB, TRP, PRU TRP, and/or reference TRP from the location server (e.g., LMF via NRPPa *Measurement Request* or *Measurement Update*). In another implementation, the gNB, TRP, PRU TRP, and/or reference TRP may self-determine an UL-based PDP, ADP, ASF, and/or DP measurement window configuration and then report this to the location server. The averaging function of each of these profiles may be performed within the window defined by the configuration.

[0115] In another aspect of the techniques, PDP and ASF samples are reported via configuration of a power threshold or power interval, $X_1 \leq \alpha \leq X_2$, where α may be the power or normalized power, while X_1 and X_2 represent the lower and upper bounds of the thresholding criteria. The values, X_1 , X_2 may be provided to a UE from the location server (e.g., LMF via NRPPa *Measurement Request* or *Measurement Update*, or equivalent signaling). In another implementation, the gNB, TRP, PRU TRP, and/or reference TRP may self-determine X_1 and X_2 and then report this to the location server. In another implementation, lower and upper angular thresholds may be defined to limit reporting ranges of the ADP and may be used in conjunction with the PDP, ADP, ASF, and/or DP window configuration.

[0116] In one or more implementations, the above-described PDP, ADP, ASF, and/or DP overhead reduction configurations may also apply to multiple gNB, TRP, PRU TRP, and/or reference TRP within a pre-defined geographic area. Further, one or more gNB, TRP, PRU TRP, and/or reference TRPs may be configured via network signaling (e.g., NRPPa) to provide a set of RPs to be measured in order to reduce PDP, ADP, ASF, and/or DP overhead from a system perspective. The RPs that perform the UL-based PDP, ADP, ASF, and/or DP measurement may be managed by the LMF using an explicit or implicit prioritization criteria, implying that UL-based PDP, ADP, ASF, and/or DP measurement from higher RP priority may be considered, while lower priority RPs may be discarded. This may be done by LMF implementation or signaled to each TRP via NRPPa as to their assigned priority.

[0117] In an aspect of the techniques, the quality of PDP, ADP, ASF, and/or DP measurements may be determined based on SNR, signal-to-interference-plus-noise ratio (SINR), timing quality, angle quality, or other received signal quality metrics. The PDP, ADP, ASF, and/or DP measurements received from a certain TRP, that are deemed to have low SNR or SINR may be discarded, where the criteria for discarding samples may be based on a configured SNR or SINR threshold. This SNR or SINR threshold may be provided to one or more gNB, TRP, PRU TRP, and/or reference TRP via network signaling (e.g., NRPPa signaling, such as NRPPa *Measurement Request* or *Measurement Update*).

[0118] In implementations, the number of reference locations, ground truth locations, and/or location pairs may be reduced via a prioritization criteria. The locations and/or location pairs which do not provide a sufficiently unique UL-based PDP, ADP, ASF, and/or DP measurements may be

explicitly assigned a lower priority or implicitly prioritized in the order of appearance within a list of locations to be measured or transmit SRS or SRS for positioning (e.g., in descending or ascending order of appearance). In another implementation, the granularity or spacing between each reference location, ground truth locations, and/or location pair may be adjusted from a network point of view. For example, an area of 100 m² (e.g., a factory warehouse) is divided into square grids of 25 grids corresponding to 25 reference locations and/or location pairs, with a spacing of 2m between each adjacent location, which implies 25 UL-based PDP, ADP, ASF, and/or DP measurements for each RP. This can be adjusted by dividing the same area in 4 square grids, corresponding to 4 reference locations and/or location pairs, with a spacing of 5m between each adjacent location, which implies 4 UL-based measurements for each RP. This is one example of reducing the UL-based PDP, ADP, ASF, and/or DP measurements at the cost of UE location estimate accuracy.

[0119] According to an aspect of the techniques, the network may determine and restrict the number of PDP, ADP, ASF, and/or DP measurements to be reported for a given fingerprint or signature based on the number of UEs actively transmitting SRS or SRS for positioning within a given pre-defined area. The pre-defined area may be in the form of physical cell ID (PCI, NR cell global identifier (NCGI ID), TRP ID, RAN area, tracking area, NR absolute radio frequency channel number (NRFCN) frequency list, or one or more combination thereof. This would control and manage the SRS or SRS for positioning transmission overhead across a number of UEs, which may be more resource efficient from a system perspective at the potential cost of individual UE accuracy. In another aspect, general quality metrics may be associated to PDP, ADP, ASF, and/or DP measurements and may be reported to the location server from the UE using e.g., NRPPa *Measurement Report* message along with the PDP, ADP, ASF, and/or DP measurements (e.g., SNR, SINR). These quality metrics can assist the positioning calculation entity to discard any so-called bad PDP, ADP, ASF, and/or DP measurements or PDP, ADP, ASF, and/or DP measurement samples.

[0120] **Figure 11** illustrates an example of a UE 1100 in accordance with aspects of the present disclosure. The UE 1100 may include a processor 1102, a memory 1104, a controller 1106, and a transceiver 1108. The processor 1102, the memory 1104, the controller 1106, or the transceiver 1108, or various combinations thereof or various components thereof may be examples of means for

performing various aspects of the present disclosure as described herein. These components may be coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

[0121] The processor 1102, the memory 1104, the controller 1106, or the transceiver 1108, or various combinations or components thereof may be implemented in hardware (e.g., circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

[0122] The processor 1102 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, or any combination thereof). In some implementations, the processor 1102 may be configured to operate the memory 1104. In some other implementations, the memory 1104 may be integrated into the processor 1102. The processor 1102 may be configured to execute computer-readable instructions stored in the memory 1104 to cause the UE 1100 to perform various functions of the present disclosure.

[0123] The memory 1104 may include volatile or non-volatile memory. The memory 1104 may store computer-readable, computer-executable code including instructions when executed by the processor 1102 cause the UE 1100 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as the memory 1104 or another type of memory. Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer.

[0124] In some implementations, the processor 1102 and the memory 1104 coupled with the processor 1102 may be configured to cause the UE 1100 to perform one or more of the functions described herein (e.g., executing, by the processor 1102, instructions stored in the memory 1104). The controller 1106 may manage input and output signals for the UE 1100. The controller 1106 may also manage peripherals not integrated into the UE 1100. In some implementations, the controller 1106 may utilize an operating system such as iOS®, ANDROID®, WINDOWS®, or

other operating systems. In some implementations, the controller 1106 may be implemented as part of the processor 1102.

[0125] In some implementations, the UE 1100 may include at least one transceiver 1108. In some other implementations, the UE 1100 may have more than one transceiver 1108. The transceiver 1108 may represent a wireless transceiver. The transceiver 1108 may include one or more receiver chains 1110, one or more transmitter chains 1112, or a combination thereof.

[0126] A receiver chain 1110 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 1110 may include one or more antennas to receive a signal over the air or wireless medium. The receiver chain 1110 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 1110 may include at least one demodulator configured to demodulate the received signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receiver chain 1110 may include at least one decoder for decoding the demodulated signal to receive the transmitted data.

[0127] A transmitter chain 1112 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 1112 may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmitter chain 1112 may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmitter chain 1112 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0128] **Figure 12** illustrates an example of a processor 1200 in accordance with aspects of the present disclosure. The processor 1200 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 1200 may include a controller 1202 configured to perform various operations in accordance with examples as described herein. The processor 1200 may optionally include at least one memory 1204, which may

be, for example, an L1/L2/L3 cache. Additionally, or alternatively, the processor 1200 may optionally include one or more arithmetic-logic units (ALUs) 1206. One or more of these components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[0129] The processor 1200 may be a processor chipset and include a protocol stack (e.g., a software stack) executed by the processor chipset to perform various operations (e.g., receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) in accordance with examples as described herein. The processor chipset may include one or more cores, one or more caches (e.g., memory local to or included in the processor chipset (e.g., the processor 1200) or other memory (e.g., random access memory (RAM), read-only memory (ROM), dynamic RAM (DRAM), synchronous dynamic RAM (SDRAM), static RAM (SRAM), ferroelectric RAM (FeRAM), magnetic RAM (MRAM), resistive RAM (RRAM), flash memory, phase change memory (PCM), and others).

[0130] The controller 1202 may be configured to manage and coordinate various operations (e.g., signaling, receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) of the processor 1200 to cause the processor 1200 to support various operations in accordance with examples as described herein. For example, the controller 1202 may operate as a control unit of the processor 1200, generating control signals that manage the operation of various components of the processor 1200. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[0131] The controller 1202 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 1204 and determine subsequent instruction(s) to be executed to cause the processor 1200 to support various operations in accordance with examples as described herein. The controller 1202 may be configured to track memory addresses of instructions associated with the memory 1204. The controller 1202 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 1202 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 1200 to cause the processor 1200 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 1202

may be configured to manage flow of data within the processor 1200. The controller 1202 may be configured to control transfer of data between registers, ALUs 1206, and other functional units of the processor 1200.

[0132] The memory 1204 may include one or more caches (e.g., memory local to or included in the processor 1200 or other memory, such as RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementations, the memory 1204 may reside within or on a processor chipset (e.g., local to the processor 1200). In some other implementations, the memory 1204 may reside external to the processor chipset (e.g., remote to the processor 1200).

[0133] The memory 1204 may store computer-readable, computer-executable code including instructions that, when executed by the processor 1200, cause the processor 1200 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. The controller 1202 and/or the processor 1200 may be configured to execute computer-readable instructions stored in the memory 1204 to cause the processor 1200 to perform various functions. For example, the processor 1200 and/or the controller 1202 may be coupled with or to the memory 1204, the processor 1200, and the controller 1202, and may be configured to perform various functions described herein. In some examples, the processor 1200 may include multiple processors and the memory 1204 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may, individually or collectively, be configured to perform various functions herein.

[0134] The one or more ALUs 1206 may be configured to support various operations in accordance with examples as described herein. In some implementations, the one or more ALUs 1206 may reside within or on a processor chipset (e.g., the processor 1200). In some other implementations, the one or more ALUs 1206 may reside external to the processor chipset (e.g., the processor 1200). One or more ALUs 1206 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 1206 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 1206 may be configured with a variety of logical and arithmetic circuits, including adders, subtractors, shifters, and logic gates, to process and manipulate the data according to the operation. Additionally, or alternatively, the one or more ALUs 1206 may support logical operations such as

AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 1206 to handle conditional operations, comparisons, and bitwise operations.

[0135] The processor 1200 may support wireless communication in accordance with examples as disclosed herein. The processor 1200 may be configured to or operable to support at least one controller (e.g., the controller 1202) coupled with at least one memory (e.g., the memory 1204) and configured to cause the processor to receive, from a positioning equipment, a measurement configuration to conduct one or more uplink channel sample-based measurement profile measurements on a reference signal; and transmit, to the positioning equipment for a positioning estimation, the one or more uplink channel sample-based measurement profile measurements performed on the reference signal based at least in part on the measurement configuration.

[0136] Additionally, the processor 1200 may be configured to or operable to support any one or combination of the measurement configuration indicates one or more types of uplink channel sample-based measurement profiles to be measured. The one or more uplink channel sample-based measurement profile measurements are associated with one or more channel profiles comprising one or more of a PDP, an ADP, an ASF, or a DP. The one or more uplink channel sample-based measurement profile measurements are input data to a machine learning model that determines the positioning estimation. The input data is usable to train the machine learning model to determine the positioning estimation. The positioning equipment is at least one of a location server, a LMF, a UE, or a PRU UE. The reference signal is at least one of a SRS, a SRS for positioning, a MIMO SRS, a PUSCH DM-RS, or a PT-RS. The configuration parameters of the measurement configuration to conduct the one or more uplink channel sample-based measurement profile measurements comprises one or more of power-delay parameters, angle-delay parameters, power-angle parameters, or time of arrival of multiple received signal paths. The at least one controller is configured to cause the processor to maintain the one or more uplink channel sample-based measurement profile measurements as one or more of a 1D, a 2D, a 3D, or a multi-dimensional signature or fingerprint vector that represents a known location of a TRP. The one or more uplink channel sample-based measurement profile measurements include channel profile measurement information determined over a configured bandwidth of the reference signal. The one or more uplink channel sample-based measurement profile measurements are performed within a defined measurement time duration that includes one or more of a start time, a periodicity, an end time, or a

time duration length. The at least one controller is configured to cause the processor to report the one or more uplink channel sample-based measurement profile measurements as a configuration of at least one of a power threshold or a power interval. A number of the one or more uplink channel sample-based measurement profile measurements to be conducted is reduced based at least in part on one or more of a prioritization of TRPs to be measured, one or more quality metrics of a channel profile, or a number of UE reporting the one or more uplink channel sample-based measurement profile measurements. The at least one controller is configured to cause the processor to transmit at least one of the one or more uplink channel sample-based measurement profile measurements and associated one or more measurement quality metrics.

[0137] **Figure 13** illustrates an example of a NE 1300 in accordance with aspects of the present disclosure. The NE 1300 may include a processor 1302, a memory 1304, a controller 1306, and a transceiver 1308. The processor 1302, the memory 1304, the controller 1306, or the transceiver 1308, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. These components may be coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

[0138] The processor 1302, the memory 1304, the controller 1306, or the transceiver 1308, or various combinations or components thereof may be implemented in hardware (e.g., circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

[0139] The processor 1302 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, or any combination thereof). In some implementations, the processor 1302 may be configured to operate the memory 1304. In some other implementations, the memory 1304 may be integrated into the processor 1302. The processor 1302 may be configured to execute computer-readable instructions stored in the memory 1304 to cause the NE 1300 to perform various functions of the present disclosure.

[0140] The memory 1304 may include volatile or non-volatile memory. The memory 1304 may store computer-readable, computer-executable code including instructions when executed by the processor 1302 cause the NE 1300 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as the memory 1304 or another type of memory. Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer.

[0141] In some implementations, the processor 1302 and the memory 1304 coupled with the processor 1302 may be configured to cause the NE 1300 to perform one or more of the functions described herein (e.g., executing, by the processor 1302, instructions stored in the memory 1304). For example, the processor 1302 may support wireless communication at the NE 1300 in accordance with examples as disclosed herein. The NE 1300 may be configured to or operable to support a means for receiving, from a positioning equipment, a measurement configuration to conduct one or more uplink channel sample-based measurement profile measurements on a reference signal; and transmitting, to the positioning equipment for a positioning estimation, the one or more uplink channel sample-based measurement profile measurements performed on the reference signal based at least in part on the measurement configuration.

[0142] Additionally, the NE 1300 may be configured to or operable to support any one or combination of the measurement configuration indicates one or more types of uplink channel sample-based measurement profiles to be measured. The one or more uplink channel sample-based measurement profile measurements are associated with one or more channel profiles comprising one or more of a PDP, an ADP, an ASF, or a DP. The one or more uplink channel sample-based measurement profile measurements are input data to a machine learning model that determines the positioning estimation. The input data is usable to train the machine learning model to determine the positioning estimation. The NE has a known location and is configured as at least one of a gNB, a TRP, a PRU TRP, or a reference TRP. The positioning equipment is at least one of a location server, a LMF, a UE, or a PRU UE. The reference signal is at least one of a SRS, a SRS for positioning, a MIMO SRS, a PUSCH DM-RS, or a PT-RS. The configuration parameters of the measurement configuration to conduct the one or more uplink channel sample-based measurement

profile measurements comprises one or more of power-delay parameters, angle-delay parameters, power-angle parameters, or time of arrival of multiple received signal paths. The method further comprising maintaining the one or more uplink channel sample-based measurement profile measurements as one or more of a 1D, a 2D, a 3D, or a multi-dimensional signature or fingerprint vector that represents a known location of a TRP. The one or more uplink channel sample-based measurement profile measurements include channel profile measurement information determined over a configured bandwidth of the reference signal. The one or more uplink channel sample-based measurement profile measurements are performed within a defined measurement time duration that includes one or more of a start time, a periodicity, an end time, or a time duration length. The method further comprising reporting the one or more uplink channel sample-based measurement profile measurements as a configuration of at least one of a power threshold or a power interval. A number of the one or more uplink channel sample-based measurement profile measurements to be conducted is reduced based at least in part on one or more of a prioritization of TRPs to be measured, one or more quality metrics of a channel profile, or a number of UE reporting the one or more uplink channel sample-based measurement profile measurements. The method further comprising transmitting at least one of the one or more uplink channel sample-based measurement profile measurements and associated one or more measurement quality metrics.

[0143] Additionally, or alternatively, the NE 1300 may support at least one memory (e.g., the memory 1304) and at least one processor (e.g., the processor 1302) coupled with the at least one memory and configured to cause the NE to receive, from a positioning equipment, a measurement configuration to conduct one or more uplink channel sample-based measurement profile measurements on a reference signal; and transmit, to the positioning equipment for a positioning estimation, the one or more uplink channel sample-based measurement profile measurements performed on the reference signal based at least in part on the measurement configuration.

[0144] Additionally, the NE 1300 may be configured to support any one or combination of the measurement configuration indicates one or more types of uplink channel sample-based measurement profiles to be measured. The one or more uplink channel sample-based measurement profile measurements are associated with one or more channel profiles comprising one or more of a PDP, an ADP, an ASF, or a DP. The one or more uplink channel sample-based measurement profile measurements are input data to a machine learning model that determines the positioning

estimation. The input data is usable to train the machine learning model to determine the positioning estimation. The NE has a known location and is configured as at least one of a gNB, a TRP, a PRU TRP, or a reference TRP. The positioning equipment is at least one of a location server, a LMF, a UE, or a PRU UE. The reference signal is at least one of a SRS, a SRS for positioning, a MIMO SRS, a PUSCH DM-RS, or a PT-RS. The configuration parameters of the measurement configuration to conduct the one or more uplink channel sample-based measurement profile measurements comprises one or more of power-delay parameters, angle-delay parameters, power-angle parameters, or time of arrival of multiple received signal paths. The at least one processor is configured to cause the NE to maintain the one or more uplink channel sample-based measurement profile measurements as one or more of a 1D, a 2D, a 3D, or a multi-dimensional signature or fingerprint vector that represents a known location of a TRP. The one or more uplink channel sample-based measurement profile measurements include channel profile measurement information determined over a configured bandwidth of the reference signal. The one or more uplink channel sample-based measurement profile measurements are performed within a defined measurement time duration that includes one or more of a start time, a periodicity, an end time, or a time duration length. The at least one processor is configured to cause the NE to report the one or more uplink channel sample-based measurement profile measurements as a configuration of at least one of a power threshold or a power interval. A number of the one or more uplink channel sample-based measurement profile measurements to be conducted is reduced based at least in part on one or more of a prioritization of TRPs to be measured, one or more quality metrics of a channel profile, or a number of additional UEs reporting the one or more uplink channel sample-based measurement profile measurements. The at least one processor is configured to cause the NE to transmit at least one of the one or more uplink channel sample-based measurement profile measurements and associated one or more measurement quality metrics.

[0145] The controller 1306 may manage input and output signals for the NE 1300. The controller 1306 may also manage peripherals not integrated into the NE 1300. In some implementations, the controller 1306 may utilize an operating system such as iOS®, ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 1306 may be implemented as part of the processor 1302.

[0146] In some implementations, the NE 1300 may include at least one transceiver 1308. In some other implementations, the NE 1300 may have more than one transceiver 1308. The transceiver 1308 may represent a wireless transceiver. The transceiver 1308 may include one or more receiver chains 1310, one or more transmitter chains 1312, or a combination thereof.

[0147] A receiver chain 1310 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 1310 may include one or more antennas to receive a signal over the air or wireless medium. The receiver chain 1310 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 1310 may include at least one demodulator configured to demodulate the received signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receiver chain 1310 may include at least one decoder for decoding the demodulated signal to receive the transmitted data.

[0148] A transmitter chain 1312 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 1312 may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmitter chain 1312 may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmitter chain 1312 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0149] **Figure 14** illustrates an example of a positioning equipment 1400 in accordance with aspects of the present disclosure. The positioning equipment 1400 may include a processor 1402, a memory 1404, a controller 1406, and a transceiver 1408. The processor 1402, the memory 1404, the controller 1406, or the transceiver 1408, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. These components may be coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

[0150] The processor 1402, the memory 1404, the controller 1406, or the transceiver 1408, or various combinations or components thereof may be implemented in hardware (e.g., circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

[0151] The processor 1402 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, or any combination thereof). In some implementations, the processor 1402 may be configured to operate the memory 1404. In some other implementations, the memory 1404 may be integrated into the processor 1402. The processor 1402 may be configured to execute computer-readable instructions stored in the memory 1404 to cause the positioning equipment 1400 to perform various functions of the present disclosure.

[0152] The memory 1404 may include volatile or non-volatile memory. The memory 1404 may store computer-readable, computer-executable code including instructions when executed by the processor 1402 cause the positioning equipment 1400 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as the memory 1404 or another type of memory. Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer.

[0153] In some implementations, the processor 1402 and the memory 1404 coupled with the processor 1402 may be configured to cause the positioning equipment 1400 to perform one or more of the functions described herein (e.g., executing, by the processor 1402, instructions stored in the memory 1404). For example, the processor 1402 may support wireless communication at the positioning equipment 1400 in accordance with examples as disclosed herein. The positioning equipment 1400 may be configured to or operable to support a means for transmitting, to a NE, a measurement configuration to conduct one or more uplink channel sample-based measurement profile measurements on a reference signal; receiving, from the NE, the one or more uplink channel sample-based measurement profile measurements performed on the reference signal based at least in part on the measurement configuration; performing a positioning estimation based at least in part

on the one or more uplink channel sample-based measurement profile measurements; and determining a location of a UE based at least in part on the positioning estimation.

[0154] Additionally, the positioning equipment 1400 may be configured to or operable to support any one or combination of the measurement configuration indicates one or more types of uplink channel sample-based measurement profiles to be measured. The one or more uplink channel sample-based measurement profile measurements are associated with one or more channel profiles comprising one or more of a PDP, an ADP, an ASF, or a DP. The method further comprising using the one or more uplink channel sample-based measurement profile measurements as input data to a machine learning model that determines the positioning estimation. The method further comprising using the input data to train the machine learning model to determine the positioning estimation. The positioning equipment is at least one of a location server, a LMF, the UE, or a PRU UE. The reference signal is at least one of a SRS, a SRS for positioning, a MIMO SRS, a PUSCH DM-RS, or a PT-RS. The configuration parameters of the measurement configuration to conduct the one or more uplink channel sample-based measurement profile measurements comprises one or more of power-delay parameters, angle-delay parameters, power-angle parameters, or time of arrival of multiple received signal paths. The one or more uplink channel sample-based measurement profile measurements include channel profile measurement information determined over a configured bandwidth of the reference signal. The one or more uplink channel sample-based measurement profile measurements are performed within a defined measurement time duration that includes one or more of a start time, a periodicity, an end time, or a time duration length.

[0155] Additionally, or alternatively, the positioning equipment 1400 may support at least one memory (e.g., the memory 1404) and at least one processor (e.g., the processor 1402) coupled with the at least one memory and configured to cause the positioning equipment to transmit, to a NE, a measurement configuration to conduct one or more uplink channel sample-based measurement profile measurements on a reference signal; receive, from the NE, the one or more uplink channel sample-based measurement profile measurements performed on the reference signal based at least in part on the measurement configuration; perform a positioning estimation based at least in part on the one or more uplink channel sample-based measurement profile measurements; and determine a location of a UE based at least in part on the positioning estimation.

[0156] Additionally, the positioning equipment 1400 may be configured to support any one or combination of the measurement configuration indicates one or more types of uplink channel sample-based measurement profiles to be measured. The one or more uplink channel sample-based measurement profile measurements are associated with one or more channel profiles comprising one or more of a PDP, an ADP, an ASF, or a DP. The at least one processor is configured to cause the positioning equipment to use the one or more uplink channel sample-based measurement profile measurements as input data to a machine learning model that determines the positioning estimation. The at least one processor is configured to cause the positioning equipment to use the input data to train the machine learning model to determine the positioning estimation. The positioning equipment is at least one of a location server, a LMF, the UE, or a PRU UE. The reference signal is at least one of a SRS, a SRS for positioning, a MIMO SRS, a PUSCH DM-RS, or a PT-RS. The configuration parameters of the measurement configuration to conduct the one or more uplink channel sample-based measurement profile measurements comprises one or more of power-delay parameters, angle-delay parameters, power-angle parameters, or time of arrival of multiple received signal paths. The one or more uplink channel sample-based measurement profile measurements include channel profile measurement information determined over a configured bandwidth of the reference signal. The one or more uplink channel sample-based measurement profile measurements are performed within a defined measurement time duration that includes one or more of a start time, a periodicity, an end time, or a time duration length.

[0157] The controller 1406 may manage input and output signals for the positioning equipment 1400. The controller 1406 may also manage peripherals not integrated into the positioning equipment 1400. In some implementations, the controller 1406 may utilize an operating system such as iOS®, ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 1406 may be implemented as part of the processor 1402.

[0158] In some implementations, the positioning equipment 1400 may include at least one transceiver 1408. In some other implementations, the positioning equipment 1400 may have more than one transceiver 1408. The transceiver 1408 may represent a wireless transceiver. The transceiver 1408 may include one or more receiver chains 1410, one or more transmitter chains 1412, or a combination thereof.

[0159] A receiver chain 1410 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 1410 may include one or more antennas to receive a signal over the air or wireless medium. The receiver chain 1410 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 1410 may include at least one demodulator configured to demodulate the received signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receiver chain 1410 may include at least one decoder for decoding the demodulated signal to receive the transmitted data.

[0160] A transmitter chain 1412 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 1412 may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmitter chain 1412 may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmitter chain 1412 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0161] **Figure 15** illustrates a flowchart of a method 1500 in accordance with aspects of the present disclosure. The operations of the method may be implemented by a NE as described herein. In some implementations, the NE may execute a set of instructions to control the function elements of the NE to perform the described functions. It should be noted that the method described herein describes a possible implementation, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible.

[0162] At 1502, the method may include receiving, from a positioning equipment, a measurement configuration to conduct one or more uplink channel sample-based measurement profile measurements on a reference signal. The operations of 1502 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1502 may be performed by a NE as described with reference to Figure 13.

[0163] At 1504, the method may include transmitting, to the positioning equipment for a positioning estimation, the one or more uplink channel sample-based measurement profile measurements performed on the reference signal based on the measurement configuration. The operations of 1504 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1504 may be performed by a NE as described with reference to Figure 13.

[0164] **Figure 16** illustrates a flowchart of a method 1600 in accordance with aspects of the present disclosure. The operations of the method may be implemented by a positioning equipment as described herein. In some implementations, the positioning equipment may execute a set of instructions to control the function elements of the positioning equipment to perform the described functions. It should be noted that the method described herein describes a possible implementation, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible.

[0165] At 1602, the method may include transmitting, to a NE, a measurement configuration to conduct one or more uplink channel sample-based measurement profile measurements on a reference signal. The operations of 1602 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1602 may be performed by a positioning equipment as described with reference to Figure 14.

[0166] At 1604, the method may include receiving, from the NE, the one or more uplink channel sample-based measurement profile measurements performed on the reference signal based on the measurement configuration. The operations of 1604 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1604 may be performed by a positioning equipment as described with reference to Figure 14.

[0167] At 1606, the method may include performing a positioning estimation based on the one or more uplink channel sample-based measurement profile measurements. The operations of 1606 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1606 may be performed by a positioning equipment as described with reference to Figure 14.

[0168] At 1608, the method may include determining a location of a UE based at least in part on the positioning estimation. The operations of 1608 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1608 may be performed a positioning equipment as described with reference to Figure 14

[0169] The description herein is provided to enable a person having ordinary skill in the art to make or use the disclosure. Various modifications to the disclosure will be apparent to a person having ordinary skill in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not limited to the examples and designs described herein but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.

CLAIMS

What is claimed is:

1. A network equipment (NE) for wireless communication, comprising:
at least one memory; and
at least one processor coupled with the at least one memory and operable to cause the NE to:
receive, from a positioning equipment, a measurement configuration to
conduct one or more uplink channel sample-based measurement profile
measurements on a reference signal; and
transmit, to the positioning equipment for a positioning estimation, the one or
more uplink channel sample-based measurement profile measurements performed on
the reference signal based at least in part on the measurement configuration.
2. The NE of claim 1, wherein the measurement configuration indicates one or more
types of uplink channel sample-based measurement profiles to be measured.
3. The NE of claim 1, wherein the one or more uplink channel sample-based
measurement profile measurements are associated with one or more channel profiles comprising
one or more of a power delay profile (PDP), an angular delay profile (ADP), an angle spectrum
function (ASF), or a delay profile (DP).
4. The NE of claim 1, wherein the one or more uplink channel sample-based
measurement profile measurements are input data to a machine learning model that determines the
positioning estimation, and wherein the input data is usable to train the machine learning model to
determine the positioning estimation.
5. The NE of claim 1, wherein:
the NE has a known location and is configured as at least one of a gNB, a transmission-
reception point (TRP), a positioning reference unit (PRU) TRP, or a reference TRP; and
the positioning equipment is at least one of a location server, a location management
function (LMF), a user equipment (UE), or a positioning reference unit (PRU) UE.

6. The NE of claim 1, wherein the reference signal is at least one of a sounding reference signal (SRS), a SRS for positioning, a multiple-input multiple-output (MIMO) SRS, a physical uplink shared channel (PUSCH) demodulation reference signal (DM-RS), or a phase tracking reference signal (PT-RS).

7. The NE of claim 1, wherein configuration parameters of the measurement configuration to conduct the one or more uplink channel sample-based measurement profile measurements comprises one or more of power-delay parameters, a start sample, a length of samples, a number of samples, a sampling resolution, an end sample, or time of arrival of multiple received signal paths.

8. The NE of claim 1, wherein the at least one processor is operable to cause the NE to maintain the one or more uplink channel sample-based measurement profile measurements as one or more of a one-dimensional (1D), a two-dimensional (2D), a three-dimensional (3D), or a multi-dimensional signature or fingerprint vector that represents a known location of a transmission-reception point (TRP).

9. The NE of claim 1, wherein the one or more uplink channel sample-based measurement profile measurements include channel profile measurement information determined over a configured bandwidth of the reference signal.

10. The NE of claim 1, wherein the one or more uplink channel sample-based measurement profile measurements are performed within a defined measurement time duration that includes one or more of a start time, a periodicity, an end time, a start sample, a length of samples, an end sample, a power threshold, a power threshold interval, or a time duration length.

11. The NE of claim 1, wherein the at least one processor is operable to cause the NE to report the one or more uplink channel sample-based measurement profile measurements as a configuration of at least one of a power threshold or a power interval.

12. The NE of claim 1, wherein a number of the one or more uplink channel sample-based measurement profile measurements to be conducted is reduced based at least in part on one or more of a prioritization of transmission-reception points (TRPs) to be measured, one or more quality metrics of a channel profile, or a number of additional UEs reporting the one or more uplink channel sample-based measurement profile measurements.

13. The NE of claim 1, wherein the at least one processor is operable to cause the NE to transmit at least one of the one or more uplink channel sample-based measurement profile measurements and associated one or more measurement quality metrics.

14. A method performed by a network equipment (NE), the method comprising:
receiving, from a positioning equipment, a measurement configuration to conduct one or more uplink channel sample-based measurement profile measurements on a reference signal; and
transmitting, to the positioning equipment for a positioning estimation, the one or more uplink channel sample-based measurement profile measurements performed on the reference signal based at least in part on the measurement configuration.

15. A positioning equipment for wireless communication, comprising:
at least one memory; and
at least one processor coupled with the at least one memory and operable to cause the positioning equipment to:

transmit, to a network equipment (NE), a measurement configuration to conduct one or more uplink channel sample-based measurement profile measurements on a reference signal;

receive, from the NE, the one or more uplink channel sample-based measurement profile measurements performed on the reference signal based at least in part on the measurement configuration;

perform a positioning estimation based at least in part on the one or more uplink channel sample-based measurement profile measurements; and

determine a location of a user equipment (UE) based at least in part on the positioning estimation.

16. The positioning equipment of claim 15, wherein the measurement configuration indicates one or more types of uplink channel sample-based measurement profiles to be measured.

17. The positioning equipment of claim 15, wherein the one or more uplink channel sample-based measurement profile measurements are associated with one or more channel profiles comprising one or more of a power delay profile (PDP), an angular delay profile (ADP), an angle spectrum function (ASF), or a delay profile (DP).

18. The positioning equipment of claim 15, wherein the at least one processor is operable to cause the positioning equipment to:

- use the one or more uplink channel sample-based measurement profile measurements as input data to a machine learning model that determines the positioning estimation; and
- use the input data to train the machine learning model to determine the positioning estimation.

19. The positioning equipment of claim 15, wherein:
the positioning equipment is at least one of a location server, a location management function (LMF), the UE, or a positioning reference unit (PRU) UE; and

the reference signal is at least one of a sounding reference signal (SRS), a SRS for positioning, a multiple-input multiple-output (MIMO) SRS, a physical uplink shared channel (PUSCH) demodulation reference signal (DM-RS), or a phase tracking reference signal (PT-RS).

20. A method performed by a positioning equipment, the method comprising:
transmitting, to a network equipment (NE), a measurement configuration to conduct one or more uplink channel sample-based measurement profile measurements on a reference signal;

receiving, from the NE, the one or more uplink channel sample-based measurement profile measurements performed on the reference signal based at least in part on the measurement configuration;

performing a positioning estimation based at least in part on the one or more uplink channel sample-based measurement profile measurements; and

determining a location of a user equipment (UE) based at least in part on the positioning estimation.