

USER EQUIPMENT LOCATION DETERMINATION

TECHNICAL FIELD

[0001] The present disclosure relates to wireless communications, and more specifically to positioning methods.

BACKGROUND

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

SUMMARY

[0003] An article “a” before an element is unrestricted and understood to refer to “at least one” of those elements or “one or more” of those elements. The terms “a,” “at least one,” “one or more,” and “at least one of one or more” may be interchangeable. As used herein, including in the claims, “or” as used in a list of items (e.g., a list of items prefaced by a phrase such as “at least one of” or “one or more of” or “one or both of”) indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase “based on” shall not be construed as a reference to a closed set of conditions. For example, an example step that is described as “based on condition A” may be based on both a condition A and a condition B without departing from the scope of the present disclosure. In other words, as

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

[0004] Some implementations of the method and apparatuses described herein may include a method performed by a network entity, the method comprising: receiving a request message for a location of a user equipment (UE); obtaining a machine learning (ML) model for positioning based at least in part on the request message, wherein the ML model comprises a set of one or more constraints, wherein the set of one or more constraints is based at least in part on a set of one or more capabilities of the UE; determining the location of the UE according to the ML model; and transmitting a response message that indicates the location of the UE.

[0005] The request message may comprise one or more of a required accuracy of the location and a duration for reporting the location of the UE, and the method may further comprise: transmitting a request message for the ML model, wherein the request message for the ML model indicates one or more of the required accuracy of the location of the UE, the duration for reporting the location of the UE, and the set of one or more constraints.

[0006] The method may further comprise receiving, from a network repository entity, an indication of a set of one or more network entities that support the ML model associated with the set of one or more constraints; selecting a network entity from the set of one or more network entities; and transmitting the request message for the ML model to the selected network entity.

[0007] Transmitting the request message for the ML model may comprise transmitting to a location management function the request message for the ML model.

[0008] Obtaining the ML model may comprise receiving the ML model.

[0009] Obtaining the ML model may comprise: receiving an indication of a network location where the ML model is stored; and retrieving the ML model from the network location.

[0010] The method may further comprise receiving the set of one or more capabilities, wherein the set of one or more capabilities comprises one or more of a positioning

procedure supported by the UE, and a condition associated with a radio environment supported by the UE.

[0011] The method may further comprise receiving a set of one or more capabilities of a radio access network (RAN) node serving the UE, and receiving a set of one or more capabilities of a set of one or more positioning reference UEs (PRUs), wherein the set of one or more constraints of the ML model is based at least in part on the set of one or more capabilities of the RAN node and the set of one or more capabilities of the set of one or more PRUs.

[0012] The set of one or more constraints may comprise one or more of: a location area validity for the ML model; a time of day validity for the ML model; a positioning procedure; an accuracy positioning accuracy quality; a model inference latency; a type of data as an input for the ML model; and a functionality ID corresponding to the constraints according to a predetermined scheme.

[0013] The method may further comprise: obtaining positioning measurement data from one or more of the UE, a radio access network (RAN) node, and a set of one or more positioning reference UEs (PRUs), wherein an input to the ML model comprises the positioning measurement data; optionally wherein the positioning measurement data includes reference signal information.

[0014] The network entity may comprise a location management function (LMF).

[0015] Some implementations of the method and apparatuses described herein may further include a network entity configured to: receive a request message for a location of a user equipment (UE); obtain a machine learning (ML) model for positioning based at least in part on the request message, wherein the ML model comprises a set of one or more constraints, wherein the set of one or more constraints is based at least in part on a set of one or more capabilities of the UE; determine the location of the UE according to the ML model; and transmit a response message that indicates the location of the UE.

[0016] Some implementations of the method and apparatuses described herein may further include a method performed by a network entity, the method comprising: receiving a request message for a machine learning (ML) model, the request message comprising

constraints of the ML model; obtaining an ML model comprising the constraints; and transmitting a response message, the response message comprising either (i) the ML model or (ii) an indication of a network location wherein the ML model can be accessed.

[0017] Obtaining the ML model may comprise training a new ML model comprising the constraints.

[0018] Training the new ML model may comprise collecting training information from one or more of: an analytic data repository function (ADRF); operations, administration and maintenance (OAM) processes; or a user equipment (UE).

[0019] Obtaining the ML model may comprise selecting an existing ML model comprising the constraints.

[0020] The method may further comprise assigning a model ID to the ML model.

[0021] The network entity may be a location management function (LMF) or a network data analytics function (NWDAF).

[0022] The request message may be received from a location management function (LMF) of the communications network.

[0023] Some implementations of the method and apparatuses described herein may further include a network entity configured to: receive a request message for a machine learning (ML) model, the request message comprising constraints of the ML model; obtain an ML model comprising the constraints; and transmit a response message, the response message comprising either (i) the ML model or (ii) an indication of a network location wherein the ML model can be accessed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] Fig. 1 illustrates an example of a wireless communications system in accordance with aspects of the present disclosure.

[0025] Fig. 2 shows a network architecture in accordance with aspects of the present disclosure.

[0026] Fig. 3 illustrates a process for locating a UE in accordance with aspects of the present disclosure.

[0027] Fig. 4 shows a further network architecture in accordance with aspects of the present disclosure.

[0028] Fig. 5 illustrates a further process for locating a UE in accordance with aspects of the present disclosure.

[0029] Fig. 6 illustrates an example of a user equipment (UE) in accordance with aspects of the present disclosure.

[0030] Fig. 7 illustrates an example of a processor in accordance with aspects of the present disclosure.

[0031] Fig. 8 illustrates an example of a network equipment (NE) in accordance with aspects of the present disclosure.

[0032] Fig. 9 illustrates a method for locating a UE in accordance with aspects of the present disclosure.

[0033] Fig. 10 illustrates a further method for locating a UE in accordance with aspects of the present disclosure.

[0034] Fig. 11 illustrates an example of direct AIML positioning.

[0035] Figs. 12A-12C illustrate an example of assisted AIML positioning.

[0036] Fig. 13 illustrates a network architecture.

DETAILED DESCRIPTION

[0037] The inventors have recognised that machine learning (ML) and more generally artificial intelligence (AI), referred to collectively as AIML, may be used to improve positioning in communications networks, especially the locating of a particular user equipment (UE).

[0038] In existing communications systems, positioning is often handled by a location management function (LMF). This is a network entity that can be queried when a particular

location needs to be determined. The LMF may use any of various known methods to determine the requested location, which is then returned to the requester.

[0039] Some systems may make use of AIML-assisted positioning. In this scheme, the location returned by the LMF may be enhanced using an ML model implemented elsewhere in the communications network.

[0040] However, the inventors have recognised that such a scheme is still limited by the accuracy of the location originally returned by the LMF, which is generally determined using legacy methods (e.g. without the use of AIML).

[0041] Implementing AIML at an earlier stage, e.g. by providing the LMF with an ML model to be used in the original determination of the UE position, may therefore provide the benefit of more accurate and precise positioning in a communications network.

[0042] Additionally, the use of AIML may allow for more accurate determination of the locations of UEs that are not able to provide accurate measurement data. For example, if a UE is only able to provide non-line of sight measurements obtained from a RAN node, methods using AIML may be able to improve the accuracy of these measurements.

[0043] Regarding AIML functionality identifications, it may be that a UE indicates what AIML functionality is supported. Particular supported models may be identified using a model ID.

[0044] The term “direct AIML positioning” may be used to refer to cases where a UE location is the output of an AIML model, with the assumption that there is an ML model at the UE or the LMF that is used to predict a location. “AIML assisted positioning” may refer to cases wherein an AI/ML model output can be a new measurement and/or an enhancement of an existing measurement, wherein e.g. AI/ML models are used by a UE or a gNB.

[0045] Within this framework, AIML positioning may be categorized as follows.

[0046] Case 1: UE-based positioning with UE-side model, direct AI/ML or AI/ML assisted positioning.

[0047] Case 2a: UE-assisted/LMF-based positioning with UE-side model, AI/ML assisted positioning.

[0048] Case 2b: UE-assisted/LMF-based positioning with LMF-side model, direct AI/ML positioning.

[0049] Case 3a: NG-RAN node assisted positioning with gNB-side model, AI/ML assisted positioning.

[0050] Case 3b: NG-RAN node assisted positioning with LMF-side model, direct AI/ML positioning.

[0051] In some examples, "one-sided" model use is prioritised, wherein inference (the use of AIML models) is performed entirely at a UE or at the network.

[0052] In particular, case 1 is mainly focused on using UE-side models for Direct AI/ML or AI/ML assisted positioning.

[0053] Cases 2a and 3a indicate that AI/ML assisted positioning is mainly used with UE-side and/or gNB-side ML models, primarily to enhance the measurements provided at the LMF for deriving location estimates (e.g. more accurate measurements taking into account NLOS conditions). Since the ML model needs to be trained either at UE(-side) or gNB(-side), this requires defining data collection mechanisms for UE and RAN as well as procedure for model delivery/transfer to UE/gNB and model identification/management.

[0054] Cases 2b and 3b indicate that LMF-side models are used for Direct AI/ML positioning either by collecting raw data or "AI/ML enhanced data" from UE and/or gNB to derive a location. The ML-model is trained at LMF-side (or CN in general). The LMF-side models used can be trained either with raw data or AI/ML enhanced data.

[0055] Fig. 11 illustrates an example of direct AIML positioning.

[0056] Figs. 12A-12C illustrate various implementations of assisted AIML positioning.

[0057] Fig. 13 illustrates a network architecture that may allow data collection relating to the use of network data analytics functions (NWDAFs). In some cases, an AnLF requests a trained ML model from the MTLF by including in the request an Analytic ID

corresponding to the Analytic ID requested by an analytics consumer. Information on the available Analytic ID(s) supported by an AnLF is provided in 3GPP TS 23.288. The MTLF trains an ML model corresponding to the Analytic ID requested by collecting data from one or more data sources (NF, OAM or UEs).

[0058] Aspects of the present disclosure are described in the context of a wireless communications system. For Direct AI/ML positioning the assumption is that there is an ML model at the UE or the LMF that is used to predict a location.

[0059] Fig. 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.

[0060] The one or more NE 102 may be dispersed throughout a geographic region to form the wireless communications system 100. One or more of the NE 102 described herein may be or include or may be referred to as a network node, a base station, a network element, a network function, a network entity, a radio access network (RAN), a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. An NE 102 and a UE 104 may communicate via a communication link, which may be a wireless or

wired connection. For example, an NE 102 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface.

[0061] An NE 102 may provide a geographic coverage area for which the NE 102 may support services for one or more UEs 104 within the geographic coverage area. For example, an NE 102 and a UE 104 may support wireless communication of signals related to services (e.g., voice, video, packet data, messaging, broadcast, etc.) according to one or multiple radio access technologies. In some implementations, an NE 102 may be moveable, for example, a satellite associated with a non-terrestrial network (NTN). In some implementations, different geographic coverage areas 112 associated with the same or different radio access technologies may overlap, but the different geographic coverage areas may be associated with different NE 102.

[0062] The one or more UE 104 may be dispersed throughout a geographic region of the wireless communications system 100. A UE 104 may include or may be referred to as a remote unit, a mobile device, a wireless device, a remote device, a subscriber device, a transmitter device, a receiver device, or some other suitable terminology. In some implementations, the UE 104 may be referred to as a unit, a station, a terminal, or a client, among other examples. Additionally, or alternatively, the UE 104 may be referred to as an Internet-of-Things (IoT) device, an Internet-of-Everything (IoE) device, or machine-type communication (MTC) device, among other examples.

[0063] A UE 104 may be able to support wireless communication directly with other UEs 104 over a communication link. For example, a UE 104 may support wireless communication directly with another UE 104 over a device-to-device (D2D) communication link. In some implementations, such as vehicle-to-vehicle (V2V) deployments, vehicle-to-everything (V2X) deployments, or cellular-V2X deployments, the communication link 114 may be referred to as a sidelink. For example, a UE 104 may support wireless communication directly with another UE 104 over a PC5 interface.

[0064] 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, N2, or network interface). In some implementations, the NE 102 may communicate with each other directly. In some other

implementations, the NE 102 may communicate with each other or 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).

[0065] 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.

[0066] The CN 106 may communicate with a packet data network over one or more backhaul links (e.g., via an S1, N2, N2, or another network interface). The packet data network may include an application server. In some implementations, one or more UEs 104 may communicate with the application server. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or the like) with the CN 106 via an NE 102. The CN 106 may route traffic (e.g., control information, data, and the like) between the UE 104 and the application server using the established session (e.g., the established PDU session). The PDU session may be an example of a logical connection between the UE 104 and the CN 106 (e.g., one or more network functions of the CN 106).

[0067] 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.

[0068] 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.

[0069] 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.

[0070] 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.

[0071] 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.

[0072] 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.

[0073] Fig. 2 illustrates an example of a network architecture 200 in accordance with aspects of the present disclosure. In some implementations, the network architecture 200 may implement or be implemented by aspects of the wireless communication system 100 described herein with reference to Figure 1.

[0074] The network architecture 200 comprises a first LMF 202 and a second LMF 204, also referred to herein as an LMF-T (training LMF) 202 and an LMF-I (inference LMF) 204. The two LMFs 202, 204 may be able to contact a network exposure function (NEF) 216. Each LMF 202, 204 may also be able to access various data sources 212, 214, such as e.g. an analytic data repository function (ADRF) and various administration and maintenance (OAM) processes of the communications network. The network architecture 200 may further comprise one or more user equipment (UEs) devices 206 (which may correspond to a UE 104 as described herein with reference to Figure 1), as well as one or more radio access network (RAN) nodes 208 (which may correspond to a NE 102 as described herein with reference to Figure 1). Each LMF 202, 204 may be able to access one or more UEs 206 and one or more RAN nodes 208. The network architecture 200 may also comprise an access and mobility management function (AMF) 210, which may be accessible to each of the LMFs 202, 204.

[0075] The LMF-T 202 may be configured to train ML models. The LMF-T 202 may also have access to a number of existing ML models which have been trained previously. These existing models may, for example, be stored in various locations that are accessible via the network.

[0076] The LMF-T 202 may be configured to obtain training data for training ML models. For example, the LMF-T 202 may access data sources 214 as described above, as well as e.g. UEs 206 and RAN nodes 208 of the network, to obtain training data. This training data may generally be positioning data, such as for example reference signal information (as generally defined in, for example, 3GPP TS 37.355 and 3GPP TS 38.355).

[0077] In some embodiments, the LMF-T 202 may be part of the core network 106, as shown in Fig. 2. Alternatively, the LMF-T 202 may be outside the core network 106. This is discussed in more detail below with reference to Fig. 3. In some embodiments the LMF-T may be part of the functionality of an NWDAF. In some embodiments the LMF-T may be part of a functionality of a Model Training Logical Function (MTLF) within the NWDAF.

[0078] The LMF-I 204 may be configured to make use of ML models in determining locations, for example in determining the location of a UE 206.

[0079] Fig. 3 illustrates a process 300 for locating a UE in accordance with aspects of the present disclosure. The process 300 may, for example, be implemented using the network architecture 200 of Fig. 2.

[0080] At step S306, a location request may be sent to the AMF 210. This request may originate directly from a client 304, or may e.g. arrive via a gateway mobile location centre (GMLC). The location request may be a request to determine and report the location of a particular UE 206.

[0081] The location request may include a set of requirements for the positioning process. For example, the location of the UE may be needed with a particular precision. Additionally or alternatively, the client 304 may require the location within a specified time.

[0082] At step S308, the AMF 210 may select an LMF that the location request will be forwarded to for handling. For example, the AMF 210 may select the LMF-I 204 of network architecture 200 as described above.

[0083] At step S310, the location request may be forwarded to the selected LMF. Taking the example whereby the LMF-I 204 is selected, at step S310 the AMF 210 transmits a location request to the LMF-I 204.

[0084] At step S312, the LMF-I 204 may establish communication with the UE 206 that is to be located, and one or more positioning reference UEs (PRUs) 302. The LMF-I 204 may use this connection to retrieve several capabilities of the UE 206 and PRUs 302,

such as for example which positioning methods the UE 206 and/or PRUs 302 are able to support, what the current radio environment conditions of the UE 206 and/or PRUs 302 are, and whether or not the UE 206 and/or any PRUs 302 are able to use ML models to enhance positioning (for example to derive effective line-of-sight measurements from non-line of sight data). Example radio environment conditions may include indication that the UE is indoors, that the UE is able to provide non-line of sight measurement data, or that the UE is mobile.

[0085] Merely to provide context, it is noted that positioning methods supported by the UE 206 may include RAT-dependent positioning techniques such as TDOA, Multi-RTT, or sidelink positioning procedures; or may include RAT-independent positioning methods such as GNSS, Wi-Fi, or Bluetooth.

[0086] The LMF-I 204 may also communicate with one or more RAN nodes 208, and retrieve capabilities of the RAN node(s) 208. For example, the LMF-I 204 may contact a RAN node 208 that serves the UE 206 and the PRUs 302. If the UE 206 and the PRUs 302 are served by more than one RAN node 208, the LMF-I 204 may obtain capabilities of each RAN node 208 that serves at least one PRU 302 or the UE 206.

[0087] At step S314, the LMF-I 204 may optionally determine whether direct AIML positioning is an appropriate method for use in handling the location request.

[0088] The determination performed at step S314 may be based on the location requirements included in the location request. For example, if the location request includes a required precision that indicates only very low precision is required, the LMF-I 204 may determine that AIML positioning is unnecessary. However, if the location request includes a required precision that indicates high precision is needed, the LMF-I 204 may be more likely to use AIML positioning. Additionally or alternatively, the determination performed at step S314 may be based on the capabilities of the UE 206 that were determined at step S312, as well as any capabilities of PRUs 302 and/or RAN nodes 208. For example, if the UE 206 is not able to provide positioning information that is suitable as an input for an ML model, the LMF-I 204 may determine that AIML positioning is not appropriate. Additionally or alternatively, the determination performed at step S314 may be based on the radio environment conditions of the UE 206. Example radio environment conditions

may include an indication that the UE 206 is indoors, that the UE 206 is able to provide only non-line of sight measurement data, or that the UE 206 is mobile.

[0089] For general context, it is noted that positioning information provided by the UE 206 may generally be in accordance with definitions provided in 3GPP TS 37.355 (NR positioning measurement information) and 3GPP TS 38.355 (sidelink positioning measurement information). Additionally or alternatively, positioning information may include channel observation fingerprinting as described in 3GPP TR 38843 that is used as input data of an ML model.

[0090] The LMF-I 204 may determine a set of requirements (otherwise referred to herein as constraints) of the model that is needed. These requirements may be determined from any requirements included in the location request, and any capabilities of the UE 206, PRUs 302, or RAN nodes 208 that have been determined, and/or the radio environment conditions of the UE 206.

[0091] For example, the requirements of the model may include that the model is able to provide location estimates with precision that meets a required precision included in the location request.

[0092] Additionally or alternatively, the requirements of the model may include a specified model inference latency; that is, a time within which the model is expected to be able to provide a position estimate.

[0093] Additionally or alternatively, the requirements of the model may include the use of a particular positioning method. For example, if the UE 206 is only able to support a particular positioning method, the ML model may need to support the same positioning method.

[0094] Additionally or alternatively, the requirements of the model may include validity for use with the UE 206. For example, the model may need to be able to operate within the particular area of interest where the UE 206 is believed to be (e.g. the area served by a RAN node 208 that is known to serve the UE 206), or may need to be valid at a particular time of day. As another example, the model may need to be valid within a particular zone ID corresponding to the UE 206. As another example, the model may need

to be able to account for a UE 206 that is indoors, and therefore unable to provide line-of-sight measurements that may generally allow better estimation of the location of a UE.

[0095] Additionally or alternatively, the requirements of the model may include the type of inputs that the model needs in order to operate. For example, if the only positioning information that the UE 206 can provide is a particular type of reference signal information, the model may need to be able to operate using this type of reference signal information as an input.

[0096] The requirements of the model may optionally be expressed in an identifier, referred to herein as a functionality ID. The functionality ID may be an analytics ID intended for use with an NWDAF and compatible with the LMF-T 202. Alternatively, the functionality ID may be an ID indicating mapping to some or all of the above-described requirements within a predetermined scheme.

[0097] Depending on the requirements, the LMF-I 204 may determine that more than one ML model is required. In that case, a separate list of requirements may be determined for each model.

[0098] Multiple ML models may be beneficial to allow for higher precision, or they may be required if a client 304 requests the location of multiple UEs 206.

[0099] At step S316, the LMF-I 204 may determine that it is necessary to request a trained ML model for use in locating the UE 206. For example, if the LMF-I 204 has access to any previously obtained ML models, the LMF-I 204 may determine that none of the previously obtained models meets the requirements.

[0100] At step S318, the LMF-I 204 may select another network entity from which to request the ML model. This may, for example, be the LMF-T 202.

[0101] In order to select where the ML model should be requested from, the LMF-I 204 may contact a network repository function (not shown) and provide the requirements of the model to the network repository function. In some embodiments requirements of the model may include the accuracy requirements received at step S306 and/or determined radio environment conditions (e.g. non-line of sight scenario) and/or retrieved capabilities

received in step S312. The network repository function may use these requirements to provide the LMF-I 204 with a list of network entities that may be suitable for training and providing a model that meets the requirements of the model. The LMF-I 204 may then select a network entity, such as the LMF-T 202, from this list.

[0102] At step S320, the LMF-I 204 may transmit a request for an ML model that meets the determined model requirements to the selected network entity. For example, the LMF-I 204 may transmit the model request to the LMF-T 202.

[0103] At step S322, the LMF-T 202 may obtain an ML model that meets the requirements. This may be done by first determining whether an ML model meeting the requirements is already available. If so, the LMF-T 202 may select such an existing model. If not, the LMF-T 202 may train a new model.

[0104] In the case where the LMF-I 204 has requested multiple models, the LMF-T 202 may perform step S322 for each of the requested models.

[0105] At step S324, if it is determined that a suitable model does not exist and a new model needs to be trained, the LMF-T 202 may train a new model as described above with reference to Fig. 2. The LMF-T 202 may train the ML model according to the requirements received in step S320.

[0106] At step S326, the LMF-T 202 may assign a model ID to any newly trained model. The model ID may, for example, allow for the model to be identified and distinguished from other ML models. That is a model ID may be a unique identifier.

[0107] Any newly trained model may optionally be stored in a data storage location accessible via the network. For example, such a model may be stored in an analytics data repository function (ADRF) of the core network 106.

[0108] At step S328, the LMF-T 202 may transmit a response to the model request back to the LMF-I 204. The response may either contain a model file of the model itself, or an indication of a storage location where the model has been stored and can be accessed. The LMF-I 204 may use this response to obtain the ML model (or multiple ML models if multiple ML models were requested).

[0109] At step S330, the LMF-I 204 may use the ML model to determine the location of the UE 206. This may be done by providing the ML model with positioning data as an input into the ML model. For example, positioning data may be obtained from the UE 206, the PRU 302, and/or a RAN node 208, or any or all of these options, to serve as a model input.

[0110] At step S332, the LMF-I 204 may respond to the AMF 210 by providing the location that was determined using the model.

[0111] At step S334, the AMF 210 may transmit the location provided by the LMF-I 204 to the client 304.

[0112] Step S336 indicates an alternative aspect of the disclosure. In some implementations, the LMF-I 204 may not request a model from the LMF-T 202. Instead, the LMF-T 202 may provide a trained ML model to the LMF-I 204 without such a request being sent. For example, the LMF-T 202 may provide an ML model to the LMF-T 204 at regular intervals (e.g. periodically).

[0113] In this alternative aspect, the LMF-I 204 may need to subscribe to the LMF-T 202 in order to receive periodic ML models from the LMF-T 202. As part of subscribing, the LMF-I 204 may specify to the LMF-T 202 how frequently models should be provided, and/or how the models should be trained.

[0114] It is envisioned that this aspect may be of particular use when the LMF-T 202 is not part of the core network 106 of the network architecture 200, but exists outside the core network as a subscription service for ML models for use in positioning.

[0115] For example, each ML model that is provided by the LMF-T 202 may have different capabilities and functionalities, such that the provided ML models may meet the requirements of various different location requests over time.

[0116] It is then envisioned that if, upon receipt of a particular location request, the LMF-I 204 determines that a suitable model has not yet been provided by the LMF-T 202, the LMF-I 204 may then determine the position of the UE 206 using legacy (non-ML based) methods. Alternatively, if the LMF-T 202 has already prepared a suitable model, the

LMF-I may then use that model to determine the location of the UE 206 as otherwise described herein.

[0117] LMF-T 202 may provide the ML model either by transmitting the model file directly or by indicating a storage location where the model may be accessed.

[0118] Fig. 4 illustrates an alternative network architecture 400 that is in accordance with a further aspect of the present disclosure.

[0119] The network architecture 400 may comprise an LMF 404, a network data analytic function (NWDAF) 402, data sources 412, 414, UEs 406, RAN nodes 408, and/or an AMF 410.

[0120] The data sources 412, 414, UEs 406, RAN nodes 408, and AMF 410 of the network architecture 400 may be substantially the same as the corresponding elements of the network architecture 200 described above with reference to Fig. 2.

[0121] The LMF 404 may be configured to receive location requests from the AMF 410 and estimate locations of UEs 406, for example using legacy (non-AI based) methods. The LMF 404 may be further configured to request analytics assistance from the NWDAF 402, for example to enhance position estimates prepared by the LMF.

[0122] The NWDAF 402 may be configured to train ML models and perform inference using the trained ML models. For example, the NWDAF 402 may be configured to train ML models for use in positioning, and to perform inference using the trained models to generate or refine position estimates. Generally speaking, the techniques and data sources used by the NWDAF 402 to train ML models are envisioned to be the same as those used by the LMF-T 202 described above with reference to Figs. 2 and 3.

[0123] Fig. 5 illustrates a process 500 for locating a UE in accordance with aspects of the present disclosure. The process 500 may, for example, be implemented using the network architecture 400 of Fig. 4.

[0124] At step S506, a location request may be sent to the AMF 410. This request may originate directly from a client 504, or may e.g. arrive via a gateway mobile location centre

(GMLC). The location request may be a request to determine and report the location of a particular UE 406.

[0125] The location request may include a set of requirements for the positioning process. For example, the location of the UE may be needed with a particular precision. Additionally or alternatively, the client 504 may require the location within a specified time.

[0126] At step S508, the AMF 410 may select an LMF that the location request will be forwarded to for handling.

[0127] At step S510, the location request may be forwarded to the selected LMF. For example, the AMF 410 may select the LMF 404 of network architecture 400 as described above.

[0128] At step S512, the LMF 404 may establish communication with the UE 406 that is to be located, and one or more positioning reference UEs (PRUs) 502. The LMF 404 may use this connection to retrieve several capabilities of the UE 406 and PRUs 502, such as for example which positioning methods the UE 406 and/or PRUs 502 are able to support, and what the current radio environment conditions of the UE 406 and/or PRUs 502 are.

[0129] The LMF 404 may also communicate with one or more RAN nodes 408, and retrieve capabilities of the RAN node(s) 408. For example, the LMF 404 may contact a RAN node 408 that serves the UE 406 and the PRUs 502. If the UE 406 and the PRUs 502 are served by more than one RAN node 408, the LMF 404 may obtain capabilities of each RAN node 408 that serves at least one PRU 502 or the UE 406.

[0130] At step S514, the LMF 404 may estimate the location of the UE 406 using any known legacy positioning method. It is generally envisioned that this step does not involve the use of AIML models.

[0131] If multiple locations were requested by the client 504, the LMF 404 may estimate each requested location.

[0132] As part of estimating the location, the LMF 404 may communicate with the UE 406, PRUs 502, and/or one or more RAN nodes 408 in order to obtain measurement information, depending on the legacy positioning method used by the LMF 404.

[0133] At step S516, the LMF 404 may determine that it is necessary for the location estimate to be enhanced. For example, if the location request includes a specified precision, the LMF 404 may determine that the location estimate does not meet this precision. Additionally or alternatively, the determination performed at step S516 may be based on the capabilities of the UE 406 that were determined at step S512, as well as any capabilities of PRUs 502 and/or RAN nodes 408. For example, if the UE 406 is not able to provide positioning information that is suitable as an input for an ML model, the LMF 404 may determine that AIML positioning is not appropriate. Additionally or alternatively, the determination performed at step S516 may be based on the radio environment conditions of the UE 406. Example radio environment conditions may include indication that the UE 406 is indoors, that the UE 406 is able to provide only non-line of sight measurement data, or that the UE 406 is mobile.

[0134] At step S518, the LMF 404 may transmit a request to the NWDAF 402 for enhancement of the location estimate, referred to herein as an analytics request. The analytics requests may, for example, include the estimated location, the method used to generate the estimated location, and the capabilities reported by the UE 404, PRUs 502, and/or RAN nodes 408.

[0135] The analytics request may also include an analytics ID indicating the form of analysis that the NWDAF 402 is being requested to perform.

[0136] It is noted that, optionally, the LMF 404 may select the NWDAF 402 to receive the analytics request by querying a network repository function (NRF) for a list of NWDAFs capable of handling the request. For example, if the request includes an analytics ID, the LMF 404 may request from the NRF a list of NWDAFs able to support the analytics ID.

[0137] At step S520, the NWDAF 402 determines whether a suitable AIML model for handling the analytics request is available. For example, the NWDAF 402 may check

whether an ML model is available that is capable of enhancing a location estimate prepared using the indicated method, and/or that is compatible with the capabilities reported by the UE 404, PRUs 502, and/or RAN nodes 408. Alternatively, if an analytics ID is provided, the NWDAF 402 may determine whether an ML model is available that is able to provide the analytics referred to by the analytics ID.

[0138] At step S522, if it is determined that a suitable model does not exist and a new model needs to be trained, the NWDAF 402 may train a new model as described above with reference to Fig. 2.

[0139] At step S524, the NWDAF 402 responds to the analytics request by providing an enhanced location estimate to the LMF 404, the enhanced location estimate having been inferred using the ML model.

[0140] At step S526, the LMF 404 may respond to the AMF 410 by providing the enhanced location estimate.

[0141] At step S528, the AMF 410 may transmit the location provided by the LMF 404 to the client 504.

[0142] Fig. 6 illustrates an example of a UE 600 in accordance with aspects of the present disclosure. The UE 600 may include a processor 602, a memory 604, a controller 606, and a transceiver 608. The processor 602, the memory 604, the controller 606, or the transceiver 608, 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.

[0143] The processor 602, the memory 604, the controller 606, or the transceiver 608, 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.

[0144] The processor 602 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 602 may be configured to operate the memory 604. In some other implementations, the memory 604 may be integrated into the processor 602. The processor 602 may be configured to execute computer-readable instructions stored in the memory 604 to cause the UE 600 to perform various functions of the present disclosure.

[0145] The memory 604 may include volatile or non-volatile memory. The memory 604 may store computer-readable, computer-executable code including instructions when executed by the processor 602 cause the UE 600 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such the memory 604 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.

[0146] In some implementations, the processor 602 and the memory 604 coupled with the processor 602 may be configured to cause the UE 600 to perform one or more of the functions described herein (e.g., executing, by the processor 602, instructions stored in the memory 604). For example, the processor 602 may support wireless communication at the UE 600 in accordance with examples as disclosed herein. The UE 600 may be configured to support a means for one or more positioning methods, potentially including AIML-based positioning methods.

[0147] The controller 606 may manage input and output signals for the UE 600. The controller 606 may also manage peripherals not integrated into the UE 600. In some implementations, the controller 606 may utilize an operating system such as iOS®, ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 606 may be implemented as part of the processor 602.

[0148] In some implementations, the UE 600 may include at least one transceiver 608. In some other implementations, the UE 600 may have more than one transceiver 608. The

transceiver 608 may represent a wireless transceiver. The transceiver 608 may include one or more receiver chains 610, one or more transmitter chains 612, or a combination thereof.

[0149] A receiver chain 610 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 610 may include one or more antennas for receive the signal over the air or wireless medium. The receiver chain 610 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 610 may include at least one demodulator configured to demodulate the receive signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receiver chain 610 may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

[0150] A transmitter chain 612 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 612 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 612 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 612 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0151] Fig. 7 illustrates an example of a processor 700 in accordance with aspects of the present disclosure. The processor 700 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 700 may include a controller 702 configured to perform various operations in accordance with examples as described herein. The processor 700 may optionally include at least one memory 704, which may be, for example, an L1/L2/L3 cache. Additionally, or alternatively, the processor 700 may optionally include one or more arithmetic-logic units (ALUs) 706. 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).

[0152] The processor 700 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 700) 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).

[0153] The controller 702 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 700 to cause the processor 700 to support various operations in accordance with examples as described herein. For example, the controller 702 may operate as a control unit of the processor 700, generating control signals that manage the operation of various components of the processor 700. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[0154] The controller 702 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 704 and determine subsequent instruction(s) to be executed to cause the processor 700 to support various operations in accordance with examples as described herein. The controller 702 may be configured to track memory address of instructions associated with the memory 704. The controller 702 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 702 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 700 to cause the processor 700 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 702 may be configured to manage flow

of data within the processor 700. The controller 702 may be configured to control transfer of data between registers, arithmetic logic units (ALUs), and other functional units of the processor 700.

[0155] The memory 704 may include one or more caches (e.g., memory local to or included in the processor 700 or other memory, such RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementations, the memory 704 may reside within or on a processor chipset (e.g., local to the processor 700). In some other implementations, the memory 704 may reside external to the processor chipset (e.g., remote to the processor 700).

[0156] The memory 704 may store computer-readable, computer-executable code including instructions that, when executed by the processor 700, cause the processor 700 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 702 and/or the processor 700 may be configured to execute computer-readable instructions stored in the memory 704 to cause the processor 700 to perform various functions. For example, the processor 700 and/or the controller 702 may be coupled with or to the memory 704, the processor 700, the controller 702, and the memory 704 may be configured to perform various functions described herein. In some examples, the processor 700 may include multiple processors and the memory 704 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.

[0157] The one or more ALUs 706 may be configured to support various operations in accordance with examples as described herein. In some implementations, the one or more ALUs 706 may reside within or on a processor chipset (e.g., the processor 700). In some other implementations, the one or more ALUs 706 may reside external to the processor chipset (e.g., the processor 700). One or more ALUs 706 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 706 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 706 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 706 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 706 to handle conditional operations, comparisons, and bitwise operations.

[0158] The processor 700 may support wireless communication in accordance with examples as disclosed herein. The processor 700 may be configured to or operable to support a means for implementing a location management function (LMF) or network data analytics function (NWDAF) as described above with reference to Figs. 2-5. For example, the processor 700 may be configured to or operable to support a means for receiving a request message for a location of a user equipment (UE); obtaining a machine learning (ML) model for positioning based at least in part on the request message, wherein the ML model comprises a set of one or more constraints, wherein the set of one or more constraints is based at least in part on a set of one or more capabilities of the UE; determining the location of the UE according to the ML model; and outputting a response message that indicates the location of the UE. In another example, the processor 700 may be configured to or operable to support a means for receiving a request message for a machine learning (ML) model, the request message comprising constraints of the ML model; obtaining an ML model comprising the constraints; and outputting a response message, the response message comprising either (i) the ML model or (ii) an indication of a network location wherein the ML model can be accessed. In another example, the processor 700 may be configured to or operable to support a means for receiving a location request to determine a location of a user equipment (UE); receiving capabilities of the UE; receiving positioning information from the UE; determining a location estimate of the UE using the positioning information; outputting an analytics request to enhance the location estimate, the analytics request comprising the location estimate and the capabilities; in response to the analytics request, receiving an enhanced location estimate; and outputting a response to the location request, the response comprising the enhanced location estimate. In another example, the processor 700 may be configured to or operable to support a means for receiving an analytics request, the analytics request comprising: a location estimate for a user equipment (UE) of the communications system; a request to enhance the location

estimate; and capabilities of the UE; obtaining an ML model configured to enhance the location estimate; using the ML model to enhance the location estimate based on the capabilities, thereby obtaining an enhanced location estimate; and outputting a response to the analytics request, the response comprising the enhanced location estimate. In another example, the processor 700 may be configured to or operable to support a means for obtaining ML models trained to determine locations of user equipments (UEs); receiving a location request to determine a location of a user equipment; receiving capabilities of the UE and one or more positioning reference UEs (PRUs); determining based on the capabilities that an obtained ML model is suitable for determining the location of the UE; using the ML model to determine the location of the UE; and outputting a response to the location request, the response comprising the location of the UE.

[0159] Fig. 8 illustrates an example of a network equipment (NE) 800 in accordance with aspects of the present disclosure. The NE may, for example, correspond to the LMF-I 204, the LMF-T 202, the LMF 404, or the NWDAF 402 as described above. The NE 800 may include a processor 802, a memory 804, a controller 806, and a transceiver 808. The processor 802, the memory 804, the controller 806, or the transceiver 808, 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.

[0160] The processor 802, the memory 804, the controller 806, or the transceiver 808, 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.

[0161] The processor 802 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 802 may be configured to operate the memory 804. In some other implementations, the memory 804 may be integrated into the processor 802.

The processor 802 may be configured to execute computer-readable instructions stored in the memory 804 to cause the NE 800 to perform various functions of the present disclosure.

[0162] The memory 804 may include volatile or non-volatile memory. The memory 804 may store computer-readable, computer-executable code including instructions when executed by the processor 802 cause the NE 800 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such the memory 804 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.

[0163] In some implementations, the processor 802 and the memory 804 coupled with the processor 802 may be configured to cause the NE 800 to perform one or more of the functions described herein (e.g., executing, by the processor 802, instructions stored in the memory 804). For example, the processor 802 may support wireless communication at the NE 800 in accordance with examples as disclosed herein. The NE 800 may be configured to support a means for implementing a location management function (LMF) or network data analytics function (NWDAF) as described above with reference to Figs. 2-5. For example the NE 800 may be configured to support a means for receiving a request message for a location of a user equipment (UE); obtaining a machine learning (ML) model for positioning based at least in part on the request message, wherein the ML model comprises a set of one or more constraints, wherein the set of one or more constraints is based at least in part on a set of one or more capabilities of the UE; determining the location of the UE according to the ML model; and transmitting a response message that indicates the location of the UE. In another example, the NE 800 may be configured to support a means for receiving a request message for a machine learning (ML) model, the request message comprising constraints of the ML model; obtaining an ML model comprising the constraints; and transmitting a response message, the response message comprising either (i) the ML model or (ii) an indication of a network location wherein the ML model can be accessed. In another example, the NE 800 may be configured to support a means for

receiving a location request to determine a location of a user equipment (UE); receiving capabilities of the UE; receiving positioning information from the UE; determining a location estimate of the UE using the positioning information; transmitting an analytics request to enhance the location estimate, the analytics request comprising the location estimate and the capabilities; in response to the analytics request, receiving an enhanced location estimate; and transmitting a response to the location request, the response comprising the enhanced location estimate. In another example, the NE 800 may be configured to support a means for receiving an analytics request, the analytics request comprising: a location estimate for a user equipment (UE) of the communications system; a request to enhance the location estimate; and capabilities of the UE; obtaining an ML model configured to enhance the location estimate; using the ML model to enhance the location estimate based on the capabilities, thereby obtaining an enhanced location estimate; and transmitting a response to the analytics request, the response comprising the enhanced location estimate. In another example, the NE 800 may be configured to support a means for obtaining ML models trained to determine locations of user equipments (UEs); receiving a location request to determine a location of a user equipment; receiving capabilities of the UE and one or more positioning reference UEs (PRUs); determining based on the capabilities that an obtained ML model is suitable for determining the location of the UE; using the ML model to determine the location of the UE; and transmitting a response to the location request, the response comprising the location of the UE.

[0164] The controller 806 may manage input and output signals for the NE 800. The controller 806 may also manage peripherals not integrated into the NE 800. In some implementations, the controller 806 may utilize an operating system such as iOS®, ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 806 may be implemented as part of the processor 802.

[0165] In some implementations, the NE 800 may include at least one transceiver 808. In some other implementations, the NE 800 may have more than one transceiver 808. The transceiver 808 may represent a wireless transceiver. The transceiver 808 may include one or more receiver chains 810, one or more transmitter chains 812, or a combination thereof.

[0166] A receiver chain 810 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 810 may include one or more antennas for receive the signal over the air or wireless medium. The receiver chain 810 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 810 may include at least one demodulator configured to demodulate the receive signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receiver chain 810 may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

[0167] A transmitter chain 812 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 812 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 812 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 812 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0168] Fig. 9 illustrates a flowchart of a method 900 in accordance with aspects of the present disclosure. The operations of the method 900 may be implemented by a network entity such as an LMF, as described herein. For example, the method 900 may be performed by the LMF-I 204 as described above with reference to Figs. 2 and 3. In some implementations, the network entity may execute a set of instructions to control the function elements of the network entity to perform the described functions.

[0169] At 902, the method may include receiving a request message for a location of a user equipment (UE).

[0170] The operations of 902 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 902 may be performed by the LMF-I 204 as described with reference to Figs. 2 and 3.

[0171] At 904, the method may include obtaining a machine learning (ML) model for positioning based at least in part on the request message, wherein the ML model comprises a set of one or more constraints, wherein the set of one or more constraints is based at least in part on a set of one or more capabilities of the UE.

[0172] The operations of 904 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 904 may be performed by the LMF-I 204 as described with reference to Figs. 2 and 3.

[0173] At 906, the method may include determining the location of the UE according to the ML model.

[0174] The operations of 906 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 906 may be performed the LMF-I 204 as described with reference to Figs. 2 and 3.

[0175] At 908, the method may include transmitting a response message that indicates the location of the UE.

[0176] The operations of 908 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 908 may be performed the LMF-I 204 as described with reference to Figs. 2 and 3.

[0177] 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.

[0178] Fig. 10 illustrates a flowchart of a method 1000 in accordance with aspects of the present disclosure. The operations of the method 1000 may be implemented by a network entity such as an LMF, as described herein. For example, the method 1000 may be performed by the LMF-T 202 as described above with reference to Figs. 2 and 3. In some implementations, the LMF may execute a set of instructions to control the function elements of the LMF to perform the described functions.

[0179] Alternatively, the method 1000 may be performed by a different network entity, such as an NWDAF of the network.

[0180] At 1002, the method may include receiving a request message for a machine learning (ML) model, the request message comprising constraints of the ML model.

[0181] The operations of 1002 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1002 may be performed by the LMF-T 202 as described with reference to Figs. 2 and 3.

[0182] At 1004, the method may include obtaining an ML model comprising the constraints.

[0183] The operations of 1004 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1004 may be performed by the LMF-T 202 as described with reference to Figs. 2 and 3.

[0184] At 1006, the method may include transmitting a response message, the response message comprising either (i) the ML model or (ii) an indication of a network location wherein the ML model can be accessed.

[0185] The operations of 1006 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1006 may be performed by the LMF-T 202 as described with reference to Figs. 2 and 3.

[0186] 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.

[0187] 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.

[0188] Further aspects of the disclosure may be appreciated with reference to the following clauses.

A1. A method performed by a network entity in a communications system, the method comprising:

- receiving a location request to determine a location of a user equipment (UE);
- receiving capabilities of the UE;
- receiving positioning information from the UE;
- determining a location estimate of the UE using the positioning information;
- transmitting an analytics request to enhance the location estimate, the analytics request comprising the location estimate and the capabilities;
- in response to the analytics request, receiving an enhanced location estimate; and
- transmitting a response to the location request, the response comprising the enhanced location estimate.

A2. The method of clause A1, wherein the location request comprises location requirements, the location requirements comprising at least one of a required precision of the location and a time by which the location must be provided, and the analytics request comprises the location requirements.

A3. The method of clause A1 or A2, wherein the capabilities comprise a positioning method supported by the UE and radio environment conditions of the UE.

A4. The method of any of clauses A1 to A3, wherein the network entity is a location management function (LMF) of the communications system.

A5. The method of any of clauses A1 to A4, wherein the analytics request is transmitted to a network data analytics function (NWDAF) of the communications system.

A6. The method of any of clauses A1 to A5, wherein the analytics request is transmitted to a further network entity, the further network entity selected by:

- establishing communication with a network repository function (NRF);
- receiving from the NRF a list of network entities capable of providing enhanced location estimates; and

selecting the further network entity from the list.

A7. The method of any of clauses A1 to A6, wherein the analytics request comprises an analytics ID, the analytics ID indicating a type of analysis to be conducted by the NWDAF.

A8. The method of any of clauses A1 to A7, further comprising receiving capabilities of one or more position reference UEs (PRUs), wherein the analytics request further comprises the capabilities of the PRUs.

A9. The method of any of clauses A1 to A8, further comprising receiving PRU positioning information from one or more position reference UEs (PRUs), wherein determining the location estimate of the UE uses the PRU positioning information.

A10. The method of any of clauses A1 to A9, further comprising receiving capabilities of one or more radio access network (RAN) nodes of the communications system, wherein the analytics request further comprises the capabilities of the RAN nodes.

A11. The method of any of clauses A1 to A10, further comprising receiving RAN positioning information from one or more radio access network (RAN) nodes of the communications system, wherein determining the location estimate of the UE uses the RAN positioning information

A12. A network entity in a communications system, the network entity configured to:
receive a location request to determine a location of a user equipment (UE);
receive capabilities of the UE;
receive positioning information from the UE;
use the positioning information to determine a location estimate of the UE;
transmit an analytics request to enhance the location estimate, the analytics request comprising the location estimate and the capabilities;
in response to the analytics request, receive an enhanced location estimate; and

transmit a response to the location request, the response comprising the enhanced location estimate.

A13. A method performed by a network entity in a communications system, the method comprising:

receiving an analytics request, the analytics request comprising:

a location estimate for a user equipment (UE) of the communications system;
a request to enhance the location estimate; and
capabilities of the UE;

obtaining an ML model configured to enhance the location estimate;

using the ML model to enhance the location estimate based on the capabilities, thereby obtaining an enhanced location estimate; and

transmitting a response to the analytics request, the response comprising the enhanced location estimate.

A14. The method of clause A13, wherein obtaining the ML model comprises training a new ML model.

A15. The method of clause A14, wherein training the new ML model comprises collecting training information from one or more of: an analytic data repository function (ADRF) of the communications system; operations, administration and maintenance (OAM) processes of the communications system; or a user equipment (UE) of the communications system.

A16. The method of clause A13, wherein obtaining the ML model comprises selecting an existing ML model.

A17. The method of any of clauses A13 to A16, wherein the network entity is a network data analytics function (NWDAF) of the communications system.

A18. The method of any of clauses A13 to A17, wherein the analytics request is received from a location management function (LMF) of the communications system.

A19. The method of any of clauses A13 to A18, wherein the analytics request further comprises further capabilities of one or more positioning reference UEs (PRUs) and/or one or more radio access network (RAN) nodes of the communication system, and wherein enhancing the location estimate is further based on the further capabilities.

A20. A network entity in a communications system, the network entity configured to:

- receive an analytics request, the analytics request comprising:
 - a location estimate for a user equipment (UE) of the communications system;
 - a request to enhance the location estimate; and
 - capabilities of the UE;
- obtain an ML model configured to enhance the location estimate;
- use the ML model to enhance the location estimate based on the capabilities, thereby obtaining an enhanced location estimate; and
- transmit a response to the analytics request, the response comprising the enhanced location estimate.

B1. A method performed by a network entity in a communications system, the method comprising:

- obtaining ML models trained to determine locations of user equipments (UEs);
- receiving a location request to determine a location of a user equipment;
- receiving capabilities of the UE and one or more positioning reference UEs (PRUs);
- determining based on the capabilities that an obtained ML model is suitable for determining the location of the UE;
- using the ML model to determine the location of the UE; and
- transmitting a response to the location request, the response comprising the location of the UE.

B2. The method of clause B1, wherein the ML models are obtained from a further network entity, the method further comprising subscribing to receive said ML models from the further network entity.

B3. The method of clause B2, wherein subscribing to receive said ML models from the further network entity comprises specifying at least one of a frequency with which the ML models should be received, and a manner in which the ML models should be trained.

B4. The method of any of clauses B1 to B3, wherein the location request comprises location requirements, the location requirements comprising at least one of a required precision of the location and a time by which the location must be provided, and wherein determining that a received ML model is suitable for determining the location of the UE is further based on the location requirements.

B5. The method of any of clauses B1 to B4, further comprising receiving capabilities of a radio access network (RAN) node serving the UE and the PRUs, wherein determining that a received ML model is suitable for determining the location of the UE is further based on the capabilities of the RAN node

B6. The method of any of clauses B1 to B5, wherein using the ML model to determine the location of the UE comprises using positioning data as input data to the ML model.

B7. The method of clause B6, further comprising obtaining the positioning data from one or more of the UE, the PRUs, and a RAN node serving the UE and the PRUs, the positioning data optionally including reference signal information.

B8. The method of any of clauses B1 to B7, wherein the network entity is a location management function (LMF) of the communications system.

B9. The method of any of clauses B1 to B8, wherein the ML models are obtained periodically.

B10. A network entity in a communications system, the network entity configured to:
receive ML models trained to determine locations of user equipments (UEs);
receive a location request to determine a location of a UE;

receive capabilities of the UE and one or more positioning reference UEs (PRUs);
determine based on the capabilities that a received ML model is suitable for
determining the location of the UE;
use the ML model to determine the location of the UE; and
transmit a response to the location request, the response comprising the location of
the UE.

CLAIMS

What is claimed is:

1. A network entity configured to:

receive a request message for a location of a user equipment (UE);

obtain a machine learning (ML) model for positioning based at least in part on the request message, wherein the ML model comprises a set of one or more constraints, wherein the set of one or more constraints is based at least in part on a set of one or more capabilities of the UE;

determine the location of the UE according to the ML model; and

transmit a response message that indicates the location of the UE.

2. The network entity of claim 1, wherein the request message comprises one or more of a required accuracy of the location and a duration for reporting the location of the UE, the network entity further configured to:

transmit a request message for the ML model, wherein the request message for the ML model indicates one or more of the required accuracy of the location of the UE, the duration for reporting the location of the UE, and the set of one or more constraints.

3. The network entity of claim 2, wherein the network entity is further configured to:

receive, from a network repository entity, an indication of a set of one or more network entities that support the ML model associated with the set of one or more constraints;

select a further network entity from the set of one or more network entities; and

transmit the request message for the ML model to the further network entity.

4. The network entity of claim 2 or 3, wherein transmitting the request message for the ML model comprises transmitting to a location management function the request message for the ML model.

5. The network entity of any preceding claim, wherein obtaining the ML model comprises receiving the ML model.
6. The network entity of any of claims 1 to 4, wherein obtaining the ML model comprises:
 - receiving an indication of a network location where the ML model is stored; and
 - retrieving the ML model from the network location.
7. The network entity of any preceding claim, wherein the network entity is further configured to:
 - receive the set of one or more capabilities, wherein the set of one or more capabilities comprises one or more of a positioning procedure supported by the UE, and a condition associated with a radio environment supported by the UE.
8. The network entity of any preceding claim, wherein the network entity is further configured to:
 - receive a set of one or more capabilities of a radio access network (RAN) node serving the UE, and receive a set of one or more capabilities of a set of one or more positioning reference UEs (PRUs),
 - wherein the set of one or more constraints of the ML model is based at least in part on the set of one or more capabilities of the RAN node and the set of one or more capabilities of the set of one or more PRUs.
9. The network entity of any preceding claim, wherein the set of one or more constraints comprises one or more of:
 - a location area validity for the ML model;
 - a time of day validity for the ML model;
 - a positioning procedure;
 - an accuracy positioning accuracy quality;
 - a model inference latency;
 - a type of data as an input for the ML model; and

a functionality ID corresponding to the constraints according to a predetermined scheme.

10. The network entity of any preceding claim, wherein the network entity is further configured to:

obtain positioning measurement data from one or more of the UE, a radio access network (RAN) node, and a set of one or more positioning reference UEs (PRUs),
wherein an input to the ML model comprises the positioning measurement data;
optionally wherein the positioning measurement data includes reference signal information.

11. The network entity of any preceding claim, wherein the network entity comprises a location management function (LMF).

12. A method performed by a network entity, the method comprising:

receiving a request message for a location of a user equipment (UE);
obtaining a machine learning (ML) model for positioning based at least in part on the request message, wherein the ML model comprises a set of one or more constraints, wherein the set of one or more constraints is based at least in part on a set of one or more capabilities of the UE;
determining the location of the UE according to the ML model; and
transmitting a response message that indicates the location of the UE.

13. A network entity configured to:

receive a request message for a machine learning (ML) model, the request message comprising constraints of the ML model;
obtain an ML model comprising the constraints; and
transmit a response message, the response message comprising either (i) the ML model or (ii) an indication of a network location wherein the ML model can be accessed.

14. The network entity of claim 13, wherein obtaining the ML model comprises training a new ML model comprising the constraints.

15. The network entity of claim 14, wherein training the new ML model comprises collecting training information from one or more of: an analytic data repository function (ADRF); operations, administration and maintenance (OAM) processes; or a user equipment (UE).

16. The network entity of claim 13, wherein obtaining the ML model comprises selecting an existing ML model comprising the constraints.

17. The network entity of any of claims 13 to 16, wherein the network entity is further configured to assign a model ID to the ML model.

18. The network entity of any of claims 13 to 17, wherein the network entity is a location management function (LMF) or a network data analytics function (NWDAF).

19. The network entity of any of claims 13 to 18, wherein the request message is received from a location management function (LMF).

20. A method performed by a network entity, the method comprising:

receiving a request message for a machine learning (ML) model, the request message comprising constraints of the ML model;

obtaining an ML model comprising the constraints; and

transmitting a response message, the response message comprising either (i) the ML model or (ii) an indication of a network location wherein the ML model can be accessed.