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(54) Title: DISCOVERY AND SUPPORT OF PROXIMITY BETWEEN MOBILE DEVICES

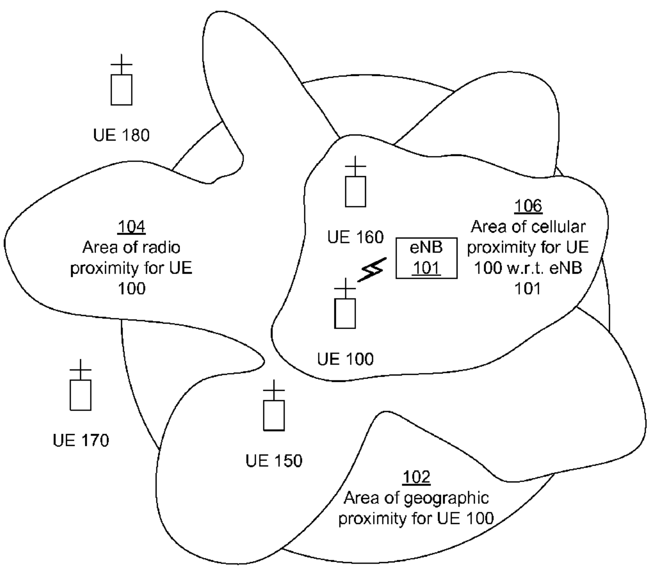

FIG. 1

(57) Abstract: Systems, apparatus and methods for discovering proximity between transceivers, such as mobile devices, are presented. Proximity may be one of geographic proximity, radio proximity and cellular proximity. Discovery of proximity may use a coarse method as an initial filter that is fast and efficient followed by a fine method that is slower and/or less efficient but more accurate, The coarse and fine methods may use proximity parameters that define different requirements for radio proximity, geographic proximity and/or cellular proximity. Proximity parameters may be combined using logical OR and AND operations. Coarse and fine methods may include a radio method, a cellular method, an iterated method, an RTT method, a location method and an OTD method. Discovery of proximity may support various proximity services such as 2-way friend finder and 1-way facility finder.

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DISCOVERY AND SUPPORT OF PROXIMITY BETWEEN MOBILE DEVICES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This patent application claims benefit of U.S. Provisional Patent Application No. 61/773,585, filed March 6, 2013, entitled, “Methods and systems for predicting and/or discovering proximity of mobile devices”, and U.S. Provisional Patent Application No. 61/735,490, filed December 10, 2012, entitled, “Discovery and support of proximity”, both of which are incorporated herein by reference and assigned to the assignee hereof.

BACKGROUND

[0002] I. Field of the Invention

[0003] This disclosure relates generally to systems, apparatus and methods for wirelessly determining proximity between two or more devices, and more particularly to using geographic proximity; radio proximity and/or cellular proximity to determine when two or more mobile devices are within proximity of each other.

[0004] II. Background

[0005] A variety of applications such as tracking applications, friend finder applications, advertising applications and proximity alert applications utilize a concept of proximity of a particular device. Traditionally, an application in a mobile device is typically not able to determine whether its mobile device is or is not in proximity to another mobile device (e.g., a mobile device belonging to a friend, relative or colleague) of interest to the user or the application. In some cases, applications may be able to exchange the locations of their respective mobile devices (e.g., obtained via periodic detection and acquisition of global navigation satellite system (GNSS) signals to calculate GNSS-based location results), but the process may be inefficient due to the amount of signaling involved and use of battery to continually acquire and measure GNSS signals.

BRIEF SUMMARY

[0006] Disclosed is an apparatus, system and method for determining proximity of two or more transceivers.

[0007] According to some aspects, disclosed is a method to discover proximity between a first mobile device and a second mobile device comprising: determining a coarse proximity result between the first mobile device and the second mobile device using a coarse method, wherein the coarse proximity result comprises at least one of: a coarse radio proximity result; a coarse geographic proximity result; and a coarse cellular proximity result; determining that the coarse proximity result indicates that the first mobile device and the second mobile device are proximate; determining a fine proximity result between the first mobile device and the second mobile device using a fine method, wherein the fine proximity result comprises one of: a fine radio proximity result; a fine geographic proximity result; and a fine cellular proximity result; and determining proximity of the first mobile device and the second mobile device when the fine proximity result indicates proximity.

[0008] According to some aspects, disclosed is a device to discover proximity between a first mobile device and a second mobile device comprising a transceiver and processor coupled to the transceiver, wherein the processor comprises code to: determining a coarse proximity result between the first mobile device and the second mobile device using a coarse method, wherein the coarse proximity result comprises at least one of: a coarse radio proximity result; a coarse geographic proximity result; and a coarse cellular proximity result; determining that the coarse proximity result indicates that the first mobile device and the second mobile device are proximate; determining a fine proximity result between the first mobile device and the second mobile device using a fine method, wherein the fine proximity result comprises one of: a fine radio proximity result; a fine geographic proximity result; and a fine cellular proximity result; and determining proximity of the first mobile device and the second mobile device when the fine proximity result indicates proximity.

[0009] According to some aspects, disclosed is a device to discover proximity between a first mobile device and a second mobile device comprising: means for determining a coarse proximity result between the first mobile device and the second mobile device using a coarse method, wherein the coarse proximity result comprises at least one of: a coarse radio proximity result; a coarse geographic proximity result; and a coarse cellular proximity result; means for determining that the coarse proximity result indicates that the first mobile device and the second mobile device are proximate; means for determining a fine proximity result between the first mobile device and the second mobile device using a fine method, wherein the fine proximity result comprises one of: a fine radio proximity result; a fine geographic proximity result; and a fine cellular proximity result; and means for determining proximity of the first mobile device and the second mobile device when the fine proximity result indicates proximity.

[0010] It is understood that other aspects will become readily apparent to those skilled in the art from the following detailed description, wherein it is shown and described various aspects by way of illustration. The drawings and detailed description are to be regarded as illustrative in nature and not as restrictive.

BRIEF DESCRIPTION OF THE DRAWING

[0011] Embodiments of the invention will be described, by way of example only, with reference to the drawings.

[0012] FIG. 1 illustrates different types of proximity, in accordance with some embodiments of the present invention.

[0013] FIG. 2 illustrates different services and user cases supported by different types of proximity, in accordance with some embodiments of the present invention.

[0014] FIG. 3 illustrates a process for use of coarse and fine methods of discovering proximity between a pair of mobile devices, in accordance with some embodiments of the present invention.

[0015] FIG. 4 illustrates a method of combining parameters related to discovery of proximity between mobile devices, in accordance with some embodiments of the present invention.

[0016] FIG. 5 illustrates an RTT method of discovering geographic proximity between a pair of mobile devices, in accordance with some embodiments of the present invention.

[0017] FIG. 6 illustrates a location method of discovering geographic proximity between a pair of mobile devices, in accordance with some embodiments of the present invention.

[0018] FIG. 7 illustrates an OTD method of discovering geographic proximity between a pair of mobile devices, in accordance with some embodiments of the present invention.

[0019] FIG. 8 illustrates a cellular method of discovering proximity between a pair of mobile devices, in accordance with some embodiments of the present invention.

[0020] FIG. 9 illustrates an iterated method of discovering proximity between a pair of UEs, in accordance with some embodiments of the present invention.

[0021] FIG. 10 illustrates a process for performing an iterated method of discovering proximity between mobile devices, in accordance with some embodiments of the present invention.

[0022] FIG. 11 illustrates a process for performing discovery of proximity using coarse and fine methods, in accordance with some embodiments of the present invention.

[0023] FIGS. 12, 13 and 14 are schematic block diagrams illustrating certain example arrangements to support a network proximity server, in accordance with an example implementation.

[0024] FIGS. 15A, 15B, 15C and 15D provide some examples of direct discovery of proximity between UEs, in accordance with some embodiments of the present invention.

[0025] FIGS. 16A, 16B and 16C provide some examples of support and discovery of proximity between UEs using a network proximity server, in accordance with some embodiments of the present invention.

[0026] FIG. 17 provides an example arrangement for enabling support of proximity services in a UE, in accordance with some embodiments of the present invention.

[0027] FIGS. 18, 19 and 20 show various apparatuses, in accordance with some embodiments of the present invention.

DETAILED DESCRIPTION

[0028] Certain abbreviations used herein are listed for convenience in the following table.

AP	Access Point
API	Application Programming Interface

CP	Control Plane
CS	Circuit Switched
D2D	Device to Device (refers to direct communication between 2 devices)
DHCP	Dynamic Host Configuration Protocol
eNB	evolved Node B (eNodeB)
E-SMLC	Evolved SMLC
Expression	A piece of data (e.g., 128 bit string) that encodes the identity of an application or service needing proximity support for one or more UEs
FQDN	Fully Qualified Domain Name
HLR	Home Location Register
HSS	Home Subscriber Service
IMS	IP Multimedia Subsystem
IMSI	International Mobile Subscriber Identity
LRF	Location and Routing Function
LTE	Long Term Evolution
LTE-D	LTE Direct (LTE version of D2D in which 2 UEs communicate directly via LTE and not via a network)
MME	Mobility Management Entity
NAS	Non-Access Stratum
OTD	Observed Time Difference
P-CSCF	Proxy Call Session Control Function
PDG	PDN Gateway
PLMN	Public Land Mobile Network
PDN	Public Data Network
PDU	Protocol Data Unit
RAN	Radio Access Network
RTT	Round Trip propagation Time
S-CSCF	Serving Call Session Control Function
SLP	SUPL Location Platform
SMLC	Serving Mobile Location Center
SUPL	Secure User Plane Location
SWG	Serving Gateway
TA	Tracking Area
TAU	Tracking Area Update
UE	User Equipment (e.g., cell phone, laptop)
WiFi-D	WiFi Direct (in which 2 UEs communicate directly using IEEE 802.11 WiFi signaling)

Table 1

[0029] The detailed description set forth below in connection with the appended drawings is intended as a description of various aspects of the present disclosure and is not intended to represent the only aspects in which the present disclosure may be practiced. Each aspect described in this disclosure is provided merely as an example or illustration of the present disclosure, and should not necessarily be construed as preferred or advantageous over other aspects. The detailed description includes specific details for the purpose of providing a thorough understanding of the present disclosure. However, it will be apparent to those skilled in the art that the present disclosure may be practiced without these specific details. In some instances, well-known structures and devices are shown in block diagram form in order to avoid obscuring the concepts of the present disclosure. Acronyms and other descriptive terminology may be used merely for convenience and clarity and are not intended to limit the scope of the disclosure.

[0030] Position determination techniques and techniques for determining proximity between devices that are described herein may be implemented in conjunction with various wireless communication networks such as a wireless wide area network (WWAN), a wireless local area network (WLAN), a wireless personal area network (WPAN), and so on. The term “network” and “system” are often used interchangeably. A WWAN may be a Code Division Multiple Access (CDMA) network, a Time Division Multiple Access (TDMA) network, a Frequency Division Multiple Access (FDMA) network, an Orthogonal Frequency Division Multiple Access (OFDMA) network, a Single-Carrier Frequency Division Multiple Access (SC-FDMA) network, a Long Term Evolution (LTE) network, and so on. A CDMA network may implement one or more radio access technologies (RATs) such as cdma2000, Wideband-CDMA (W-CDMA), and so on. Cdma2000 includes IS-95, IS-2000, HRPD (High Rate Packet Data) and IS-856 standards. A TDMA network may implement Global System for Mobile Communications (GSM), Digital Advanced Mobile Phone System (D-AMPS), or some other RAT. GSM, W-CDMA and LTE are described in documents from a consortium named “3rd Generation Partnership Project” (3GPP). Cdma2000 is described in documents from a consortium named “3rd Generation Partnership Project 2” (3GPP2). 3GPP and 3GPP2 documents are publicly available. A WLAN may be an IEEE 802.11x network, and a WPAN may be a Bluetooth network, an IEEE 802.15x, or some other type of network. The techniques may also be implemented in conjunction with any combination of WWAN, WLAN and/or WPAN.

[0031] A satellite positioning system (SPS) typically includes a system of transmitters positioned to enable entities to determine their location on or above the Earth based, at least in part, on signals received from the transmitters. Such a transmitter typically transmits a signal marked with a repeating pseudo-random noise (PN) code of a set number of chips and may be located on ground based control stations, user equipment and/or space vehicles. In a particular example, such transmitters may be located on Earth orbiting satellite vehicles (SVs). For example, a SV in a constellation of Global Navigation Satellite System (GNSS) such as Global Positioning System (GPS), Galileo or GLONASS may transmit a signal marked with a PN code that is distinguishable from PN codes transmitted by other SVs in the constellation (e.g., using different PN codes for each satellite as in GPS or using the same code on different frequencies as in GLONASS). In accordance with certain aspects, the techniques presented herein are not restricted to global systems (e.g., GNSS) for SPS. For example, the techniques provided herein may be applied to or otherwise enabled for use in various regional systems, such as, e.g., Quasi-Zenith Satellite System (QZSS) over Japan, Indian Regional Navigational Satellite System (IRNSS) over India, Beidou over China, etc., and/or various augmentation systems (e.g., an Satellite Based Augmentation System (SBAS)) that may be associated with or otherwise enabled for use with one or more global and/or regional navigation satellite systems. By way of example but not limitation, an SBAS may include an augmentation system(s) that provides integrity information, differential corrections, etc., such as, e.g., Wide Area Augmentation System (WAAS), European Geostationary Navigation Overlay Service (EGNOS), Multi-functional Satellite Augmentation System (MSAS), GPS Aided Geo Augmented Navigation or GPS and Geo Augmented Navigation system (GAGAN), and/or the like. Thus, as used herein an SPS may include any combination of one or more global and/or regional navigation satellite systems and/or augmentation systems, and SPS signals may include SPS, SPS-like, and/or other signals associated with such one or more SPS.

[0032] As used herein, a mobile device, sometimes referred to as a mobile station (MS), a mobile terminal, a device, a terminal or user equipment (UE), can refer to a cellular phone, mobile phone, smart phone or other wireless communication device, personal communication system (PCS) device, personal navigation device (PND), Personal Information Manager (PIM), Personal Digital Assistant (PDA), laptop, tablet or other suitable mobile device which is capable of receiving wireless communication and/or navigation signals. The term “mobile device” is also intended to include devices which communicate with a personal navigation device (PND), such as by short-range wireless, infrared, wireline connection, or other connection – regardless of whether satellite signal reception, assistance data reception, and/or position-related processing occurs at the device or at the PND. Also, "mobile device" is intended to include all devices, including wireless communication devices, computers, laptops, etc. which are capable of communication with a server, such as via the Internet, WiFi, or other network, and regardless of whether satellite signal reception, assistance data reception, position-related processing and/or determination of proximity occurs at the device, at a server, or at another device associated with the network. Any operable combination of the above are also considered a "mobile device." The terms "mobile device" and "UE" are synonymous and are used interchangeably herein. The term "transceiver" is also used herein to refer to both mobile devices and fixed devices that have a wireless communications capability enabling communication with other devices including other transceivers and different types of network.

[0033] **Types of Proximity – Radio, Geographic, Cellular**

[0034] Different types of proximity are disclosed, in accordance with some embodiments of the present invention. Geographic proximity, Radio proximity and Cellular proximity may be defined and determined in several ways as follows.

[0035] Geographic proximity of a first transceiver from a second transceiver may be defined to occur when the transceivers are within a predefined geographic distance from each other. The first and second transceivers may comprise two mobile devices, a fixed device (e.g., an access point or a fixed user device such as a PC or server) and a mobile device, or two fixed devices. The term access point (AP) is used herein generically to include a node-B for W-CDMA, an eNode B (eNB) for LTE, a WiFi access point, a cellular base station, a femtocell, a home base station and the like. For convenience, the first transceiver and the second transceiver are referred below each as a mobile device. As such, geographic proximity between two mobile devices occurs when the mobile devices are within a predefined distance from each other. For example, two mobile devices may satisfy geographic proximity when the mobile devices are within 100 meters of each other. If a group containing more than two mobile devices is considered, geographic proximity may be defined if the group of mobile devices is within a certain local area such as a circle of a predefined diameter.

[0036] Radio proximity of mobile devices occurs when the mobile devices may communicate directly with each other via a radio channel. Two mobile devices may satisfy radio proximity when they may communicate via an RF channel (e.g., a cellular frequency) such that signals transmitted by either of the mobile devices may be received and in some cases demodulated and decoded by the other mobile device. Three or more mobile devices may be considered to be in radio proximity when each mobile device in the group may directly communicate with every other mobile device in the group.

[0037] Cellular proximity may be determined if two mobile devices are serviced by the same cell or same AP (e.g., a WiFi AP). Alternatively, cellular proximity may be determined if two mobile devices have radio coverage of the same cell or same AP. Alternatively, two mobile devices may be considered to have cellular proximity when the two mobile devices are serviced (or have coverage) by neighboring cells or neighboring APs where neighboring cells and neighboring APs have coverage areas that overlap one another or are nearby to one another. Three or more mobile devices may be considered to have cellular proximity when all mobile devices: (1) are serviced by the same cell or same AP; (2) have coverage of the same cell or same AP; (3) are serviced by neighboring cells or neighboring APs; or (4) have coverage of neighboring cells or neighboring APs.

[0038] FIG. 1 illustrates different types of proximity, in accordance with some embodiments of the present invention. The figure illustrates areas of radio proximity, geographic proximity and cellular proximity for a UE 100 that is served by or in coverage of an LTE eNode B (eNB) 101. Area 102 illustrates an area of geographic proximity for UE 100 and is a horizontal circle with a certain radius with the UE 100 at its center. The radius of the circle of area 102 corresponds to whatever predefined distance is used to define geographic proximity – e.g., 100 meters. Any other UE that is within the area 102 will (by definition of the area 102) be at a distance of less than or equal to the radius of the circle of area 102 from UE 100, Therefore, the UE will be within geographic proximity to UE 100. UEs outside the area 102 will be at a distance more than the radius of the circle of area 102 from UE 100 and thus will not be in geographic proximity to UE 100. Thus the area 102 includes all possible locations for UEs that are in geographic proximity to UE 100. As an example, UEs 150 and 160 are shown as within the area 102 and are thus within geographic proximity to UE 100. UEs 170 and 180 are shown as outside the area 102 and are thus not in geographic proximity to UE 100 – at least using a predefined distance corresponding to the radius of the circle of area 102. It should be noted that area 102 only considers horizontal distance which may be adequate when UEs are on or near the ground. In the case of UEs (and their users) inside buildings or in a subway, distance in three dimensions may need to be considered in order to define geographic proximity more accurately. In that case, the circular area 102 may be replaced with a spherical volume with the same radius as the circle of area 102 and with UE 100 at its center. Any other UE within such a sphere would be within geographic proximity to UE 100 (as defined by a distance equal to the radius of the sphere) and any UE outside the sphere would not be in geographic proximity to UE 100.

[0039] Area 104 in FIG. 1 illustrates an area of radio proximity for UE 100 and represents the limit of direct radio coverage of UE 100, such that any UE within the area 104 can receive (and in some definitions demodulate and decode) direct radio signals from UE 100 and UEs outside the area 104 cannot. The area of radio proximity may depend on local terrain and other radio propagation conditions (e.g., the presence of buildings, walls, trees, hills etc.) and may thus be an irregular shape and not a circle like area 102. Further, area 104 may depend on various criteria such as whether signals from UE 100 need to be correctly demodulated and decoded as well as received by another UE, whether signals need to be received with a certain minimum signal strength and/or minimum signal quality (e.g., a certain minimum signal to noise ratio, S/N), the receiving characteristics of the UE receiving the signal from UE 100 (e.g., antenna gain and sensitivity), the transmission characteristics of UE 100 (e.g., transmission power and antenna gain) and whether UE 100 also needs to receive (and possible demodulate and decode) signals transmitted by a UE that receives signals from UE 100. Area 104 may also vary over time – e.g., if there are changes in radio propagation conditions – and may be discontinuous (e.g., with certain areas, such as an area of a sub-basement in a building within which communication with others areas is not possible, being excluded from the area 104). Therefore, the area 104 may vary depending on the particular combination of criteria that are defined to be of relevance. However, once a particular set of criteria are chosen, the area 104 may be well defined and any UE within the area 104 may be in radio proximity of UE 100 and any UE outside the area may not be in radio proximity to UE 100. For example, according to this definition, UEs 150 and 160 that are shown as within area 104 are in radio proximity to UE 100 and UEs 170 and 180 that are shown as outside the area 104 are not in radio proximity to UE 100.

[0040] Area 106 in FIG. 1 illustrates an area of cellular proximity to UE 100 with respect to eNB 101. Area 106 illustrates the radio coverage area of eNB 101 within which a UE may be served by eNB 101 or at least able to receive radio coverage from eNB 101. The area 106 may also be irregular and potentially discontinuous (as for area 104) and depend on local terrain and other conditions (e.g., buildings, walls, trees) that affect radio propagation from and to eNB 101. UEs within area 106 may be served by or at least able to receive radio coverage from eNB 101. UEs 100 and 160 are shown as being within area 106. Therefore, UE 160 is within cellular proximity of UE 100. UEs 150, 170 and 180 are shown as being outside area 106 and are thus not in cellular proximity to UE 100.

[0041] FIG. 1 illustrates that a UE can be in one type of proximity to another UE but not in another type of proximity. For example, UE 150 is shown as being in geographic proximity and radio proximity to UE 100 but not in cellular proximity. In general, any UE that lies within the intersection of two of the three areas in FIG. 1 will be have two types of proximity to UE 100 – e.g., as in the case of UE 150. Any UE that lies within the intersection of all three areas will have all three types of proximity to UE 100 – e.g., UE 160 is such a UE. The fact that a UE may have one type of proximity to another UE but not another type of proximity shows that the three types of proximity can generally be distinct and may need to be supported separately.

[0042] The different types of proximity may each be useful to support different types of applications or different services for the users of mobile devices as discussed next.

[0043] FIG. 2 illustrates different services and user cases that may be supported by different types of proximity, in accordance with some embodiments of the present invention. The figure shows different services that may be supported by different types of proximity between pairs of mobile devices. The services may be supported when a pair of mobile devices is discovered to be in proximity to one another according to one of the preceding definitions of proximity – geographic, radio or cellular. The services may be referred to as “proximity services” or “proximity user cases”.

[0044] Each row in FIG. 2 except the first shows a different service that is indicated in the first column of that row. Each column in FIG. 2 except the first represents discovery of a different types of proximity between a pair of mobile devices (radio proximity, geographic proximity or cellular proximity) as indicated in the top row for that column. A service that may be supported by discovery of a particular type of proximity between a pair of mobile devices is indicated by an “X” at the intersection of the row representing the service and the column representing the proximity type. The lack of an “X” indicates that the service may not be supported (or not always be supported) by discovery of the particular proximity type. As an example, a 2-way friend finder service (second row) may be supported by the discovery of geographic proximity (third column) as indicated by the presence of an “X” but may not be supported by the discovery of cellular proximity (fourth column) as indicated by the lack of an “X”.

[0045] Each service may be performed for or on behalf of a user or an application on a mobile device or for or on behalf of a serving network once proximity between the mobile device and some other mobile or fixed device has been discovered. A 2-way friend finder service (row 2 in FIG. 2) may provide an indication to an application and/or to a user when the mobile device for the user is within some predefined distance of another mobile device belonging to a friend or relative of the user. This service may depend on knowing whether two devices are within a predefined distance of one another and thus may be supported by an ability to discover when two devices are in geographic proximity. However, the service may not be supported so well by discovering when two devices are in radio proximity or cellular proximity to one another because, as illustrated in FIG. 1, these types of proximity do not always guarantee that mobile devices are within a fixed predefined distance of one another.

[0046] Similarly, a 1-way facility finder service (row 3 in FIG. 2) in which a user or application is informed when the mobile device of a user in within a predefined distance of some fixed device (e.g., a device in a certain store in a shopping mall or next to a certain exhibit in a museum) may be supported by an ability to discover geographic proximity but not so well by an ability to discover radio proximity or cellular proximity. In addition, a service that provides information to a user or application on the presence and/or location of another user (presence/location enhancement of row 7 in FIG. 2) may be better supported by an ability to discover geographic proximity.

[0047] Services in FIG. 2 that may be better supported by an ability to discover when two mobile devices are within radio proximity of one another may include support of direct communication between public safety users in the absence of network coverage (public safety without network coverage in row 4 in FIG. 2), network offload in which mobile devices are enabled to communicate directly with little or no network support (network offload via D2D communications in row 5 in FIG. 2) and direct communication between vehicles or between a vehicle and a user (vehicle to vehicle/vehicle to user communication in row 8 in FIG. 2). A service that may be better supported by an ability to discover cellular proximity between pairs of mobile devices may include a service (row 6 of FIG. 2) that provides direct communication between two mobile devices via an AP (e.g., a WiFi AP or an LTE eNB) but not via additional elements in a network such as switches, gateways and/or routers. The fact that the discovery of each type of proximity between mobile devices can support certain services better than other types of proximity may be a reason for supporting discovery of each of the three types of proximity separately from the others.

[0048] Discovery of different types of proximity (e.g., geographic, radio and/or cellular proximity) between a pair of mobile devices may be important to subsequently supporting certain services for users or applications on a mobile device as described previously in relation to FIG. 2. Therefore, there may be a benefit in methods that enable discovery of one or more types of proximity between pairs of mobile devices and an additional benefit in the case of methods that discover proximity reliably, quickly (e.g., with low latency) and with low usage of resources – e.g., mobile device battery use, use of signaling bandwidth and use of network resources. One method that be used to reduce latency and usage of resources may be to employ a coarse method of discovering one or more types of proximity between two mobile devices and then, having discovered proximity coarsely, using a fine method to discover or verify proximity more reliably.

[0049] As described below, the coarse method may comprise one of: a Round Trip propagation Time (RTT) method; a location method; an Observed Time Difference (OTD) method; a radio method; a cellular method; and an iterated method. The fine method is different from the coarse method and may comprise one of: a Round Trip propagation Time (RTT) method; a location method; an Observed Time Difference (OTD) method; a radio method; and a cellular method.

[0050] The coarse method may thus be used to filter pairs of mobile devices that need to be evaluated by the fine method. The coarse method may have low resource usage but be less reliable (less accurate) whereas the fine method may have higher resource usage but be more reliable (more accurate). Since most pairs of mobile devices will not usually be in proximity, use of the coarse method may reduce resource usage for discovery of proximity between most pairs of mobile devices whereas while the fine method will increase resource usage, its application to a smaller number of pairs of mobile devices (that have been filtered by the coarse method) may limit resource usage to confirm proximity.

[0051] FIG. 3 illustrates a process 300 for use of coarse and fine methods of discovering proximity between a pair of mobile devices, in accordance with some embodiments of the present invention. The figure illustrates the use of coarse and fine methods of discovering proximity between some UE, designated UE A, and other UEs that have an interest in supporting the same proximity services as UE A. For example, the proximity services supported by any UE may be indicated by expressions where an expression is a bit string or octet string that defines a particular service (e.g., the 2-way friend service or 1-way facility finder service in FIG. 2) or a particular class or set of services.

[0052] Expressions may be broadcast by one UE to another UE to enable other UEs to determine which services any UE supports and whether any of those services are shared by the recipient UE. Alternatively or in addition, expressions may be conveyed to a serving network or server on a serving network by a UE or by the home network of the UE to enable the serving network or a server on the serving network to determine whether different UEs support the same service or services.

[0053] At block 302 in FIG. 3 which may be performed periodically by UE A, a coarse method of discovering proximity is used to determine a set S of UEs that may be in proximity to the UE A. As an example, the coarse method may discover a set S of UEs whose signals can be received by UE A and which indicate (via the received signals) support of one or more services supported by UE A.

[0054] At block 304 which may be performed each time block 302 is performed, a fine method of discovering proximity may be used to discover a subset s of UEs in the set S that are in proximity to UE A. As an example, the fine method may use the geographic locations of UE A and each UE in the set S to discover which UEs in the set S are in geographic proximity to UE A. Alternatively, the fine method may compare the serving cells, serving APs or cells or APs that are visible to each UE to determine which UEs in the set S are in cellular proximity to UE A.

[0055] At block 306, one or more proximity services may be supported between each UE in the subset s and UE A. For example, the proximity services that are supported may correspond to one or more of the services shown in FIG. 2.

[0056] As described in relation to FIG. 3, instead of performing a fine method for determining a certain proximity for all mobile devices near a target mobile device, a coarse method (step one) may be used on a first group of mobile devices then a fine method (step two) may be used on a second group of mobile devices that is a subset of the first group.

[0057] In some embodiments, a coarse method quickly reduces the candidate pool or a superset of mobile devices and the fine method determines proximity for a second smaller set of mobile devices whose proximity is unsure. In other embodiments, the coarse method acts as a first pass to narrow a set into a subset and the fine method acts as a second pass filter to further narrow the subset into mobile devices (e.g., one or a few) that are in actual proximity to a certain mobile device. Often a coarse method is efficient and fast and a fine method is slower, less efficient but more accurate. In some cases, the coarse method is over inclusive and errs on the side of assuming a mobile device may be in proximity to another mobile derive when there is some doubt. In these cases, if the coarse method finds no mobile devices or a small number of mobile devices, then time and processing power may be saved by not performing a fine method or only performing the fine method for a small number of mobile devices in each case, respectively.

[0058] As previously described, there may be some value in being able to discover different types of proximity between pairs of mobile devices. In order to discover each type of proximity (radio, geographic and cellular) in a precise manner, there may be a benefit in defining specific parameters, referred to here as “proximity parameters”, for each type of proximity that define the precise meaning of the particular type of proximity and what may need to be determined or verified to discover whether the type of proximity exists between a pair of mobile devices.

[0059] As an example, proximity parameters related to discovery of radio proximity may include: (a1) an indication of whether direct communication (e.g., using LTE-D) is required between 2 UEs; (a2) a minimum signal strength and/or signal quality received by one UE from another; and (a3) an amount of bandwidth required for direct communication (e.g., using LTE-D) between two mobile devices.

[0060] Proximity parameters related to discovery of geographic proximity between two mobile devices may include: (b1) a maximum distance between two mobile devices; (b2) a required state of motion of each mobile device (e.g., a maximum velocity to be considered in geographic proximity); and (b3) a required location of each mobile device (e.g., where geographic proximity may only be discovered for mobile devices in some areas but not in other areas).

[0061] Proximity parameters related to discovery of cellular proximity between two mobile devices may include: (c1) an indication of whether two mobile devices must be served by a common AP or common base station; and (c2) an indication of whether two mobile devices must be in coverage of a common AP or common base station.

[0062] Certain other proximity parameters may be common parameters and applicable to more than one type of proximity (e.g., may be applicable to all types) and may include: (d1) a minimum length of time that proximity must persist following discovery and before discovery is confirmed (e.g., to avoid transient proximity determination for devices passing one another at high speed); (d2) a required network attachment status for each mobile device (e.g., whether both mobile devices must attach to same network); and (d3) a maximum latency for discovering proximity.

[0063] The proximity parameters related to defining discovery of different types of proximity (e.g., as exemplified in (a1) to (a3), (b1) to (b3), (c1), (c2) and (d1) to (d3)) could be defined differently by different networks, different services, different applications and different users. For example, a 2-way friend finder service may define maximum distance for discovering geographic proximity for (b1) of 1000 meters whereas a 1-way facility finder service may define a distance for (b1) of 100 meters.

[0064] Similarly, one application may define a minimum time T that proximity must exist before being confirmed for (d1) of 5 minutes while another application may define a value for T of 1 minute. Different sets of proximity parameters defined by different networks, services, applications and users may be reconciled by employing certain rules that enable different proximity parameters of the same type to be combined. For example, priorities may be defined in which, for example, a network provided definition for proximity parameters takes precedence over a user or an application provided definition for the same proximity parameters.

[0065] Alternatively or in addition, maximum or minimum values of proximity parameters may be obtained. For example, if a network uses a default distance of 500 meters in (b1) to discover geographic proximity and a user or application specifies a distance of 250 meters for (b1), the maximum of these values (500 meters) may be used or the minimum (250 meters) according to certain rules known to entities (e.g., a UE or a network proximity server) that perform discovery.

[0066] The different proximity parameters used to define each type of proximity imply that discovery of each type of proximity may need to be supported separately. However, different types of proximity parameters could be combined to enable discovery of more than one type of proximity, For example, the proximity parameters (a1), (a2) and (a3) described above for radio proximity might be combined with the proximity parameters (b1), (b2) and (b3) described above for geographic proximity.

[0067] The combining of different proximity parameters could be performed by an application in a mobile device belonging to one user that needs to discover similar applications in certain other mobile devices (e.g., mobile devices belonging to friends relatives or colleagues of the user) that are in proximity. The application need not be aware that some proximity parameters relate to one type of proximity and that other proximity parameters relate to another type of proximity. Proximity parameters may be combined using logical OR and logical AND operations where a combination of two proximity parameters using a logical AND operation may mean that discovery of proximity must fulfill the conditions associated with both proximity parameters whereas a combination using a logical OR operation may mean that discovery of proximity may support the conditions associated with either one proximity parameter or the other proximity parameter.

[0068] For example, proximity parameter (b1) above related to geographic proximity may be specified by an application on some mobile device D to discover other mobile devices within a circle around D such as the area 102 in FIG. 1. Proximity parameter (a1) or (a2) may be specified by the same application on D to discover other mobile devices that can receive signals from D or that can send signals to D that D can receive. Such mobile devices may be included inside a different area such as the area 104 in FIG. 1. If the application combines the proximity parameter (b1) and the proximity parameter (a1) or (a1) using a logical AND operation, then because discovery of proximity will need to support the conditions for (b1) and the conditions for (a1) or (a2), the area within which mobile devices may be discovered may become the intersection of the area associated with parameter (b1) and the area associated with parameter (a1) or (a2) – for example the intersection of the areas 102 and 104 in FIG. 1. Conversely, if the application combines the proximity parameter (b1) and the proximity parameter (a1) or (a2) using a logical OR operation, then because discovery of proximity will only need to support the conditions for (b1) or the conditions for (a1) or (a2), the area within which mobile devices may be discovered may become the union of the area associated with parameter (b1) and the area associated with parameter (a1) or (a2) – for example the union of the areas 102 and 104 in FIG. 1.

[0069] For proximity services associated with just one type of proximity (i.e., radio, geographic or cellular proximity), such as the various proximity services shown in FIG. 2, it may only be useful to combine proximity parameters related to one type of proximity with proximity parameters common to all types of proximity. For example, to support a 2-way friend finder proximity service, which as shown in FIG. 2 is associated with geographic proximity, it may only be useful to combine one or more of proximity parameters (b1), (b2) and (b3) that support geographic proximity with zero or more of proximity parameters (d1), (d2) and (d3) that are common to all proximity types. However, it may not be useful to combine parameters (b1)-(b3) with any of proximity parameters (a1), (a2) and (a3) related to radio proximity or any of proximity parameters (c1) and (c2) related to cellular proximity. However, there may be proximity services that are related to more than one type of proximity and for which combining proximity parameters related to more than one type of proximity may be useful. For example, a proximity service related to traffic safety may be defined that needs to use direct communication between two UEs embedded in two separate vehicles in order to efficiently transfer certain data related to traffic safety between the vehicles but also requires the two UEs (i.e., their respective vehicles) to be within a maximum geographic distance of one another (e.g., 50 meters) in order that the data relate to possible interaction of the two vehicles on a common highway or at a common intersection. In this case, one or more of proximity parameters (a1), (a2) and (a3) that are related to radio proximity may be combined with one or more of proximity parameters (b1), (b2) and (b3) that are related to geographic proximity. For example, parameter (a1) which may provide an indication that direct communication is required between the two UEs may be combined using a logical AND operation with parameter (b1) which may specify the maximum required distance between the two UEs.

[0070] A benefit of allowing an application to combine different proximity parameters related to discovery of different types of proximity may be that the application need not be aware of the different types of proximity or of the association of different proximity parameters to different types of proximity and may instead treat proximity as being of one type only with a set of different proximity parameters that may be used to specify how proximity should be discovered. However, a server in a network or a process on a mobile device that supports discovery of proximity may need to remain aware of which types of proximity different proximity parameters are associated with in order to perform different methods for discovering the different types of proximity.

[0071] FIG. 4 illustrates a method of combining parameters related to discovery of proximity between mobile devices, in accordance with some embodiments of the present invention. The figure illustrates how proximity parameters, such as proximity parameters (a1) to (a3), (b1) to (b3), (c1), (c2) and (d1) to (d3) described above, may be combined by an application (or App) in a mobile device or UE 400 and how such combined proximity parameters may then be used to discover proximity of UE 400 to other UEs.

[0072] A user 402 in FIG. 4 may receive services related to proximity from an application 404 supported by UE 400. For example, the user 402 may be informed when the mobile device of a friend or relative is discovered to be geographic proximity to UE

400 in the case of a 2-way friend finder service. In another example, the user 402 may receive an advertisement or other notification when UE 400 is discovered to be in geographic proximity to a fixed device associated with some facility (e.g., a shop or railway station) for the 1-way facility finder service. The user 402 may interact with the application 404 via I/O facilities supported by UE 400 (e.g., a touchscreen, keyboard, monitor, microphone, speaker).

[0073] Application 404 may present to user 402 unified proximity related services based on unified proximity capabilities. The unified proximity services may be services that can be supported via discovery of any of the three types of proximity (radio, geographic and cellular). For example, the unified proximity services may comprise some or all of the services described with reference to FIG. 2. Thus, the unified proximity services may include services enabled by any of the three different types of proximity. The unified proximity capabilities may include an ability to discover proximity based on the combined set of proximity parameters described previously. The unified services may be defined and provided in relation to an interface 424 between the application 404 and the user 402.

[0074] The application 404 which provides proximity related services to the user 402 may access a UE proximity engine (or proximity process) 406 on UE 400 or a network proximity capability (e.g., a network server) 408 resident in a serving network for UE 400 in order to discover when UE 400 is in proximity to other UEs that support the same proximity service(s) as UE 400 such as a proximity service of interest to user 402.

[0075] The application 404 may make use of combined proximity parameters (e.g., any or all of parameters (a1), (a2), (a3), (b1), (b2), (b3), (c1), (c2), (d1), (d2) and (d3) described previously) to inform the UE proximity engine 406 or network proximity capability 408 (e.g., by sending proximity parameters set to particular values to UE proximity engine 406 or network proximity capability 408) of the required criteria for discovering proximity to other UEs.

[0076] The application 404 may also indicate the types of proximity service of interest (e.g., 2-way friend finder, 1-way facility finder etc.) – e.g., by providing an expression or expressions to UE proximity engine 406 or network proximity capability 408 that encode one or more proximity services. The application 404 may interact with UE proximity engine 406 or network proximity capability 408 via an interface 422 that enables proximity parameters to be transferred from application 404 to UE proximity engine 406 or network proximity capability 408 and possibly the reverse if UE proximity engine 406 or network proximity capability 408 are allowed to negotiate these proximity parameters (e.g., by returning proximity parameter values to application 404 different to proximity parameter values sent by application 404).

[0077] UE proximity engine 406 or network proximity capability 408 may support discovery of each type of proximity (radio, geographic and cellular proximity) separately and independently and may make use of network and/or UE support, that may be standardized (e.g., by 3GPP), to discover each type of proximity. Some example methods that enable discovery of each type of proximity are described later herein and may be used by UE proximity engine 406 or by network proximity capability 408. In providing this support, UE proximity engine 406 or network proximity capability 408 may need to be aware of which types of proximity each of the proximity parameters is associated with and may not be able to treat the proximity parameters as being associated with a common type of proximity.

[0078] UE proximity engine 406 or network proximity capability 408 may make use of a method 410 to discover radio proximity, a method 412 to discover geographic proximity, a method 414 to discover cellular proximity and/or a method 416 associated with discovering proximity contingent on common proximity parameters. These methods may use one or more interfaces 420 that may be partly or completely standardized (e.g., by 3GPP) to one or more other entities. In contrast, the interactions on interfaces 422 and 424 may be proprietary – e.g., may be according to vendor or operator proprietary standards.

[0079] **Discovery of Geographic Proximity**

[0080] As described previously, methods of discovering proximity between mobile devices may be coarse or fine. In the case of geographic proximity, fine methods may not be very efficient but may be more reliable and more accurate and may include a Round Trip propagation Time (RTT) Method, a location method, an Observed Time Difference (OTD) method and a combination of two or more of the RTT method, location method and OTD method. For geographic proximity, coarse methods may be more efficient but less accurate and less reliable and may include a radio method, a cellular method and an iterated method. These different methods are described herein with reference to certain figures.

[0081] FIG. 5 illustrates an RTT method of discovering geographic proximity between a pair of mobile devices, in accordance with some embodiments of the present invention. With this method a round trip propagation time is measured between different pairs of UEs using direct signaling (e.g., via LTE-D or WiFi-D) between the UEs. The measurement may be performed by either UE and may be assisted by the other UE.

[0082] A number of different methods of accurately measuring RTT exist in the art (e.g., as defined in IEEE 802.11 specifications in the case of WiFi-D) and any of them, may be used. The measurement of the RTT between a pair of UEs enables the current distance between the UEs to be determined making use of the known speed of signal transmission (typically the speed of light). Hence it becomes possible to determine whether the UEs are in geographic proximity given some maximum distance associated with being in geographic proximity. RTT measurements may be preformed between other pairs of UEs enabling proximity to be discovered between these other pairs of UEs.

[0083] However, when there are a large number of UEs, it may be impractical to measure the RTT, or attempt to measure the RTT, between all pairs of UEs. In that case, distances between pairs UEs for which an RTT was not measured may be determined based on other known distances between other pairs of UEs. This is illustrated in FIG. 5 in which a solid line joining any pair of UEs shown in FIG. 5 represents a known distance based on measurement of an RTT between the pair of UEs. For UEs not joined by a solid line in FIG. 5, no RTT would have been measured. To obtain the distance between these UEs, the known distances are used to determine the location of each UE relative to other UEs. The known distances constrain the location of each UE relative to another UE and act like rigid rods. When a sufficient number of UE to UE distances are known, the constraints on the UE positions force the UEs into a fixed arrangement that would be analogous to a fixed structure formed by connecting UEs via rigid rods of lengths equal to their respective distances.

[0084] In reality, RTTs and the UE-UE distances may have errors preventing an exact arrangement (or fixed structure) from being unambiguously obtained. In this case, the distance between each pair of UEs can be allowed to have some difference to the measured value and an arrangement of all the UEs can be found that minimizes some function of these distances such as the sum of the squares of the differences. The ensuing arrangement of UEs can be used to determine other distances – for example the distance between UE 2 and UE 10 in FIG. 5 in which the dashed line represents a distance between the UEs inferred from the relative locations of the UEs determined by the RTT measurements (solid lines).

[0085] With the location method of discovering geographic proximity, the geographic location (e.g., latitude, longitude and possibly altitude) of each UE is obtained by the UE or by some server in a network serving the UE. The location may be obtained using one or more known position methods that are applicable to positioning of mobile wireless devices such as Assisted-GNSS, Advanced Forward Link Trilateration (AFLT), Observed Time Difference Of Arrival (OTDOA), Enhanced Cell ID (E-CID), WLAN AP positioning, use of inertial sensors.

[0086] The use of these position methods may be defined and controlled by a user plane location solution such as the Secure User Plane Location (SUPL) solution defined by the Open Mobile Alliance (OMA) or by a control plane (CP) location solution such as the CP location solution for LTE, WCDMA or GSM access defined by 3GPP or the CP location solution for cdma2000 defined by 3GPP2. A user plane location solution may employ a location server in a network (e.g., location server 2040 described later in FIG. 20 or SLP 1314 described later in FIG. 13) that employs data communication with UEs (e.g., using TCP/IP) in order to assist in obtaining the UE locations. A control plane location solution may employ a location server in a network (e.g., location server 2040 described later in FIG. 20 or E-SMLC 1210 dscribed later in FIG. 12) that employs communication with UEs via existing network signaling interfaces and protocols in order to assist in obtaining the UE locations. The location for each UE thereby obtained may be used to calculate the distance between any pair of UEs and thereby discover if the UEs are in geographic proximity.

[0087] For any UE for which a location cannot be determined using normal position methods, distances from that UE to two or more other UEs whose locations are known may be measured (e.g., by measuring RTT values) in order to obtain a location for the UE. This location may then be used to determine distances from the UE to other UEs and discover whether the UE is in geographic proximity to any UE of interest.

[0088] FIG. 6 illustrates a location method of discovering geographic proximity between a pair of mobile devices, in accordance with some embodiments of the present invention. The location method shows three UEs 601, 602 and 603 whose locations have been determined using position methods and positioning solutions such as those described above. In many cases, location determination may not be exact (e.g., due to measurement errors and errors in positioning assistance data such as any base station locations used for OTDOA or AFLT or any satellite locations used for A-GNSS). This may result in location estimates being obtained for UEs 601, 602, 603, as represented in FIG. 6 by the locations of the UEs, together with corresponding uncertainty areas (or volumes) within which each UE may be with some known probability (e.g., 67% or 95%) which are represented in FIG. 6 by the ellipses of the uncertainty areas 611, 612 and 613.

[0089] The distance between each pair of UEs, represented in FIG. 6 by the solid straight lines, may then be obtained as the distance between the location estimates for any pair of UEs. Due to the uncertainty areas, the true distance may be more or less than the distance between the location estimates.

[0090] Maximum and minimum values for the distance between each pair of UEs in FIG. 6 may be approximately obtained using the uncertainty areas. For example, double arrow 631 in FIG. 6 shows the distance between the location estimates for UEs 601 and 603 and may provide an expected distance between these UEs. Double arrow 632 shows a minimum distance between UEs 601 and 603 given by the minimum distance between uncertainty areas 611 and 613. Double arrow 633 shows a maximum distance between UEs 601 and 603 given by the maximum distance between any location in uncertainty area 611 and any location in uncertainty area 613.

[0091] Minimum and maximum distances may be calculated in other ways – e.g., using known probability distributions for possible locations of UEs 601 and 603. The minimum, maximum and expected distances between UEs 601 and 603 may be used to discover whether UEs 601 and 603 are within geographic proximity of one another. For example, geographic proximity may be discovered if the expected distance is less than a predefined threshold distance according to one set of rules.

[0092] According to a different set of rules, geographic proximity may be discovered if the minimum distance (or the maximum distance) is less than a predefined threshold. FIG. 6 further illustrates a UE 604 for which an absolute location is not known. For UE 602, RTT measurements may be possible between UE 604 and each of UEs 602 and 603, as illustrated by the dashed lines 620 and 621. The location of UE 604 relative to UEs 602 and 603 may then be obtained from which a distance estimate may be determined between UEs 601 and 604, thereby allowing discovery of any geographic proximity between UEs 601 and 604, for example.

[0093] With the OTD method of discovering geographic proximity between UEs, UEs measure transmission timing differences between pairs of other UEs which may be possible when UEs transmit signals that contain implicit timing markers such as provided by particular bits or symbols within a regularly repeating frame or some other standardized signal structure for a particular wireless transmission type such as LTE, W-CDMA, GSM or cdma2000. When the actual transmission timing offsets, known as Real Time Differences (RTDs), between different UEs are also known, as may be possible when each UE synchronizes its transmission to a common timing source such as GNSS time or the timing of a common base station (e.g., a common eNB) or when each UE can provide the timing offset between its own transmission time and that of some common timing source, the distance between pairs of UEs may be determined.

[0094] FIG. 7 illustrates an OTD method of discovering geographic proximity between a pair of mobile devices, in accordance with some embodiments of the present invention. The figure includes a set of four UEs 701, 702, 703 and 704. The distances between each pair of UEs in FIG. 7s are shown as solid lines. Distances, OTD measurements and RTDs are represented using the following notation.

[0095] D_{xy} = Distance between UE 70x and UE 70y

[0096] $OTDx_{yz}$ = OTD measured by UE 70x between UEs 70y and 70z

[0097] RTD_{yz} = RTD between UEs 70y and 70z

[0098] As is well known, for a positioning method based on measurement of OTDs such as OTDOA or AFLT, the distance between the entities (such as UEs 701, 702, 703 and 704 in FIG. 7) for which OTDs are measured and RTDs are known are related by the following equation:

$$c\,(OTDx_{yz} - RTD_{yz}) = D_{xy} - D_{xz} \qquad \text{(Equation 1)}$$

where c = signal speed (e.g., speed of light).

[0099] In the absence of other measurements or known locations for any of the UEs in FIG. 7, OTD measurements between pairs of UEs will not quite be sufficient to determine the distances between the UEs. For example in FIG. 7, the distances shown between each pair of UEs are for convenience each abbreviated by an upper case letter (e.g., the distance between UEs 701 and 702 is abbreviated as B and the distance between UEs 703 and 704 is abbreviated as D).

[00100] In FIG. 7, OTDs may be measured that, when augmented with known RTD values, provide values for the following five independent differences between UE to UE distances according to equation 1: A-B, A-C, A-D, A-E, and B-F. While other differences between distances may be obtained from OTD measurements (e.g., E-F) they will not be independent, since they will be related to some of the five independent differences above (e.g., E-F = (A-B) + (B-F) – (A-E)).

[00101] Since there are six distances in FIG. 7 and five relationships can be obtained between them, the distances cannot be obtained. Adding additional UEs to FIG. 7 one at a time would enable more OTD measurements to be obtained by each UE added but would also contribute an equal number of UE to UE distances that would need to be obtained – e.g., adding a UE to a group of N UEs would enable N new independent OTD measurements to be obtained by that UE between pairs of the N UEs but would contribute N new unknown UE-UE distance values.

[00102] To obtain distances, the RTT may be measured between one or more pairs of UEs, or the locations of two or more UEs may be obtained or some UEs may obtain OTDs between APs at known locations. For example, in FIG, 7, if an RTT between UEs 703 and 704 is measured or if the locations of UEs 703 and 704 can be obtained, the distance D can be determined from which the other distances can be obtained from the previous five independent differences between UE to UE distances in FIG. 7. The obtained distances may then be used to determine whether particular pairs of UEs are in geographic proximity – e.g., whether UEs 701 and 702 in FIG. 7 are in proximity.

[00103] A radio method of discovering geographic proximity between a pair of UEs may be a coarse method and may depend on one UE (designated UE 1) being able to receive and measure signals from another UE (designated UE 2). For example, UE 1 may measure the signal strength or signal quality (e.g., S/N ratio) of signals received from UE 2 and determine that UE 2 may be geographic proximity to UE 2 if the signal strength or signal quality is above some predefined threshold. This method may be efficient if each UE periodically broadcasts a signal that can be received by other UEs and other UEs periodically listen for and measure these signals may not be very accurate geographically since the distance between the UEs may not be related very exactly to the measured signal strength or signal quality. Furthermore, when UEs are so far apart that signals cannot be received or if there are intervening obstacles to signal propagation (like buildings and walls etc.), then even when UEs are in geographic proximity, it may not be possible to determine this using the radio method.

[00104] FIG. 8 illustrates a cellular method of discovering proximity between a pair of mobile devices, in accordance with some embodiments of the present invention. A cellular method of discovering geographic proximity between a pair of UEs may be a coarse method and may depend on determining that UEs are served by or in coverage of nearby cells or nearby APs. For example, in one aspect, UEs may be determined to be in coarse proximity of served by or in coverage of the same cell or same AP.

[00105] FIG. 8 shows two APs (e.g., two LTE eNBs) 801 and 802 with supported coverage areas (or supported cells) of 811 and 812, respectively. UEs that can receive signals from either AP, or are served by either AP, may be assumed to be within the coverage of that AP. In FIG. 8, UEs with IDs in the range 821 to 830 are in the coverage

area 811 of AP 801 while UEs with IDs in the range 841 to 856 plus UE 830 are in the coverage area 812 of IE 802. Hence UEs 821 to 830 may be considered to be within geographic proximity to one another and UEs 841 to 856 plus UE 830 may be considered to be within geographic proximity to one another.

[00106] In another aspect, UEs that are in coverage of the same AP or of nearby APs may be assumed to be in geographic proximity, Because the coverage areas 811 and 812 of APs 801 and 802 overlap in FIG. 8, the APs may be assumed to be nearby one another in which case all UEs shown in FIG. 8 may be assumed to be in geographic proximity to one another. The cellular method may be efficient because a network (e.g., network server) may obtain the current serving cells and a list of visible APs from each UE as part of normal network operation – e.g., to enable handover of UEs to other cells or other APs when changing radio conditions or UE movement cause coverage in the current cell or by the current AP to fail or diminish. Hence, the already obtained information from UEs may be compared to determine UEs that are in coverage of the same AP, same cell or the same set of nearby APs or cells.

[00107] However, the cellular method may not be accurate because the distances between UEs may be highly variable and may in some cases exceed any predefined threshold for discovering geographic proximity. For example, in FIG. 8, the distance between UEs 824 and 850 may be much greater than between UEs 823 and 845 even though each UE in each pair is in coverage of a different AP. Hence, while the distance between UEs 824 and 845 may be within a predefined threshold for geographic proximity, the distance between UEs 824 and 850 may not be.

[00108] For some wireless access types, it may not always be possible to efficiently determine which cells or APs a UE is in coverage of – for example, if the UE is idle and not interacting with its serving network. In this case, larger areas may be used. For example with LTE wireless access, a UE in idle mode (with no radio bearers) may only interact with its serving network when it changes its current tracking area (TA) where a TA is a collection of different LTE cells. In this case, the serving MME in the serving network for the UE may only know the UE's current TA. When the UE's current TA changes, the UE may perform a TA update procedure with its serving network (e.g., serving MME) to provide the serving network (e.g., serving MME) with its new TA. In this case, the serving network may only know the current TA for an idle UE and not which cell it is in coverage of. In this case, the cellular method may assume that UEs may be in geographic proximity if they are within the same TA or within neighboring TAs. The serving network (e.g., a server in the serving network) may then make a more accurate assessment of geographic proximity by bringing UEs into connected LTE mode in which the serving cell of each UE would be known. This could be done periodically while two UEs for which discovery of proximity may be important are within the same TA or different neighboring TAs. The method remains coarse even when UEs are brought into connected mode but may not use much resources if UEs are brought into connected mode only infrequently.

[00109] FIG. 9 illustrates an iterated method of discovering proximity between a pair of UEs, in accordance with some embodiments of the present invention. The iterated method of discovering geographic proximity may be based on determining groups of UEs that are in proximity to either one another or to one particular UE. The groups may

then be successively combined (e.g., in an iterative process) based on common UEs in different groups.

[00110] In FIG. 9, UEs 902, 903 and 904 may be discovered to be within geographic proximity to a UE 901 using any of the preceding methods – e.g., RTT method, location method, OTD method, radio method or cellular method. For greater efficiency, only the radio method or cellular method may be used to determine that UEs 902, 903 and 904 may be geographic proximity to UE 901.

[00111] In an aspect, all four UEs (901, 902, 903, 904) may be discovered to be within geographic proximity to one another. A similar determination may occur (using any of the preceding methods or just using the radio method or cellular method) to determine that UEs 921 and 922 may be in geographic proximity to UE 902, that UEs 931, 932 and 933 may be geographic proximity to UE 903 and that UEs 941 and 942 may be in geographic proximity to UE 904.

[00112] In an aspect, the methods may be used to discover that UEs 902, 921 and 922 may be in proximity to one another, that UEs 903, 931, 932 and 933 may be in proximity to one another and that UEs 904, 941 and 942 may be in geographic proximity to one another. The initial group of UEs in proximity to UE 901 (or the initial group of UEs in proximity to one another in an aspect) may then be extended using UEs common to other groups. Thus, because UE 902 may be proximity to UE 901, UEs 921 and 922 that may be in proximity to UE 902 may be considered as being in proximity to UE 901. Similarly because UE 903 may be in proximity to UE 901, UEs 931, 932 and 933 that may be in proximity to UE 903 may be considered to also be in proximity to

UE 901. Finally, UEs 941 and 942 that may be in proximity to UR 904, which may in turn be in proximity to UE 901, may be considered to be in proximity to UE 901. In an aspect groups of UEs that may be in proximity to one another may be similarly extended by other groups of UEs that may be in proximity to one another – e.g., in FIG. 9, by combining the group 902, 921 and 922 with the group 901, 902, 903, 904 based on a common UE 902 and similarly for the group 903, 931, 932 and 933 and the group 904, 941 and 942.

[00113] Additional UEs may be added in further iterations based on UEs that may be in proximity to UE 901 that were added in earlier iterations. For example, UEs 935 and 936 in FIG. 9 may be in proximity to UE 933 and, once UE 933 has been added to a list of UEs in possible proximity to UE 901, may be added in a subsequent iteration to the list of UEs in possible proximity to UE 901. Adding additional UEs that may be in proximity to a particular UE (e.g., UE 901 in FIG. 9) or in an aspect may be in proximity to a set of UEs may not guarantee that the UEs actually are in proximity and thus may be a coarse but efficient method of discovering UEs that may be in proximity to one particular UE, or in an aspect may be in proximity to all UEs within a particular set. One of the fine methods of discovery proximity (e.g., RTT method, location method or OTD method) may then be used to discover which UEs are in actual proximity. Because the coarse method may reduce the number of UEs whose proximity to a particular UE, or in aspect to one another, needs to be verified, the fine method may use fewer resources than if applied to all UEs without the benefit of filtering out UEs using a coarse method.

[00114] FIG. 10 illustrates a process 1000 for performing an iterated method of discovering proximity between mobile devices, in accordance with some embodiments of the present invention. In the figure, an iterative method to discover UEs that are or may be in proximity to a certain target UE such as the UE 901 is shown.

[00115] In a first step 1002, the target UE (e.g., the UE 901 in FIG. 9) is placed in an initially empty set S1 of UEs and in an initially empty set S2 of UEs (that thus each contain just the target UE). Another set S3 of UEs is initialized to contain no UEs and an iteration counter is initialized to zero.

[00116] In a next step 1004, the iteration counter is tested to determine whether it has reached a limit on the number of iterations. If so, the procedure terminates at step 1012 with all UEs that are or may be in proximity to the target E contained in the set S1. For example, if the iteration counter limit is set to zero, the process 1000 will terminate the first time step 1004 is performed and no other UEs will be found in proximity to the target UE. If the iteration counter has not reached the limit (e.g., exceeds zero the first time step 1004 is performed), then at step 1006, the iteration counter is incremented by one.

[00117] Then at step 1008, UEs are selected one at a time from the set S2 and other UEs are found that are or may be in proximity to the selected UE and that are not in either of the sets S1 or S2 and are placed in the set S3. For each UE B selected from the set S2, any of the previously described methods of discovering other UEs that are or may be in proximity to the UE B may be used to find UEs to place in the set S3. For example, the RTT method, location method, OTD method, radio method or cellular

method may be used. In an aspect, the same method of discovering UEs that are or may be in proximity to each selected UE B may be used for all UEs B selected from the set S2 and for all occurrences of the step 1008. As an example of the step 1008 in the case of FIG. 9 when the sets S1 and S2 each start by containing UE 901, the UE B selected in step 1008 the first time it is performed will just be the UE 901 and the UEs found to be in proximity to the UE B (i.e., UE 901) will comprise UEs 902, 903 and 904, which will then be placed in the set S3. At the next step 1010, all of the UEs added to the set S3 in step 1008 are copied to the set S1, all of the UEs in the set S2 are replaced by the UEs in the set S3 and all of the UEs in the set S3 are removed. Note that these various operations refer to placing and transferring UE identities into and between the various sets.

[00118] In the example of FIG. 9, if the sets S1 and S2 initially contain the UE 901 and the set S3 contains the UEs 902, 903 and 904 following step 1008, the set S1 will contain the UEs 901. 902, 903 and 904 after step 1010, the set S2 will contain the UEs 902, 903 and 904 after step 1010 and the set S3 will be empty after step 1010. The process now moves back to step 1004 where the iteration counter is tested to see if it has reached its limit. If so, the procedure terminates at step 1012 with UEs in proximity or in possible proximity to the target UE contained in the set S1.

[00119] For example, in the case of FIG. 9, if the iteration limit was set to one, the procedure would terminate at step 1012 after one iteration with the UEs 901, 902, 903 and 904 in the set S1. If the iteration limit is not reached, then the steps 1006, 1008 and 1010 are performed again as described above. For example in the case of FIG. 9 and for a second iteration, the iteration counter will be incremented to the value two in step

1006, the UEs 902, 903 and 904 will be selected one at a time in step 1008 and the UEs 921, 922, 931, 932, 933, 941 and 942 will be found in step 1008 (as being in proximity or in possible proximity to one of the UEs 902, 903, 904) and will be added to the set S3. Then at step 1010, the UEs in the set S3 (UEs 921, 922, 931, 932, 933, 941 and 942) will be added to the set S1 and will replace the UEs 902, 903 and 904 in the set S2 and the set S3 will be emptied. The process then returns to step 1004 where the iteration counter is again tested to determine if the limit was reached and if so the procedure terminates at step 1012. In the case of FIG. 9, if the procedure terminates after the second iteration (i.e., with an iteration limit of two), the UEs in the set S1 would comprise the UEs 901, 902, 903, 904, 921, 922, 931, 932, 933, 941 and 942. The process may continue further for higher iteration limits. For example in the case of FIG. 9, the UEs 935 and 936 may be found at the third iteration in step 1008.

[00120] The iterated method of discovering proximity between UEs (e.g., as described in association with FIG. 9) may rely on another method of discovering proximity between pairs of UEs before the iterated method is applied. For example, in FIG. 9, another method of discovering proximity may first be used to discover proximity between the pairs of UEs shown as connected by straight lines in FIG. 9. Therefore, the iterated method may only be used in some implementations in combination with another method (e.g., the RTT, location, OTD, radio or cellular method).

[00121] The previously described methods of discovering geographic proximity between pairs of UEs or groups of UEs may be used in two stages. In the first stage, a coarse but fast and efficient method of discovering proximity may be used to determine

a superset of UEs in potential geographic proximity to a particular target UE. In a second stage, a fine but less efficient method may be used to narrow down the superset of UEs that are in potential proximity to the target UE to a smaller set that are in actual proximity to the target UE. In particular, while the coarse method used in the first stage may need to be applied to a large number of UEs, the fine method may be applied to a smaller number of UEs that initially pass the coarse proximity criteria. As part of performing the coarse and/or fine proximity discovery, it may be verified that candidates UEs for proximity to the target UE share at least one service whose support depends on proximity with the target UE – e.g., a 2-way friend finder service or a public safety related service – and that any restriction on the identities of the UEs (such as requiring that a UE belong to a particular group) is also satisfied. UEs that share no such services with the target UE can be ignored and not included for discovery of proximity whereas UEs that possess at least one such service (and that satisfy any group related restriction) can be included by the method(s) used to discover proximity. The discovery of proximity may be performed by the target UE or by a serving or home network for the target UE (e.g., by a proximity server in the serving network or home network). The coarse method used in the first stage of proximity discovery may be the radio method, the cellular radio or the iterated method described previously. The fine method used in the second stage may be the RTT method, the location method or the OTD method described previously.

[00122] In an aspect, if the area (or volume) that defines precise geographic proximity to some target UE X is an area (or volume) A, then all UEs may be determined that: (a) are within the area A or may be within the area A;(b) share at least

one service dependent on proximity with the target UE X; and (c) satisfy any group related restriction on UE identity. To verify condition (a), a coarse method of discovering proximity may be used such as the radio method, cellular method or iterative method.

[00123] Once UEs in or possibly within the area (or volume) A are determined that also satisfy the service condition (b) and any UE identity condition (c), the geographic distances between each such UE and the target UE X may be verified more accurately using the RTT method, location method or OTD method in order to discover proximity more accurately. Only UEs that are within some precise distance threshold of the target UE X may be considered to be in actual proximity to UE X.

[00124] While this approach still requires accurate UE-UE distances to be verified, it may reduce the number of distance calculations to some small number of pairs of UEs.

[00125] The various coarse and fine methods of discovering proximity that were described previously may be used to discover geographic proximity between pairs of UEs. However, the same methods may also be used to discover radio proximity or cellular proximity between UEs. For example, the RTT method which may be a fine method of discovering geographic proximity may be used as a fine method of discovering radio proximity, since the RTT method may rely on the ability to directly communicate between two UEs to measure the RTT. The RTT method may also be used as a coarse method of discovering cellular proximity between a pair of UEs since any distance between the pair of UEs determined from an RTT measurement may indicate a probability of the two UEs being served by the same cell or the same AP or being in

coverage of the same cell or the same AP, but may not guarantee this. Similarly, the location method and OTD method may each provide a coarse method of determining either radio proximity or cellular proximity between two UEs since any distance between the UEs determined from their respective locations in the case of the location method or from OTD measurements in the case of the OTD method may only provide a probability of the UEs being in radio proximity or cellular proximity but not a guarantee. The radio method may provide a fine method of determining radio proximity in the case that two UEs each receive and measure characteristics (e.g., signal strength or S/N ratio) of a signal transmitted from one UE to the other. However, the radio method may only provide a coarse method of determining cellular proximity between two UEs since an ability of either UE to receive and possibly demodulate signals transmitted by the other UE may only provide a probability for the conditions for cellular proximity and not a guarantee. The cellular method may provide a fine method of determining cellular proximity between two UEs since the cellular method may determine if two UEs are served by or in coverage of the same cell or the same AP which may be the condition for determining cellular proximity. However, the cellular method may only provide a coarse method of determining radio proximity between two UEs since UEs that are served by the same cell or the same AP or that are in coverage of the same cell or the same AP may only sometimes be able to communicate with one another directly. The iterated method may also be a coarse method of discovering radio proximity or cellular proximity since discovery of UEs in proximity to another UE using the iterated method may not guarantee the conditions for either radio proximity or cellular proximity even when applied to certain pairs of UEs (such as the pairs of UEs shown as connected by straight lines in FIG. 9) that are known to be in radio proximity or cellular proximity to one another.

[00126] The preceding properties of the different methods of discovering proximity may mean that, with the exception of the iterated method, a particular method of discovering proximity (e.g., the RTT method, location method, OTD method, radio method or cellular method) may be a fine method of discovering one type of proximity and a coarse method of discovering a different type of proximity. For example, the location method may be a fine method of discovering geographic proximity but a coarse method of discovering radio proximity or cellular proximity. Although, it was assumed previously herein that the RTT, location and OTD methods would be slower and less efficient than the radio and cellular methods in the case of discovering geographic proximity, there may be situations where this does not apply. For example, if UEs are able to determine their current locations accurately (e.g., with an error of 100 meters or less) on a continuous basis with low usage of resources (e.g., making use of internal sensors and/or knowledge of the locations of nearby WiFi APs and/or using GNSS measurements), then the location method may be used as an efficient and fast coarse method of determining radio proximity or cellular proximity.

[00127] FIG. 11 illustrates a process 1100 for performing discovery of proximity between a first mobile device and a second mobile device using coarse and fine methods, in accordance with some embodiments of the present invention.

[00128] The process 1100 may be performed by the first mobile device, the second mobile device or by a network server – e.g., by a network proximity server. If the

process 1100 is performed by the first or second mobile device, this mobile device may obtain some of the data needed to perform the process 1100 (e.g., information about the identity, supported proximity services, location and serving cell for the other mobile device) from the other mobile device using direct signaling with the other mobile device (such as via LTE-D or WiFi-D) or by using direct signaling with a third mobile device that relays the data from the other mobile device (e.g., either directly or via a fourth mobile device that also acts as a relay). The first or second mobile device may also or instead obtain some of the data needed to perform the process 1100 (e.g., information on the identity, location and serving cell of the other mobile device) from its serving network or home network – e.g., from a proximity server in its serving network or home network.

[00129] If the process 1100 is performed by a network proximity server, the proximity server may obtain some of the data needed to perform process 1100 from the first mobile device and/or from the second mobile device (e.g., data concerning the identity, supported proximity services, location and serving cell of the first and/or second mobile device). The proximity server may also or instead obtain some of the data for performing process 1100 (e.g., information on the identities, location, serving cell, supported proximity services for the first and/or second mobile device) from other network entities such as an MME or eNodeB in the case of LTE access. Transfer of data needed to support process 1100 in the case that the data is transferred to or from a network proximity server may be as described later herein in association with FIGS. 12, 13, 14 and 16.

[00130] At step 1102 of process 1100, a processor determines a coarse proximity result for the first and second mobile devices using a coarse method. The coarse proximity result may indicate if the first and second mobile devices may be in proximity to one another. The coarse proximity result may be one of a coarse radio proximity result if radio proximity is to be determined, a coarse geographic proximity result if geographic proximity is to be determined or a coarse cellular proximity result if cellular proximity is to be determined. The coarse method may comprise one or more of of the RTT method described in association with FIG. 5, the location method described in association with FIG. 6, the OTD method described in association with FIG. 7, the radio method, the cellular method described in association with FIG. 8 or the iterated method described in association with FIG. 9.

[00131] At step 1104, the coarse proximity result is tested and the processor proceeds to step 1106 if the coarse proximity result does not indicate proximity of the first and second mobile devices and to step 1108 if the coarse proximity result does indicate that the first and second mobile devices may be in proximity to one another.

[00132] At step 1106, the processor refrains from verifying whether the first and second mobile devices are in proximity using a fine method and may after some delay (e.g., a few minutes) repeat the coarse proximity determination of step 1102.

[00133] At step 1108, the processor determines a fine proximity result for the first and second mobile devices using a fine method. The fine proximity result may indicate if the first and second mobile devices are in proximity to one another. The fine proximity result may be one of a fine radio proximity result if radio proximity is to be

determined, a fine geographic proximity result if geographic proximity is to be determined or a fine cellular proximity result if cellular proximity is to be determined. The fine proximity result may be of the same type (e.g., radio proximity, geographic proximity or cellular proximity) as the coarse proximity result determined in step 1102. The fine method may comprise one or more of the RTT method described in association with FIG. 5, the location method described in association with FIG. 6, the OTD method described in association with FIG. 7, the radio method, or the cellular method described in association with FIG. 8. The fine method may be different than the coarse method used in step 1102 and may be less efficient (e.g., may use more resources) and/or may be slower but may also be more accurate than the coarse method. If the fine method used in step 1108 is the location method, the location of the first mobile device and/or the location of the second mobile device may be determined using a user plane location solution (e.g., the OMA SUPL solution) or a control plane location solution (e.g., a 3GPP defined control plane location solution).

[00134] At step 1110, the processor tests the fine proximity result and verifies whether the fine proximity result indicates that the first and second mobile devices are in proximity. If proximity is not indicated in step 1110, then after some time interval (e.g., a few minutes), the processor may branch to either step 1108 to repeat the fine proximity verification or to step 1102 to repeat the coarse proximity verification. If proximity is indicated in step 1110, then at step 1112, the processor determines that the first and second mobile devices are in proximity and may inform a user or application associated with the first mobile device and/or the second mobile device that proximity was discovered.

[00135] The coarse proximity result in step 1102 and/or the fine proximity result in step 1108 may be determined using one or more proximity parameters that define the conditions for determining whether two mobile devices are in proximity. The proximity parameters may include one or more of the parameters (a1), (a2), (a3), (b1), (b2), (b3), (c1), (c2), (d1), (d2) and (d3) described previously – e.g., in association with FIG. 4. The use of the proximity parameters may be related to whether radio proximity, geographic proximity or cellular proximity is to be determined particularly in the case of the fine proximity result. For example, one or more of proximity parameters (a1) to (a3) may be used to determine a fine radio proximity result in step 1108, one or more of proximity parameters (b1) to (b3) may be used to determine a fine geographic proximity result in step 1108, and one or more of proximity parameters (c1) and (c2) may be used to determine a fine cellular proximity result in step 1108. In addition, multiple proximity parameters may be used and may be combined using logical OR and/or logical AND operations in step 1102 and/or in step 1108.

[00136] **Implementation of Proximity**

[00137] A proximity service may be a service available to a set of participating UEs in which radio, geographic or cellular proximity is the dominant or only criterion for triggering the provision of service to the participating UEs – e.g., to applications on the UEs and/or to users of the UEs. Some examples of proximity services were described previously in association with FIG. 2.

[00138] A "symmetric proximity service" may be a proximity service where exactly the same service is available to each UE that is discovered to be in proximity to one or

more other UEs. Examples of symmetric proximity services may include the 2-way friend finder service and the vehicle to vehicle communication service referred to in FIG. 2.

[00139] An “asymmetric proximity service” may be a proximity service where exactly the same service is not always available to each UE that is discovered to be in proximity to one or more other UEs. For example, with an asymmetric proximity service, different components or facets of a service may be defined that are selectively made available to some but not all UEs. Examples of an asymmetric proximity service may include the 1-way facility finder service described for FIG. 2 in which UEs found to be in proximity to another (e.g., fixed) UE belonging to a facility receive one type of service (e.g., advertisements or information related to the facility) whereas the UE owned by the facility receives a different service (e.g., notification of the number of UEs in proximity to the facility at any time and/or information enabling communication with UEs that are in proximity to the facility such as the addresses or identities of these UEs).

[00140] A “proximity group” may comprise a group of UEs that are enabled to receive one or more proximity services that are provided only to UEs within the group that are in proximity to one another (e.g., and are not provided to UEs outside the group). An example of a proximity group could be a group of UEs belonging to friends and/or relatives who receive a 2-way friend finder proximity service restricted to the group.

[00141] A UE may be a member of more than one proximity group for the same proximity service. For example, a UE could belong to several different groups each receiving a 2-way friend service. A “symmetric proximity group” may support only symmetric proximity services (e.g., a 2-way friend finder service) and may use symmetric discovery of proximity. Any UE within a symmetric group may then be able to discover and authenticate any other UE that is within the same group. An “asymmetric proximity group” may support one or more asymmetric proximity services (e.g., a 1-way facility finder service). There may also be restrictions on which UEs in an asymmetric group are allowed to discover other UEs within the group. For example, to support a 1-way facility finder service within an asymmetric proximity group G, a subset A of UEs (the clients) in G may be allowed to discover and authenticate other UEs in the subset G-A (the servers). However, UEs in either the subset A or the subset G-A may not be allowed to discover (or authenticate) UEs in the subset A.

[00142] The identity of a proximity group as well as the identity of a proximity service may be encoded using “expressions” which may comprise a string of bits (e.g., 128 bits) that may have some structure (e.g., a hierarchical structure) that includes codes for different categories of service as well as codes identifying particular services and different groups of UEs.

[00143] A UE that belongs to certain proximity groups and/or that makes use of certain proximity services may broadcast a set of expressions to other UEs where each expression being broadcast identifies a certain proximity service or proximity group that the UE uses or belongs to, respectively.

[00144] Other UEs that receive the broadcast expressions can then determine whether they may use any of the same proximity services and/or whether they belong to the any of the same proximity groups. For example, a receiving UE may achieve this by comparing the expressions received from a broadcasting UE with expressions that the receiving UE would broadcast and by looking for any matches between these expressions. If a receiving UE discovers one or more matches, the receiving UE may attempt to determine whether the broadcasting UE is in proximity in order to invoke a proximity service if proximity in discovered.

[00145] In another aspect, UEs may provide a list of their expressions to a serving network or home network (e.g., to a proximity server in the serving network or home network). The serving network or home network (or a proximity server in either network) may then compare expressions received from different UEs in order to find possible matches. If matching expressions are found for two or more UEs, the network or server may attempt to discover whether the UEs are in proximity in order to provide proximity services to the UEs if proximity is discovered.

[00146] When broadcasting expressions, UEs may also broadcast their identities or, for privacy reasons, may broadcast a temporary ID (e.g., assigned by the network) or an encoded ID (e.g., derived using hashing and/or ciphering from a global UE ID such as an IMSI). True UE identities may then be revealed to other UEs found to be in proximity only following authentication of the other UEs.

[00147] Authentication of UEs found to be in proximity to one another prior to providing or enabling any proximity service for the UEs may be important and useful

for users and applications. Authentication may include verifying the claimed identity of a UE, its claimed membership in a particular proximity group and/or its claimed right to use a particular proximity service. Authentication may help avoid cases where a UE that is not a member of a particular proximity group or is not entitled to receive a particular proximity service is able to engage in proximity services with another UE that is a member of the particular proximity group or is entitled to use the particular proximity service. Authentication may also help detect and avoid cases where one UE A engages in proximity services with another UE B but provides a false identity to the UE B – e.g., provides an identity that falsely implies that the user of the UE A is a friend or relative of the user of the other UE B. Authentication of UEs may be supported when or after UEs are discovered to be in proximity – e.g., using a coarse or fine method of discovering proximity. Authentication may also be supported using different methods that depend on the type of proximity being supported – e.g., radio proximity, geographic proximity or cellular proximity as described with respect to FIG. 1. Authentication may make use of ciphering and authentication keys associated with authentication methods known in the art – e.g., RSA or CMAC method of authentication.

[00148] For radio proximity, shared secret keys or public-private key pairs may be used to support direct authentication of one UE by another UE. Shared secret keys may enable mutual authentication and may support a symmetric proximity group. Public-private key pairs may enable 1-way authentication and may support an asymmetric proximity group.

[00149] When proximity between UEs is discovered by a trusted server in a serving network or home network, authentication may be based on each UE in any proximity

group knowing the identities of all the other UEs in the same group. A serving of home network (e.g., an MME or proximity server in this network) may then authenticate the identity of each UE found to be in proximity to one or more other UEs and may provide the authenticated UE identity to these other UEs which can then verify that the authenticated identity belongs to the proximity group.

[00150] Authentication could instead be based on subscription. For example an HSS in the home network of a UE may provide a serving network or proximity server in a serving network with the home network assigned ID for each proximity group to which the UE belongs. The received IDs may be trusted by the serving network or proximity server due to being provided by a trusted network. The serving network or proximity server may then verify that two or more UEs found to be in proximity have been assigned the same group IDs.

[00151] In another method, authentication may be supported using a shared secret key for each proximity group with the shared secret key known to (e.g., assigned by) a serving network or home network. For two or more UEs found to be in proximity, a server in the serving network or home network may then authenticate each UE separately using the shared secret key. If there are N UEs ($N \geq 2$) in proximity, it will then be necessary to authenticate N UEs and thus perform N authentication operations. In contrast, if UEs were authenticated bilaterally (e.g., by having each UE in the N UEs separately authenticate the other N-1 UEs) there would be N^2 authentication operations. Hence, having a network or network server authenticate each UE separately may be more efficient.

[00152] If a group's secret key(s) is(are) unknown to a network or network server, the network or network server may authenticate each UE in a group using a public-private key pair, where the network or network server uses the public key and each UE uses the private key. In an aspect, each UE may prove its membership in a particular proximity group to a network or to a network server by digitally signing (using the private key of a public-private key pair) data that is sent to the network or network server that may include, for example, the current date, current time, the group ID, and/or the UE ID. One UE in the proximity group may also provide a certificate to the network or network server that certifies the public key needed to verify the digital signatures for the various UEs in the proximity group. The network or network server may then cache the received public key and use it later to verify the digital signatures received from the other UEs.

[00153] For some groups (e.g., a group supporting a 1-way facility finder service), authentication of UEs may not always be needed if the main purpose of the group is to offer a proximity service in which member UEs receive but do not send data.

[00154] Discovery of proximity between UEs may employ direct signaling between UEs (e.g., LTE-D or WiFi-D signaling) and may be referred to as "direct discovery". Direct discovery may be autonomous (e.g., controlled only by participating UEs) or may be network controlled (e.g., where a network provides permission and signaling channels for UEs to directly discover one another). For direct discovery, some UEs may act as relays, for example by relaying via broadcast the expressions received from other UEs to extend the range of these UEs. For example, a UE B may relay expressions broadcast by a UE A to a UE C and may relay any response from the UE C back to the

UE A thereby enabling UEs A and C to discover one another and determine whether they may be in proximity. To determine whether UEs A and C are in proximity in this case, some of the previous methods may be used such as the RTT, location, OTD, radio, cellular and iterated methods. For example, RTTs may be measured between UEs A and B and between UEs B and C and/or the locations of UEs A, B and C may be obtained and/or the fact that UEs A and C are within coverage of UE B may be used to infer proximity.

[00155] Discovery of proximity may instead or in addition be supported by a network proximity server. In this case, UEs (or a serving network) may provide requirements concerning support of proximity services and data for each proximity group that each UE may belong to (e.g., including a group ID, current UE location, proximity service related parameters including expressions identifying proximity services of interest) to a network server. UEs may also provide data to the proximity server on other UEs that are detected via direct discovery. The server may then broadcast all the information received from all UEs in a certain area back to those UEs and/or may evaluate the received data internally – e.g., by determining UEs that belong to the same proximity groups or that use the same proximity services (e.g., have the same expressions). The server may then determine whether UEs that belong to the same proximity groups or that share the same proximity services are in proximity by making use of any of the previously described methods of determining proximity (e.g., RTT, location, OTD, cellular, radio or iterative methods) and/or by making use of coarse and fine methods of discovering proximity as described in association with FIG. 3 and FIG. 11.

[00156] Network proximity servers may also interact with other servers in the same network or in other networks (e.g., by sharing some or all of their received data) to determine whether UEs served by different servers and/or by different networks may be in proximity.

[00157] With direct discovery of proximity as discussed previously, a UE may discover other UEs via direct signaling with other UEs (e.g., using LTE-D or WiFi-D). UEs may then interact via direct signaling to verify membership in the same proximity group(s), use of the same proximity service(s) and proximity to one another. Signal characteristics (e.g., signal strength, S/N ratio) and RTT measurements may be used to verify proximity, whereas membership in the same proximity group or use of the same proximity service may be verified (and possibly authenticated) by exchange of proximity related information.

[00158] However, the method may not detect some UEs if the UEs do not broadcast proximity related information or if broadcast signal propagation is impeded by obstacles (e.g., walls, buildings, floors) or if the UEs are distant. To detect these other UEs, a UE A can interact with a network proximity server to send to the server its own proximity data (e.g., proximity groups to which UE A belongs and proximity services that UE A uses) and possibly data for other nearby UEs discovered by UE A via direct signaling. The server may then send back to UE A data on other UEs that: (i) may be members of the same proximity groups as UE A; and/or (ii) may make use of the same proximity services as UE A; and that (iii) may also be in proximity to UE A.

[00159] When discovery of proximity is supported by a network proximity server, the server may obtain proximity data for all UEs in a certain served area directly from the UEs and/or from entities in the serving network for these UEs such as MMEs and/or eNodeBs in the case of LTE access. The proximity server could be a new entity or a new logical function in an existing entity or subsystem (e.g., could be a new logical function in an eNodeB, MME, PDG, IMS, SLP or E-SMLC in the case of LTE access). The proximity server may scan the proximity related data that it receives for UEs or from UEs in its serving area for potential proximity matches. The server may then: (A) find all UEs belonging to the same proximity group; (B) authenticate membership claimed by each UE in each proximity group; (C) verify geographic, cellular or probable radio proximity conditions for UEs in the same group; and/or (D) for each proximity group where a set S of UEs are discovered to be in proximity, send data related to the discovered UEs in S to some/all of the UEs in S according to which UEs in S are allowed to receive this data. The server can instead or in addition broadcast the proximity data it receives from all UEs back to each of these UEs (i.e., so that each UE receives data related to all the other UEs) with the UEs then becoming responsible for discovering their proximity to other UEs. The data broadcast by the server in each cell may just contain data on UEs in or nearby to the cell (e.g., and may not contain data for UEs in distant cells) to reduce the amount of broadcast data.

[00160] Each UE (or an entity in the serving network such as the serving MME or serving eNB for each UE) may update data in a proximity server periodically or whenever there is some change in the data such as caused by: (i) a change of UE serving cell; (ii) a change of UE location; (iii) a change in the set of UEs detected by a UE via

direct signaling; and/or (iv) a change of user or application requirements for a proximity group. A server may also delete any data that it previously received for any UE following a timeout on no more received data for the UE. The server may also receive proximity related data for UEs (e.g., for network defined proximity groups) via Operations and Maintenance (O&M) or from other servers.

[00161] Network control of direct discovery of proximity may be optional. For example, a network may tell served UEs (e.g., when UEs attach to the network or via broadcast) whether or not direct discovery of proximity is permitted and may provide physical and transport related parameters to enable broadcast and signaling by UEs for direct discovery.

[00162] A network may also indicate to served UEs whether a proximity server is supported by the network to support discovery of proximity. A network may then indicate to UEs whether the network proximity server shall be used to discover proximity rather than direct discovery. Network control information regarding direct discovery and use of a network proximity server may be broadcast to UEs and/or provided to UEs individually by point to point means on network attachment or (for IMS control) on IMS registration. Network control information may specify how discovery will work – e.g., whether UEs need to send data to a network proximity server concerning UEs discovered via direct discovery.

[00163] FIGS. 12, 13 and 14 are schematic block diagrams illustrating certain example arrangements to support a network proximity server, in accordance with an example implementation.

[00164] FIG. 12 shows a schematic block diagram illustrating an example arrangement 1200 in which discovery of proximity between nearby UEs is discovered by or with the assistance of a network proximity server in an LTE network that makes use of control plane based signaling to communicate with other entities. As illustrated, example arrangement 1200 may comprise an eNB 1204 coupled to a UE 1202 and also an MME 1206. MME 1206 may be coupled to a proximity server 1208 and possibly to an E-SMLC 1210. In certain implementations, as illustrated by the dashed-line box 1211, proximity server 1208 and E-SMLC 1210, though logically separate, may be physically combined, e.g., to benefit from proximity & location synergies, etc., or may be physically separate and enabled to communicate via a communications link. Control plane based signaling may be supported between UE 1202 and proximity server 1208, for example, using NAS capabilities and NAS signaling that may be partly defined already for 3GPP networks in such 3GPP Technical Specifications (TSs) as TS 24.301.

[00165] Proximity server 1208 may obtain proximity related information for UE 1202 (e.g., UE identity, UE location, UE serving cell, serving eNB or TA, nearby UEs detected by direct radio means, proximity services supported by or of interest to the UE) directly from UE 1202 (e.g., using the aforementioned NAS signaling) and/or from eNB 1204 and/or MME 1206.

[00166] Location related information for UE 1202 may in addition or instead be obtained by proximity server 1208 from E-SMLC 1210. To locate a target UE (e.g., UE 1202), proximity server 1208 may send a location request to (serving) MME 1206 for UE 1202.

[00167] In certain instances, MME 1206 may transfer such a request to E-SMLC 1210 which may then locate UE 1202 using 3GPP control plane procedures (e.g., as defined in 3GPP TS 36.305) and return the location result to MME 1206 and thence to proximity server 1208. Proximity server 1208 may use the information obtained for UE 1202 and other UEs to determine which UEs may be in proximity. For example, proximity server 1208 may perform the process 300 of FIG. 3 or the process 1100 of FIG. 11 to discover proximity between UEs. Proximity server 1208 may then inform UEs (e.g., UE 1202) discovered to be in proximity to other UEs using control plane signaling.

[00168] FIG. 13 shows a schematic block diagram illustrating an example arrangement 1300 in which discovery of proximity between nearby UEs is discovered by or with the assistance of a network proximity server in an LTE network that makes of user plane based signaling to communicate with other entities. In contrast to control plane support as illustrated in FIG. 12, user plane support may reduce impacts to network eNBs and MMEs to support discovery of proximity.

[00169] Example arrangement 1300 may comprise an eNB 1304 coupled to UE 1302 and also an MME 1306. MME 1306 may be coupled to a proximity server 1312. As shown, eNB 1304 may be coupled to an SGW 1308, which may be further coupled to a PDG 1310. PDG 1310 may be coupled to proximity server 1312 and to a SLP 1314 (such as a SUPL SLP), and proximity server 1312 may be coupled to SLP 1314. In certain implementations, as illustrated by the dashed-line box 1313, proximity server 1312 and SLP 1314, though logically separate, may be physically combined, e.g., to benefit from proximity & location synergies, etc.

[00170] In this example, two potential signaling paths are indicated, the first comprising MME-Proximity Server Signaling (e.g., which may add efficiency), and the second comprising UE-Proximity Server Signaling. As for a control plane based proximity server (e.g., proximity server 1208 in FIG. 12), proximity server 1312 may obtain information to support discovery of proximity between UEs directly from the UEs (e.g., UE 1302) using user plane signaling in which information may be sent in the form of data (e.g., using TCP/IP) from a network perspective. The information may be similar to or the same as in FIG. 12 – e.g., may include UE identity, UE location, UE serving cell, serving eNB or TA, other nearby UEs detected and proximity services supported by or of interest to the UE.

[00171] Proximity server 1312 may also obtain some or all of this information from MME 1306 if proximity server 1312 is linked to MMEs. In certain implementations, a proximity server address (e.g., the IP address or the FQDN for proximity server 1312) may be discovered by UE 1302 (e.g., using the IETF DHCP protocol) or may be provided to UE 1302, e.g., on network attachment by MME 1306 or on connection to PDG 1310 or may be broadcast to all UEs by eNBs such as eNB 1304. UE 1302 may then use the discovered address for proximity server 1312 to transfer data to proximity server 1312 and/or to request data from proximity server 1312. In some instances, proximity server 1312 may use a (SUPL) SLP 1314 to assist with UE location. Thus, for example, proximity server 1312 may send a location request for some target UE directly to an associated SLP 1314 after which SLP 1314 may invoke SUPL to locate the UE and return the location to proximity server 1312. Proximity server 1312 may also

perform the process 300 of FIG. 3 or the process 1100 of FIG. 11 to discover proximity between UEs.

[00172] FIG. 14 shows a schematic block diagram illustrating an example arrangement 1400 in which discovery of proximity between nearby UEs is discovered by or with the assistance of a network proximity server that makes use of IMS based signaling to communicate with other entities.

[00173] Example arrangement 1400 may support UE-proximity server signaling in an LTE network and may comprise an eNB 1404 coupled to UE 1402 and also an MME 1406. As shown, eNB 1404 may be coupled to an SGW 1408, which may be further coupled to a PDG 1410. PDG 1410 may be coupled to an SLP 1412 and to an IMS 1414. In this example, IMS 1414 may comprise a P-CSCF 1416, coupled to PDG 1410 and to an S-CSCF 1418. S-CSCF 1418 may be coupled to a proximity server 1422.

[00174] Proximity server 1422 may be coupled to an LRF 1420 which may support location and routing services (e.g., may be able to locate UEs). Proximity server 1422 may function as an IMS Application Server (AS) in some implementations. In certain implementations, as illustrated by the dashed-line box 1424, proximity server 1422 and LRF 1420, though logically separate, may be physically combined, e.g., to benefit from proximity & location synergies, etc.

[00175] As for a control plane or a user plane based proximity server (e.g., proximity server 1208 in FIG. 12 or proximity server 1312 in FIG. 13), proximity server 1422 may obtain information to support discovery of proximity between UEs directly from the UEs (e.g., UE 1402) using IMS based signaling in which information may be sent in the

form of data and contained in SIP messages. The information may be similar to or the same as in FIGS. 12 and 13 – e.g., may include UE identity, UE location, UE serving cell, serving eNB or serving TA, other nearby UEs detected and proximity services supported by or of interest to the UE.

[00176] In certain implementations, proximity server 1422 may reside in the home network of UE 1402 rather than in the serving network for UE 1402 (except when the serving network for UE 1402 is the home network). However, in certain instances this variation may be unable to detect proximity for roaming UEs without some further interaction between the home network of a roaming UE and the serving network of the UE (e.g., involving interaction between the proximity servers in different networks). In certain implementations, it may be beneficial to make use of certain (e.g., new) SIP signaling parameters. One advantage may be proximity support of certain IMS services, e.g., use of LTE-D for network offload, which may trigger IMS communication between two UEs, e.g., after proximity is detected. Proximity server 1422 may also perform the process 300 of FIG. 3 or the process 1100 of FIG. 11 to discover proximity between UEs.

[00177] FIGS. 15A, 15B, 15C and 15D provide some examples of direct discovery of proximity between UEs, in accordance with some embodiments of the present invention. As previously described, direct discovery of proximity may include direct signaling between UEs to enable UEs to discover other UEs that are in proximity.

[00178] FIG. 15A shows an example where a UE 2 1500-2 broadcasts expressions 1502 to other UEs including UE 1 1500-1. The expressions 1502 may indicate (e.g.,

may encode) the proximity services supported by UE 2 and/or the proximity groups for which UE 2 is a member. UE 1 may compare the received expressions 1502 with expressions used by UE 1 in order to determine whether UE 1 and UE 2 share any proximity services or are members of the same proximity group(s). If so, UE 1 and UE 2 may engage in additional direct signaling (not shown in FIG. 15A) to determine an RTT between them and may use the RTT to determine whether they are in geographic proximity. In addition or alternatively, UE 1 may use the detection of the expressions 502 broadcast by UE 2 and/or the received signal strength or S/N ratio for the signal broadcast by UE 2 to determine whether UE 2 is or may be in radio proximity to UE 1.

[00179] FIG. 15B shows an example where a UE 1 1500-1 sends expressions 1504 to a UE 2 1500-2 that match expressions 1502 previously received from UE 2 in FIG. 15A. In addition, UE 1 may send proximity data 1506 to UE 2 for the matching expressions 1504 to verify if there is a real match between expressions 1502 and 1504.

[00180] Proximity data 1506 may, for example, include data allowing UE 1 to authenticate the identity of UE 2, UE 2's support for proximity services indicated by expressions 1502 and/or UE 2's membership in proximity groups indicated by expressions 1502. Proximity data 1506 may also contain information to help determine whether UE 1 and UE 2 are in proximity – e.g., information related to RTT measurement.

[00181] The signals in FIG. 15B may be sent after the signals in FIG. 15A – e.g., UE 1 may respond to receipt of expressions 1502 in FIG. 15A by sending expressions 1504

and proximity data 1506 in FIG. 2. UE 2 may respond to receipt of expressions 1504 and proximity data 1506 in FIG. 2 by returning proximity data 1508 to UE 1.

[00182] Proximity data 1508 may help enable UE 1 to authenticate UE 2 (e.g., authenticate the identity of UE 2, the proximity services supported by UE 2 and/or the proximity groups to which UE 2 belongs). Proximity data 1508 may also help enable UE 2 to authenticate the identity of UE 1, the proximity services supported by UE 1 that were indicated in expressions 1504 and/or the proximity groups to which UE 1 belongs that were indicated by expressions 1504.

[00183] The signals in FIG. 15B may be broadcast or may be sent using channels intended for point to point communication. Additional exchange of proximity related data between UE 1 and UE 2 not shown in FIG. 15B may occur in order to allow UE 1 and UE 2 to verify support of common proximity services and/or membership in common proximity groups and verify that UE 1 and UE 2 are in geographic or radio proximity.

[00184] FIG. 15C shows an example where applications that support one or more proximity services in two UEs support at least one of these proximity services by exchanging voice and/or data 1510 via direct signaling (e.g., LTE-D) or via a network after proximity between the two UEs has been verified – e.g., via the signaling in FIGS. 15A and 15B. The applications may support proximity services or proximity groups that are verified to be common to both UEs using the signaling in FIG. 15B.

[00185] FIG. 15D shows an example where two UEs (UE 1 1500-1 and UE 2 1500-2) that have discovered one another (e.g., using the signaling in FIGS. 15A and 15B)

and that support common proximity services and/or are members of common proximity groups continue to monitor whether they are in proximity via exchange of proximity data 1506 (sent from UE 1 to UE 2) and proximity data 1508 (sent from UE 2 to UE 1). If the UEs are initially in proximity (e.g., as verified using the signaling shown in FIG. 15B) then the signaling in FIG. 15D may be used to verify if and when the UEs are no longer in proximity. If the UEs are not initially in proximity (e.g., as verified using the signaling shown in FIG. 15B) then the signaling in FIG. 15D may be used to verify if and when the UEs are in proximity.

[00186] As previously described, proximity may also be discovered between UEs using a network proximity server – e.g., such as proximity server 1208, 1312 or 1422 in FIG. 12, 13 or 14, respectively. In this case, discovery of proximity may require interaction between UEs and a network proximity server as described below.

[00187] FIGS. 16A, 16B and 16C provide some examples of support and discovery of proximity between UEs using a network proximity server, in accordance with some embodiments of the present invention.

[00188] FIG. 16A shows an example where a UE 1600 interacts with a network proximity server 1602 (e.g., where network proximity server 1602 may also be proximity server 1208 in FIG. 12, 1312 in FIG. 13 or 1422 in FIG. 14). In FIG. 16A, UE 1600 periodically sends to network proximity server 1602: (i) expressions 1604 indicating the proximity services that UE 1600 supports; (ii) group IDs 1606 indicating the proximity groups to which UE 1600 belongs; and/or (iii) proximity data 1608 indicating UE 1600 requirements or preferences for proximity services (e.g., such as a

set of proximity parameters) and/or data (e.g., a digital signature) that may be used by network proximity server 1602 to authenticate UE 1600 support for proximity services indicated by expressions 1604 and/or membership in proximity groups indicated by group IDs 1606.

[00189] In an aspect, proximity data 1608 may include the identity of UE 1600 and additional data on other UEs discovered by UE 1600 using direct discovery (e.g., as described in association with FIGS. 15A, 15B, 15C and 15D) where such additional data may include the identities of these UEs, their locations and/or distance from UE 1600.

[00190] Network proximity server 1602 may use the expressions 1604, group IDs 1606 and proximity data 1608 received from UE 1600 and from other UEs to determine UEs that share the same proximity services or that are members of the same proximity groups and that are in proximity to one another. Network proximity server 1602 may also validate UE claims (e.g., UE 1600 claims) to support certain proximity services or belong to certain proximity group. Validation may be possible if a trusted home network of each UE (e.g., an HSS for UE 1600) provides data on supported proximity services and supported proximity groups to network proximity server 1602 either directly or indirectly (e.g., via an MME in the network containing network proximity server 1602).

[00191] FIG. 16B shows an example where a network proximity server 1602 broadcasts proximity related data 1610 related to many UEs in each cell of a serving network to one or more UEs such as UE 1600. The proximity related data 1610 that is broadcast may include some or all of the data received by network proximity server

1602 from UEs, such as UE 1600, as shown in FIG. 16A. For example, the proximity related data 1610 may include expressions indicating proximity services supported by UEs such as UE 1600, proximity groups to which UEs such as UE 1600 belong, proximity parameters and other information for these UEs such as UE identities and locations. The proximity related data 1610 broadcast in each cell may also include information related only to UEs served by this cell and possibly neighboring cells but not data for UEs served by distant cells in order to reduce the data broadcast and reduce the burden of receiving and processing the data in recipient UEs such as UE 1600. UEs such as UE 1600 that receive the proximity related data 1610 may use it to help determine whether other UEs that support the same proximity services and/or belong to the same proximity groups may be in proximity.

[00192] FIG. 16C shows an example where a network proximity server 1602 discovers proximity itself between UEs that support the same proximity services or belong to the same proximity groups – e.g., as described above in association with FIG. 16A. Having discovered proximity between pairs or groups of UEs, network proximity server 1602 may send proximity data 1612 using point to point signaling to UEs, such as UE 1600, that are found to be in proximity to one or more other UEs. In the case of UE 1600, proximity data 1612 may include the identities of UEs found to be in proximity to UE 1600, an indication of the proximity services or proximity groups common to each such UE and UE 1600, information on the location of each such UE and possibly information to enable or assist direct communication between UE 1600 and each UE found to be in proximity to UE 1600.

[00193] Any of UEs 1500-1, 1500-2 in FIGS. 15A-15D and UE 1600 FIGS. 16A-16C may support process 300 in FIG. 3 and/or process 1100 in FIG. 11 to determine proximity to other UEs – e.g., making use of the signaling and data that may be received according to these figures. Similarly, network proximity server 1602 in FIGS. 16A-16C may support process 300 in FIG. 3 and/or process 1100 in FIG. 11 to determine proximity between UEs – e.g., making use of the data that may be received according to these figures.

[00194] FIG. 17 provides an example arrangement for enabling support of proximity services in a UE, in accordance with some embodiments of the present invention. The figure shows an example arrangement 1750 for supporting discovery of proximity by or on behalf of a UE 1700.

[00195] In an aspect, parts of FIG. 17 may correspond to parts of FIG. 4 whereby UE 400, user 402, application 404 and UE proximity engine 406 in FIG. 4 may correspond to UE 1700, user 1702, application 1704 and proximity engine 1706, respectively, in FIG. 17.

[00196] In FIG. 17, UE 1700 contains an application 1704 that supports different proximity services and/or proximity groups on behalf of a user 1702 for UE 1700. The proximity services supported by application 1704 may include one or more of the services described in association with FIG. 2. UE 1700 also contains a proximity engine 1706 which may be a process, module (e.g., hardware or software module) or program in UE 1700 or a portion of a process, module or program in UE 1700 that enables and supports discovery of proximity between UE 1700 and one or more other UEs that

support one or more of the same proximity services or proximity groups supported by application 1704.

[00197] Further, UE 1700 contains a positioning engine 1708 which may be a process, module (e.g., hardware or software module) or program in UE 1700 or a portion of a process, module or program in UE 1700 that enables and supports determination of the current location (e.g., latitude and longitude) and possibly the current velocity of UE 1700.

[00198] User 1702 may interact with application 1704 (e.g., via a keyboard, screen, touchscreen, voice, speaker) in order to request certain proximity services and/or receive certain proximity services including being notified when UEs belonging to other users that share the same proximity services or belong to the same proximity groups are in proximity to UE 1700. Application 1704 may request support of discovery of proximity to other UEs via an interface (e.g., an API) 1710 to proximity engine 1706.

[00199] Interface 1710 may allow application 1704 to provide preferences for proximity support – e.g., an indication of the proximity services supported by application 1704, the proximity groups to which application 1704 belongs and proximity parameters or combined proximity parameters for the supported proximity services such as the combined proximity parameters described in relation to FIG. 4.

[00200] Proximity engine 1706 may attempt to discover proximity of UE 1700 to other UEs that support some of the same proximity services or belong to some of the same proximity groups as application 1704 by making use of direct proximity discovery 1722 and/or network proximity discovery 1720. Direct proximity discovery 1722 may

include signaling with other UEs using procedures exemplified in FIGS. 15A, 15B, 15C and 15D and may enable proximity engine 1706 to discover UEs in proximity to UE 1700. Network proximity discovery 1720 may include information exchange with a network proximity server using procedures exemplified in FIGS. 16A, 16B and 16C that enable proximity engine 1706 either to discover other UEs in proximity to UE 1700 or be informed of other UEs in proximity to UE 1700 by the network proximity server.

[00201] To assist proximity engine 1706 to discover proximity of UE 1700 to one or more other UEs, proximity engine may be enabled to request and obtain the current location of UE 1700 and possibly the current velocity of UE 1700 using an interface (e.g., an API) 1712 to the positioning engine 1708 in UE 1700. The same interface 1712 may also be available to application 1704 to enable application 1704 to obtain the current location and optionally the current velocity of UE 1700 from positioning engine 1708. Positioning engine 1708 may receive positioning support 1724 from one or more external entities such as a location server which may be an E-SMLC or SUPL SLP in some implementations. Positioning support 1724 may enable positioning engine 1708 to request and receive location assistance data (e.g., from an SLP or E-SMLC location server) and/or may enable positioning engine to send location related measurements (e.g., measurements of GNSS satellites, eNBs or WiFi APs) to a location server which may subsequently return to positioning engine 1708 a computed location estimate for UE 1700.

[00202] Arrangement 1750 may enable support of proximity services and proximity groups by application 1704 in UE 1700 on behalf of user 1702 making use of the various exemplary methods and procedures described herein. For example, proximity

engine 1706 may support process 300 in FIG. 3 or process 1100 in FIG. 11 to discover proximity of UE 1700 to other UEs, may support the interactions with other UEs shown in FIGS. 15A-15D to assist with discovery of proximity and/or may support the interactions with a network proximity server shown in FIGS. 16A-16C to assist with discovery of proximity. The application 1704 in UE 1700 may activate and deactivate proximity support for a particular proximity group or proximity service by sending commands to proximity engine 1706 over interface 1710. To activate support for a particular proximity service or proximity group, an application 1704 could provide data to proximity engine 1706 comprising: (i) the proximity group ID or proximity service ID; (ii) performance related parameters for the proximity service such as one or more of proximity parameters (a1) to (a3), (b1) to (b3), (c1), (c2) and (d1) to (d3) described in association with FIG. 4; (iii) authentication related data; and (iv) allowed discovery directions such as whether UE 1700 permits discovery of UE 1700 by other UEs or only requires discovery of other UEs by UE 1700. Expressions identifying any proximity services or proximity groups provided in item (i) above may be provided by application 1704 or may, in some implementations, be determined by the proximity engine (e.g., from a proximity group ID or proximity service ID).

[00203] Following activation of a proximity service or activation of support for a proximity group by application 1704, the proximity engine 1706 may notify application 1704 when proximity to other UEs that support the same proximity service or belong to the same proximity group is discovered. Proximity engine 1706 may also provide information to application 1704 for these UEs such as their identities, current locations and any radio channels that may be used for direct communication (e.g., using LTE-D

or WiFi-D) with these UEs. Proximity engine 1706 may provide further notifications to application 1704 whenever proximity to other UEs ceases.

[00204] Following notification of proximity or notification of cessation of proximity to other UEs, application 1704 can decide how to react – e.g., application 1704 may notify user 1702, establish a data or voice session (e.g., using direct signaling or via network IMS) with one or more of the other UEs, exchange text messages with other UEs, etc..

[00205] Proximity engine 1706 may also enable application 1704 to communication directly with applications on other UEs that are in proximity to UE 1700 – either via direct signaling or via a serving network.

[00206] To enable more efficient support of discovery of proximity between UEs using a network proximity server such as exampled in FIGS. 16A, 16B and 16C, the following may be done (e.g., by the network proximity server): (i) set latency values high (e.g., up to 5 minutes) to allow more time to discover proximity (e.g., to allow up to 5 minutes to detect proximity); (ii) dynamically adjust latency values according to network load); (iii) force lower priority UEs and/or lower priority services to use direct discovery rather than proximity server assisted discovery by reducing distance parameters such that direct discovery (e.g., using the radio method) can generally succeed; and/or (iv) combine UE and proximity server updates so that when a UE updates the proximity server (e.g., with a new UE location), the server can also update the UE with other UEs currently in proximity to the UE.

[00207] If UEs broadcast one or more of a temporary UE ID, an ID in the form of an expression for each proximity group or proximity service that the UE supports and a current UE location as part of direct discovery (e.g., as allowed by the signaling described in FIGS. 15A and 15B), base stations and APs nearby to the UEs such as eNodeBs may read the broadcast data, accumulate the data received from multiple UEs and periodically send this accumulated data to a proximity sever. Such data gathering by base stations and APs may avoid the need for UEs to send the data explicitly to the proximity server (e.g., as exemplified in FIG. 16A) thereby reducing use of resources by UEs and the network.

[00208] UE proximity related data may also be piggybacked on other network signaling – e.g., a Tracking Area Update for LTE, a UE triggered network service request – and forwarded by the recipient of this signaling (e.g., an MME) to a proximity server.

[00209] For LTE access, MMEs could periodically provide a list of all attached UEs to a proximity server together with either the serving eNodeB IDs for UEs in connected state or the Tracking Areas for UEs in idle state. This information may enable a proximity server to employ the cellular method of discovering proximity between UEs and may avoid the need for UEs themselves to send this data to the proximity server, thereby reducing use of network and UE resources.

[00210] For LTE access, MMEs may also provide IDs (e.g., temporary UE IDs) to attached UEs and may provide proximity related subscription information for attached UEs to a proximity server when a UE first attaches or performs a Tracking Area update

to a new MME. The proximity server or MME could periodically poll attached UEs for location information and current proximity related data (e.g., data for proximity groups and proximity services currently activated by applications in a UE). Alternatively, UEs may periodically push the same information to a proximity server with the server replying with a preferred periodicity for future updates from the UE.

[00211] For LTE access, a proximity server may use the serving cells or serving eNBs or Tracking Areas (TAs) received from UEs or from MMEs (as described for the cellular method of proximity discovery) to detect coarse proximity between UEs. When coarse proximity is detected for two or more UEs in a proximity group, the server can request the serving eNB IDs from the MMEs if only the TAs for UEs are known or location information from the UEs if serving eNB IDs are known. The server can then use the received eNB IDs or received locations to more accurately determine (e.g., as a fine method of discovering proximity) which UEs are in proximity to each other. This may avoid or reduce UE-server interaction when no proximity exists between UEs.

[00212] The following alternatives may enable UE data related to proximity groups and/or UE data related to proximity services to be configured and updated in a proximity server in the case of LTE access: (A) the serving MME for any UE provides proximity subscription data to the proximity server for each UE following network attachment by the UE; and (B) the UE provides proximity data to the proximity server whenever support for a proximity service or proximity group is activated in a UE and whenever the data changes.

[00213] Inside the UE, proximity related data may change as users activate and deactivate applications that support proximity services and where the applications that are activated or deactivated may in turn activate, deactivate and/or modify data for different proximity groups and different proximity services in a proximity engine. Data changes for any proximity group or proximity service may be infrequent if users typically maintain a default profile of active proximity services. When a new proximity group or new proximity service is activated, a UE could also initially perform a search for signals broadcast by others UEs (e.g., as exemplified in FIG. 15A and FIG. 15B) and determine whether any such UEs may be in proximity before interacting with a proximity server. Proximity services that can be fully supported via direct discovery (e.g., using the radio method) may not need to be conveyed to and supported by a proximity server.

[00214] In some implementations, discovery of geographic proximity between mobile devices by a network proximity server (e.g., proximity server 1208 in FIG. 12, proximity server 1312 in FIG. 13 or proximity server 1422 in FIG. 14) may be assisted if a logically separate location server (e.g., a SUPL SLP or an E-SMLC) is physically combined (or linked to) the proximity server. For example, the proximity server may then be able to access geographic location estimates for mobile devices that are obtained by the location server for other reasons (e.g., obtained whenever a mobile device or an external client requests the location of the mobile device). In addition or alternatively, the proximity server may request the location of one or more mobile devices from the location server which may then obtain the location of the one or more mobile devices – e.g., using the OMA SUPL location solution when the location server is a SUPL SLP.

[00215] Existing location geofencing support in a UE or network (e.g., as supported by SUPL) could assist implementation of geographic proximity discovery using absolute location. For example, a location geofence may be a geographic area that a UE (or a positioning engine in a UE such as positioning engine 1708 in FIG. 17) monitors in order to detect when the UE enters, leaves and/or remains with the geographic area. Monitoring of a location geofence by a UE may be used to determine when two mobile devices are in the same geographic area (e.g., within the same geofence) and are thus in proximity or possibly in proximity. Discovery of proximity could also be used by applications or a network to support new forms of geofencing (e.g., geofencing related to areas around a mobile device).

[00216] When a location server and a proximity server are co-located or combined (e.g., as in the case of the combination of a location server and proximity server dashed-line boxes 1211, 1313, or 1424 shown in FIGS. 12, 13 or 14, respectively), the proximity server could use the location server to obtain UE locations. The location server could also or instead use the proximity server to determine UEs (and their locations) in proximity to a target UE whose location is needed. The location server may then request: (i) the target UE to make measurements of the other UEs that are in proximity to it (e.g., OTD measurements); and/or (ii) the other UEs to make measurements of the target UE (e.g., Time of arrival measurements). The measurements in (i) and/or (ii) may be used by the location server to locate the target UE and/or the other UEs.

[00217] Signaling between a UE and a proximity server may employ the same protocols (e.g., TLS, TCP/IP or NAS) and the same authentication mechanisms as used

between a UE and a location server– e.g., same protocols as for the SUPL location solution. To enable fast and efficient updates between a proximity server and a UE, a UE signaling session with the proximity server could remain connected for long periods (to avoid repeated connection setup/release and new authentication). However, radio bearers could still be released during idle periods.

[00218] As already remarked, there may be a similarity between geographic proximity and location geofencing – meaning UE support might be partly common to both functions. The geofencing similarity may also enable proximity services where one device remaining within proximity of another device for some length of time or ceasing proximity after some period of time (e.g., a child going astray from a parent) could be of use.

[00219] FIGS. 18, 19 and 20 show various apparatuses, in accordance with some embodiments of the present invention.

[00220] In FIG. 18, a UE 1800 is shown which may represent any of: UE 100 in FIG. 1; UE 400 in FIG. 4; any of UEs 1 to 10 in FIG. 5; any of UEs 601 to 603 in FIG. 6; any of UEs 701 to 704 in FIG. 7; any of UEs 821 to 830 and UEs 840 to 853 in FIG. 8; any of UEs 901-904, 921, 922, 931-933, 935, 936, 941, 942 in FIG. 9; UE 1202 in FIG. 12; UE 1302 in FIG. 13; UE 1402 in FIG. 14; any of UEs 1500-1 and 1500-2 in FIG. 15; UE 1600 in FIG. 16; and UE 1700 in FIG. 17. UE 1800 may also represent the first mobile device or second mobile device referred to in FIG. 11 and the UE A or any UE in the set S referred to in FIG. 3. UE 1800 in FIG. 18 includes a processor 1810 (e.g., a general-purpose processor 1815 and/or a digital signal processor (DSP 1820)), one or

more wireless transceivers 1830 electrically connected to an antenna 1832 to receive and transmit signals 1834, one or more sensors 1840 (e.g., an accelerometer, gyrometer and/or a barometer), memory 1860 and a GNSS receiver 1870 electrically connected to an antenna 1872 to receive GNSS signals 1874. These components may be coupled together with a bus 1801(as shown), directed connected together, or a combination of both. The memory 1860 may contain executable code or software instructions for the processor 1810 to perform methods described herein (e.g., methods and processes performed by the different UEs that UE 1800 may represent). For example, memory 1860 may contain software modules to determine results for two types of proximity (e.g., fine proximity and coarse proximity) and logically combine the results.

[00221] Memory 1860 may contain software modules to determine a coarse proximity result, to determine a fine proximity result based on the coarse proximity result indicating proximity, and to determine based on the fine proximity result whether UE 1800 is in proximity to some other UE.

[00222] Memory 1860 may contain software modules to enable UE 1800 to perform the various methods described herein for discovering proximity of UE 1800 to certain other UEs that support the same proximity services as UE 1800 or belong to the same proximity groups as UE 1800. Such methods may include communicating proximity related data to other UEs via direct signaling (e.g., sending and receiving expressions and proximity data) and/or communicating proximity related data to a network or network proximity server (e.g., sending and receiving expressions, UE identity, UE location, proximity parameters).

[00223] Memory 1860 may contain software modules to support applications on UE 1800 such as application 404 in FIG. 4 and application 1704 in FIG. 17. Memory 1860 may contain software modules to support a proximity engine such as proximity engine 1706 in FIG. 17 and UE proximity engine 406 in FIG. 4. Memory 1860 may contain software modules to support a positioning engine such as positioning engine 1708 in FIG. 17.

[00224] UE 1800 may contain a module 1850 supporting a proximity engine such as proximity engine 1706 in FIG. 17 and UE proximity engine 406 in FIG. 4. Module 1850 may consist of hardware (e.g., a separate chip or chipset) or may be supported by firmware running code on processor 1810.

[00225] UE 1800 may contain a module 1890 supporting a positioning engine such as positioning engine 1708 in FIG. 17. Module 1890 may consist of hardware (e.g., a separate chip or chipset) or may be supported by firmware running code on processor 1810. Modules 1850 and 1890 may be the same module – e.g., may comprise the same hardware chip or chip set.

[00226] In FIG. 19, a network proximity server 1900 is shown. Network proximity server may represent any of: network proximity servers 1208 in FIG. 12; 1312 in FIG. 13; 1422 in FIG. 14; and 1602 in FIG. 16. Network proximity server 1900 may support the process 300 in FIG. 3 or the process 1100 in FIG. 11 for determining proximity between two UEs. The network proximity server 1900 includes a processor 1910 and a transceiver 1930. The transceiver 1930 is configured to receive from a mobile device (e.g., any of the UEs represented by UE 1800 in FIG. 18) proximity information on the

mobile device and/or other nearby mobile devices. The received proximity information may include expressions, mobile device identities, locations and proximity parameters as an example. The transceiver 1930 is also configured to send proximity information to a mobile device. The processor 1910 is coupled to the transceiver 1930 and configured to execute functions and modules described herein for a network proximity server 1900. Network proximity server 1900 may also include memory 1920 which may contain software to support the various methods described herein that a network proximity server may support. Processor 1910, memory 1920 and transceiver 1930 may communicate information via a bus 1940 or via direct connections.

[00227] FIG. 20 shows a system including a mobile device 2000, GNSS satellites 2010, a macrocell base station 2020 (e.g., an LTE eNB), an access point 2030 (e.g., a WiFi AP), a location server 2040 and a proximity server 2050, in accordance with some embodiments of the present invention. The figure also shows at least one more mobile device 2000-1..n in proximity to the mobile device 2000. The mobile device 2000 receives signals 2012 from GNSS satellites 2010. The signals 2012 may be used to compute a position fix. The mobile device 2000 also communicates with the macrocell base station 2020 using signals 2022 and/or with the access point 2030 using signals 2032. In addition, the mobile device 2000 may communicate with the location server 2040 and/or the proximity server 2050 through a network 2090, such as a wireless network (e.g., a GSM, W-CDMA or LTE network), the Internet or a private network, via either the macrocell base station 2020 or the access point 2030.

[00228] Mobile device 2000 and mobile devices 2000-1 to 2000-n may represent any of: UE 100 in FIG. 1; UE 400 in FIG. 4; any of UEs 1 to 10 in FIG. 5; any of UEs 601

to 603 in FIG. 6; any of UEs 701 to 704 in FIG. 7; any of UEs 821 to 830 and UEs 840 to 853 in FIG. 8; any of UEs 901-904, 921, 922, 931-933, 935, 936, 941, 942 in FIG. 9; UE 1202 in FIG. 12; UE 1302 in FIG. 13; UE 1402 in FIG. 14; any of UEs 1500-1 and 1500-2 in FIG. 15; UE 1600 in FIG. 16; and UE 1700 in FIG. 17. Network proximity server 2050 may represent any of: network proximity servers 1208 in FIG. 12; 1312 in FIG. 13; 1422 in FIG. 14; and 1602 in FIG. 16. Location server 2040 may represent any of E-SMLC 1210 in FIG. 12, SLP 1314 in FIG. 13 and LRF 1420 in FIG. 14.

[00229] Mobile device 2000 and one or more of mobile devices 2000-1 to 2000-n may employ direct signaling to discover one another and discover proximity between one another as described herein. Mobile device 2000 may communicate with proximity server 2050 according to methods described herein to enable discovery of proximity between mobile device 2000 and one or more of mobile devices 2000-1 to 2000-n.

[00230] The methodologies described herein may be implemented by various means depending upon the application. For example, these methodologies may be implemented in hardware, firmware, software, or any combination thereof. For a hardware implementation, the processing units may be implemented within one or more application specific integrated circuits (ASICs), digital signal processors (DSPs), digital signal processing devices (DSPDs), programmable logic devices (PLDs), field programmable gate arrays (FPGAs), processors, controllers, micro-controllers, microprocessors, electronic devices, other electronic units designed to perform the functions described herein, or a combination thereof.

[00231] For a firmware and/or software implementation, the methodologies may be implemented with modules (e.g., procedures, functions, and so on) that perform the functions described herein. Any machine-readable medium tangibly embodying instructions may be used in implementing the methodologies described herein. For example, software codes may be stored in a memory and executed by a processor unit. Memory may be implemented within the processor unit or external to the processor unit. As used herein the term “memory” refers to any type of long term, short term, volatile, nonvolatile, or other memory and is not to be limited to any particular type of memory or number of memories, or type of media upon which memory is stored.

[00232] If implemented in firmware and/or software, the functions may be stored as one or more instructions or code on a computer-readable medium. Examples include computer-readable media encoded with a data structure and computer-readable media encoded with a computer program. Computer-readable media includes physical computer storage media. A storage medium may be any available medium that can be accessed by a computer. By way of example, and not limitation, such computer-readable media can comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to store desired program code in the form of instructions or data structures and that can be accessed by a computer; disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above should also be included within the scope of computer-readable media.

[00233] In addition to storage on computer readable medium, instructions and/or data may be provided as signals on transmission media included in a communication apparatus. For example, a communication apparatus may include a transceiver having signals indicative of instructions and data. The instructions and data are configured to cause one or more processors to implement the functions outlined in the claims. That is, the communication apparatus includes transmission media with signals indicative of information to perform disclosed functions. At a first time, the transmission media included in the communication apparatus may include a first portion of the information to perform the disclosed functions, while at a second time the transmission media included in the communication apparatus may include a second portion of the information to perform the disclosed functions.

[00234] The previous description of the disclosed aspects is provided to enable any person skilled in the art to make or use the present disclosure. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects without departing from the spirit or scope of the disclosure.

CLAIMS

What is claimed is:

1. A method to discover proximity between a first mobile device and a second mobile device comprising:

determining a coarse proximity result between the first mobile device and the second mobile device using a coarse method, wherein the coarse proximity result comprises at least one of:

a coarse radio proximity result;

a coarse geographic proximity result; and

a coarse cellular proximity result;

determining that the coarse proximity result indicates that the first mobile device and the second mobile device are proximate;

determining a fine proximity result between the first mobile device and the second mobile device using a fine method, wherein the fine proximity result comprises one of:

a fine radio proximity result;

a fine geographic proximity result; and

a fine cellular proximity result; and

determining proximity of the first mobile device and the second mobile device when the fine proximity result indicates proximity.

2. The method of claim 1, wherein the coarse method comprises one of:

a Round Trip propagation Time (RTT) method;

a location method;

an Observed Time Difference (OTD) method;

a radio method;

a cellular method; and

an iterated method.

3. The method of claim 1, wherein the fine method is different from the coarse method and comprises one of:

a Round Trip propagation Time (RTT) method;

a location method;

an Observed Time Difference (OTD) method;

a radio method; and

a cellular method.

4. The method of claim 3, wherein the location method uses a control plane location solution or a user plane location solution to obtain a geographic location of at least one of the first mobile device and the second mobile device.

5. The method of claim 1, wherein the coarse method discovers the coarse proximity result faster than the fine method discovers the fine proximity result.

6. The method of claim 1, wherein the coarse method uses fewer resources than the fine method.

7. The method of claim 1, wherein the fine proximity result is more accurate than the coarse proximity result.

8. The method of claim 1, wherein at least one of the coarse proximity result and the fine proximity result are determined using proximity parameters for at least one of the first mobile device and the second mobile device.

9. The method of claim 8, wherein the proximity parameters comprises at least one of:

(a1) an indication of whether direct communication is required between the first mobile device and the second mobile device;

(a2) a minimum signal strength and/or signal quality received by the first mobile device or the second mobile device from the other of the first mobile device and the second mobile device;

(a3) an amount of bandwidth required for direct communication between first mobile device and the second mobile device;

(b1) a maximum distance between the first mobile device and the second mobile device;

(b2) a required state of motion of the first mobile device or the second mobile device;

(b3) a required location of the first mobile device or the second mobile device;

(c1) an indication of whether the first mobile device or the second mobile device is served by a common access point (AP) or common base station;

(c2) an indication of whether the first mobile devices and the second mobile device are in coverage of a common AP or common base station;

(d1) a minimum length of time that proximity persists following discovery and before discovery is confirmed;

(d2) a network attachment status for the first mobile device or the second mobile device; and

(d3) a maximum latency for discovering proximity.

10. The method of claim 9, wherein the proximity parameters are combined using logical OR and logical AND operations.

11. The method of claim 9, wherein:

the fine radio proximity result is determined from at least one of proximity parameters (a1), (a2) and (a3);

the fine geographic proximity result is determined from at least one of proximity parameters (b1), (b2) and (b3); and

the fine cellular proximity result is determined from at least one of proximity parameters (c1) and (c2).

12. The method of claim 11, wherein at least one of the fine radio proximity result, the fine geographic proximity result and the fine cellular proximity result is further determined from at least one of proximity parameters (d1), (d2) and (d3).

13. The method of claim 1, wherein the method is performed on the first mobile device.

14. The method of claim 1, wherein the method is performed on a network proximity server.

15. The method of claim 1, wherein the method is performed on a location server.

16. A device to discover proximity between a first mobile device and a second mobile device comprising a transceiver and processor coupled to the transceiver, wherein the processor comprises code to:

determining a coarse proximity result between the first mobile device and the second mobile device using a coarse method, wherein the coarse proximity result comprises at least one of:

a coarse radio proximity result;

a coarse geographic proximity result; and

a coarse cellular proximity result;

determining that the coarse proximity result indicates that the first mobile device and the second mobile device are proximate;

determining a fine proximity result between the first mobile device and the second mobile device using a fine method, wherein the fine proximity result comprises one of:

a fine radio proximity result;

a fine geographic proximity result; and

a fine cellular proximity result; and

determining proximity of the first mobile device and the second mobile device when the fine proximity result indicates proximity.

17. The device of claim 16, wherein at least one of the coarse proximity result and the fine proximity result are determined using proximity parameters for at least one of the first mobile device and the second mobile device.

18. The device of claim 17, wherein the proximity parameters comprises at least one of:

(a1) an indication of whether direct communication is required between the first mobile device and the second mobile device;

(a2) a minimum signal strength and/or signal quality received by the first mobile device or the second mobile device from the other of the first mobile device and the second mobile device;

(a3) an amount of bandwidth required for direct communication between the first mobile device and the second mobile device;

(b1) a maximum distance between the first mobile device and the second mobile device;

(b2) a required state of motion of the first mobile device or the second mobile device;

(b3) a required location of the first mobile device or the second mobile device;

(c1) an indication of whether the first mobile device or the second mobile device is served by a common access point (AP) or common base station;

(c2) an indication of whether the first mobile devices and the second mobile device are in coverage of a common AP or common base station;

(d1) a minimum length of time that proximity persists following discovery and before discovery is confirmed;

(d2) a network attachment status for the first mobile device or the second mobile device; and

(d3) a maximum latency for discovering proximity.

19. The device of claim 16, wherein the device comprises the first mobile device.

20. The device of claim 16, wherein the device comprises the second mobile device.

21. The device of claim 16, wherein the device comprises a network proximity server.

22. A device to discover proximity between a first mobile device and a second mobile device comprising:

means for determining a coarse proximity result between the first mobile device and the second mobile device using a coarse method, wherein the coarse proximity result comprises at least one of:

a coarse radio proximity result;

a coarse geographic proximity result; and

a coarse cellular proximity result;

means for determining that the coarse proximity result indicates that the first mobile device and the second mobile device are proximate;

means for determining a fine proximity result between the first mobile device and the second mobile device using a fine method, wherein the fine proximity result comprises one of:

a fine radio proximity result;

a fine geographic proximity result; and

a fine cellular proximity result; and

means for determining proximity of the first mobile device and the second mobile device when the fine proximity result indicates proximity.

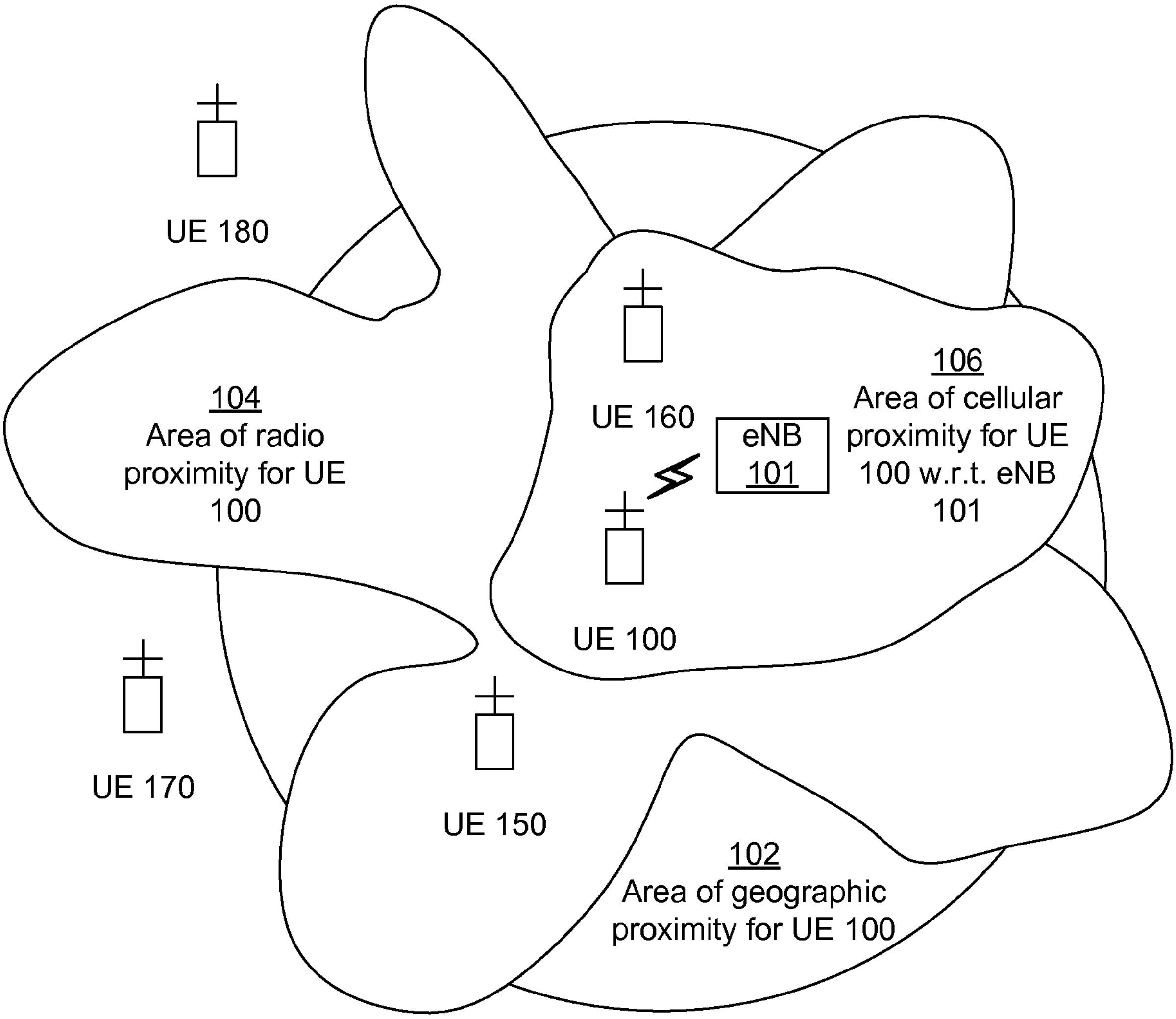

UE 180
104
Area of radio proximity for UE 100
UE 160
eNB
101
106
Area of cellular proximity for UE 100 w.r.t. eNB 101
UE 100
UE 170
UE 150
102
Area of geographic proximity for UE 100

FIG. 1

1	Proximity Service / Proximity Type	Radio	Geographic	Cellular
2	2-way Friend Finder		X	
3	1-way Facility Finder		X	
4	Public Safety without network coverage	X		
5	Network offload via D2D communication	X		
6	Network offload via direct AP communication			X
7	Presence/location enhancement		X	
8	Vehicle to Vehicle/Vehicle to User communication	X		

FIG. 2

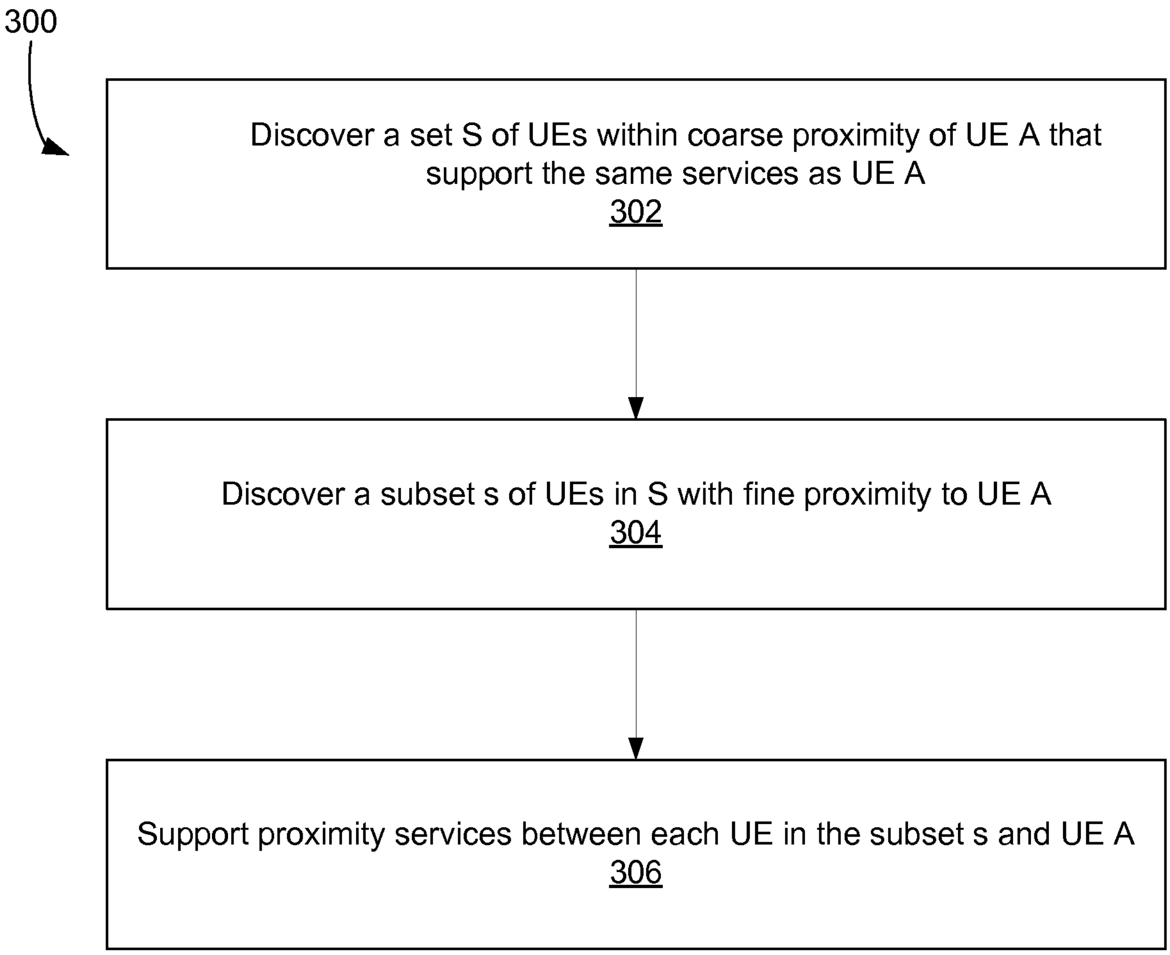

300
Discover a set S of UEs within coarse proximity of UE A that support the same services as UE A
302
Discover a subset s of UEs in S with fine proximity to UE A
304
Support proximity services between each UE in the subset s and UE A
306

FIG. 3

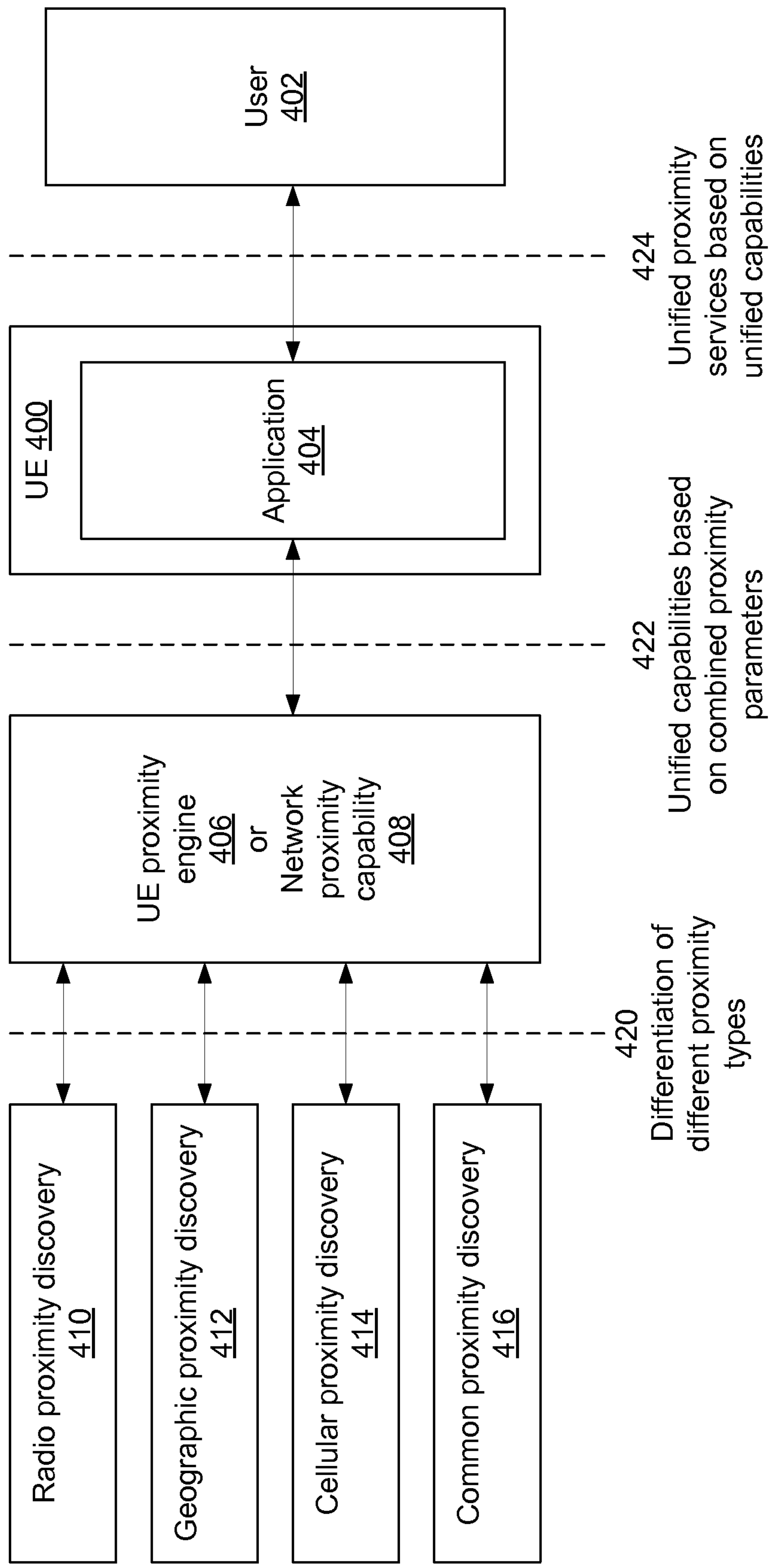

User
402
UE 400
Application
404
UE proximity engine
406
or
Network proximity capability
408
Radio proximity discovery
410
Geographic proximity discovery
412
Cellular proximity discovery
414
Common proximity discovery
416
420
Differentiation of different proximity types
422
Unified capabilities based on combined proximity parameters
424
Unified proximity services based on unified capabilities

FIG. 4

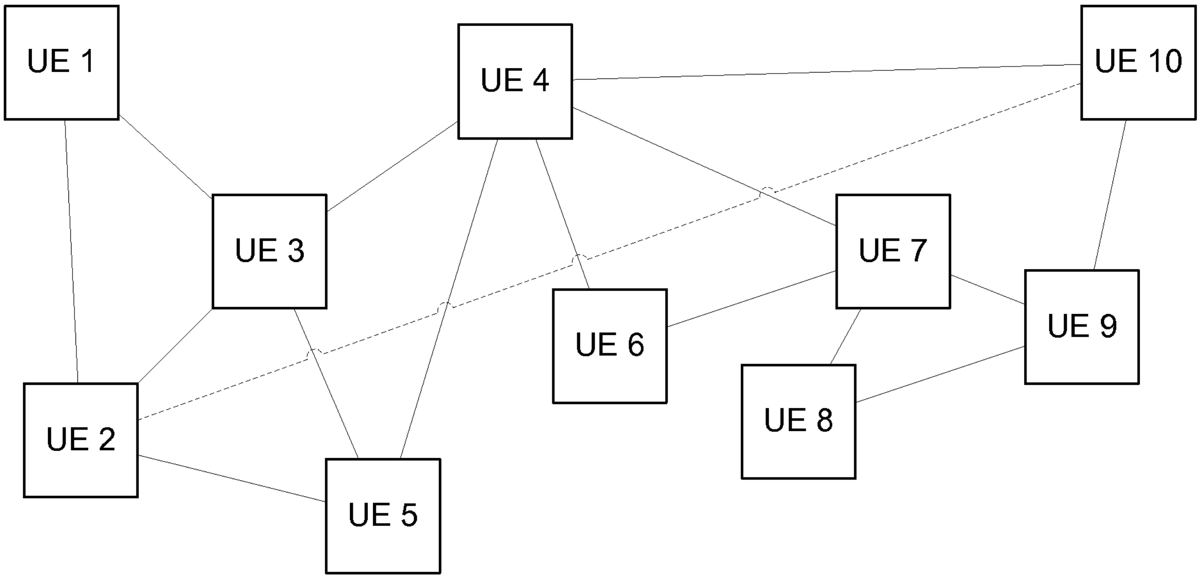

UE 1
UE 4
UE 10
UE 3
UE 7
UE 6
UE 9
UE 2
UE 8
UE 5

FIG. 5

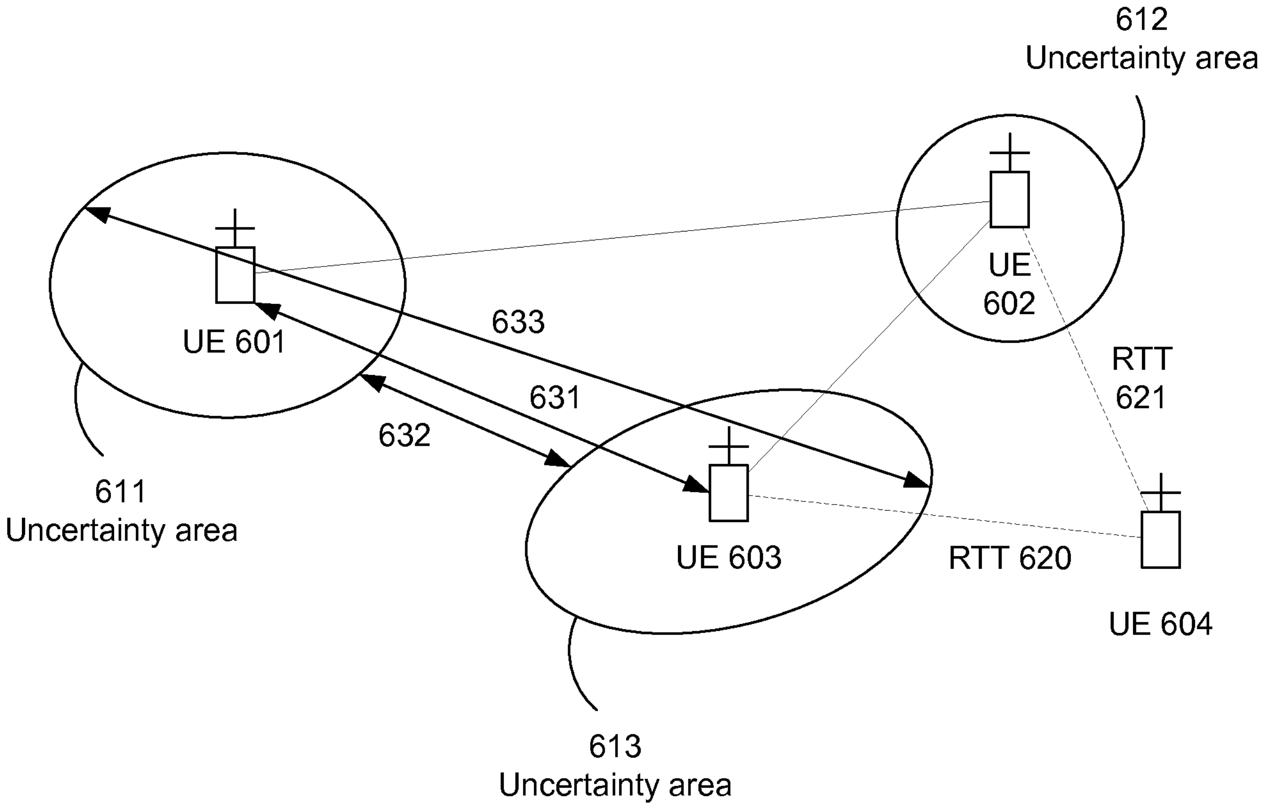

612
Uncertainty area
UE
602
633
UE 601
631
RTT
621
632
611
Uncertainty area
UE 603
RTT 620
UE 604
613
Uncertainty area

FIG. 6

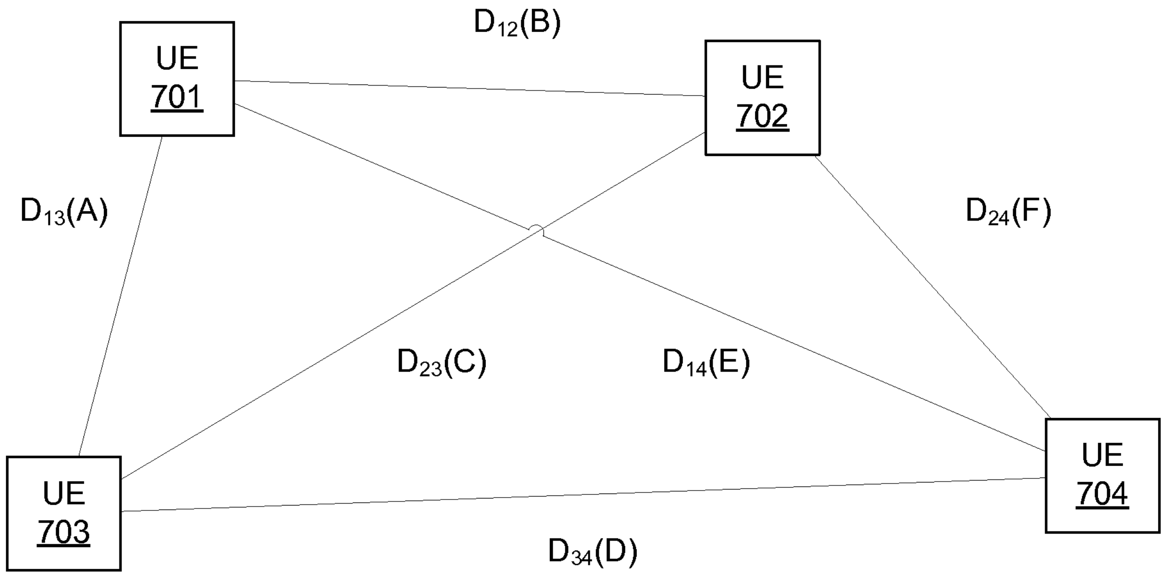
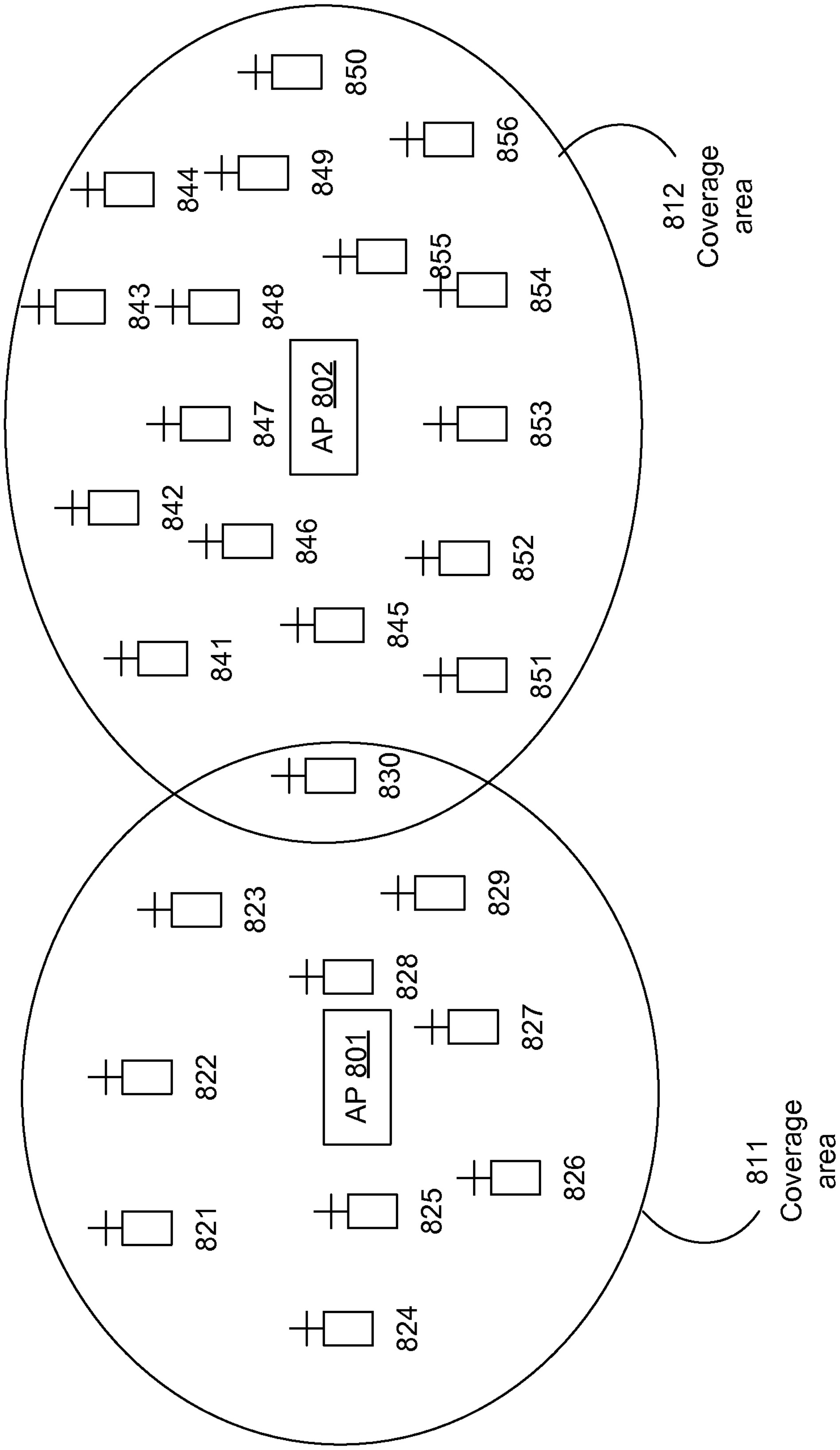


FIG. 7



AP 802
AP 801
812 Coverage area
811 Coverage area
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
821
822
823
824
825
826
827
828
829
830

FIG. 8

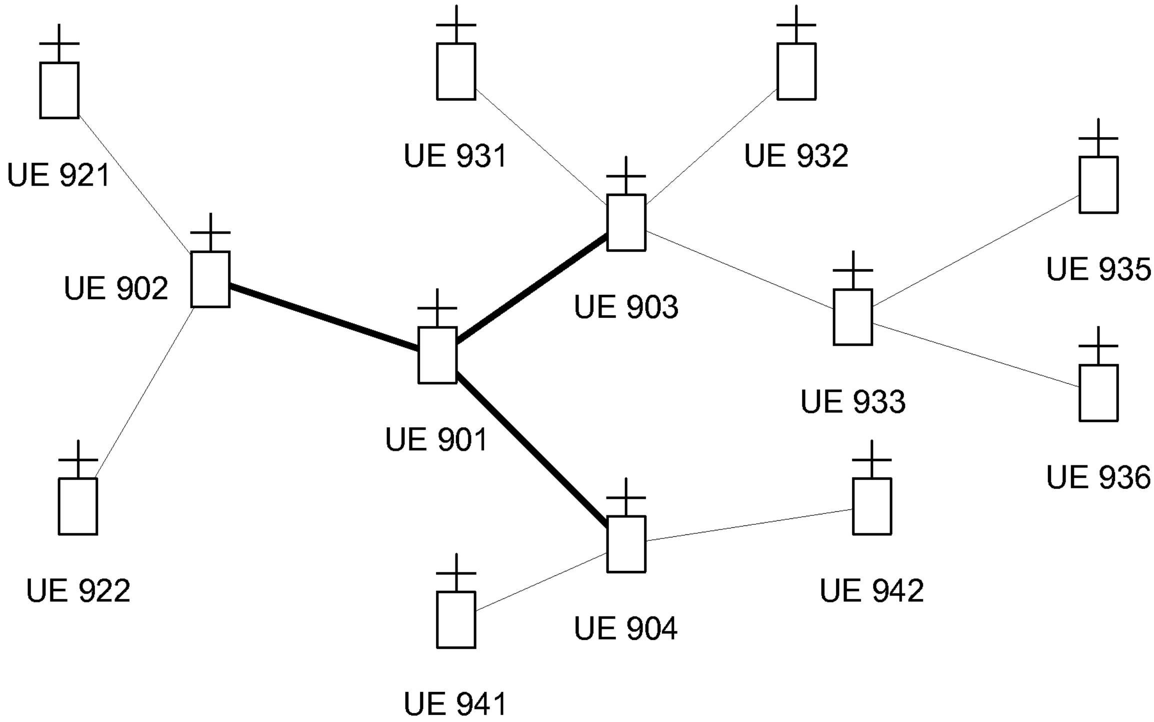

UE 921
UE 931
UE 932
UE 935
UE 902
UE 903
UE 933
UE 901
UE 936
UE 922
UE 942
UE 904
UE 941

FIG. 9

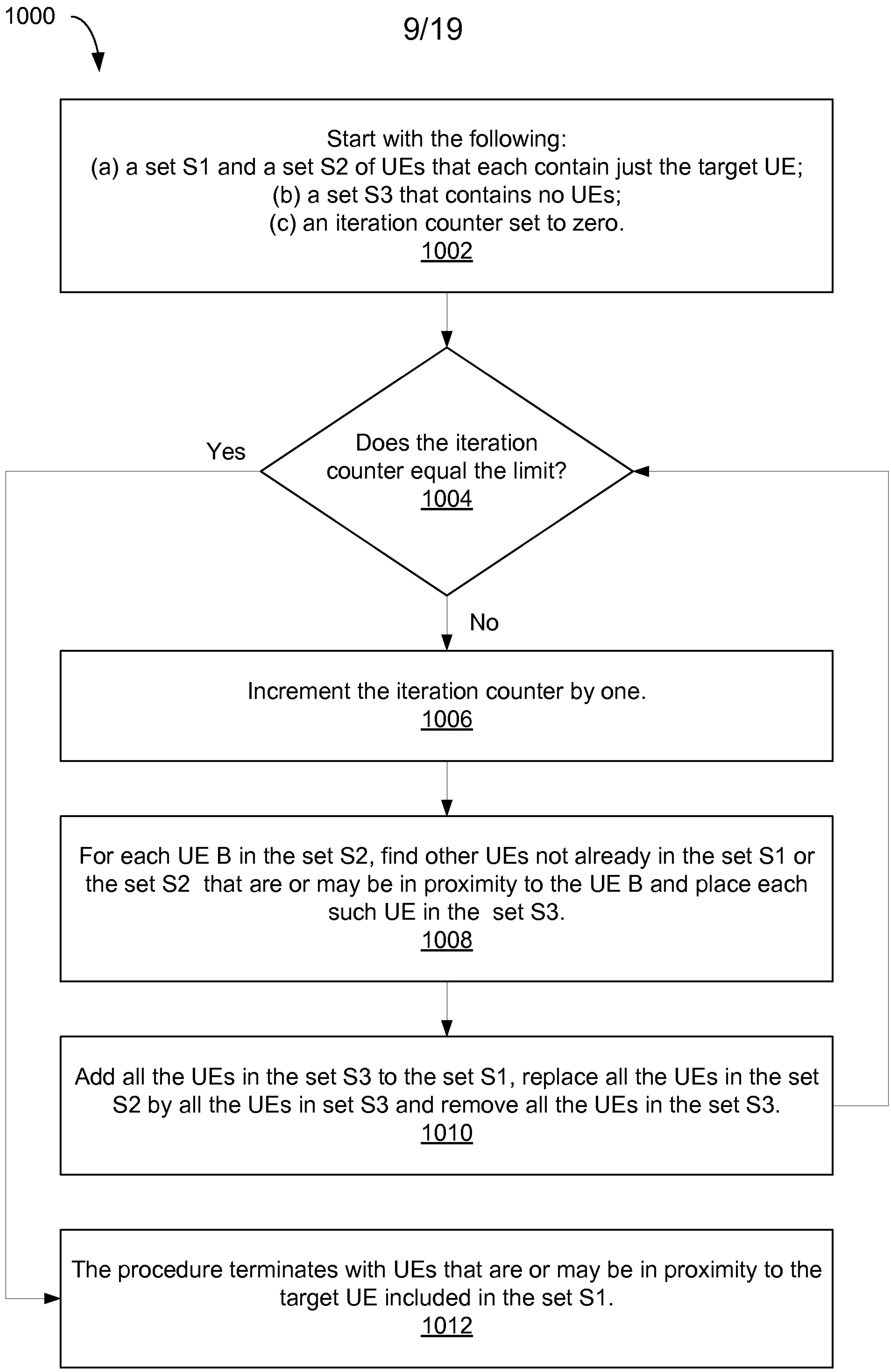

1000
Start with the following:
(a) a set S1 and a set S2 of UEs that each contain just the target UE;
(b) a set S3 that contains no UEs;
(c) an iteration counter set to zero.
1002
Does the iteration counter equal the limit?
1004
Yes
No
Increment the iteration counter by one.
1006
For each UE B in the set S2, find other UEs not already in the set S1 or the set S2 that are or may be in proximity to the UE B and place each such UE in the set S3.
1008
Add all the UEs in the set S3 to the set S1, replace all the UEs in the set S2 by all the UEs in set S3 and remove all the UEs in the set S3.
1010
The procedure terminates with UEs that are or may be in proximity to the target UE included in the set S1.
1012

FIG. 10

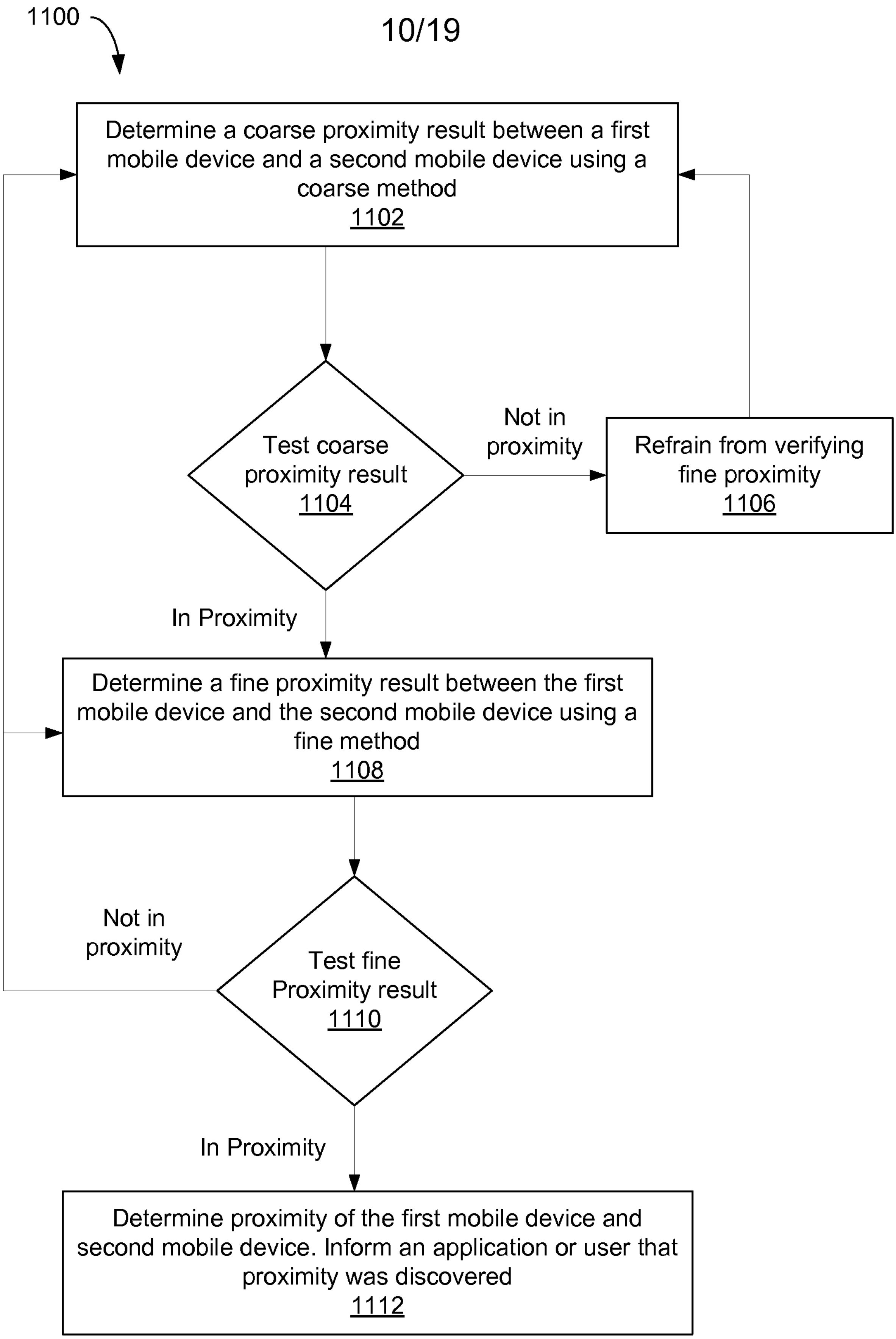

1100
Determine a coarse proximity result between a first mobile device and a second mobile device using a coarse method
1102
Test coarse proximity result
1104
Not in proximity
Refrain from verifying fine proximity
1106
In Proximity
Determine a fine proximity result between the first mobile device and the second mobile device using a fine method
1108
Not in proximity
Test fine Proximity result
1110
In Proximity
Determine proximity of the first mobile device and second mobile device. Inform an application or user that proximity was discovered
1112

FIG. 11

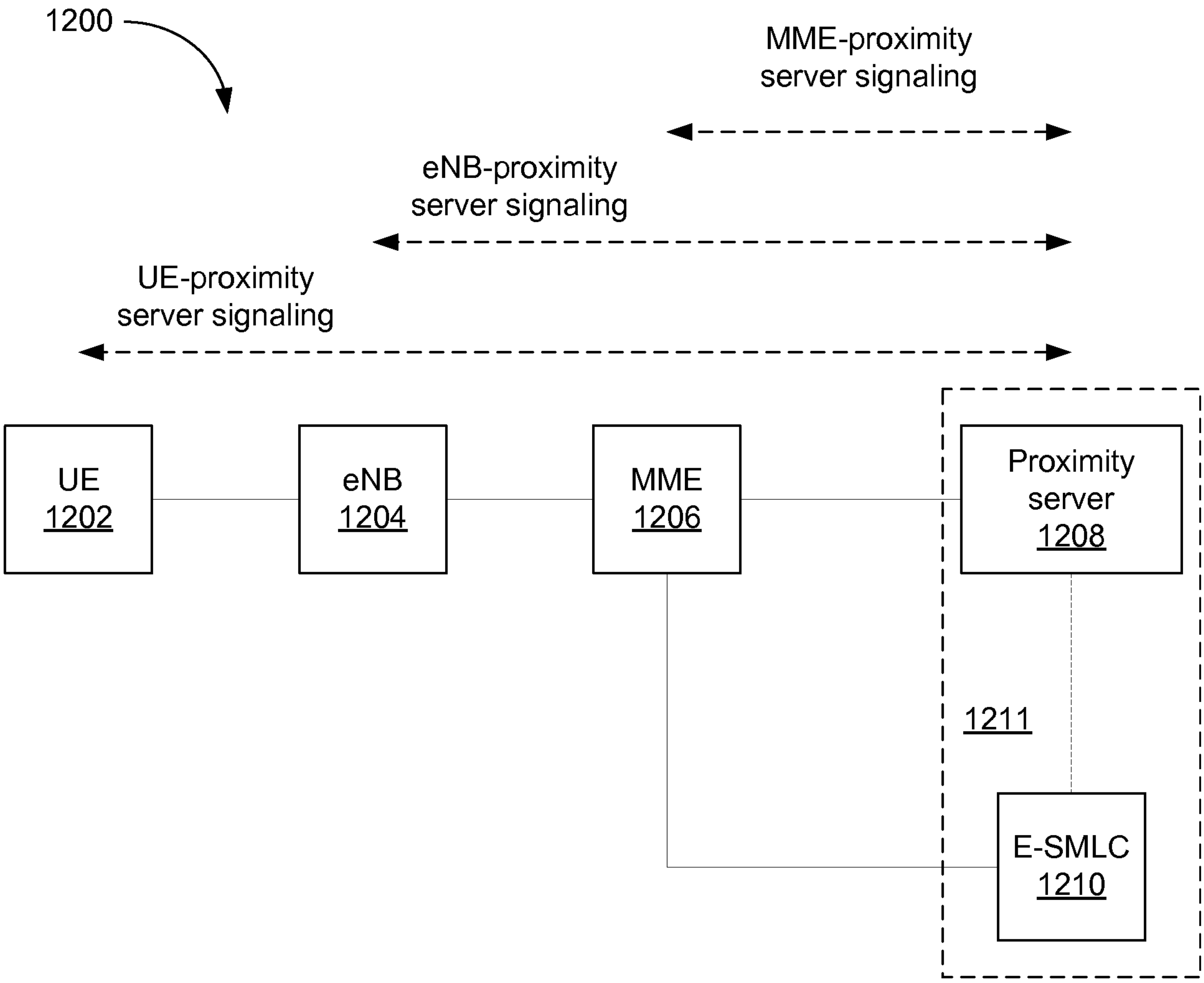

1200
MME-proximity server signaling
eNB-proximity server signaling
UE-proximity server signaling
UE 1202
eNB 1204
MME 1206
Proximity server 1208
1211
E-SMLC 1210

FIG. 12

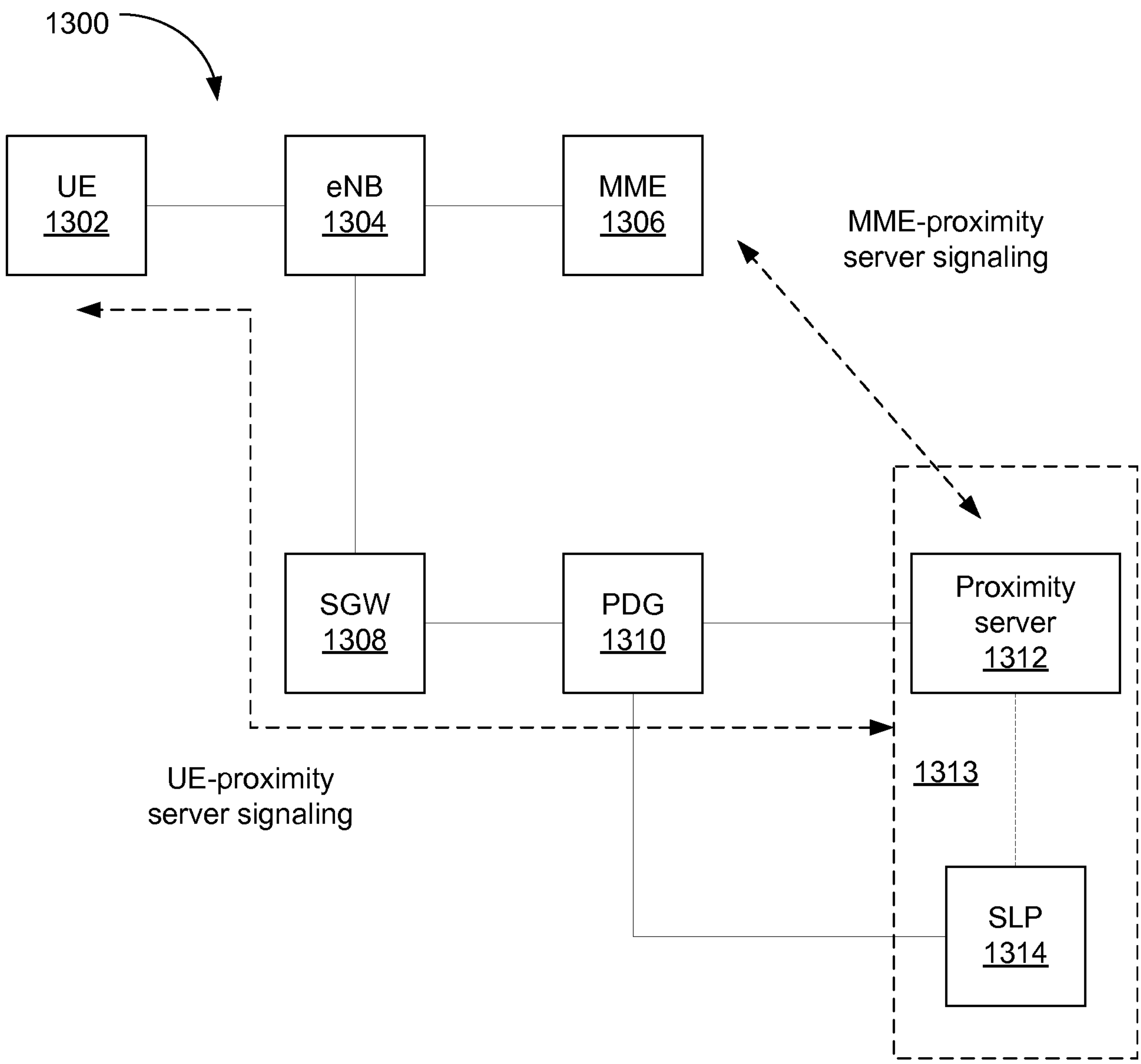

1300
UE
1302
eNB
1304
MME
1306
MME-proximity
server signaling
SGW
1308
PDG
1310
Proximity
server
1312
1313
UE-proximity
server signaling
SLP
1314

FIG. 13

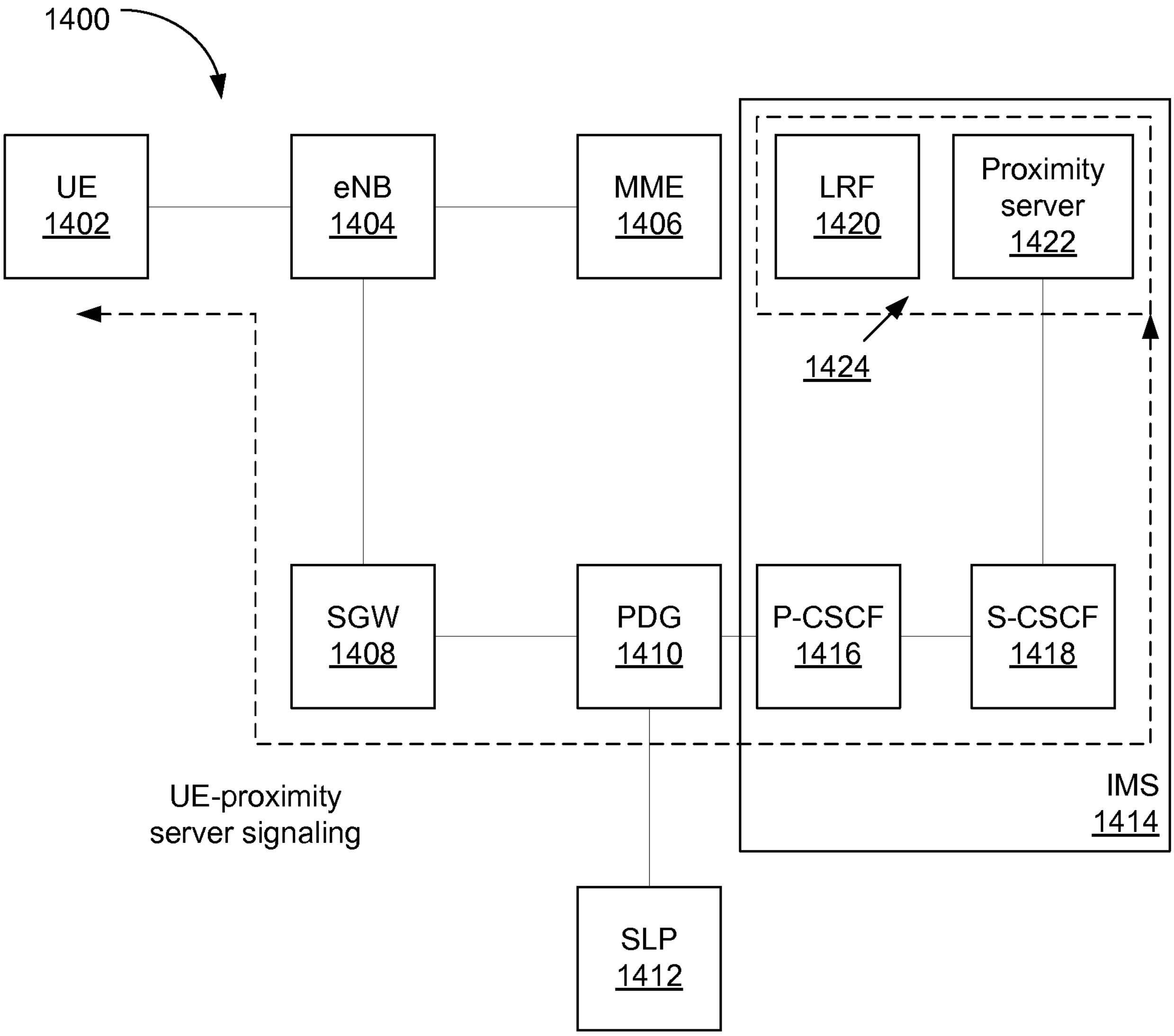

1400
UE
1402
eNB
1404
MME
1406
LRF
1420
Proximity server
1422
1424
SGW
1408
PDG
1410
P-CSCF
1416
S-CSCF
1418
UE-proximity server signaling
IMS
1414
SLP
1412

FIG. 14

FIG. 15A

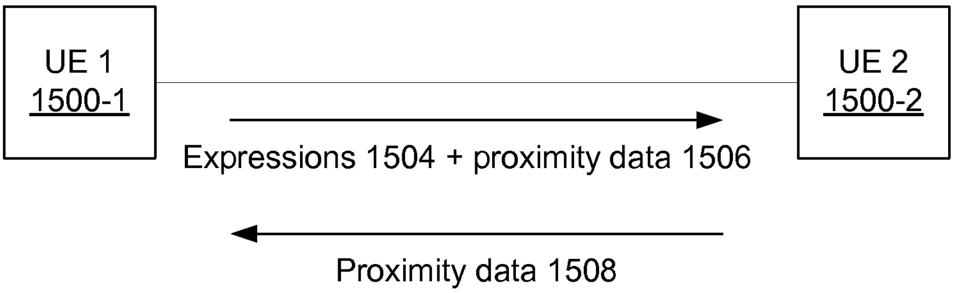


FIG. 15B

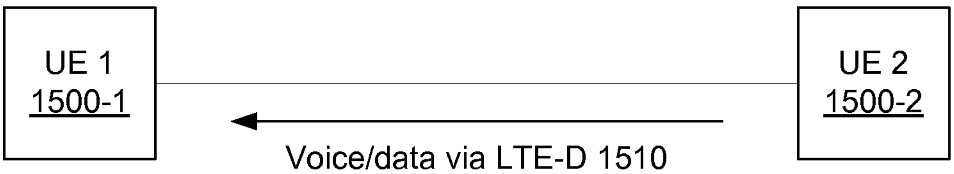


FIG. 15C

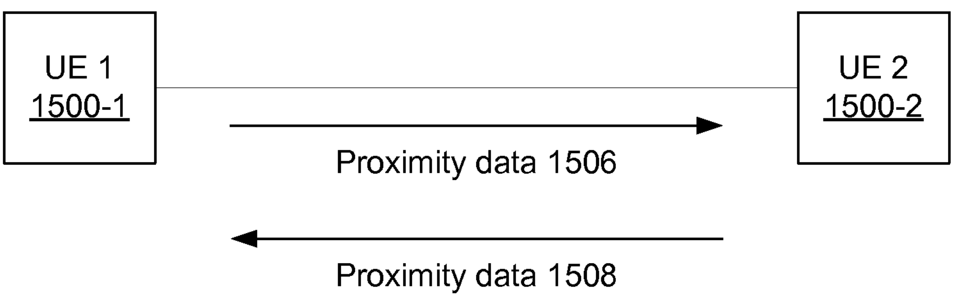


FIG. 15D

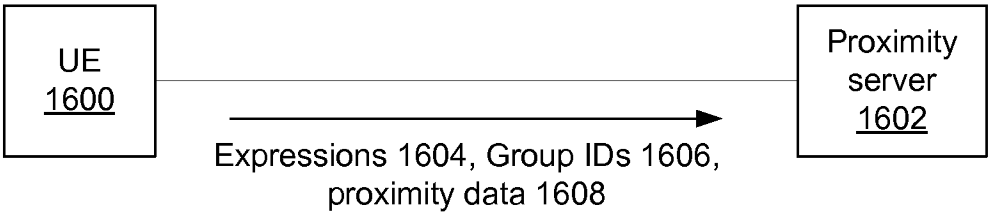


FIG. 16A

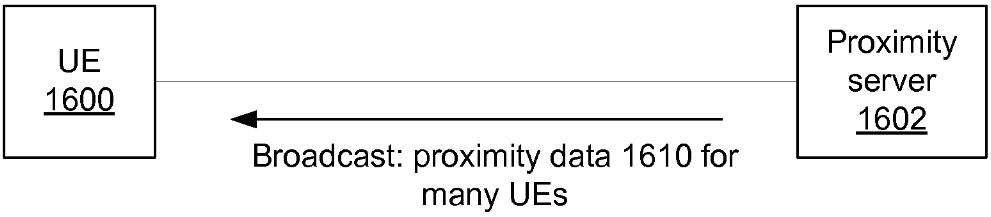


FIG. 16B

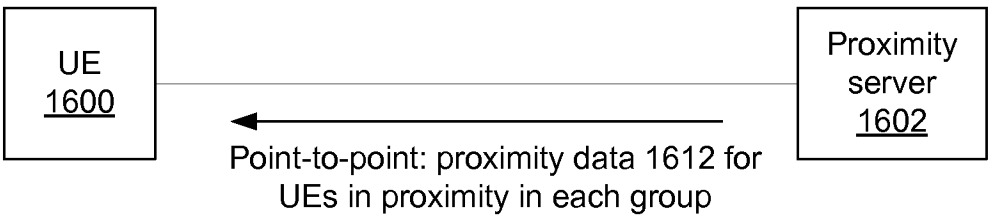


FIG. 16C

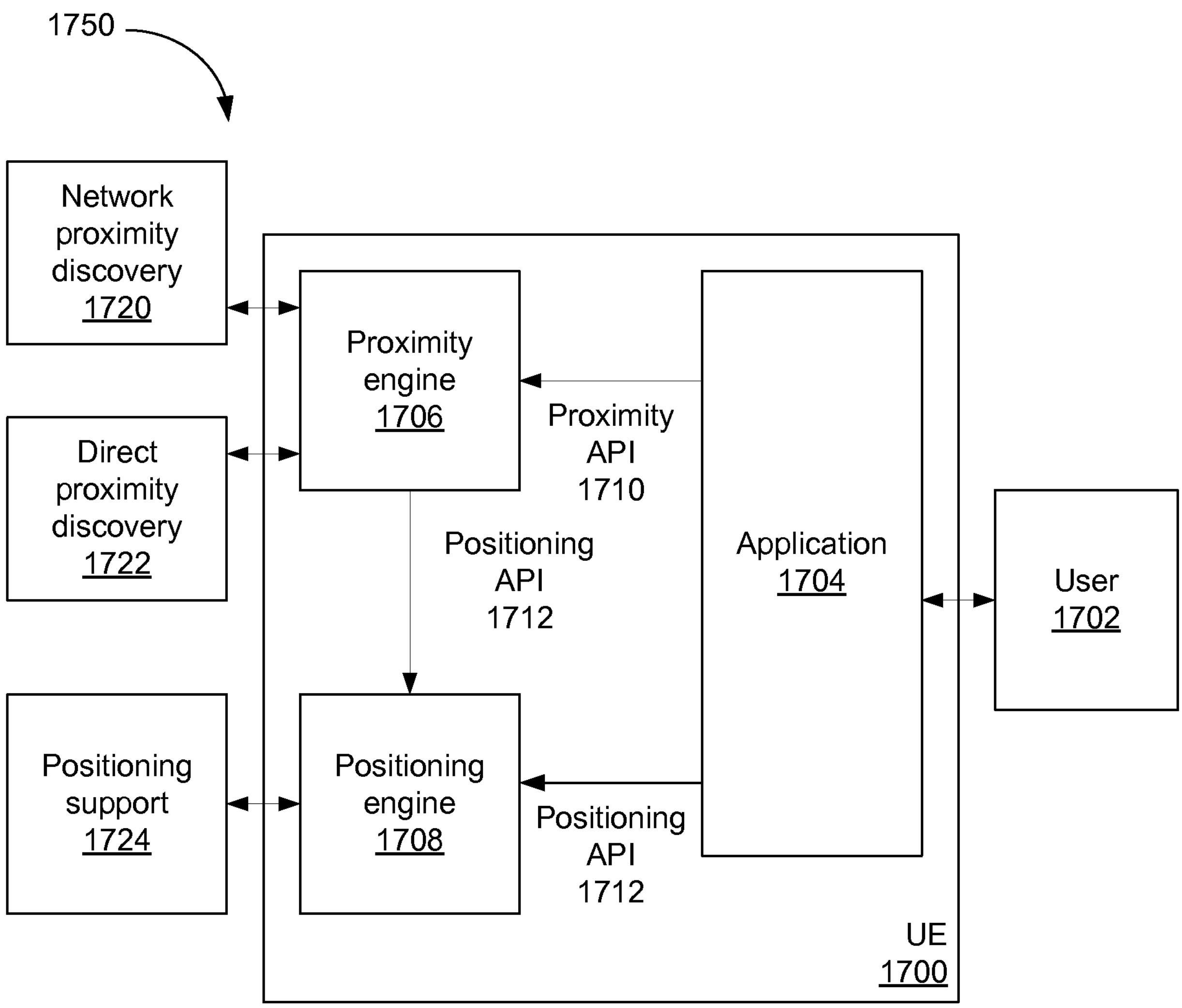

1750
Network proximity discovery 1720
Direct proximity discovery 1722
Positioning support 1724
Proximity engine 1706
Proximity API 1710
Positioning API 1712
Positioning engine 1708
Positioning API 1712
Application 1704
User 1702
UE 1700

FIG. 17

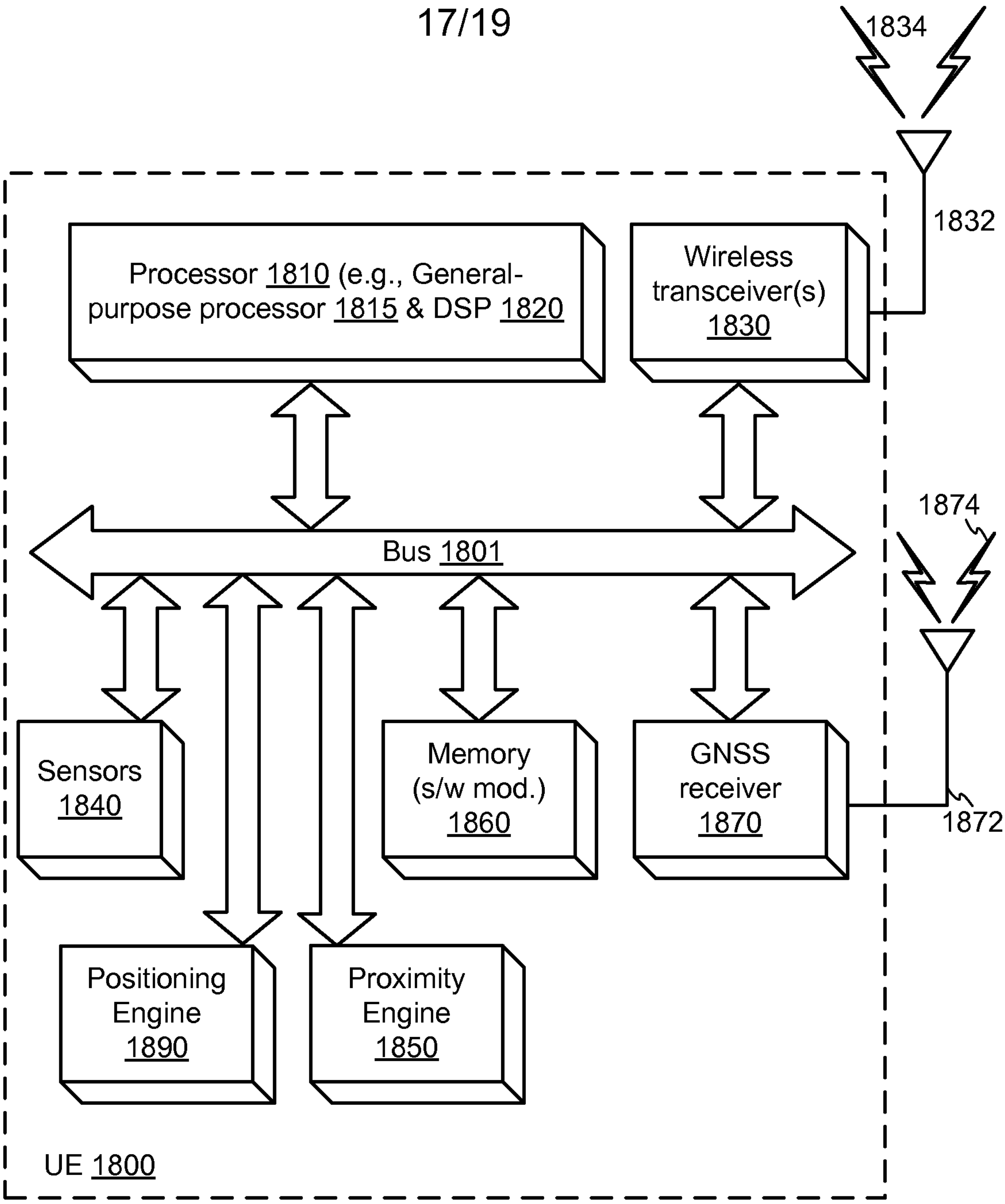

1834
1832
Processor 1810 (e.g., General-purpose processor 1815 & DSP 1820
Wireless transceiver(s) 1830
1874
Bus 1801
Sensors 1840
Memory (s/w mod.) 1860
GNSS receiver 1870
1872
Positioning Engine 1890
Proximity Engine 1850
UE 1800

FIG. 18

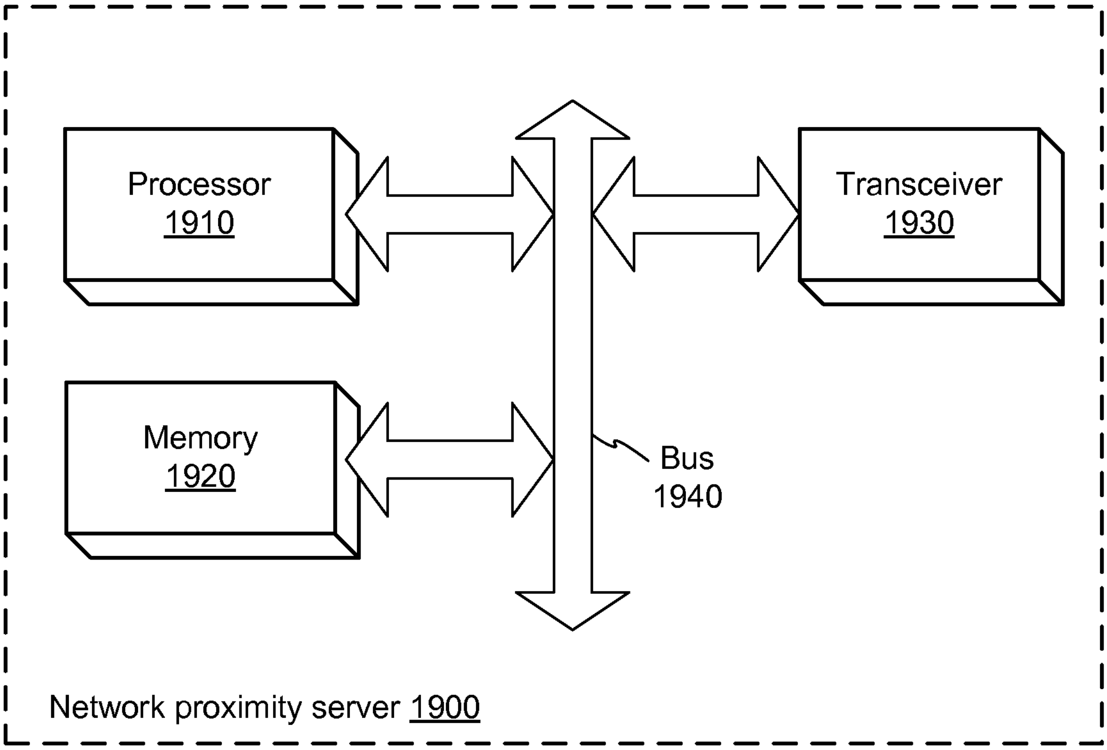

Processor
1910
Transceiver
1930
Memory
1920
Bus
1940
Network proximity server 1900

FIG. 19

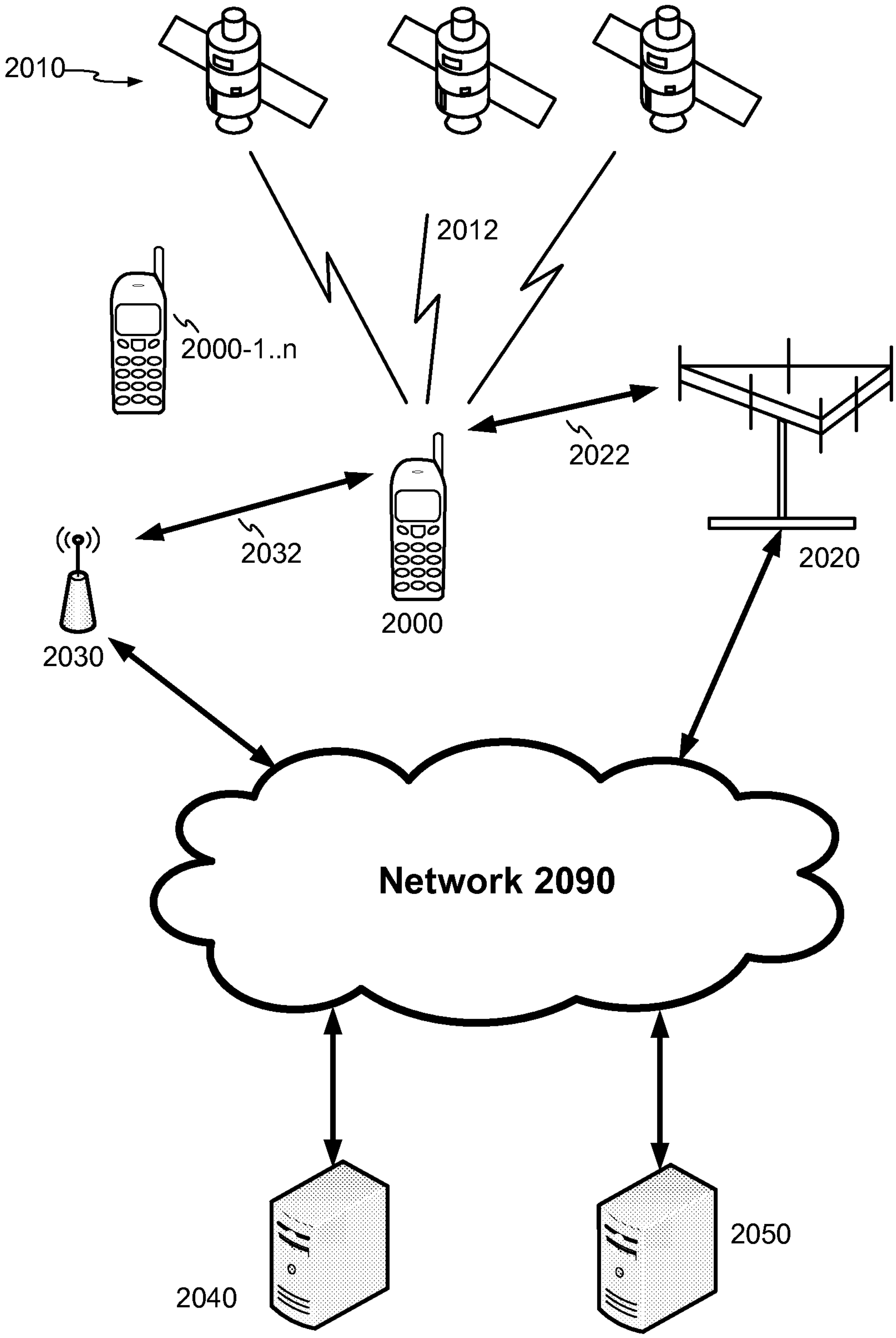

2010
2012
2000-1..n
2022
2020
2032
2030
2000
Network 2090
2040
2050

FIG. 20