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(54) **DETERMINING PROXIMITY OF USER EQUIPMENT FOR DEVICE-TO-DEVICE COMMUNICATION**

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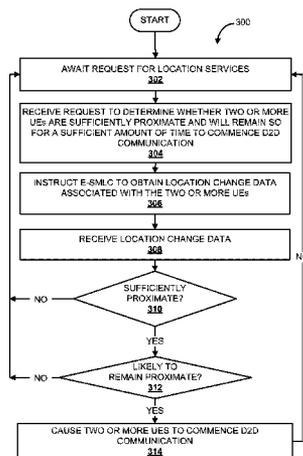
(57) **ABSTRACT**

Embodiments of apparatus, packages, computer-implemented methods, systems, devices, and computer-readable media (transitory and non-transitory) are described herein for ascertaining, e.g., by a traffic detection function (“TDF”), that a first user equipment (“UE”) and a second UE are, potentially, sufficiently proximate to each other to wirelessly exchange data directly. In various embodiments, an evolved serving mobile location center (“E-SMLC”) may be instructed, e.g., by the TDF, to obtain location change data associated with the first and second UEs. In various embodiments, a determination may be made, e.g., by the TDF, based on the location change data, whether the first and second UEs are sufficiently proximate to exchange data directly, and whether the first and second UEs are likely to remain proximate for at least a predetermined time interval. In various embodiments, the first and second UEs may be caused to commence device-to-device (“D2D”) communication based on the determination.

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- H04W 56/00* (2013.01); *H04W 72/042* (2013.01); *H04W 72/0413* (2013.01); *H04W 72/0426* (2013.01); *H04W 72/082* (2013.01); *H04W 72/085* (2013.01); *H04W 72/10* (2013.01); *H04W 72/1215* (2013.01); *H04W 76/023* (2013.01); *H04W 76/027* (2013.01); *H04W 76/048* (2013.01); *H04W 16/14* (2013.01); *H04W 36/18* (2013.01); *H04W 36/30* (2013.01); *H04W 72/02* (2013.01); *H04W 88/06* (2013.01); *Y02B 60/50* (2013.01)

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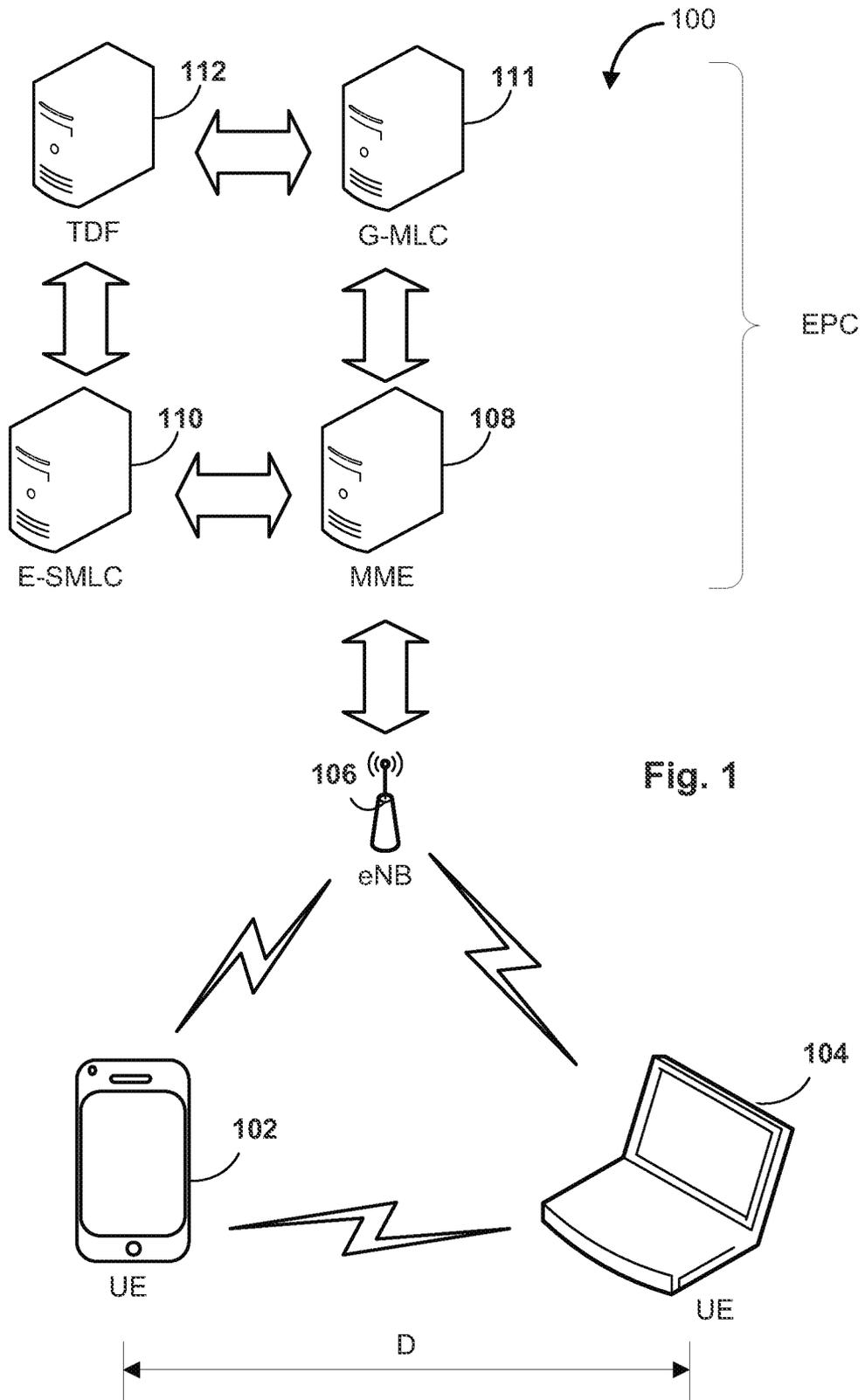
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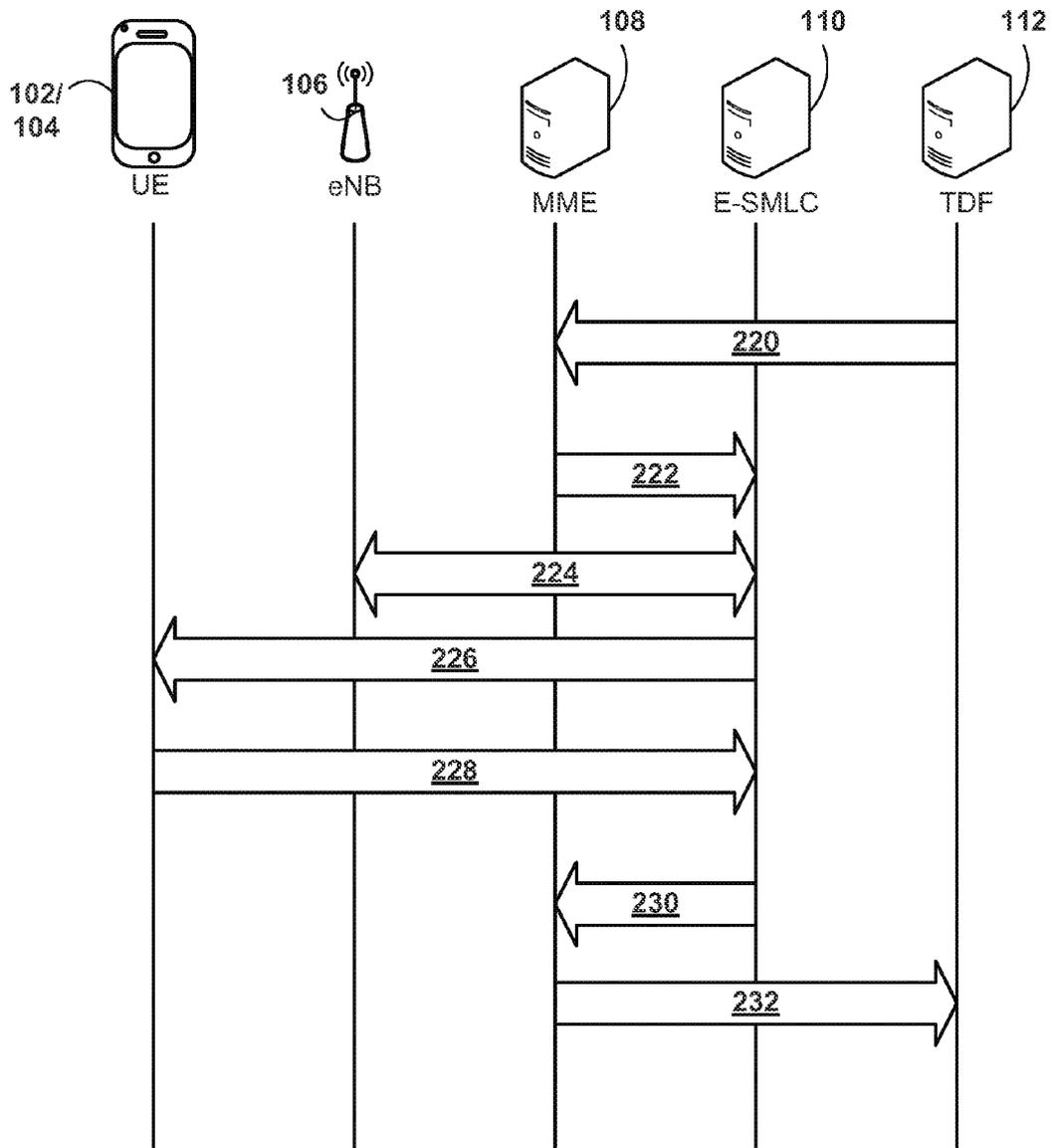
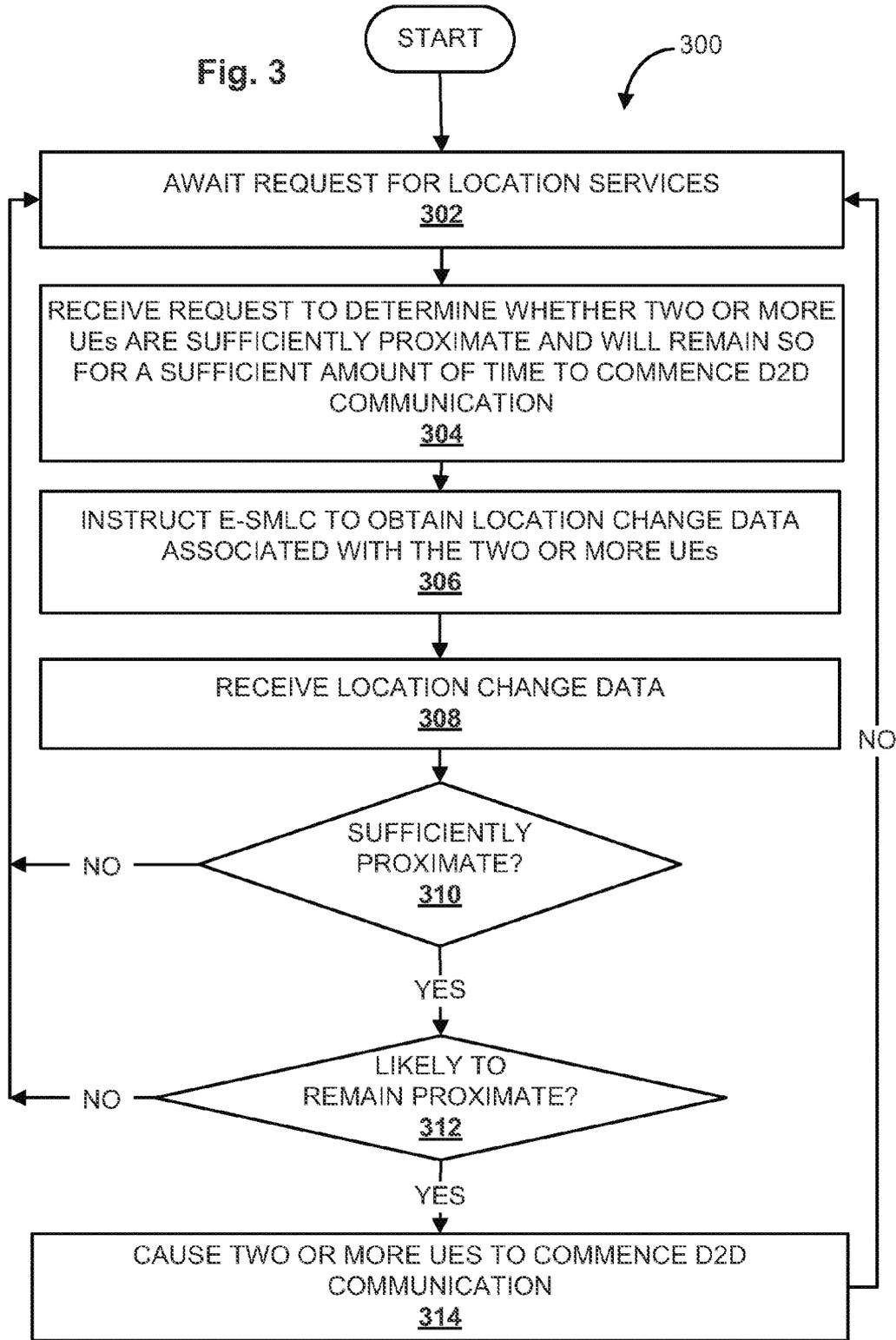


Fig. 2

Fig. 3



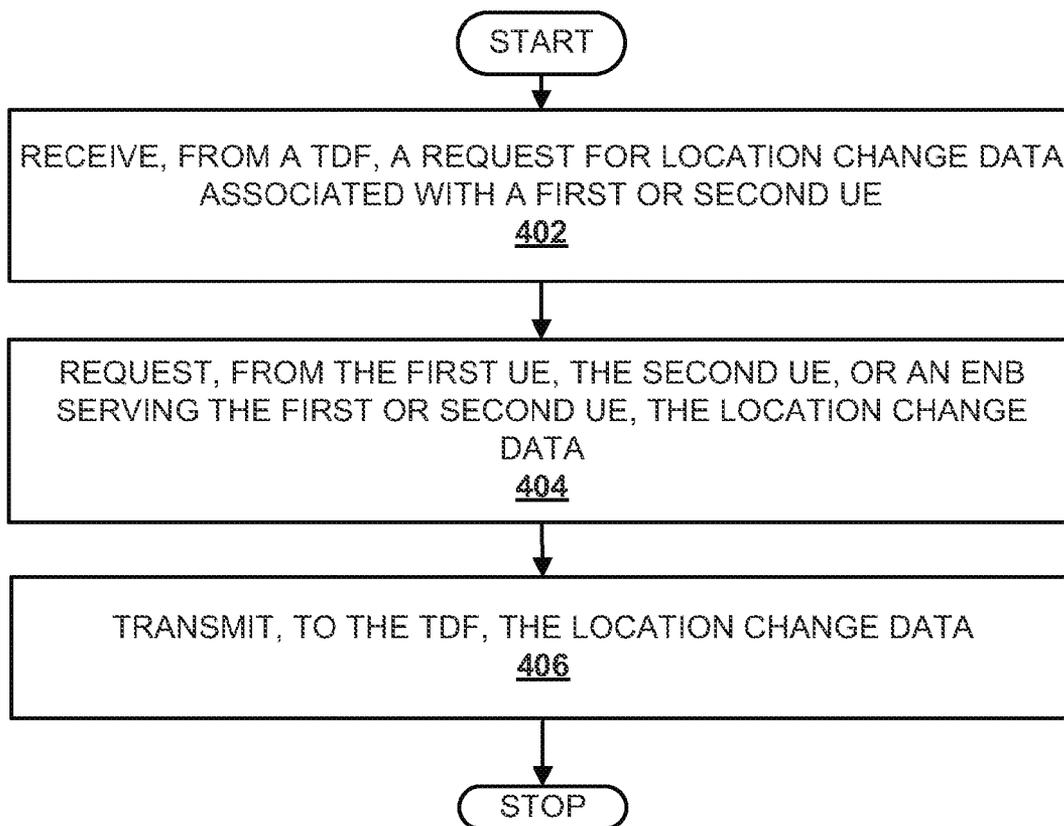


Fig. 4

400 ↷

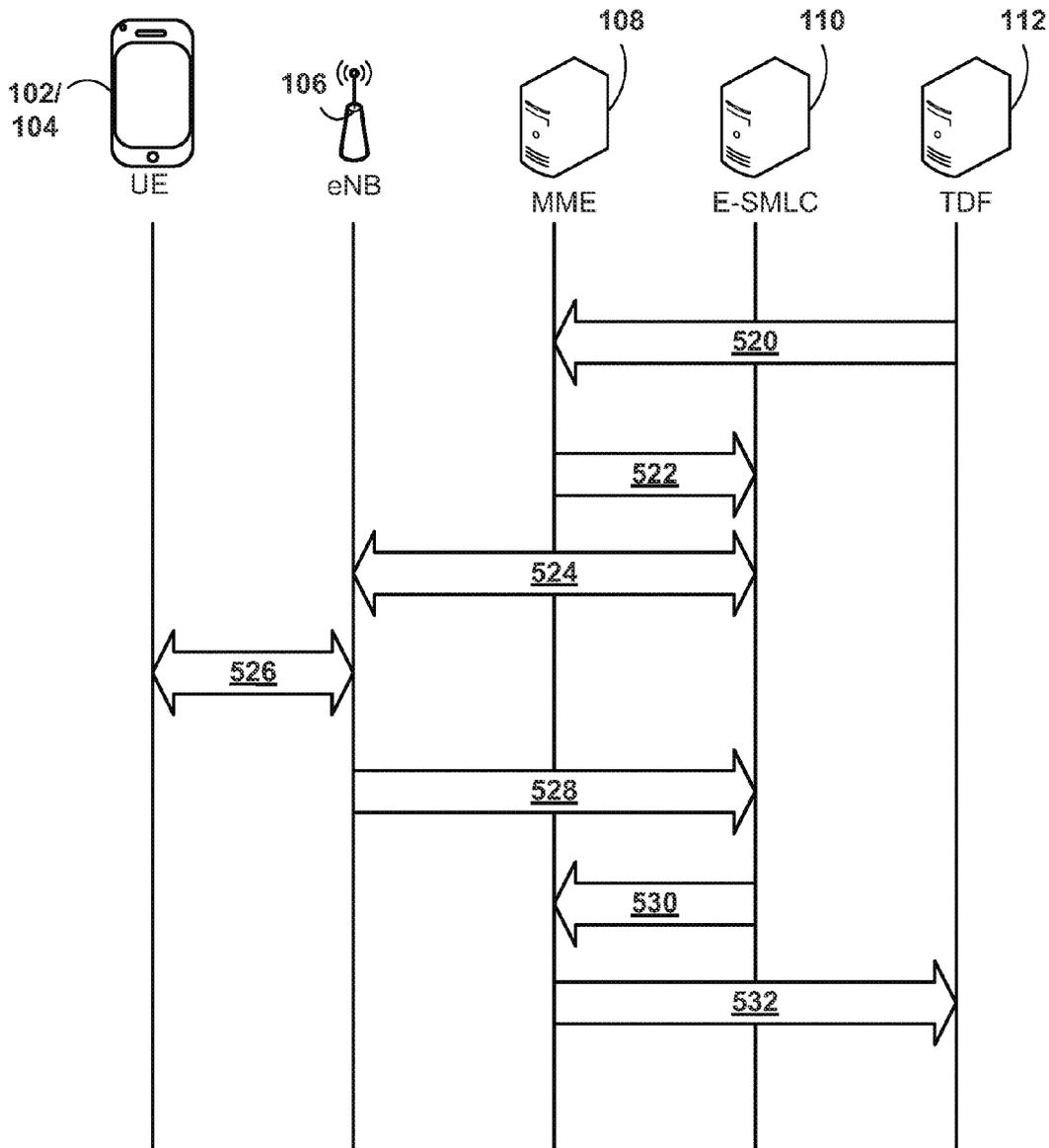


Fig. 5

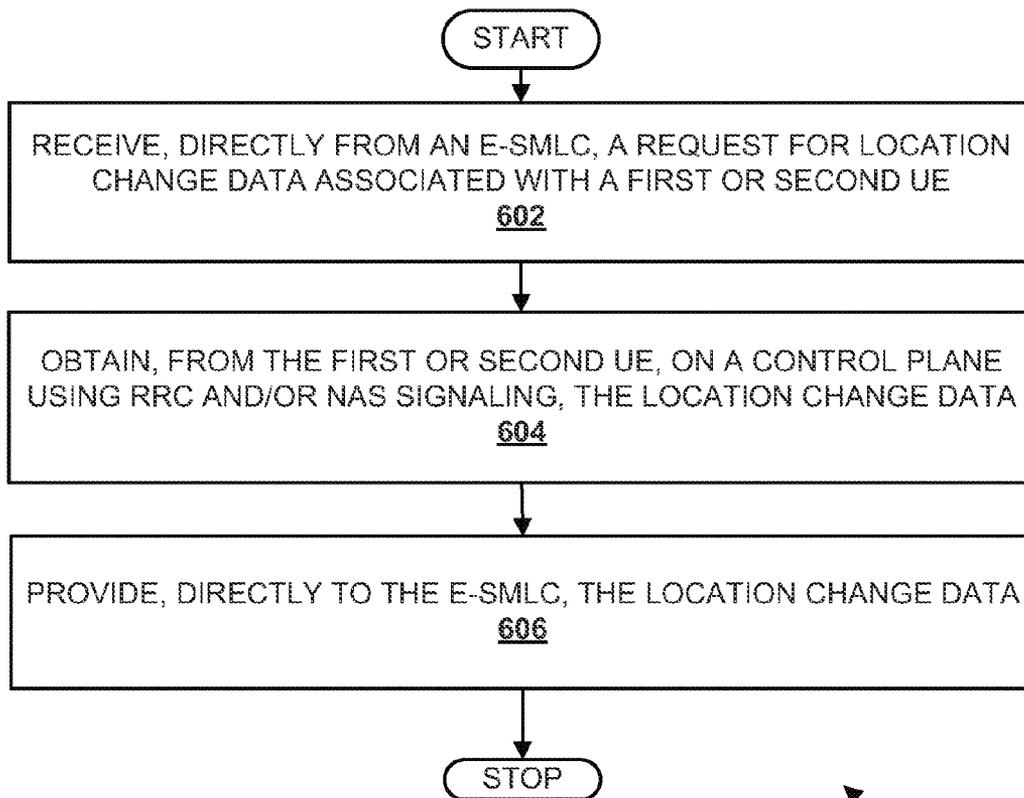


Fig. 6

600 ↷

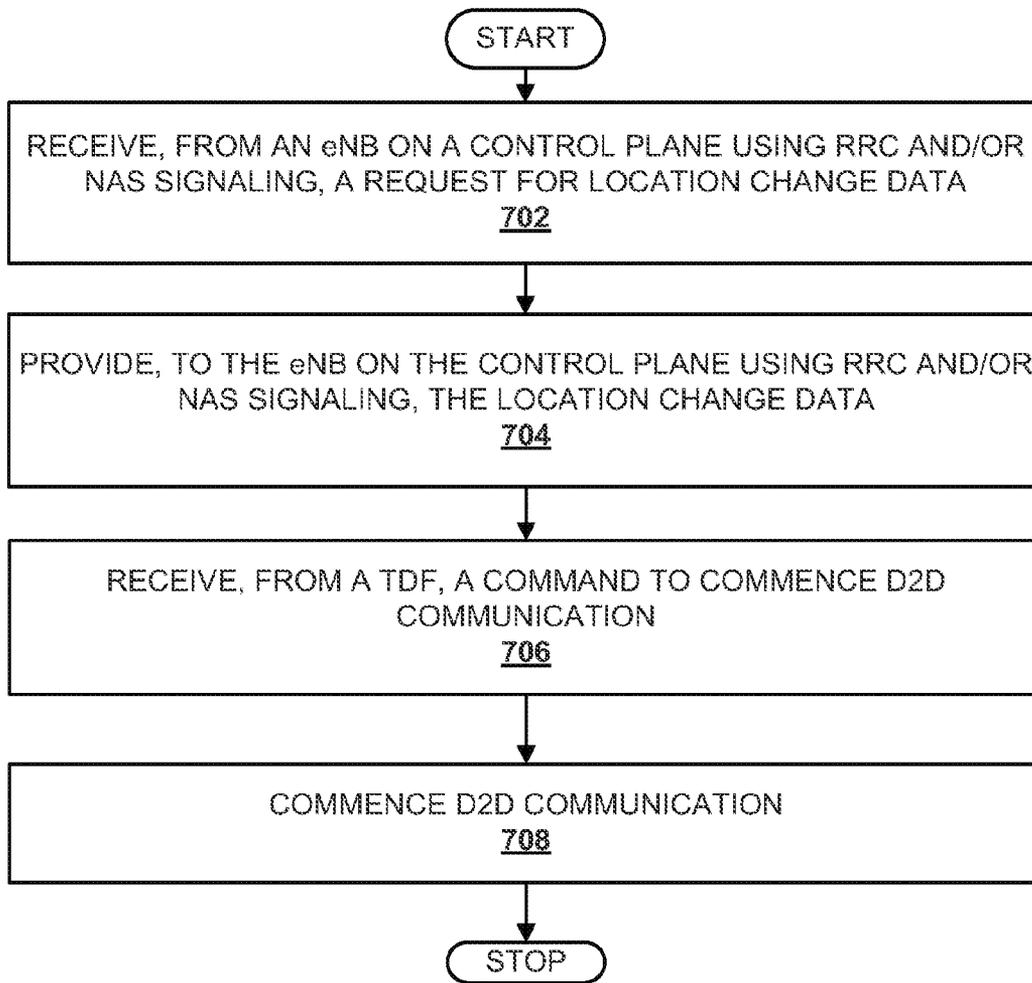
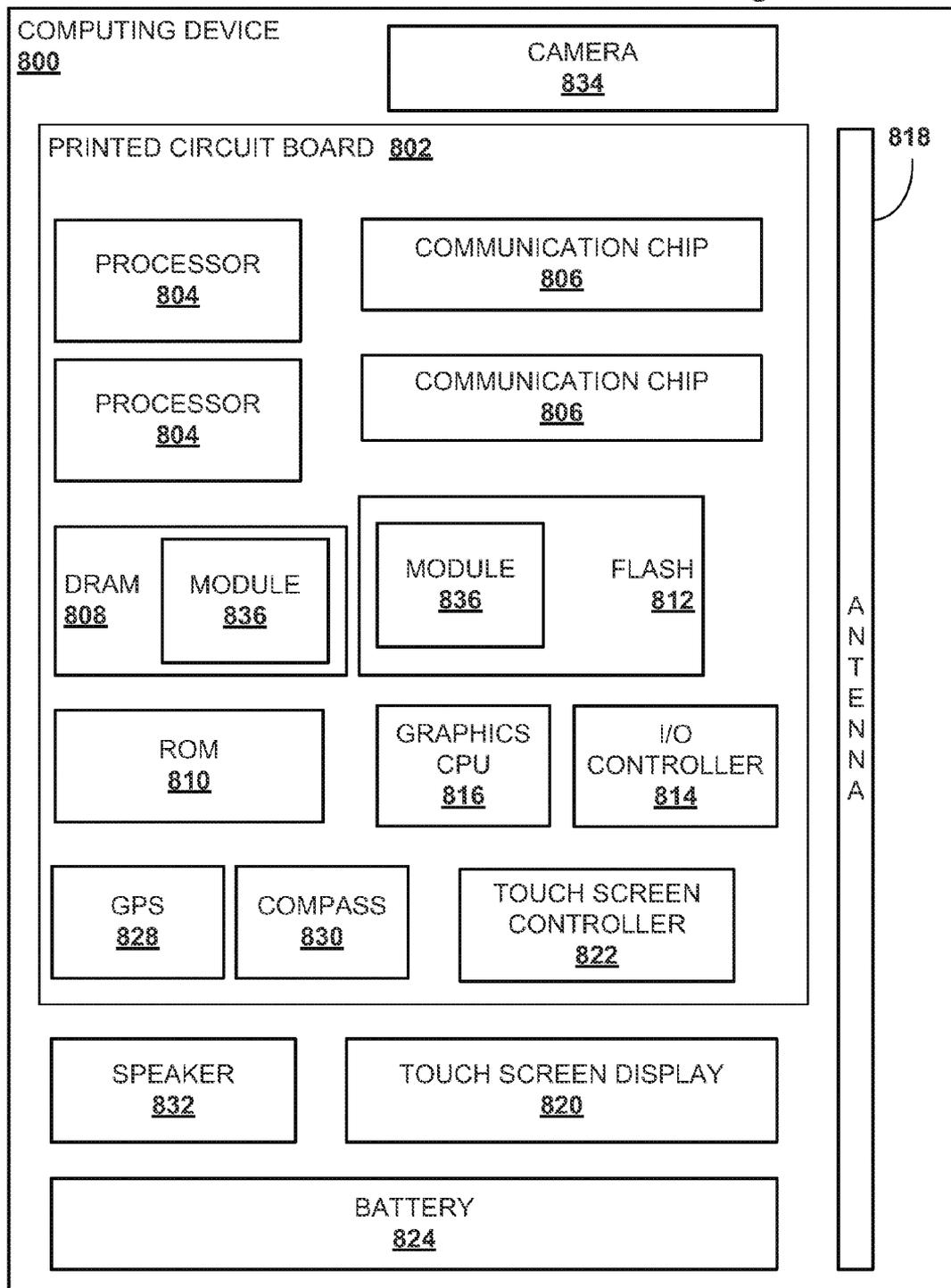


Fig. 7

700 ↷

Fig. 8



DETERMINING PROXIMITY OF USER EQUIPMENT FOR DEVICE-TO-DEVICE COMMUNICATION

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S. patent application Ser. No. 13/681,361 entitled "DETERMINING PROXIMITY OF USER EQUIPMENT FOR DEVICE-TO-DEVICE COMMUNICATION," filed Nov. 19, 2012 and issued as U.S. Pat. No. 8,874,103 on Oct. 28, 2014, which claims priority to U.S. Provisional Patent Application No. 61/646,223 entitled "ADVANCED WIRELESS COMMUNICATION SYSTEMS AND TECHNIQUES," filed May 11, 2012, both disclosures of which are incorporated herein by their references.

FIELD

Embodiments of the present invention relate generally to the technical field of data processing, and more particularly, to determining proximity of user equipment ("UE") for device-to-device ("D2D") communication.

BACKGROUND

The background description provided herein is for the purpose of generally presenting the context of the disclosure. Work of the presently named inventors, to the extent it is described in this background section, as well as aspects of the description that may not otherwise qualify as prior art at the time of filing, are neither expressly nor impliedly admitted as prior art against the present disclosure. Unless otherwise indicated herein, the approaches described in this section are not prior art to the claims in the present disclosure and are not admitted to be prior art by inclusion in this section.

Wireless mobile devices (e.g., user equipment, or "UE") may communicate with each other over a wireless wide area network ("WWAN"), e.g., using radio access technologies ("RAT") such as the 3GPP Long Term Evolution ("LTE") Advanced Release 10 (March 2011) (the "LTE-A Standard"), the IEEE 802.16 standard, IEEE Std. 802.16-2009, published May 29, 2009 ("WiMAX"), as well as any other wireless protocols that are designated as 3G, 4G, 5G, and beyond.

Some UEs also may be configured to communicate directly with other UEs, e.g., using device-to-device ("D2D") communication. D2D communication may be used, e.g., when UEs initiate communication with each other while within direct wireless range of each other. RATs that may be used in this manner may include 802.11 ("WiFi"), Bluetooth, near field communication ("NFC"), FlashLinq by Qualcomm®, and so forth.

UEs may initiate communication with each other over a WWAN, but may be in, or move into, sufficient proximity to exchange data directly, e.g., using WiFi Direct, Bluetooth, Flashlinq, NFC, etc. Continuing to using WWAN resources to communicate in such a situation may drain WWAN resources that may be put to better use for communications between UEs that are remote from each other.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments will be readily understood by the following detailed description in conjunction with the accompanying drawings. To facilitate this description, like reference numerals designate like structural elements. Embodiments are illus-

trated by way of example and not by way of limitation in the figures of the accompanying drawings.

FIG. 1 schematically illustrates various network entities configured with applicable portions of the present disclosure to facilitate commencement of device-to-device ("D2D") communication between user equipment ("UE"), in accordance with various embodiments of the present disclosure.

FIG. 2 schematically depicts an example of communications that may be exchanged between various network entities configured with applicable portions of the teachings of the present disclosure, in accordance with various embodiments of the present disclosure.

FIG. 3 schematically depicts an example method that may be implemented by a traffic detection function ("TDF"), in accordance with various embodiments of the present disclosure.

FIG. 4 schematically depicts an example method that may be implemented by an evolved serving mobile location center ("E-SMLC"), in accordance with various embodiments.

FIG. 5 schematically depicts an example of communications, similar to those shown in FIG. 2, that may be exchanged between various network entities configured with applicable portions of the teachings of the present disclosure, in accordance with various embodiments of the present disclosure.

FIG. 6 schematically depicts an example method that may be implemented by an evolved Node B ("eNB"), in accordance with various embodiments.

FIG. 7 schematically depicts an example method that may be implemented by a UE, in accordance with various embodiments.

FIG. 8 schematically depicts an example computing device on which disclosed methods and computer-readable media may be implemented, in accordance with various embodiments.

DETAILED DESCRIPTION

In the following detailed description, reference is made to the accompanying drawings which form a part hereof wherein like numerals designate like parts throughout, and in which is shown by way of illustration embodiments that may be practiced. It is to be understood that other embodiments may be utilized and structural or logical changes may be made without departing from the scope of the present disclosure. Therefore, the following detailed description is not to be taken in a limiting sense, and the scope of embodiments is defined by the appended claims and their equivalents.

Various operations may be described as multiple discrete actions or operations in turn, in a manner that is most helpful in understanding the claimed subject matter. However, the order of description should not be construed as to imply that these operations are necessarily order dependent. In particular, these operations may not be performed in the order of presentation. Operations described may be performed in a different order than the described embodiment. Various additional operations may be performed and/or described operations may be omitted in additional embodiments.

For the purposes of the present disclosure, the phrases "A or B" and "A and/or B" mean (A), (B), or (A and B). For the purposes of the present disclosure, the phrase "A, B, and/or C" means (A), (B), (C), (A and B), (A and C), (B and C), or (A, B and C).

The description may use the phrases "in an embodiment," or "in embodiments," which may each refer to one or more of the same or different embodiments. Furthermore, the terms

“comprising,” “including,” “having,” and the like, as used with respect to embodiments of the present disclosure, are synonymous.

As used herein, the terms “module” and/or “logic” may refer to, be part of, or include an Application Specific Integrated Circuit (“ASIC”), an electronic circuit, a processor (shared, dedicated, or group) and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit, and/or other suitable components that provide the described functionality.

An example wireless wide area network (“WWAN”) **100** is depicted in FIG. 1. A first mobile device in the form of a first user equipment (“UE”) **102** (configured with applicable portions of the teachings of the present disclosure) and a second mobile device in the form of a second UE **104** (configured with applicable portions of the teachings of the present disclosure) may be in wireless communication with each other via WWAN **100**. In particular, first UE **102** and second UE **104** may be in direct communication with a radio access network (“RAN”) via an access point in the form of an evolved Node B (“eNB”) **106**.

Although first UE **102** is depicted as a touch screen smart phone, and second UE **104** is depicted as a laptop computer, this is not meant to be limiting. As discussed below, mobile devices (e.g., UEs) described herein may be any type of data processing device, including but not limited to a tablet computer, a personal digital assistant (“PDA”), a portable gaming device, and so forth.

eNB **106** may be in network communication with various components of an Evolved Packet Core (“EPC”). For example, eNB **106** may be in network communication with a mobility management entity (“MME”) **108**. MME **108** may be configured to perform various functions, including but not limited to non-access stratum (“NAS”) signaling and NAS signaling security, idle mode UE reachability, public data network (“PDN”) and serving gateway selection, MME selection for handoffs, authentication, bearer management functions, and so forth.

MME **108** may itself be in network communication with various other nodes. For instance, MME **108** may be in network communication with an evolved serving mobile location center (“E-SMLC”) **110**. E-SMLC **110** may be configured to perform various functions related to location services (“LCS”). For example, E-SMLC **110** may manage the support of different location services for target UEs, e.g., including positioning of UEs and delivery of assistance data to UEs. In various embodiments, E-SMLC **110** may interact with the serving eNB (e.g., **106**) for a target UE (e.g., **102**, **104**) in order to obtain position measurements for the target UE. These position measurements may include but are not limited to uplink measurements made by the serving eNB and downlink measurements made by the target UE. The downlink measurements may have been provided to the serving eNB as part of other functions, such as support of handover. E-SMLC **110** may interact with a target UE (e.g., **102**, **104**) in order to deliver assistance data if requested for a particular location service, or to obtain a location estimate if that was requested. In various embodiments, in addition to or instead of E-SMLC **110**, a gateway mobile location center (“G-MLC”) **111** may perform similar functions as E-SMLC **110**.

For positioning of a target UE (e.g., **102**, **104**), E-SMLC **110** (or G-MLC **111**) may determine the positioning method to be used, based on factors such as LCS client type, a required quality of service (“QoS”), UE positioning capabilities, and/or eNB positioning capabilities. E-SMLC **110** may invoke these positioning methods in the target UE and/or serving eNB. UE-based positioning methods may yield a

location estimate. UE-assisted and network-based positioning methods may yield positioning measurements. E-SMLC **110** may combine received results and, based on those results, determine a single location estimate for the target UE, as well as other information such as an accuracy of the estimate.

E-SMLC **110** (or G-MLC **111**) may be in network communication with various other network entities. For instance, E-SMLC **110** may be in network communication with a traffic detection function (“TDF”) **112**. While TDF **112** is depicted in FIG. 1 as operating on a separate server computer, this is not meant to be limiting. TDF **112** may be implemented using any combination of hardware and software on any network computing device, such as those shown in FIG. 1 and others that are not shown but are often found in wireless communication networks. Moreover, in various embodiments, one or more of the entities depicted in FIG. 1 may be implemented on the same or different computing devices.

In various embodiments, if first UE **102** and second UE **104** are sufficiently proximate, and assuming both first UE **102** and second UE **104** are equipped with the same direct radio access technology (“RAT”), e.g., WiFi Direct, Bluetooth, near field communication (“NFC”), Flashing, etc. then first UE device **102** and second UE device **104** may be able to exchange data directly. For example, in FIG. 1, assume first UE **102** and second UE **104** are in communication already via WWAN **100** and are separated by a distance D. If D is less than a particular threshold, such as a maximum range of a particular RAT, then first UE **102** and second UE **104** may be able to communicate directly, e.g., using device-to-device (“D2D”) communication, rather than through WWAN **100**.

However, while first UE **102** and second UE **104** may momentarily be within sufficient proximity to commence D2D communication, they might not necessarily remain in sufficient proximity for long enough to justify a transition to D2D communication. For instance, a user of first UE **102** may be moving in one direction, and a user of second UE **104** may be moving in a different direction. The WWAN resources gained by commencing D2D communication between first UE **102** and second UE **104** may not be worth the network resources expended to implement the transition if the D2D communication will be short-lived.

Accordingly, in various embodiments, various network entities may be configured to determine not only whether first UE **102** and second UE **104** are sufficiently proximate to exchange data directly, but also whether they will remain proximate for an amount of time that justifies commencing D2D communication between the UEs.

In various embodiments, TDF **112** may be configured to ascertain that first UE **102** and second UE **104** are, potentially, sufficiently proximate to each other to wirelessly exchange data directly. Various events may cause TDF **112** to make this ascertainment. As one non-limiting example, eNB **106** may determine that it is serving both first UE **102** and second UE **104**. In such case, eNB **106** may be configured to transmit a request (e.g., an LCS request) to TDF **112** to determine whether first UE **102** and second UE **104** are sufficiently proximate to exchange data directly, e.g., using D2D communication. As another non-limiting example, first UE **102** or second UE **104** may itself determine that there is a possibility that the other is, potentially, sufficiently proximate to commence D2D communication. In such case, the UE device may transmit a request (e.g., an LCS request) to TDF **112** to determine whether first UE **102** and second UE **104** are sufficiently proximate to exchange data directly.

Upon ascertaining that first UE **102** and second UE **104** are, potentially, sufficiently proximate to exchange data directly, TDF **112** may instruct E-SMLC **110** (or G-MLC **111**) to

obtain location change data associated with the first UE **102** and/or second UE **104**. As used herein, the term “location change data” may include any data that demonstrates a change of location of a UE. For instance, location change data may include a velocity of a UE. Being a vector, a UE velocity may include a both speed component and a direction component. For instance, if the distance D between first UE **102** and second UE is growing at a particular rate over time, that may indicate that first UE **102** and second UE **104** are moving away from each other. Location change data may include any other indications of movement of UEs, such as acceleration.

In some embodiments, TDF **112** may instruct E-SMLC **110** (or G-MLC **111**) to obtain location change data associated with one or more UEs via a direct signaling interface. In other embodiments, such as the example shown in FIG. 2, this may be done through other nodes. Referring now to FIG. 2, at arrow **220**, TDF **112** may send a request for location change information associated with the first UE **102** and/or second UE **104** to MME **108**. At arrow **222**, MME **108** may forward this request to E-SMLC **112** (or G-MLC **111**). In other embodiments, TDF **112** may transmit this instruction via other nodes. For example, TDF **112** may transmit the instruction to E-SMLC **110** (or G-MLC **111**) through MME **108**, e.g., using a logical tunnel.

At arrow **224**, E-SMLC **110** (or G-MLC **111**) may instigate location procedures with serving eNB **106**. For example, E-SMLC **110** (or G-MLC **111**) may request that eNB **108** provide location change data associated with first UE **102** and/or second UE **104**. In various embodiments, E-SMLC **110** (or G-MLC **111**) may also obtain assistance data from eNB **106**, for provision to a target UE such as **102** or **104**.

Additionally or alternatively to arrow **224**, at arrow **226**, E-SMLC **110** (or G-MLC **111**) may instigate location procedures with UE **102** or **104**. In various embodiments, E-SMLC **110** (or G-MLC **111**) may obtain a location estimate (e.g., a GPS coordinate) or location change data from UE **102** or **104**. In various embodiments, E-SMLC **110** (or G-MLC **111**) may transfer, to UE **102** or **104**, the assistance data obtained from eNB **106** at block **224**. This assistance data may be used to assist with UE-based and/or UE-assisted positioning methods. At arrow **228**, UE **102** or **104** may transmit location change data associated with first UE **102** or second UE **104** to E-SMLC **110** (or G-MLC **111**), e.g., through eNB **106** and/or MME **108**.

Upon receiving location change data associated with first UE **102** and/or second UE **104**, E-SMLC **110** (or G-MLC **111**) may provide the location change data to TDF. In some embodiments, e.g., where TDF **112** and E-SMLC **110** (or G-MLC **111**) establish a direct signaling interface, this communication may be sent directly. In other embodiments, such as the one depicted in FIG. 2, at arrow **230**, E-SMLC **110** (or G-MLC **111**) may forward the location change data to MME **108**. MME **108** may in turn forward the location change data to TDF **112** at arrow **232**.

Once it receives the location change data, TDF **112** may determine, based on the location change data, whether first UE **102** and second UE **104** are sufficiently proximate to exchange data directly, and whether they are likely to remain proximate for at least a predetermined time interval. In various embodiments, the predetermined time interval may be selected to be long enough so that the benefits of commencing D2D communication (e.g., reduced WWAN network traffic) outweigh the costs of the transition. This predetermined time interval may be set, e.g., by a network administrator, or may be dynamic, e.g., based on current network traffic. In various embodiments, the determination as to whether the UEs will remain proximate for a sufficient time may be made based on

various laws of physics and motion. For instance, relative velocities and/or accelerations of two UEs reveal, e.g., as input in standard physics/motion equations, that the UEs will be within direct wireless range for a sufficient amount of time to justify commencement of D2D communication.

If TDF **112** determines that first UE **102** and second UE **104** will be in proximity for at least the predetermined time interval, TDF **112** may cause first UE **102** and second UE **104** to commence D2D communication. For example, in various embodiments, TDF **112** may instruct MME **108** to cause first UE **102** and second UE **104** to commence D2D communication. In various embodiments, MME **108** may utilize NAS signaling to instruct first UE **102** and second UE **104** to commence D2D communication.

FIG. 3 depicts an example method **300** that may be implemented by a computing device as part of operating a TDF such as TDF **112**. At block **302**, TDF **112** may await a request to instigate and/or perform location services. At block **304**, TDF **112** may receive, from various network nodes, a request to determine whether two or more UEs, e.g., first UE **102** and second UE **104**, exchanging data indirectly through a WWAN are in sufficient proximity to exchange data directly, e.g., using D2D communication. The request may also seek to have TDF **112** determine whether the first and second UEs will be proximate for a sufficient amount of time, such as a predetermined time interval, to warrant commencement of D2D communication.

At **306**, TDF **112** may instruct an E-SMLC or G-MLC, e.g., E-SMLC **110**, to obtain location change data associated with the first and second UEs (e.g., **102** and **104**). In some embodiments, TDF **112** may have a direct signaling interface with E-SMLC **110**, and therefore may transmit this instruction directly, e.g., bypassing MME **108**. In other embodiments, TDF **112** may transmit this instruction to MME **108**, which in turn may forward the instruction to E-SMLC **110**. At block **308**, TDF **112** may receive location change data, e.g., from E-SMLC **110** by way of MME **108**.

At block **310**, TDF **112** may determine, based on the received location change data, whether the first and second UEs are sufficiently proximate to exchange data directly. If the answer is yes, then at block **312**, TDF **112** may determine whether the first and second UEs are likely to remain proximate for at least a predetermined time interval (e.g., based on standard laws of physics/motion). If the answer is yes, then at block **314**, TDF **112** may cause first UE **102** and second UE **104** to commence D2D communication. If the answer at either block **310** or block **312** is no, then method **300** may proceed back to block **302**.

FIG. 4 depicts an example method **400** that may be implemented by, e.g., E-SMLC **110** or G-MLC **111**, in accordance with various embodiments. At block **402**, E-SMLC **110**/G-MLC **111** may receive, e.g., from TDF **112**, a request for location change data associated with first UE **102** or second UE **104**. At block **404**, E-SMLC **110**/G-MLC **111** may request, e.g., from first UE **102**, second UE **104**, or eNB **106** serving first UE **102** or second UE **104**, the location change data. At block **406**, E-SMLC **110**/G-MLC **111** may transmit the location change data, e.g., to TDF **112**.

FIG. 5 depicts a slight variation of the data exchange shown in FIG. 2. In this example, arrows **520**, **522**, **524**, **530** and **532** represent data exchanges similar to those represented by arrows **220**, **222**, **224**, **230** and **232** in FIG. 2, respectively. However, FIG. 5 differs from FIG. 2 at arrows **526** and **528**. Rather than E-SMLC **110** (or G-MLC **111**) instigating location procedures with UE **102** or **104**, at arrow **626**, eNB **106** may instigate (e.g., at the request of E-SMLC **110**) location procedures with UE **102** or **104**. For example, eNB **106** may

encapsulate a request for location services in an radio resource control (“RRC”) and/or NAS signal to UE 102 or UE 104. UE 102 or 104 may encapsulate a response in an RRC and/or NAS signal back to eNB 106. eNB 106 may then forward the UE location data to E-SMLC 110 at arrow 528.

FIG. 6 depicts an example method 600 that may be implemented by, e.g., eNB 106, to exchange communications as shown in FIG. 5. At block 602, eNB 106 may receive, e.g., from E-SMLC 110 (or G-MLC 111), a request for location change data associated with first UE 102 or a second UE 104. At block 604, eNB 106 may obtain, e.g., from first UE 102 or second UE 104, e.g., on a control plane over an air interface using RRC and/or NAS signaling, the location change data. For example, eNB 106 may encapsulate a location message (e.g., a request) into an RRC and/or NAS message and send it first UE 102 using RRC. First UE 102 may decapsulate the RRC and/or NAS message and consume the contents (e.g., the request). First UE 102 may likewise encapsulate location change data into a return RRC and/or NAS message, and send it back to eNB 106 using RRC and/or NAS signaling. At block 606, eNB 106 may decapsulate the message and provide the contents, e.g., the location change data, to E-SMLC 110 (or G-MLC 111).

FIG. 7 depicts an example method 700 that may be implemented by, e.g., first UE 102 or second UE 104. At block 702, a UE (e.g., first UE 102) may receive, from an eNB (e.g., eNB 106) serving the UE, on a control plane using at least one of RRC and NAS signaling, a request for location change data. At block 704, the UE may provide, to the eNB on a control plane using at least one of RRC and NAS signaling, the location change data. At block 706, the UE may receive, e.g., from a TDF (e.g., TDF 112), a command to commence D2D communication with another UE (e.g., second UE 104) served by the eNB, e.g., upon the TDF determining that the UE and the another UE are sufficiently proximate to exchange data directly and are likely to remain proximate for at least a predetermined time interval. At block 708, the UE may commence D2D with the another UE served by the eNB.

FIG. 8 illustrates an example computing device 800, in accordance with various embodiments. UE (e.g., 102, 104) or another network entity (e.g., 108, 110, 112) as described herein may be implemented on a computing device such as computing device 800. Computing device 800 may include a number of components, one or more processor(s) 804 and at least one communication chip 806. In various embodiments, the one or more processor(s) 804 each may be a processor core. In various embodiments, the at least one communication chip 806 may also be physically and electrically coupled to the one or more processors 804. In further implementations, the communication chip 806 may be part of the one or more processors 804. In various embodiments, computing device 800 may include printed circuit board (“PCB”) 802. For these embodiments, the one or more processors 804 and communication chip 806 may be disposed thereon. In alternate embodiments, the various components may be coupled without the employment of PCB 802.

Depending on its applications, computing device 800 may include other components that may or may not be physically and electrically coupled to the PCB 802. These other components include, but are not limited to, volatile memory (e.g., dynamic random access memory 808, also referred to as “DRAM”), non-volatile memory (e.g., read only memory 810, also referred to as “ROM”), flash memory 812, an input/output controller 814, a digital signal processor (not shown), a crypto processor (not shown), a graphics processor 816, one or more antenna 818, a display (not shown), a touch screen display 820, a touch screen controller 822, a battery 824, an

audio codec (not shown), a video codec (not shown), a global positioning system (“GPS”) device 828, a compass 830, an accelerometer (not shown), a gyroscope (not shown), a speaker 832, a camera 834, and a mass storage device (such as hard disk drive, a solid state drive, compact disk (“CD”), digital versatile disk (“DVD”))(not shown), and so forth. In various embodiments, the processor 804 may be integrated on the same die with other components to form a System on Chip (“SoC”).

In various embodiments, volatile memory (e.g., DRAM 808), non-volatile memory (e.g., ROM 810), flash memory 812, and the mass storage device may include programming instructions configured to enable computing device 800, in response to execution by one or more processors 804, to practice all or selected aspects of methods 300, 400, 600 or 700, depending on whether computing device 800 is used to implement first UE 102, second UE 104, TDF 112, eNB 106, E-SMLC 110, or G-MLC 111. More specifically, one or more of the memory components such as volatile memory (e.g., DRAM 808), non-volatile memory (e.g., ROM 810), flash memory 812, and the mass storage device may include temporal and/or persistent copies of instructions that, when executed, by one or more processors 804, enable computing device 800 to operate one or more modules 836 configured to practice all or selected aspects of methods 300, 400, 600 or 700, depending on whether computing device 800 is used to implement first UE 102, second UE 104, TDF 112, eNB 106, E-SMLC 110, or G-MLC 111.

The communication chips 806 may enable wired and/or wireless communications for the transfer of data to and from the computing device 800. The term “wireless” and its derivatives may be used to describe circuits, devices, systems, methods, techniques, communications channels, etc., that may communicate data through the use of modulated electromagnetic radiation through a non-solid medium. The term does not imply that the associated devices do not contain any wires, although in some embodiments they might not. The communication chip 806 may implement any of a number of wireless standards or protocols, including but not limited to IEEE 802.20, General Packet Radio Service (“GPRS”), Evolution Data Optimized (“Ev-DO”), Evolved High Speed Packet Access (“HSPA+”), Evolved High Speed Downlink Packet Access (“HSDPA+”), Evolved High Speed Uplink Packet Access (“HSUPA+”), Global System for Mobile Communications (“GSM”), Enhanced Data rates for GSM Evolution (“EDGE”), Code Division Multiple Access (“CDMA”), Time Division Multiple Access (“TDMA”), Digital Enhanced Cordless Telecommunications (“DECT”), Bluetooth, derivatives thereof, as well as any other wireless protocols that are designated as 3G, 4G, 5G, and beyond. The computing device 800 may include a plurality of communication chips 806. For instance, a first communication chip 806 may be dedicated to shorter range wireless communications such as Wi-Fi and Bluetooth and a second communication chip 806 may be dedicated to longer range wireless communications such as GPS, EDGE, GPRS, CDMA, WiMAX, LTE, Ev-DO, and others.

In various implementations, the computing device 800 may be a laptop, a netbook, a notebook, an ultrabook, a smart phone, a computing tablet, a personal digital assistant (“PDA”), an ultra mobile PC, a mobile phone, a desktop computer, a server, a printer, a scanner, a monitor, a set-top box, an entertainment control unit (e.g., a gaming console), a digital camera, a portable music player, or a digital video recorder. In further implementations, the computing device 800 may be any other electronic device that processes data.

Embodiments of apparatus, packages, computer-implemented methods, systems, devices, and computer-readable media (transitory and non-transitory) are described herein for a TDF configured to ascertain that a first UE and a second UE are, potentially, sufficiently proximate to each other to wirelessly exchange data directly. In various embodiments, the TDF may instruct an E-SMLC to obtain location change data associated with the first and second UEs. In various embodiments, the TDF may determine, based on the location change data, whether the first and second UEs are sufficiently proximate to exchange data directly, and whether the first and second UEs are likely to remain proximate for at least a predetermined time interval. In various embodiments, the TDF may cause the first and second UEs to commence D2D communication based on the determination.

In various embodiments, the location change data may include information about a velocity and/or acceleration of the first or second UE. In various embodiments, the location change data may include comprises information about a rate of change of relative locations of the first and second UEs.

In various embodiments, the TDF may instruct the E-SMLC to obtain the location change data via at least one of RRC or NAS signaling over a control plane of a RAN. In various embodiments, the TDF may instruct an MME to cause the first and second UEs to commence D2D communication. In various embodiments, the TDF may instruct the MME to use NAS signaling to instruct the first and second UEs to commence D2D communication. In various embodiments, the TDF may instruct the E-SMLC using a direct signaling interface.

In various embodiments, the TDF may ascertain that the first and second UEs are, potentially, sufficiently proximate to each other to wirelessly exchange data directly based on a request from the first or second UE. In various embodiments, the TDF may ascertain that the first and second UEs are, potentially, sufficiently proximate to each other to wirelessly exchange data directly based on a request for location services from an eNB in communication with and/or serving the first or second UE.

In various embodiments, an eNB may be configured to obtain, from an E-SMLC, a request for location change data associated with a first UE or a second UE. In various embodiments, the eNB may obtain, from the first or second UE using RRC and/or NAS signaling, the location change data. In various embodiments, the eNB may provide the location change data to the E-SMLC. In various embodiments, receipt of the request for location change data and provision of the location change data are direct to the E-SMLC, bypassing a MME.

In various embodiments, a system may include one or more processors, memory operably coupled to the one or more processors, and instructions in the memory that, when executed by the one or more processors, cause the one or more processors to operate an E-SMLC. In various embodiments, the E-SMLC may be configured to receive, from a TDF, a request for location change data associated with a first UE or a second UE. In various embodiments, the E-SMLC may be configured to request, from the first UE, the second UE, or an eNB serving the first or second UE, the location change data. In various embodiments, the E-SMLC may be configured to transmit the location change data to the TDF. In various embodiments, the location change data may include information about a velocity of the first or second UE. In various embodiments, the E-SMLC may be further configured to cause the eNB to obtain the location change data from the first or second UE using radio resource control signaling. In various embodiments, the E-SMLC may be configured to receive

the request from the TDF via an MME. In various embodiments, the E-SMLC may be configured to receive the request directly from the TDF, bypassing an MME. In various embodiments, the E-SMLC may include a Bluetooth transceiver.

In various embodiments, a UE may include processing circuitry to receive, from an eNB serving the UE, using at least one of RRC and NAS signaling, a request for location change data. In various embodiments, the processing circuitry may be configured to provide, to the eNB using at least one of RRC and NAS signaling, the location change data. In various embodiments, the processing circuitry may be configured to commence D2D communication with another UE served by the eNB responsive to a determination that the UE and the another UE are sufficiently proximate to exchange data directly and are likely to remain proximate for at least a predetermined time interval. In various embodiments, the processing circuitry may be configured to commence the D2D communication with the another UE responsive to a command from a TDF.

Although certain embodiments have been illustrated and described herein for purposes of description, this application is intended to cover any adaptations or variations of the embodiments discussed herein. Therefore, it is manifestly intended that embodiments described herein be limited only by the claims.

Where the disclosure recites “a” or “a first” element or the equivalent thereof, such disclosure includes one or more such elements, neither requiring nor excluding two or more such elements. Further, ordinal indicators (e.g., first, second or third) for identified elements are used to distinguish between the elements, and do not indicate or imply a required or limited number of such elements, nor do they indicate a particular position or order of such elements unless otherwise specifically stated.

What is claimed is:

1. An apparatus to be included in a network entity, the apparatus comprising:

receiver circuitry to receive location change data that is indicative of a location change over time of at least one of a first user equipment (“UE”) or a second UE;

processing circuitry, coupled with the receiver circuitry, to determine the location change over time of the at least one of the first UE or the second UE based on the location change data and to further determine that the first UE and the second UE are to be proximate with one another for a predetermined period of time based on the determined location change over time; and

transmitter circuitry, coupled with the processing circuitry, to transmit, based on the determination that the first UE and the second UE are to be proximate with one another for the predetermined period of time, an instruction to cause the first UE and the second UE to establish a direct wireless connection with one another.

2. The apparatus of claim 1, wherein the location change data comprises at least one of a velocity of the first or second UE, an acceleration of the first or second UE, or a rate of change of relative locations of the first and second UEs.

3. The apparatus of claim 1, wherein the receiver circuitry is to receive a first location associated with the first UE and a second location associated with the second UE, and further wherein the determination, by the processing circuitry, that the first UE and the second UE are to be proximate with one another is based on the first and second locations.

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4. The apparatus of claim 1, wherein the transmitter circuitry is to transmit an instruction to an evolved serving mobile location center (“E-SMLC”) to obtain the location change data.

5. The apparatus of claim 4, wherein the instruction to the E-SMLC indicates use of one of radio resource control (“RRC”) or non-access stratum (“NAS”) signaling over a control plane of a radio access network (“RAN”).

6. The apparatus of claim 1, wherein the transmitter circuitry is to transmit the instruction to a mobility management entity (“MME”).

7. The apparatus of claim 1, wherein the receiver circuitry is to receive a request associated with the first UE or the second UE, and further wherein the determination, by the processing circuitry, that the first UE and the second UE are to be proximate with one another is based on the request.

8. The apparatus of claim 7, wherein the request comprises a request for location services from an evolved Node B (“eNB”) that is to serve at least one of the first or the second UEs.

9. One or more non-transitory, computer-readable media having instructions that, when executed, cause a device to:

instruct an evolved serving mobile location center (“E-SMLC”) to obtain location change data that is indicative of a location change over time of at least one of a first user equipment (“UE”) or a second UE;

determine, based on the location change over time, that the first UE and the second UE are to be proximate with one another for a predetermined period of time; and

transmit an instruction that is to cause the first and second UEs to establish a direct wireless connection based on said determination.

10. The one or more non-transitory, computer-readable media of claim 9, wherein the location change data comprises at least one of a velocity of the first or second UE, an acceleration of the first or second UE, or a rate of change of relative locations of the first and second UEs.

11. The one or more non-transitory, computer-readable media of claim 9, wherein the instruction to obtain the location change data includes an indication of whether to use radio resource control (“RRC”) or non-access stratum (“NAS”) signaling over a control plane of a radio access network (“RAN”).

12. The one or more non-transitory, computer-readable media of claim 9, wherein the instructions, when executed, further cause the device to:

instruct a mobility management entity (“MME”) to cause the first and second UEs to establish the direct wireless connection.

13. The one or more non-transitory, computer-readable media of claim 9, wherein the instructions, when executed, further cause the device to:

process a request associated with the first UE or the second UE; and

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determine that the first UE and the second UE are to be proximate with one another based on the request.

14. The method of claim 13, wherein the request comprises a request for location services from an evolved Node B (“eNB”) that is to serve at least one of the first or the second UEs.

15. Evolved Node B (“eNB”) circuitry comprising:

receiver circuitry to receive, from an evolved mobile location center (“E-SMLC”), a first request for location change data that is indicative of a location change over time of a first user equipment (“UE”) and to receive the location change data from the first UE based on a second request;

transmitter circuitry to transmit the second request to the first UE using radio resource control (“RRC”) or non-access stratum (“NAS”) signaling and to transmit the location change data to the E-SMLC based on the first request; and

processing circuitry, coupled with the receiver circuitry and the transmitter circuitry, to serve the first UE and to determine the location change over time based on the location change data received from the first UE.

16. The eNB circuitry of claim 15, wherein the location change data comprises at least one of a velocity of the first UE, an acceleration of the first UE, or a rate of change of relative locations of the first UE to a second UE that is also served by the eNB circuitry.

17. The eNB circuitry of claim 15, wherein the request for the location change data is received directly from the E-SMLC and not from a mobility management entity (“MME”).

18. At least one non-transitory computer-readable medium comprising instructions that, in response to execution of the instructions by a user equipment (“UE”), enable the UE to: process a request, received via radio resource control (“RRC”) or non-access stratum (“NAS”) signaling, for location change data that is indicative of a location change over time of the UE; and

transmit, via the RRC or the NAS signaling, the location change data to an eNB that is to serve the UE based on the request.

19. The at least one non-transitory computer-readable medium of claim 18, wherein the instructions further enable the UE to:

establish a direct wireless connection with another UE.

20. The at least one non-transitory computer-readable medium of claim 19, wherein the instructions further enable the UE to:

process an instruction, received from a traffic detection function (“TDF”), to establish the direct wireless connection with the other UE.

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