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(71) Applicant: INTEL IP CORPORATION [US/US]; 2200  
Mission College Boulevard, Santa Clara, California 95054  
(US).

(72) Inventor: SIROTKIN, Alexander; 94 Em Hamoshavot  
Way, Park Azorim. P.O. Box 10097, 49527 Petach Tikva,  
M (IL).

(74) Agents: VRBANAC, Michael D. et al.; 1211 SW 5th Av-  
enue, Suite 1600, Portland, Oregon 97204 (US).

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(57) Abstract: The present disclosure describes embodiments of apparatuses, systems, and methods related to positioning of a user equipment using indications of time of flight between the user equipment and access points of a wireless local area network and the coordinates of the access points. The various embodiments may be implemented in user equipment and/or location servers and may further be implemented in existing positioning apparatuses, systems, and methods, such as global navigation satellite systems and/or evolved node B networks in long term evolution systems.



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## POSITIONING WITH WLAN TIME OF FLIGHT

### CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims priority to U.S. Provisional Patent Application No. 62/112,928 filed February 6, 2015 entitled “Computing Apparatus with Time-of-Flight Based Positioning,” the entire disclosure of which is hereby incorporated by reference herein in its entirety for all purposes.

### FIELD

Embodiments of the present disclosure generally may relate to the field of wireless communications. More specifically, embodiments of the present disclosure generally may relate to positioning for wireless communications in wireless communication devices, systems, and methods.

### BACKGROUND

Positioning is determining the geographical location of a device such as a mobile phone, laptop or tablet computer, a personal digital assistant (PDA), or navigation or tracking equipment. After the geographical coordinates of a device are obtained, they may be mapped to a location, including a road, a building, a park, or a landmark. The geographical location may be sent back to a requesting service. Device location knowledge may be used, for example, in support of Radio Resource Management functions, as well as location-based services for operators, subscribers, and third-party service providers. Generally, positioning may use global navigation satellite system (GNSS) and/or base stations of a cellular network. Generally, GNSS positioning requires a line of sight to work properly, and accurate positioning using base stations requires sufficient signal from at least three stations. The challenge to identify the geographical location of a device is considerably more difficult when the device to be located is in a dense urban environment and/or is indoors because of the interference caused by buildings, walls, and objects of various shapes and comprised of various materials.

### BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments will be readily understood by reference to the following detailed description in conjunction with the accompanying drawings. To facilitate this description, like reference numerals designate like structural elements. Embodiments are illustrated by way of example and not by way of limitation in the figures of the accompanying drawings.

FIG. 1 illustrates a Time of Flight (ToF) diagram to determine a ToF between Station A and Station B in a wireless local area network (WLAN), in accordance with some embodiments.

FIG. 2 illustrates a Location Measurement Unit (LMU) Location Services (LCS) Protocol (LLP) system in which time of flight positioning may be added.

FIG. 3 illustrates a positioning system, in accordance with some embodiments.

FIG. 4 illustrates a user equipment (UE), in accordance with some embodiments.

FIG. 5 illustrates a location server coupled to an eNB for positioning of a UE, in accordance with some embodiments.

FIG. 6 illustrates a process of positioning that may be implemented in a user equipment (UE), in accordance with some embodiments.

FIG. 7 illustrates a process of positioning that may be implemented in a location server, in accordance with some embodiments.

FIG. 8 illustrates, for one embodiment, an example system comprising radio frequency (RF) circuitry, baseband circuitry, application circuitry, memory/storage, display, camera, sensor, and input/output (I/O) interface, coupled with each other at least as shown, in accordance with various embodiments.

### DETAILED DESCRIPTION

Embodiments of the present disclosure describe various apparatuses, systems, and methods for positioning in wireless communications. The following detailed description refers to the accompanying drawings. The same reference numbers may be used in different drawings to identify the same or similar elements and features. In the following description, for purposes of explanation and not limitation, specific details are set forth such as particular structures, architectures, interfaces, and/or techniques in order to provide an understanding of the various aspects of the embodiments disclosed herein. However, a person having ordinary skill in the art will understand and appreciate that various aspects of the embodiments described herein may be practiced in other embodiments and that some such embodiments may depart from the specific details of combinations and/or sub-combinations described herein for specific embodiments. In certain instances, descriptions of well-known devices, circuits, and methods are omitted so as not to obscure the description of the embodiments herein with unnecessary detail. Therefore, the following detailed description is not to be taken in a limiting sense.

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 some embodiments,” “in an  
5 embodiment,” or “in embodiments,” which may each refer to one or more of the same or different embodiments. Furthermore, the terms “including,” “having,” and the like, as used with respect to embodiments of the present disclosure, are synonymous.

The terms “coupled with” and “coupled to” and the like, may be used herein. “Coupled” may mean one or more of the following. “Coupled” may mean that two or  
10 more elements are in direct physical or electrical contact. However, “coupled” may also mean that two or more elements indirectly contact each other, but yet still cooperate or interact with each other, and may mean that one or more other elements are coupled or connected between the elements that are said to be coupled with each other. By way of example and not limitation, “coupled” may mean two or more elements or devices are  
15 coupled by electrical connections on a printed circuit board such as a motherboard for example. By way of example and not limitation, “coupled” may mean two or more elements/devices cooperate and/or interact through one or more network linkages such as wired and/or wireless networks. By way of example and not limitation, a computing apparatus may include two or more computing devices “coupled” on a motherboard or by  
20 one or more network linkages.

As used herein, the terms “module” and/or “circuitry” may refer to, be part of, or include an Application Specific Integrated Circuit (ASIC), an electronic circuit, a system-on-chip (SoC), a processor (shared, dedicated, or group), and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs, a  
25 combinational logic circuit, and/or other suitable components that provide the described functionality. Modules and circuitry generally may be executed by one or more processors using memory coupled to the one or more processors as necessary to execute the logic of a module and/or circuitry, as one of ordinary skill in the art would readily understand.

The term “LTE” refers to long term evolution and may include LTE advanced.  
30 The term “UE” refers to user equipment and may include mobile and fixed devices, including devices for voice and/or data. A UE may be a SUPL Enabled Terminal (SET). The term UE may include general devices capable of communicating in a cellular network such as a LTE network. The term “eNB” refers to an evolved node B, which may be referred to as a base station in a cellular system.

The term “logic” may refer to computing logic embedded in circuitry of a computing apparatus and/or computing logic stored in a memory of a computing apparatus, wherein the logic is accessible by a processor of the computing apparatus to execute the computing logic to perform computing functions. By way of example and not  
5 limitation, logic may be embedded in various types of memory and/or firmware, e.g. silicon blocks of various chips and/or processors. Logic may be in various circuitry, e.g. radio circuitry, receiver circuitry, control circuitry, transmitter circuitry, transceiver circuitry, and the like. By way of example and not limitation, logic may be embedded in volatile memory and/or non-volatile memory, including random access memory, read only  
10 memory, programmable memory, magnetic memory, flash memory, persistent memory, and the like. Logic generally may be executed by one or more processors using memory coupled to the one or more processors as necessary to execute the logic, as one of ordinary skill in the art would readily understand.

In some embodiments, LTE positioning protocol (LPP) may be improved by  
15 incorporation of wireless local area network (WLAN) Time of Flight (ToF), as disclosed herein. An example WLAN includes Wi-Fi. ToF means the same as Fine Timing Measurement (FTM), and FTM and ToF may be used interchangeably. The difference is terminology, and the FTM terminology may be used by some standards setting bodies. In some embodiments, LPP extensions (LPPE) may be improved by incorporation of WLAN  
20 ToF positioning, as disclosed herein. LPPE may be referred to as OMA-TS-LPPE. OMA refers to The Open Mobile Alliance. TS refers to technical specifications. Generally, there are numerous TS of various versions in LPPE. OMA develops the TS for LPPE. The LPP elementary messages (Request and Provision of Capabilities and Location Information and Assistance Data) include a container, an External Protocol Data Unit (EPDU), which can  
25 be used by standardization forums outside 3GPP to define their own extensions to LPP messages. OMA LPPE takes advantage of this option. The flexibility of LPPE allows for further features such as support for an additional positioning process, e.g. WLAN, WiMAX, and sensors. In some embodiments, UE-assisted or UE-based approaches may be used in conjunction with WLAN ToF positioning to improve positioning in LTE. In  
30 some embodiments, LTE positioning architecture may be enhanced to support WLAN ToF incorporation into LPP or LPPE.

Generally, a WLAN ToF approach to positioning is geometric-based, where the location of a device is determined using distances from one or more access points (APs). Three APs may be desirable to position a device. More than three APs may be used to

position a device. The distance from an AP may be acquired by measuring the round trip time (RTT) of signals transmitted between a device and the AP. The ToF protocol uses four timing measurements, two Time of Arrival (ToA) measurements and two Time of Departure (ToD) measurements. These time stamps may be denoted as t1, t2, t3, and t4.

5 FIG. 1 illustrates a Time of Flight (ToF) diagram 100 to determine a ToF between Station A 102 and Station B 104 in a wireless local area network (WLAN), in accordance with some embodiments.

In some embodiments, ToF as illustrated in FIG. 1 may be incorporated in an Evolved Universal Transmission Radio Access Network (E-UTRAN) positioning protocol system as an ancillary component or a main component of a positioning protocol. At time 10 t1 (ToD) 102.1, Station A 102 sends a packet M1 106 to Station B 104. The packet M1 106 arrives at time t2 (ToA) 104.1 at Station B 104. Station B 104 transmits a response packet, which may be an acknowledgement (ACK) 108 at time t3 (ToD) 104.2. The ACK 108 is received by Station A 102 at time t4 (ToA) 102.2. Station B 104 may transmit a 15 packet M2 110 including times t2 104.1 and t3 104.2 at a time 104.3, and Station A 102 may receive packet M2 at a time 102.3. Station A may transmit an ACK 112 to Station B 104 after receiving and in response to packet M2 110, and Station B 104 may receive the ACK 112 at a time 104.4. In some embodiments, Station A 102 may be a UE and/or a SUPL Enabled Terminal (SET). In some embodiments, Station B 104 may be a UE and/or a 20 SET. In some embodiments, Station A 102 may transmit a packet M3 (not shown) including times t1 102.1 and t4 102.2 to Station B 104, and Station B 104 may transmit an ACK (not shown) to Station A 102 in response to receiving packet M3.

ToF may be calculated using Equation 1 as follows:

$$25 \quad \text{ToF} = \frac{(t4 - t1) - (t3 - t2)}{2} \quad [1]$$

The total roundtrip time is (t4 –t1), and the processing time at Station B 104 is (t3-t2). Subtracting the latter from the former provides the total time over the air for a transmission from Station A 102 to Station B 104 and from Station B 104 to Station A 30 102. The ToF between Station A 102 and Station B 104 is obtained by dividing the total time over the air by two. Multiplying ToF by the speed of light provides the distance

between the two stations. Station A 102 calculates the time of departure  $t_1$  102.1, and Station B 104 calculates the time of arrival,  $t_2$  104.1.

In some embodiments, Station A 102 may calculate ToF between Station A 102 and Station B 104 using times  $t_1$  102.1,  $t_2$  104.1,  $t_3$  104.2, and  $t_4$  102.2. In some  
5 embodiments, Station A 102 may calculate a  $t_1$  error value, a  $t_2$  error value, a  $t_3$  error value, and a  $t_4$  error value. In some embodiments, Station B 104 may calculate ToF between Station A 102 and Station B 104 using times  $t_1$  102.1,  $t_2$  104.1,  $t_3$  104.2, and  $t_4$  102.2. In some embodiments, Station B 102 may calculate a  $t_1$  error value, a  $t_2$  error value, a  $t_3$  error value, and a  $t_4$  error value. In some embodiments, Station A may  
10 calculate a ToF error value. In some embodiments, Station B may calculate a ToF error value.

In some embodiments, Station B 104 may transmit a response packet after about 30 to 40 ms at time  $t_3$  104.2, of which packet may be an ACK 108 as illustrated in FIG. 1. Station B 104 calculates the time  $t_3$  104.2 and a  $t_3$  error value. Station A 102 calculates  
15 the time of arrival  $t_4$  102.2 of the ACK 108 and a  $t_4$  error value. In some embodiments after  $t_2$  104.1 and  $t_3$  104.2 and/or respective error values are transmitted to Station A 102, Station A 102 may calculate the ToF and the ToF error value between Station A 102 and Station B 104. In some embodiments after  $t_1$  102.1 and  $t_4$  102.2 and/or respective error values are transmitted to Station B 104, Station B 104 may calculate the ToF and ToF  
20 error value between Station A 102 and Station B 104. In some embodiments, Station A and/or Station B may transmit times  $t_1$ ,  $t_2$ ,  $t_3$ , and  $t_4$  and the respective error values to Station C 103, which may calculate ToF and ToF error value between Station A 102 and Station B 104 or may transmit the times and respective error values to a server (e.g. a location server) or another station coupled to Station C for calculation of the ToF and the  
25 ToF error value between Station A 102 and Station B 104. In some embodiments, after the ToF is calculated, the range/distance of a station from one or more APs may be calculated by multiplying the ToF by the speed of light. An error associated with a range/distance may be calculated from error values associated with the departure and arrival times used to calculate the ToF.

FIG. 2 illustrates a Location Measurement Unit (LMU) Location Services (LCS) Protocol (LLP) system 200 in which time of flight positioning may be added.

Except as otherwise described herein, aspects of the LPP system 200 may be similar to those described in 3GPP Specification TS 36.355, version 12.3.0, January 5, 2015 or OMA specifications for LPPe. The LPP system 200 may be compatible with

3GPP Rel-12, LLP, which supports Observed Time Difference Of Arrival (OTDOA), Assisted-GNSS, and Enhanced Cell ID (E-CellID or E-CID) positioning processes. In some embodiments, the LPP system 200 may use point-to-point data shared with a location server 206 and a target device 208 for LPP positioning of the target device 208.

5 Position-related measurements 214 are obtained using one or more reference sources, for example, GNSS reference sources 202 and eNB reference sources 204, as illustrated in FIG. 2.

The target device 208, which may be a UE or a SET, may receive assistance data 212 from the location server 206. It will be understood that communication between the target device 208 and the location server 206 may take place over a number of network components including, but not limited to, an eNB. The assistance data 212 may include location data from one or more reference sources, for example, GNSS Reference Sources 202 or eNB Reference Sources 204 that may respectively transmit GNSS signals 218 and LTE Radio Signals to the target device 208. The GNSS reference sources 202 may be assisted GNSS (A-GNSS). The eNB reference sources 204 may, or may not, include the eNB that provides communication between the target device 208 and the location server 206.

The target device 208 may determine measurements 214 based on the assistance data 212 and the GNSS signals 218 or LTE radio signals 210. The measurements 214 may include information that may serve as a basis for determining a 2-D or 3-D location of the target device 208. In other embodiments, the measurements 214 may include the 2-D or 3-D location of the target device 208. The target device 208 may transmit the measurements 214 to the location server 206.

When the measurements 214 serve as a basis for determining location, the location server 206 may calculate a location of the target device 208 based on the measurements 214. When the measurements 214 indicate the location, the location server 206 may simply determine the location based on the indication in the measurements 214.

A positioning process in which the measurements 214, which serve as a basis for determining location, are transmitted to the location server 206 for calculation of the location of the target device 208 may be referred to as a device (for example UE/SET) - assisted positioning process. A positioning process in which the target device 208 determines its location may be referred to as a device-based positioning process. A positioning process in which the location of the target device 208 is performed by the location server 206 is referred to as device-assisted positioning process.

The location server 206 may include one or more logical entities Evolved Serving Mobile Location Center (E-SMLC) 206.2 and/or Secure User Plane Location (SUPL) Location Platform (SLP) 206.1. Generally, SLP 206.1 operates over a user-plane and E-SMLC operates over a control plane.

FIG. 3 illustrates a positioning system 300 for positioning a target device 308 using one or more APs 304 in a WLAN in accordance with some embodiments. The components of the positioning system 300 may be similar to like-named components described above with respect to LPP system 200 unless otherwise noted. In some embodiments, the positioning system 300 may be considered to be an LPP or LPPE positioning system that is enhanced to support WLAN ToF positioning processes as described. In some embodiments, the positioning system 300 may be considered to be an LPP annex (LPPa) positioning system that is enhanced to support WLAN ToF positioning processes as described. In embodiments where positioning system 300 is an LPP or LPPE positioning system, measurements 314 and assistance data 312 may be communicated between target device 308 and location server 306 through, but transparent to, eNB 316. In embodiments where positioning system 300 is an LPPa positioning system, measurements 314 and assistance data 312 may be communicated between target device 308 and location server 306 via eNB 316 using radio resource control (RRC) and then communicated between eNB 316 and location server 306 using RRC. LPPa may be as defined in 3GPP Specification Release-12 version 12.1.0.

The target device 308 may transmit and receive signals 304.1 from the APs 304 and use resulting ToF information to obtain positioning data to calculate location of the target device 308. In some embodiments, the target device 308 may obtain ToF information, e.g., ToF and ToF error values, as described above with respect to Figure 1, with the target device 308 corresponding to Station A of FIG. 1 and individual APs of the APs 304 corresponding to Station B. In some embodiments, the target device 308 may obtain ToF information with respect to a plurality of the APs 304, for example, three or more APs.

In some embodiments, the target device 308 may transmit the ToF information for the APs 304 to a location server 306 in measurements 314. In some embodiments, the measurements 314 may also include measurements based on assistance data 312, GNSS signals 318, or LTE radio signals 310 as described above with respect to FIG. 2.

In some embodiments, the target device 308 may calculate its range/location from one or more APs using the ToF information by multiplying the ToF by the speed of

light. The target device 308 may transmit the range/location to the location server 306 via the eNB 316. The target device 308 may calculate an error associated with the range/location and transmit the error to location server 306 via eNB 316.

5 In some embodiments, the assistance data may include data related the APs 304 in addition to, or as an alternative to, data related to GNSS reference sources 302 or eNB reference sources 304.

For ToF the assistance data 312 may be identifiers of WLAN APs 304, e.g., service set identifier (SSID), basic service set identification (BSSID), homogenous extended service set identifier (HESSID), hot spot (HS) 2.0 realm/domain, and the like, and absolute coordinates of these APs 304. WLAN AP identifiers may be needed for the target device 308 to know which APs 304 it may use for ToF. Absolute AP coordinates may be needed for target device 308-based positioning method in which is target device 308 estimates its coordinates (location) because ToF by itself may only be used to estimate the target device location relative to APs 304. Assistance data 312 may be optional, as all this information may be obtained by the target device 308 via WLAN. ToF may be self-contained, in which case LPP/LPPE enhancements may be limited to target device 308 capabilities, so that the target device 308 may let the location server 306 know that target device 308 supports ToF, and the location server 306 may request positioning information based on a particular method supported by target device 308. Additionally, LPP/LPPE may be enhanced to provide the assistance data 312 to the target device 308.

In some embodiments, target device 308 may calculate its location using data transmitted in signals from one or more GNSS reference sources 302, one or more eNB reference sources 304, and/or one or more APs 304 and the measurements 314 may include an indication of the location of target device 308. In these device-based positioning processes, the location server 306 may determine the location of the target device 308 by referencing the indication in the measurements 314. In device-assisted positioning processes, the measurements 314 may include data that serves as a basis for determining a location of the target device 308. In these device-assisted positioning processes, the location server 306 may calculate the location based on the measurements 314.

In some embodiments, a device-based positioning process may be supported by an LPP Provide Assistance (LPA) process. An LPA process may include enhancing the assistance data 312 to include information relevant for determining location with respect to the APs 304. This information, which may be referred to as LPA location information,

may include, for example, identifiers for the WLAN APs 304, such as SSID, BSSID, HESSID, HS 2.0 realm/domain, and the like, and absolute coordinates of these APs 304, as well as synchronization information that may be used to determine location relevant to the APs 304 based on the ToF information. In some embodiments, the LPA location  
5 information may be included in existing information elements (IEs) or by adding new IEs. For example, in an LPPE positioning system enhanced to support a WLAN ToF positioning process, an OMA-LPPE-WLAN-DataSet IE may be configured to carry the LPA location information. Messages within LPP positioning systems may be enhanced in similar ways.

10 In some embodiments, a device-assisted positioning process may also be supported by an LPA process. In some embodiments, the Target Device 308 may send ToF information to the location server 306. The ToF information may include, for example, times t1, t2, t3, t4 or any other information derived from the times, including ToF, error estimation of ToF, location/range (from multiplying ToF by the speed of light),  
15 and error associated with location/range. Location/range may be any distance measurement such as meters or feet. In some embodiments, the UE may determine ToF information including, for example, times t1, t2, t3, t4, and/or other information derived from the times, and send the ToF information to the location server 306 in the measurements 314. For some embodiments in UE-based and UE-assisted processes, LPP  
20 Request/Provide Capability messages may be enhanced to indicate WLAN ToF support.

In various embodiments, target device 308 or the location server 306 may initiate positioning of target device 308. In some embodiments, the location server 306 may initiate positioning of target device 308 in response to a request from another apparatus.

FIG. 4 illustrates a UE 400 with UE circuitry 402 with a first radio 404, a second  
25 radio 406, and positioning circuitry 408, to determine ToF information, in accordance with various embodiments. In some embodiments, the UE circuitry 402 may be a UE 400, or it may be incorporated into or otherwise be part of a UE 400.

The first radio circuitry 404 may include receive circuitry 404.1 and/or transmit circuitry 404.2. The receive circuitry 404.1 and transmit circuitry 404.2 may be referred to  
30 or combined as transceiver circuitry 404.3. In some embodiments, the second radio circuitry 406 may include receive circuitry 406.1 and/or transmit circuitry 406.2. The receive circuitry 406.1 and transmit circuitry 406.2 may be referred to or combined as transceiver circuitry 406.3. In some embodiments, the first radio circuitry 404 and second radio circuitry 406 may be coupled with positioning circuitry 408. In some embodiments,

the first radio circuitry 404 and second radio circuitry 406 may be elements or modules of transceiver circuitry 404.3 and 406.3, respectively.

The UE circuitry 402 may be coupled with one or more antenna elements of one or more antennas 410. The UE circuitry 402 and/or the components of the UE circuitry 402 (for example, first radio 404, second radio 406, or positioning circuitry 408) may be configured to perform operations or methods similar to those described elsewhere in this disclosure. In some embodiments, the first radio circuitry 404 may be configured to transmit or receive one or more wireless signals via an EUTRAN via the antennas 410. In some embodiments, the second radio circuitry 406 may be configured to transmit or receive one or more wireless signals via a WLAN via the antennas 410. In some embodiments, the positioning circuitry 408 may be configured to determine ToF information based on the one or more wireless signals transmitted and/or received by the second radio circuitry 406 via the WLAN using antennas 410. In some embodiments, first radio 404 and second radio 406 may be combined into a single transceiver circuitry coupled to positioning circuitry 408, where positioning circuitry 408 may receive and transmit communications over an EUTRAN and/or a WLAN via antennas 410.

In some embodiments UE 400 may include a processor 420, a memory 430, and other components 440. In some embodiments, positioning circuitry 408, first radio 404, and second radio 406 may use processor 420 and memory 430 to execute modules and/or control circuit elements, as described in embodiments herein. Components 400 may include input/output components, cameras, screens, sensors, and similar components.

FIG. 5 illustrates a location server 502 coupled 580 to an eNB 550 for positioning of a UE, in accordance with some embodiments. In embodiments using LPP or LPPe, location server 502 may communicate directly with a target device via the eNB 550 as a pass through conduit/component of the wireless network, where the location server 502 views the eNB as a passive transport component of the network. In embodiments using LPPa, location server 502 may communicate via RRC with eNB 550 and eNB 550 may communicate with a target device to transmit and receive information between the location server 502 and a target device, where the location server 502 views the eNB 550 as an active component. In some embodiments, location server 502 may include control circuitry 504, receive circuitry 506, transmit circuitry 508, processor 510, memory 512, network port 514, components 516, and positioning circuitry 518, coupled by bus 520. In some embodiments, bus 520 may comprise one or more buses. In some embodiments, receive circuitry 506 and transmit circuitry 508 may be combined into transceiver

circuitry. In some embodiments, components 516 may include any number of components that may be included in location server 502, as a person of ordinary skill in the art would readily understand.

5 In some embodiments, eNB 550 may include control circuitry 552, receive circuitry 554, transmit circuitry 556, processor 558, memory 560, network port 562, and components 564, coupled by bus 570. In some embodiments, bus 570 may comprise one or more buses. In some embodiments, receive circuitry 554 and transmit circuitry 556 may be combined to transceiver circuitry. In some embodiments, components 564 may include any number of components that may be included in eNB 550, as a person of ordinary skill  
10 in the art would readily understand. In some embodiments, eNB may be couple to antennas 580. In some embodiments, location server 502 and eNB 550 may be coupled 580 by a wireless and/or wired network or by one or more parallel and/or serial connections.

In some embodiments, eNB 550 may receive over antennas 580 using receive  
15 circuitry 554 indications of ToF between a UE of an EUTRAN and one or more APs of a WLAN. In some embodiments, eNB 550 may transmit using transmit circuitry 556 via coupling 580 to receive circuitry 506 of location server 502 the indications of ToF between the UE and APs. In some embodiments, location server 502 may receive via network port 514 using receive circuitry 506 coordinates of the APs. In some embodiments, location  
20 server 502 may receive via coupling 580 from eNB 550 coordinates of the APs received over antennas 580 from the UE. In some embodiments, positioning circuitry 518 may perform ToF calculations using the indications of ToF. In some embodiments, the location server 502 may use indications of ToF and coordinates of the APs to determine a geographic, physical, and/or locational position of the UE. In some embodiments, the  
25 indications of ToF between the UE and one or more APs may be based on signals transmitted to and/or received from the APs. The location server 502 may be to perform operations similar to those described elsewhere in this disclosure.

In some embodiments, circuitry and/or modules of location server 502 may use processor 510 and memory 512 to execute the logic of such circuitry and/or modules, as  
30 described in embodiments herein. In some embodiments, circuitry and/or modules of eNB 550 may use processor 558 and memory 560 to execute the logic of such circuitry and/or modules, as described in embodiments herein.

FIG. 6 illustrates a process 600 of positioning that may be implemented in a user equipment (UE), in accordance with some embodiments. In some embodiments, the

process 600, or various aspects of the process 600, may be implemented in the UE 400 of FIG. 4.

In some embodiments, the process 600 may include, at 601, receiving identifiers of one or more APs. The identifiers may include SSID, BSSID, HESSID, HS 2.0

5 realm/domain, and the like, and absolute coordinates of APs.

In some embodiments, the process 600 may include, at 602, transmitting one or more wireless signals to one or more APs. In some embodiments, the transmitting, at 602, may be initiated by positioning circuitry 408 formulating or otherwise constructing the signals using processor 420 and memory 430. The positioning circuitry 408 may then

10 control the second radio 406 to cause transmission of the signals by the antennas 410 using processor 420 and memory 430. In some embodiments, the process 600, at 602, may include transmitting, by the second radio 406 of via a transceiver circuitry 406.3 or transmit circuitry 406.2, one or more signals to APs of a WLAN.

In some embodiments, the process 600 further may include, at 604, receiving one  
15 or more wireless signals from one or more APs. In some embodiments, the receiving, at 604, may be initiated by positioning circuitry 408 by controlling second radio 406 to receive the signals via antennas 410 using processor 420 and memory 430. The positioning circuitry 408 may then process the signals using processor 420 and memory 430. In some embodiments, the process 600, at 604 may be receiving, by the second radio  
20 406 via the transceiver circuitry 406.3 or receive circuitry 406.1 of the second radio 406 of the UE, one or more signals from the one or more APs of the WLAN.

In some embodiments, the process 600 further may include, at 606, performing one or more time-of-flight (ToF) measurements based on the one or more wireless signals sent or received to or from the WLAN AP. In some embodiments, the ToF measurements  
25 may be performed by the positioning circuitry 408 using processor 420 and memory 430. In some embodiments, the process 600, at 606, may include calculating, by positioning circuitry 408 coupled to the second radio 406, ToF between the UE and the one or more APs based on the one or more signals transmitted by the UE to the one or more APs and the one or more signals received by the UE from the one or more APs.

30 In some embodiments, the process 600 further may include, at 608, receiving, by the second radio 406 via the transceiver circuitry 406.3 or receive circuitry 406.1, coordinates of the one or more APs. In some embodiments, the coordinates may be received from at least one of a computing apparatus coupled to the UE circuitry 402 via the first radio 404 over an EUTRAN or from the one or more APs via the second radio

406. In some embodiments, the first radio 404 and/or the second radio 406 may use processor 420 and memory 430 to receive the coordinates.

In some embodiments, the process 600 further may include, at 610, calculating, by the positioning circuitry 408 of the UE, the location of the UE based on the ToF  
5 between the UE and the one or more APs and the coordinates of the one or more APs. Positioning circuitry 408 may use processor 420 and memory 430 to perform calculations of the location of the UE.

In some embodiments, the process 600 further may include, at 612, transmitting, by the first radio 404 via the transceiver circuitry 404.3 or transmit circuitry 404.2, the  
10 location of the UE to a computing apparatus. The computing apparatus may be coupled to the EUTRAN. In some embodiments, the positioning circuitry 408 may initiate and formulate framing to transmit the location using processor 420 and memory 430 over the antennas 410 via the first radio 404.

FIG. 7 illustrates a process 700 of positioning that may be implemented in a  
15 location server, in accordance with some embodiments. In some embodiments, the location server 502 of FIG. 5 may be to perform one or more processes such as the process of FIG. 7.

In some embodiments, the process 700 may include, at 701, transmitting, by transceiver or transmit circuitry of a location server via an eNB, WLAN AP identifiers to a  
20 user equipment (UE) in an evolved universal terrestrial radio access network (EUTRAN). The identifiers may include SSID, BSSID, HESSID, HS 2.0 realm/domain, and the like, and absolute coordinates of APs.

In some embodiments, the process 700 may include, at 702, receiving, by transceiver or receive circuitry 506 of a location server 502 via an eNB 550, indications  
25 related to ToF measurements between a UE in a EUTRAN and one or more APs in a WLAN. In embodiments using LPP or LPPe, location server 502 may communicate directly with a target device via the eNB 550 as a pass through conduit/component of the wireless network, where the location server 502 views the eNB as a passive transport component of the network. In embodiments using LPPa, location server 502 may  
30 communicate via RRC with eNB 550 and eNB 550 may communicate with a target device to transmit and receive information between the location server 502 and a target device, where the location server 502 views the eNB 550 as an active component. In some embodiments, the eNB 550 receives the ToF measurements using receive circuitry 554 via antennas 580 coupled thereto. In some embodiments, the control circuitry 552 may control

receive circuitry 554 to receive the ToF measurements using processor 558 and memory 562. In some embodiments, control circuitry 552 may control transmit circuitry 556 to transmit the ToF measurements to location server 502 via coupling 580. Control circuitry 504 and/or positioning circuitry 518 may control receive circuitry 506 to receive the ToF measurements using processor 510 and memory 512. In some embodiments, positioning circuitry 518 may initiate a request for the ToF measurements and transmit via coupling 580 to eNB 550 the request. In some embodiments, positioning circuitry 518 may formulate the request in one or more data transmission packets and transmit to the UE the request via the eNB 550 and antennas 580 coupled thereto.

In some embodiments, the process 700 further may include, at 704, receiving, by the transceiver or receive circuitry 506 of the location server 502, coordinates of the one or more APs in the WLAN and to store the coordinates in a database of WLAN APs of the location server when the coordinates are missing or need to be updated. In some embodiments, the coordinates may be received via from the UE via the eNB. In some embodiments, the coordinates may be received via network port 514 from a computing apparatus coupled thereto. In some embodiments, positioning circuitry 518 may initiate and control transmission of the request to receive coordinates using processor 510 and memory 512. In some embodiments, positioning circuitry 518 may control receive circuitry to receive the coordinates via network port 514 or via eNB coupled via 580 to location server 502.

In some embodiments, the process 700 further may include, at 706, calculating, by positioning circuitry 518 of the location server 502, the location of the UE based on the indications related to the ToF measurements between the UE and the one or more APs and the coordinates of the one or more APs. In some embodiments, the positioning circuitry 518 may use processor 510 and memory 512 to calculate the location of the UE.

In some embodiments, the process 700 further may include, at 708, transmitting, by the transceiver or transmit circuitry 508 of the location server, the location of the UE to a computing apparatus coupled to the EUTRAN. The location server 502 may transmit the location of the UE via the eNB 550 coupled 580 to the UE. In some embodiments, the positioning circuitry 518 or the control circuitry 504 may initiate transmitting the location of the UE and may formulate one or more data packets containing the location and may control the transmit circuitry 508 to transmit via coupling 580 to eNB 550, which may transmit via transmit circuitry 556 over antennas 580 to the computing apparatus.

Embodiments described herein may be implemented into a system and/or a device using any suitably configured hardware and/or software. FIG. 8 illustrates, for one embodiment, an example system 800 comprising radio frequency (RF) circuitry 814, baseband circuitry 812, application circuitry 810, memory/storage 816, display 802, camera 804, sensor 806, and input/output (I/O) interface 808, coupled with each other at least as shown. Example system 800 may be a user equipment or a location server of a wireless system such as an LTE system.

The application circuitry 810 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) may include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors may be coupled with memory/storage and configured to execute instructions stored in the memory/storage to enable various applications and/or operating systems running on the system.

The baseband circuitry 812 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) may include a baseband processor. The baseband circuitry may handle various radio control functions that enables communication with one or more radio networks via the RF circuitry. The radio control functions may include, but are not limited to, signal modulation, encoding, decoding, radio frequency shifting, etc. In some embodiments, the baseband circuitry may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry may support communication with an evolved universal terrestrial radio access network (EUTRAN) and/or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), a wireless personal area network (WPAN). Embodiments in which the baseband circuitry is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

In various embodiments, baseband circuitry 812 may include circuitry to operate with signals that are not strictly considered as being in a baseband frequency. For example, in some embodiments, baseband circuitry may include circuitry to operate with signals having an intermediate frequency, which is between a baseband frequency and a radio frequency.

In various embodiments, RF circuitry 814 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium.

In various embodiments, the RF circuitry may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network.

In various embodiments, RF circuitry 814 may include circuitry to operate with signals that are not strictly considered as being in a radio frequency. For example, in some  
5     embodiments, RF circuitry 814 may include circuitry to operate with signals having an intermediate frequency, which is between a baseband frequency and a radio frequency.

In various embodiments, first radio circuitry 404, second radio circuitry 406, transmit circuitry 404.2, 406.2, positioning circuitry 408, receive circuitry 404.1, 406.1, and/or transceiver circuitry 404.3, 406.3 discussed or described herein may be embodied  
10    in whole or in part in one or more of the RF circuitry 814, the baseband circuitry 812, and/or the application circuitry 810.

In various embodiments, transmit circuitry 506, positioning circuitry 508, receive circuitry 504, and/or transceiver circuitry discussed or described herein may be embodied in whole or in part in one or more of the RF circuitry 814, the baseband circuitry 812,  
15    and/or the application circuitry 810.

In some embodiments, some or all of the constituent components of the baseband circuitry 812, the application circuitry 810, and/or the memory/storage 816 may be implemented together on a system on a chip (SOC).

Memory/storage 816 may be used to load and store data and/or instructions, for  
20    example, for system. Memory/storage 816 for one embodiment may include any combination of suitable volatile memory (e.g., dynamic random access memory (DRAM)) and/or non-volatile memory (e.g., Flash memory).

In various embodiments, the I/O interface 808 may include one or more user interfaces designed to enable user interaction with the system and/or peripheral component  
25    interfaces designed to enable peripheral component interaction with the system. User interfaces may include, but are not limited to a physical keyboard or keypad, a touchpad, a speaker, a microphone, etc. Peripheral component interfaces may include, but are not limited to, a non-volatile memory port, a universal serial bus (USB) port, an audio jack, and a power supply interface.

30    In various embodiments sensor 806 may include one or more sensing devices to determine environmental conditions and/or location information related to the system. In some embodiments, the sensors 806 may include, but are not limited to, a gyro sensor, an accelerometer, a proximity sensor, an ambient light sensor, and a positioning unit. The positioning unit may also be part of, or interact with, the baseband circuitry and/or RF

circuitry to communicate with components of a positioning network, e.g., a global positioning system (GPS) satellite.

In various embodiments, the display 802 may include a display (e.g., a liquid crystal display, a touch screen display, etc.).

5 In various embodiments, the system 800 may be a mobile computing device such as, but not limited to, a laptop computing device, a tablet computing device, a netbook, an ultrabook, a smartphone, etc. In various embodiments, system may have more or less components, and/or different architectures.

### EXAMPLES

10 According to various embodiments, the present disclosure describes control channel scheduling for wireless communications in wireless communication devices, systems, and methods.

In Example 1 of an apparatus to be implemented in a location server, the apparatus may comprise: storage circuitry to store instructions; and processing circuitry,  
15 coupled to the storage circuitry, to execute the instructions to: determine coordinates of one or more access points (APs) in a Wireless Local Area Network (WLAN), the coordinates retrieved from a memory coupled to the processing circuitry or received via a transceiver, coupled to the processing circuitry, of the location server; determine a Time of Flight (ToF) between a user equipment (UE) in an evolved universal terrestrial radio  
20 access network (EUTRAN) and an AP of the one or more APs based on indications of the ToF or indications of a time of arrival (ToA) and a time of departure (ToD) for a transmission between the UE and the AP; calculate a location of the UE based on the ToF and the coordinates of the one or more APs; and transmit the location of the UE via the transceiver of the location server to a computing apparatus coupled to the location server  
25 by a network.

Example 2 may include the apparatus of Example 1 and other examples herein, wherein the processing circuitry further is to determine a range between the UE and the AP.

Example 3 may include the apparatus of Example 1 and other examples herein,  
30 wherein the coordinates of the one or more APs are received from a second computing apparatus coupled to the transceiver of the location server by the network, and the processing circuitry is further to transmit via the transceiver the coordinates of one or more APs to the UE.

Example 4 may include the apparatus of Example 1 and other examples herein, wherein processing circuitry is to receive and transmit signals via the transceiver over a user plane of the EUTRAN.

Example 5 may include the apparatus of Example 1 and other examples herein,  
5 wherein the one or more APs includes at least three APs.

Example 6 may include the apparatus of Example 1 and other examples herein, wherein the processing circuitry is further to receive via the transceiver a request for the location of the UE.

Example 7 may include the apparatus of Example 1 and other examples herein,  
10 wherein the processing circuitry further is to receive an estimated error of ToF between the UE and the one or more APs, or an estimated error of ToA and ToD data.

Example 8 may include the apparatus of Example 7 and other examples herein, wherein the processing circuitry is further to calculate an estimated error of the location of the UE based on the estimated error of ToF between the UE and the one or more APs, or  
15 the estimated error of ToA and ToD data.

Example 9 may include the apparatus of Example 8 and other examples herein, wherein the processing circuitry is further to transmit via the transceiver AP assistance data to the UE, wherein the assistance data includes AP identifiers and a location.

Example 10 of one or more non-transitory computer readable media may  
20 comprise instructions to cause a computing apparatus, in response to execution of the instructions by a processor of the computing apparatus, to: transmit, over a Wireless Local Area Network (WLAN), first transmissions to one or more Access Points (APs), wherein the first transmissions have a time of departure (ToD) at the computing apparatus; receive, over the WLAN, response transmissions from the one or more APs, wherein the response  
25 transmissions include acknowledgement of the first transmissions and have a time of arrival (ToA) at the computing apparatus; receive, over the WLAN, data packets from the one or more APs, wherein the data packets include, for the one or more APs, ToA of the first transmissions and ToD of the response transmissions; and transmit, to a location server via an evolved node B (eNB) of an evolved universal terrestrial radio access  
30 network (EUTRAN), the ToD at the computing apparatus of the first transmissions, the ToA at the computing apparatus of the response transmissions, the ToA of the first transmissions of the one or more APs, and the ToD of the response transmissions of the one or more APs.

Example 11 may include the subject matter of Example 10 and other examples herein, wherein the instructions are further to cause the computing apparatus to: receive coordinates of the one or more APs of the WLAN from the location server via the eNB or from the one or more APs.

5           Example 12 may include the subject matter of Example 10 and other examples herein, wherein the instructions are further to cause the computing apparatus to: receive from the EUTRAN location information of the computing apparatus.

Example 13 may include the subject matter of Example 10 and other examples herein, wherein the one or more APs includes at least three APs.

10           Example 14 may include the subject matter of Example 10 and other examples herein, wherein the instructions are further to cause the computing apparatus to: communicate with the EUTRAN over a user plane.

Example 15 may include the subject matter of Example 10 and other examples herein, wherein the instructions are further to cause the computing apparatus to: receive a  
15           request from the EUTRAN for the computing apparatus location.

Example 16 may include the subject matter of Example 10 and other examples herein, wherein the instructions are further to cause the computing apparatus to: obtain estimated error of the ToD at the computing apparatus of the first transmissions, the ToA at the computing apparatus of the response transmissions, the ToA of the first  
20           transmissions of the one or more APs, and the ToD of the response transmissions of the one or more APs; and transmit the estimated error to the EUTRAN.

Example 17 may include the subject matter of Example 10 and other examples herein, wherein the response transmissions include acknowledgement of the first transmissions.

25           In Example 18 of an apparatus to be implemented in a location server, the apparatus may comprise: storage circuitry to store instructions; and processing circuitry, coupled to the storage circuitry, to execute instructions to: determine coordinates of one or more access points (APs) in a Wireless Local Area Network (WLAN), the coordinates retrieved from a memory coupled to the processing circuitry or received via a transceiver,  
30           coupled to the processing circuitry, of the location server; transmit the coordinates via the transceiver to a user equipment (UE) in an evolved universal terrestrial radio access network (EUTRAN); and receive a location of the UE from the UE.

Example 19 may include the subject matter of Example 18 and other examples herein, wherein the process circuitry further is to transmit via the transceiver of the

location server the location of the UE to at least one of the EUTRAN, a second UE, or a computing apparatus coupled to the location server by a network.

Example 20 may include the subject matter of Example 18 and other examples herein, wherein the coordinates of the one or more APs are received from a computing  
5 apparatus coupled to the location server by a network.

Example 21 may include the subject matter of Example 18 and other examples herein, wherein location server is to receive from and transmit to the UE over a user plane of the EUTRAN.

Example 22 may include the subject matter of Example 18 and other examples  
10 herein, wherein the one or more APs includes at least three APs.

Example 23 may include the subject matter of Example 18 and other examples herein, wherein the processing circuitry further is to receive a request via the transceiver of the location server for the location of the UE.

Example 24 may include the subject matter of Example 18 and other examples  
15 herein, wherein the processing circuitry further is to transmit via the transceiver of the location server a request for the location of the UE to the UE.

Example 25 may include the subject matter of Example 18 and other examples herein, wherein the processing circuitry is further to receive from the UE via the transceiver of the location server estimated error of the location of the UE.

20 In Example 26 of an apparatus to be implemented in a user equipment (UE) in an evolved universal terrestrial radio access network (EUTRAN), the apparatus may comprise: radio frequency (RF) circuitry to: receive, via a transceiver of the UE, coordinates of one or more access points (APs) in a Wireless Local Area Network (WLAN); and receive, via the transceiver, a time of arrival (ToA) of a first transmission  
25 from the UE to an AP of the one or more APs and a time of departure (ToD) of a second transmission from the AP of the one or more APs to the UE; and positioning circuitry, coupled to the RF circuitry, to calculate a location of the UE based on a ToD and the ToA of the first transmission, a ToA and the ToD of the second transmission and the coordinates of the one or more APs, wherein the RF circuitry is further to transmit the  
30 location of the UE via the transceiver to a computing apparatus coupled to the EUTRAN.

Example 27 may include the subject matter of Example 26 and other examples herein, wherein the one or more APs includes at least three APs.

Example 28 may include the subject matter of Example 26 and other examples herein, wherein the RF circuitry is to receive a request via the transceiver from the EUTRAN for the location of the UE.

5 Example 29 may include the subject matter of Example 26 and other examples herein, wherein the RF circuitry is to communicate via the transceiver with the EUTRAN over a user plane.

Example 30 may include the subject matter of Example 26 and other examples herein, wherein positioning circuitry is to calculate an estimated error of the UE location and to transmit via the transceiver the estimated error to the computing apparatus coupled  
10 to the EUTRAN.

In Example 31 of a location server, the location server may comprise:  
communicate means for communicating with a user equipment (UE) in an evolved  
universal terrestrial radio access network (EUTRAN); receive means for receiving  
coordinates of one or more access points (APs) in a Local Area Network (WLAN); receive  
15 means for receiving from the UE at least one of (i) Time of Flight (ToF) between the UE  
and the one or more APs or (ii) time of arrival (ToA) and time of departure (ToD) data  
between the one or more APs and the UE; calculate means for calculating a location of the  
UE based at least in part on at least one of (i) the ToF between the UE and the one or more  
APs or (ii) the the ToA and ToD data between the one or more APs and the UE; and  
20 transmit means for transmitting to the UE the location of the UE.

Example 32 may include the subject matter of Example 31 and other examples herein, wherein the receive means for receiving the coordinates of one or more APs further comprises: receive means for receiving the coordinates from the UE.

Example 33 may include the subject matter of Example 31 and other examples  
25 herein, wherein the location server further may comprise: transmit means for transmitting  
to the UE the coordinates of one or more APs.

Example 34 may include the subject matter of Example 31 and other examples herein, wherein the communication means, receive means, and transmit means uses a user  
plane of the EUTRAN.

30 Example 35 may include the subject matter of Example 31 and other examples herein, wherein the one or more APs includes at least three APs.

Example 36 may include the subject matter of Example 31 and other examples herein, wherein the location server further may comprise: receive means for receiving a  
request for the location of the UE.

Example 37 may include the subject matter of Example 31 and other examples herein, wherein the location server further may comprise: receive means for receiving from the UE at least one of (i) estimated error of ToF between the UE and the one or more APs or (ii) estimated error of ToA and ToD data between the UE and the one or more APs.

5           The location server of claim 37, further comprising:

Example 38 may include the subject matter of Example 37 and other examples herein, wherein the location server further may comprise: calculate means for calculating an estimated error of the location of the UE based at least in part on at least one of (i) the estimated error of ToFs between the UE and the one or more APs or (ii) the estimated error of ToA and ToD data between the UE and the one or more APs.

Example 39 may include the subject matter of Example 38 and other examples herein, wherein the location server further may comprise: transmit means for transmitting the estimated error of the location of the UE to the UE or to a second UE.

In Example 40 of one or more non-transitory computer readable media, the media may comprise instructions to cause a location server, in response to execution of the instructions by a processor of the location server, to: receive, from an evolved universal terrestrial radio access network (EUTRAN) or a computing apparatus coupled to the location server by a network, coordinates of one or more access points (APs) in a Wireless Local Area Network (WLAN); transmit, to a user equipment (UE) in the EUTRAN, the coordinates of the one or more APs; and receive, from the UE, a location of the UE.

The non-transitory computer readable media of claim 40, wherein the instructions are further to cause the location server, to:

Example 41 may include the subject matter of Example 40 and other examples herein, wherein the instructions are further to cause the location server, to: transmit, to at least one of the EUTRAN, a second UE, the computing apparatus, or a second computing apparatus coupled to the location server by the network, the location of the UE.

Example 42 may include the subject matter of Example 40 and other examples herein, wherein the instructions are further to cause the location server, to: transmit to and receive from the UE over a user plane of the EUTRAN.

Example 43 may include the subject matter of Example 40 and other examples herein, wherein the instructions are further to cause the location server, to: receive a request for the location of the UE.

Example 44 may include the subject matter of Example 40 and other examples herein, wherein the one or more APs includes at least three APs.

Example 45 may include the subject matter of Example 40 and other examples herein, wherein the instructions are further to cause the location server, to: receive from the UE estimated error of the location of the UE.

5 Example 46 may include the subject matter of Example 40 and other examples herein, wherein the instructions are further to cause the location server, to: transmit the estimated error of the location of the UE to at least one of the EUTRAN, a second UE, the computing apparatus, or a second computing apparatus coupled to the location server by the network, the location of the UE.

10 In Example 47 of a location server, the location server may comprise: communicate means for communicating with a user equipment (UE) in an evolved universal terrestrial radio access network (EUTRAN); receive means for receiving coordinates of one or more access points (APs) in a Wireless Local Area Network (WLAN) from the EUTRAN or a computing apparatus coupled to the location server by a network; receive means for receiving from the UE the location of the UE; and transmit  
15 means for transmitting the location of the UE to at least one of the EUTRAN, a second UE, the computing apparatus, or a second computing apparatus coupled to the location server by the network.

Example 48 may include the subject matter of Example 47 and other examples herein, wherein the location server further may comprise: transmit means for transmitting  
20 to the UE the coordinates of one or more APs.

Example 49 may include the subject matter of Example 47 and other examples herein, wherein the communication means, receive means, and transmit means uses a user plane of the EUTRAN.

Example 50 may include the subject matter of Example 47 and other examples  
25 herein, wherein the one or more APs includes at least three APs.

Example 51 may include the subject matter of Example 47 and other examples herein, wherein the location server further may comprise: receive means for receiving a request for the location of the UE.

Example 52 may include the subject matter of Example 47 and other examples  
30 herein, wherein the location server further may comprise: receive means for receiving from the UE estimated error of the location of the UE.

Example 53 may include the subject matter of Example 52 and other examples herein, wherein the location server further may comprise: transmit means for transmitting the estimated error of the location of the UE to at least one of the EUTRAN, a second UE,

the computing apparatus, or a second computing apparatus coupled to the location server by the network..

In Example 54 of one or more non-transitory computer readable media, the media may comprise instructions to cause a location server, in response to execution of the  
5 instructions by a processor of the location server, to: receive, from a user equipment (UE) in an evolved universal terrestrial radio access network (EUTRAN), an indication of a Time of Flight (ToF) between the UE and one or more Access Points (APs) in a Wireless Local Area Network (WLAN) or time of arrival (ToA) and time of departure (ToD) data between the UE and the one or more APs; and calculate a location of the UE based at least  
10 in part on the indication of the ToF between the UE and the one or more APs or the ToA and ToD data between the UE and the one or more APs.

Example 55 may include the subject matter of Example 54 and other examples herein, wherein the instructions are further to cause the location server, to: transmit the location of the UE, wherein the location is transmitted to at least one of the EUTRAN, the  
15 UE, a second UE, or a computing apparatus coupled to the location server by a network.

Example 56 may include the subject matter of Example 54 and other examples herein, wherein the instructions are further to cause the location server, to: receive coordinates of the one or more APs, wherein the coordinates are received from at least one of the UE or a computing apparatus coupled to the location server by a network.

20 Example 57 may include the subject matter of Example 54 and other examples herein, wherein the instructions are further to cause the location server, to: transmit coordinates of the one or more APs to the UE.

Example 58 may include the subject matter of Example 54 and other examples herein, wherein the instructions are further to cause the location server, to: communicate  
25 with the UE over a user plane of the EUTRAN.

Example 59 may include the subject matter of Example 54 and other examples herein, wherein the instructions are further to cause the location server, to: receive a request for the location of the UE.

30 Example 60 may include the subject matter of Example 54 and other examples herein, wherein the one or more APs includes at least three APs.

Example 61 may include the subject matter of Example 54 and other examples herein, wherein the instructions are further to cause the location server, to: receive from the UE at least one of (i) estimated error of ToF between the UE and the one or more APs or (ii) estimated error of ToA and ToD data between the UE and the one or more APs.

Example 62 may include the subject matter of Example 61 and other examples herein, wherein the instructions are further to cause the location server, to: calculate an estimated error of the location of the UE based at least in part on at least one of (i) the estimated error of ToFs between the UE and the one or more APs or (ii) the estimated error of ToA and ToD data between the UE and the one or more APs.

Example 63 may include the subject matter of Example 62 and other examples herein, wherein the instructions are further to cause the location server, to: transmit the estimated error of the location of the UE to at least one of the EUTRAN, the UE, a second UE, or a computing apparatus coupled to the location server by a network.

The foregoing description of one or more implementations provides illustration and description, but is not intended to be exhaustive or to limit the scope of the invention to the precise form disclosed. Modifications and variations are possible in light of the above teachings or may be acquired from practice of various implementations of the invention.

## Claims

What is claimed is:

1. An apparatus to be implemented in a location server, the apparatus comprising:  
storage circuitry to store instructions; and  
5 processing circuitry, coupled to the storage circuitry, to execute the instructions to  
determine coordinates of one or more access points (APs) in a Wireless  
Local Area Network (WLAN), the coordinates retrieved from a memory coupled to the  
processing circuitry or received via a transceiver, coupled to the processing circuitry, of  
the location server;  
10 determine a Time of Flight (ToF) between a user equipment (UE) in an  
evolved universal terrestrial radio access network (EUTRAN) and an AP of the one or  
more APs based on indications of the ToF or indications of a time of arrival (ToA) and a  
time of departure (ToD) for a transmission between the UE and the AP;  
calculate a location of the UE based on the ToF and the coordinates of the  
15 one or more APs; and  
transmit the location of the UE via the transceiver of the location server to a  
computing apparatus coupled to the location server by a network.
2. The apparatus of claim 1, wherein the processing circuitry further is to determine a  
20 range between the UE and the AP.
3. The apparatus of claim 1, wherein the coordinates of the one or more APs are  
received from a second computing apparatus coupled to the transceiver of the location  
server by the network, and the processing circuitry is further to transmit via the transceiver  
25 the coordinates of one or more APs to the UE.
4. The apparatus of claim 1, wherein processing circuitry is to receive and transmit  
signals via the transceiver over a user plane of the EUTRAN.
- 30 5. The apparatus of claim 1, wherein the one or more APs includes at least three APs.
6. The apparatus of claim 1, wherein the processing circuitry is further to receive via  
the transceiver a request for the location of the UE.

7. The apparatus of claim 1, wherein the processing circuitry further is to receive an estimated error of ToF between the UE and the one or more APs, or an estimated error of ToA and ToD data.

5 8. The apparatus of claim 7, wherein the processing circuitry is further to calculate an estimated error of the location of the UE based on the estimated error of ToF between the UE and the one or more APs, or the estimated error of ToA and ToD data.

9. The apparatus of claim 8, wherein the processing circuitry is further to transmit via  
10 the transceiver AP assistance data to the UE, wherein the assistance data includes AP identifiers and a location.

10. One or more non-transitory computer readable media comprising instructions to cause a computing apparatus, in response to execution of the instructions by a processor of  
15 the computing apparatus, to:

transmit, over a Wireless Local Area Network (WLAN), first transmissions to one or more Access Points (APs), wherein the first transmissions have a time of departure (ToD) at the computing apparatus;

receive, over the WLAN, response transmissions from the one or more APs,  
20 wherein the response transmissions include acknowledgement of the first transmissions and have a time of arrival (ToA) at the computing apparatus;

receive, over the WLAN, data packets from the one or more APs, wherein the data packets include, for the one or more APs, ToA of the first transmissions and ToD of the response transmissions; and

25 transmit, to a location server via an evolved node B (eNB) of an evolved universal terrestrial radio access network (EUTRAN), the ToD at the computing apparatus of the first transmissions, the ToA at the computing apparatus of the response transmissions, the ToA of the first transmissions of the one or more APs, and the ToD of the response transmissions of the one or more APs.

30

11. The non-transitory computer readable media of claim 10, wherein the instructions are further to cause the computing apparatus to:

receive coordinates of the one or more APs of the WLAN from the location server via the eNB or from the one or more APs.

12. The non-transitory computer readable media of claim 10, wherein the instructions are further to cause the computing apparatus to:

receive from the EUTRAN location information of the computing apparatus.

5

13. The non-transitory computer readable media of claim 10, wherein the one or more APs includes at least three APs.

14. The non-transitory computer readable media of claim 10, wherein the instructions are further to cause the computing apparatus to:

10

communicate with the EUTRAN over a user plane.

15. The non-transitory computer readable media of claim 10, wherein the instructions are further to cause the computing apparatus to:

15

receive a request from the EUTRAN for the computing apparatus location.

16. The non-transitory computer readable media of claim 10, wherein the instructions are further to cause the computing apparatus to:

obtain estimated error of the ToD at the computing apparatus of the first

20

transmissions, the ToA at the computing apparatus of the response transmissions, the ToA of the first transmissions of the one or more APs, and the ToD of the response transmissions of the one or more APs; and

transmit the estimated error to the EUTRAN.

17. The non-transitory computer readable media of claim 10, wherein the response transmissions include acknowledgement of the first transmissions.

25

18. An apparatus to be implemented in a location server, the apparatus comprising: storage circuitry to store instructions; and

30

processing circuitry, coupled to the storage circuitry, to execute instructions to

determine coordinates of one or more access points (APs) in a Wireless Local Area Network (WLAN), the coordinates retrieved from a memory coupled to the processing circuitry or received via a transceiver, coupled to the processing circuitry, of the location server;

transmit the coordinates via the transceiver to a user equipment (UE) in an evolved universal terrestrial radio access network (EUTRAN); and  
receive a location of the UE from the UE.

5 19. The apparatus of claim 18, wherein the process circuitry further is to transmit via the transceiver of the location server the location of the UE to at least one of the EUTRAN, a second UE, or a computing apparatus coupled to the location server by a network.

10 20. The apparatus of claim 18, wherein the coordinates of the one or more APs are received from a computing apparatus coupled to the location server by a network.

21. The apparatus of claim 18, wherein location server is to receive from and transmit to the UE over a user plane of the EUTRAN.

15

22. The apparatus of claim 18, wherein the one or more APs includes at least three APs.

23. The apparatus of claim 18, wherein the processing circuitry further is to receive a  
20 request via the transceiver of the location server for the location of the UE.

24. The apparatus of claim 18, wherein the processing circuitry further is to transmit via the transceiver of the location server a request for the location of the UE to the UE.

25 25. The apparatus of claim 18, wherein the processing circuitry is further to receive from the UE via the transceiver of the location server estimated error of the location of the UE.

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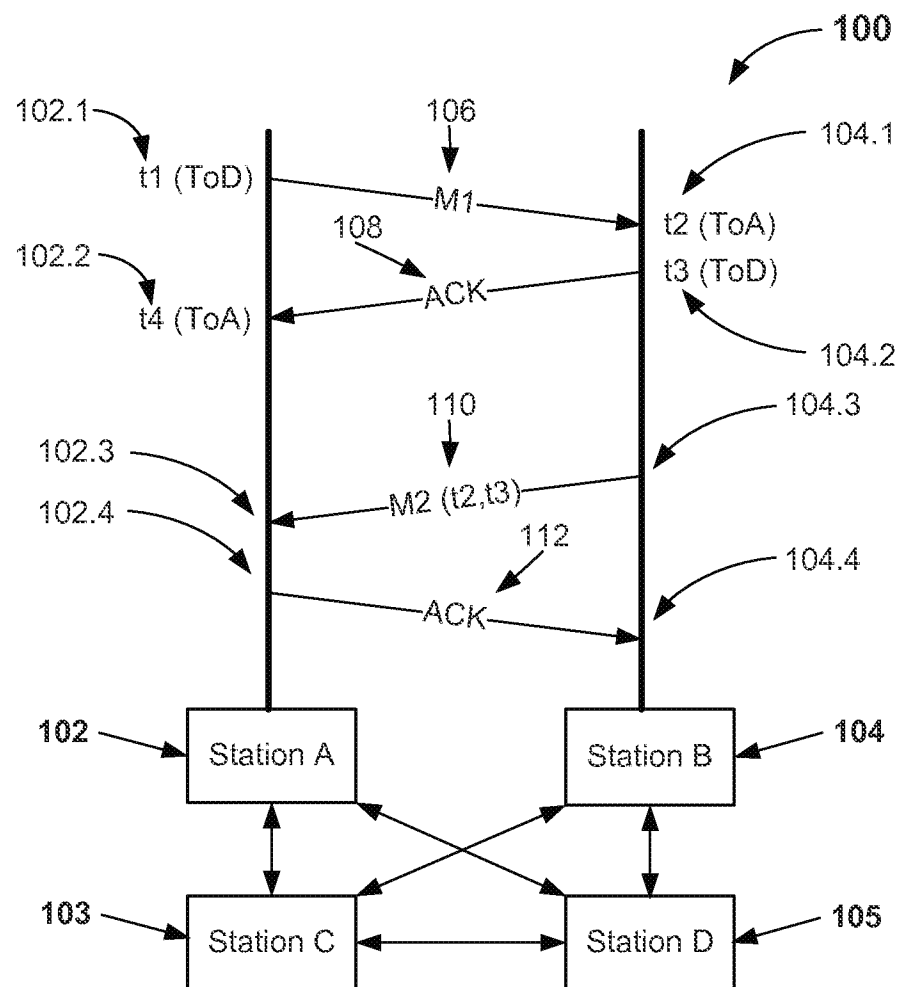


FIG. 1

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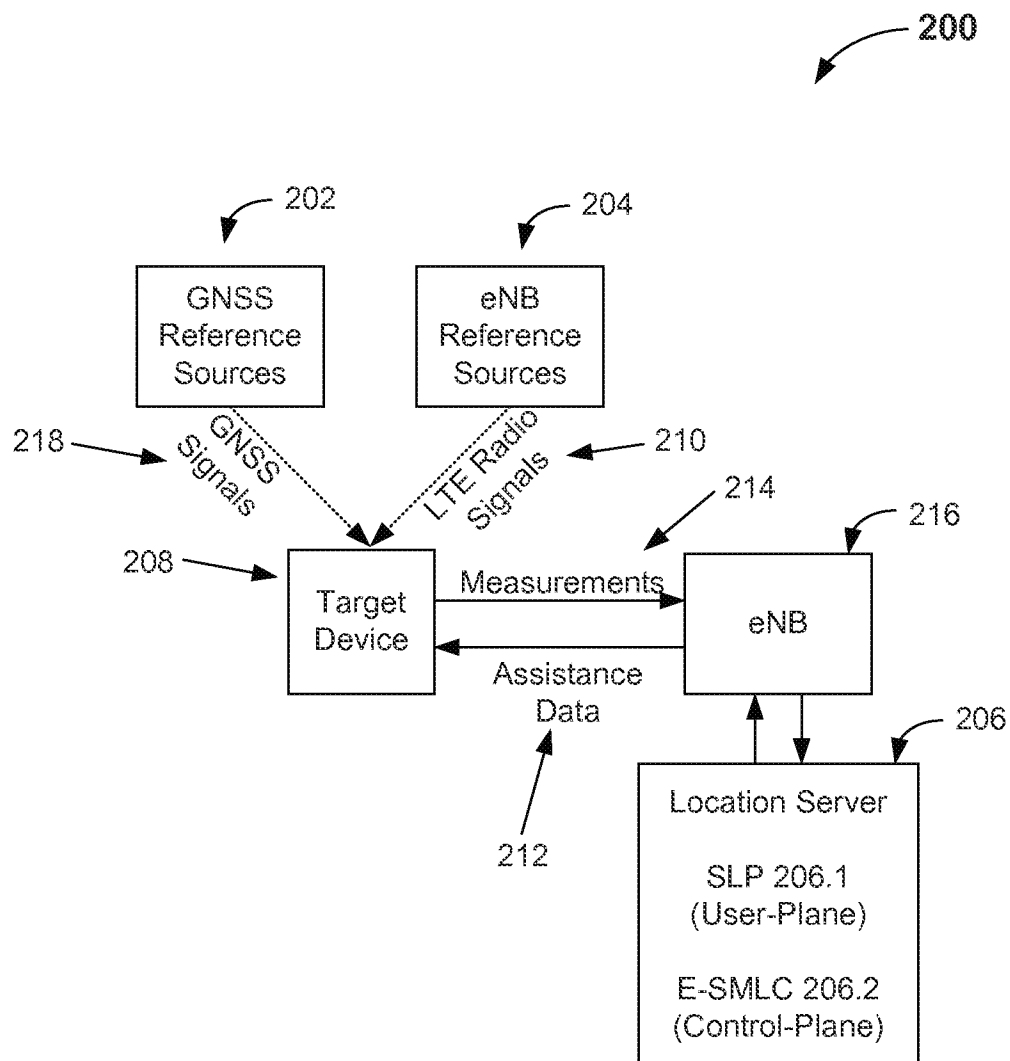


FIG. 2

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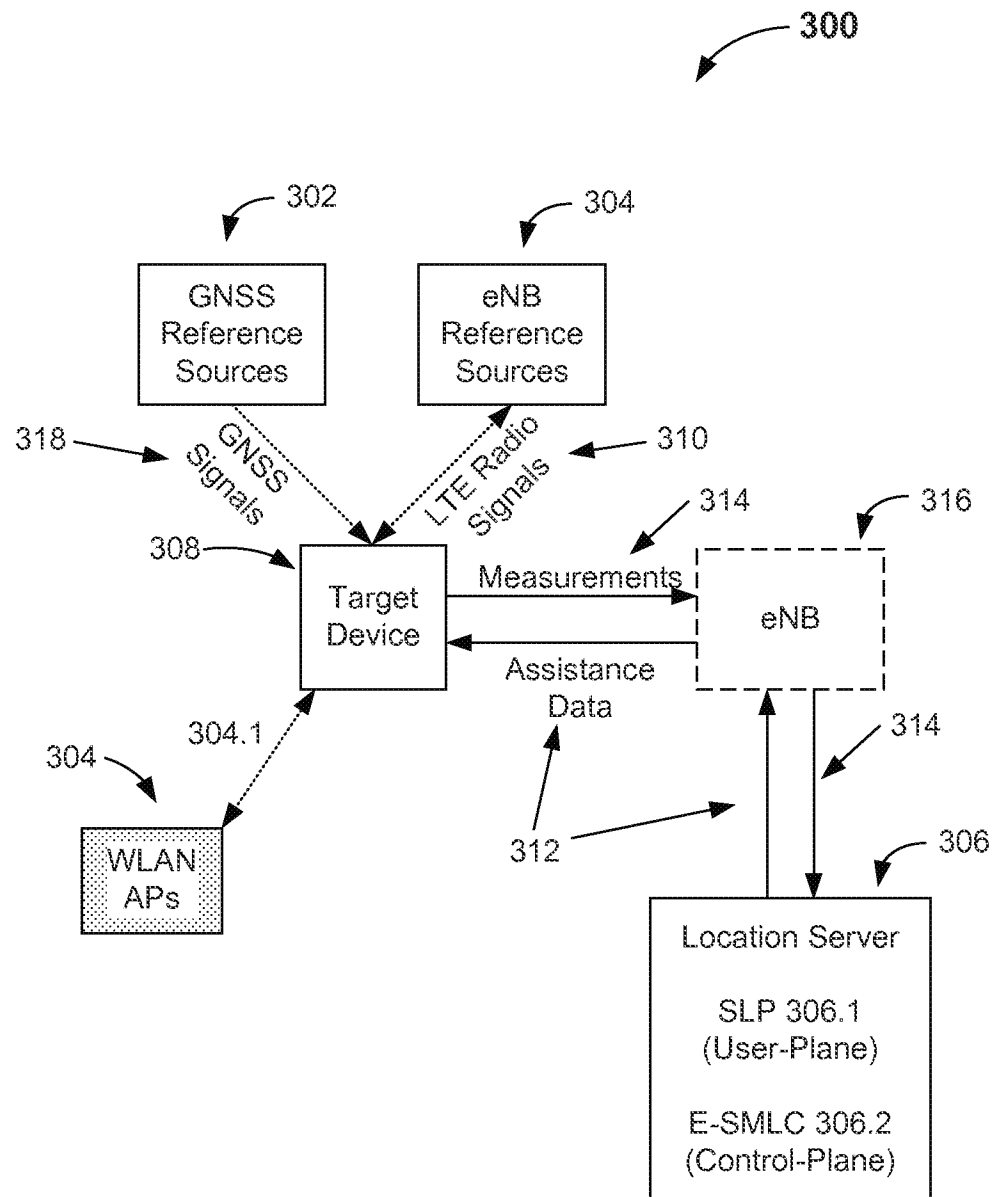


FIG. 3

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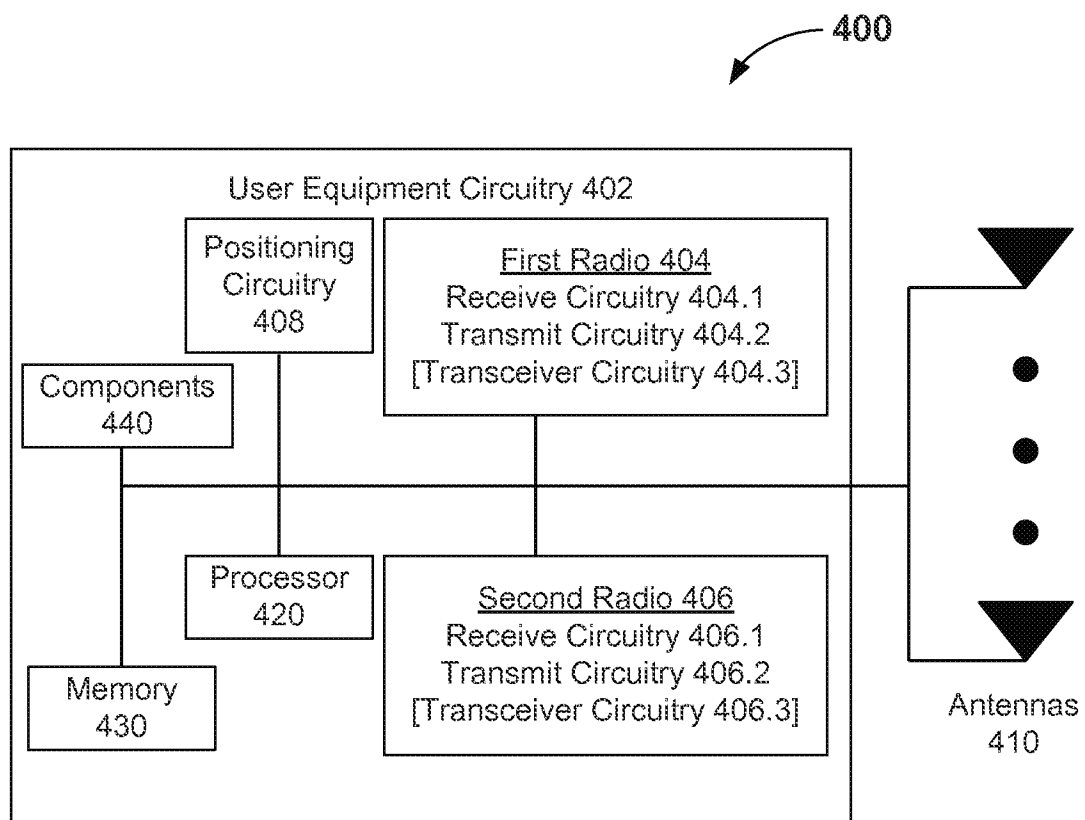


FIG. 4

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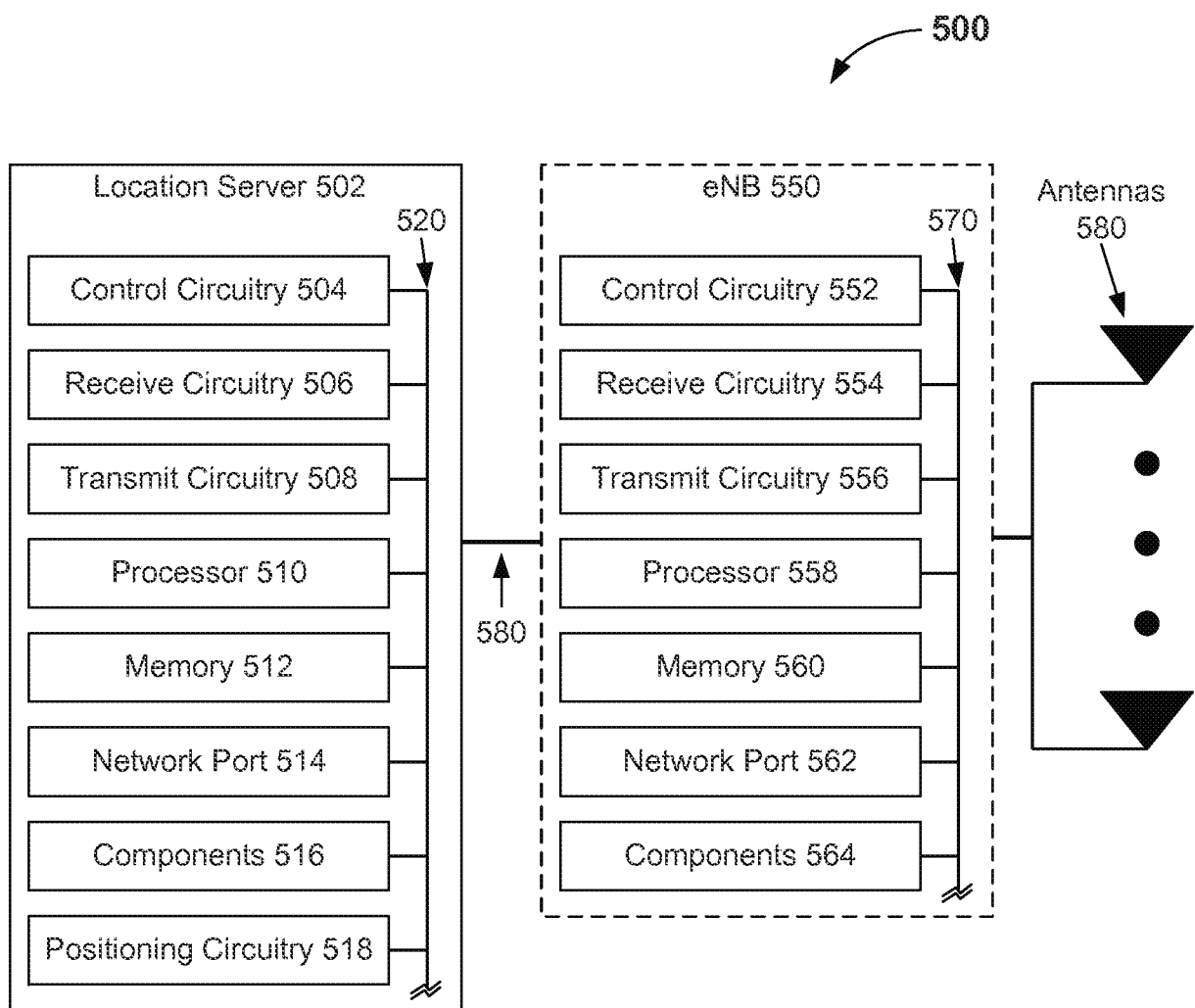


FIG. 5

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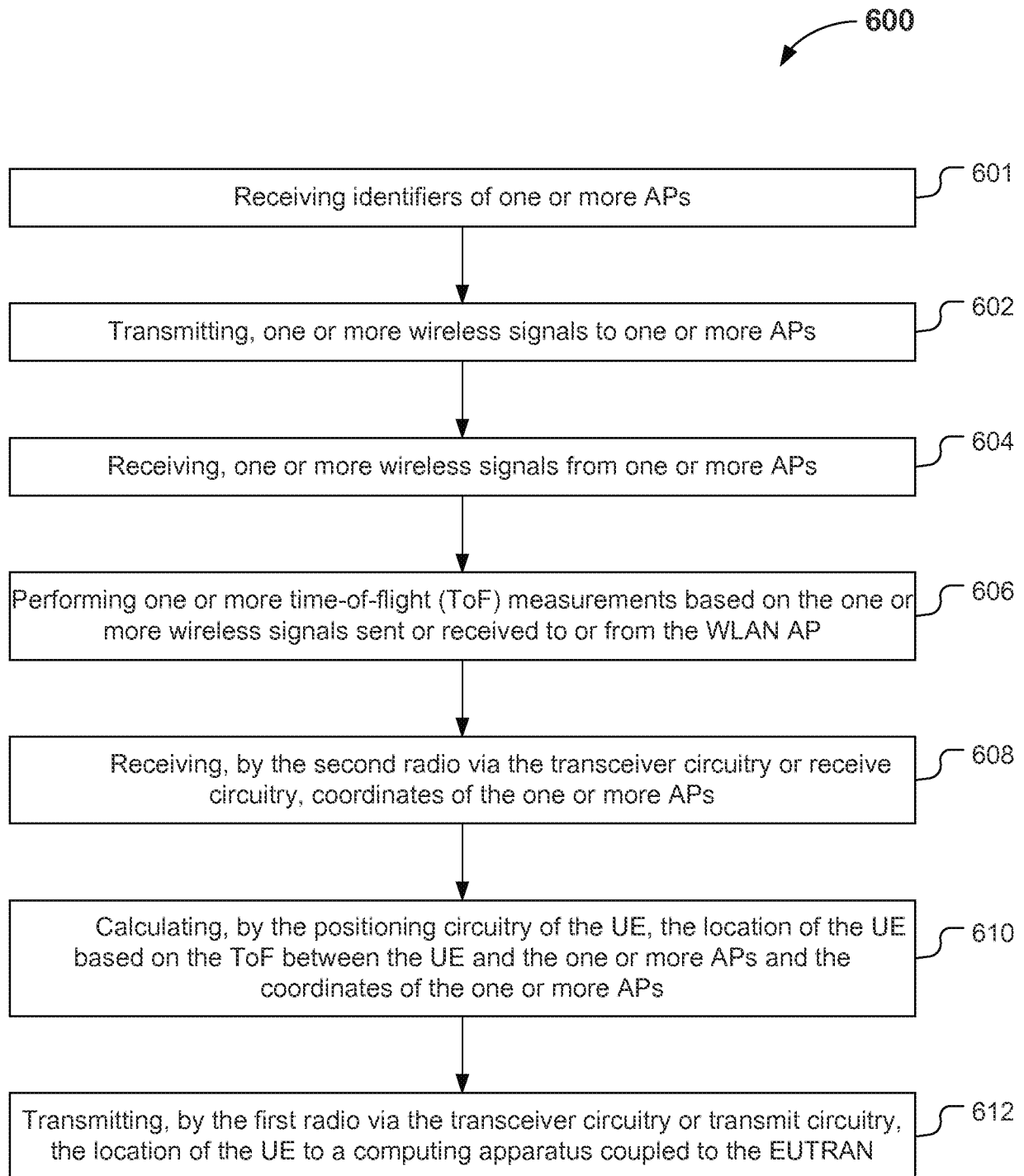


FIG. 6

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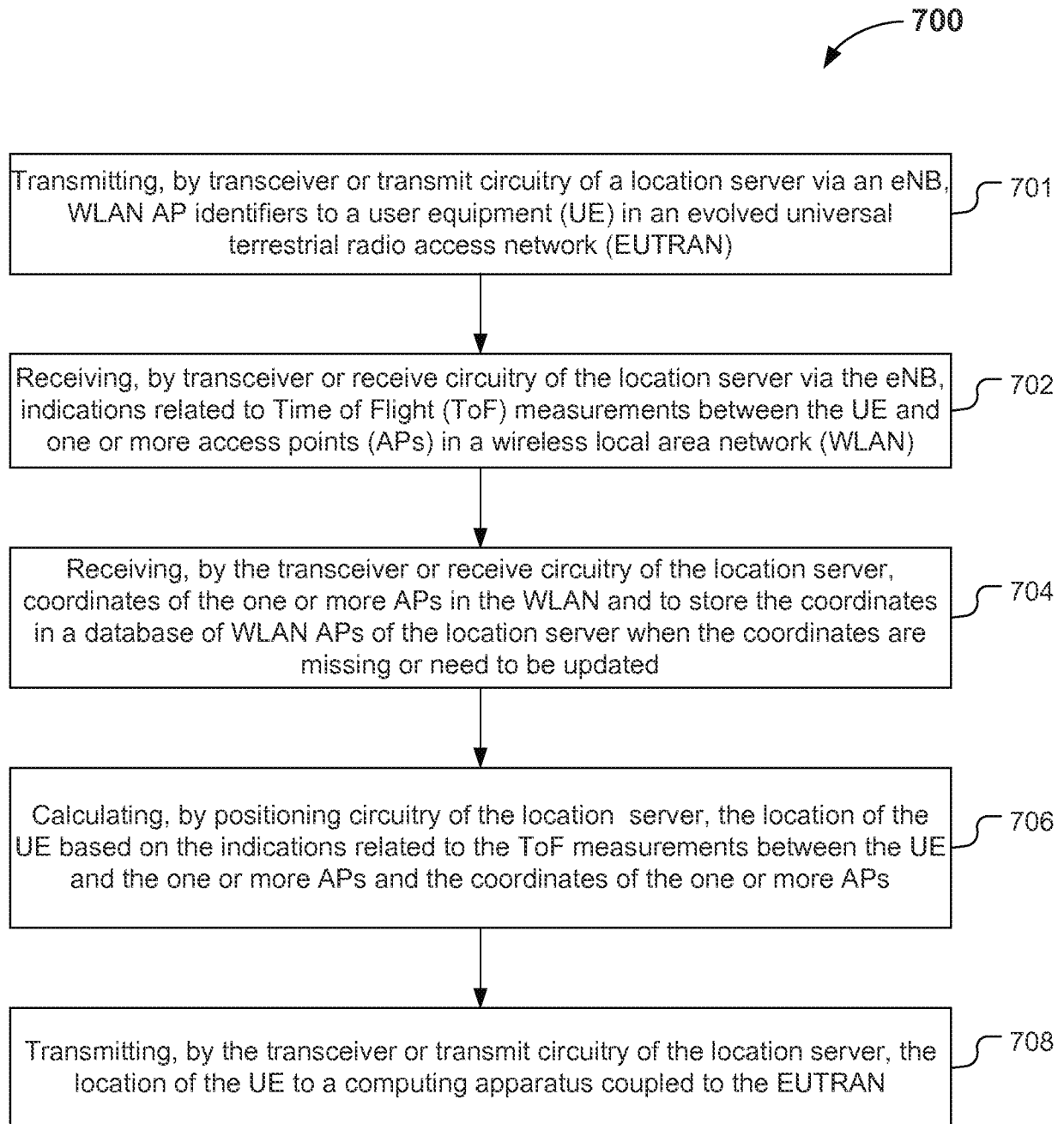


FIG. 7

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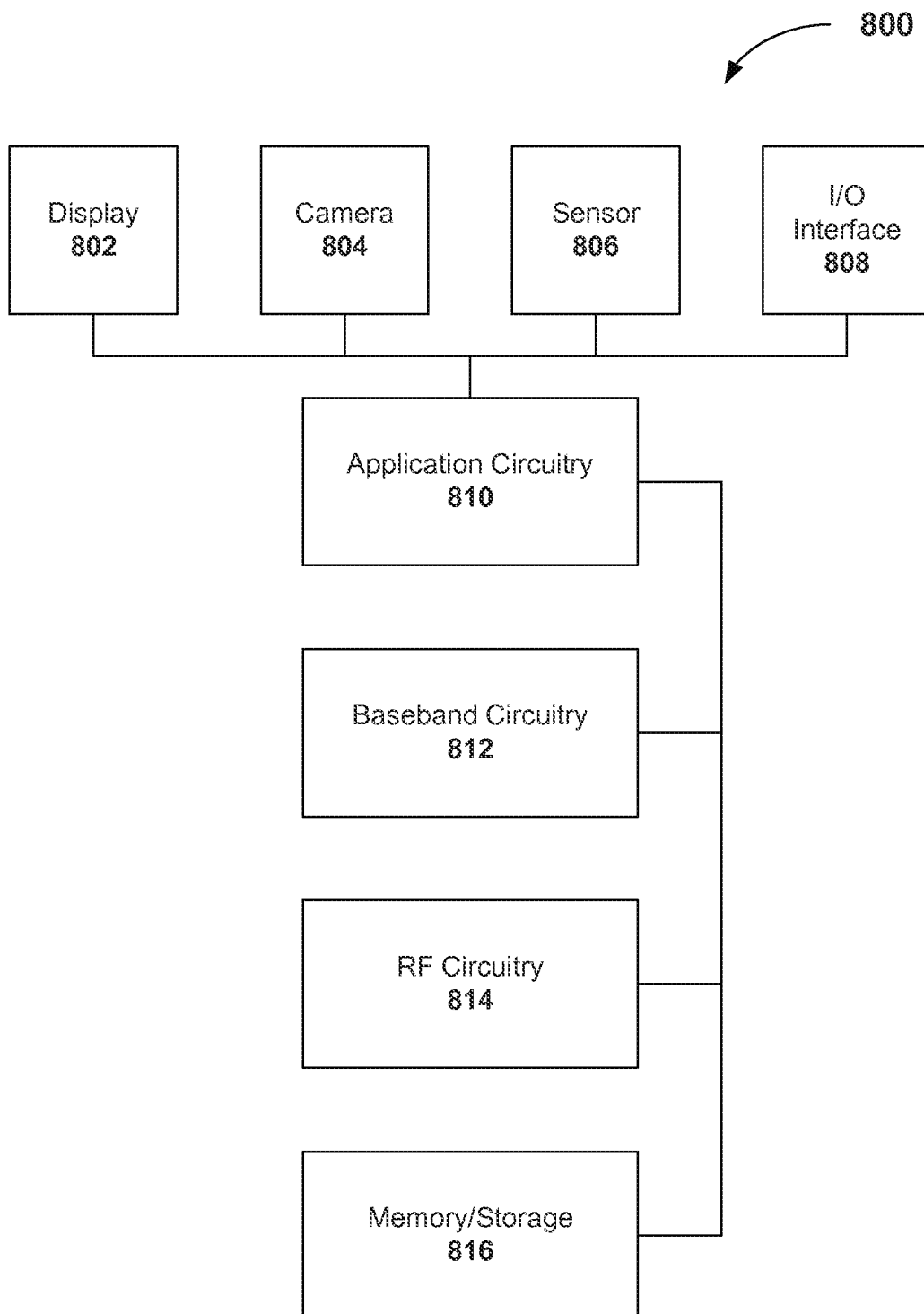


FIG. 8

## INTERNATIONAL SEARCH REPORT

International application No

PCT/US2015/037910

## A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W64/00

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                                                                                                                                                                                                                                               | Relevant to claim No. |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| X         | WO 2007/056738 A2 (QUALCOMM INC [US]; EDGE STEPHEN W [US]) 18 May 2007 (2007-05-18)<br>paragraph [0040] - paragraph [0043]<br>paragraph [0103] - paragraph [0131]<br>-----                                                                                                                                                                                                                                                                                                       | 1-25                  |
| A         | BANIN L ET AL: "Next Generation Indoor Positioning System Based on WiFi Time of Flight",<br>GNSS 2013 - PROCEEDINGS OF THE 26TH INTERNATIONAL TECHNICAL MEETING OF THE SATELLITE DIVISION OF THE INSTITUTE OF NAVIGATION (ION GNSS+ 2013), THE INSTITUTE OF NAVIGATION, 8551 RIXLEW LANE SUITE 360 MANASSAS, VA 20109, USA,<br>20 September 2013 (2013-09-20), pages 975-982, XP056007452,<br>page 976, left-hand column, line 1 - page 977, right-hand column, line 29<br>----- | 1-25                  |



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&amp;" document member of the same patent family

Date of the actual completion of the international search

6 October 2015

Date of mailing of the international search report

26/10/2015

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040,  
Fax: (+31-70) 340-3016

Authorized officer

Poort, Ingrid

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2015/037910

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s) | Publication<br>date |
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