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(54) Title: SIGNALING REDUCTION USING LONG TIME-TO-TRIGGER DURATION

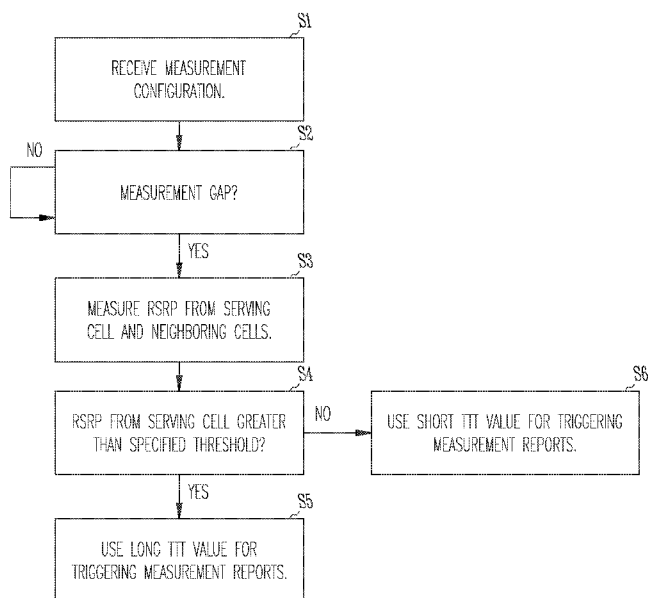


Fig. 3

(57) Abstract: Described herein are techniques for the triggering of measurement reports transmitted by a UE to its serving cell where such measurement reports are to be used by the serving cell to detect a handover condition. Such measurement reports may be triggered periodically and/or in response to an event that lasts for a duration at least equal to the value of a specified time-to-trigger (TTT) parameter. The described techniques reduce the number of measurement reports in certain situations in order to reduce signaling overhead and UE power consumption and to help avoid unnecessary handovers.



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Signaling Reduction Using Long Time-To-Trigger Duration

Priority Claim

- 5 **[0001]** This application claims priority to United States Provisional Patent Application Serial No. 62/146,037, filed April 10, 2015, which is incorporated herein by reference in its entirety.

Technical Field

- 10 **[0002]** Embodiments described herein relate generally to wireless networks and communications systems.

Background

- 15 **[0003]** In Long Term Evolution (LTE) systems, a mobile terminal (referred to as a User Equipment or UE) connects to the cellular network via a base station (referred to as an evolved Node B or eNB). The eNB to which a UE is currently attached is termed the serving cell. When the UE moves to a different geographic area, the downlink signal strengths may diminish sufficiently that is
20 necessary for the UE's serving cell to be changed to a nearer eNB. The process of transferring a UE from one eNB to another is called handover and is controlled by the network in LTE systems based, in part, upon signal measurements transmitted to the serving cell eNB by the UE. Efficiently triggering such signal measurements and consequent handovers, particularly in
25 the context of a heterogeneous network, is a concern of the present disclosure.

Brief Description of the Drawings

- [0004]** Fig. 1 illustrates an example heterogeneous network according to some embodiments.

[0005] Fig. 2 illustrates an example of a terminal, a macro cell base station, and a small cell base station according to some embodiments.

[0006] Fig. 3 illustrates an example procedure executed by a terminal according to some embodiments.

5 [0007] Fig. 4 illustrates an example of a user equipment device.

[0008] Fig. 5 illustrates an example of a computing machine.

Detailed Description

10 [0009] Described herein are techniques for the triggering of measurement reports transmitted by a UE to its serving cell where such measurement reports are to be used by the serving cell to detect a handover condition. Such measurement reports may be triggered periodically and/or in response to an event that lasts for a duration at least equal to the value of a specified time-to-trigger (TTT) parameter. The described techniques reduce the number of
15 measurement reports in certain situations in order to help avoid unnecessary handovers.

[0010] A heterogeneous network refers to an architecture in which a relatively large geographic area or macro cell is served by a macro cell base station or eNB overlays one or more smaller cells served by small cell base stations or eNBs. The small cell base station eNBs may operate at different frequencies and/or transmission powers than the macro cell eNB or even use different radio access technologies. These additional small cells may primarily be deployed for capacity improvement (e.g., in traffic hot spots) or for coverage
20 enhancements. Fig. 1 shows an example of a heterogeneous network that includes a macro cell base station or eNB 10 with a coverage zone 11, a small cell base station or eNB 20 with a coverage zone 21, a small cell base station or eNB 30 with a coverage zone 31, and mobile devices or UEs 40, 50, and 60 that may associate with either the macro cell or one of small cells when they are in
25 the appropriate coverage zone.

[0011] Fig. 2 illustrates an example of the components of a UE 400, a small cell eNB 200, and a macro cell eNB 300. The UE 400 includes processing circuitry 401 connected to an LTE transceiver 402 for providing an LTE interface and connected to a radio transceiver for providing an LTE air interface.

The small cell eNB 200 includes processing circuitry 201 connected to an LTE transceiver 202 for providing an LTE interface. The macro cell eNB 300 includes processing circuitry 301 connected to an LTE transceiver 302 for providing an LTE interface. Each of the transceivers in the devices are
5 connected to antennas 55. A backhaul link (e.g., an X2 interface) between the macro cell eNB 300 and the small cell eNB 200 may be provided and used to coordinate handovers between one cell to the other.

[0012] When a UE is attached to an eNB as its serving cell, the UE is said to be in an RRC_CONNECTED state, referring to the Radio Resource Control
10 (RRC) protocol which is the topmost control-plane layer of the LTE radio access protocol stack in the eNB. In RRC_CONNECTED state, the network controls UE mobility by deciding when the UE should move to another cell. The RRC sublayer in the eNB may make handover decisions based on neighbor cell measurements reported by the UE. The UE transmits this information to its
15 serving cell eNB in the form of measurement reports (MR). The eNB configures the UE to perform measurement reporting using a measurement configuration that specifies the manner in which measurement reports are to be generated and that may include measurement gaps (i.e., periods of no transmission to the UE) during which measurements are to be taken. One type of measurement
20 configuration specifies an event-based triggering of measurement reports in which the UE measures the signal strengths of the serving and neighboring cells (e.g., by measuring the received power of reference signals, referred to as reference signal received power or RSRP) and transmits a measurement report if a defined relation between the measured RSRPs persists for a specified duration.
25 The specified duration is defined by the value of a time-to-trigger (TTT) parameter. For example, the LTE specifications define an event designated as A3 when the neighboring cell RSRP exceeds the serving cell RSRP by a specified offset for a time duration equal to the value of TTT. Typically, transmission of the measurement report in response to the A3 event would cause
30 the serving cell eNB to initiate a handover of the UE to the neighboring cell.

[0013] In a heterogeneous network with a macro cell underlain by small cells such as illustrated in Fig. 1, a TTT value appropriate for the homogeneous network situation may result in too frequent transmission of measurement

reports by the UE. This results in increased signaling overhead and unnecessary power consumption by the UE and may cause too many consequent handovers. This may occur as the UE transmits measurement reports as it moves into and out of small cell coverage areas and causes repeated handovers between the macro cell and the small cells, a situation sometimes called ping-ponging.

[0014] As described above, due to the large number of cells in heterogeneous networks, there will be an increase in the number of cell boundaries which may lead to a significant increase in the number of cell handovers and generation of MRs thereby increasing signaling overhead.

Furthermore, the irregular placement of the small cells in the network may also significantly degrade mobility performance and increase handover failures (HOF) and ping-pongs (PP). This is especially evident for medium and high speed UEs in the network. These users would move in and move out of the coverage area of the small cell leading to increased number of handovers (higher signaling overhead) and may also lead to substantially larger handover failures and ping-pongs. Embodiments described herein address these issues by configuring a longer TTT value in under certain conditions. For medium and high speed UEs, this would help reduce signaling overhead and UE power consumption. Also, in the case of a low mobility or stationary UE, the longer TTT would help in a more stable handover.

[0015] In one embodiment, a longer than usual TTT value is configured when the when the serving cell base station or eNB RSRP is greater than a specified threshold. In another embodiment, a longer than usual TTT value is configured when an RSRP is measured from a neighboring cell belonging to a specified cell list. In another embodiment, a longer than usual TTT value is configured when the serving cell base station or eNB RSRP is greater than a specified threshold and/or when an RSRP is measured from a neighboring cell belonging to a specified cell list. By configuring a longer TTT value, the number of measurement reports (MRs) sent to the serving eNB reduces. As a result, there is a decrease in the number of handover attempts thereby decreasing handover failures. The longer TTT also helps to reduce ping-pong (PP) scenarios.

[0016] A simulation was conducted to demonstrate these ideas in a scenario with macro cells on one frequency and small cells on another frequency. A total

of fifty-seven macro cells were simulated with small cells randomly deployed within each macro cell. The UEs performed inter-frequency measurement with a measurement gap 40 ms. The UEs either used $TTT = 40$ ms or 160ms to trigger a MR event in the fixed TTT scenario. In the long TTT value scenario, the UE
5 used a longer TTT of 512 ms for the macro cell to small cell situation when the serving cell signal was greater than -85 dBm. For the case of UEs moving at 30km/h, a significant decrease in HOF/UE/s (handover failure/UE/second) was observed for the long TTT value scenario relative to both the fixed TTT scenarios $TTT = 40$ ms and $TTT = 160$ ms. It was also demonstrated that the
10 total number of measurement reporting is 50% lesser relative to the fixed TTT scenario when the long TTT value is used. The ping-pong scenario was also shown to be significantly improved (more than 60%) when the long TTT value is applied. The long TTT value technique as described herein thus reduces not only the number of measurement reports (by 50%) and the HOF performance, but
15 also reduces the ping-pong rate by more than 60%. In advanced network scenarios where more and more frequencies are deployed, this technique will be able to significantly enhance mobility performance.

[0017] Fig. 3 illustrates an example procedure performed by a UE in implementing a long TTT value for transmitting measurement reports when
20 event A3 is configured by the eNB. At stage S1, the UE receives a measurement configuration from its serving cell eNB. The measurement configuration includes a designation of measurement gaps during which signals from the serving cell and neighboring cells are to be measured and instructions for using either a long TTT value or a short TTT value. At stage S2, the UE waits for the
25 occurrence of a measurement gap. At stage S3, the UE measures the RSRPs (or other metrics) of the serving cell and neighboring cells. At stage S4, the UE tests whether the RSRP from the serving cell is greater than a specified threshold. If so, a long TTT value is employed for measurement reporting at stage S5. Otherwise, a normal short TTT value is used at stage S6.

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Example UE Description

[0018] As used herein, the term "circuitry" 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 hardware components that provide the described functionality. In some embodiments, the circuitry may be implemented in, or functions associated with the circuitry may be implemented by, one or more software or firmware modules. In some embodiments, circuitry may include logic, at least partially operable in hardware.

[0019] Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software. Fig. 4 illustrates, for one embodiment, example components of a User Equipment (UE) device 100. In some embodiments, the UE device 100 may include application circuitry 102, baseband circuitry 104, Radio Frequency (RF) circuitry 106, front-end module (FEM) circuitry 108 and one or more antennas 110, coupled together at least as shown.

[0020] The application circuitry 102 may include one or more application processors. For example, the application circuitry 102 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 and/or may include memory/storage and may be configured to execute instructions stored in the memory/storage to enable various applications and/or operating systems to run on the system.

[0021] The baseband circuitry 104 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 104 may include one or more baseband processors and/or control logic to process baseband signals received from a receive signal path of the RF circuitry 106 and to generate baseband signals for a transmit signal path of the RF circuitry 106. Baseband processing circuitry 104 may interface with the application circuitry 102 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 106. For example, in some embodiments, the baseband circuitry 104 may include a second generation (2G) baseband processor 104a, third generation (3G) baseband processor 104b, fourth generation (4G) baseband processor 104c, and/or other baseband processor(s)

104d for other existing generations, generations in development or to be developed in the future (e.g., fifth generation (5G), 6G, etc.). The baseband circuitry 104 (e.g., one or more of baseband processors 104a-d) may handle various radio control functions that enable communication with one or more
5 radio networks via the RF circuitry 106. The radio control functions may include, but are not limited to, signal modulation/demodulation, encoding/decoding, radio frequency shifting, etc. In some embodiments, modulation/demodulation circuitry of the baseband circuitry 104 may include Fast-Fourier Transform (FFT), precoding, and/or constellation
10 mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 104 may include convolution, tail-biting convolution, turbo, Viterbi, and/or Low Density Parity Check (LDPC) encoder/decoder functionality. Embodiments of modulation/demodulation and encoder/decoder functionality are not limited to these examples and may include
15 other suitable functionality in other embodiments.

[0022] In some embodiments, the baseband circuitry 104 may include elements of a protocol stack such as, for example, elements of an evolved universal terrestrial radio access network (EUTRAN) protocol including, for example, physical (PHY), media access control (MAC), radio link control
20 (RLC), packet data convergence protocol (PDCP), and/or radio resource control (RRC) elements. A central processing unit (CPU) 104e of the baseband circuitry 104 may be configured to run elements of the protocol stack for signaling of the PHY, MAC, RLC, PDCP and/or RRC layers. In some embodiments, the baseband circuitry may include one or more audio digital signal processor(s)
25 (DSP) 104f. The audio DSP(s) 104f may include elements for compression/decompression and echo cancellation and may include other suitable processing elements in other embodiments. Components of the baseband circuitry may be suitably combined in a single chip, a single chipset, or disposed on a same circuit board in some embodiments. In some embodiments,
30 some or all of the constituent components of the baseband circuitry 104 and the application circuitry 102 may be implemented together such as, for example, on a system on a chip (SOC).

- [0023] In some embodiments, the baseband circuitry 104 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 104 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 104 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.
- 10 [0024] RF circuitry 106 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 106 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 106 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 108 and provide baseband signals to the baseband circuitry 104. RF circuitry 106 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 104 and provide RF output signals to the FEM circuitry 108 for transmission.
- 20 [0025] In some embodiments, the RF circuitry 106 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 106 may include mixer circuitry 106a, amplifier circuitry 106b and filter circuitry 106c. The transmit signal path of the RF circuitry 106 may include filter circuitry 106c and mixer circuitry 106a. RF circuitry 106 may also include synthesizer circuitry 106d for synthesizing a frequency for use by the mixer circuitry 106a of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 106a of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 108 based on the synthesized frequency provided by synthesizer circuitry 106d. The amplifier circuitry 106b may be configured to amplify the down-converted signals and the filter circuitry 106c may be a low-pass filter (LPF) or band-pass filter (BPF) configured to remove unwanted signals from the down-converted signals to generate output baseband signals. Output baseband signals may be
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- 30

provided to the baseband circuitry 104 for further processing. In some embodiments, the output baseband signals may be zero-frequency baseband signals, although this is not a requirement. In some embodiments, mixer circuitry 106a of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[0026] In some embodiments, the mixer circuitry 106a of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 106d to generate RF output signals for the FEM circuitry 108. The baseband signals may be provided by the baseband circuitry 104 and may be filtered by filter circuitry 106c. The filter circuitry 106c may include a low-pass filter (LPF), although the scope of the embodiments is not limited in this respect.

[0027] In some embodiments, the mixer circuitry 106a of the receive signal path and the mixer circuitry 106a of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and/or upconversion respectively. In some embodiments, the mixer circuitry 106a of the receive signal path and the mixer circuitry 106a of the transmit signal path may include two or more mixers and may be arranged for image rejection (e.g., Hartley image rejection). In some embodiments, the mixer circuitry 106a of the receive signal path and the mixer circuitry 106a may be arranged for direct downconversion and/or direct upconversion, respectively. In some embodiments, the mixer circuitry 106a of the receive signal path and the mixer circuitry 106a of the transmit signal path may be configured for super-heterodyne operation.

[0028] In some embodiments, the output baseband signals and the input baseband signals may be analog baseband signals, although the scope of the embodiments is not limited in this respect. In some alternate embodiments, the output baseband signals and the input baseband signals may be digital baseband signals. In these alternate embodiments, the RF circuitry 106 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 104 may include a digital baseband interface to communicate with the RF circuitry 106.

[0029] In some dual-mode embodiments, a separate radio IC circuitry may be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect.

[0030] In some embodiments, the synthesizer circuitry 106d may be a fractional-N synthesizer or a fractional $N/N+1$ synthesizer, although the scope of the embodiments is not limited in this respect as other types of frequency synthesizers may be suitable. For example, synthesizer circuitry 106d may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[0031] The synthesizer circuitry 106d may be configured to synthesize an output frequency for use by the mixer circuitry 106a of the RF circuitry 106 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 106d may be a fractional $N/N+1$ synthesizer.

[0032] In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although that is not a requirement. Divider control input may be provided by either the baseband circuitry 104 or the applications processor 102 depending on the desired output frequency. In some embodiments, a divider control input (e.g., N) may be determined from a look-up table based on a channel indicated by the applications processor 102.

[0033] Synthesizer circuitry 106d of the RF circuitry 106 may include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider may be a dual modulus divider (DMD) and the phase accumulator may be a digital phase accumulator (DPA). In some embodiments, the DMD may be configured to divide the input signal by either N or $N+1$ (e.g., based on a carry out) to provide a fractional division ratio. In some example embodiments, the DLL may include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-flop. In these embodiments, the delay elements may be configured to break a VCO period up into N_d equal packets of phase, where N_d is the number of delay elements in the delay line. In this way, the DLL provides negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

[0034] In some embodiments, synthesizer circuitry 106d may be configured to generate a carrier frequency as the output frequency, while in other

embodiments, the output frequency may be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency) and used in conjunction with quadrature generator and divider circuitry to generate multiple signals at the carrier frequency with multiple different phases with respect to
5 each other. In some embodiments, the output frequency may be a LO frequency (f_{LO}). In some embodiments, the RF circuitry 106 may include an IQ/polar converter.

[0035] FEM circuitry 108 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more
10 antennas 110, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 106 for further processing. FEM circuitry 108 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 106 for transmission by one or more of the one or more antennas 110.

15 [0036] In some embodiments, the FEM circuitry 108 may include a TX/RX switch to switch between transmit mode and receive mode operation. The FEM circuitry may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry may include a low-noise amplifier (LNA) to amplify received RF signals and provide the amplified received RF
20 signals as an output (e.g., to the RF circuitry 106). The transmit signal path of the FEM circuitry 108 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 106), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 110).

25 [0037] In some embodiments, the UE device 100 may include additional elements such as, for example, memory/storage, display, camera, sensor, and/or input/output (I/O) interface.

Example Machine Description

30 [0038] Fig. 5 illustrates a block diagram of an example machine 500 upon which any one or more of the techniques (e.g., methodologies) discussed herein may perform. In alternative embodiments, the machine 500 may operate as a standalone device or may be connected (e.g., networked) to other machines. In a

networked deployment, the machine 500 may operate in the capacity of a server machine, a client machine, or both in server-client network environments. In an example, the machine 500 may act as a peer machine in peer-to-peer (P2P) (or other distributed) network environment. The machine 500 may be a user
5 equipment (UE), evolved Node B (eNB), Wi-Fi access point (AP), Wi-Fi station (STA), personal computer (PC), a tablet PC, a set-top box (STB), a personal digital assistant (PDA), a mobile telephone, a smart phone, a web appliance, a network router, switch or bridge, or any machine capable of executing instructions (sequential or otherwise) that specify actions to be taken by that
10 machine. Further, while only a single machine is illustrated, the term “machine” shall also be taken to include any collection of machines that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein, such as cloud computing, software as a service (SaaS), other computer cluster configurations.

15 **[0039]** Examples, as described herein, may include, or may operate on, logic or a number of components, modules, or mechanisms. Modules are tangible entities (e.g., hardware) capable of performing specified operations and may be configured or arranged in a certain manner. In an example, circuits may be arranged (e.g., internally or with respect to external entities such as other
20 circuits) in a specified manner as a module. In an example, the whole or part of one or more computer systems (e.g., a standalone, client or server computer system) or one or more hardware processors may be configured by firmware or software (e.g., instructions, an application portion, or an application) as a module that operates to perform specified operations. In an example, the software may
25 reside on a machine readable medium. In an example, the software, when executed by the underlying hardware of the module, causes the hardware to perform the specified operations.

[0040] Accordingly, the term “module” is understood to encompass a tangible entity, be that an entity that is physically constructed, specifically
30 configured (e.g., hardwired), or temporarily (e.g., transitorily) configured (e.g., programmed) to operate in a specified manner or to perform part or all of any operation described herein. Considering examples in which modules are temporarily configured, each of the modules need not be instantiated at any one

moment in time. For example, where the modules comprise a general-purpose hardware processor configured using software, the general-purpose hardware processor may be configured as respective different modules at different times. Software may accordingly configure a hardware processor, for example, to
5 constitute a particular module at one instance of time and to constitute a different module at a different instance of time.

[0041] Machine (e.g., computer system) 500 may include a hardware processor 502 (e.g., a central processing unit (CPU), a graphics processing unit (GPU), a hardware processor core, or any combination thereof), a main memory
10 504 and a static memory 506, some or all of which may communicate with each other via an interlink (e.g., bus) 508. The machine 500 may further include a display unit 510, an alphanumeric input device 512 (e.g., a keyboard), and a user interface (UI) navigation device 514 (e.g., a mouse). In an example, the display unit 510, input device 512 and UI navigation device 514 may be a touch screen
15 display. The machine 500 may additionally include a storage device (e.g., drive unit) 516, a signal generation device 518 (e.g., a speaker), a network interface device 520, and one or more sensors 521, such as a global positioning system (GPS) sensor, compass, accelerometer, or other sensor. The machine 500 may include an output controller 528, such as a serial (e.g., universal serial bus
20 (USB), parallel, or other wired or wireless (e.g., infrared (IR), near field communication (NFC), etc.) connection to communicate or control one or more peripheral devices (e.g., a printer, card reader, etc.).

[0042] The storage device 516 may include a machine readable medium 522 on which is stored one or more sets of data structures or instructions 524 (e.g.,
25 software) embodying or utilized by any one or more of the techniques or functions described herein. The instructions 524 may also reside, completely or at least partially, within the main memory 504, within static memory 506, or within the hardware processor 502 during execution thereof by the machine 500. In an example, one or any combination of the hardware processor 502, the main
30 memory 504, the static memory 506, or the storage device 516 may constitute machine readable media.

[0043] While the machine readable medium 522 is illustrated as a single medium, the term "machine readable medium" may include a single medium or

multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) configured to store the one or more instructions 524.

[0044] The term “machine readable medium” may include any medium that is capable of storing, encoding, or carrying instructions for execution by the machine 500 and that cause the machine 500 to perform any one or more of the techniques of the present disclosure, or that is capable of storing, encoding or carrying data structures used by or associated with such instructions. Non-limiting machine readable medium examples may include solid-state memories, and optical and magnetic media. Specific examples of machine readable media may include: non-volatile memory, such as semiconductor memory devices (e.g., Electrically Programmable Read-Only Memory (EPROM), Electrically Erasable Programmable Read-Only Memory (EEPROM)) and flash memory devices; magnetic disks, such as internal hard disks and removable disks; magneto-optical disks; Random Access Memory (RAM); and CD-ROM and DVD-ROM disks. In some examples, machine readable media may include non-transitory machine readable media. In some examples, machine readable media may include machine readable media that is not a transitory propagating signal.

[0045] The instructions 524 may further be transmitted or received over a communications network 526 using a transmission medium via the network interface device 520 utilizing any one of a number of transfer protocols (e.g., frame relay, internet protocol (IP), transmission control protocol (TCP), user datagram protocol (UDP), hypertext transfer protocol (HTTP), etc.). Example communication networks may include a local area network (LAN), a wide area network (WAN), a packet data network (e.g., the Internet), mobile telephone networks (e.g., cellular networks), Plain Old Telephone (POTS) networks, and wireless data networks (e.g., Institute of Electrical and Electronics Engineers (IEEE) 802.11 family of standards known as Wi-Fi®, IEEE 802.16 family of standards known as WiMax®, IEEE 802.15.4 family of standards, a Long Term Evolution (LTE) family of standards, a Universal Mobile Telecommunications System (UMTS) family of standards, peer-to-peer (P2P) networks, among others. In an example, the network interface device 520 may include one or more physical jacks (e.g., Ethernet, coaxial, or phone jacks) or one or more antennas to connect to the communications network 526. In an example, the

network interface device 520 may include a plurality of antennas to wirelessly communicate using at least one of single-input multiple-output (SIMO), multiple-input multiple-output (MIMO), or multiple-input single-output (MISO) techniques. In some examples, the network interface device 520 may wirelessly
5 communicate using Multiple User MIMO techniques. The term “transmission medium” shall be taken to include any intangible medium that is capable of storing, encoding or carrying instructions for execution by the machine 500, and includes digital or analog communications signals or other intangible medium to facilitate communication of such software.

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Additional Notes and Examples

[0046] In Example 1, a method for operating a user equipment (UE) device, comprises: connecting to a macro cell eNB as a serving cell for the UE; receiving a measurement configuration from the macro cell eNB instructing the
15 UE to measure the signal strength from the macro cell eNB and one or more neighboring small cell eNBs and wherein the measurement configuration further instructs the UE to transmit a measurement report comprising information relating to the signal strength measurements when the signal strength measurements meet specified criteria of a measurement triggering event for a
20 duration equal to the value of a time-to-trigger (TTT) parameter; and, setting the TTT parameter to a specified short TTT value unless the macro cell eNB signal strength measurement from the macro cell eNB is above a specified threshold value in which case the TTT parameter is set to a specified long TTT value. The specified short TTT value is smaller than the specified long TTT value. The
25 signal strength measurements may be in the form of, for example, a reference signal received power (RSRP), a reference signal received quality (RSRQ), and/or a signal to noise plus interference ratio (SINR).

[0047] In Example 2, a method for operating a user equipment (UE) device, comprises: connecting to a macro cell eNB as a serving cell for the UE;
30 receiving a measurement configuration from the macro cell eNB instructing the UE to measure the signal strength from the macro cell eNB and one or more neighboring small cell eNBs and wherein the measurement configuration further instructs the UE to transmit a measurement report comprising information

relating to the signal strength measurements when the macro cell eNB signal strength measurement meets specified criteria of a measurement triggering event for a duration equal to the value of a time-to-trigger (TTT) parameter; and, setting the TTT parameter to a specified short TTT value unless the signal strength measurements are taken from a small cell eNB belonging to a cell list transmitted to the UE from the macro cell eNB in which case the TTT parameter is set to a specified long TTT value. The specified short TTT value is smaller than the specified long TTT value. The signal strength measurements may be in the form of, for example, a reference signal received power (RSRP), a reference signal received quality (RSRQ), and/or a signal to noise plus interference ratio (SINR).

[0048] In Example 3, the subject matter of Example 1 or any of the Examples described herein may optionally further comprise receiving the short TTT value and long TTT value from the macro cell eNB.

[0049] In Example 4, the subject matter of Example 1 or any of the Examples described herein may optionally further comprise receiving the specified threshold value from the macro cell eNB.

[0050] In Example 5, the subject matter of Example 1 or any of the Examples described herein may optionally further comprise receiving the short TTT value, long TTT value, and specified threshold as part of the measurement configuration transmitted from the macro cell eNB using radio resource control (RRC) signaling.

[0051] In Example 6, the subject matter of Example 1 or any of the Examples described herein may optionally further comprise setting the TTT parameter to the specified long TTT value if the signal strength measurements are taken from a small cell eNB belonging to a cell list received by the UE from the macro cell eNB.

[0052] In Example 7, the subject matter of Example 1 or any of the Examples described herein may optionally further comprise measuring the small cell eNB signal strength during a specified measurement gap.

[0053] In Example 8, the subject matter of Example 1 or any of the Examples described herein may optionally further comprise measuring the small cell eNB and macro cell eNB signal strengths at different frequencies.

[0054] In Example 9, a base station for operating as a macro cell eNB (e.g., in a Long Term Evolution (LTE) network), comprises: a radio transceiver for providing an air interface to user equipments (UEs); processing circuitry interfaced to the radio transceiver; wherein the processing circuitry is to connect to a UE as a serving cell for the UE and further to: transmit a measurement configuration to the UE instructing the UE to measure the signal strength from the base station and one or more neighboring small cell eNBs and wherein the measurement configuration further instructs the UE to transmit a measurement report comprising information relating to the signal strength measurements when the signal strength measurements meet specified criteria of a measurement triggering event for a duration equal to the value of a time-to-trigger (TTT) parameter; and, instruct the UE to set the TTT parameter to a specified short TTT value unless the signal strength measurement from the base station is above a specified threshold value in which case the TTT parameter is set to a specified long TTT value. The specified short TTT value is smaller than the specified long TTT value. The signal strength measurements may be in the form of, for example, a reference signal received power (RSRP), a reference signal received quality (RSRQ), and/or a signal to noise plus interference ratio (SINR).

[0055] In Example 10, a base station for operating as a macro cell eNB (e.g., in a Long Term Evolution (LTE) network), comprises: a radio transceiver for providing an air interface to user equipments (UEs); processing circuitry interfaced to the radio transceiver; wherein the processing circuitry is to connect to a UE as a serving cell for the UE and further to: transmit a measurement configuration to the UE instructing the UE to measure the signal strengths from the base station and one or more neighboring small cell eNBs and wherein the measurement configuration further instructs the UE to transmit a measurement report comprising information relating to the signal strength measurements when the signal strength measurements meet specified criteria of a measurement triggering event for a duration equal to the value of a time-to-trigger (TTT) parameter; and, instruct the UE to set the TTT parameter to a specified short TTT value unless the signal strength measurements are taken from a small cell eNB belonging to a cell list transmitted to the UE from the base station in which case the TTT parameter is set to a specified long TTT value. The specified short

TTT value is smaller than the specified long TTT value. The signal strength measurements may be in the form of, for example, a reference signal received power (RSRP), a reference signal received quality (RSRQ), and/or a signal to noise plus interference ratio (SINR).

- 5 **[0056]** In Example 11, the subject matter of claim 9 or any other Example described herein may optionally include wherein the processing circuitry is to transmit the short TTT value, long TTT value, and specified threshold as part of the measurement configuration transmitted using radio resource control (RRC) signaling.
- 10 **[0057]** In Example 12, the subject matter of claim 9 or any other Example described herein may optionally include wherein the processing circuitry is further instruct the UE to set the TTT parameter to the specified long TTT value if the signal strength measurements are taken from a small cell eNB belonging to a cell list transmitted to the UE from the base station.
- 15 **[0058]** In Example 13, an apparatus for a user equipment (UE) comprises a radio transceiver (that may be configured to provide a Long Term Evolution (LTE) air interface); processing circuitry interfaced to the radio transceiver; wherein the processing circuitry is to connect to a macro cell eNB as a serving cell for the UE and further to perform any the methods recited by Examples 1
- 20 through 8.
- [0059]** In Example 14, a non-transitory computer-readable medium comprises instructions to cause a user equipment (UE), upon execution of the instructions by processing circuitry of the UE, to perform any of the methods recited in Examples 1 through 8.
- 25 **[0060]** In Example 15, a method for operating a base station comprises the functions performed by the processing circuitry as recited in any of Examples 9 through 12.
- [0061]** In Example 16, a non-transitory computer-readable medium comprises instructions to cause a base station, upon execution of the instructions
- 30 by processing circuitry of the base station, to perform any of the methods recited in Example 15.

[0062] In Example 17, the subject matter of any of the examples described herein may include that the value of the long TTT value is a function of the mobility state and/or speed of the UE.

5 [0063] In Example 18, the subject matter of any of the examples described herein may include that the value of signal strength threshold for using the long TTT value is a function of the mobility state and/or speed of the UE.

[0064] The above detailed description includes references to the accompanying drawings, which form a part of the detailed description. The drawings show, by way of illustration, specific embodiments that may be practiced. These embodiments are also referred to herein as “examples.” Such examples may include elements in addition to those shown or described. However, also contemplated are examples that include the elements shown or described. Moreover, also contemplate are examples using any combination or permutation of those elements shown or described (or one or more aspects thereof), either with respect to a particular example (or one or more aspects thereof), or with respect to other examples (or one or more aspects thereof) shown or described herein.

[0065] Publications, patents, and patent documents referred to in this document are incorporated by reference herein in their entirety, as though individually incorporated by reference. In the event of inconsistent usages between this document and those documents so incorporated by reference, the usage in the incorporated reference(s) are supplementary to that of this document; for irreconcilable inconsistencies, the usage in this document controls.

[0066] In this document, the terms “a” or “an” are used, as is common in patent documents, to include one or more than one, independent of any other instances or usages of “at least one” or “one or more.” In this document, the term “or” is used to refer to a nonexclusive or, such that “A or B” includes “A but not B,” “B but not A,” and “A and B,” unless otherwise indicated. In the appended claims, the terms “including” and “in which” are used as the plain-English equivalents of the respective terms “comprising” and “wherein.” Also, in the following claims, the terms “including” and “comprising” are open-ended, that is, a system, device, article, or process that includes elements in addition to

those listed after such a term in a claim are still deemed to fall within the scope of that claim. Moreover, in the following claims, the terms “first,” “second,” and “third,” etc. are used merely as labels, and are not intended to suggest a numerical order for their objects.

[0067] The embodiments as described above may be implemented in various hardware configurations that may include a processor for executing instructions that perform the techniques described. Such instructions may be contained in a machine-readable medium such as a suitable storage medium or a memory or
5 other processor-executable medium.

[0068] The embodiments as described herein may be implemented in a number of environments such as part of a wireless local area network (WLAN), 3rd Generation Partnership Project (3GPP) Universal Terrestrial Radio Access Network (UTRAN), or Long-Term-Evolution (LTE) or a Long-Term-Evolution
10 (LTE) communication system, although the scope of the invention is not limited in this respect. An example LTE system includes a number of mobile stations, defined by the LTE specification as User Equipment (UE), communicating with a base station, defined by the LTE specifications as an eNodeB.

[0069] Antennas referred to herein may comprise one or more directional or
15 omnidirectional antennas, including, for example, dipole antennas, monopole antennas, patch antennas, loop antennas, microstrip antennas or other types of antennas suitable for transmission of RF signals. In some embodiments, instead of two or more antennas, a single antenna with multiple apertures may be used. In these embodiments, each aperture may be considered a separate antenna. In
20 some multiple-input multiple-output (MIMO) embodiments, antennas may be effectively separated to take advantage of spatial diversity and the different channel characteristics that may result between each of antennas and the antennas of a transmitting station. In some MIMO embodiments, antennas may be separated by up to 1/10 of a wavelength or more.

[0070] In some embodiments, a receiver as described herein may be
25 configured to receive signals in accordance with specific communication standards, such as the Institute of Electrical and Electronics Engineers (IEEE) standards including IEEE 802.11 standards and/or proposed specifications for WLANs, although the scope of the invention is not limited in this respect as they

may also be suitable to transmit and/or receive communications in accordance with other techniques and standards. In some embodiments, the receiver may be configured to receive signals in accordance with the IEEE 802.16-2004, the IEEE 802.16(e) and/or IEEE 802.16(m) standards for wireless metropolitan area networks (WMANs) including variations and evolutions thereof, although the scope of the invention is not limited in this respect as they may also be suitable to transmit and/or receive communications in accordance with other techniques and standards. In some embodiments, the receiver may be configured to receive signals in accordance with the Universal Terrestrial Radio Access Network (UTRAN) LTE communication standards. For more information with respect to the IEEE 802.11 and IEEE 802.16 standards, please refer to "IEEE Standards for Information Technology -- Telecommunications and Information Exchange between Systems" - Local Area Networks - Specific Requirements -- Part 11 "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY), ISO/IEC 8802-11: 1999", and Metropolitan Area Networks - Specific Requirements -- Part 16: "Air Interface for Fixed Broadband Wireless Access Systems," May 2005 and related amendments/versions. For more information with respect to UTRAN LTE standards, see the 3rd Generation Partnership Project (3GPP) standards for UTRAN-LTE, including variations and evolutions thereof.

[0071] The above description is intended to be illustrative, and not restrictive. For example, the above-described examples (or one or more aspects thereof) may be used in combination with others. Other embodiments may be used, such as by one of ordinary skill in the art upon reviewing the above description. The Abstract is to allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. Also, in the above Detailed Description, various features may be grouped together to streamline the disclosure. However, the claims may not set forth every feature disclosed herein as embodiments may feature a subset of said features. Further, embodiments may include fewer features than those disclosed in a particular example. Thus, the following claims are hereby incorporated into the Detailed Description, with a claim standing on its own as a separate embodiment. The scope of the

embodiments disclosed herein is to be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled.

CLAIMS

1. An apparatus of a user equipment (UE) device, comprising:

a radio transceiver;

processing circuitry interfaced to the radio transceiver;

5 wherein the processing circuitry is to connect to a macro cell eNB as a serving cell for the UE and further to:

receive a measurement configuration from the macro cell eNB instructing the UE to measure a signal strength from the macro cell eNB and one or more neighboring small cell eNBs and wherein the measurement configuration further
10 instructs the UE to transmit a measurement report comprising information relating to the signal strength measurements when the signal strength measurements meet specified criteria of a measurement triggering event for a duration equal to the value of a time-to-trigger (TTT) parameter; and,

set the TTT parameter to a specified short TTT value unless the signal
15 strength measurement from the macro cell eNB is above a specified threshold value in which case the TTT parameter is set to a specified long TTT value, wherein the short TTT value is smaller than the long TTT value.
2. The apparatus of claim 1 wherein the processing circuitry is to receive
20 the short TTT value and long TTT value from the macro cell eNB.
3. The apparatus of claim 1 wherein the processing circuitry is to receive the specified threshold value from the macro cell eNB.
- 25 4. The apparatus of claim 1 wherein the processing circuitry is to receive the short TTT value, long TTT value, and specified threshold as part of the

measurement configuration transmitted from the macro cell eNB using radio resource control (RRC) signaling.

5. The apparatus of claim 1 wherein the processing circuitry is further to set the TTT parameter to the specified long TTT value if the signal strength measurements are taken from a small cell eNB belonging to a cell list received by the UE from the macro cell eNB.
6. The apparatus of any of claims 1 through 5 wherein the processing circuitry is to measure small cell eNB signal strength during a specified measurement gap.
7. The apparatus of any of claims 1 through 5 wherein the processing circuitry is to measure small cell eNB and macro cell eNB signal strengths at different frequencies.
8. The apparatus of any of claims 1 through 5 wherein the macro cell eNB and small cell eNB signal strength measurements are a reference signal received power (RSRP), a reference signal received quality (RSRQ), or a signal to noise plus interference ratio (SINR).
9. The apparatus of any of claims 1 through 5 wherein the value of the long TTT value is a function of the UE's speed.
10. An apparatus of a base station for operating as a macro cell eNB, comprising:
 - a radio transceiver for providing an air interface to user equipments (UEs);

processing circuitry interfaced to the radio transceiver;

wherein the processing circuitry is to connect to a UE as a serving cell for the UE and further to:

transmit a measurement configuration to the UE instructing the UE to
5 measure signal strengths from the base station and one or more neighboring
small cell eNBs and wherein the measurement configuration further instructs the
UE to transmit a measurement report comprising information relating to the
signal strength measurements when the signal strength measurements meet
specified criteria of a measurement triggering event for a duration equal to the
10 value of a time-to-trigger (TTT) parameter; and,

instruct the UE to set the TTT parameter to a specified short TTT value
unless the signal strength measurement from the base station is above a specified
threshold value in which case the TTT parameter is set to a specified long TTT
value, wherein the short TTT value is smaller than the long TTT value.

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11. The apparatus of claim 10 wherein the processing circuitry is to transmit
the short TTT value, long TTT value, and specified threshold as part of the
measurement configuration transmitted using radio resource control (RRC)
signaling.

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12. The apparatus of claim 10 wherein the processing circuitry is further to
instruct the UE to set the TTT parameter to the specified long TTT value if
signal strength measurements are taken from a small cell eNB belonging to a cell
list transmitted to the UE from the base station.

25

13. A computer-readable medium comprising instructions to cause a user
equipment (UE), upon execution of the instructions by processing circuitry of
the UE, to:

connect to a macro cell eNB as a serving cell for the UE;

receive a measurement configuration from the macro cell eNB instructing the UE to measure a signal strength from the macro cell eNB and one or more neighboring small cell eNBs and wherein the measurement configuration further
5 instructs the UE to transmit a measurement report comprising information relating to the signal strength measurements when the signal strength measurements meet specified criteria of a measurement triggering event for a duration equal to the value of a time-to-trigger (TTT) parameter; and,

set the TTT parameter to a specified short TTT value unless the signal
10 strength measurement from the macro cell eNB is above a specified threshold value in which case the TTT parameter is set to a specified long TTT value, wherein the short TTT value is smaller than the long TTT value.

14. The medium of claim 13 further comprising instructions to receive the
15 short TTT value and long TTT value from the macro cell eNB.

15. The medium of claim 13 further comprising instructions to receive the specified threshold value from the macro cell eNB.

20 16. The medium of claim 13 further comprising instructions to receive the short TTT value, long TTT value, and specified threshold as part of the measurement configuration transmitted from the macro cell eNB using radio resource control (RRC) signaling.

25 17. The medium of claim 13 further comprising instructions to set the TTT parameter to the specified long TTT value if the signal strength measurements are taken from a small cell eNB belonging to a cell list received by the UE from the macro cell eNB.

18. The medium of any of claims 13 through 17 further comprising instructions to measure small cell eNB signal strength during a specified measurement gap.

5

19. The medium of any of claims 13 through 17 further comprising instructions to measure small cell eNB and macro cell eNB signal strengths at different frequencies.

10 20. The medium of any of claims 13 through 17 further comprising instructions such that the macro cell eNB and small cell eNB signal strength measurements are a reference signal received power (RSRP), a reference signal received quality (RSRQ), or a signal to noise plus interference ratio (SINR).

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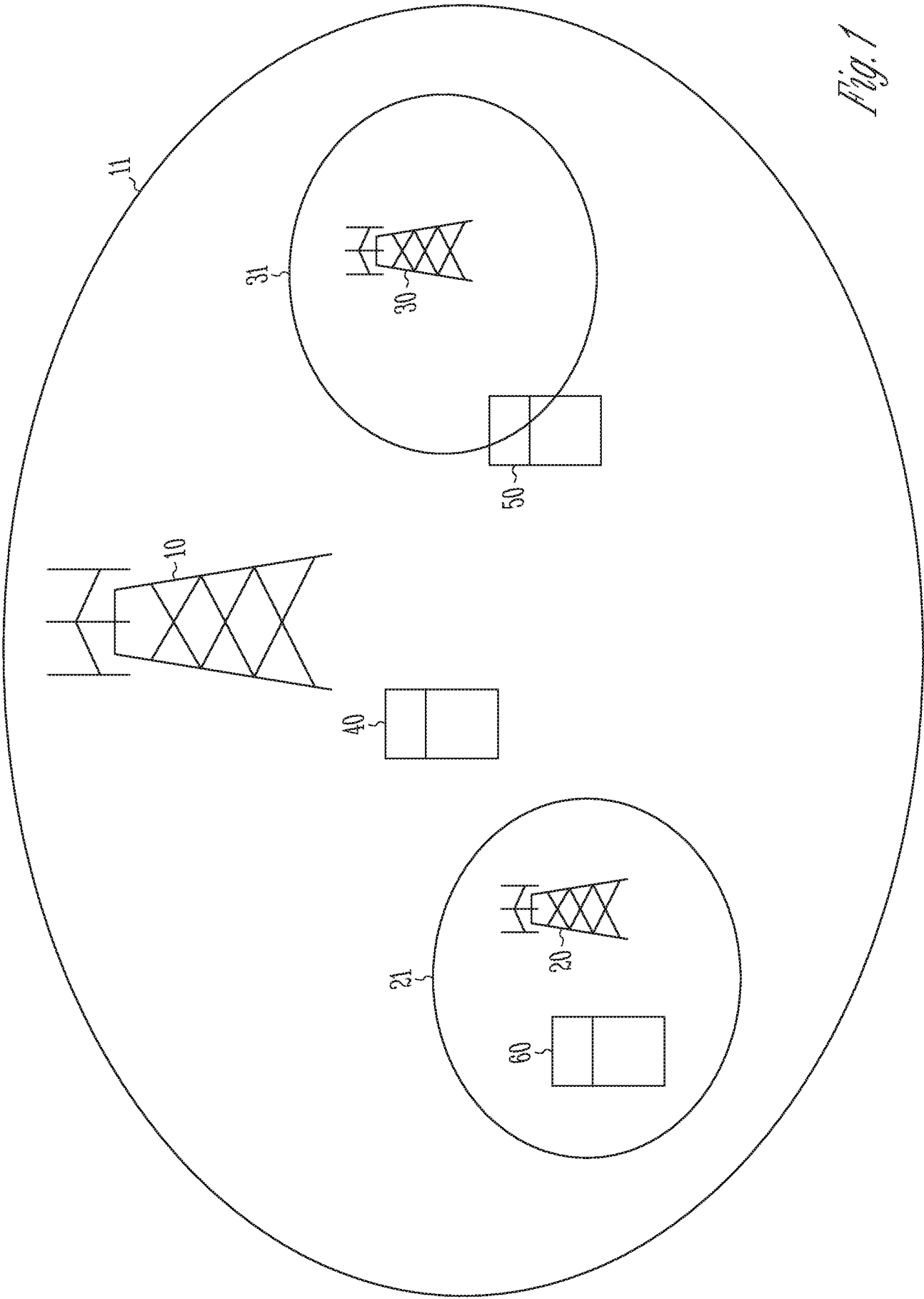
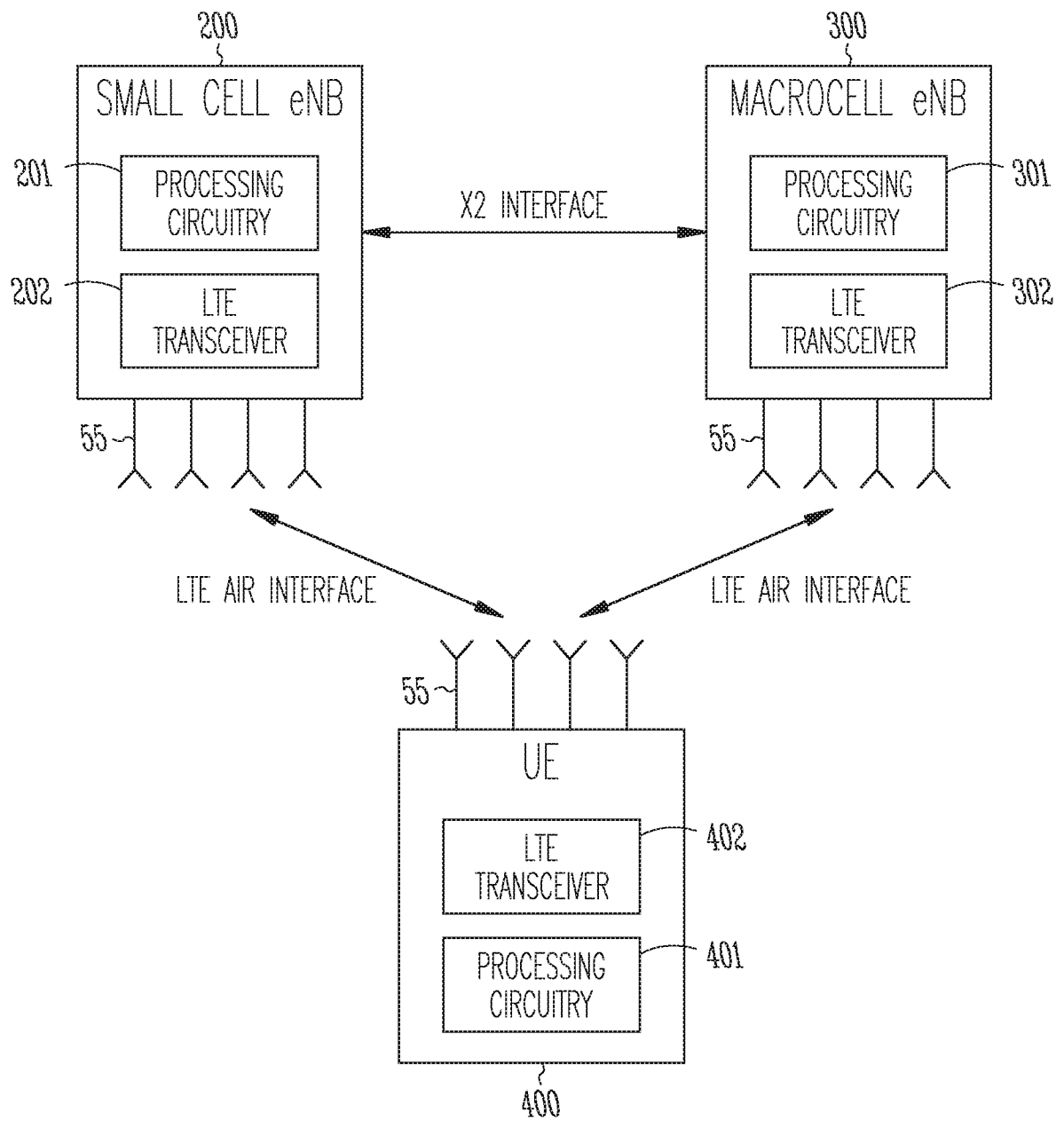
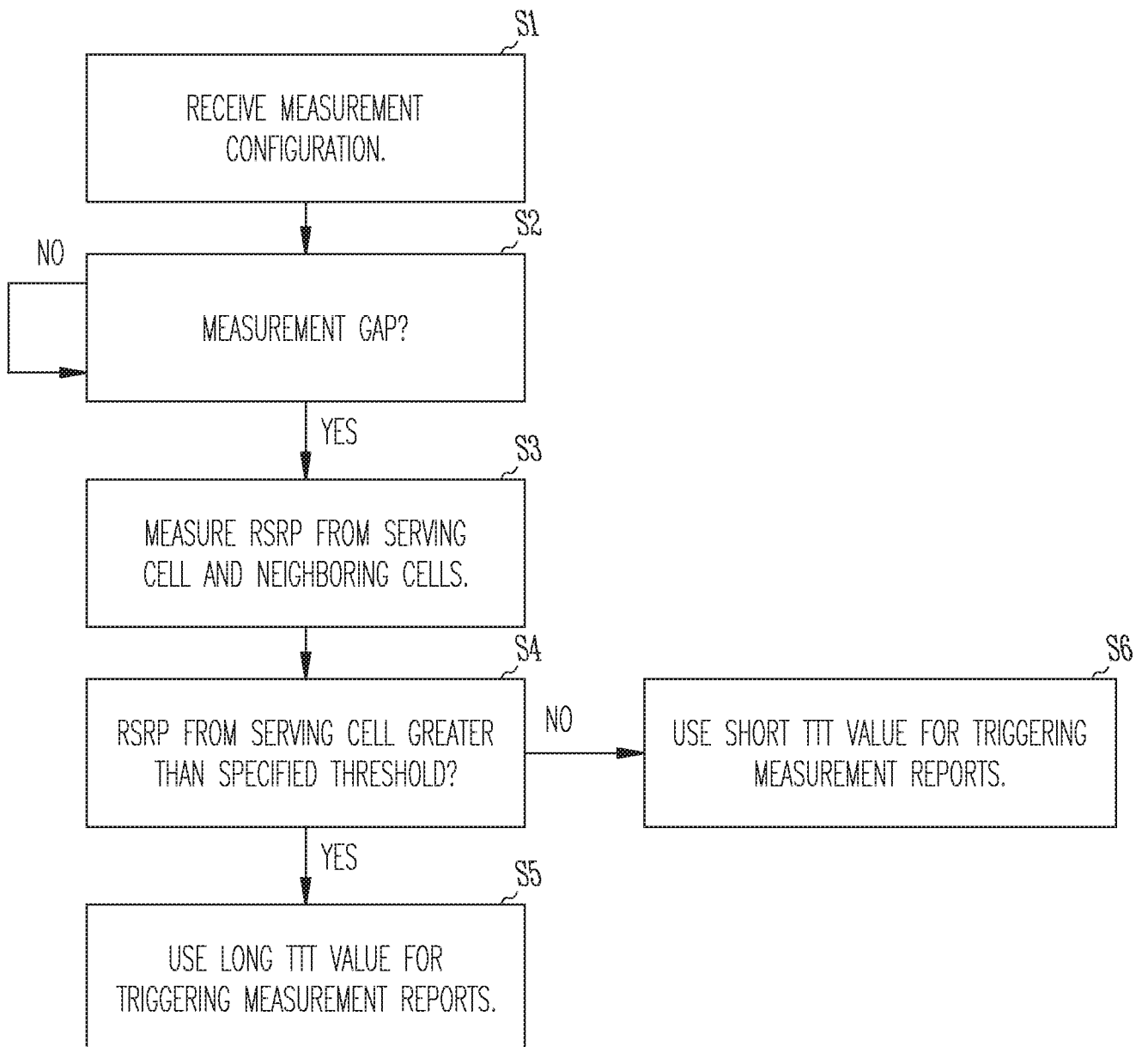


Fig. 1

*Fig. 2*

*Fig. 3*

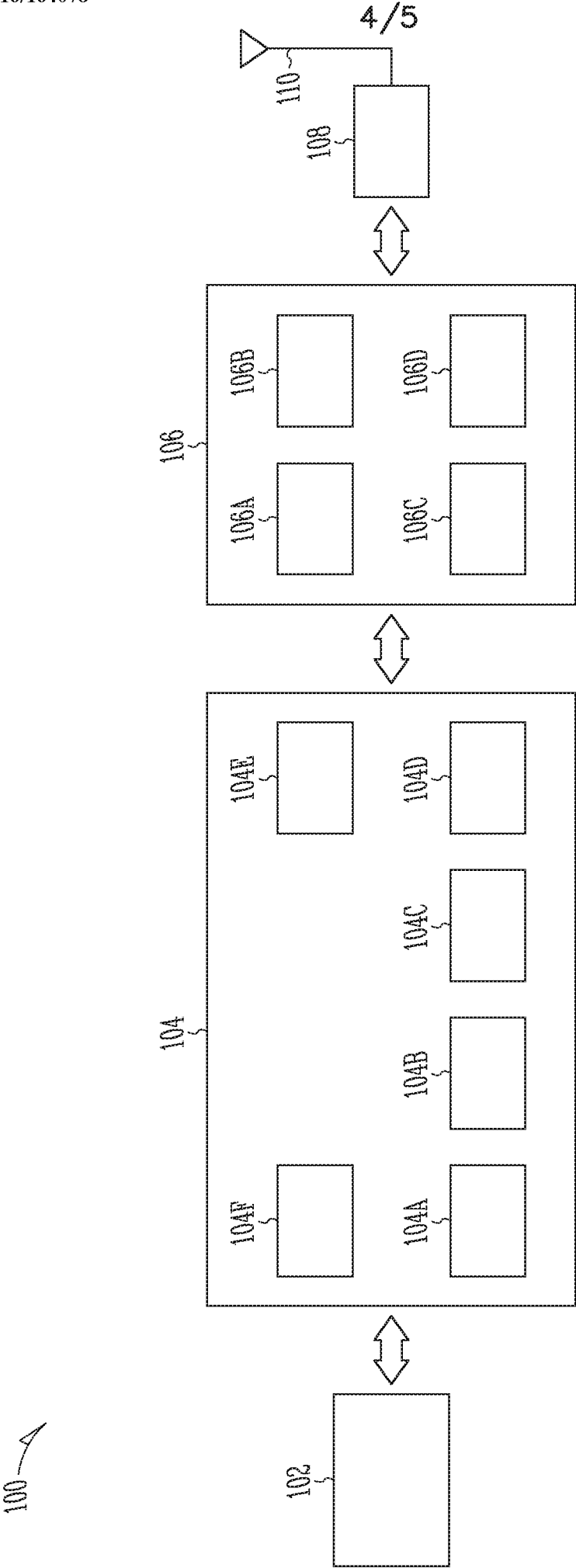
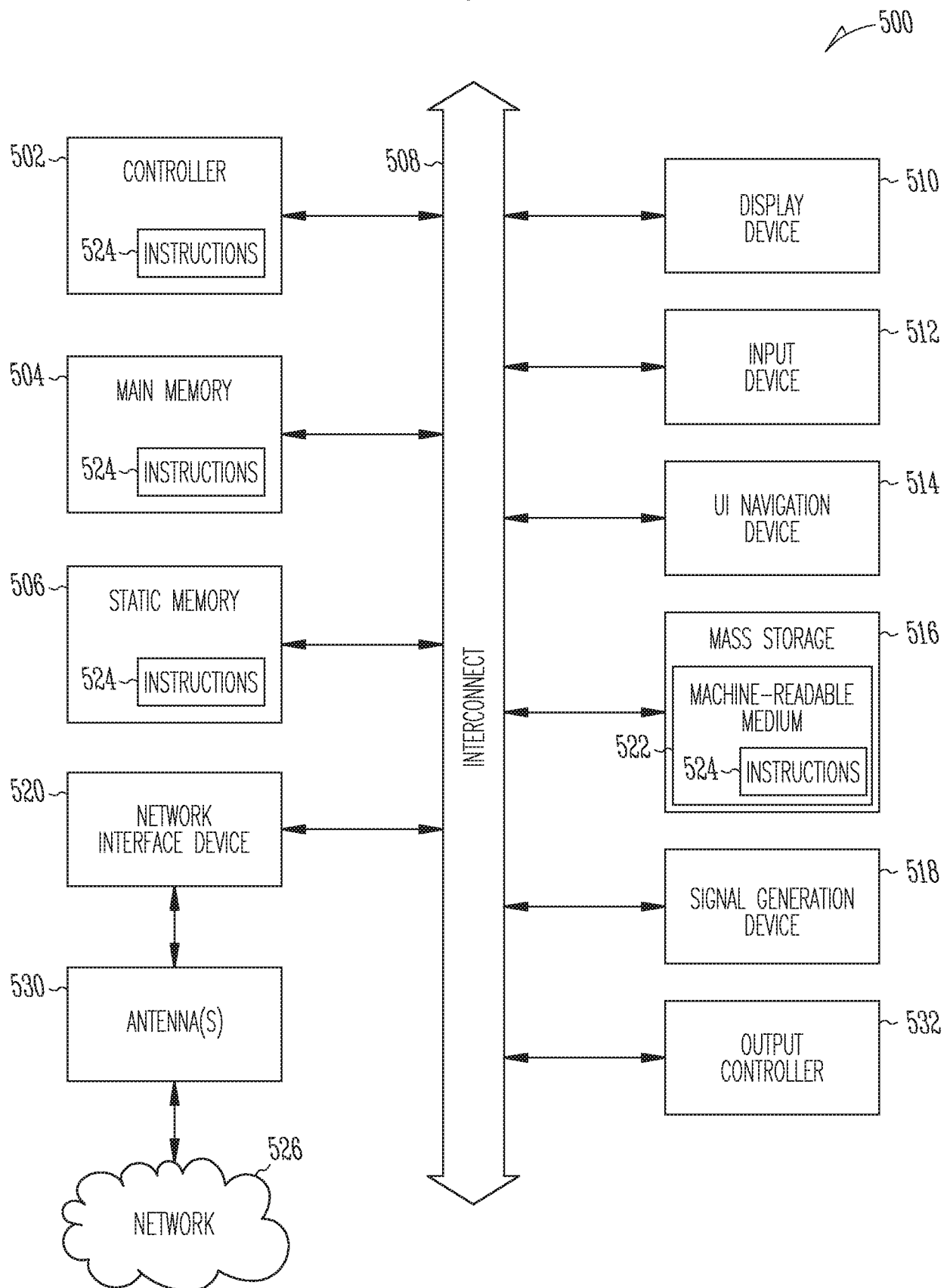


Fig. 4

5/5

*Fig. 5*

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/065087**A. CLASSIFICATION OF SUBJECT MATTER****H04W 36/00(2009.01)i, H04W 36/30(2009.01)i, H04W 24/10(2009.01)i, H04W 88/02(2009.01)i**

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 36/00; H04Q 7/00; H04W 24/10; H04Q 7/20; H04J 3/00; H04W 36/30; H04W 36/24; H04W 88/02

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: measurement configuration, RSRP, a time-to-trigger (TTT) parameter, report, threshold

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2015-0045036 A1 (QUALCOMM INCORPORATED) 12 February 2015 See paragraphs [0039], [0056]–[0060]; claims 1, 15; and figure 6.	1–20
Y	US 2009-0059871 A1 (ALI G. NADER et al.) 05 March 2009 See paragraphs [0026]–[0029]; and claim 1.	1–20
Y	US 2014-0092873 A1 (RENESAS MOBILE CORPORATION) 03 April 2014 See paragraphs [0021]–[0022], [0025], [0030], [0039]; and figures 3–4.	3–4, 7–8, 11, 15–16, 19–20
Y	US 2007-0097914 A1 (FRANCESCO GRILLI et al.) 03 May 2007 See paragraphs [0044], [0048]; and figure 5.	6, 18
Y	US 2010-0298001 A1 (KONSTANTINOS DIMOU et al.) 25 November 2010 See paragraph [0008]; and claim 23.	9



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

20 March 2016 (20.03.2016)

Date of mailing of the international search report

21 March 2016 (21.03.2016)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea

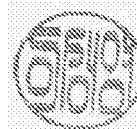


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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/065087

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