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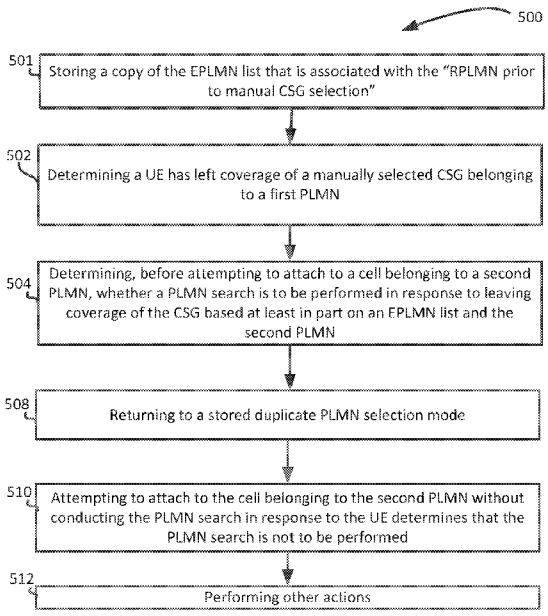


Fig. 5

(57) Abstract: Embodiments provide computer readable media having instructions that, when executed, cause a user equipment to determine the UE has left coverage of a manually selected closed subscriber group (CSG) belonging to a first public land mobile network (PLMN) and determine, before attempting to register with a cell belonging to a second PLMN, whether a PLMN search is to be performed in response to leaving coverage of the CSG, based at least in part on an equivalent PLMN list and the second PLMN. Other embodiments may be described and/or claimed.

RECOVERY AFTER LOSS OF CLOSED SUBSCRIBER GROUP COVERAGE USING EQUIVALENT PLMN LIST

TECHNICAL FIELD

Embodiments described herein generally relate to the field of wireless communications systems and, in particular, to the handling of the loss of closed subscriber group coverage in a wireless communications system.

BACKGROUND

Implementations of the disclosure generally may relate to the field of wireless communications.

BRIEF DESCRIPTION OF THE DRAWINGS

Aspects, features and advantages of embodiments of the present disclosure will become apparent from the following description of embodiments in reference to the appended drawings in which like numerals denote like elements and in which:

Figure 1 shows a schematic diagram of network coverage for a user equipment (UE), according to various embodiments;

Figure 2 shows a schematic diagram of network coverage for a UE, according to some embodiments;

Figure 3 shows a schematic diagram of network coverage for a UE, according to various embodiments;

Figure 4 shows an example implementation of an electronic device in accordance with some embodiments;

Figure 5 shows an example method in accordance with some embodiments; and

Figure 6 shows a diagrammatic representation of hardware resources according to various embodiments.

DETAILED DESCRIPTION

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. In the following description, for purposes of explanation and not limitation, specific details are set forth such as particular structures, architectures, interfaces, techniques, etc. in order to provide a thorough understanding of the various aspects of the present disclosure. However, it will be apparent to those skilled in the art having the benefit of the present disclosure that the various aspects of the claims may be practiced in

other examples that depart from these specific details. In certain instances, descriptions of well-known devices, circuits, and methods are omitted so as not to obscure the description of the present disclosure with unnecessary detail.

Generally, wireless telecommunications services are offered by public land mobile network (PLMN) operators, and a closed subscriber group (CSG) identifies subscribers of an operator who are permitted to access one or more cells of the PLMN that have restricted access (CSG cells). The wireless telecommunication services may be provided to users (subscribers) of user equipment (UEs) in a variety of contexts that may include macro cells, pico cells, and CSG cells. Macro cells are outdoor cells with a large cell radius, pico cells are mainly indoor cells, with a radius typically less than 50 meters, and CSG cells broadcast a specific CSG Identity (CSGID) and are accessible by the members of the CSG identified by that CSGID. There is an automatic mode and a manual mode of CSG selection. Various embodiments may relate to handling loss of CSG coverage after manual CSG selection where a UE presents a list of available CSGs to a user and the user manually selects a CSG from the presented list for registration. Registration is the process of camping on a cell of the PLMN and doing any necessary location registrations (LRs) by which the UE registers its presence in a registration area. The location registration may occur regularly and/or when entering a registration area. The PLMN for which the UE has most recently performed a location registration successfully is the registered PLMN (RPLMN). When registering with a CSG cell, a UE may store a copy of the previous RPLMN (duplicate RPLMN) before storing the PLMN of the CSG cell as the RPLMN so the UE can still use the duplicate RPLMN for further action and/or revert to the duplicate RPLMN upon leaving the CSG cell.

Each UE may store an equivalent PLMN (EPLMN) list. This list is typically replaced or deleted at the end of each location update procedure, routing area update procedure, GPRS attach procedure, tracking area update procedure, and evolved packet system (EPS) attach procedure. In various embodiments, the terms “to attach” and “to register” may be used as synonyms, unless “attach” is referring to a GPRS attach or EPS attach procedure. The EPLMN list includes a list of EPLMNs as downloaded to the UE by the network plus a PLMN code of the RPLMN that downloaded the EPLMN list to the UE. Generally, all PLMNs in the stored EPLMN list are regarded as equivalent to each other for PLMN selection, cell selection/re-selection and handover. The EPLMN list may be provided to the UE from a network component such as a serving general packet radio

service (GPRS) support node (SGSN), mobile switching center (MSC), or mobility management entity (MME). The EPLMN list may be signaled to the UE as part of a location area update, routing area update, tracking area update, or attach procedure. The EPLMN list may be included in a Location Updating Accept, Routing Area Updating Accept, Tracking Area Updating Accept, Attach Accept, or other message type.

Legacy wireless communications networks provide procedures for manual CSG selection within an RPLMN and manual CSG selection in a PLMN different from the RPLMN. In these procedures, if a UE leaves CSG coverage a fallback action is specified to get service on the RPLMN prior to manual CSG selection. However, in some situations relating to manual CSG selection in a PLMN different from the RPLMN, there are some cases where as part of the fallback action the UE would unnecessarily attempt to find a suitable cell on a PLMN (RPLMN prior to manual CSG selection) when the access stratum (AS) has already found a suitable cell within an equivalent PLMN (EPLMN) list (e.g., based on regular neighbor cell measurements and suitability criteria) and re-selected to it. In these cases, unnecessary search and wasting of the UE's battery may be performed by the UE as well as interruption in being able to receive paging messages may occur, affecting the UE's reachability, if the UE does not support parallel PLMN search while already camping on a suitable cell (e.g., if a UE is not capable of performing a PLMN search without any interruption to paging).

In various embodiments, it may be determined whether the PLMN search is to be performed based at least in part on an EPLMN list. In some embodiments, this determination may reduce the unnecessary search and wasting of the UE's battery as well as the reachability of UE's without support for parallel PLMN search.

Figure 1 shows a schematic diagram of network coverage 100 for a UE 102 according to various embodiments. In some embodiments, the network coverage 100 may include a first macro cell 104, a second macro cell 106, and a CSG cell 108.

In various embodiments, the first macro cell 104 may belong to a first PLMN, the second macro cell 106 may belong to a second PLMN, and the CSG cell 108 may belong to the second PLMN. For convenience, the first PLMN is designated as PLMN X and the second PLMN is designated as PLMN Y. In some embodiments, the UE 102 may be located at a first location 110 covered by both the first macro cell 104 and the CSG cell 108 when manual CSG selection is performed by a user. In various embodiments, before manual CSG selection is performed, the UE 102 may have been camped on the first macro

cell 104. Thus, the RPLMN of the UE 102 would be the first PLMN (PLMN X). In some embodiments, an EPLMN list 109 associated with the first PLMN may be received by the UE 102 when the first PLMN becomes the RPLMN of the UE during registration at the first macro cell 104. In various embodiments, the EPLMN list 109 associated with the first PLMN may include the first PLMN (PLMN X), the second PLMN (PLMN Y), and a third PLMN (PLMN Z).

In various embodiments, the UE 102 may camp on the CSG cell 108 after successful registration with the CSG cell 108. In some embodiments, the PLMN of the CSG cell 108 (e.g., the second PLMN) may have an EPLMN list 111 that includes the first PLMN (PLMN X), the second PLMN (PLMN Y),and the third PLMN (PLMN Z), with the second PLMN (PLMN Y) being the RPLMN of the UE 102 after successful registration with the CSG cell 108. The EPLMN list 111 associated with the PLMN of the CSG cell 108 may be received by the UE 102 during registration with the CSG cell 108. In various embodiments, the UE 102 may move from the first location 110 to a second location 112 where the UE 102 may leave coverage of the CSG cell 108.

In some embodiments, cell reselection may occur from the CSG cell 108 to the second macro cell 106 at the second location 112. In various embodiments, if both the PLMN of the second macro cell 106 (e.g., the second PLMN (PLMN Y) in this case) and the PLMN of the first macro cell 104 (e.g., the first PLMN (PLMN X) in this case) are part of the EPLMN list 111 associated with the PLMN of the CSG cell 108, and if the second PLMN (PLMN Y) is part of the EPLMN list 109 associated with the PLMN of the first macro cell 104, then a PLMN search may not be performed in various embodiments to find the first PLMN (PLMN X) when the UE leaves coverage of the CSG cell 108 and reselection occurs at the second position 112. In the situation shown, the PLMN search may not be performed because both the PLMN of the second macro cell 106 (PLMN Y) and the PLMN of the first macro cell 104 (PLMN X) are part of the EPLMN list 111 associated with the PLMN of the CSG cell 108, which includes PLMN X, PLMN Y, and PLMN Z, and the second PLMN (PLMN Y) is part of the EPLMN list 109 associated with the PLMN of the first macro cell 104, which includes PLMN X, PLMN Y, and PLMN Z.

Figure 2 shows a schematic diagram of network coverage 200 for a UE 202 according to various embodiments. In similar fashion to that described with respect to Figure 1, the network coverage 200 may include a first macro cell 204, a second macro cell 206, and a CSG cell 208. In some embodiments, the first macro cell 204 may belong

to the first PLMN (PLMN X), the CSG cell 208 may belong to the second PLMN (PLMN Y), and the second macro cell 206 may belong to the third PLMN (PLMN Z). In some embodiments, the UE 202 may be located at a first location 210 covered by both the first macro cell 204 and the CSG cell 208 when manual CSG selection is performed by a user. In various embodiments, before manual CSG selection is performed, the UE 202 may have been camped on the first macro cell 204. Thus, the RPLMN of the UE 202 would be the first PLMN (PLMN X). In some embodiments, an EPLMN list 209 associated with the first PLMN may be received by the UE 202 when the first PLMN becomes the RPLMN of the UE 202 during registration at the first macro cell 204. In various embodiments, the EPLMN list 209 associated with the first PLMN may include the first PLMN (PLMN X), the second PLMN (PLMN Y), and the third PLMN (PLMN Z).

In various embodiments, the UE 202 may camp on the CSG cell 208 after successful registration with the CSG cell 208. In some embodiments, the PLMN of the CSG cell 208 may have an EPLMN list 211 that includes the first PLMN (PLMN X), the second PLMN (PLMN Y), and the third PLMN (PLMN Z), with the second PLMN (PLMN Y) being the RPLMN of the UE 202 after successful registration with the CSG cell 208. The EPLMN list 211 associated with the PLMN of the CSG cell 208 may be received by the UE 202 during registration with the CSG cell 208. In various embodiments, the UE 202 may move from the first location 210 to a second location 212 where the UE 202 may leave coverage of the CSG cell 208.

In some embodiments, cell reselection may occur from the CSG cell 208 to the second macro cell 206 at the second location 212. In various embodiments, if both the PLMN of the second macro cell 206 (e.g., the third PLMN (PLMN Z) in this case) and the PLMN of the first macro cell 204 (e.g., the first PLMN (PLMN X) in this case) are part of the EPLMN list 211 associated with the PLMN of the CSG cell 208, and if the second PLMN (PLMN Y) is part of the EPLMN list 209 associated with the PLMN of the first macro cell 204, then a PLMN search may not be performed in various embodiments to find the first PLMN (PLMN X) when the UE 202 leaves coverage of the CSG cell 208 and reselection occurs at the second position 212.

Figure 3 shows a schematic diagram of network coverage 300 for a UE 302 according to various embodiments. In similar fashion to that described with respect to Figures 1 and 2, network coverage 300 may include a first macro cell 304, a second macro cell 306, and a CSG cell 308. In some embodiments, the first macro cell 304 may belong

to the first PLMN (PLMN X), the CSG cell 308 may belong to the second PLMN (PLMN Y), and the second macro cell 306 may belong to the third PLMN (PLMN Z). In some embodiments, the UE 302 may be located at a first location 310 covered by both the first macro cell 304 and the CSG cell 308 when manual CSG selection is performed by a user. In various embodiments, before manual CSG selection is performed, the UE 302 may have been camped on the first macro cell 304. Thus, the RPLMN of the UE 302 would be the first PLMN (PLMN X). In some embodiments, an EPLMN list 309 associated with the first PLMN may be received by the UE 302 when the first PLMN becomes the RPLMN of the UE 302 during registration at the first macro cell 304. In various embodiments, the EPLMN list 309 associated with the first PLMN may include the first PLMN (PLMN X) and the second PLMN (PLMN Y), but not the third PLMN (PLMN Z).

In various embodiments, the UE 302 may camp on the CSG cell 308 after successful registration with the CSG cell 308. In some embodiments, the PLMN of the CSG cell 308 may have an EPLMN list 311 that includes the first PLMN (PLMN X), the second PLMN (PLMN Y), and the third PLMN (PLMN Z), with the second PLMN (PLMN Y) being the RPLMN of the UE 302 after successful registration with the CSG cell 308. The EPLMN list 311 associated with the PLMN of the CSG cell 308 may be received by the UE 302 during registration with the CSG cell 308. In various embodiments, the UE 302 may move from the first location 310 to a second location 312 where the UE 302 may leave coverage of the CSG cell 308.

In some embodiments, cell reselection may occur from the CSG cell 308 to the second macro cell 306 at the second location 312. In various embodiments, if both the PLMN of the second macro cell 306 (e.g., the third PLMN (PLMN Z) in this case) and the PLMN of the first macro cell 304 (e.g., the first PLMN (PLMN X) in this case) are part of the EPLMN list 311 associated with the PLMN of the CSG cell 308, and if the second PLMN (PLMN Y) is part of the EPLMN list 309 associated with the PLMN of the first macro cell 304, then a PLMN search may not be performed in various embodiments to find the first PLMN (PLMN X) when the UE 302 leaves coverage of the CSG cell 308 and reselection occurs at the second position 312.

In some embodiments, the AS or radio layer in the user equipment 102, 202, or 302 may perform cell reselection based at least in part on one or more of the EPLMN lists 109, 111, 209, 211, 309, or 311. In various embodiments, at any particular point in time, the cell reselection process may use just one of the EPLMN lists 109, 111, 209, 211, 309,

or 311. In some embodiments, more than one of the EPLMN lists 109, 111, 209, 211, 309, or 311 may be used to determine whether a PLMN search is to be performed in response to leaving coverage of a CSG and/or used to determine whether other actions are to be performed. Initially, the UE 102, 202, or 302 may be camping on the manually selected CSG cell 108, 208, or 308, respectively of the CSG PLMN. Then, due to cell reselection, the UE 102, 202, or 302 may move to a new cell (e.g., macro cell 106, 206, or 306) that is not a CSG cell, and the AS may inform mobility management in the non-access stratum (NAS) in the UE 102, 202, or 302 about this change, indicating the PLMN identity and cell identity of the new cell. In various embodiments, the AS may also inform mobility management in the NAS about the location area identity and/or tracking area identity, and may indicate that the new cell is not a CSG cell such that the UE 102, 202, or 302 may determine it is no longer within coverage of the selected CSG. In some embodiments, if the AS loses coverage of its current cell and cannot find a cell belonging to one of the EPLMNs, that may include the RPLMN, the AS may inform the NAS that the NAS needs to perform a PLMN selection.

In various embodiments, if the UE 102, 202, or 302 is no longer in the coverage of the selected CSG (e.g., CSG cell 108, 208, or 308) and finds a new cell in an EPLMN, then if a stored duplicate RPLMN is not part of the current EPLMN list, the UE 102, 202, or 302 may return to a stored duplicate PLMN selection mode (e.g., manual or automatic PLMN selection mode in effect before manually selecting the CSG cell) and use the stored duplicate value of RPLMN as RPLMN for further action (e.g., for PLMN selection and cell selection/re-selection). If the stored duplicate RPLMN is part of the current EPLMN list, then the UE 102, 202, or 302 may return to the stored duplicate PLMN selection mode, but stay on the current PLMN and delete the stored duplicate RPLMN. In some embodiments, if the UE 102, 202, or 302 is no longer in the coverage of the selected CSG and could not find a new cell in an EPLMN, then the UE 102 may return to the stored duplicate selection mode and use the stored duplicate value of RPLMN for further action.

In some embodiments, the UE 102, 202, or 302 may be registered with a first PLMN with a first EPLMN list (e.g., EPLMN list 109, 209, or 309) before a user initiates manual CSG selection. At this point, the current EPLMN list may be the first EPLMN list and the current PLMN may be the first PLMN and may be the RPLMN in various embodiments. In some embodiments, the UE 102, 202, or 302 may then perform a scan for CSG cells. In a manual CSG selection process, a user may select a CSG from among any

CSGs found during the scan for CSG cells in some embodiments. In various embodiments, the user-selected CSG cell may belong to a second PLMN different from the first PLMN. In some embodiments, the UE 102, 202, or 302 may then perform successful registration to the selected CSG cell (and the second PLMN) and may receive a second EPLMN list (e.g., EPLMN list 111, 211, or 311). In various embodiments, at this point, the current EPLMN list may be the second EPLMN list and the current PLMN may be the second PLMN and may be the RPLMN. In some embodiments, the UE 102, 202, or 302 may then reselect to a non-CSG cell (e.g., macro cell 106, 206, or 306) belonging to a third PLMN from the second EPLMN list or the UE 102, 202, or 302 may lose coverage of the CSG cell and not find any cell belonging to a PLMN from the second EPLMN list.

In various embodiments, a PLMN search may be skipped in a number of situations. In a first situation, a PLMN search may be skipped when the CSG PLMN belongs to the EPLMN list associated with the RPLMN prior to manual CSG selection (e.g., EPLMN list 109, 209, or 309), the RPLMN prior to manual CSG selection belongs to the EPLMN list associated with the CSG PLMN during registration to the CSG cell (e.g., EPLMN list 111, 211, or 311), and the PLMN associated with the cell to which selection is being considered (e.g., macro cell 106, 206, or 306) belongs to the EPLMN list associated with the CSG PLMN during registration to the CSG cell. In various embodiments, the check relating to whether the CSG PLMN belongs to the EPLMN list associated with the RPLMN prior to manual CSG selection may be performed before registration with the CSG PLMN (before that EPLMN list has been overwritten), or a copy of the EPLMN list associated with the RPLMN prior to manual CSG selection can be stored and the check can be performed later using the copy (duplicate). In some embodiments, the check of whether the PLMN associated with the cell to which selection is being considered belongs to the EPLMN list associated with the CSG PLMN during registration may be performed on an AS level and the other two checks may be performed on a NAS level. In various embodiments, the check of whether the RPLMN prior to manual CSG selection belongs to the EPLMN list associated with the CSG PLMN during registration may be performed before or after the check performed by the AS. This check may be performed either when the UE 102, 202, or 302 is receiving the EPLMN list associated with the CSG PLMN during registration to the CSG cell from the network, or later when the AS indicates that the UE 102, 202, or 302 has left the CSG cell and moved to a new cell of the EPLMN list associated with the CSG PLMN during registration to the CSG cell. In some embodiments, the check of

whether the CSG PLMN belongs to the EPLMN list associated with the RPLMN prior to manual CSG selection may also be performed before or after the check performed by the AS if the UE 102, 202, or 302 is storing a copy of the EPLMN list associated with the RPLMN prior to manual CSG selection. In some embodiments, the check relating to the EPLMN list associated with the RPLMN prior to manual CSG selection may be performed before registration to the CSG cell and the EPLMN list may be overwritten with the EPLMN list associated with the CSG PLMN during registration to the CSG cell without storing a copy of the EPLMN list associated with the RPLMN prior to manual CSG selection.

In a second situation, the PLMN search may be skipped when the RPLMN prior to manual CSG selection belongs to the EPLMN list associated with the CSG PLMN during registration to the CSG cell (e.g., EPLMN list 111, 211, or 311) and the PLMN associated with the cell to which selection is being considered belongs to the EPLMN list associated with the CSG PLMN during registration to the CSG cell. In various embodiments, the checks relating to skipping of the PLMN search in the second situation are similar to the checks performed in the first situation but do not include checking whether the CSG PLMN belongs to the EPLMN list associated with the RPLMN prior to manual CSG selection (e.g., EPLMN list 109, 209, or 309).

In a third situation, the PLMN search may be skipped when the PLMN associated with the cell to which selection is being considered (e.g., macro cell 106, 206, or 306) belongs to the EPLMN list associated with the RPLMN prior to manual CSG selection (e.g., EPLMN list 109, 209, or 309). In this situation, the check would be performed with a stored copy (duplicate) of the EPLMN list associated with the RPLMN prior to manual CSG selection which would otherwise not be accessible because it would have been overwritten with the EPLMN list associated with the CSG PLMN during registration to the CSG cell (e.g., EPLMN list 111, 211, or 311). In various embodiments, the checks and associated skipping of the PLMN search relating to the third situation may be combined with the checks of one or more of the checks described with respect to the first and/or second situations. In some embodiments, the EPLMN list associated with the RPLMN prior to manual CSG selection may be stored when the subscriber selects the CSG. In embodiments, when the UE 102, 202, or 302 loses coverage of the CSG, it may revert to the duplicate RPLMN and to the stored EPLMN list.

Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software. Figure 4 illustrates example components of an electronic device 400 in accordance with various embodiments. In embodiments, the electronic device 400 may be, implement, be incorporated into, or otherwise be a part of a user equipment (UE) (e.g., UE 102), base station (BS) such as an evolved NodeB (eNB), a RAN controller, or some other electronic device or network entity that is capable and arranged to perform the disclosed techniques, methods, and/or functions relating to the loss of CSG handling using an EPLMN list. In some embodiments, the electronic device 400 may include application circuitry 410, control circuitry, such as baseband circuitry 420, Radio Frequency (RF) circuitry 430, front-end module (FEM) circuitry 440 and one or more antennas 450, coupled together at least as shown.

The application circuitry 410 may include one or more application processors. For example, the application circuitry 410 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.

The baseband circuitry 420 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 420 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 430 and to generate baseband signals for a transmit signal path of the RF circuitry 430. Baseband processing circuity 420 may interface with the application circuitry 410 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 430. For example, in some embodiments, the baseband circuitry 420 may include a second generation (2G) baseband processor 421, third generation (3G) baseband processor 422, fourth generation (4G) baseband processor 423, and/or other baseband processor(s) 424 for other existing generations, generations in development or to be developed in the future (e.g., fifth generation (5G), 6G, etc.). The baseband circuitry 420 (e.g., one or more of baseband processors 421-424) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 430. 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 420 may include Fast-Fourier Transform (FFT), precoding, and/or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 420 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 other suitable functionality in other embodiments.

In some embodiments, the baseband circuitry 420 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 (RLC), packet data convergence protocol (PDCP), radio resource control (RRC) elements, and/or Non-Access Stratum (NAS) elements. A central processing unit (CPU) 426 of the baseband circuitry 420 may be configured to run elements of the protocol stack for signaling of the PHY, MAC, RLC, PDCP and/or RRC Layers, and/or NAS. In some embodiments, the baseband circuitry may include one or more audio digital signal processor(s) (DSP) 427. The audio DSP(s) 427 may be include elements for compression/decompression and echo cancellation and may include other suitable processing elements in other embodiments.

The baseband circuitry 420 may further include memory/storage 425. The memory/storage 425 may be used to load and store data and/or instructions for operations performed by the processors of the baseband circuitry 420. Memory/storage for one embodiment may include any combination of suitable volatile memory and/or non-volatile memory. The memory/storage 425 may include any combination of various levels of memory/storage including, but not limited to, read-only memory (ROM) having embedded software instructions (e.g., firmware), random access memory (e.g., dynamic random access memory (DRAM)), cache, buffers, etc. The memory/storage 425 may be shared among the various processors or dedicated to particular processors.

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, some or all of the constituent components of the baseband circuitry 420 and

the application circuitry 410 may be implemented together such as, for example, on a system on a chip (SOC).

In some embodiments, the baseband circuitry 420 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 420 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 420 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

RF circuitry 420 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 430 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 430 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 440 and provide baseband signals to the baseband circuitry 420. RF circuitry 430 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 420 and provide RF output signals to the FEM circuitry 440 for transmission.

In some embodiments, the RF circuitry 430 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 430 may include mixer circuitry 431, amplifier circuitry 432 and filter circuitry 433. The transmit signal path of the RF circuitry 430 may include filter circuitry 433 and mixer circuitry 431. RF circuitry 430 may also include synthesizer circuitry 434 for synthesizing a frequency for use by the mixer circuitry 431 of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 431 of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 440 based on the synthesized frequency provided by synthesizer circuitry 434. The amplifier circuitry 432 may be configured to amplify the down-converted signals and the filter circuitry 433 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 provided to the baseband circuitry 420 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 431 of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

In some embodiments, the mixer circuitry 431 of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 434 to generate RF output signals for the FEM circuitry 440. The baseband signals may be provided by the baseband circuitry 420 and may be filtered by filter circuitry 433. The filter circuitry 433 may include a low-pass filter (LPF), although the scope of the embodiments is not limited in this respect.

In some embodiments, the mixer circuitry 431 of the receive signal path and the mixer circuitry 431 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 431 of the receive signal path and the mixer circuitry 431 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 431 of the receive signal path and the mixer circuitry 431 may be arranged for direct downconversion and/or direct upconversion, respectively. In some embodiments, the mixer circuitry 431 of the receive signal path and the mixer circuitry 431 of the transmit signal path may be configured for super-heterodyne operation.

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 430 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 420 may include a digital baseband interface to communicate with the RF circuitry 430.

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.

In some embodiments, the synthesizer circuitry 434 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 434 may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

The synthesizer circuitry 434 may be configured to synthesize an output frequency for use by the mixer circuitry 431 of the RF circuitry 430 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 434 may be a fractional N/N+1 synthesizer.

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 420 or the applications processor 410 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 410.

Synthesizer circuitry 434 of the RF circuitry 430 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 Nd equal packets of phase, where Nd 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.

In some embodiments, synthesizer circuitry 434 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 each other. In some embodiments, the output frequency may be a LO frequency (fLO). In some embodiments, the RF circuitry 430 may include an IQ/polar converter.

FEM circuitry 440 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 450, amplify the

received signals and provide the amplified versions of the received signals to the RF circuitry 430 for further processing. FEM circuitry 440 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 430 for transmission by one or more of the one or more antennas 450.

In some embodiments, the FEM circuitry 440 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 signals as an output (e.g., to the RF circuitry 430). The transmit signal path of the FEM circuitry 440 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 430), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 450). In some embodiments, the electronic device 400 may include additional elements such as, for example, memory/storage, display, camera, sensor, and/or input/output (I/O) interface.

In some embodiments, the electronic device 400 may be, implement, incorporate, or be otherwise part of a UE. In embodiments, one or more processors of the baseband circuitry 420 and/or other components or circuitry of the electronic device 400 may be to: detect the UE has left coverage of a manually selected CSG that belongs to a first PLMN; and determine whether to maintain use of the first PLMN as a RPLMN for further action after leaving the CSG based at least in part on an EPLMN list before attempting to register with a cell belonging to a second PLMN. In some embodiments, one or more processors of the baseband circuitry 420 and/or other components or circuitry may also be to determine whether a PLMN search is to be performed based at least in part on the RPLMN and the second PLMN in response to the UE selecting the cell and may also be to perform a registration attempt with the cell without performing the PLMN search. In various embodiments, one or more processors of the baseband circuitry 420 and/or other components or circuitry of the electronic device 400 may also be to determine whether the PLMN search is to be performed based at least in part on the EPLMN list, where the PLMN search is to not be performed in response to the EPLMN list includes the second PLMN. In some embodiments, the EPLMN list may be an EPLMN list (e.g., EPLMN list 111, 211, or 311) associated with the first PLMN (CSG PLMN during registration to the CSG cell). In various embodiments, one or more processors of the baseband circuitry 420

and/or other components or circuitry may be to perform a registration attempt in response to determining whether the PLMN search is to be performed. In some embodiments, the registration attempt may be with a cell belonging to the second PLMN (e.g., macro cell 106, macro cell 206, or macro cell 306) in response to determining the PLMN search is not to be performed. In various embodiments, the registration attempt may be with a cell belonging to the last RPLMN prior to manual CSG selection in response to determining the PLMN search is to be performed.

In some embodiments, the EPLMN list may be a first EPLMN list and one or more processors of the baseband circuitry 420 and/or other components or circuitry of the electronic device 400 may also be to determine whether to maintain use of the first PLMN as a RPLMN for further action based at least in part on a second EPLMN list associated with a last RPLMN the UE was in prior to entering the CSG (e.g., EPLMN list 109, 209, or 309). In some embodiments, one or more processors of the baseband circuitry 420 and/or other components or circuitry of the electronic device 400 may also be to determine whether the PLMN search is to be performed also based at least in part on the second EPLMN list, where the PLMN search is to not be performed in response to the second EPLMN list includes the second PLMN. In various embodiments, one or more processors of the baseband circuitry 420 and/or other components or circuitry of the electronic device 400 may also be to cause the UE to store a copy of an EPLMN list associated with the last RPLMN of a cell the UE was in prior to entering the CSG in the memory/storage 425. In some embodiments, one or more processors of the baseband circuitry 420 and/or other components or circuitry of the electronic device 400 may also be to cause the UE to return to a stored duplicate PLMN selection mode.

In some embodiments, the memory/storage 425 may store the first EPLMN list (e.g., EPLMN list 111, 211, or 311) associated with the first PLMN (CSG PLMN during registration to the CSG cell), the second EPLMN list (e.g., EPLMN list 109, 209, or 309) associated with a last RPLMN the UE was in prior to entering the CSG, and/or a copy of the second EPLMN list. In some embodiments, determinations based at least in part on the second EPLMN list in memory/storage 425 may be performed before storing the first EPLMN list, and the second EPLMN list may be overwritten with the first EPLMN list without storing a copy of the second EPLMN list such that the contents of the second EPLMN list are no longer accessible. In other embodiments, a copy of the second EPLMN list may be stored in memory/storage 425, the second EPLMN list may be overwritten

with the first EPLMN list in memory/storage 425, and determinations based at least in part on the second EPLMN list may be performed after the second EPLMN list is overwritten using the stored copy of the second EPLMN list.

In various embodiments, one or more processors of the baseband circuitry 420 and/or other components or circuitry of the electronic device 400 may be to: respond to a manual user input selecting a CSG belonging to a first PLMN; register to the CSG in response to the manual user input selection; detect the UE has left coverage of the CSG; detect a second PLMN; and determine whether a PLMN search is to be performed in response to leaving coverage of the CSG based at least in part on an EPLMN list before attempting to register with a cell belonging to the second PLMN.

In various embodiments, one or more processors of the baseband circuitry 420 and/or other components or circuitry of the electronic device 400 may be to identify that a CSG selection is within an EPLMN list valid prior to manual CSG selection (e.g., EPLMN list 109, 209, or 309), and after successful registration to the selected CSG, check if the RPLMN prior to manual CSG selection is within the new EPLMN list valid after manual CSG selection (e.g., EPLMN list 111, 211, or 311), received during registration to the selected CSG cell. If both checks are met, one or more processors of the baseband circuitry 420 and/or other components or circuitry of the electronic device 400 may avoid unnecessary PLMN search when the UE is leaving CSG coverage and may rely on mobility based on AS cell reselection within EPLMNs as per suitability criteria and/or reselection criteria that may be priority and/or ranking based. In various embodiments, if the UE reselects to a cell from a PLMN which is either the RPLMN prior to manual CSG selection or within the new EPLMN list, PLMN search and selection may not be performed, with PLMN search and selection to be performed otherwise.

In various embodiments, one or more processors of the baseband circuitry 420 and/or other components or circuitry of the electronic device 400 may store a duplicate of the RPLMN prior to manual CSG selection to be used for later checks. In some embodiments, if the registration with a CSG fails, then the UE may return to the stored duplicate PLMN selection mode and use the stored duplicate value of RPLMN for further action. In some embodiments, if the UE is no longer in the coverage of the selected CSG, if the stored duplicate RPLMN is not part of the current equivalent PLMN list, then the UE may return to the stored duplicate PLMN selection mode and use the stored duplicate value of RPLMN as RPLMN for further action. In various embodiments, if the stored

duplicate RPLMN is part of the current EPLMN list, then the UE may return to the stored duplicate PLMN selection mode, but stay on the current PLMN and delete the stored duplicate RPLMN.

In some embodiments, the electronic device 400 of Figure 4 may be configured to perform one or more processes, techniques, and/or methods as described herein, or portions thereof. Figure 5 depicts one such process 500. For example, in embodiments where the electronic device is, implements, is incorporated into, or is otherwise part of a user equipment (UE) (e.g., UE 102, 202, or 302), or a portion thereof, the process may include storing a copy of the EPLMN list that is associated with the "RPLMN prior to manual CSG selection" (e.g., EPLMN list 109, 209, or 309) at a block 501. In some embodiments, the method 500 may include determining that the UE has left coverage of a manually selected CSG (e.g., CSG cell 108, 208, or 308) belonging to a first PLMN at a block 502; and determining, before attempting to register with a cell belonging to a second PLMN (e.g., the PLMN of macro cell 106, 206, or 306), whether a PLMN search is to be performed in response to leaving coverage of the CSG based at least in part on an EPLMN list and the second PLMN at a block 504.

In some embodiments, the method 500 may include performing a registration attempt with a cell in response to determining whether the PLMN search is to be performed. In various embodiments, the registration attempt may be with a cell belonging to the second PLMN (e.g., macro cell 106, macro cell 206, or macro cell 306) in response to determining the PLMN search is not to be performed. In some embodiments, the registration attempt may be with a cell belonging to the last RPLMN prior to manual CSG selection in response to determining the PLMN search is to be performed. In some embodiments, the method 500 of Figure 5 may further comprise returning to a stored duplicate PLMN selection mode at a block 508, attempting to register with the cell belonging to the second PLMN (e.g., macro cell 106, 206, or 306) without conducting the PLMN search in response to the UE determines that the PLMN search is not to be performed at a block 510, and/or performing other actions at a block 512.

In some embodiments, the EPLMN list (e.g., EPLMN list 111, 211, or 311) may be associated with the first PLMN (CSG PLMN during registration to the CSG cell) and determining whether the PLMN search is to be performed at the block 504 may include: determining whether a last RPLMN associated with a cell (e.g., macro cell 104, 204, or 304) the UE was in prior to being in the CSG is within the EPLMN list; determining

whether the second PLMN is within the EPLMN list; and skipping the PLMN search in response to determinations that the RPLMN is within the EPLMN list and the second PLMN is within the EPLMN list.

In various embodiments, the EPLMN list may be a first EPLMN list associated with the first PLMN (CSG PLMN during registration to the CSG cell) and determining whether the PLMN search is to be performed at the block 504 may include: determining whether a last RPLMN associated with a cell (e.g., macro cell 104, 204, or 304) the UE was in prior to being in the CSG is within the first EPLMN list; determining whether the first PLMN is within a second EPLMN list (e.g., EPLMN list 109, 209, or 309) associated with the RPLMN prior to manual CSG selection; determining whether the second PLMN is within the first EPLMN list; determining whether the second PLMN is within the first EPLMN list; and skipping the PLMN search in response to determinations that the RPLMN prior to manual CSG selection is within the first EPLMN list (e.g., EPLMN list 111, 211, or 311), the first PLMN is within the second EPLMN list (e.g., EPLMN list 109, 209, or 309), and the second PLMN is within the first EPLMN list.

In some embodiments, the EPLMN list (e.g., EPLMN list 109, 209, or 309) may be associated with a last RPLMN of a cell (e.g., macro cell 104, 204, or 304) the UE was in prior to being in the CSG and determining whether the PLMN search is to be performed at the block 504 may include: determining whether the second PLMN is within the EPLMN list; and skipping the PLMN search in response to determination that the second PLMN is within the EPLMN list.

Figure 6 is a block diagram illustrating components, according to some example embodiments, able to read instructions from a machine-readable or computer-readable medium (e.g., a machine-readable storage medium) and perform any one or more of the methodologies discussed herein (e.g., the techniques described with respect to process 500 of Fig. 5, or the functions and/or checks described with respect to Figs. 1-3). Specifically, Figure 6 shows a diagrammatic representation of hardware resources 600 including one or more processors (or processor cores) 610, one or more memory/storage devices 620, and one or more communication resources 630, each of which are communicatively coupled via a bus 640.

The processors 610 (e.g., a central processing unit (CPU), a reduced instruction set computing (RISC) processor, a complex instruction set computing (CISC) processor, a graphics processing unit (GPU), a digital signal processor (DSP) such as a baseband

processor, an application specific integrated circuit (ASIC), a radio-frequency integrated circuit (RFIC), another processor, or any suitable combination thereof) may include, for example, a processor 612 and a processor 614. The memory/storage devices 620 may include main memory, disk storage, or any suitable combination thereof.

The communication resources 630 may include interconnection and/or network interface components or other suitable devices to communicate with one or more peripheral devices 604 and/or one or more databases 606 via a network 608. For example, the communication resources 630 may include wired communication components (e.g., for coupling via a Universal Serial Bus (USB)), cellular communication components, Near Field Communication (NFC) components, Bluetooth® components (e.g., Bluetooth® Low Energy), Wi-Fi® components, and other communication components.

Instructions 650 may comprise software, a program, an application, an applet, an app, or other executable code for causing at least any of the processors 610 to perform any one or more of the methodologies discussed herein. The instructions 650 may reside, completely or partially, within at least one of the processors 610 (e.g., within the processor's cache memory), the memory/storage devices 620, or any suitable combination thereof. Furthermore, any portion of the instructions 650 may be transferred to the hardware resources 600 from any combination of the peripheral devices 604 and/or the databases 606. Accordingly, the memory of processors 610, the memory/storage devices 620, the peripheral devices 604, and the databases 606 are examples of computer-readable and machine-readable media. In some embodiments, one or more components of the hardware resources 600 may be included as a part of the electronic device 400 described with respect to Fig. 4, or one or more components of the electronic device 400 described with respect to Fig. 4 may be included as a part of the hardware resources 600. In some embodiments, instructions on non-transitory and/or transitory computer-readable media may be stored on and/or executed by one or more components of the electronic device 400 of Fig. 4 instead of or in addition to the hardware resources 600 of Fig. 6.

Embodiments can be realized according to any of the following examples taken jointly and severally in any and all permutations:

Example 1 may include one or more computer-readable media having instructions that, when executed, cause a user equipment (UE) to: determine the UE has left coverage of a manually selected closed subscriber group (CSG) belonging to a first Public Land Mobile Network (PLMN); determine, before attempting to register with a cell belonging to

a second PLMN, whether a PLMN search is to be performed in response to leaving coverage of the CSG, based at least in part on an Equivalent PLMN (EPLMN) list and the second PLMN; and perform a registration attempt with a cell in response to determining whether the PLMN search is to be performed.

Example 2 may include the subject matter of Example 1, wherein the EPLMN list is associated with the first PLMN and the instructions are also to cause the UE to: determine whether a last registered PLMN (RPLMN) associated with a cell the UE was in prior to being in the CSG is within the EPLMN list; determine whether the second PLMN is within the EPLMN list; and skip the PLMN search in response to determinations that the RPLMN is within the EPLMN list and the second PLMN is within the EPLMN list.

Example 3 may include the subject matter of Example 1, wherein the EPLMN list is a first EPLMN list associated with the first PLMN and the instructions are also to cause the UE to: determine whether a last registered PLMN (RPLMN) associated with a cell the UE was in prior to being in the CSG is within the first EPLMN list; determine whether the first PLMN is within a second EPLMN list associated with the RPLMN; determine whether the second PLMN is within the first EPLMN list; and skip the PLMN search in response to determinations that the RPLMN is within the first EPLMN list, the first PLMN is within the second EPLMN list, and the second PLMN is within the first EPLMN list.

Example 4 may include the subject matter of Example 3, wherein the instructions are also to cause the UE to: determine whether the second PLMN is within the second EPLMN list; and skip the PLMN search in response to determination that the second PLMN is within the second EPLMN list.

Example 5 may include the subject matter of Example 1, wherein the EPLMN list is associated with a last registered PLMN (RPLMN) of a cell the UE was in prior to being in the CSG, and the instructions are also to cause the UE to: determine whether the second PLMN is within the EPLMN list; and skip the PLMN search in response to determination that the second PLMN is within the EPLMN list.

Example 6 may include the subject matter of any one of Examples 3-5, wherein the instructions are also to cause the UE to store a copy of the EPLMN list associated with the RPLMN.

Example 7 may include the subject matter of any one of Examples 1-6, wherein the instructions are also to cause the UE to return to a stored duplicate PLMN selection mode.

Example 8 may include the subject matter of any one of Examples 3-7, wherein the instructions are also to cause the UE to skip the PLMN search in response to the second PLMN is the same as the first PLMN.

Example 9 may include the subject matter of any one of Examples 3-8, wherein the instructions are also to cause the UE to attempt to register with the cell belonging to the second PLMN without conducting the PLMN search in response to the UE determines that the PLMN search is not to be performed.

Example 10 may include an apparatus to be implemented in a User Equipment (UE), the apparatus comprising: a memory to store an Equivalent Public Land Mobile Network (EPLMN) list; and one or more processors to: detect the UE has left coverage of a manually selected closed subscriber group (CSG) that belongs to a first Public Land Mobile Network (PLMN); determine, before attempting to register with a cell belonging to a second PLMN, whether to maintain use of the first PLMN as a registered PLMN (RPLMN) for further action after leaving the CSG based at least in part on the EPLMN list; and perform a registration attempt in response to determining whether to maintain use of the first PLMN as the RPLMN for further action.

Example 11 may include the subject matter of Example 10, wherein the one or more processors are also to determine whether a PLMN search is to be performed based at least in part on a last RPLMN associated with a cell the UE was in prior to being in the CSG and the second PLMN in response to the UE selecting the cell.

Example 12 may include the subject matter of Example 11, wherein the one or more processors are also to perform a registration attempt with the cell without performing the PLMN search in response to a PLMN search is not to be performed.

Example 13 may include the subject matter of any one of Examples 11-12, wherein the one or more processors are also to determine whether a PLMN search is to be performed is also to determine whether the PLMN search is to be performed based at least in part on the EPLMN list, wherein the PLMN search is to not be performed in response to the EPLMN list includes the second PLMN.

Example 14 may include the subject matter of any one of Examples 10-13 wherein the EPLMN list is associated with the first PLMN.

Example 15 may include the subject matter of any one of Examples 10-14, wherein the EPLMN list is a first EPLMN list and wherein the one or more processors are also to determine whether to maintain use of the first PLMN as a RPLMN for further action is to

determine whether to maintain use of the first PLMN as a RPLMN for further action also based at least in part on a second EPLMN list associated with a last RPLMN the UE was in prior to entering the CSG.

Example 16 may include the subject matter of any one of Examples 10-14, wherein the EPLMN list is a first EPLMN list and wherein the one or more processors are also to determine whether a PLMN search is to be performed is to determine whether the PLMN search is to be performed also based at least in part on a second EPLMN list associated with a last RPLMN the UE was in prior to entering the CSG, wherein the PLMN search is to not be performed in response to the second EPLMN list includes the second PLMN.

Example 17 may include the subject matter of any one of Examples 10-16, wherein the one or more processors are also to cause the UE to store a copy of an EPLMN list associated with the last RPLMN of a cell the UE was in prior to entering the CSG in the memory.

Example 18 may include the subject matter of any one of Examples 10-17, wherein the one or more processors are also to cause the UE to return to a stored duplicate PLMN selection mode.

Example 19 may include the subject matter of any one of Examples 10-18, wherein the one or more processors are also to cause the UE to determine whether to return to use of a last RPLMN associated with a cell the UE was in prior to entering the CSG as RPLMN.

Example 20 may include an apparatus to be implemented in a User Equipment (UE), the apparatus comprising: means for manually selecting a closed subscriber group (CSG) belonging to a first Public Land Mobile Network (PLMN); means for detecting the UE has left coverage of the CSG; means for detecting a second PLMN; means for determining whether a PLMN search is to be performed in response to leaving coverage of the CSG based at least in part on an Equivalent PLMN (EPLMN) list before attempting to register with a cell belonging to the second PLMN; and means for performing a registration attempt in response to determining whether the PLMN search is to be performed.

Example 21 may include the subject matter of Example 20, wherein the EPLMN list is associated with the first PLMN and the apparatus further includes: means for determining whether a last registered PLMN (RPLMN) of a cell the UE was in prior to being in the CSG is within the EPLMN list; means for determining whether the second

PLMN is within the EPLMN list; and means for determining a PLMN search is not needed in response to the RPLMN is within the EPLMN list and the second PLMN is within the EPLMN list.

Example 22 may include the subject matter of Example 20, wherein the EPLMN list is a first EPLMN list associated with the first PLMN and the apparatus further includes: means for determining whether the second PLMN is within the first EPLMN list; means for determining whether a last RPLMN of a cell the UE was in prior to being in the CSG is within the first EPLMN list; means for determining whether the first PLMN is within a second EPLMN list associated with the RPLMN; and means for determining a PLMN search is not needed in response to the RPLMN is within the first EPLMN list, the first PLMN is within the second EPLMN list, and the second PLMN is within the first EPLMN list.

Example 23 may include the subject matter of Example 22, further comprising: means for determining whether the second PLMN is within the second EPLMN list; and means for determining a PLMN search is not needed in response to the second PLMN is within the second EPLMN list.

Example 24 may include the subject matter of any one of Examples 22-23, further comprising means for storing a copy of the second EPLMN list.

Example 25 may include the subject matter of any one of Examples 20-24, further comprising means for returning to a stored duplicate PLMN selection mode.

Example 26 may include an apparatus comprising means to perform one or more elements of a method described in or related to any of examples 1-9, or any other method or process described herein.

Example 27 may include one or more computer-readable media comprising instructions to cause an electronic device, upon execution of the instructions by one or more processors of the electronic device, to perform one or more elements of a method described in or related to any of examples 1-9, or any other method or process described herein, or to provide the functionality of the apparatus or device according to any of examples 10-24 and/or any other example disclosed herein.

Example 28 may include an apparatus comprising logic, modules, and/or circuitry to perform one or more elements of a method described in or related to any of examples 1-9, or any other method or process described herein.

Example 29 may include an apparatus comprising one or more processors and one or more computer readable media comprising instructions that, when executed by the one or more processors, cause the one or more processors to perform the method of any of examples 1-9, or any other method or process described herein.

Example 30 may include a method of communicating in a wireless network as shown and described herein.

Example 31 may include a system for providing wireless communication as shown and described herein.

Example 32 may include a device for providing wireless communication as shown and described herein.

As used herein, any reference to computer program product or computer readable medium, may include reference to both transitory (e.g. physical media) and non-transitory forms (e.g. signals or data structures thereof).

Various examples disclosed herein may provide many advantages by not performing unnecessary PLMN search and/or selection, for example, but not limited to: avoiding unnecessary power drain and/or decreasing the time a UE would otherwise spend out-of-service or during which it would not be able to monitor or receive paging until the UE camps on a suitable cell after a PLMN search for those UEs that cannot perform a PLMN search while camping on a cell without any interruption to paging or monitoring.

As herein described, specific examples have been used to explain the disclosed methods and functions (and function units that carry out those functions), however, the disclosure is not so limited.

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 or software components, including a one or more virtual machines that can 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. In some embodiment, the processing/execution may be distributed instead of centralized processing/execution.

As used herein, any reference to a (RAN) architecture may include anything that may be defined as or thought of as any form of specific process(es), technique(s), technology(ies), implementation detail, improvement in or type of operation of a wireless network (or similar networking system entity), particularly in the RAN. Architectures may be typically introduced, maintained and updated in the standards documents for the respective wireless network technologies in use, for example the third generation partnership project (3GPP) standards, and the like.

It will be appreciated that any of the disclosed methods (or corresponding apparatuses, programs, data carriers, etc.) may be carried out by either a host or client, depending on the specific implementation (i.e. the disclosed methods/apparatuses are a form of communication(s), and as such, may be carried out from either 'point of view', i.e. in corresponding to each other fashion). Furthermore, it will be understood that the terms "receiving" and "transmitting" encompass "inputting" and "outputting" and are not limited to an RF context of transmitting and receiving radio waves. Therefore, for example, a chip or other device or component for realizing embodiments could generate data for output to another chip, device or component, or have as an input data from another chip, device or component, and such an output or input could be referred to as "transmit" and "receive" including gerund forms, that is, "transmitting" and "receiving", as well as such "transmitting" and "receiving" within an RF context.

As used in this specification, any formulation used of the style "at least one of A, B or C", and the formulation "at least one of A, B and C" use a disjunctive "or" and a disjunctive "and" such that those formulations comprise any and all joint and several permutations of A, B, C, that is, A alone, B alone, C alone, A and B in any order, A and C in any order, B and C in any order and A, B, C in any order. There may be more or less than three features used in such formulations.

In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. The word 'comprising' does not exclude the presence of other elements or steps then those listed in a claim. Furthermore, the terms "a" or "an," as used herein, are defined as one or more than one. Also, the use of introductory phrases such as "at least one" and "one or more" in the claims should not be construed to imply that the introduction of another claim element by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim element to inventions containing only one such element, even when the same claim includes the introductory phrases "one

or more" or "at least one" and indefinite articles such as "a" or "an." The same holds true for the use of definite articles. Unless stated otherwise, terms such as “first” and “second” are used to arbitrarily distinguish between the elements such terms describe. Thus, these terms are not necessarily intended to indicate temporal or other prioritization of such elements. The mere fact that certain measures are recited in mutually different claims does not indicate that a combination of these measures cannot be used to advantage.

Unless otherwise explicitly stated as incompatible, or the physics or otherwise of the embodiments, example or claims prevent such a combination, the features of the foregoing embodiments and examples, and of the following claims may be integrated together in any suitable arrangement, especially ones where there is a beneficial effect in doing so. This is not limited to only any specified benefit, and instead may arise from an “ex post facto” benefit. This is to say that the combination of features is not limited by the described forms, particularly the form (e.g. numbering) of the example(s), embodiment(s), or dependency of the claim(s). Moreover, this also applies to the phrase “in one embodiment”, “according to an embodiment” and the like, which are merely a stylistic form of wording and are not to be construed as limiting the following features to a separate embodiment to all other instances of the same or similar wording. This is to say, a reference to ‘an’, ‘one’ or ‘some’ embodiment(s) may be a reference to any one or more, and/or all embodiments, or combination(s) thereof, disclosed. Also, similarly, the reference to “the” embodiment may not be limited to the immediately preceding embodiment.

In the foregoing, reference to ‘layer’ may be a reference to a predefined (or definable) portion of the infrastructure, whereas reference to ‘Layer’ may be a reference to a network protocol Layer in operation on/in the network infrastructure, or portion thereof. Reference to MAC Layer may also comprise a reference to the MAC Layer and above, up to just below the IP Layer, and for example may comprise the RRC functions of the wireless network (or RAN). As used herein, any machine executable instructions may carry out a disclosed method, and may therefore be used synonymously with the term method.

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 claims 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 disclosure.

CLAIMS:

1. One or more computer-readable media having instructions that, when executed, cause a user equipment (UE) to:

determine the UE has left coverage of a manually selected closed subscriber group (CSG) belonging to a first Public Land Mobile Network (PLMN);

determine, before attempting to register with a cell belonging to a second PLMN, whether a PLMN search is to be performed in response to leaving coverage of the CSG, based at least in part on an Equivalent PLMN (EPLMN) list and the second PLMN; and

perform a registration attempt with a cell in response to determining whether the PLMN search is to be performed.

2. The one or more computer-readable media of claim 1, wherein the EPLMN list is associated with the first PLMN and the instructions are also to cause the UE to:

determine whether a last registered PLMN (RPLMN) associated with a cell the UE was in prior to being in the CSG is within the EPLMN list;

determine whether the second PLMN is within the EPLMN list; and

skip the PLMN search in response to determinations that the RPLMN is within the EPLMN list and the second PLMN is within the EPLMN list.

3. The one or more computer-readable media of claim 1, wherein the EPLMN list is a first EPLMN list associated with the first PLMN and the instructions are also to cause the UE to:

determine whether a last registered PLMN (RPLMN) associated with a cell the UE was in prior to being in the CSG is within the first EPLMN list;

determine whether the first PLMN is within a second EPLMN list associated with the RPLMN;

determine whether the second PLMN is within the first EPLMN list; and

skip the PLMN search in response to determinations that the RPLMN is within the first EPLMN list, the first PLMN is within the second EPLMN list, and the second PLMN is within the first EPLMN list.

4. The one or more computer-readable media of claim 3, wherein the instructions are also to cause the UE to:

determine whether the second PLMN is within the second EPLMN list; and

skip the PLMN search in response to determination that the second PLMN is within the second EPLMN list.

5. The one or more computer-readable media of claim 1, wherein the EPLMN list is associated with a last registered PLMN (RPLMN) of a cell the UE was in prior to being in the CSG, and the instructions are also to cause the UE to:

determine whether the second PLMN is within the EPLMN list; and

skip the PLMN search in response to determination that the second PLMN is within the EPLMN list.

6. The one or more computer-readable media of any one of claims 3-5, wherein the instructions are also to cause the UE to store a copy of the EPLMN list associated with the RPLMN.

7. The one or more computer-readable media of any one of claims 1-5, wherein the instructions are also to cause the UE to return to a stored duplicate PLMN selection mode.

8. The one or more computer-readable media of any one of claims 3-5, wherein the instructions are also to cause the UE to skip the PLMN search in response to the second PLMN is the same as the first PLMN.

9. The one or more computer-readable media of any one of claims 3-5, wherein the instructions are also to cause the UE to attempt to register with the cell belonging to the second PLMN without conducting the PLMN search in response to the UE determines that the PLMN search is not to be performed.

10. An apparatus to be implemented in a User Equipment (UE), the apparatus comprising:

a memory to store an Equivalent Public Land Mobile Network (EPLMN) list; and

one or more processors coupled with the memory to:

detect the UE has left coverage of a manually selected closed subscriber group (CSG) that belongs to a first Public Land Mobile Network (PLMN);

determine, before attempting to register with a cell belonging to a second PLMN, whether to maintain use of the first PLMN as a registered PLMN (RPLMN) for further action after leaving the CSG based at least in part on the EPLMN list; and

perform a registration attempt with a cell in response to determining whether to maintain use of the first PLMN as the RPLMN for further action.

11. The apparatus of claim 10, wherein the one or more processors are also to determine whether a PLMN search is to be performed based at least in part on a last RPLMN associated with a cell the UE was in prior to being in the CSG and the second PLMN in response to the UE selecting the cell.

12. The apparatus of claim 11, wherein the one or more processors are also to perform a registration attempt with the cell without performing the PLMN search in response to a PLMN search is not to be performed.

13. The apparatus of any one of claims 11-12, wherein the one or more processors are also to determine whether a PLMN search is to be performed is also to determine whether the PLMN search is to be performed based at least in part on the EPLMN list, wherein the PLMN search is to not be performed in response to the EPLMN list includes the second PLMN.

14. The apparatus of any one of claims 10-12 wherein the EPLMN list is associated with the first PLMN.

15. The apparatus of any one of claims 10-12, wherein the EPLMN list is a first EPLMN list and wherein the one or more processors are also to determine whether to maintain use of the first PLMN as a RPLMN for further action is to determine whether to maintain use of the first PLMN as a RPLMN for further action also based at least in part on a second EPLMN list associated with a last RPLMN the UE was in prior to entering the CSG.

16. The apparatus of any one of claims 10-12, wherein the EPLMN list is a first EPLMN list and wherein the one or more processors are also to determine whether a PLMN search is to be performed is to determine whether the PLMN search is to be performed also based

at least in part on a second EPLMN list associated with a last RPLMN the UE was in prior to entering the CSG, wherein the PLMN search is to not be performed in response to the second EPLMN list includes the second PLMN.

17. The apparatus of any one of claims 10-12, wherein the one or more processors are also to cause the UE to store a copy of an EPLMN list associated with the last RPLMN of a cell the UE was in prior to entering the CSG in the memory.

18. The apparatus of any one of claims 10-12, wherein the one or more processors are also to cause the UE to return to a stored duplicate PLMN selection mode.

19. The apparatus of any one of claims 10-12, wherein the one or more processors are also to cause the UE to determine whether to return to use of a last RPLMN associated with a cell the UE was in prior to entering the CSG as RPLMN.

20. An apparatus to be implemented in a User Equipment (UE), the apparatus comprising:

means for manually selecting a closed subscriber group (CSG) belonging to a first Public Land Mobile Network (PLMN);

means for detecting the UE has left coverage of the CSG;

means for detecting a second PLMN;

means for determining whether a PLMN search is to be performed in response to leaving coverage of the CSG based at least in part on an Equivalent PLMN (EPLMN) list before attempting to register with a cell belonging to the second PLMN; and

means for performing a registration attempt in response to determining whether the PLMN search is to be performed.

21. The apparatus of claim 20, wherein the EPLMN list is associated with the first PLMN and the apparatus further includes:

means for determining whether a last registered PLMN (RPLMN) of a cell the UE was in prior to being in the CSG is within the EPLMN list;

means for determining whether the second PLMN is within the EPLMN list; and

means for determining a PLMN search is not needed in response to the RPLMN is within the EPLMN list and the second PLMN is within the EPLMN list.

22. The apparatus of claim 20, wherein the EPLMN list is a first EPLMN list associated with the first PLMN and the apparatus further includes:

means for determining whether the second PLMN is within the first EPLMN list;

means for determining whether a last RPLMN of a cell the UE was in prior to being in the CSG is within the first EPLMN list;

means for determining whether the first PLMN is within a second EPLMN list associated with the RPLMN; and

means for determining a PLMN search is not needed in response to the RPLMN is within the first EPLMN list, the first PLMN is within the second EPLMN list, and the second PLMN is within the first EPLMN list.

23. The apparatus of claim 22, further comprising:

means for determining whether the second PLMN is within the second EPLMN list; and

means for determining a PLMN search is not needed in response to the second PLMN is within the second EPLMN list.

24. The apparatus of any one of claims 22-23, further comprising means for storing a copy of the second EPLMN list.

25. The apparatus of any one of claims 20-23, further comprising means for returning to a stored duplicate PLMN selection mode.

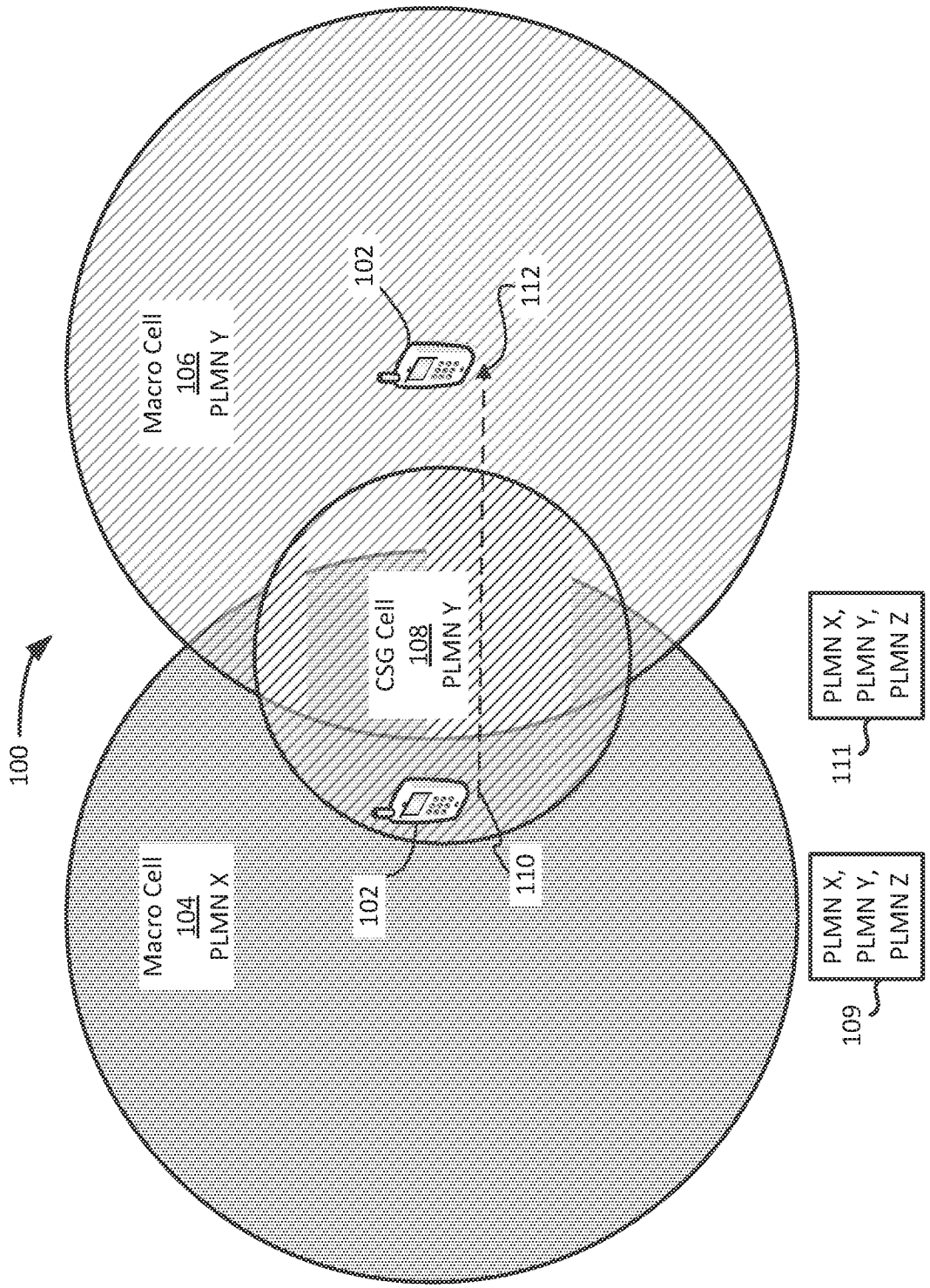

100
Macro Cell
104
PLMN X
CSG Cell
108
PLMN Y
Macro Cell
106
PLMN Y
102
102
110
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109
PLMN X,
PLMN Y,
PLMN Z
111
PLMN X,
PLMN Y,
PLMN Z

Fig. 1

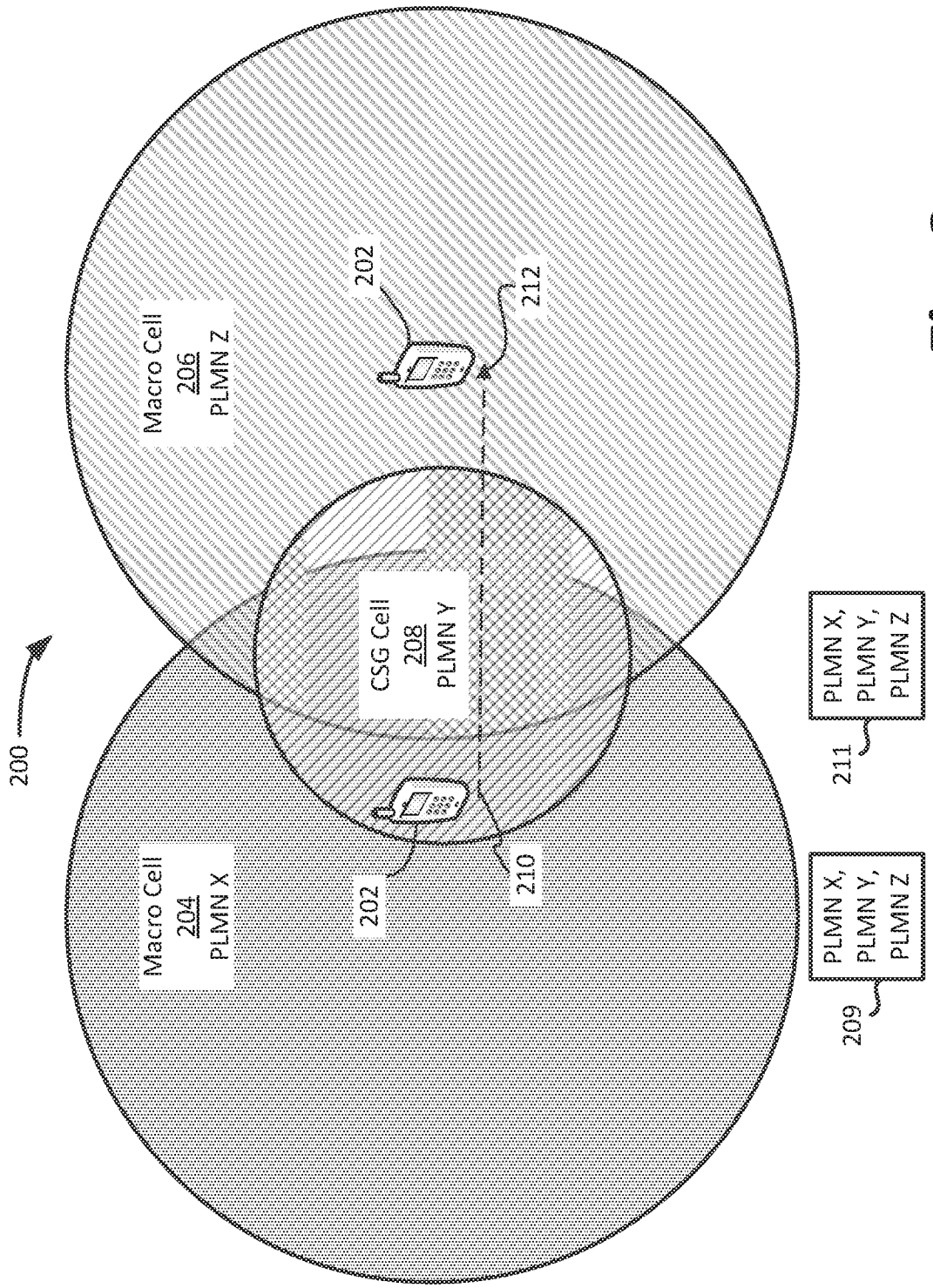

200
Macro Cell
204
PLMN X
CSG Cell
208
PLMN Y
Macro Cell
206
PLMN Z
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PLMN Y,
PLMN Z
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PLMN X,
PLMN Y,
PLMN Z
211

Fig. 2

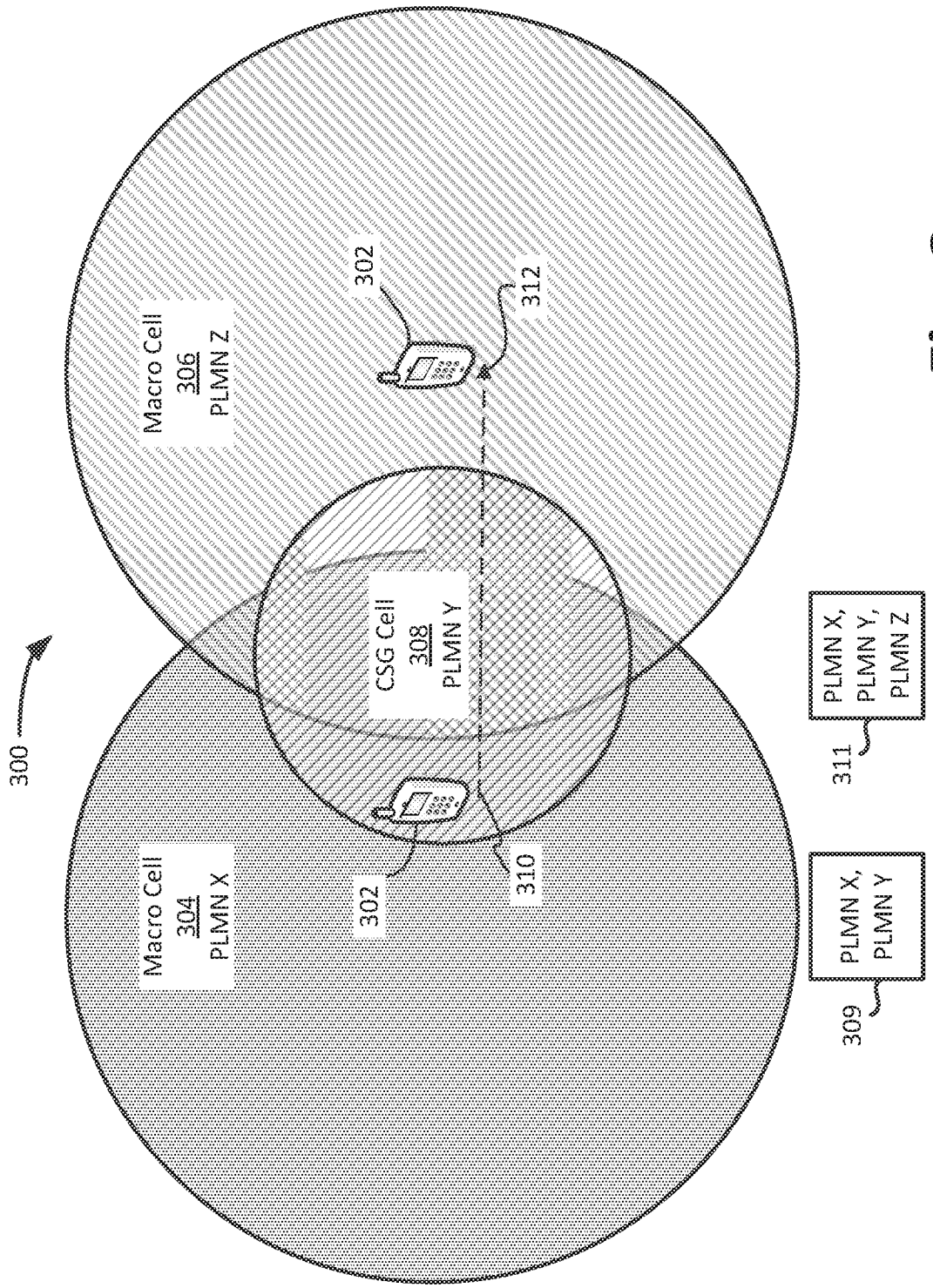

300
Macro Cell
304
PLMN X
CSG Cell
308
PLMN Y
Macro Cell
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PLMN Z
302
302
310
312
309
PLMN X,
PLMN Y
311
PLMN X,
PLMN Y,
PLMN Z

Fig. 3

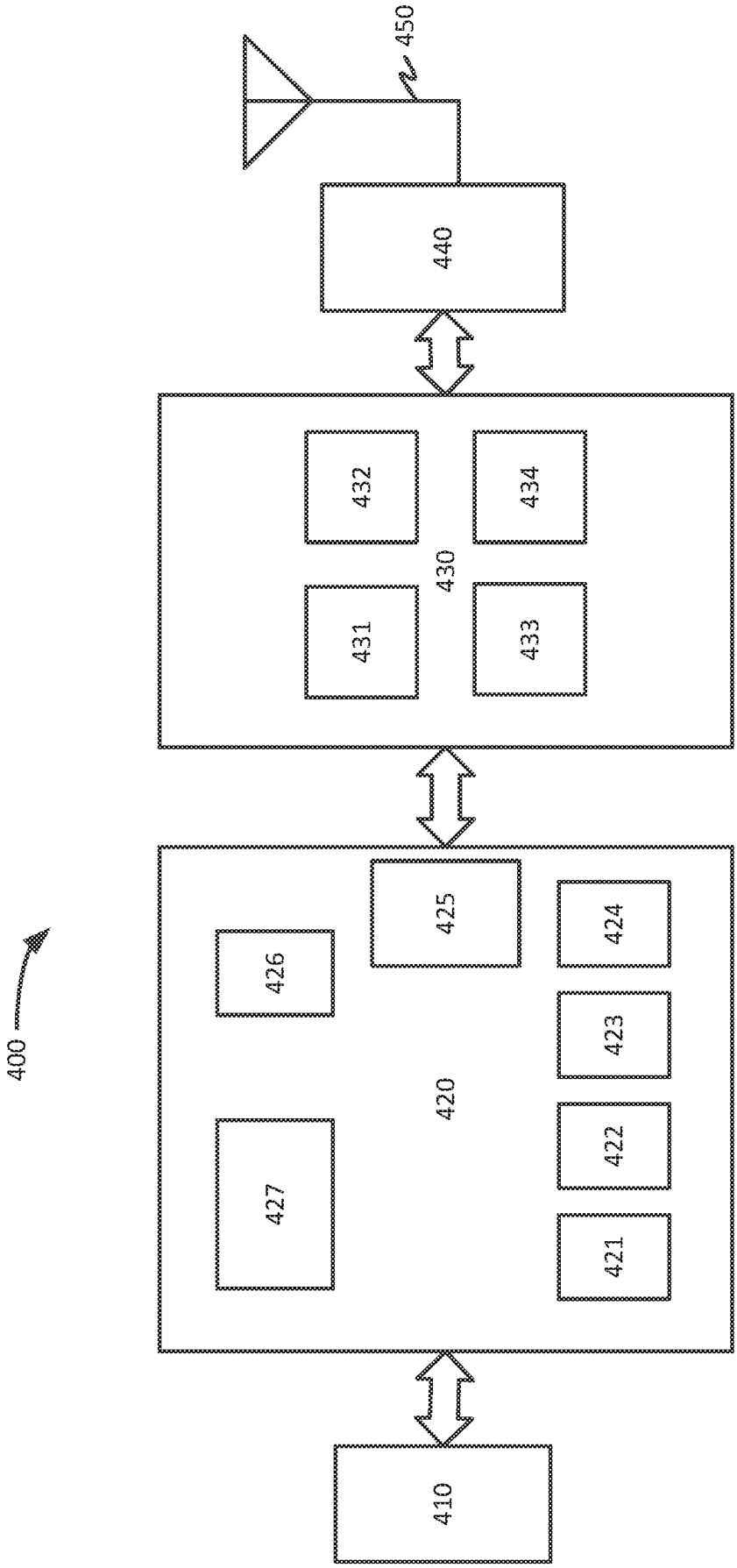

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Fig. 4

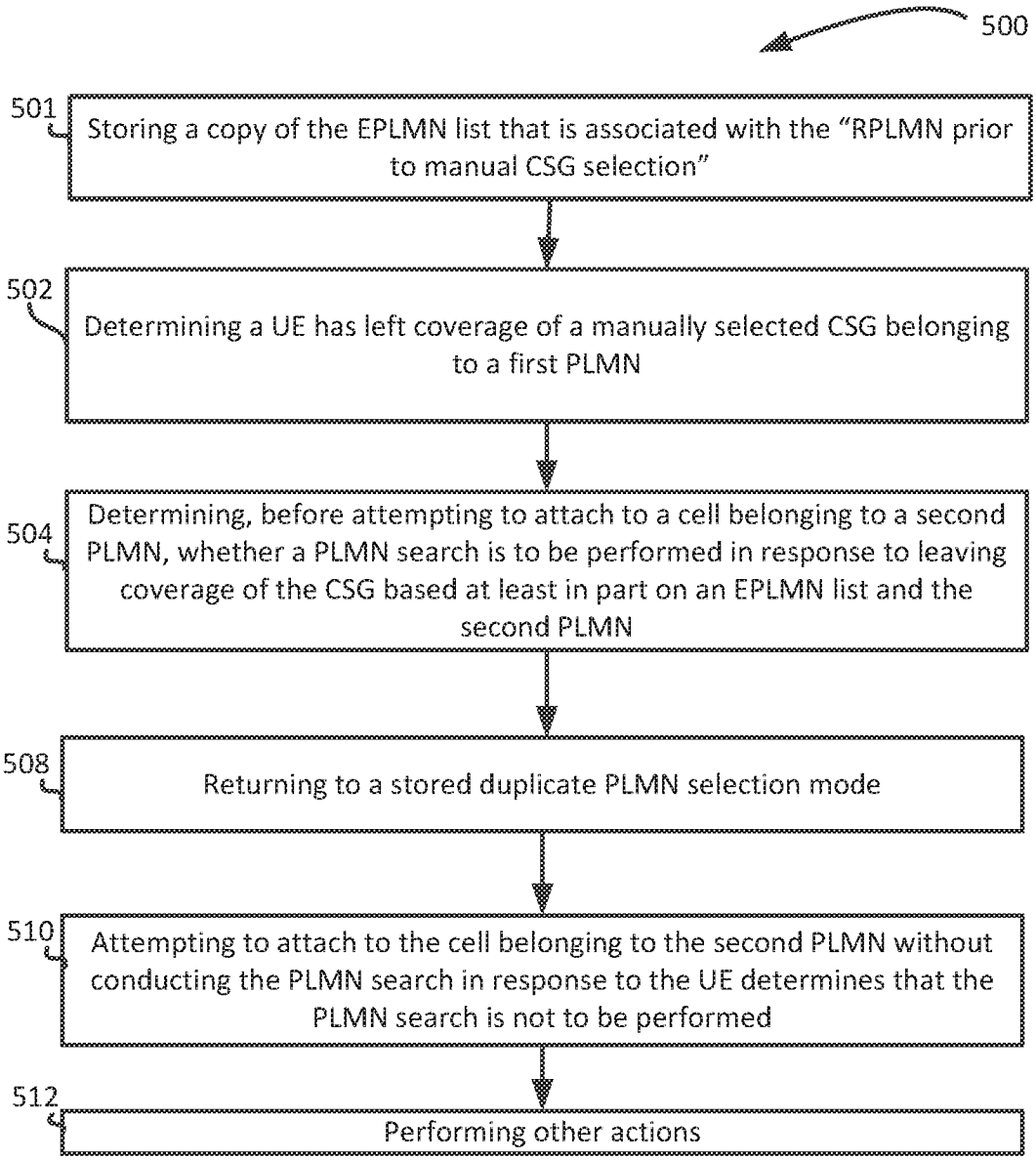

500
501
Storing a copy of the EPLMN list that is associated with the "RPLMN prior to manual CSG selection"
502
Determining a UE has left coverage of a manually selected CSG belonging to a first PLMN
504
Determining, before attempting to attach to a cell belonging to a second PLMN, whether a PLMN search is to be performed in response to leaving coverage of the CSG based at least in part on an EPLMN list and the second PLMN
508
Returning to a stored duplicate PLMN selection mode
510
Attempting to attach to the cell belonging to the second PLMN without conducting the PLMN search in response to the UE determines that the PLMN search is not to be performed
512
Performing other actions

Fig. 5

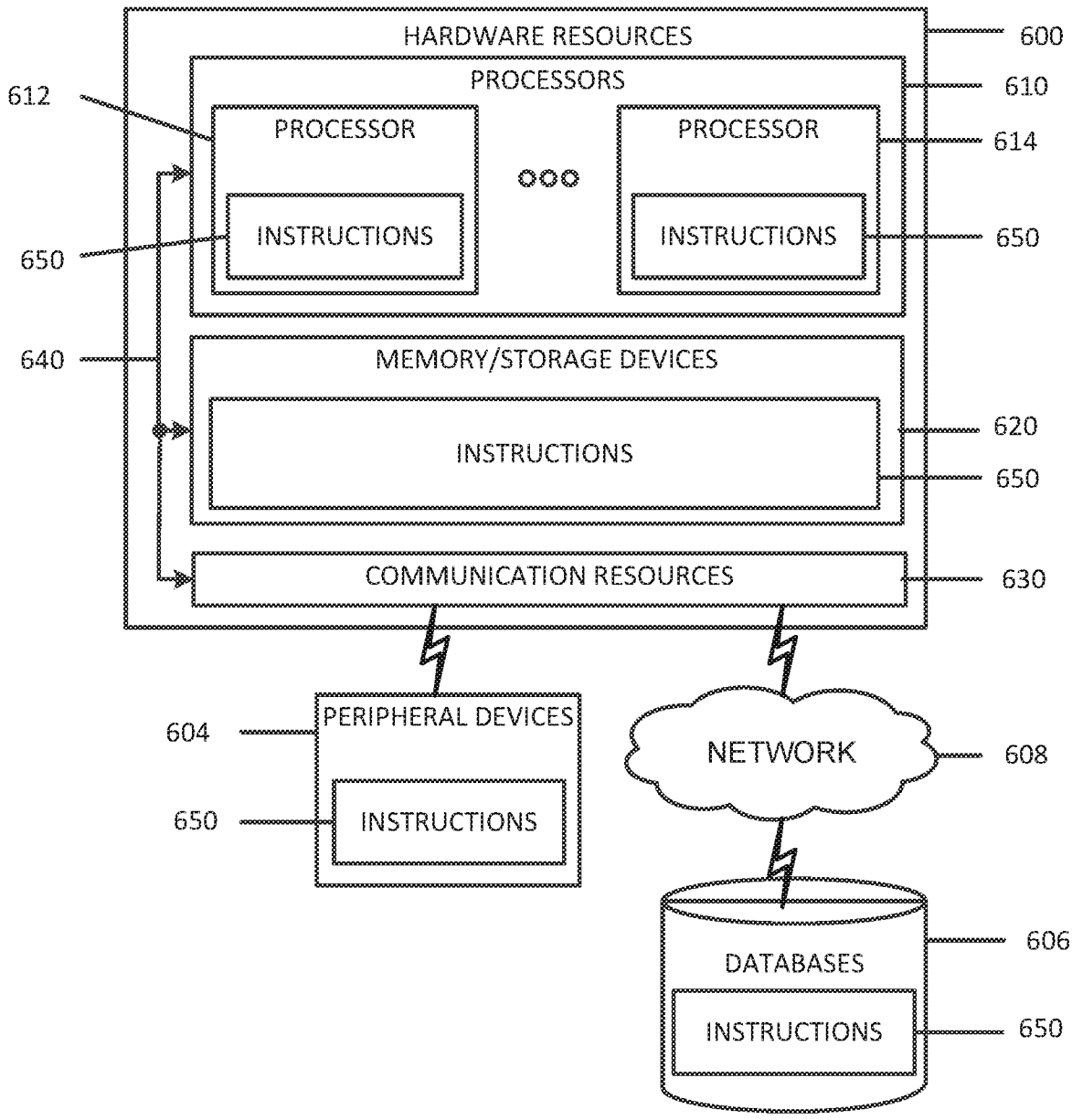

HARDWARE RESOURCES
600
PROCESSORS
610
612
PROCESSOR
PROCESSOR
614
INSTRUCTIONS
INSTRUCTIONS
650
650
640
MEMORY/STORAGE DEVICES
INSTRUCTIONS
620
650
COMMUNICATION RESOURCES
630
PERIPHERAL DEVICES
604
650
INSTRUCTIONS
NETWORK
608
DATABASES
606
INSTRUCTIONS
650

Fig. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/048335

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W48/00
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 2015/050301 A1 (SAMSUNG ELECTRONICS CO LTD [KR]) 9 April 2015 (2015-04-09)	1,10,20
Y	paragraph [0003] - paragraph [0016]; figures 1,3,7 paragraphs [0031], [0045] - paragraph [0047] paragraph [0065] - paragraph [0067]	2-9, 11-19, 21-25

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[X] Further documents are listed in the continuation of Box C.

[X] 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

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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	Date of mailing of the international search report
27 April 2017	08/05/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Tozlovanu, Ana-Delia

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/048335

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	"3rd Generation Partnership Project; Technical Specification Group Core Network and Terminals; Non-Access-Stratum (NAS) functions related to Mobile Station (MS) in idle mode (Release 12)", 3GPP STANDARD; 3GPP TS 23.122, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. CT WG1, no. V12.9.0, 24 June 2016 (2016-06-24), pages 1-48, XP051123609, [retrieved on 2016-06-24] cited in the application page 19 - page 24	2-9, 11-19, 21-25
A	US 2015/094062 A1 (NIEMI MARKO TAPANI [FI] ET AL) 2 April 2015 (2015-04-02) paragraph [0046] - paragraph [0075]	1-25

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2016/048335

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2015050301 A1	09-04-2015	CN 105594265 A	18-05-2016
		EP 3053392 A1	10-08-2016
		US 2016242138 A1	18-08-2016
		WO 2015050301 A1	09-04-2015
US 2015094062 A1	02-04-2015	NONE	