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(54) Title: CIRCUIT-SWITCHED FALLBACK DELAY MITIGATION

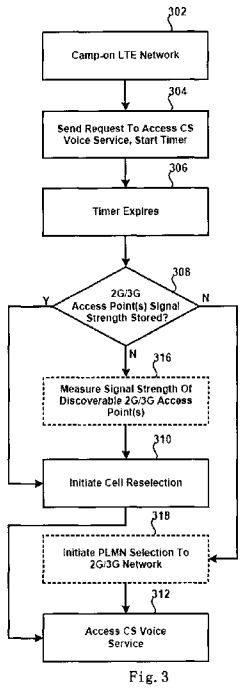


Fig. 3

(57) Abstract: System and methods for mitigating circuit-switched fallback delay. A user equipment may initiate connection of the user equipment to a packet-switched network. A request may be sent by the user equipment to the packet-switched network to access a circuit-switched service. A timer may be started to determine elapsed duration between sending the request and receiving a response from the packet-switched network that confirms resource allocation to access the circuit-switched service. The user equipment may select in response to timer expiration, indicating absence of response to the request, a particular algorithm when implemented initiates connection of the user equipment to a particular circuit-switched network to access the circuit-switched service.

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CIRCUIT-SWITCHED FALLBACK DELAY MITIGATION

Description

BACKGROUND

[0001] Evolved Packet System may be considered a core network supporting the Long Term Evolution wireless mobile radio access technology. In general, circuit-switched fallback in Evolved Packet System enables the provisioning of circuit-switched-domain services (e.g., voice service) by reuse of circuit-switched infrastructure when requested by an appropriately configured mobile user equipment. For example, a particular user equipment configured to support Long Term Evolution and a Second Generation and/or Third Generation radio access technology may initiate, on a Long Term Evolution network, access to a particular circuit-switched service through circuit-switched fallback. The Long Term Evolution network may then redirect the user equipment to a particular Second Generation/Third Generation network for circuit-switched service.

SUMMARY

[0002] This Summary does not in any way limit the scope of the claimed subject matter.

[0003] In an aspect, a method for mitigating circuit-switched fallback delay is disclosed. The method may include initiating, by a user equipment, connection of the user equipment to a packet-switched network. The method may include sending, by the user equipment to the packet-switched network, a request to access a circuit-switched service. The method may include starting, by the user equipment concurrently with sending the request, a timer to determine elapsed duration between sending the request and receiving a response from the packet-switched network that confirms resource allocation to access the circuit-switched service. The method may include selecting, by the user equipment in response to timer expiration, indicating absence of response to the request, a particular algorithm

that when implemented initiates connection of the user equipment to a particular circuit-switched network to access the circuit-switched service.

[0004] In an aspect, a computer-implemented method is disclosed. The method may include initiating, by a mobile terminal, connection of the mobile terminal to a packet-switched network. The method may include sending, by the mobile terminal to the packet-switched network, a request to access a circuit-switched service. The method may include starting, by the mobile terminal, a timer to determine elapsed duration between sending the request and receiving a response from the packet-switched network that confirms resource allocation to access the circuit-switched service. The method may include detecting, by the mobile terminal, expiration of the timer indicating absence of response to the request. The method may include initiating, by the mobile terminal in response to detecting expiration of the timer, connection of the mobile terminal to a particular circuit-switched network to access the circuit-switched service.

[0005] In an aspect, a multi-mode mobile user equipment (UE) including a processing unit and a system memory connected to the processing unit is disclosed. The system memory may include instructions that, when executed by the processing unit, cause the processing unit to instantiate at least one module to select, in response to expiration of a timer, a particular algorithm that when implemented initiates connection of the UE to a particular circuit-switched network to access a circuit-switched service. The at least one module may be configured to initiate connection of the UE to a packet-switched network. The at least one module may be configured to send to the packet-switched network a request to access the circuit-switched service. The at least one module may be configured to start a timer to determine elapsed duration between sending the request and receiving a response from the packet-switched network that confirms resource allocation to access the circuit-switched service. The at least one module may be configured to select, in response to expiration of the timer indicating absence of response to the request, the particular algorithm that when implemented initiates

connection of the user equipment to the particular circuit-switched network to access the circuit-switched service.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] A further understanding of the nature and advantages of the present invention may be realized by reference to the remaining portions of the specification, and the drawings, wherein like reference numerals are used throughout to refer to similar components. In some instances, a sub-label may be associated with a reference numeral to denote one of multiple similar components. When reference is made to a reference numeral without specification to an existing sub-label, it is intended to refer to all such multiple similar components.

[0007] FIG. 1 shows a block diagram of an example EPS architecture for mitigating circuit-switched fallback delay in accordance with the present disclosure.

[0008] FIG. 2 shows an example circuit-switched feedback engine in accordance with the present disclosure

[0009] FIG. 3 shows an example method for mitigating circuit-switched fallback delay in accordance with the present disclosure.

[0010] FIG. 4 shown the relationship between example LTE Cells, example 2G/3G cells, and geographic location of a multi-mode mobile user equipment in accordance with the present disclosure.

[0011] FIGS. 5 and 6 describe an environment where a connection may be established through the access stratum (AS) and the non-access stratum (NAS) in accordance with the present disclosure.

[0012] FIG. 7 shows an example computing system or device.

DETAILED DESCRIPTION

[0013] UMTS (Universal Mobile Telecommunication System) is a 3G (Third Generation) wireless telecommunication network technology standard organized and defined by the 3GPP (Third Generation Partnership Project). In general, a UMTS network is composed of a core network and an access network, where

the core network may comprise of a CS (Circuit-Switched) domain and a PS (Packet-Switched) domain. The CS domain provides CS-based services, such as voice service, while the PS domain offers PS-based service, such as Internet access. The 3GPP further organizes, maintains, or formulates 2G (Second Generation) standards such as GSM (*Global System for Mobile* Communications), GPRS (*General packet radio service)*, EDGE (Enhanced Data rates for GSM Evolution), as well as 3G standards such as W-CDMA (*Wideband Code Division Multiple Access)* and TD-SCDMA (Time Division Synchronous Code Division Multiple Access). The 3G standard CDMA2000 (Code Division Multiple Access) is generally organized and defined by the 3GPP2 (Third Generation Partnership Project 2).

[0014] LTE (Long Term Evolution) is a standard for wireless data communications technology, and supports both TDD (Time-Division Duplexing) and FDD (Frequency Division Duplexing). Among 3GPP standard operations, LTE is directed towards access network evolution, while SAE (System Architecture Evolved) is directed towards core network evolution. Both LTE and SAE, however, focus on optimization of PS domain service, as opposed to a combined PS domain service and CS domain service model. For example, in LTE, traditional CS domain voice service is not supported. Instead, voice service(s) may be provided via alternate methods such as, for example, VoLTE (Voice Over LTE), SVLTE (Simultaneous Voice and LTE), and CSFB (Circuit-Switched Fallback).

[0015] In the example of CSFB, a particular mobile UE (User Equipment) configured to support both LTE and a 2G and/or 3G RAT (Radio Access Technology) may initiate, on an LTE network, access to a particular CS service through CSFB. For example, the UE may initiate a mobile originating call by sending an ESR (Extended Service Request) for CSFB to a MME (Mobile Management Entity) to coordinate CSFB. For example, the MME may release certain resources and/or modify certain configurations to support access to the particular CS service through CSFB. In certain scenarios, however, an unintended delay may occur between a request for CSFB by the UE, and a response by the LTE network (e.g., MME) indicating certain resources/configurations are or have been allocated to support CSFB. For example,

signal strength between the UE and LTE network may be prohibitively weak for transmission of the request to the LTE network. In another example, the LTE network may take an "excessive" amount of time to process the request. In these and other examples, the UE may be unable to start or otherwise access CS service in a timely manner. This may be perceived by an end user as a relatively "poor" quality of service. The present disclosure addresses these and other issues by providing systems and methods to mitigate CSFB delay.

[0016] For example, referring now to **FIG. 1**, a block diagram **100** of an example EPS architecture for mitigating circuit-switched fallback delay is shown in accordance with the present disclosure. For brevity, the example diagram **100** is depicted in a simplified and conceptual form, and may generally include more or fewer systems, devices, networks, and/or other components as desired. Further, number and type of features or elements incorporated within the diagram **100** may or may not be implementation-specific. Still further, while certain connections are shown between certain features or elements within the diagram **100**, other additional or alternative connections are possible.

[0017] In the present example, the diagram **100** illustrates a multi-mode UE **102**, a E-UTRAN (Evolved UMTS Terrestrial Radio Access Network) **104**, a UTRAN/GERAN (UMTS Terrestrial Radio Access Network/GSM EDGE Radio Access Network) **106**, at least one MME (Mobile Management Entity) **108**, at least one SGSN (Serving GPRS Support Node) **110**, and at least one MSC (Mobile Switching Center/Server) **112**. Here, in the example of a GSM network, the MSC **112** may refer to a Mobile Switching Center. In the example of a 3G network, the MSC **112** may refer to a Mobile Switching Server.

[0018] In practice, the MME **108** serves the UE **102** via the E-UTRAN **104** when in LTE access mode. The SGSN **110** serves the UE **102** via the UTRAN/GERAN **106** when in 2G/3G access mode, for data services. The MSC **112** serves the UE **102** via the UTRAN/GERAN **106** when in 2G/3G access mode, for voice services. A CSFB engine **114** of the UE **102** may be configured to interact with at least one or both of the MME **108** and the MSC **112** to coordinate redirection of the UE **102** from the E-UTRAN **104** to the UTRAN/GERAN **106** for CS service. Additionally, the CSFB engine **114** may be

configured to mitigate circuit-switched fallback delay in accordance with the present disclosure.

[0019] For example, referring now additionally to FIG. 2, the CSFB engine 114 is shown in accordance with the present disclosure. In particular, the CSFB engine 114 is shown to include a control module 116, a timer module 118, a cell list module 120, a cell reselection module 122, a signal measurement module 124, and a PLMN (Public Land Mobile Network) selection module 126. In the following, it is assumed that the UE 102 is initially camped-on a particular cell of the E-UTRAN 104, and may or may not be accessing a particular packet-switched service offered by the E-UTRAN 104, such as Internet access. Other embodiment are possible.

[0020] While the UE 102 is camped-on a particular cell of the E-UTRAN 104, the control module 116 may receive a MOC (Mobile Originating Call) indication 128 from the UE 102. For example, a user of the UE 102 may initiate a voice call using the UE 102. In response to receiving the MOC indication 128, the control module 116 may send a request message 130 to the MME 108 for CSFB from the E-UTRAN 104 to the UTRAN/GERAN 106 for access to CS (Circuit-Switched) voice service. Concurrently, or at least "approximately" concurrently or "about" concurrently, with sending of the request message 130, the control module 116 may activate the timer module 118 to start or otherwise instantiate a particular timer that is associated with the request message 130. For example, at arbitrary time t_0 corresponding to sending of the request message 130, a timer "A" initialized to zero (0) (e.g., $t_0 = 0$) may be started that may keep running track of time (e.g., with reference to a particular clock of the UE 102) until a response message 132 is received by the CSFB engine 114. The response message 132 may confirm release of certain resources and/or modification of certain configurations, as coordinated by at least the MME 108, to support CSFB from the E-UTRAN 104 to the UTRAN/GERAN 106. When CSFB is successfully "completed," the user of the UE 102 may engage in a voice call using the UE 102.

[0021] In the present example, when the response message 132 is received before the passage of a predetermined period of time, as gauged by the timer module 118,

the CSFB engine **114** may proceed to initiate connection of the UE **102** to the UTRAN/GERAN **106** for access to CS voice service. For example, when the response message **132** is received within a time period defined as t_t-t_0, where t_t is an integer value that corresponds to a configurable response threshold and t_0 = 0, the CSFB engine **114** may proceed to initiate connection of the UE **102** to the UTRAN/GERAN **106** for access to CS voice service.

[0022] In certain scenarios, however, an unintended or undesired delay may occur between sending of the request message **130** and receiving of the response message **132** where, in some instances, the response message **132** may not be received at all. Such a scenario may be identified when the response message **132** is received following passage of the predetermined period of time discussed above. For example, this may occur when the response message **132** is received at a time $t_1 \geqslant t_t$, where t_1 is an integer value greater than or at least equal to the configurable response threshold t_t. Such an event may be referred to as "CSFB failure," where it may be determined by the UE **102** that the CSFB engine **114** is unable to proceed to initiate connection of the UE **102** to the UTRAN/GERAN **106**. Here, the CSFB engine **114** may discontinue its attempt to initiate connection of the UE **102** to the UTRAN/GERAN **106** for access to CS voice service. An end user may perceive this as an "incomplete" call or a "dropped" call, etc.

[0023] In another example, however, the CSFB engine **114** may continue its attempt to initiate connection of the UE **102** to the UTRAN/GERAN **106** following expiration of the timer (e.g., $t_1 \geqslant t_t$ in the discussed example), independent of further interaction with the E-UTRAN **104**, at least with respect to CSFB. Such an implementation may be referred to as "circuit-switched fallback delay mitigation" in accordance with the present disclosure.

[0024] For example, referring now additionally to **FIG. 3**, an example method **300** for mitigating circuit-switched fallback delay is shown in accordance with the present disclosure. In general, the example method **300** may be wholly or at least partially implemented by a special-purpose computing system or device, which itself may, in some embodiments, be configured based on implementation-specific

requirements or specifications. For example, the method **300** is described with reference to the UE **102**, along with other components of the diagram **100**, as described above in connection with **FIG. 1** and **FIG. 2**. Other embodiments are possible.

[0025] At operation **302**, the UE **102** may camp-on a particular cell of the E-UTRAN **104**. Upon residing on the particular cell, the MME **108** may register the UE **102** with the E-UTRAN **104** and the UTRAN/GERAN **106**. In one embodiment, the UE **102** may initiate connection to the E-UTRAN **104** at operation **302** upon a power-on event of the UE **102**. Additionally, the UE **102** may enter into an operating state selected from an idle mode and active mode at or during operation **302**. In general, idle mode may correspond to a state by which a reduced amount of resources are allocated to communication with the E-UTRAN **104**, as compared to active mode. When in idle mode, the UE **102** may enter into active mode to access service(s) provided by the E-UTRAN **104**. Other embodiments are possible.

[0026] At operation **304**, the UE **102** may send the request message **130** to the MME **108** for CSFB from the E-UTRAN **104** to the UTRAN/GERAN **106** for access to CS voice service. In one embodiment, the UE **102** may send the request message **130** to the MME **108** in response to receiving the MOC indication **128** from the UE **102**, corresponding to a user of the UE **102** initiating a voice call (e.g., mobile originating call) using the UE **102**, as discussed above. Additionally, at operation **304**, the UE **102** may concurrently activate the timer module **118** and start or otherwise instantiate a particular timer that is associated with the request message **130**. Here, the particular timer is configured to determine elapsed duration between sending of the request message **130** and receiving of the response message **132** (if received at all), where timer expiration indicates lack of receiving the response message **132** within a predetermined, user-configurable time period.

[0027] In accordance with the present disclosure, upon expiration of the timer, the UE **102** is not configured to discontinue its attempt to initiate connection to the UTRAN/GERAN **106** for access to CS voice service. Rather, the UE **102** is

configured to continue its attempt to initiate connection of the UE 102 to the UTRAN/GERAN 106, following expiration of the timer, in a "circuit-switched fallback delay mitigation" implementation.

[0028] For example, at operation 306, the UE 102 may determine that the timer has expired, indicating that the response message 132 has not been received within the predetermined, user-configurable time period. Next, at operation 308, a determination may be made by the UE 102 as to whether a listing is available that specifies measured signal strength of one or more circuit-switched network access points (e.g., signal strength of a particular base station transmitter). For example, referring additionally now to FIG. 2, the control module 116 of the CSFB engine 114 may access the cell list module 120 to determine whether the UE 102 has previously measured and stored signal strength of particular circuit-switched network access points of the UTRAN/GERAN 106. Details associated with the listing of the cell list module 120, as well as measuring and storing signal strength of particular circuit-switched network access points, are discussed in further detail below in connection with FIG. 4.

[0029] Flow may branch to operation 310 upon determination that a listing that specifies measured signal strength of circuit-switched network access points is available at operation 308. At operation 310, the UE 102 may initiate connection of the UE 102 to the UTRAN/GERAN 106 to access CS voice service. For example, the control module 116 of the CSFB engine 114 may activate the cell reselection module 122 to implement an inter-RAT (Radio Access Technology) cell reselection algorithm (e.g., "inter" because cell reselection may be performed across 2G and/or 3G networks) to access CS voice service based on information within the listing (e.g. see operation 308).

[0030] In some embodiments, the control module 116 may rank access points within the listing according to signal strength, and then activate the cell reselection module 122 to implement an inter-RAT cell reselection algorithm. Still other embodiments are possible. For example, the control module 116 may select a particular access point within the listing having signal strength at least greater

than other access points within the listing, and then activate the cell reselection module **122** to implement an inter-RAT cell reselection algorithm. Such an implementation may, among other things, ensure that a target cell has a strong enough signal such that the UE **102** may camp-on the target cell following inter-RAT cell reselection. Flow may then proceed to operation **312** following operation **310**. At operation **312**, CSFB according to the present disclosure may be "completed," and the UE **102** may access CS voice service as offered by the UTRAN/GERAN **106**.

[0031] Referring back to operation **308**, flow may optionally (indicated by intermittent line in **FIG. 3**) branch to operation **316** or operation **318** upon determination that a listing that specifies measured signal strength of circuit-switched network access points is unavailable at operation **308**. Flow may be directed between or to operation **316** and operation **318** by the control module **116** of the CSFB engine **114**. For example, the control module **116** may be programmed to direct flow to operation **316**, instead of operation **318**, based on certain criteria. For example, flow may be directed to operation **316** upon a number of discoverable 2G/3G access points exceeding a predetermined number, such as greater than or at least equal to one (1) for example. In contrast, flow may be directed to operation **318** upon a number of discoverable 2G/3G access points being less than the predetermined number. Other embodiments are possible. For example, flow may be directed to operation **318** directly upon determination that a listing that specifies measured signal strength of circuit-switched network access points is unavailable at operation **308**. Still other embodiments are possible.

[0032] At operation **316**, the UE **102** may measure and store signal strength of discoverable circuit-switched network access points of the UTRAN/GERAN **106**. For example, the control module **116** of the CSFB engine **114** may activate the signal measurement module **124** to measure signal strength of an associated discoverable circuit-switched network access point. Details associated with measuring and storing signal strength of particular circuit-switched network access points by the signal measurement module **124** are discussed in further detail below in connection with **FIG. 4**. Following operation **316**, flow may then proceed to

operation 310, and then operation 312, in a manner as described above. In particular, at operation 312, CSFB according to the present disclosure may be "completed," and the UE 102 may access CS voice service as offered by the UTRAN/GERAN 106.

[0033] Referring back to operation 308, as mentioned above, flow may optionally branch to operation 318. At operation 318, the UE 102 may initiate a PLMN (Public Land Mobile Network) selection process to camp-on a particular cell of the UTRAN/GERAN 106. In particular, the control module 116 of the CSFB engine 114 may activate the PLMN selection module 126 of FIG. 2, in certain implementations in tandem with activation of the signal measurement module 124, to initiate a PLMN (Public Land Mobile Network) selection process to camp-on a particular cell of the UTRAN/GERAN 106. PLMN selection may be considered a "supplement" to inter-RAT cell reselection. This is because, generally, a PLMN connects to a PSTN (Public Switched Telephone Network). In this manner, CSFB according to the present disclosure may be "completed" by PLMN selection such that the UE 102, once camped-on a particular cell of the UTRAN/GERAN 106, may access CS voice service. For example, following operation 316, flow may then proceed to operation 312 where CSFB according to the present disclosure may be "completed," and the UE 102 may access CS voice service as offered by the UTRAN/GERAN 106.

[0034] The example method 300 of FIG. 3 may be beneficial in many respects. For example, when the UE 102 does not timely receive the response message 132 from the E-UTRAN 104 for CSFB, the UE 102 may discontinue seeking CSFB supported by the E-UTRAN 104, and independently launch an inter-RAT cell reselection process or a PLMN selection process to acquire the UTRAN/GERAN 106. As a result, the UE 102 may decrease waiting time(s) for indication(s) from the E-UTRAN 104, and avoid CSFB failure due to network and other issues (e.g., poor signal strength, etc.). This may at least improve customer quality of experience and satisfaction.

[0035] Additionally or alternately, when the UE 102 does not timely receive the response message 132 from the E-UTRAN 104 for CSFB, the UE 102 may discontinue seeking CSFB supported by the E-UTRAN 104, and independently launch an inter-RAT

cell reselection process to acquire the UTRAN/GERAN 106 by referring to existing access point measurement results of the UTRAN/GERAN 106 (e.g., measured signal strength of 2G/3G neighbor cells). As a result, the UE 102 may at least decrease inter-RAT cell reselection period, and improve probability of success for cell reselection to the UTRAN/GERAN 106.

[0036] Additionally or alternately, when the UE 102 does not timely receive the response message 132 from the E-UTRAN 104 for CSFB, the UE 102 may discontinue seeking CSFB supported by the E-UTRAN 104, and independently launch an inter-RAT cell reselection process to acquire the UTRAN/GERAN 106 by referring to existing access point measurement results of the UTRAN/GERAN 106 (e.g., as contained within the "listing" discussed above). In this example, the measurement results may be ranked, and the inter-RAT cell reselection process may be implemented in accordance with the ranked results. As a result, the UE 102 may at least decrease inter-RAT cell reselection period, and improve probability of success for cell reselection to the UTRAN/GERAN 106.

[0037] Additionally or alternately, when the UE 102 does not timely receive the response message 132 from the E-UTRAN 104 for CSFB, the UE 102 may discontinue seeking CSFB supported by the E-UTRAN 104, and independently launch an inter-RAT cell reselection process to acquire the UTRAN/GERAN 106 by referring to existing access point measurement results of the UTRAN/GERAN 106 (e.g., as contained within the "listing" discussed above). In this example, the measurement results may be ranked, and the inter-RAT cell reselection process may be preferentially implemented with regard to a "strongest" ranked result. As a result, the UE 102 may at least simplify cell reselection, and decrease inter-RAT cell reselection period.

[0038] Additionally or alternately, when the UE 102 does not timely receive the response message 132 from the E-UTRAN 104 for CSFB, the UE 102 may discontinue seeking CSFB supported by the E-UTRAN 104, and independently launch an inter-RAT cell reselection process to acquire the UTRAN/GERAN 106 by measuring and storing access point measurement results (e.g., measuring signal strength of discoverable

access points, and storing within the "listing" discussed above) of the UTRAN/GERAN **106**. In this example, the inter-RAT cell reselection process may be implemented with regard to the "most recent" signal strength measurement. As a result, the UE **102** may at least improve probability of success for cell reselection to the UTRAN/GERAN **106**.

[0039] Additionally or alternately, when the UE **102** does not timely receive the response message **132** from the E-UTRAN **104** for CSFB, the UE **102** may discontinue seeking CSFB supported by the E-UTRAN **104**, and when the UE **102** determines unavailability of a listing that specifies measured signal strength of circuit-switched network access points (e.g., see operation **308**), the UE 102 may optionally implement PLMN selection to the UTRAN/GERAN **106**.

[0040] Other benefits and/or advantages of the example method **300** of **FIG. 3** may be understood from the above-description provided in connection with **FIG. 1** and **FIG. 2**, and from the below-description provided in connection with **FIG. 4**.

[0041] For example, referring now to **FIG. 4**, the relationship between example LTE Cells, example 2G/3G cells, and geographic location of a multi-mode mobile user equipment is shown in accordance with the present disclosure. In particular, a diagram **400** of **FIG. 4** shows overlap between legacy cells **402** of the UTRAN/GERAN **106**, and LTE cells **404** of the E-UTRAN **104** in relation to position of the UE **102**. Other embodiments are possible.

[0042] In this example, simplified for purpose of discussion, a listing **406** is shown to specify 2G/3G cells "A-G" and LTE cells "A-G." Associated with each respective one of the 2G/3G cells "A-G," and LTE cells "A-G," is a corresponding "Measured Signal Strength" and an associated "Timestamp." The "Measured Signal Strength" and an associated "Timestamp" may be acquired by the signal measurement module **124** upon command by the control module **116** of the CSFB engine **114** of **FIG. 2**. For example, when the UE **102** is positioned within 2G/3G cell "A" as shown in **FIG. 4**, the control module **116** may activate the signal measurement module **124** which, in turn, may "discover" one or more of the 2G/3G cells "A-G" and LTE cells "A-G," measure signal strength of the one or more

of the 2G/3G cells "A-G" and LTE cells "A-G," and then populate the listing **406** with measured signal strength(s) along with a corresponding timestamp.

[0043] The listing **406** of **FIG. 4** may corresponding to the "listing" discussed above in connection with **FIG. 3**. Thus, the example listing **406** may be used within a "circuit-switched fallback delay mitigation" implementation as discussed throughout the present disclosure. For example, in some embodiments, the control module **116** may evaluate measured signal strength(s), along with a corresponding timestamp, within the listing **406** to identify a "strongest" signal strength and/or a "most recent" single measurement such that the UE **102** may continue its attempt to initiate connection of the UE **102** to the UTRAN/GERAN **106** following expiration of the timer of the timer module **118** as discussed above.

[0044] In one embodiment, **FIGs. 5** and **6** describe an environment where a connection may be established through the AS and the NAS. The AS is a component associated with the wireless connection, and the NAS is a component not associated with the wireless connections, or the part of the core network, responsible for starting the UE, registration, location update, initiating CS or PS requests, etc. Cell selection originates from PRC, and the PLMN selection originates from NAS.

[0045] **FIG. 7** illustrates an embodiment of an example computer system/device **700**. An example of a computer system or device includes a multi-mode mobile user equipment or terminal (e.g., a smartphone configured to access multiple RATs), a server computer, desktop computer, laptop computer, personal data assistant, gaming console, and others. The example computer device **700** may be configured to perform and/or include instructions that, when executed, cause the computer system **700** to perform the example method of **FIG. 1**. The computer system **700** may be wholly or at least partially incorporated as part of previously-described computing devices, such as the UE **102**, E-UTRAN **104**, UTRAN/GERAN **106**, MME **108**, SGSN **110**, and MSC **112** of **FIG. 1**. It should be noted that **FIG. 7** is intended only to provide a generalized illustration of various components, any or all of which may be utilized as appropriate. **FIG. 7**, therefore, broadly illustrates how

individual system elements may be implemented in a relatively separated or relatively more integrated manner.

[0046] The computer device 700 is shown comprising hardware elements that can be electrically coupled via a bus 702 (or may otherwise be in communication, as appropriate). The hardware elements may include a processing unit with one or more processors 704, including without limitation one or more general-purpose processors and/or one or more special-purpose processors (such as digital signal processing chips, graphics acceleration processors, and/or the like); one or more input devices 706, which can include without limitation a remote control, a mouse, a keyboard, and/or the like; and one or more output devices 708, which can include without limitation a presentation device (e.g., television), a printer, and/or the like.

[0047] The computer system 700 may further include (and/or be in communication with) one or more non-transitory storage devices 710, which can comprise, without limitation, local and/or network accessible storage, and/or can include, without limitation, a disk drive, a drive array, an optical storage device, a solid-state storage device, such as a random access memory ("RAM"), and/or a read-only memory ("ROM"), which can be programmable, flash-updateable, and/or the like. Such storage devices may be configured to implement any appropriate data stores, including without limitation, various file systems, database structures, and/or the like.

[0048] The computer device 700 might also include a communications subsystem 712, which can include without limitation a modem, a network card (wireless or wired), an infrared communication device, a wireless communication device, and/or a chipset (such as a Bluetooth™ device, an 802.11 device, a WiFi device, a WiMax device, cellular communication facilities (e.g., GSM, WCDMA, LTE, etc.), and/or the like. The communications subsystem 712 may permit data to be exchanged with a network (such as the network described below, to name one example), other computer systems, and/or any other devices described herein. In many embodiments,

the computer system 700 will further comprise a working memory 714, which can include a RAM or ROM device, as described above.

[0049] The computer device 700 may also comprise software elements, shown as being currently located within the working memory 714, including an operating system 716, device drivers, executable libraries, and/or other code, such as one or more application programs 718, which may comprise computer programs provided by various embodiments, and/or may be designed to implement methods, and/or configure systems, provided by other embodiments, as described herein. Merely by way of example, one or more procedures described with respect to the method(s) discussed above, and/or system components might be implemented as code and/or instructions executable by a computer (and/or a processor within a computer); in an aspect, then, such code and/or instructions can be used to configure and/or adapt a general purpose computer (or other device) to perform one or more operations in accordance with the described methods.

[0050] A set of these instructions and/or code might be stored on a non-transitory computer-readable storage medium, such as the storage device(s) 710 described above. In some cases, the storage medium may be incorporated within a computer system, such as computer system 700. In other embodiments, the storage medium might be separate from a computer system (e.g., a removable medium, such as flash memory), and/or provided in an installation package, such that the storage medium can be used to program, configure, and/or adapt a general purpose computer with the instructions/code stored thereon. These instructions might take the form of executable code, which is executable by the computer device 700 and/or might take the form of source and/or installable code, which, upon compilation and/or installation on the computer system 700 (e.g., using any of a variety of generally available compilers, installation programs, compression/decompression utilities, etc.), then takes the form of executable code.

[0051] It will be apparent to those skilled in the art that substantial variations may be made in accordance with specific requirements. For example, customized hardware might also be used, and/or particular elements might be

implemented in hardware, software (including portable software, such as applets, etc.), or both. Further, connection to other computing devices such as network input/output devices may be employed.

[0052] As mentioned above, in one aspect, some embodiments may employ a computer system (such as the computer device 700) to perform methods in accordance with various embodiments of the invention. According to a set of embodiments, some or all of the procedures of such methods are performed by the computer system 700 in response to processor 704 executing one or more sequences of one or more instructions (which might be incorporated into the operating system 716 and/or other code, such as an application program 718) contained in the working memory 714. Such instructions may be read into the working memory 714 from another computer-readable medium, such as one or more of the storage device(s) 710. Merely by way of example, execution of the sequences of instructions contained in the working memory 714 might cause the processor(s) 704 to perform one or more procedures of the methods described herein.

[0053] The terms "machine-readable medium" and "computer-readable medium," as used herein, refer to any medium that participates in providing data that causes a machine to operate in a specific fashion. In an embodiment implemented using the computer device 700, various computer-readable media might be involved in providing instructions/code to processor(s) 704 for execution and/or might be used to store and/or carry such instructions/code. In many implementations, a computer-readable medium is a physical and/or tangible storage medium. Such a medium may take the form of a non-volatile media or volatile media. Non-volatile media include, for example, optical and/or magnetic disks, such as the storage device(s) 710. Volatile media include, without limitation, dynamic memory, such as the working memory 714.

[0054] Common forms of physical and/or tangible computer-readable media include, for example, a floppy disk, a flexible disk, hard disk, magnetic tape, or any other magnetic medium, a CD-ROM, any other optical medium, punchcards, papertape, any other physical medium with patterns of holes, a RAM, a PROM, EPROM, a FLASH-EPROM,

any other memory chip or cartridge, or any other medium from which a computer can read instructions and/or code.

[0055] Various forms of computer-readable media may be involved in carrying one or more sequences of one or more instructions to the processor(s) 704 for execution. Merely by way of example, the instructions may initially be carried on a magnetic disk and/or optical disc of a remote computer. A remote computer might load the instructions into its dynamic memory and send the instructions as signals over a transmission medium to be received and/or executed by the computer system 700.

[0056] The communications subsystem 712 (and/or components thereof) generally will receive signals, and the bus 702 then might carry the signals (and/or the data, instructions, etc. carried by the signals) to the working memory 714, from which the processor(s) 704 retrieves and executes the instructions. The instructions received by the working memory 714 may optionally be stored on a non-transitory storage device 710 either before or after execution by the processor(s) 704.

[0057] The methods, systems, and devices discussed above are examples. Various configurations may omit, substitute, or add various method steps or procedures, or system components as appropriate. For instance, in alternative configurations, the methods may be performed in an order different from that described, and/or various stages may be added, omitted, and/or combined. Also, features described with respect to certain configurations may be combined in various other configurations. Different aspects and elements of the configurations may be combined in a similar manner. Also, technology evolves and, thus, many of the elements are examples and do not limit the scope of the disclosure or claims.

[0058] Specific details are given in the description to provide a thorough understanding of example configurations (including implementations). However, configurations may be practiced without these specific details. For example, well-known circuits, processes, algorithms, structures, and techniques have been shown without unnecessary detail in order to avoid obscuring the configurations. This description provides example configurations only, and does not limit the

scope, applicability, or configurations of the claims. Rather, the preceding description of the configurations will provide those skilled in the art with an enabling description for implementing described techniques. Various changes may be made in the function and arrangement of elements without departing from the spirit or scope of the disclosure.

[0059] Also, configurations may be described as a process which is depicted as a flow diagram or block diagram. Although each may describe the operations as a sequential process, many of the operations can be performed in parallel or concurrently. In addition, the order of the operations may be rearranged. A process may have additional steps not included in the figure. Furthermore, examples of the methods may be implemented by hardware, software, firmware, middleware, microcode, hardware description languages, or any combination thereof. When implemented in software, firmware, middleware, or microcode, the program code or code segments to perform the necessary tasks may be stored in a non-transitory computer-readable medium such as a storage medium. Processors may perform the described tasks.

[0060] Furthermore, the example embodiments described herein may be implemented as logical operations in a computing device in a networked computing system environment. The logical operations may be implemented as any combination of: (i) a sequence of computer implemented instructions, steps, or program modules running on a computing device; and (ii) interconnected logic or hardware modules running within a computing device.

[0061] Although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as example forms of implementing the claims.

Claims

1. A method for mitigating circuit-switched fallback delay, comprising:

initiating, by a user equipment, connection of the user equipment to a packet-switched network;

sending, by the user equipment to the packet-switched network, a request to access a circuit-switched service;

starting, by the user equipment concurrently with sending the request, a timer to determine elapsed duration between sending the request and receiving a response from the packet-switched network that confirms resource allocation to access the circuit-switched service; and

selecting, by the user equipment in response to timer expiration, indicating absence of response to the request, a particular algorithm that when implemented initiates connection of the user equipment to a particular circuit-switched network to access the circuit-switched service.

2. The method of claim 1, further comprising determining, by the user equipment, availability of a listing that specifies measured signal strength of circuit-switched network access points.

3. The method of claim 2, further comprising, upon determining availability of the listing, implementing an inter-RAT (Radio Access Technology) cell reselection algorithm to access the circuit-switched service based on access points within the listing.

4. The method of claim 2, further comprising, upon determining availability of the listing, ranking access points within the listing according to signal strength, and implementing an inter-RAT (Radio Access Technology) cell reselection algorithm to access the circuit-switched service based on the ranking.

5. The method of claim 2, further comprising, upon determining availability of the listing, selecting a particular access point within the listing having signal strength at least greater than other access points within the listing, and implementing an inter-RAT (Radio Access Technology) cell reselection algorithm to connect to the user equipment to the particular access point to access the circuit-switched service.

6. The method of claim 2, further comprising, upon determining unavailability of the listing, measuring signal strength of discoverable circuit-switched network access points, and implementing an inter-RAT (Radio Access Technology) cell reselection algorithm to access the circuit-switched service based on measured signal strength of the discoverable circuit-switched network access points.

7. The method of claim 2, further comprising, upon determining unavailability of the listing, measuring signal strength of discoverable circuit-switched network access points, ranking access points according to measured signal strength, and implementing an inter-RAT (Radio Access Technology) cell reselection algorithm to access the circuit-switched service based on the ranking.

8. The method of claim 2, further comprising, upon determining unavailability of the listing, measuring signal strength of discoverable circuit-switched network access points, selecting a particular access point having a measured signal strength at least greater than other measured signal strengths, and implementing an inter-RAT (Radio Access Technology) cell reselection algorithm to connect to the user equipment to the particular access point to access the circuit-switched service.

9. The method of claim 1, further comprising:

attempting, by the UE, cell re-selection to another RAT; and

in response to failure of the attempt, selecting, by a non-access stratum (NAS), the cell to another RAT which is unaware of signal strength.

10. The method of claim 1, further comprising sending the request in response to launching of a mobile originating call by the user equipment.

11. A computer-implemented method, comprising:

initiating, by a mobile terminal, connection of the mobile terminal to a packet-switched network;

sending, by the mobile terminal to the packet-switched network, a request to access a circuit-switched service;

starting, by the mobile terminal, a timer to determine elapsed duration between sending the request and receiving a response from the packet-switched network that confirms resource allocation to access the circuit-switched service;

detecting, by the mobile terminal, expiration of the timer indicating absence of response to the request; and

initiating, by the mobile terminal in response to detecting expiration of the timer, connection of the mobile terminal to a particular circuit-switched network to access the circuit-switched service.

12. The method of claim 11, further comprising determining availability of a listing that specifies measured signal strength of circuit-switched network access points.

13. The method of claim 12, further comprising implementing an inter-RAT (Radio Access Technology) cell reselection algorithm to access the circuit-switched service based on access points within the listing.

14. The method of claim 12, further comprising ranking access points within the listing according to signal strength, and implementing an inter-RAT (Radio Access

Technology) cell reselection algorithm to access the circuit-switched service based on the ranking.

15. The method of claim 12, further comprising selecting a particular access point within the listing having signal strength at least greater than other access points within the listing, and implementing an inter-RAT (Radio Access Technology) cell reselection algorithm to connect to the mobile terminal to the particular access point to access the circuit-switched service.

16. The method of claim 12, further comprising measuring signal strength of discoverable circuit-switched network access points, and implementing an inter-RAT (Radio Access Technology) cell reselection algorithm to access the circuit-switched service based on measured signal strength of the discoverable circuit-switched network access points.

17. The method of claim 12, further comprising measuring signal strength of discoverable circuit-switched network access points, ranking access points according to measured signal strength, and implementing an inter-RAT (Radio Access Technology) cell reselection algorithm to access the circuit-switched service based on the ranking.

18. The method of claim 12, further comprising measuring signal strength of discoverable circuit-switched network access points, selecting a particular access point having a measured signal strength at least greater than other measured signal strengths, and implementing an inter-RAT (Radio Access Technology) cell reselection algorithm to connect to the mobile terminal to the particular access point to access the circuit-switched service.

19. The method of claim 12, further comprising, ranking access points within the listing, and implementing an inter-RAT (Radio Access Technology) cell reselection

algorithm to access the circuit-switched service based on the ranking.

20. The method of claim 11, further comprising:

attempting, by a UE, cell re-selection to another RAT; and

in response to failure of the attempt, selecting, by a non-access stratum (NAS), the cell to another RAT which is unaware of signal strength.

21. A multi-mode mobile user equipment (UE), comprising:

a processing unit; and

a system memory connected to the processing unit, the system memory including instructions that, when executed by the processing unit, cause the processing unit to instantiate at least one module to select, in response to expiration of a timer, a particular algorithm that when implemented initiates connection of the UE to a particular circuit-switched network to access a circuit-switched service, the at least one module configured to:

initiate connection of the UE to a packet-switched network;

send to the packet-switched network a request to access the circuit-switched service;

start a timer to determine elapsed duration between sending the request and receiving a response from the packet-switched network that confirms resource allocation to access the circuit-switched service; and

select, in response to expiration of the timer indicating absence of response to the request, the particular algorithm that when implemented initiates connection of the user equipment to the particular circuit-switched network to access the circuit-switched service.

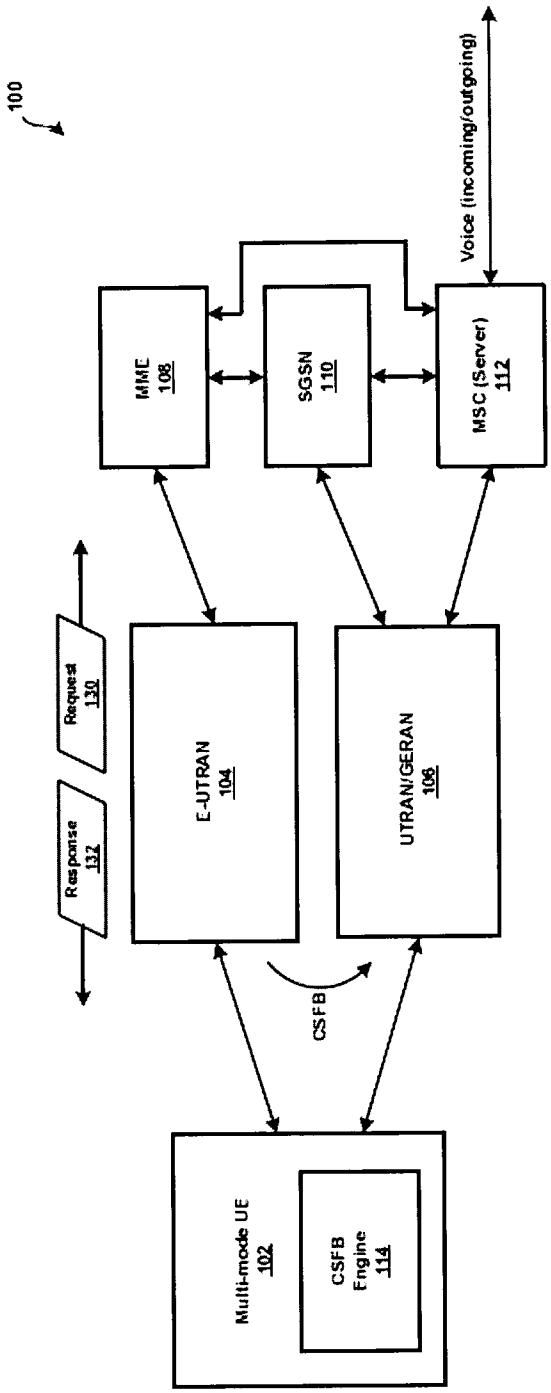

100
Voice (incoming/outgoing)
MME 108
SGSN 110
MSC (Server) 112
Request 130
Response 132
E-UTRAN 104
UTRAN/GERAN 106
CSFB
Multi-mode UE 102
CSFB Engine 114

Fig. 1

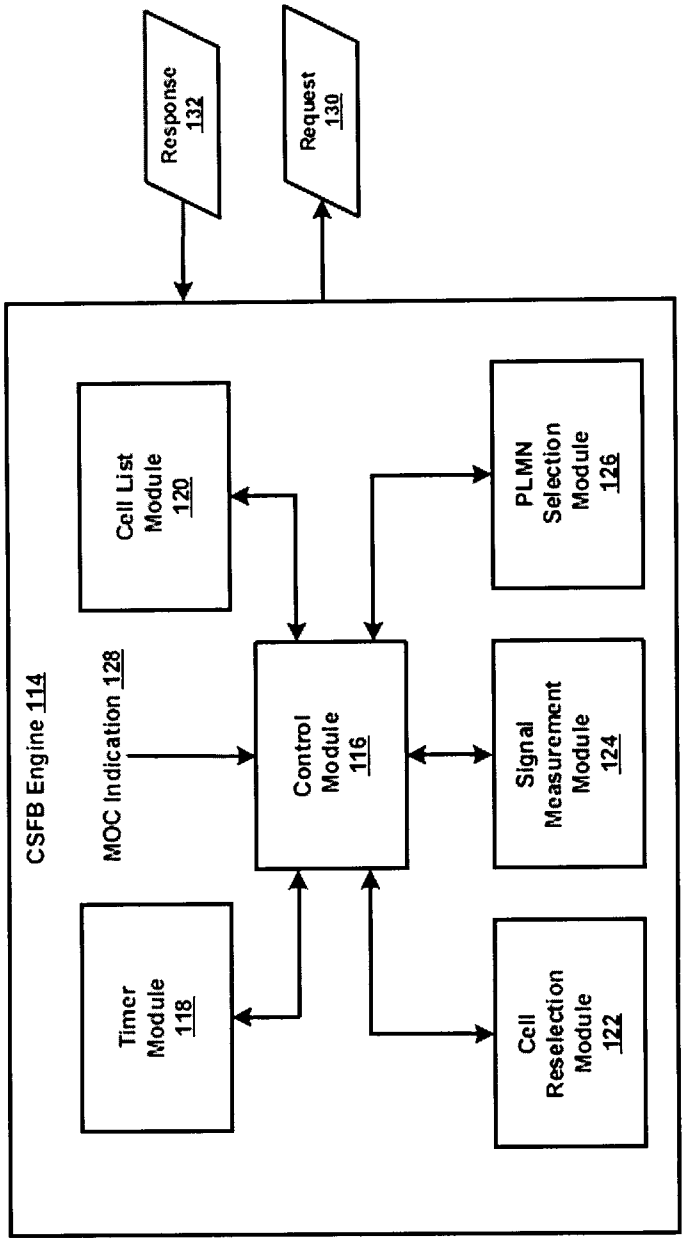

Response 132
Request 130
CSFB Engine 114
Cell List Module 120
PLMN Selection Module 126
MOC Indication 128
Control Module 116
Signal Measurement Module 124
Timer Module 118
Cell Reselection Module 122

Fig. 2

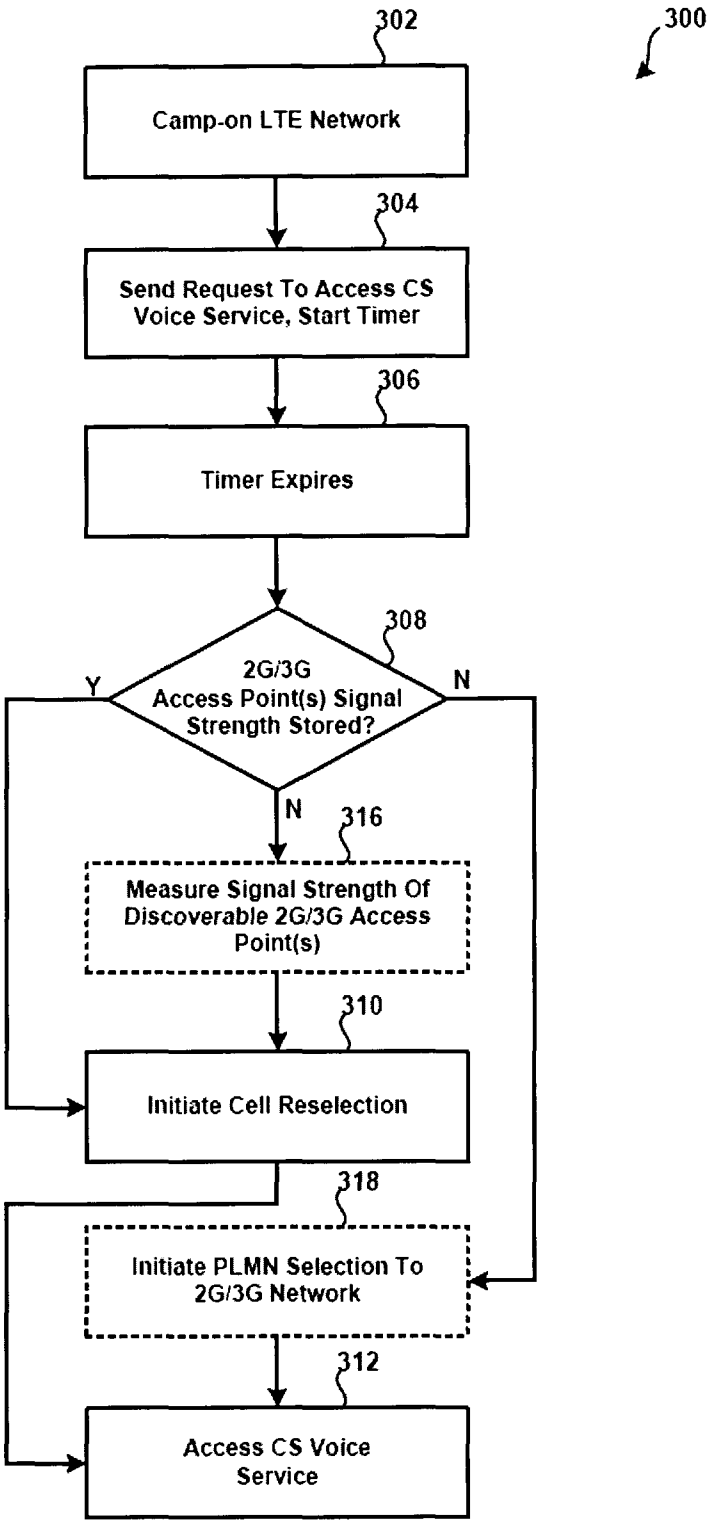

300
302
Camp-on LTE Network
304
Send Request To Access CS Voice Service, Start Timer
306
Timer Expires
308
2G/3G Access Point(s) Signal Strength Stored?
Y
N
N
316
Measure Signal Strength Of Discoverable 2G/3G Access Point(s)
310
Initiate Cell Reselection
318
Initiate PLMN Selection To 2G/3G Network
312
Access CS Voice Service

Fig. 3

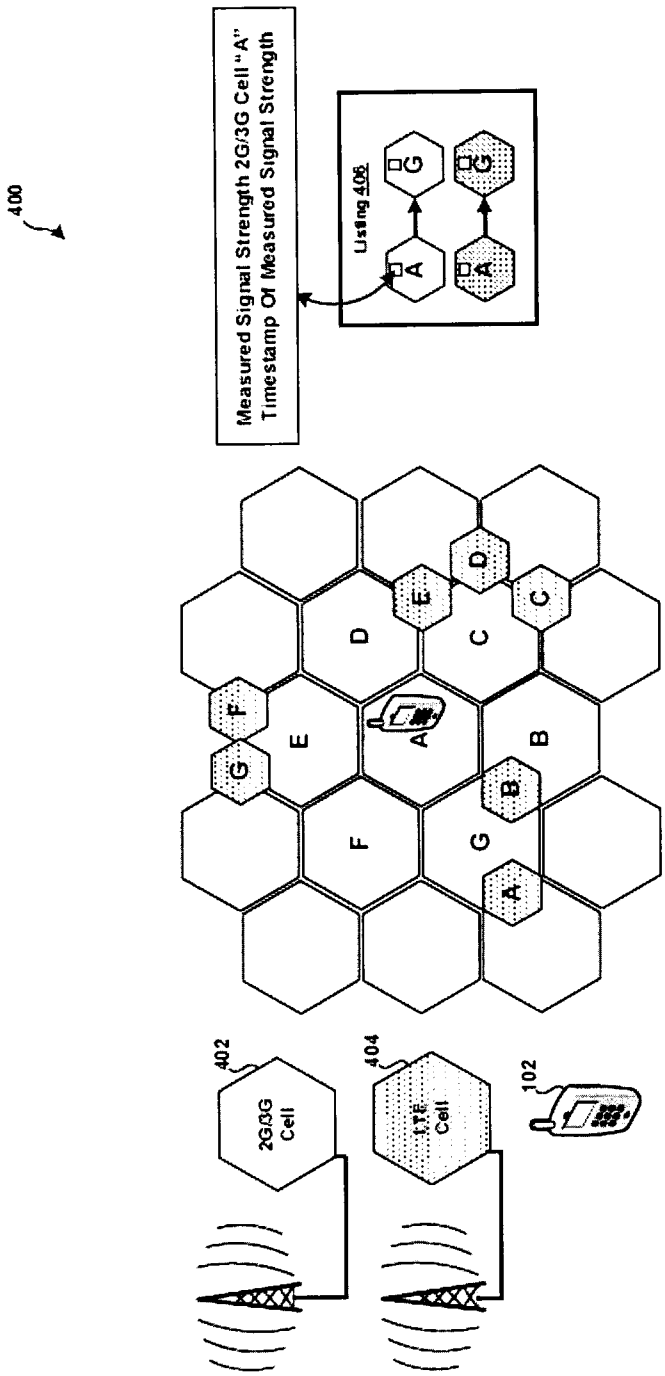

400
Measured Signal Strength 2G/3G Cell "A"
Timestamp Of Measured Signal Strength
Listing 406
A
G
A
G
A
B
C
D
E
F
G
402
2G/3G Cell
404
LTE Cell
102

Fig. 4

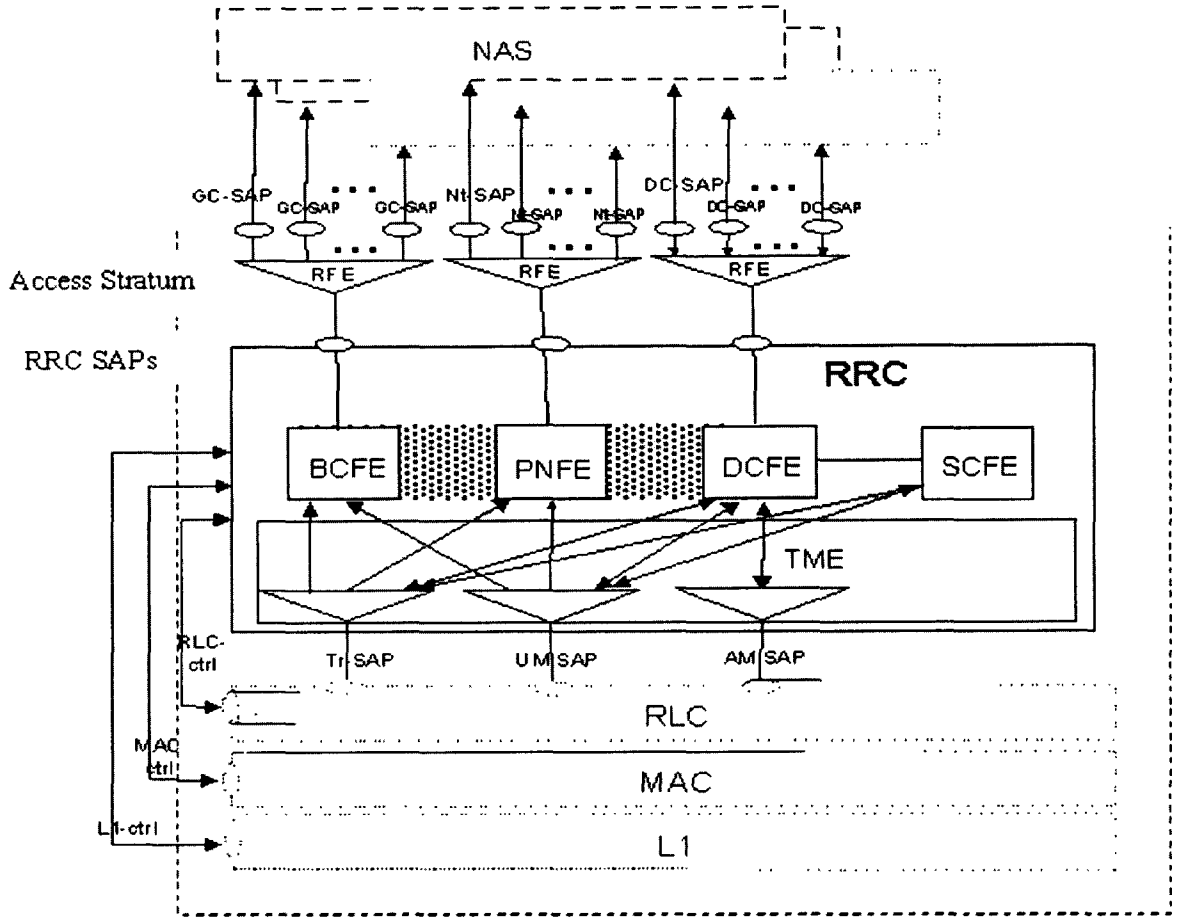

NAS
GC-SAP
GC-SAP
GC-SAP
Nt-SAP
Nt-SAP
Nt-SAP
DC-SAP
DC-SAP
DC-SAP
RFE
RFE
RFE
Access Stratum
RRC SAPs
RRC
BCFE
PNFE
DCFE
SCFE
TME
RLC-ctrl
Tr-SAP
UM-SAP
AM-SAP
RLC
MAC-ctrl
MAC
L1-ctrl
L1

Fig. 5

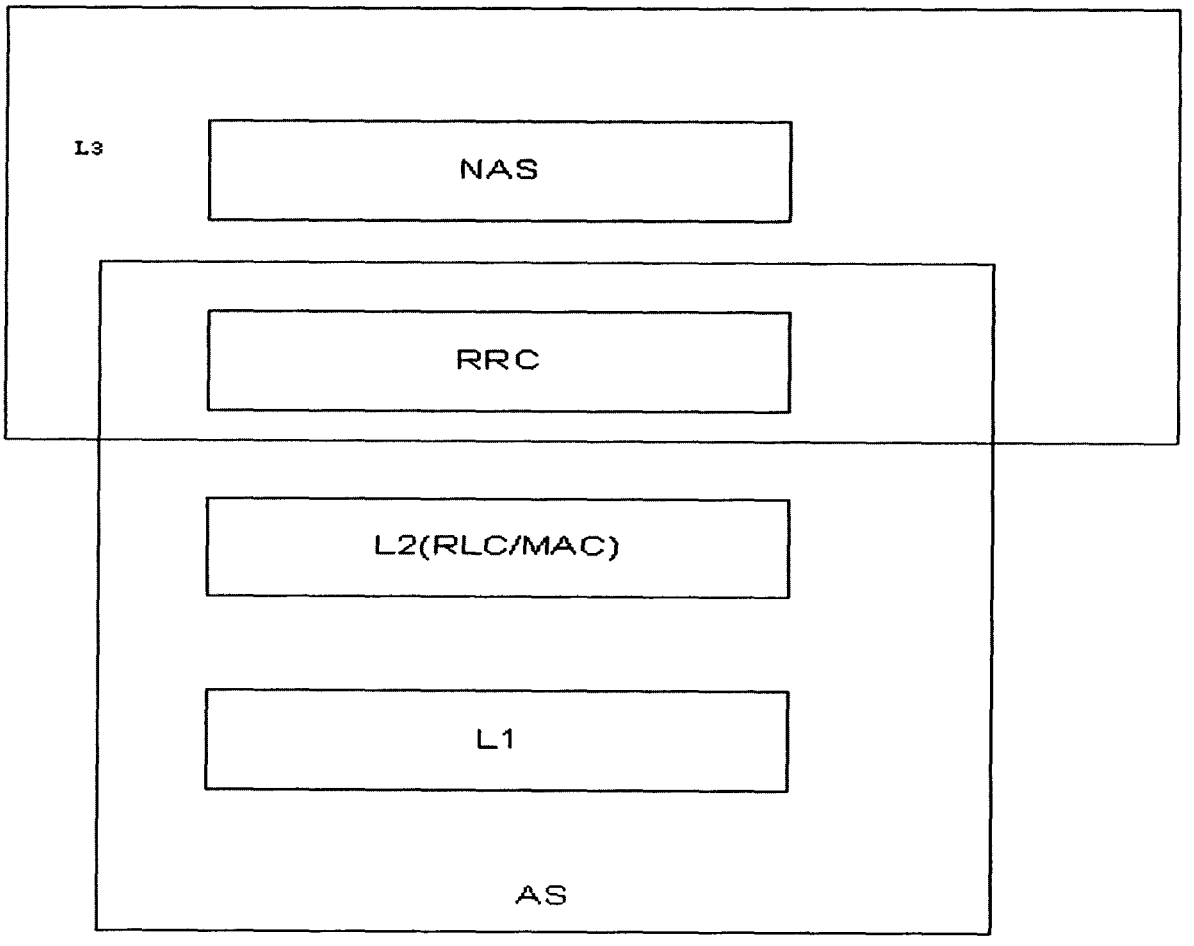


Fig. 6

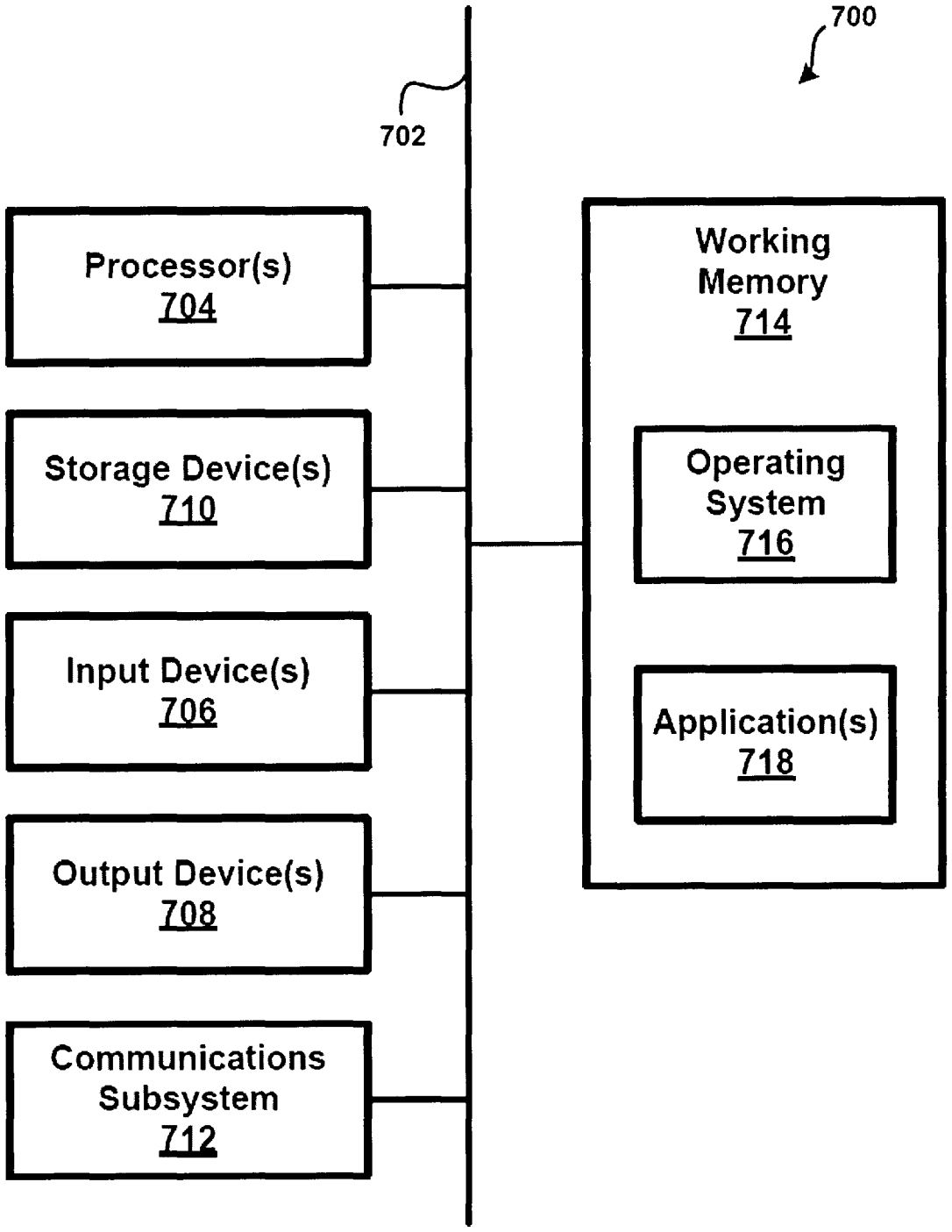

700
702
Processor(s)
704
Storage Device(s)
710
Input Device(s)
706
Output Device(s)
708
Communications
Subsystem
712
Working
Memory
714
Operating
System
716
Application(s)
718

Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2013/086282

A. CLASSIFICATION OF SUBJECT MATTER

H04W 76/02(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

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)

CNABS,CNKI,WPI,EPODOC: circuit 3w switch+, fallback+, delay+, request+, respons+,timer, mitigat+, packet 3w switch+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012/0002545A1 (INTERDIGITAL PATENT HOLDINGS, INC.) 05 January 2012 (2012-01-05) description, paragraphs[0007], [0050]-[0096], figures3-5	1-21
A	CN 1816196A (HUAWEI TECH. CO., LTD.) 09 August 2006 (2006-08-09) the whole document	1-21
A	CN 101834789A (NANJING UNIVERSITY) 15 September 2010 (2010-09-15) the whole document	1-21

☐ 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

"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
30 May 2014	**04 August 2014**

Name and mailing address of the ISA/	Authorized officer
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Facsimile No. **(86-10)62019451**	Telephone No. **(86-10)62414442**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2013/086282

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
US 2012/0002545A1	05 January 2012	WO 2011156264A2	15 December 2011
		TW 201218815A	01 May 2012
		CA 2801918A1	15 December 2011
		EP 2578021A2	10 April 2013
		CN 102893668A	23 January 2013
		KR 20130080836A	15 July 2013
		JP 2013534090A	29 August 2013
		HK 1181242A0	01 November 2013
		SG 185115A1	28 December 2012
CN 1816196A	09 August 2006	None	
CN 101834789A	15 September 2010	None	