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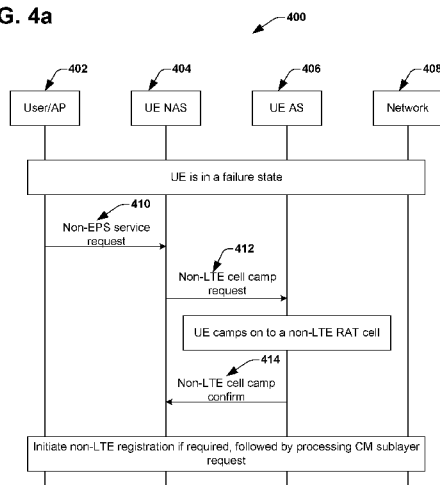
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FIG. 4a



(57) Abstract: An apparatus for a user equipment (UE) in a circuit-switched fall back (CSFB) enabled long term evolution (LTE) network is disclosed. The apparatus comprises one or more processors to determine that a circuit-switched (CS) communication session comprising a mobile originating (MO) CS voice call is to be established for the UE and determine whether the UE is in a failure state comprising an evolved packet system mobility management (EMM)-REGISTERED.ATTEMPTING-TO-UPDATE-MM or an EMM-REGISTERED.PLMN-SEARCH or an EMM-REGISTERED.LIMITED-SERVICE. The one or more processors is further configured to attempt to select an available non-LTE network that supports CS services, by providing one or more service related messages to a base station of the available non-LTE network as part of an establishment of a CS communication session comprising the CS call, when the UE is in the failure state.

CIRCUIT SWITCHED FALL BACK (CSFB) IMPROVED STATE HANDLING**REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims the benefit of provisional Application No. 62/304,027, filed March 4, 2016, entitled "NAS STATE HANDLING FOR CIRCUIT SWITCHED FALLBACK", the contents of which are herein incorporated by reference in their entirety.

FIELD

[0002] The present disclosure relates to circuit switched fall back (CSFB) enabled long term evolution (LTE) networks and in particular, to a method for improved state handling for CSFB procedure in CSFB enabled LTE networks.

BACKGROUND

[0003] A mobile network may support communication with mobile devices. In some cases, a mobile device may experience degradation in performance for any number of reasons. As an example, the mobile device may be out of coverage of base stations in the network. As another example, the network may experience congestion or other issues. In these and other scenarios, a performance of the device and/or a user experience may suffer. Accordingly, there is a general need for methods and systems for improving performance in these and other scenarios.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] Some examples of circuits, apparatuses and/or methods will be described in the following by way of example only. In this context, reference will be made to the accompanying Figures.

[0005] Fig. 1 illustrates a simplified block diagram of a circuit switched fall back (CSFB) enabled packet switched (PS) network, according to one embodiment of the disclosure.

[0006] Fig. 2 illustrates a simplified block diagram of a circuit switched fall back (CSFB) enabled long term evolution (LTE) network, according to one embodiment of the disclosure.

[0007] Fig. 3 illustrates a block diagram of an apparatus for use in a user equipment (UE) in a CSFB enabled PS network, according to various embodiments described herein.

[0008] Fig. 4a illustrates the events that may occur and/or the operations that may be performed related to a reception of a non-EPS service request for initiating a mobile originating (MO) CS voice call, from the connection management (CM) sub-layer within a user equipment (UE) while the UE operates in a failure state, according to an embodiment of the disclosure.

[0009] Fig. 4b illustrates the events that may occur and/or the operations that may be performed related to a reception of a CS domain paging for initiating a mobile terminating (MT) CS voice call at a user equipment (UE) while the UE operates in EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM state, according to an embodiment of the disclosure.

[0010] Fig. 5 illustrates a flow chart of a method for a UE in a CSFB enabled PS network, according to one embodiment of the disclosure.

[0011] Fig. 6 illustrates, example components of a User Equipment (UE) device, for the various embodiments described herein.

[0012] FIG. 7 is a functional diagram of a 3GPP long term evolution (LTE) network, in accordance with some embodiments.

DETAILED DESCRIPTION

[0013] In one embodiment of the disclosure, an apparatus for a user equipment (UE) in a circuit-switched fall back (CSFB) enabled long term evolution (LTE) network is disclosed. The apparatus comprises one or more processors; and a memory including instructions comprising operations, for execution via the one or more processors, to determine that a circuit-switched (CS) communication session comprising a mobile

originating (MO) CS call or a mobile terminating (MT) CS call is to be established for the UE and determine whether the UE is in a failure state comprising an evolved packet system mobility management (EMM)-REGISTERED.ATTEMPTING-TO-UPDATE-MM or an EMM-REGISTERED.PLMN-SEARCH or an EMM-REGISTERED.LIMITED-SERVICE. The instructions comprise further operations to attempt to select an available non-LTE network that supports CS services, when the UE is in the failure state, by providing, via the one or more processors, one or more service related messages to a base station of the available non-LTE network as part of an establishment of a CS communication session comprising the MO CS call.

[0014] In one embodiment of the disclosure, an apparatus for a user equipment (UE) in a circuit-switched fall back (CSFB) enabled packet-switched (PS) network is disclosed. The apparatus comprises one or more processors; and a memory including instructions comprising operations, for execution via the one or more processors, to determine that a circuit-switched (CS) communication session comprising a mobile originating (MO) CS call or a mobile terminating (MT) CS call is to be established for the UE and determine whether the UE is in a failure state comprising a first state wherein the UE is successfully registered for a PS communication session with a PS-domain associated with the CSFB enabled PS network, and wherein the UE is not registered for a CS-communication session with a CS-domain associated with the CSFB enabled PS network, at least partly due to a temporary issue associated with the CS-domain; or a second state wherein the UE is searching for public land mobile networks (PLMNs); or a third state wherein a cell selected by the UE is known not to be able to provide normal service and wherein the UE is searching for a suitable cell. The instructions comprise further operations to attempt to select an available CS network, when the UE is in the failure state, by providing, via the one or more processors, one or more service related messages to a CS base station of the available CS network as part of an establishment of the CS communication session comprising the MO CS call.

[0015] In one embodiment of the disclosure, a method for a user equipment (UE) in a circuit-switched fall back (CSFB) enabled packet-switched (PS) network is disclosed. The method comprises determining that a circuit-switched (CS) communication session comprising a mobile originating (MO) CS call or a mobile terminating (MT) CS call is to be established for the UE, at a processing circuit and determining, at the processing

circuit, whether the UE is in a failure state comprising a first state wherein the UE is successfully registered for a PS communication session with a PS-domain associated with the CSFB enabled PS network, and wherein the UE is not registered for a CS-communication session with a CS-domain associated with the CSFB enabled PS network, at least partly due to a temporary issue associated with the CS-domain; or a second state wherein the UE is searching for public land mobile networks (PLMNs); or a third state wherein a cell selected by the UE is known not to be able to provide normal service and wherein the UE is searching for a suitable cell. The method further comprises attempting to select an available CS network, by providing , by the processing circuit, one or more service related messages to a CS base station of the available CS network as part of an establishment of the CS communication session comprising the MO CS call, when the UE is in the failure state.

[0016] The present disclosure will now be described with reference to the attached drawing figures, wherein like reference numerals are used to refer to like elements throughout, and wherein the illustrated structures and devices are not necessarily drawn to scale. As utilized herein, terms “component,” “system,” “interface,” “circuit” and the like are intended to refer to a computer-related entity, hardware, software (e.g., in execution), and/or firmware. For example, a component can be a processor (e.g., a microprocessor, a controller, or other processing device), a process running on a processor, a controller, an object, an executable, a program, a storage device, a computer, a tablet PC and/or a user equipment (e.g., mobile phone, etc.) with a processing device. By way of illustration, an application running on a server and the server can also be a component. One or more components can reside within a process, and a component can be localized on one computer and/or distributed between two or more computers. A set of elements or a set of other components can be described herein, in which the term “set” can be interpreted as “one or more.”

[0017] Further, these components can execute from various computer readable storage media having various data structures stored thereon such as with a module, for example. The components can communicate via local and/or remote processes such as in accordance with a signal having one or more data packets (e.g., data from one component interacting with another component in a local system, distributed system,

and/or across a network, such as, the Internet, a local area network, a wide area network, or similar network with other systems via the signal).

[0018] As another example, a component can be an apparatus with specific functionality provided by mechanical parts operated by electric or electronic circuitry, in which the electric or electronic circuitry can be operated by a software application or a firmware application executed by one or more processors. The one or more processors can be internal or external to the apparatus and can execute at least a part of the software or firmware application. As yet another example, a component can be an apparatus that provides specific functionality through electronic components without mechanical parts; the electronic components can include one or more processors therein to execute software and/or firmware that confer(s), at least in part, the functionality of the electronic components.

[0019] Use of the word exemplary is intended to present concepts in a concrete fashion. As used in this application, the term “or” is intended to mean an inclusive “or” rather than an exclusive “or”. That is, unless specified otherwise, or clear from context, “X employs A or B” is intended to mean any of the natural inclusive permutations. That is, if X employs A; X employs B; or X employs both A and B, then “X employs A or B” is satisfied under any of the foregoing instances. In addition, the articles “a” and “an” as used in this application and the appended claims should generally be construed to mean “one or more” unless specified otherwise or clear from context to be directed to a singular form. Furthermore, to the extent that the terms “including”, “includes”, “having”, “has”, “with”, or variants thereof are used in either the detailed description and the claims, such terms are intended to be inclusive in a manner similar to the term “comprising.”

[0020] 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 various embodiments. However, it will be apparent to those skilled in the art having the benefit of the present disclosure that the various aspects of the various

embodiments 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 various embodiments with unnecessary detail.

[0021] As indicated above, a mobile device may experience degradation in performance for any number of reasons. For instance, in a circuit switched fall back (CSFB) enabled packet switched (PS) network such as a CSFB enabled 3GPP long term evolution (LTE) network, the network comprises a PS-portion (or PS-domain) that handles PS communication sessions or PS services (i.e., data services) associated with the network and a circuit-switched (CS) portion (or CS-domain) that handles CS communication sessions or CS services (i.e., voice calls) associated with the network. A typical PS network supports only PS services. When a voice call (also referred to as CS call or a CS voice call throughout the disclosure) is initiated in a CSFB enabled PS network, the network may cause the voice call to be transferred from the PS portion of the network to the CS portion of the network. Transferring a voice call in this manner is referred to as the CSFB. In some embodiments, a core network associated with the CSFB enabled PS network allows different radio access technologies (RATs) to work together in an integrated manner, in order to support both PS services and CS services associated with the network. For example, in the CSFB enabled 3GPP long term evolution (LTE) network, the PS-domain can include a 3GPP LTE network that supports only PS services and the CS-domain can include universal mobile telecommunications system (UMTS), global system for mobile communications (GSM) etc. that supports CS services. Alternately, in other embodiments, the PS-domain and the CS domain can include other RATs. In some embodiments, in order to facilitate the CSFB procedure, the LTE coverage should be overlapped by either the GSM or the UMTS coverage, in the CSFB enabled 3GPP LTE network.

[0022] A user equipment (UE) that is camped on to the CSFB enabled PS network may support multiple RATs and is known as a multi-mode UE. In further discussions below, all instances of UEs include multi-mode UEs and will be referred to hereinafter as a "UE". A CSFB enabled multi-mode UE has the capability to switch from the PS portion to the CS portion of the CSFB enabled PS network in order to send/receive CS voice calls using the CSFB procedure. In some embodiments, in order to facilitate a

voice call for the UE using the CSFB procedure, the CSFB enabled PS network redirects the multi-mode UE from the PS portion of the network to the CS portion of the network. However, mobile originated (MO) CS calls and mobile terminated (MT) CS calls in CSFB enabled PS networks through CSFB procedure are not always successful. There are some conditions in which the UE in the CSFB enabled PS network is unable to successfully perform a voice call through CSFB procedure. In some embodiments, these conditions include states or sub-states associated with the UE, referred to herein as failure states. In some embodiments, for example, the states include EPS mobility management (EMM) states associated with the UE, as defined in the 3GPP standard for LTE networks and the failure states includes one or more specific EMM states associated with the UE. When the UE is in a failure state, a MO CS voice call (e.g., user triggered voice call) or a MT CS voice call at the UE will be rejected or delayed due to additional signaling overhead between the UE and the network to first recover from the failure state before the CS call request can be processed, thus resulting in a dropped phone call. That is, in typical CSFB enabled PS network, for example, the CSFB enabled 3GPP LTE network, a CS voice call through CSFB procedure will be successful only when the UE is in a non-failure state associated therewith.

[0023] In some embodiments, the failure states associated with the UE does not indicate unavailability of CS-domain services for UE in served CSFB enabled PS network or a served LTE cell. Rather these states indicate, in some embodiments, a temporary failure due to race condition with other non-access stratum (NAS) procedure or temporary failure at access stratum (AS) due to bad radio conditions of the serving CSFB enabled PS network or the serving LTE cell. Therefore, in such embodiments, there is a high possibility to make mobile originated CS calls and mobile terminated CS calls successful, even when the UE is in a failure state. Therefore, in order to improve the success rate of mobile originated (MO) CS calls and mobile terminated (MT) CS calls in CSFB enabled PS networks, a method for improved state handling of the multi-mode UEs, is proposed in this disclosure. In some embodiments, the proposed method enables to handle MO CS calls or MT CS calls in CSFB enabled PS networks, even when the UE is in a failure state, the details of which are given in various embodiments described herein.

[0024] Fig. 1 illustrates a simplified block diagram of a circuit switched fall back (CSFB) enabled packet switched (PS) network 100, according to one embodiment of the disclosure. The CSFB enabled PS network 100 comprises a UE 102, a PS base station 104 and a core network 112. In some embodiments, the core network 112 comprises a PS core 106 configured to handle PS communication sessions or services (data services) associated with the CSFB enabled PS network 100 and a CS core 108 configured to handle circuit switched (CS) communication sessions or services (i.e., voice call) associated with the CSFB enabled PS network 100. In some embodiments, the CSFB enabled PS network 100 further comprises a CS base station 110 associated with the CS core 108 and configured to facilitate CS services associated with the CSFB enabled PS network 100. In some embodiments, CS base station referred to herein comprises base stations supporting CS services and in some instances, PS services.

[0025] In some embodiments, the PS base station 104 and the PS core 106 comprises a PS portion 116 of the CSFB enabled PS network 100, and the CS base station 110 and the CS core 108 comprises a CS portion 118 of the CSFB enabled PS network 100. In some embodiments, the CS base station 110 and the CS core 108 can handle both the CS services and PS services. As a non-limiting example, the PS portion 116 may support a packet service such as Evolved Packet Service (EPS) and the PS communication session may include an EPS communication session. Similarly, the CS portion 118 may support both EPS services and non-EPS services and the CS communication session may include a non-EPS communication session. In some embodiments, the CS portion 118 may comprise one or more CS networks that support both CS and in some instances, PS services. In some embodiments, the CSFB enabled PS network 100 further comprises an interface 114 that couples the PS core 106 and the CS core 108. In some embodiments, the interface 114 facilitates the PS portion 116 of the network 100 and the CS portion 118 of the network 100 to work in an integrated manner to provide both PS services and CS services to the UE 102. In some embodiments, the UE 102, when camped on to the PS portion 116 of the CSFB enabled PS network 100, is configured to be registered to both the PS core 106 and the CS core 108.

[0026] In some embodiments, the CSFB enabled PS network 100 allows different radio access technologies (RATs) to work together in an integrated manner, in order to

support both PS services and CS services associated with the network. As a non-limiting example, in some embodiments, the CSFB enabled PS network 100 can comprise a CSFB enabled 3GPP long term evolution (LTE) network. In some embodiments, the CSFB enabled LTE network can comprise a 3GPP LTE network as the PS portion and a non-LTE RAT as the CS portion. In some embodiments, the non-LTE RAT can comprise universal terrestrial radio access network (UTRAN) or 3G network. In other embodiments, the non-LTE RAT can comprise a GSM EDGE radio access network (GERAN) or 2G network. Further, in other embodiments, the non-LTE RAT can comprise other RATs that supports CS services and in some instances, PS services.

[0027] In some embodiments, when the UE 102 is camped on to the PS portion 116 of the CSFB enabled PS network 100, the UE 102 is configured to establish a PS communication session or a CS communication session or both, based on a state or sub-state associated with the UE 102. In some embodiments, for example, in 3GPP LTE networks, these states correspond to the EPS mobility management (EMM) states associated with a UE. In some embodiments, the EMM states of the UE result from mobility management (MM) procedures associated with the UE, e.g., attach and tracking area update (TAU) procedures. In some embodiments, the state associated with the UE 102 comprises a failure state and a normal state (which may be a non-failure state in some cases).

[0028] In some embodiments, the UE 102 is configured to determine a state associated with the UE 102, prior to establishing a CS communication (i.e., an mobile originated (MO) voice call or a mobile terminated (MT) voice call) for the UE 102. As an example, it may be determined whether the UE 102 is to operate in the failure state and/or normal state based at least partly on a network condition of the PS portion 116, such as network congestion and/or other condition. As another example, it may be determined that the UE 102 is to operate in the failure state and/or normal state based at least partly on issues related to an air interface between the UE 102 and the PS base station 104, network coverage of the UE 102 and/or other performance measurement related to a wireless link between the UE 102 and the PS base station 104. As another example, it may be determined that the UE 102 is to operate in the failure state and/or normal state based at least partly on a temporary issue of the interface 114 between the

PS core 106 and the CS core 108. These examples are not limiting, however, as other factors may be used to determine whether the UE 102 is to operate in the failure state and/or normal state.

[0029] In some embodiments, the failure state associated with the UE 102 can comprises one or more failure states. In some embodiments, a first failure state comprises a state in which the UE 102 is successfully registered for a PS communication session with the PS core 106 associated with the CSFB enabled PS network 100, and wherein the UE is not registered for a CS-communication session with the CS core 108 associated with the CSFB enabled PS network 100. In some embodiments, the UE 102 may enter the first failure state due to temporary issue of the interface 114 between the PS core 106 and the CS core 108. However, in other embodiments, other factors can also cause the UE 102 to operate in the first failure state. As a non-limiting example, for example, in the case of 3GPP LTE networks, the first failure state can comprise an EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM state of the UE.

[0030] In some embodiments, a second failure state of the UE 102 comprises a state in which the UE 102 is searching for public land mobile networks (PLMNs). In some embodiments, the UE 102 may enter the second failure state due to a network coverage issue of the UE 102 (with the PS portion 116) or due to a rejection from a current PLMN the UE 102 is associated with. However, in other embodiments, other factors can also cause the UE 102 to operate in the second failure state. As a non-limiting example, for example, in the case of 3GPP LTE networks, the second failure state can comprise an EMM-REGISTERED.PLMN-SEARCH state of the UE. In some embodiments, a third failure state of the UE 102 comprises a state in which the UE 102 is searching for a suitable cell. In some embodiments, the UE 102 may enter the third failure state when a cell selected by the UE is known not to be able to provide normal service due to a high-load situation or other factors associated with the network (e.g., the PS portion 116). As a non-limiting example, for example, in the case of 3GPP LTE networks, the third failure state can comprise an EMM-REGISTERED.LIMITED-SERVICE state of the UE. In some embodiments, a normal state (or non-failure state) associated with the UE 102 comprises a state in which the UE 102 is successfully registered for a PS communication session with the PS core 106 associated with the

CSFB enabled PS network 100, and for a CS-communication session with the CS core 108 associated with the CSFB enabled PS network 100 and has no other network related issues. As a non-limiting example, for example, in the case of 3GPP LTE networks, the normal state can comprise an EMM-REGISTERED.NORMAL-SERVICE state of the UE.

[0031] In some embodiments, in order to establish a CS communication session comprising a MO CS voice call or an MT CS voice call for the UE 102 that is camped on to the PS portion 116, the UE 102 is configured to determine that a CS communication session (i.e., the MO CS voice call or the MT CS voice call) is to be established. As a non-limiting example, the determination that the CS communication session (i.e., mobile originated (MO) voice call) is to be established may be based at least partly on a service request generated, at the UE 102, by a connection management (CM) sub-layer of the UE 102. Further, in some embodiments, the determination that the CS communication session comprising the MT CS call is to be established may be based on a CS domain paging indicating that an MT CS call is to be established for the UE 102, received from the core network 112 associated with the CSFB enabled PS network 100. In some embodiments, the CS communication session may include a non-EPS communication session, although embodiments are not limited as such, and any suitable CS communication session may be used. Upon determining that the CS communication session is to be established, the UE 102 is configured to determine a state (e.g., the EMM state in 3GPP) associated with the UE. For example, the UE 102 is configured to determine if the UE 102 is operating in the first failure state, the second failure state, the third failure state or the normal state.

[0032] In some embodiments, if it is determined that the UE 102 is operating in the normal state (or the non-failure state), the UE 102 is configured to transmit a message, for example, an extended service request message, to the PS base station 104, in order to establish the CS communication session (i.e., the MO CS voice call or the MT CS voice call). In some embodiments, the extended service request message may include status information for a PS communication session and may further include an indicator that the CS communication session is to be established. In such embodiments, the CS communication session is established by switching the UE 102 from the PS portion 116 of the network 100 to the CS portion 118 of the network 100. In such embodiments, the

switching the UE 102 from the PS portion 116 to the CS portion 118 is initiated by the network (e.g., the PS core 106). As a non-limiting example, in 3GPP enabled LTE networks, when the UE is in the EMM-REGISTERED.NORMAL-SERVICE (i.e., the normal state), the CS communication session (i.e., the MO CS voice call or the MT CS voice call) is established through the CSFB procedure. In some embodiments, the CSFB procedure comprises switching the UE from an LTE network to a non-LTE RAT (e.g., UTRAN or GERAN), in order to establish the CS communication session. In such embodiments, the switching of the UE from an LTE network to the non-LTE RAT is initiated by the LTE network, for example, by a mobility management entity (MME) associated with the LTE network.

[0033] However, in some embodiments, if it is determined that UE 102 is operating in the first failure state, the second failure state or the third failure state, and it is determined that the UE 102 is configured to establish a CS communication session comprising an MO CS voice call, the UE 102 is configured to attempt to select an available CS network (e.g., a non-LTE RAT) in order to establish the CS communication session (i.e., the MO voice call). For example, in some embodiments, the UE 102 is configured to transmit one or more service related messages to a CS base station of the CS network that facilitates standard mobility management (MM) procedures, in order to establish the CS communication session. In some embodiments, where the UE 102 is not registered with the available CS network, the one or more service related messages can include a CS registration message to establish registration with the CS network, in order to establish the CS communication session comprising the MO CS voice call. In some embodiments, the UE 102 may transmit, when it is determined that a group of one or more CS base stations is available, a service related message for the CS connection to at least one of the CS base stations in the group. In some embodiments, the available CS base stations may be part of the CS portion 118 of the CSFB enabled PS network 100. However, in other embodiments, the available CS base stations may not be inclusive to the CS portion 118 of the CSFB enabled PS network 100.

[0034] In such embodiments, the UE 102 is further configured to refrain from transmission of messages (e.g., the extended service request message to initiate the CSFB procedure) to the PS base station 104 for the establishment of the CS communication session (i.e., the MO CS voice call). In such embodiments, the network

(e.g., the PS core 106) is not involved in initiating the CS communication session and is initiated by the UE 102 itself. As a non-limiting example, in 3GPP enabled LTE networks, when the UE is in a failure state comprising the EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM or the EMM-REGISTERED.PLMN-SEARCH or the EMM-REGISTERED.LIMITED-SERVICE, the UE is configured to select an available UTRAN or a GERAN network (i.e., legacy networks), in order to establish the CS communication session (i.e., the MO CS voice call).

[0035] In some embodiments, the UE 102 is configured to determine an availability of one or more CS networks, prior to selecting a CS network for the CS communication session. Non-limiting examples of such CS networks may include UMTS, GERAN and/or other CS network which may or may not operate in accordance with the 3GPP standard. In some embodiments, the determination of the availability of the CS network(s) may be based at least partly on a monitoring for transmissions by CS networks. For instance, the UE 102 may monitor for such transmissions by attempting to receive a signal (such as a beacon signal or other) from a CS network. Accordingly, the UE 102 may attempt to detect a presence of one or more CS base stations based at least partly on a monitoring, by the UE 102, for CS network signals. In some embodiments, the UE 102 may attempt to determine an availability of at least one CS base station to support the CS communication session.

[0036] Further, as indicated above, the UE 202 may enter the first failure state due to temporary issue of the interface 114 between the PS core 106 and the CS core 108. In such embodiments, the CS core 108 may not be able to provide an MT CS paging message to the UE 102, in order to establish a CS communication session comprising the MT CS voice call. However, in some embodiments, when the temporary issue of the interface 114 is resolved and an MT voice call has to be established for the UE 102, the CS core 108 is configured to provide a paging message (e.g., the MT CS paging) to the UE 102 via the PS core 106, with the IMSI identifier that identifies the UE 102, in order to initiate a re-registration of the UE 102 with the CS core 108. In such embodiments, the UE 202 can receive the MT CS paging message that indicates that an MT voice call is to be established for the UE 102, even when the UE 102 is in the first failure state. In some embodiments, upon receiving the MT CS paging, when the UE 102 is in the first failure state, the UE 102 is configured to provide/receive one or

more registration related messages to the core network 112, in order to register (or re-register) the UE 102 with the PS core 106 and the CS core 108. Upon completion of the re-registration or registration procedure, the UE 102 is establish the MT voice call through appropriate CSFB procedure. In some embodiments, the UE 102 is configured to provide an extended service request message comprising an indicator that the CS communication session comprising the MT CS voice call is to be established, in order to initiate the CSFB procedure.

[0037] Fig. 2 illustrates a simplified block diagram of a circuit switched fall back (CSFB) enabled long term evolution (LTE) network 200, according to one embodiment of the disclosure. In some embodiments, the CSFB enabled LTE network 200 depicts one possible way of implementation of the CSFB enabled PS network 100 in Fig. 1. However, other possible ways of implementation of the CSFB enabled LTE network 100 are also contemplated to be within the scope of this disclosure. The CSFB enabled LTE network 200 comprises a UE 202, an EUTRAN (or eNodeB) 204 and a core network 212. In some embodiments, the core network 212 comprises a mobility management entity (MME) 206 configured to handle PS communication sessions or services (data services) associated with the CSFB enabled LTE network 200 and a non-LTE core 207 configured to handle circuit switched (CS) communication sessions or services (i.e., voice call) associated with the CSFB enabled LTE network 200. In some embodiments, the CSFB enabled LTE network 200 further comprises a non-LTE base station 210 associated with the non-LTE core 207 and configured to facilitate CS services associated with the CSFB enabled PS network 200. In some embodiments, the non-LTE core 207 and the non-LTE base station 210 facilitates both PS services and CS services.

[0038] In some embodiments, the EUTRAN 204 and the MME 206 comprises an LTE network 216 which forms a PS portion of the CSFB enabled LTE network 200, and the non-LTE base station 210 and the non-LTE core 207 comprises a legacy network 218, which forms a CS portion of the CSFB enabled LTE network 200. In some embodiments, the legacy network 218 can comprise one or more legacy networks or CS networks, for example, UTRAN (i.e., 3G), GERAN (i.e., 2G) etc. However, other CS networks can also be part of the legacy network 218, in other embodiments. In some embodiments, the non-LTE base station 210 can comprise one or more base stations

associated with the one or more legacy networks, for example, GERAN, UTRAN etc. In some embodiments, the non-LTE core 207 comprises an MSC server 208 configured to handle CS services associated with the legacy network 218 and a serving GPRS support node (SGSN) 209 configured to handle PS services associated with the legacy network 218. In some embodiments, the CSFB enabled LTE network 200 further comprises an SGs interface 214 that couples the MME 206 and the MSC server 208. In some embodiments, the SG interface 214 facilitates the LTE network 216 and the legacy network 218 of the CSFB enabled LTE network 200 to work in an integrated manner to provide both PS services and CS services to the UE 202. In some embodiments, the UE 202, when camped on to the LTE network 216 of the CSFB enabled LTE network 200, is configured to be registered to both the MME 206 and the MSC server 208.

[0039] In some embodiments, when the UE 202 is camped on to the LTE network 216 of the CSFB enabled LTE network 200, the UE 202 is configured to establish a PS communication session or a CS communication session or both, based on a state or sub-state associated with the UE 202. In some embodiments, these states correspond to the EPS mobility management (EMM) states associated with the UE 202. In some embodiments, the EMM states of the UE 202 result from mobility management (MM) procedures associated with the UE 202, e.g., attach and tracking area update (TAU) procedures. In some embodiments, the state associated with the UE 202 comprises a failure state and a normal state (which may be a non-failure state in some cases). In some embodiments, the UE 202 is configured to determine a state associated with the UE 202, prior to establishing a CS communication (i.e., a mobile originating (MO) CS voice call or mobile terminating (MT) CS voice call) for the UE 202. In some embodiments, the failure state associated with the UE 202 comprises one or more failure states, for example, a first failure state, a second failure state and a third failure state.

[0040] In some embodiments, the first failure state can comprise an EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM state of the UE 202. In some embodiments, in the EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM state, the UE 202 is successfully registered for a PS communication session with the MME 206 not registered for a CS-communication session with the MSC server 208. In some

embodiments, the UE 202 may enter the EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM state due to temporary issue of the SG interface 214 between the MME 206 and the MSC server 208. As a non-limiting example, in some embodiments, the UE 202 can enter the EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM state when a combined attach procedure or a combined tracking area update (TAU) procedure for the UE 202 in the CSFB enabled LTE network 200 is successful for EPS services only, as indicated in the 3GPP technical specification (TS) 24.301. In such embodiments, the UE 202 enters the EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM state when an attach accept message associated with the combined attach procedure or a TAU accept message associated with the combined TAU procedure, returns EMM cause values #16 (MSC temporarily not reachable), #17 (Network failure) or #22 (Congestion), as indicated in the 3GPP TS 24.301. However, in other embodiments, other factors can also cause the UE 202 to operate in the EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM state.

[0041] In some embodiments, the second failure state of the UE 202 can comprise an EMM-REGISTERED.PLMN-SEARCH state of the UE 202. In some embodiments, in the EMM-REGISTERED.PLMN-SEARCH state, the UE 202 is searching for public land mobile networks (PLMNs). In some embodiments, the UE 202 may enter the EMM-REGISTERED.PLMN-SEARCH state due to a network coverage issue of the UE 202 or due to a rejection from a current PLMN the UE 202 is associated with. As a non-limiting example, in some embodiments, the UE 202 can enter the EMM-REGISTERED.PLMN-SEARCH state if tracking area updating/combined tracking area updating of the UE 202 cannot be accepted by the network 216 and the MME 206 sends a TRACKING AREA UPDATE REJECT message to the UE 202 including an appropriate EMM cause value, for example, #13 (roaming not allowed in this tracking area), as indicated in the 3GPP TS 24.301. As another non-limiting example, in some embodiments, the UE 202 can enter the EMM-REGISTERED.PLMN-SEARCH state, if a service request from the UE 202 cannot be accepted by the network 216 and the MME 206 shall return a SERVICE REJECT message to the UE 202 including an appropriate EMM cause value, for example, #13 (roaming not allowed in this tracking area), as indicated in the 3GPP TS 24.301. However, in other embodiments, other factors can also cause the UE 202 to operate in the EMM-REGISTERED.PLMN-SEARCH state.

[0042] In some embodiments, the third failure state of the UE 202 can comprise an EMM-REGISTERED.LIMITED-SERVICE state. In some embodiments, in the EMM-REGISTERED.LIMITED-SERVICE state, the UE 202 is searching for a suitable cell. In some embodiments, the UE 202 may enter the EMM-REGISTERED.LIMITED-SERVICE state when a cell selected by the UE is known not to be able to provide normal service due to a high-load situation or other factors associated with the LTE network 216. As a non-limiting example, in some embodiments, the UE 202 can enter the EMM-REGISTERED.LIMITED-SERVICE state if tracking area updating/combined tracking area updating of the UE 202 cannot be accepted by the network 216 and the MME 206 sends a TRACKING AREA UPDATE REJECT message to the UE 202 including an appropriate EMM cause value, for example, #15 (no suitable cells in the tracking area), #25 (not authorized for this CSG), as indicated in the 3GPP TS 24.301. As another non-limiting example, in some embodiments, the UE 202 can enter the EMM-REGISTERED.LIMITED-SERVICE state, if a service request from the UE 202 cannot be accepted by the network 216 and the MME 206 shall return a SERVICE REJECT message to the UE 202 including an appropriate EMM cause value, for example, #15 (no suitable cells in the tracking area), #25 (not authorized for this CSG), as indicated in the 3GPP TS 24.301. However, in other embodiments, other factors can also cause the UE 202 to operate in the EMM-REGISTERED.LIMITED-SERVICE state. In some embodiments, a normal state (or non-failure state) associated with the UE 202 can comprise an EMM-REGISTERED.NORMAL-SERVICE state.

[0043] In some embodiments, the UE 202 is configured to determine that a CS communication session is to be established, in order to establish a mobile originated (MO) CS voice call or an MT CS voice call for the UE 202 that is camped on to the LTE network 216. As a non-limiting example, the determination that the CS communication session (i.e., the MO CS voice call) is to be established may be based at least partly on a service request generated, at the UE 202, by a connection management (CM) sub-layer of the UE 202. Further, in some embodiments, the determination that the CS communication session comprising the MT CS call is to be established may be based on a CS domain paging indicating that an MT CS call is to be established for the UE 202, received from the core network 212 associated with the CSFB enabled LTE network 200. In some embodiments, the CS communication session may include a non-EPS communication session, although embodiments are not limited as such, and

any suitable CS communication session may be used. Upon determining that a CS communication session (i.e., the MO CS voice call or the MT CS voice call) is to be established, the UE 202 is configured to determine the EMM state associated with the UE 202. For example, the UE 202 is configured to determine if the UE 102 is operating in the first failure state, the second failure state, the third failure state or the normal state.

[0044] In some embodiments, if it is determined that the UE 202 is operating in the EMM-REGISTERED.NORMAL-SERVICE, the UE 202 is configured to establish the CS communication session (i.e., an MO voice call or a mobile terminating (MT) voice call) through the CSFB procedure. In some embodiments, the CSFB procedure comprises switching the UE 202 from the LTE network 216 to the non-LTE network 218. In some embodiments, the switching the UE 202 from the LTE network 216 to the non-LTE network 218 is initiated by the LTE network 216 (e.g., the MME 206). In such embodiments, in order to establish the MO CS voice call or the MT CS through the CSFB procedure, the UE 202 is configured to transmit a message, for example, an extended service request message to the eNodeB 204. In some embodiments, the extended service request message may include status information for a PS communication session and may further include an indicator that the CS communication session (i.e., the MO CS voice call or the MT CS voice call) is to be established. In some embodiments, the determination that the MT CS voice call is established for the UE 202 is made, based on a paging message from the MME.

[0045] However, in some embodiments, if it is determined that UE 202 is operating in the EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM state or the EMM-REGISTERED.PLMN-SEARCH state or the EMM-REGISTERED.LIMITED-SERVICE state, and it is determined that the UE 202 is configured to establish a CS communication session comprising a MO CS voice call, UE 202 is configured to transmit one or more service related messages to a non-LTE base station (e.g., the non-LTE base station 210) that facilitates standard mobility management (MM) procedures, as part of an establishment of the CS communication session (i.e., the MO CS voice call). In some embodiments, the UE 202 may transmit, when it is determined that a group of one or more non-LTE base stations (e.g., GERAN, UTRAN etc.) is available, one or more service related messages for the CS connection to at least one

of the non-LTE base stations in the group. In some embodiments, the available non-LTE base stations may be part of the non-LTE base stations 210 of the non-LTE network 218. However, in other embodiments, the available non-LTE base stations may not be inclusive to the non-LTE network 218 of the CSFB enabled LTE network 200.

[0046] In such embodiments, the MME 206 is not involved in initiating the CS communication session and is initiated by the UE 202 itself. In such embodiments, the UE 202 is further configured to refrain from transmission of messages (e.g., the extended service request message) to the MME 206 for the establishment of the CS communication session through the CSFB procedure. In some embodiments, the UE 202 is configured to determine an availability of one or more non-LTE networks, prior to transmitting the one or more service related messages message to the non-LTE base stations of the one or more non-LTE networks. In some embodiments, the determination of the availability of the non-LTE network(s) may be based at least partly on a monitoring for transmissions by the non-LTE networks. For instance, the UE 202 may monitor for such transmissions by attempting to receive a signal (such as a beacon signal or other) from a non-LTE network.

[0047] Further, as indicated above, the UE 202 may enter the EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM state due to temporary issue of the SG interface 214 between the MME 206 and the MSC server 208. In some embodiments, when the temporary issue of the SG interface 214 is resolved and an MT CS voice call has to be established for the UE 202, the MSC server 208 is configured to provide a paging message (i.e., an MT CS paging) to the UE 202 via the MME 206, with the IMSI identifier that identifies the UE 202, in order to initiate a re-registration of the UE 202 with the MSC server 208. In such embodiments, the UE 202 is configured to receive the MT CS paging message that indicates that an MT voice call is to be established for the UE 202, even when the UE 202 is in the EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM state. In some embodiments, upon receiving the MT CS paging, when the UE 202 is in the EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM state, the UE 202 is configured to provide/receive one or more registration related messages to the core network 212, in order to register (or re-register) the UE 202 with the MME 206 and the MSC server 208. Upon completion of the re-registration or registration

procedure, the UE 202 is configured to establish the MT CS voice call through appropriate CSFB procedure. In some embodiments, the UE 202 is configured to provide a service request message, for example, an extended service request message comprising an indicator that the CS communication session comprising the MT CS voice call is to be established, in order to initiate the CSFB procedure, upon completion of the re-registration procedure.

[0048] Fig. 3 illustrates a block diagram of an apparatus 300 for use in a user equipment (UE) in a CSFB enabled PS network, according to various embodiments described herein. In some embodiments, the apparatus 300 can be included within the UE 102 in Fig. 1 or the UE 202 in Fig. 2. The apparatus 300 is described herein with reference to the UE 102 in Fig. 1 and the UE 202 in Fig. 2. The apparatus 300 includes a receiver circuit 310, a processing circuit 330, and a transmitter circuit 320. Further, in some embodiments, the apparatus 300 comprises a memory circuit 340 coupled to the processing circuit 330. In some embodiments, the memory circuit 340 comprises a computer readable storage device that includes instructions to be executed by the processor 330. In some embodiments, the memory circuit 340 can be an independent circuit and in other embodiments, the memory circuit 340 can be integrated on chip with the processor 330. Alternately, in other embodiments, the instructions to be executed by the processor 330 can be stored on a non-transitory storage medium like CR-ROM, flash drive etc., and can be downloaded to the memory circuit 340 for execution. Each of the receiver circuit 310 and the transmitter circuit 320 are configured to be coupled to one or more antennas, which can be the same or different antenna(s). In some embodiments, the receiver circuit 310 and transmitter circuit 320 can have one or more components in common, and both can be included within a transceiver circuit, while in other aspects they are not. In various embodiments, the apparatus 300 can be included within a UE, for example, with apparatus 300 (or portions thereof) within a receiver and transmitter or a transceiver circuit of a UE.

[0049] In some embodiments, when a CS communication session comprising a mobile originating (MO) voice call or a mobile terminating (MT) voice call is to be established for the UE (e.g., the UE 102 in Fig. 1 or the UE 202 in Fig. 2), the processing circuit 330 is configured to determine that a CS communication session comprising the MO voice call or the MT voice call is to be established for the UE. In

some embodiments, the determination that the CS communication session comprising the MO CS voice call is to be established at the processing circuit 330, may be based at least partly on a service request generated, at the processing circuit 330, by a connection management (CM) sub-layer of the UE. Further, in some embodiments, the determination that the CS communication session comprising the MT CS call is to be established at the processing circuit 330, may be based on a CS domain paging indicating that an MT CS call is to be established for the UE, received from the core network associated with the CSFB enabled PS network. Upon determining that the CS communication session is to be established, the processing circuit 330 is further configured to determine a state (e.g., the EMM state in 3GPP) associated with the UE. In some embodiments, the processing circuit 330 is configured to determine the state associated with the UE, based on instructions stored in the memory circuit 340. In some embodiments, the state associated with the UE can comprise a failure state or a non-failure state. In some embodiments, the failure state comprises a first failure state, a second failure state or a third failure state, as explained above with respect to Fig. 1 and Fig. 2. In particular, according the 3GPP standard, the UE is determined to be in a failure state, if the EMM state associated with the UE comprises an EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM state or an EMM-REGISTERED.PLMN-SEARCH state or an EMM-REGISTERED.LIMITED-SERVICE state. Further, a UE is determined to be in a non-failure state (i.e., a normal state), if the EMM state associated with the UE comprises an EMM-REGISTERED.NORMAL-SERVICE state.

[0050] In some embodiments, if the state associated with the UE is determined to be a failure state, and it is determined that the CS communication session to be established comprises an MO CS voice call, the processing circuit 330 is configured to transmit one or more service request messages to establish standard mobility management (MM) procedures, via the transmitter circuit 320, to a CS base station (e.g., the CS base station 110 or the non-LTE base station 210) of an available CS network (or a non-LTE network), as part of the establishment of the CS communication session comprising the MO CS voice call. In some embodiments, the processing circuit 330 is further configured to process one or more messages (e.g., communication signals) received from the CS base station, via the receive circuit 310, in response to the one or more service request messages, in order to complete the CS communication

session. In some embodiments, the processing circuit 330 is configured to determine an availability of one or more CS networks (or non-LTE networks), prior to transmitting the one or more service request messages to the CS base station of the one or more CS networks. In some embodiments, the determination of the availability of the CS network(s) at the processing circuit 330 may be based at least partly on a monitoring for transmissions by the CS networks, received at the processing circuit 330, via the receive circuit 310.

[0051] In some embodiments, if the state associated with the UE is determined to be a failure state comprising the EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM state, and it is determined that the CS communication session comprising an MT CS voice call is to be established based on an MT CS paging message from the core network (e.g., the core network 112 in Fig. 1 or the core network 212 in Fig. 2), the processing circuit 330 is configured to transmit a message (e.g., an extended service request message) comprising an indicator that the CS communication session is to be established, via the transmit circuit 320, to the PS base station (e.g., the eNodeB 204 in Fig. 2), in order to establish the CS communication session comprising the MT CS voice call through the CSFB procedure.

[0052] In other embodiments, if the state associated with the UE is determined to be a non-failure state (or normal state), the processing circuit 330 is configured to establish the CS communication session comprising the MO CS voice call or the MT CS voice call through the standard 3GPP circuit switched fall back (CSFB) procedure. As a non-limiting example, in some embodiments, the processing circuit 330 is configured to transmit a message (e.g., an extended service request message) comprising an indicator that the CS communication session is to be established, via the transmit circuit 320, to the PS base station (e.g., the eNodeB 204 in Fig. 2), in order to establish the CS communication session comprising the MO CS voice call and the MT CS voice call through the CSFB procedure.

[0053] Fig. 4a illustrates the events that may occur and/or the operations that may be performed related to a reception of a non-EPS service request for initiating a mobile originating (MO) CS voice call, from the connection management (CM) sub-layer within a user equipment (UE) 400 while the UE operates in a failure state, according to an

embodiment of the disclosure. In some embodiments, the UE 400 is assumed to be camped onto a CSFB enabled LTE cell or a CSFB enabled PS network. In some embodiments, the UE 400 described herein can comprise the UE 102 of Fig. 1 or the UE 202 of Fig. 2. In some embodiments, the UE 400 comprises a non-access stratum (NAS) layer and/or module 404, an access stratum (AS) layer and/or module 406 and a user/application layer 402 (which may include and/or be part of a connection management (CM) layer and/or module in some cases). In some embodiments, the UE 400 may include other modules and/or layers. In some embodiments, the UE 102 of Fig. 1 or the UE 202 of Fig. 2 may also include same or similar modules/layers.

[0054] In some embodiments, the user/application layer 402 of the UE 400 is configured to initiate a non-EPS service request 410 (e.g., a voice call). In some embodiments, the non-EPS service request 410 is provided by the user/application layer 402 to the NAS layer 404 of the UE 400. The UE 400 is assumed to be in a failure state in this embodiment. In some embodiments, the failure state of the UE 400 can comprise the first failure state, the second failure state or the third failure state, as explained above with respect to Fig. 1. According to the 3GPP standard, in some embodiments, the failure state of the UE 400 can comprise the EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM state or the EMM-REGISTERED.PLMN-SEARCH state or the EMM-REGISTERED.LIMITED-SERVICE, as explained above with respect to Fig. 2.

[0055] Upon receiving the non-EPS service request 410 from the user/application layer 402 and upon determining that the UE 400 is in the failure state, the NAS layer 404 is configured to generate a non-LTE camp request 412 and provide the non-LTE camp request 412 to the AS layer 406 of the UE 400, in order to complete the voice call through the non-LTE cell. Upon receiving the non-LTE camp request 412, the AS layer 406 is configured to camp on to an available non-LTE RAT. In some embodiments, camping on to a suitable non-LTE cell comprises identifying a non-LTE cell in the vicinity of the UE 400. Once the UE 400 is camped on to the non-LTE cell, the AS layer 406 is further configured to generate and provide a non-LTE cell camp confirm message 414 to the NAS layer 404. Upon receiving the non-LTE cell camp confirm message 414, in some embodiments, the UE 400 or the NAS layer 404 is configured to provide one or more messages (e.g., the service related messages in Fig. 1 and Fig. 2) to a

non-LTE base station associated with the non-LTE RAT, in order to initiate the non-LTE registration. Upon registration in the non-LTE RAT, the NAS layer 404 is further configured to process the CM sub-layer request (i.e., the MO voice call) using standard mobility management (MM) procedures. However, in some embodiments, where the UE 400 does not require non-LTE registration (for example, if UE 400 is already registered in the non-LTE RAT), the NAS layer 404 is configured to directly process the CM sub-layer request (i.e., the voice call), via the one or more service related messages, using standard mobility management (MM) procedures, upon receiving the non-LTE camp confirm message 414.

[0056] Fig. 4b illustrates the events that may occur and/or the operations that may be performed related to a reception of a CS domain paging for initiating a mobile terminating (MT) CS voice call at a user equipment (UE) 450 while the UE operates in EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM state, according to an embodiment of the disclosure. In some embodiments, the UE 450 is assumed to be camped onto a CSFB enabled LTE cell or a CSFB enabled CS network. In some embodiments, the UE 450 described herein can comprise the UE 102 of Fig. 1 or the UE 202 of Fig. 2. In some embodiments, the UE 450 comprises a non-access stratum (NAS) layer and/or module 454, an access stratum (AS) layer and/or module 456 and a user/application layer 452 (which may include and/or be part of a connection management (CM) layer and/or module in some cases). In some embodiments, the UE 450 is camped on to a network 458 (e.g., the CSFB enabled PS network in Fig. 1 or the CSFB enabled LTE network in Fig. 2). In some embodiments, the UE 450 may include other modules and/or layers. In some embodiments, the UE 102 of Fig. 1 or the UE 202 of Fig. 2 may also include same or similar modules/layers.

[0057] In some embodiments, an MT CS voice call is initiated at the UE 450 based on a CS domain paging 460 received from the network 458. In some embodiments, the AS layer 456 of the UE 450 is configured to receive the CS domain paging 460 from the network 458. The UE 450 is assumed to be in a failure state in this embodiment. In some embodiments, the failure state of the UE 450 comprises a state wherein the UE 450 is successfully registered for a PS communication session with a PS-domain associated with network 458, and wherein the UE 458 is not registered for a CS-communication session with a CS-domain associated with the network 458, at least

partly due to a temporary issue associated with the CS-domain. According to the 3GPP standard, in some embodiments, the failure state of the UE 450 can comprise the EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM state.

[0058] Upon receiving the CS domain paging 460, the AS layer 450 of the UE 450 is configured to generate and provide a CS paging notification 462 to the NAS layer 454 of the UE 450. Upon receiving the CS paging notification 462, the NAS layer 454 is configured to initiate the CSFB procedure in Fig. 1 and Fig. 2) to the network 458. In some embodiments, the CSFB procedure is initiated by the NAS layer 454 by generating and providing a service request message (e.g., an extended service request message in some embodiments) to the network 458. In some embodiments, the service request message indicates the network 458 that an MT CS call is to be established for the UE 450. Upon receiving the extended service request message, the network 458 is configured to initiate the MT CSFB procedure as per the 3GPP standard. Alternately, in other embodiments, the NAS layer 454 can initiate the CSFB procedure differently.

[0059] Fig. 5 illustrates a flow chart of a method 500 for a UE in a CSFB enabled PS network, according to one embodiment of the disclosure. The UE is explained herein with reference to the apparatus 300 in Fig. 3. In some embodiments, the UE can comprise the UE 102 in the CSFB enabled PS network 100 in Fig. 1 and in some embodiments, the UE can comprise the CSFB enabled LTE network 200 in Fig. 2. However, in other embodiments, the method 500 can be utilized for any UE in any CSFB enabled PS network. At 502, a determination that a CS communication session comprising a mobile originating (MO) CS call or a mobile terminating (MT) CS call is to be established for the UE (e.g., the UE 102 in Fig. 1 or the UE 202 in Fig. 2) in a CSFB enabled PS network, is made at the processing circuit 330. In some embodiments, the determination that the CS communication session comprising the MO CS call is to be established at the processing circuit 330, may be based at least partly on a service request generated, at the processing circuit 330, by a connection management (CM) sub-layer (e.g., the user/application layer 402 in Fig. 4) of the UE. Further, in some embodiments, the determination that the CS communication session comprising the MT CS call is to be established at the processing circuit 330, may be based on a CS

domain paging indicating that an MT CS call is to be established for the UE, received from a core network associated with the CSFB enabled PS network.

[0060] At 504, a determination whether the UE is in a failure state or a normal state, is made at the processing circuit 330. In some embodiments, the failure state of the UE can comprise the first failure state, the second failure state or the third failure state, as explained above with respect to Fig. 1. According to the 3GPP standard, in some embodiments, the failure state of the UE can comprise the EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM state or the EMM-REGISTERED.PLMN-SEARCH state or the EMM-REGISTERED.LIMITED-SERVICE, as explained above with respect to Fig. 2. At 506, one or more registration related messages is provided to a PS base station of the PS network, by the processing circuit, in order to initiate registration with the core network of the CSFB enabled PS network, as part of the establishment of the CSFB procedure for establishing the MT CS voice call, when the UE is in a failure state comprising EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM state.. At 508, one or more service related messages is provided to a CS base station of an available CS network, by the processing circuit, in order to attempt to select the available CS network, as part of an establishment of a CS communication session comprising the MO CS voice call, when the UE is in the failure state. At 510, an extended service request message is provided to a PS base station of the PS network, by the processing circuit 330, in order to establish a CSFB procedure, when the UE is in the normal state.

[0061] While the methods are illustrated and described above as a series of acts or events, it will be appreciated that the illustrated ordering of such acts or events are not to be interpreted in a limiting sense. For example, some acts may occur in different orders and/or concurrently with other acts or events apart from those illustrated and/or described herein. In addition, not all illustrated acts may be required to implement one or more aspects or embodiments of the disclosure herein. Also, one or more of the acts depicted herein may be carried out in one or more separate acts and/or phases.

[0062] While the apparatus has been illustrated and described with respect to one or more implementations, alterations and/or modifications may be made to the illustrated examples without departing from the spirit and scope of the appended claims.

In particular regard to the various functions performed by the above described components or structures (assemblies, devices, circuits, systems, etc.), the terms (including a reference to a "means") used to describe such components are intended to correspond, unless otherwise indicated, to any component or structure which performs the specified function of the described component (e.g., that is functionally equivalent), even though not structurally equivalent to the disclosed structure which performs the function in the herein illustrated exemplary implementations of the invention.

[0063] In particular regard to the various functions performed by the above described components (assemblies, devices, circuits, systems, etc.), the terms (including a reference to a "means") used to describe such components are intended to correspond, unless otherwise indicated, to any component or structure which performs the specified function of the described component (e.g., that is functionally equivalent), even though not structurally equivalent to the disclosed structure which performs the function in the herein illustrated exemplary implementations of the disclosure. In addition, while a particular feature may have been disclosed with respect to only one of several implementations, such feature may be combined with one or more other features of the other implementations as may be desired and advantageous for any given or particular application.

[0064] Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software. Fig. 6 illustrates, for one embodiment, example components of a User Equipment (UE) device 600. In some embodiments, the UE device 600 may include application circuitry 602, baseband circuitry 604, Radio Frequency (RF) circuitry 606, front-end module (FEM) circuitry 608 and one or more antennas 610, coupled together at least as shown. In some embodiments, the UE 600 can be a part of the UE 204 in Fig. 2 or the UE 304 in Fig. 3.

[0065] The application circuitry 602 may include one or more application processors. For example, the application circuitry 602 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.

[0066] The baseband circuitry 604 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 604 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 606 and to generate baseband signals for a transmit signal path of the RF circuitry 606. Baseband processing circuitry 604 may interface with the application circuitry 602 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 606. For example, in some embodiments, the baseband circuitry 604 may include a second generation (2G) baseband processor 604a, third generation (3G) baseband processor 604b, fourth generation (4G) baseband processor 604c, and/or other baseband processor(s) 604d for other existing generations, generations in development or to be developed in the future (e.g., fifth generation (5G), 6G, etc.). The baseband circuitry 604 (e.g., one or more of baseband processors 604a-d) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 606. 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 604 may include Fast-Fourier Transform (FFT), precoding, and/or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 604 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.

[0067] In some embodiments, the baseband circuitry 604 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), and/or radio resource control (RRC) elements. A central processing unit (CPU) 604e of the baseband circuitry 604 may be configured to run elements of the protocol

stack for signaling of the PHY, MAC, RLC, PDCP and/or RRC layers. In some embodiments, the baseband circuitry may include one or more audio digital signal processor(s) (DSP) 604f. The audio DSP(s) 604f may include elements for compression/decompression and echo cancellation and may include other suitable processing elements in other embodiments. Components of the baseband circuitry may be suitably combined in a single chip, a single chipset, or disposed on a same circuit board in some embodiments. In some embodiments, some or all of the constituent components of the baseband circuitry 604 and the application circuitry 602 may be implemented together such as, for example, on a system on a chip (SOC).

[0068] In some embodiments, the baseband circuitry 604 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 604 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 604 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

[0069] RF circuitry 606 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 606 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 606 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 608 and provide baseband signals to the baseband circuitry 604. RF circuitry 606 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 604 and provide RF output signals to the FEM circuitry 608 for transmission.

[0070] In some embodiments, the RF circuitry 606 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 606 may include mixer circuitry 606a, amplifier circuitry 606b and filter circuitry 606c. The transmit signal path of the RF circuitry 606 may include filter circuitry 606c and mixer circuitry 606a. RF circuitry 606 may also include synthesizer circuitry 606d for synthesizing a frequency for

use by the mixer circuitry 606a of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 606a of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 608 based on the synthesized frequency provided by synthesizer circuitry 606d. The amplifier circuitry 606b may be configured to amplify the down-converted signals and the filter circuitry 606c 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 604 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 606a of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[0071] In some embodiments, the mixer circuitry 606a of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 606d to generate RF output signals for the FEM circuitry 608. The baseband signals may be provided by the baseband circuitry 604 and may be filtered by filter circuitry 606c. The filter circuitry 606c may include a low-pass filter (LPF), although the scope of the embodiments is not limited in this respect.

[0072] In some embodiments, the mixer circuitry 606a of the receive signal path and the mixer circuitry 606a 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 606a of the receive signal path and the mixer circuitry 606a 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 606a of the receive signal path and the mixer circuitry 606a may be arranged for direct downconversion and/or direct upconversion, respectively. In some embodiments, the mixer circuitry 606a of the receive signal path and the mixer circuitry 606a of the transmit signal path may be configured for super-heterodyne operation.

[0073] 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 606 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 604 may include a digital baseband interface to communicate with the RF circuitry 606.

[0074] 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.

[0075] In some embodiments, the synthesizer circuitry 606d 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 606d may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[0076] The synthesizer circuitry 606d may be configured to synthesize an output frequency for use by the mixer circuitry 606a of the RF circuitry 606 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 606d may be a fractional $N/N+1$ synthesizer.

[0077] 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 604 or the applications processor 602 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 602.

[0078] Synthesizer circuitry 606d of the RF circuitry 606 may include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider may be a dual modulus divider (DMD) and the phase accumulator may be a digital phase accumulator (DPA). In some embodiments, the DMD may be configured to divide the input signal by either N or $N+1$ (e.g., based on a carry out) to provide a fractional division ratio. In some example embodiments, the DLL may include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-

flop. In these embodiments, the delay elements may be configured to break a VCO period up into N_d equal packets of phase, where N_d is the number of delay elements in the delay line. In this way, the DLL provides negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

[0079] In some embodiments, synthesizer circuitry 606d 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 (f_{LO}). In some embodiments, the RF circuitry 606 may include an IQ/polar converter.

[0080] FEM circuitry 608 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 610, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 606 for further processing. FEM circuitry 608 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 606 for transmission by one or more of the one or more antennas 610.

[0081] In some embodiments, the FEM circuitry 608 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 606). The transmit signal path of the FEM circuitry 608 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 606), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 610).

[0082] In some embodiments, the UE device 600 may include additional elements such as, for example, memory/storage, display, camera, sensor, and/or input/output (I/O) interface.

[0083] FIG. 7 is a functional diagram of a 3GPP network in accordance with some embodiments. It should be noted that embodiments are not limited to the example 3GPP network shown in FIG. 7, as other networks may be used in some embodiments. Such networks may or may not include some or all of the components shown in FIG. 7, and may include additional components and/or alternative components in some cases. The network comprises a radio access network (RAN) (e.g., as depicted, the E-UTRAN or evolved universal terrestrial radio access network) 701 and the core network 720 (e.g., shown as an evolved packet core (EPC)) coupled together through an S1 interface 715. For convenience and brevity sake, only a portion of the core network 720, as well as the RAN 701, is shown.

[0084] The core network 720 includes a mobility management entity (MME) 722, a serving gateway (serving GW) 724, and packet data network gateway (PDN GW) 726. The RAN 701 includes Evolved Node-B's (eNBs) 704 (which may operate as base stations) for communicating with User Equipment (UE) 702. The eNBs 704 may include macro eNBs and low power (LP) eNBs. In some embodiments, the UE 702 may exchange data signals, control signals and/or other signals with the eNB 704. The signals may be exchanged, in some embodiments, according to one or more packet-switched (PS) techniques, including but not limited to Evolved Packet System (EPS) techniques. These embodiments will be described in more detail below.

[0085] The MME 722 is similar in function to the control plane of legacy Serving GPRS Support Nodes (SGSN). The MME 722 manages mobility aspects in access such as gateway selection and tracking area list management. The serving GW 724 terminates the interface toward the RAN 701, and routes data packets between the RAN 701 and the core network 720. In addition, it may be a local mobility anchor point for inter-eNB handovers and also may provide an anchor for inter-3GPP mobility. Other responsibilities may include lawful intercept, charging, and some policy enforcement. The serving GW 724 and the MME 722 may be implemented in one physical node or separate physical nodes. The PDN GW 726 terminates an SGi interface toward the packet data network (PDN). The PDN GW 726 routes data packets between the EPC 720 and the external PDN, and 5 may be a key node for policy enforcement and charging data collection. It may also provide an anchor point for mobility with non-LTE

accesses. The external PDN can be any kind of IP network, as well as an IP Multimedia Subsystem (IMS) domain.

[0086] The PDN GW 726 and the serving GW 724 may be implemented in one physical node or separated physical nodes. The eNBs 704 (macro and micro) terminate the air interface protocol and may be the first point of contact for a UE 702. In some embodiments, an eNB 704 may fulfill various logical functions for the RAN 701 including but not limited to RNC (radio network controller functions) such as radio bearer management, uplink and downlink dynamic radio resource management and data packet scheduling, and mobility management. In accordance with embodiments, UEs 702 may be configured to communicate Orthogonal Frequency Division Multiplexing (OFDM) communication signals with an eNB 704 over a multicarrier communication channel in accordance with an Orthogonal Frequency Division Multiple Access (OFDMA) communication technique. The OFDM signals may comprise a plurality of orthogonal subcarriers.

[0087] The S1 interface 715 is the interface that separates the RAN 701 and the EPC 720. It is split into two parts: the S1-U, which carries traffic data between the eNBs 704 and the serving GW 724, and the S1-MME, which is a signaling interface between the eNBs 704 and the MME 722. The X2 interface is the interface between eNBs 704. The X2 interface comprises two parts, the X2-C and X2-U. The X2-C is the control plane interface between the eNBs 704, while the X2-U is the user plane interface between the eNBs 704.

[0088] With cellular networks, LP cells are typically used to extend coverage to indoor areas where outdoor signals do not reach well, or to add network capacity in areas with very dense phone usage, such as train stations. As used herein, the term low power (LP) eNB refers to any suitable relatively low power eNB for implementing a narrower cell (narrower than a macro cell) such as a femtocell, a picocell, or a micro cell. Femtocell eNBs are typically provided by a mobile network operator to its residential or enterprise customers. A femtocell is typically the size of a residential gateway or smaller and generally connects to the user's broadband line. Once plugged in, the femtocell connects to the mobile operator's mobile network and provides extra coverage in a range of typically 30 to 50 meters for residential femtocells. Thus, a LP

eNB might be a femtocell eNB since it is coupled through the PDN GW 726. Similarly, a picocell is a wireless communication system typically covering a small area, such as in-building (offices, shopping malls, train stations, etc.), or more recently in-aircraft. A picocell eNB can generally connect through the X2 link to another eNB such as a macro eNB through its base station controller (BSC) functionality. Thus, LP eNB may be implemented with a picocell eNB since it is coupled to a macro eNB via an X2 interface. Picocell eNBs or other LP eNBs may incorporate some or all functionality of a macro eNB. In some cases, this may be referred to as an access point base station or enterprise femtocell.

[0089] In some embodiments, a downlink resource grid may be used for downlink transmissions from an eNB 704 to a UE 702, while uplink transmission from the UE 702 to the eNB 704 may utilize similar techniques. The grid may be a time-frequency grid, called a resource grid or time-frequency resource grid, which is the physical resource in the downlink in each slot. Such a time-frequency plane representation is a common practice for OFDM systems, which makes it intuitive for radio resource allocation. Each column and each row of the resource grid correspond to one OFDM symbol and one OFDM subcarrier, respectively. The duration of the resource grid in the time domain corresponds to one slot in a radio frame. The smallest time-frequency unit in a resource grid is denoted as a resource element (RE). Each resource grid comprises a number of resource blocks (RBs), which describe the mapping of certain physical channels to resource elements. Each resource block comprises a collection of resource elements in the frequency domain and may represent the smallest quanta of resources that currently can be allocated. There are several different physical downlink channels that are conveyed using such resource blocks.

[0090] With particular relevance to this disclosure, two of these physical downlink channels are the physical downlink shared channel and the physical down link control channel. The physical downlink shared channel (PDSCH) carries user data and higher-layer signaling to a UE 702 (FIG. 7). The physical downlink control channel (PDCCH) carries information about the transport format and resource allocations related to the PDSCH channel, among other things. It also informs the UE 702 about the transport format, resource allocation, and hybrid automatic repeat request (HARQ) information related to the uplink shared channel. Typically, downlink scheduling (e.g., assigning

control and shared channel resource blocks to UEs 702 within a cell) may be performed at the eNB 704 based on channel quality information fed back from the UEs 702 to the eNB 704, and then the downlink resource assignment information may be sent to a UE 702 on the control channel (PDCCH) used for (assigned to) the UE 702.

[0091] The PDCCH uses CCEs (control channel elements) to convey the control information. Before being mapped to resource elements, the PDCCH complex-valued symbols are first organized into quadruplets, which are then permuted using a sub-block inter-leaver for rate matching. Each PDCCH is transmitted using one or more of these control channel elements (CCEs), where each CCE corresponds to nine sets of four physical resource elements known as resource element groups (REGs). Four QPSK symbols are mapped to each REG. The PDCCH can be transmitted using one or more CCEs, depending on the size of DCI and the channel condition. There may be four or more different PDCCH formats defined in LTE with different numbers of CCEs (e.g., aggregation level, $L=1, 2, 4$, or 8).

[0092] As used herein, the term "circuitry" may refer to, be part of, or include an Application Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group), and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit, and/or other suitable hardware components that provide the described functionality. In some embodiments, the circuitry may be implemented in, or functions associated with the circuitry may be implemented by, one or more software or firmware modules. In some embodiments, circuitry may include logic, at least partially operable in hardware. Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software.

[0093] While the invention has been illustrated, and described with respect to one or more implementations, alterations and/or modifications may be made to the illustrated examples without departing from the spirit and scope of the appended claims. In particular regard to the various functions performed by the above described components or structures (assemblies, devices, circuits, systems, etc.), the terms (including a reference to a "means") used to describe such components are intended to correspond, unless otherwise indicated, to any component or structure which performs

the specified function of the described component (e.g., that is functionally equivalent), even though not structurally equivalent to the disclosed structure which performs the function in the herein illustrated exemplary implementations of the invention.

[0094] 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 example embodiments 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 example embodiments.

[0095] In the present disclosure like reference numerals are used to refer to like elements throughout, and wherein the illustrated structures and devices are not necessarily drawn to scale. As utilized herein, terms “module”, “component,” “system,” “circuit,” “circuitry,” “element,” “slice,” and the like are intended to refer to a computer-related entity, hardware, software (e.g., in execution), and/or firmware. For example, circuitry or a similar term can be a processor, a process running on a processor, a controller, an object, an executable program, a storage device, and/or a computer with a processing device. By way of illustration, an application running on a server and the server can also be circuitry. One or more circuitries can reside within a process, and circuitry can be localized on one computer and/or distributed between two or more computers. A set of elements or a set of other circuitry can be described herein, in which the term “set” can be interpreted as “one or more.”

[0096] As another example, circuitry or similar term can be an apparatus with specific functionality provided by mechanical parts operated by electric or electronic circuitry, in which the electric or electronic circuitry can be operated by a software application or a firmware application executed by one or more processors. The one or more processors can be internal or external to the apparatus and can execute at least a part of the software or firmware application. As yet another example, circuitry can be an apparatus that provides specific functionality through electronic components without mechanical parts; the electronic components can include one or more processors therein to execute software and/or firmware that confer(s), at least in part, the functionality of the electronic components.

[0097] It will be understood that when an element is referred to as being “electrically connected” or “electrically coupled” to another element, it can be physically connected or coupled to the other element such that current and/or electromagnetic radiation can flow along a conductive path formed by the elements. Intervening conductive, inductive, or capacitive elements may be present between the element and the other element when the elements are described as being electrically coupled or connected to one another. Further, when electrically coupled or connected to one another, one element may be capable of inducing a voltage or current flow or propagation of an electro-magnetic wave in the other element without physical contact or intervening components. Further, when a voltage, current, or signal is referred to as being “applied” to an element, the voltage, current, or signal may be conducted to the element by way of a physical connection or by way of capacitive, electro-magnetic, or inductive coupling that does not involve a physical connection.

[0098] In this regard, while the disclosed subject matter has been described in connection with various embodiments and corresponding Figures, where applicable, it is to be understood that other similar embodiments can be used or modifications and additions can be made to the described embodiments for performing the same, similar, alternative, or substitute function of the disclosed subject matter without deviating therefrom. Therefore, the disclosed subject matter should not be limited to any single embodiment described herein, but rather should be construed in breadth and scope in accordance with the appended claims below.

[0099] Examples can include subject matter such as a method, means for performing acts or blocks of the method, at least one machine-readable medium including instructions that, when performed by a machine cause the machine to perform acts of the method or of an apparatus or system for concurrent communication using multiple communication technologies according to embodiments and examples described herein.

[00100] Example 1 is an apparatus for a user equipment (UE) in a circuit-switched fall back (CSFB) enabled long term evolution (LTE) network, comprising one or more processors; and a memory including instructions comprising operations, for execution via the one or more processors, to determine that a circuit-switched (CS)

communication session comprising a mobile originating (MO) CS call or a mobile terminating (MT) CS call is to be established for the UE; determine whether the UE is in a failure state comprising an evolved packet system mobility management (EMM)-REGISTERED.ATTEMPTING-TO-UPDATE-MM or an EMM-REGISTERED.PLMN-SEARCH or an EMM-REGISTERED.LIMITED-SERVICE; and attempt to select an available non-LTE network that supports CS services, when the UE is in the failure state, by providing, via the one or more processors, one or more service related messages to a base station of the available non-LTE network as part of an establishment of a CS communication session comprising the MO CS call.

[00101] Example 2 is an apparatus including the subject matter of example 1, wherein the instructions comprise further operations, for execution via the one or more processors to provide, when the failure state of the UE comprises EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM, one or more registration related messages to a core network associated with the CSFB enabled LTE network to register to the core network, as part of an establishment of a CS communication session comprising the MT CS call.

[00102] Example 3 is an apparatus including the subject matter of examples 1-2, including or omitting elements, wherein the instructions comprise further operations, for execution via the one or more processors to determine an availability of the CS network based at least partly on a monitoring for transmissions by CS networks, prior to selecting the CS network for establishing the MO CS call.

[00103] Example 4 is an apparatus including the subject matter of examples 1-3, including or omitting elements, wherein the determination that the CS communication session comprising the MO CS call is to be established is based at least partly on a service request generated, at the UE, by a connection management (CM) sublayer of the UE.

[00104] Example 5 is an apparatus including the subject matter of examples 1-4, including or omitting elements, wherein the determination that the CS communication session comprising the MT CS call is to be established is based on a CS domain paging message received from a core network associated with the LTE network.

[00105] Example 6 is an apparatus including the subject matter of examples 1-5, including or omitting elements, wherein the instructions comprise further operations, for execution via the one or more processors to, when the UE is operating in a non-failure state comprising an EMM-REGISTERED.NORMAL-SERVICE, establish the CS communication session comprising the MO CS call or the MT CS call through CSFB procedure.

[00106] Example 7 is an apparatus including the subject matter of examples 1-6, including or omitting elements, wherein the instructions comprise further operations, for execution via the one or more processors to, provide an extended service request message comprising an indicator that the CS communication session comprising the MO CS call or the MT CS call is to be established, to an evolved node-B (eNodeB) of the CSFB enabled LTE network, in order to establish the CS communication session through the CSFB procedure.

[00107] Example 8 is an apparatus including the subject matter of examples 1-7, including or omitting elements, wherein the CSFB enabled LTE network includes a packet-switched (PS) core and a CS core associated therewith.

[00108] Example 9 is an apparatus including the subject matter of examples 1-8, including or omitting elements, wherein the failure state comprising the EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM of the UE comprises a state in which the UE is successfully registered for a PS communication session with the PS core, and wherein the UE is not registered for a CS-communication session with the CS core, at least partly due to a temporary issue associated with the CS core of the CSFB enabled LTE network.

[00109] Example 10 is an apparatus including the subject matter of examples 1-9, including or omitting elements, wherein the failure state comprising the EMM-REGISTERED.PLMN-SEARCH of the UE comprises a state in which the UE is searching for public land mobile networks (PLMNs).

[00110] Example 11 is an apparatus including the subject matter of examples 1-10, including or omitting elements, wherein the failure state comprising the EMM-REGISTERED.LIMITED-SERVICE of the UE comprises a state wherein a cell selected

by the UE is known not to be able to provide normal service and wherein the UE is searching for a suitable cell.

[00111] Example 12 is an apparatus including the subject matter of examples 1-11, including or omitting elements, wherein the available CS network comprises a non-LTE network.

[00112] Example 13 is an apparatus for a user equipment (UE) in a circuit-switched fall back (CSFB) enabled packet-switched (PS) network, comprising one or more processors; and a memory including instructions comprising operations, for execution via the one or more processors, to determine that a circuit-switched (CS) communication session comprising a mobile originating (MO) CS call or a mobile terminating (MT) CS call is to be established for the UE; determine whether the UE is in a failure state comprising a first state wherein the UE is successfully registered for a PS communication session with a PS-domain associated with the CSFB enabled PS network, and wherein the UE is not registered for a CS-communication session with a CS-domain associated with the CSFB enabled PS network, at least partly due to a temporary issue associated with the CS-domain; or a second state wherein the UE is searching for public land mobile networks (PLMNs); or a third state wherein a cell selected by the UE is known not to be able to provide normal service and wherein the UE is searching for a suitable cell; and attempt to select an available CS network, when the UE is in the failure state, by providing, via the one or more processors, one or more service related messages to a CS base station of the available CS network as part of an establishment of the CS communication session comprising the MO CS call.

[00113] Example 14 is an apparatus including the subject matter of example 13, wherein the instructions comprise further operations, for execution via the one or more processors to provide, when the failure state of the UE comprises the first state, one or more registration related messages to a core network associated with the CSFB enabled PS network to register to the core network, as part of an establishment of a CS communication session comprising the MT CS call.

[00114] Example 15 is an apparatus including the subject matter of examples 13-14, including or omitting elements, wherein the CSFB enabled PS network comprises a

third-generation partnership project (3GPP) long term evolution (LTE) network that supports CSFB.

[00115] Example 16 is an apparatus including the subject matter of examples 13-15, including or omitting elements, wherein the first state comprises an EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM state, wherein the second state comprises an EMM-REGISTERED.PLMN-SEARCH state and wherein the third state comprises an EMM-REGISTERED.LIMITED-SERVICE state.

[00116] Example 17 is an apparatus including the subject matter of examples 13-16, including or omitting elements, wherein the instructions comprise further operations, for execution via the one or more processors to, when the UE is operating in a non-failure state comprising an EMM-REGISTERED.NORMAL-SERVICE, establish the CS communication session comprising the MO CS call or the MT CS call through CSFB procedure.

[00117] Example 18 is an apparatus including the subject matter of examples 13-17, including or omitting elements, wherein the instructions comprise further operations, for execution via the one or more processors to, provide an extended service request message comprising an indicator that the CS communication session comprising the MO CS call or the MT CS call is to be established, to an evolved node-B (eNodeB) of the 3GPP LTE network, in order to establish the CS communication session through the CSFB procedure.

[00118] Example 19 is an apparatus including the subject matter of examples 13-18, including or omitting elements, wherein the PS communication session includes an evolved packet system (EPS) communication session and the CS communication session includes a non-EPS communication session.

[00119] Example 20 is a method for a user equipment (UE) in a circuit-switched fall back (CSFB) enabled packet-switched (PS) network, comprising determining that a circuit-switched (CS) communication session comprising a mobile originating (MO) CS call or a mobile terminating (MT) CS call is to be established for the UE, at a processing circuit; determining, at the processing circuit, whether the UE is in a failure state comprising a first state wherein the UE is successfully registered for a PS

communication session with a PS-domain associated with the CSFB enabled PS network, and wherein the UE is not registered for a CS-communication session with a CS-domain associated with the CSFB enabled PS network, at least partly due to a temporary issue associated with the CS-domain; or a second state wherein the UE is searching for public land mobile networks (PLMNs); or a third state wherein a cell selected by the UE is known not to be able to provide normal service and wherein the UE is searching for a suitable cell; and attempting to select an available CS network, by providing, by the processing circuit, one or more service related messages to a CS base station of the available CS network as part of an establishment of the CS communication session comprising the MO CS call, when the UE is in the failure state.

[00120] Example 21 is a method including the subject matter of example 20, further comprising providing, by the processing circuit, one or more registration related messages to a core network associated with the CSFB enabled PS network to register to the core network, as part of an establishment of a CS communication session comprising the MT CS call, when the failure state of the UE comprises the first state.

[00121] Example 22 is a method including the subject matter of examples 20-21, including or omitting elements, wherein the CSFB enabled PS network comprises a third-generation partnership project (3GPP) long term evolution (LTE) network that supports CSFB.

[00122] Example 23 is a method including the subject matter of examples 20-22, including or omitting elements, wherein the first state comprises an EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM state, wherein the second state comprises an EMM-REGISTERED.PLMN-SEARCH state and wherein the third state comprises an EMM-REGISTERED.LIMITED-SERVICE state.

[00123] Example 24 is a method including the subject matter of examples 20-23, including or omitting elements, further comprising establishing, by the processing circuit, the CS communication session comprising the MO CS call or the MT CS call through CSFB procedure, when the UE is operating in a non-failure state comprising an EMM-REGISTERED.NORMAL-SERVICE.

[00124] Example 25 is an apparatus for a user equipment (UE) in a circuit-switched fall back (CSFB) enabled long term evolution (LTE) network, comprising one or more processors to: determine that a circuit-switched (CS) communication session comprising a mobile originating (MO) CS call or a mobile terminating (MT) CS call is to be established for the UE; determine whether the UE is in a failure state comprising an evolved packet system mobility management (EMM)-REGISTERED.ATTEMPTING-TO-UPDATE-MM or an EMM-REGISTERED.PLMN-SEARCH or an EMM-REGISTERED.LIMITED-SERVICE; and attempt to select an available non-LTE network that supports CS services, when the UE is in the failure state, by providing one or more service related messages to a base station of the available non-LTE network as part of an establishment of a CS communication session comprising the MO CS call; and a transceiver circuitry to exchange communication signals with the base station of the available non-LTE network.

[00125] Example 26 is an apparatus including the subject matter of example 25, wherein the one or more processors is further configured to provide, when the failure state of the UE comprises EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM, one or more registration related messages, via the transceiver circuitry, to a core network associated with the CSFB enabled LTE network to register to the core network, as part of an establishment of a CS communication session comprising the MT CS call.

[00126] Example 27 is an apparatus including the subject matter of examples 25-26, including or omitting elements, wherein the one or more processors is further configured to determine an availability of the CS network based at least partly on a monitoring for transmissions by CS networks, prior to selecting the CS network for establishing the MO CS call.

[00127] Example 28 is an apparatus including the subject matter of examples 25-27, including or omitting elements, wherein the determination that the CS communication session comprising the MO CS call is to be established is based at least partly on a service request generated, at the UE, by a connection management (CM) sublayer of the UE.

[00128] Example 29 is an apparatus including the subject matter of examples 25-28, including or omitting elements, wherein the determination that the CS communication session comprising the MT CS call is to be established is based on a CS domain paging message received from a core network associated with the LTE network.

[00129] Example 30 is an apparatus including the subject matter of examples 25-29, including or omitting elements, wherein the one or more processors is further configured to, when the UE is operating in a non-failure state comprising an EMM-REGISTERED.NORMAL-SERVICE, establish the CS communication session comprising the MO CS call or the MT CS call through CSFB procedure.

[00130] Example 31 is an apparatus including the subject matter of examples 25-30, including or omitting elements, wherein the one or more processors is further configured to, provide an extended service request message comprising an indicator that the CS communication session comprising the MO CS call or the MT CS call is to be established, to an evolved node-B (eNodeB) of the CSFB enabled LTE network, via the transceiver circuitry, in order to establish the CS communication session through the CSFB procedure.

[00131] Example 32 is an apparatus including the subject matter of examples 25-31, including or omitting elements, wherein the CSFB enabled LTE network includes a packet-switched (PS) core and a CS core associated therewith.

[00132] Example 33 is an apparatus including the subject matter of examples 25-32, including or omitting elements, wherein the failure state comprising the EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM of the UE comprises a state in which the UE is successfully registered for a PS communication session with the PS core, and wherein the UE is not registered for a CS-communication session with the CS core, at least partly due to a temporary issue associated with the CS core of the CSFB enabled LTE network.

[00133] Example 34 is an apparatus including the subject matter of examples 25-33, including or omitting elements, wherein the failure state comprising the EMM-REGISTERED.PLMN-SEARCH of the UE comprises a state in which the UE is searching for public land mobile networks (PLMNs).

[00134] Example 35 is an apparatus including the subject matter of examples 25-34, including or omitting elements, wherein the failure state comprising the EMM-REGISTERED.LIMITED-SERVICE of the UE comprises a state wherein a cell selected by the UE is known not to be able to provide normal service and wherein the UE is searching for a suitable cell.

[00135] Example 36 is an apparatus including the subject matter of examples 25-35, including or omitting elements, wherein the available CS network comprises a non-LTE network.

[00136] Example 37 is an apparatus for a user equipment (UE) in a circuit-switched fall back (CSFB) enabled packet-switched (PS) network, comprising: one or more processors to determine that a circuit-switched (CS) communication session comprising a mobile originating (MO) CS call or a mobile terminating (MT) CS call is to be established for the UE; determine whether the UE is in a failure state comprising: a first state wherein the UE is successfully registered for a PS communication session with a PS-domain associated with the CSFB enabled PS network, and wherein the UE is not registered for a CS-communication session with a CS-domain associated with the CSFB enabled PS network, at least partly due to a temporary issue associated with the CS-domain; or a second state wherein the UE is searching for public land mobile networks (PLMNs); or a third state wherein a cell selected by the UE is known not to be able to provide normal service and wherein the UE is searching for a suitable cell; and attempt to select an available CS network, when the UE is in the failure state, by providing, via the one or more processors, one or more service related messages to a CS base station of the available CS network as part of an establishment of the CS communication session comprising the MO CS call; and a transceiver circuitry to exchange communication signals with the CS base station of the available CS network.

[00137] Example 38 is an apparatus including the subject matter of example 37, wherein the one or more processors is further configured to provide, when the failure state of the UE comprises the first state, one or more registration related messages, via the transceiver circuitry, to a core network associated with the CSFB enabled PS network to register to the core network, as part of an establishment of a CS communication session comprising the MT CS call.

[00138] Example 39 is an apparatus including the subject matter of examples 37-38, including or omitting elements, wherein the CSFB enabled PS network comprises a third-generation partnership project (3GPP) long term evolution (LTE) network that supports CSFB.

[00139] Example 40 is an apparatus including the subject matter of examples 37-39, including or omitting elements, wherein the first state comprises an EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM state, wherein the second state comprises an EMM-REGISTERED.PLMN-SEARCH state and wherein the third state comprises an EMM-REGISTERED.LIMITED-SERVICE state.

[00140] Example 41 is an apparatus including the subject matter of examples 37-40, including or omitting elements, wherein the one or more processors is further configured to, when the UE is operating in a non-failure state comprising an EMM-REGISTERED.NORMAL-SERVICE, establish the CS communication session comprising the MO CS call or the MT CS call through CSFB procedure.

[00141] Example 42 is an apparatus including the subject matter of examples 37-41, including or omitting elements, wherein the one or more processors is further configured to, provide an extended service request message comprising an indicator that the CS communication session comprising the MO CS call or the MT CS call is to be established, to an evolved node-B (eNodeB) of the 3GPP LTE network, via the transceiver circuitry, in order to establish the CS communication session through the CSFB procedure.

[00142] Example 43 is an apparatus including the subject matter of examples 37-42, including or omitting elements, wherein the PS communication session includes an evolved packet system (EPS) communication session and the CS communication session includes a non-EPS communication session.

[00143] Example 44 is an apparatus comprising, means for executing any of the methods of examples 20-24.

[00144] Various illustrative logics, logical blocks, modules, and circuits described in connection with aspects disclosed herein can be implemented or performed with a general-purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform functions described herein. A general-purpose processor can be a microprocessor, but, in the alternative, processor can be any conventional processor, controller, microcontroller, or state machine.

[00145] The above description of illustrated embodiments of the subject disclosure, including what is described in the Abstract, is not intended to be exhaustive or to limit the disclosed embodiments to the precise forms disclosed. While specific embodiments and examples are described herein for illustrative purposes, various modifications are

possible that are considered within the scope of such embodiments and examples, as those skilled in the relevant art can recognize.

[00146] In this regard, while the disclosed subject matter has been described in connection with various embodiments and corresponding Figures, where applicable, it is to be understood that other similar embodiments can be used or modifications and additions can be made to the described embodiments for performing the same, similar, alternative, or substitute function of the disclosed subject matter without deviating therefrom. Therefore, the disclosed subject matter should not be limited to any single embodiment described herein, but rather should be construed in breadth and scope in accordance with the appended claims below.

CLAIMS

What is claimed is:

1. An apparatus for a user equipment (UE) in a circuit-switched fall back (CSFB) enabled long term evolution (LTE) network, comprising:
 - one or more processors; and
 - a memory including instructions comprising operations, for execution via the one or more processors, to:
 - determine that a circuit-switched (CS) communication session comprising a mobile originating (MO) CS call or a mobile terminating (MT) CS call is to be established for the UE;
 - determine whether the UE is in a failure state comprising an evolved packet system mobility management (EMM)-REGISTERED.ATTEMPTING-TO-UPDATE-MM or an EMM-REGISTERED.PLMN-SEARCH or an EMM-REGISTERED.LIMITED-SERVICE; and
 - attempt to select an available non-LTE network that supports CS services, when the UE is in the failure state, by providing, via the one or more processors, one or more service related messages to a base station of the available non-LTE network as part of an establishment of a CS communication session comprising the MO CS call.
2. The apparatus of claim 1, wherein the instructions comprise further operations, for execution via the one or more processors to provide, when the failure state of the UE comprises EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM, one or more registration related messages to a core network associated with the CSFB enabled LTE network to register to the core network, as part of an establishment of a CS communication session comprising the MT CS call.
3. The apparatus of claim 1, wherein the instructions comprise further operations, for execution via the one or more processors to determine an availability of the CS network based at least partly on a monitoring for transmissions by CS networks, prior to selecting the CS network for establishing the MO CS call.

4. The apparatus of any of the claims 1-3, wherein the determination that the CS communication session comprising the MO CS call is to be established is based at least partly on a service request generated, at the UE, by a connection management (CM) sublayer of the UE.
5. The apparatus of any of the claims 1-3, wherein the determination that the CS communication session comprising the MT CS call is to be established is based on a CS domain paging message received from a core network associated with the LTE network.
6. The apparatus of any of the claims 1-3, wherein the instructions comprise further operations, for execution via the one or more processors to, when the UE is operating in a non-failure state comprising an EMM-REGISTERED.NORMAL-SERVICE, establish the CS communication session comprising the MO CS call or the MT CS call through CSFB procedure.
7. The apparatus of claim 6, wherein the instructions comprise further operations, for execution via the one or more processors to, provide an extended service request message comprising an indicator that the CS communication session comprising the MO CS call or the MT CS call is to be established, to an evolved node-B (eNodeB) of the CSFB enabled LTE network, in order to establish the CS communication session through the CSFB procedure.
8. The apparatus of any of the claims 1-3, wherein the CSFB enabled LTE network includes a packet-switched (PS) core and a CS core associated therewith.
9. The apparatus of claim 8, wherein the failure state comprising the EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM of the UE comprises a state in which the UE is successfully registered for a PS communication session with the PS core, and wherein the UE is not registered for a CS-communication session with the CS core, at least partly due to a temporary issue associated with the CS core of the CSFB enabled LTE network.

10. The apparatus of any of the claims 1-3, wherein the failure state comprising the EMM-REGISTERED.PLMN-SEARCH of the UE comprises a state in which the UE is searching for public land mobile networks (PLMNs).
11. The apparatus of any of the claims 1-3, wherein the failure state comprising the EMM-REGISTERED.LIMITED-SERVICE of the UE comprises a state wherein a cell selected by the UE is known not to be able to provide normal service and wherein the UE is searching for a suitable cell.
12. The apparatus of any of the claims 1-3, wherein the available CS network comprises a non-LTE network.
13. An apparatus for a user equipment (UE) in a circuit-switched fall back (CSFB) enabled packet-switched (PS) network, comprising:
one or more processors; and
a memory including instructions comprising operations, for execution via the one or more processors, to:
determine that a circuit-switched (CS) communication session comprising a mobile originating (MO) CS call or a mobile terminating (MT) CS call is to be established for the UE;
determine whether the UE is in a failure state comprising:
a first state wherein the UE is successfully registered for a PS communication session with a PS-domain associated with the CSFB enabled PS network, and wherein the UE is not registered for a CS-communication session with a CS-domain associated with the CSFB enabled PS network, at least partly due to a temporary issue associated with the CS-domain; or
a second state wherein the UE is searching for public land mobile networks (PLMNs); or
a third state wherein a cell selected by the UE is known not to be able to provide normal service and wherein the UE is searching for a suitable cell; and

attempt to select an available CS network, when the UE is in the failure state, by providing, via the one or more processors, one or more service related messages to a CS base station of the available CS network as part of an establishment of the CS communication session comprising the MO CS call.

14. The apparatus of claim 13, wherein the instructions comprise further operations, for execution via the one or more processors to provide, when the failure state of the UE comprises the first state, one or more registration related messages to a core network associated with the CSFB enabled PS network to register to the core network, as part of an establishment of a CS communication session comprising the MT CS call.

15. The apparatus of any of the claims 13-14, wherein the CSFB enabled PS network comprises a third-generation partnership project (3GPP) long term evolution (LTE) network that supports CSFB.

16. The apparatus of claim 15, wherein the first state comprises an EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM state, wherein the second state comprises an EMM-REGISTERED.PLMN-SEARCH state and wherein the third state comprises an EMM-REGISTERED.LIMITED-SERVICE state.

17. The apparatus of claim 15, wherein the instructions comprise further operations, for execution via the one or more processors to, when the UE is operating in a non-failure state comprising an EMM-REGISTERED.NORMAL-SERVICE, establish the CS communication session comprising the MO CS call or the MT CS call through CSFB procedure.

18. The apparatus of claim 17, wherein the instructions comprise further operations, for execution via the one or more processors to, provide an extended service request message comprising an indicator that the CS communication session comprising the MO CS call or the MT CS call is to be established, to an evolved node-B (eNodeB) of the 3GPP LTE network, in order to establish the CS communication session through the CSFB procedure.

19. The apparatus of any of the claims 13-14, wherein the PS communication session includes an evolved packet system (EPS) communication session and the CS communication session includes a non-EPS communication session.

20. A method for a user equipment (UE) in a circuit-switched fall back (CSFB) enabled packet-switched (PS) network, comprising:

- determining that a circuit-switched (CS) communication session comprising a mobile originating (MO) CS call or a mobile terminating (MT) CS call is to be established for the UE, at a processing circuit;

- determining, at the processing circuit, whether the UE is in a failure state comprising:

- a first state wherein the UE is successfully registered for a PS communication session with a PS-domain associated with the CSFB enabled PS network, and wherein the UE is not registered for a CS-communication session with a CS-domain associated with the CSFB enabled PS network, at least partly due to a temporary issue associated with the CS-domain; or

- a second state wherein the UE is searching for public land mobile networks (PLMNs); or

- a third state wherein a cell selected by the UE is known not to be able to provide normal service and wherein the UE is searching for a suitable cell; and

- attempting to select an available CS network, by providing, by the processing circuit, one or more service related messages to a CS base station of the available CS network as part of an establishment of the CS communication session comprising the MO CS call, when the UE is in the failure state.

21. The method of claim 20, further comprising providing, by the processing circuit, one or more registration related messages to a core network associated with the CSFB enabled PS network to register to the core network, as part of an establishment of a CS communication session comprising the MT CS call, when the failure state of the UE comprises the first state.

22. The method of any of the claims 20-21, wherein the CSFB enabled PS network comprises a third-generation partnership project (3GPP) long term evolution (LTE) network that supports CSFB.

23. The method of any of the claims 20-21, wherein the first state comprises an EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM state, wherein the second state comprises an EMM-REGISTERED.PLMN-SEARCH state and wherein the third state comprises an EMM-REGISTERED.LIMITED-SERVICE state.

24. The method of any of the claims 20-21, further comprising establishing, by the processing circuit, the CS communication session comprising the MO CS call or the MT CS call through CSFB procedure, when the UE is operating in a non-failure state comprising an EMM-REGISTERED.NORMAL-SERVICE.

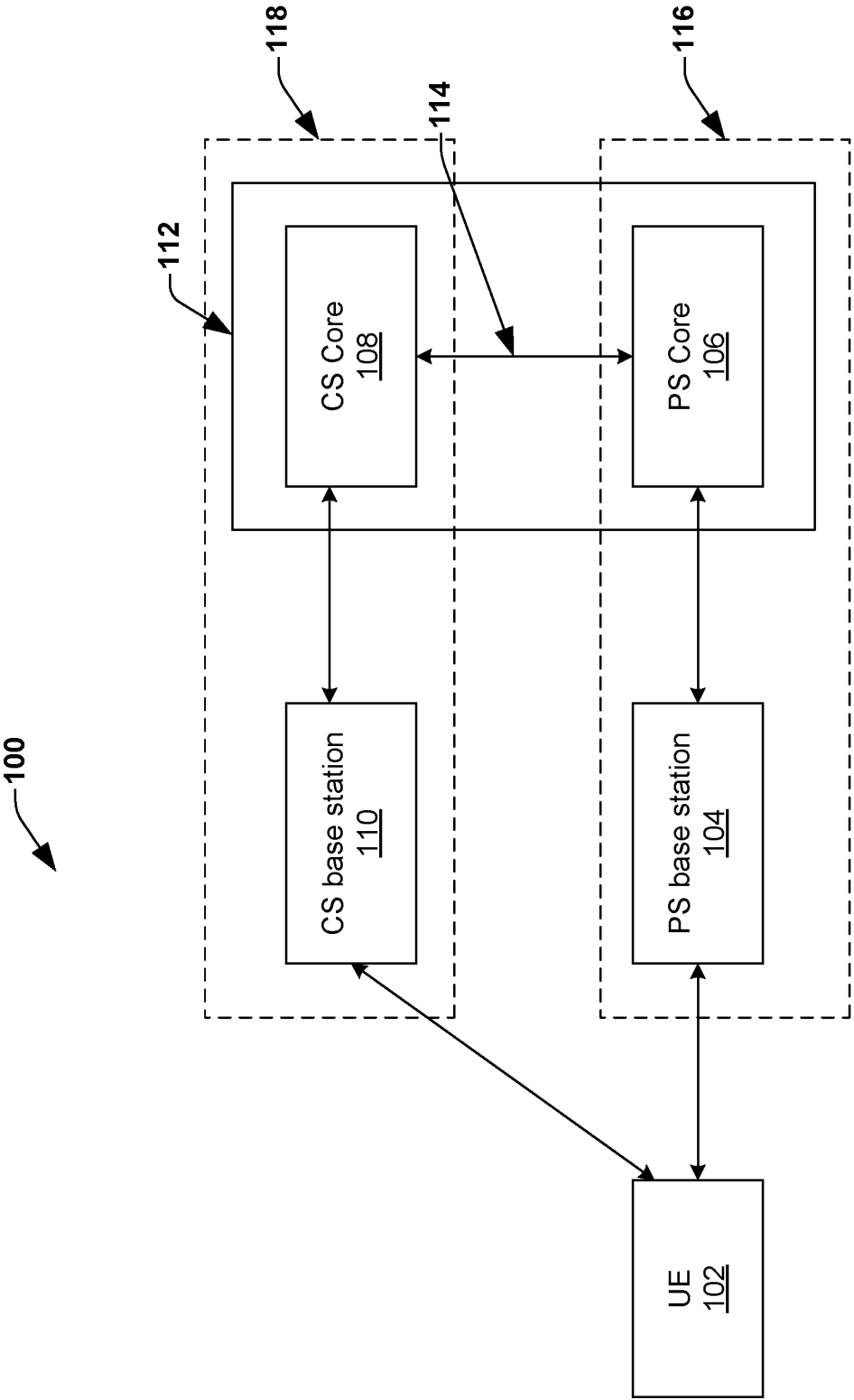


Fig. 1

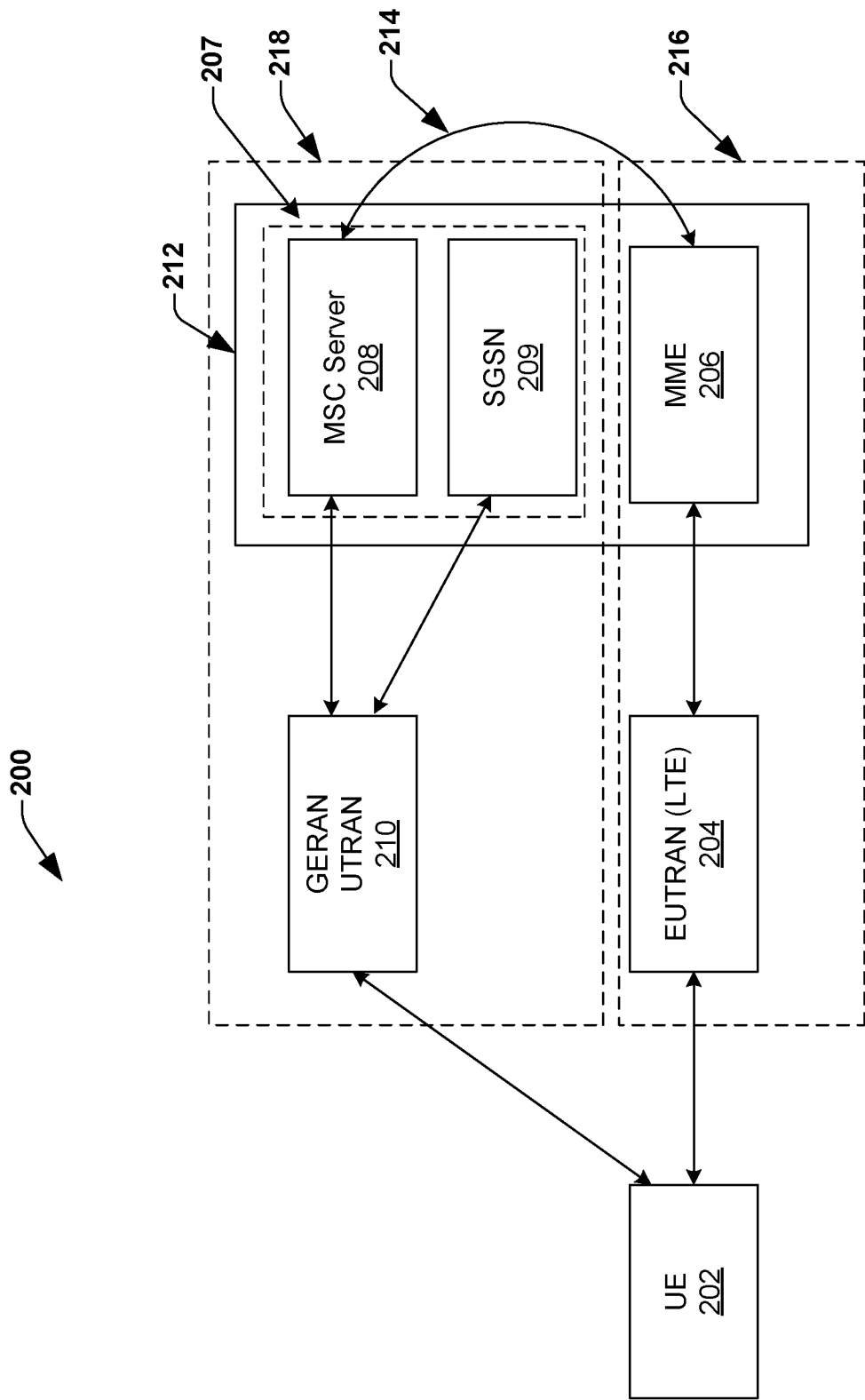


Fig. 2

300

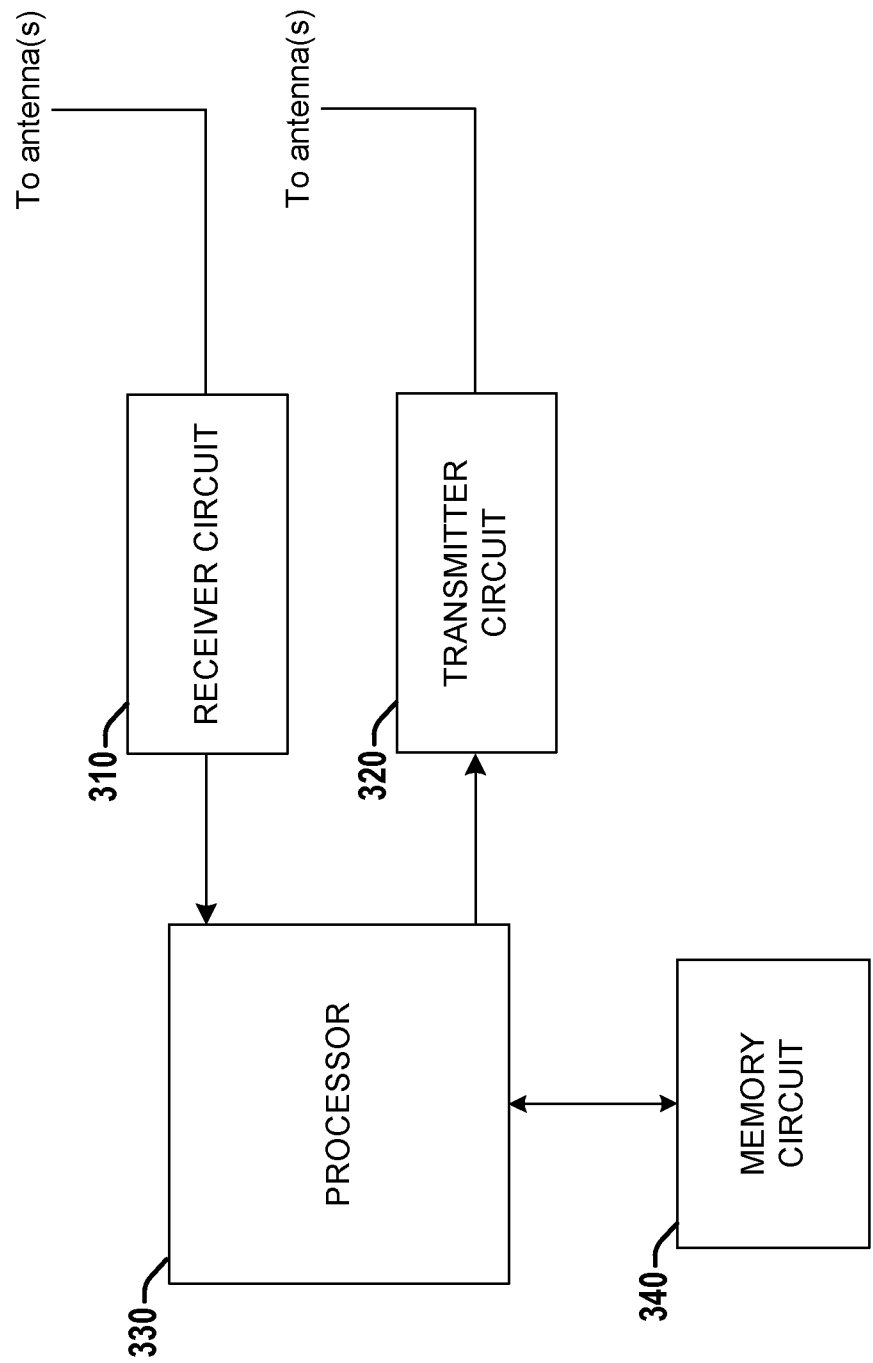


FIG. 3

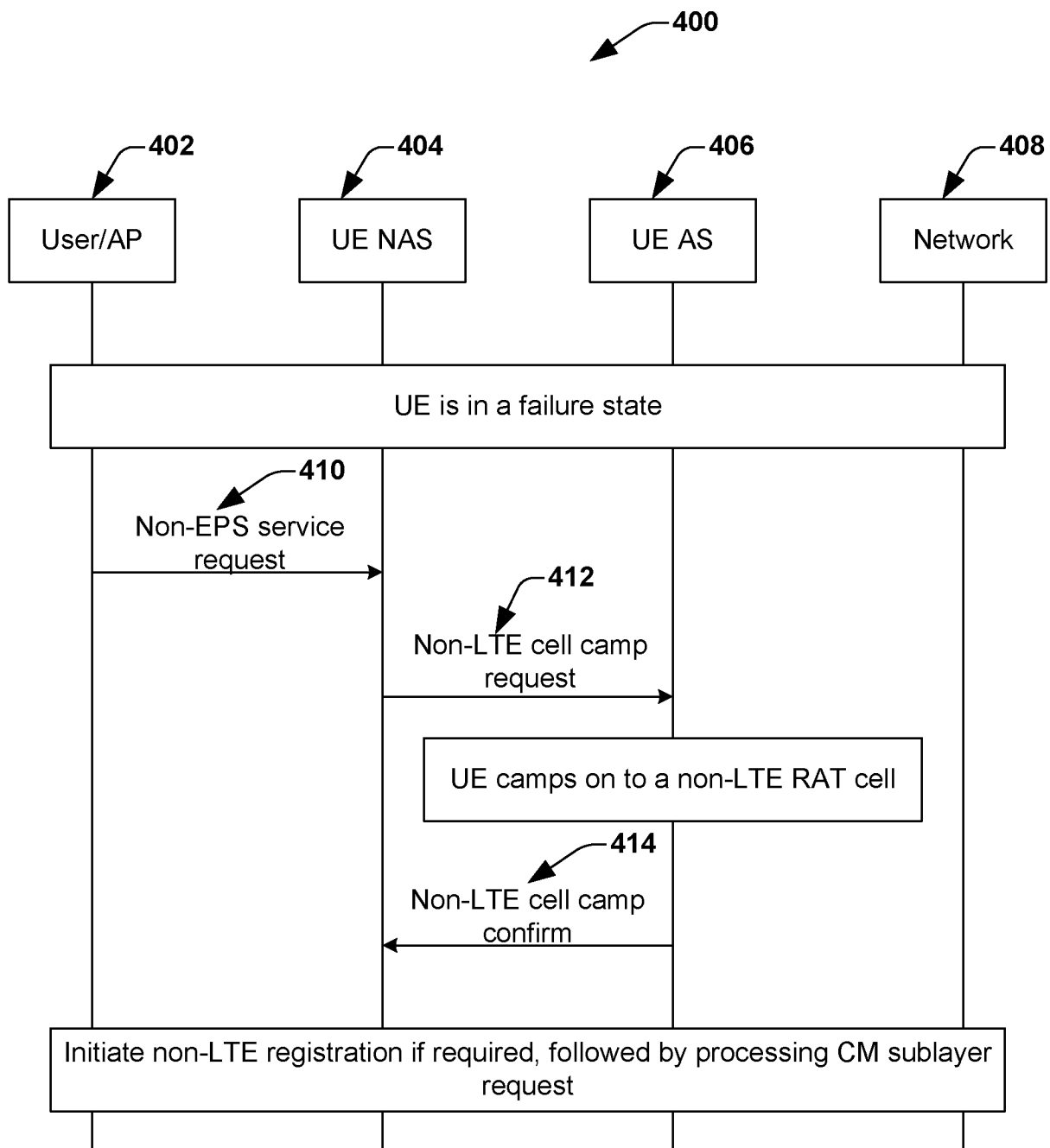
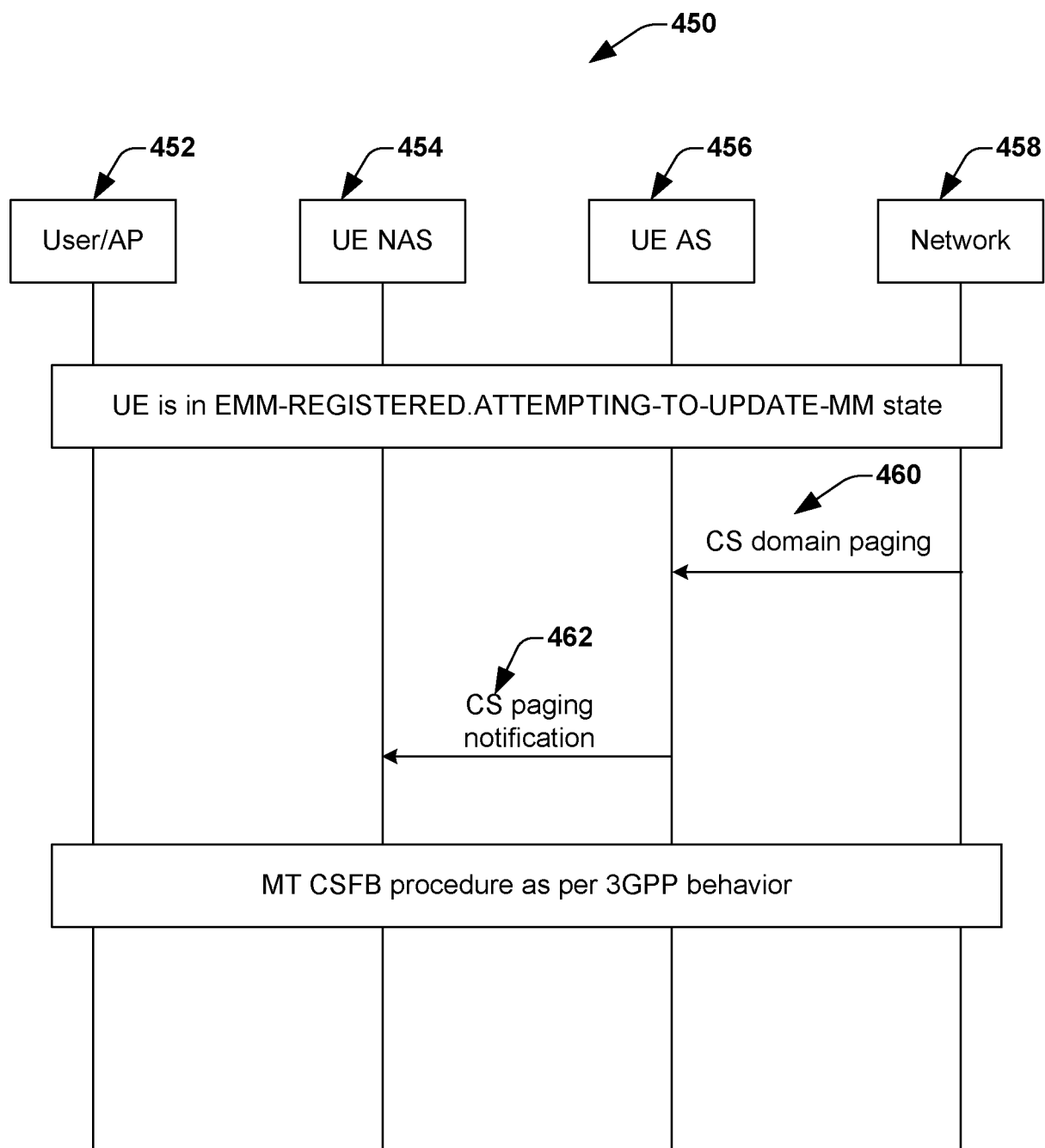
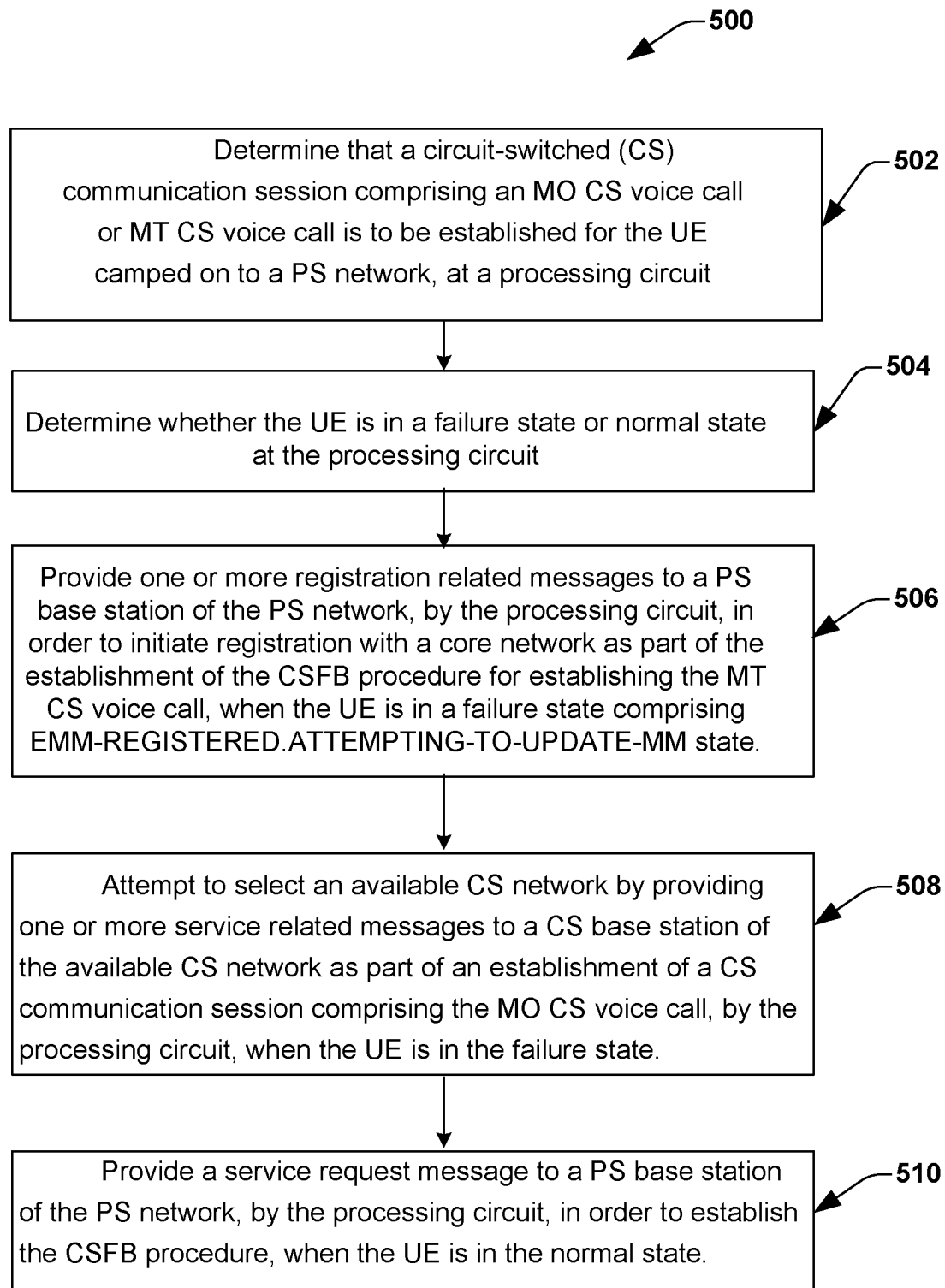
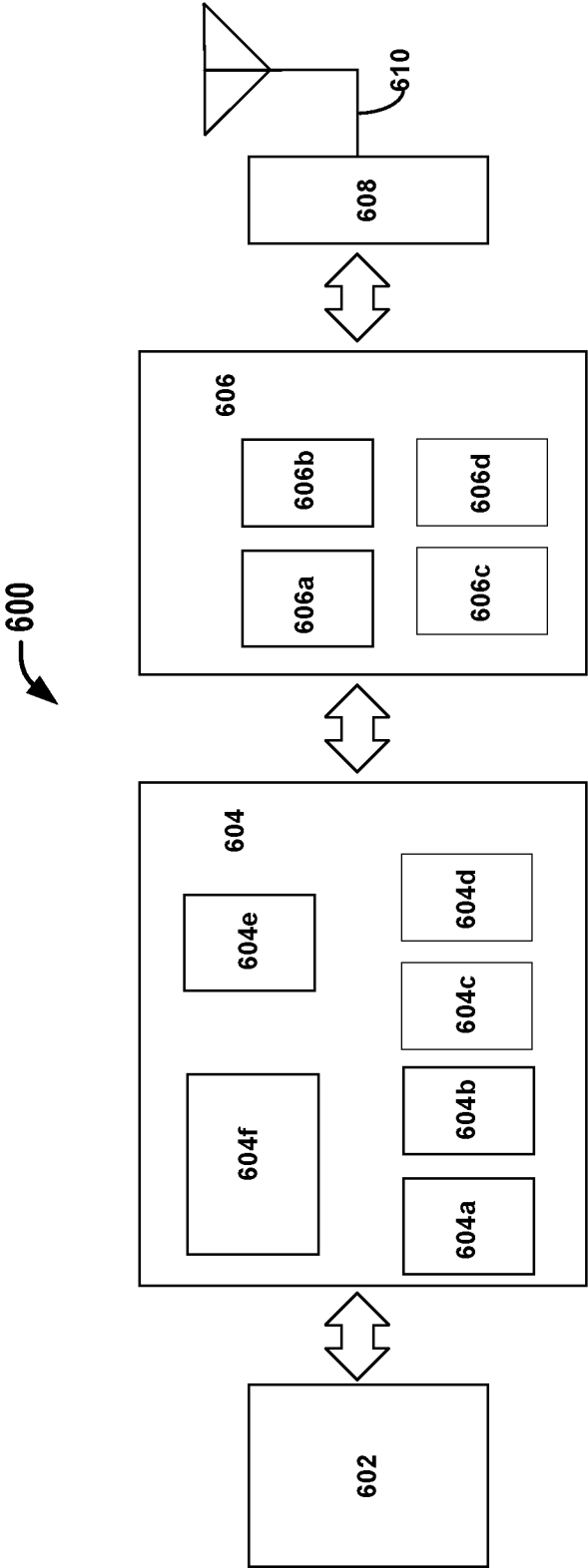


FIG. 4a

**FIG. 4b**

**FIG. 5**



Example UE

FIG. 6

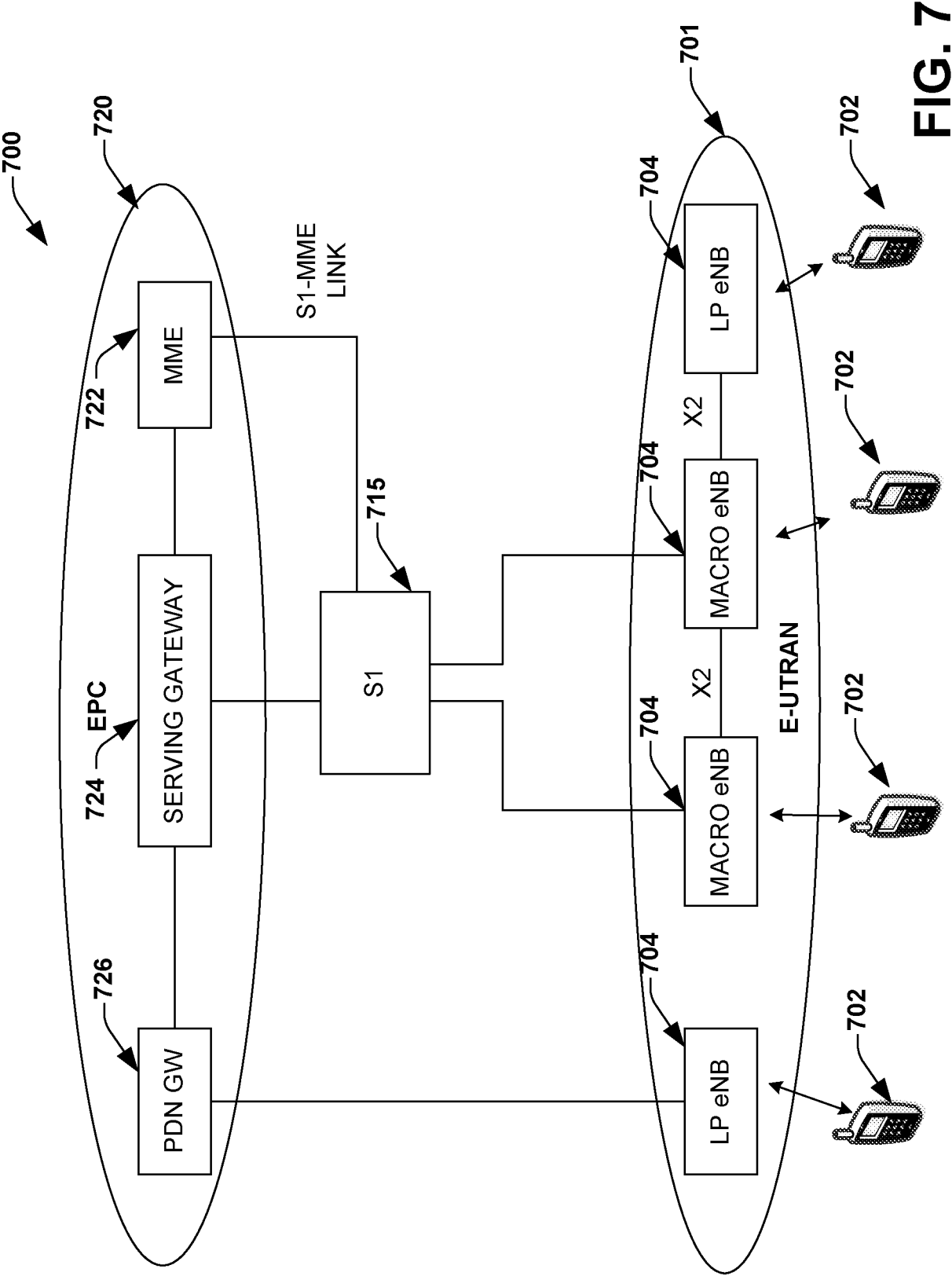


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/015788

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W36/00 H04W36/14
ADD. H04W76/02 H04W60/00

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	US 2015/099509 A1 (MAHMOOD HAMID [CA] ET AL) 9 April 2015 (2015-04-09) abstract figures 1,3,4 paragraph [0004] paragraph [0011] - paragraph [0012] paragraph [0017] - paragraph [0023] paragraph [0042] - paragraph [0051] paragraph [0055] - paragraph [0063] -----	1-24
X	US 2013/044613 A1 (EDARA KIRAN K [US] ET AL) 21 February 2013 (2013-02-21) abstract figures 1,3,5 paragraph [0024] - paragraph [0025] paragraph [0047] - paragraph [0050] ----- -/-	1-24



Further documents are listed in the continuation of Box C.



See patent family annex.

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"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

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Date of the actual completion of the international search

17 March 2017

Date of mailing of the international search report

31/03/2017

Name and mailing address of the ISA/

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Authorized officer

Matt, Stefan

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2017/015788

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 8 761 138 B2 (MOISANEN MATTI [FI] ET AL) 24 June 2014 (2014-06-24) abstract figures 1-7 column 3, line 31 - column 5, line 13 -----	1-24
T	INTEL: "Handling of MO/MT CSFB in EMM-REGISTERED.ATTEMPTING-TO-UPDATE-MM", 3GPP DRAFT; C1-162751 24.301 ATTEMPTING-TO-UPDATE-MM HANDLING FOR CSFB, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; , vol. CT WG1, no. Osaka, Japan; 20160523 - 20160527 22 May 2016 (2016-05-22), XP051101126, Retrieved from the Internet: URL: http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/CT1/Docs/ [retrieved on 2016-05-22] -----	1-24

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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