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(54) **USER EQUIPMENT REGISTRATION RECOVERY UPON CORE NODE FAILURE**

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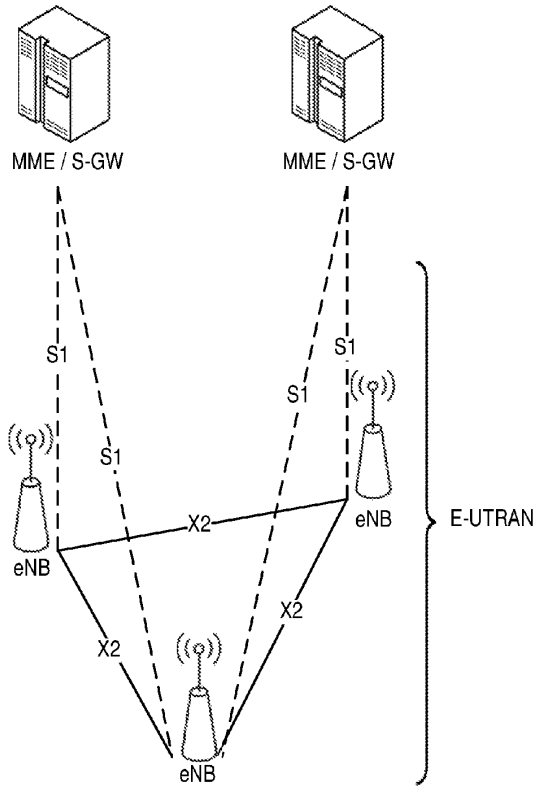
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H04W 8/20	(2006.01)

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CPC ***H04W 8/30*** (2013.01); ***H04W 8/20*** (2013.01); ***H04W 24/04*** (2013.01)

(57) **ABSTRACT**

In one aspect, a network node determines there is a loss of user context information for one or more user equipments and signals to radio base stations connected to the network node to notify the one or more user equipments of the loss of user context information in broadcast system information. A radio base station transmits an information element indicating the loss of user context information in broadcast system information. A user equipment receives the information element in broadcast system information and detaches and reattaches to the network node upon a determination that the network node indicated by the information element matches a network node in registration information stored at the user equipment.



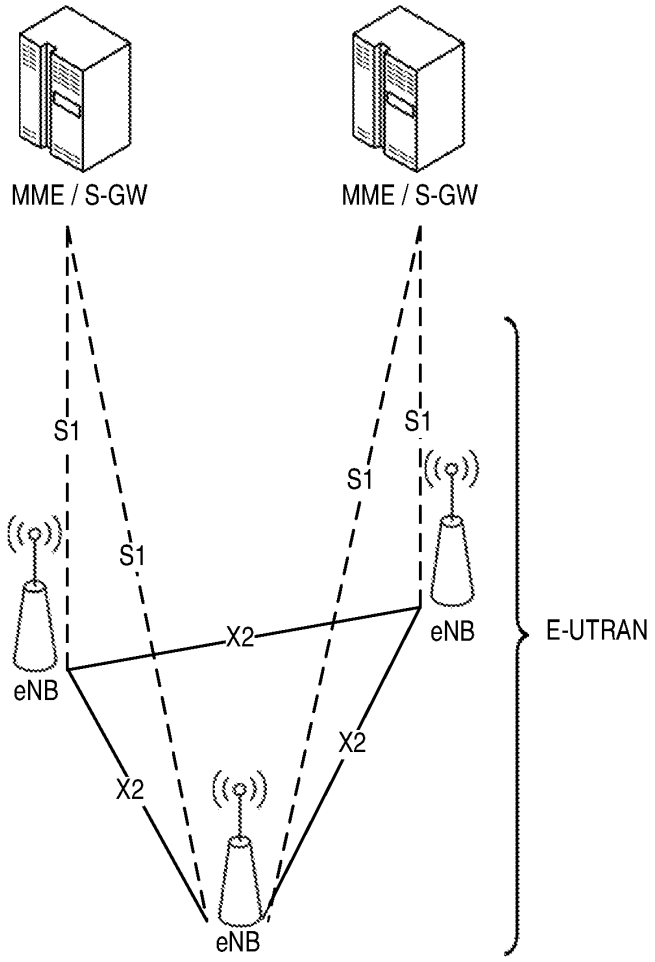


FIG. 1

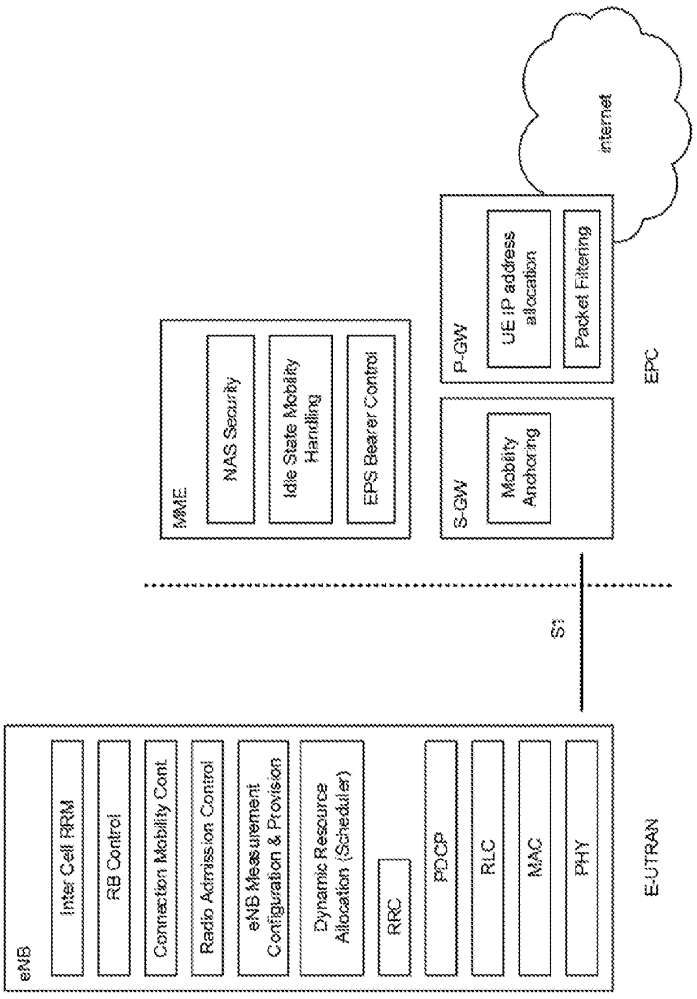

eNB
Inter Cell RRM
RB Control
Connection Mobility Cont.
Radio Admission Control
eNB Measurement Configuration & Provision
Dynamic Resource Allocation (Scheduler)
RRC
PDCP
RLC
MAC
PHY
E-UTRAN
S1
MME
NAS Security
Idle State Mobility Handling
EPS Bearer Control
S-GW
Mobility Anchoring
P-GW
UE IP address allocation
Packet Filtering
EPC
Internet

FIG. 2

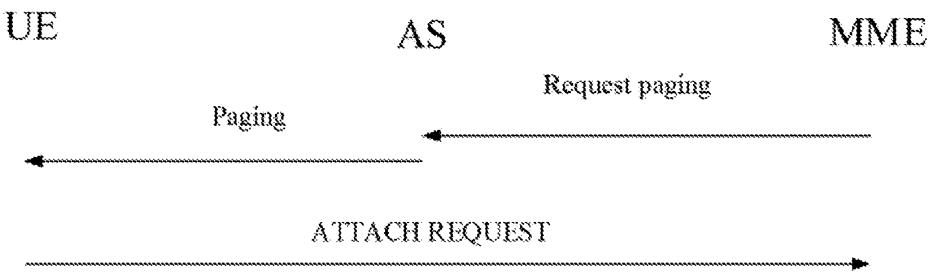


FIG. 3

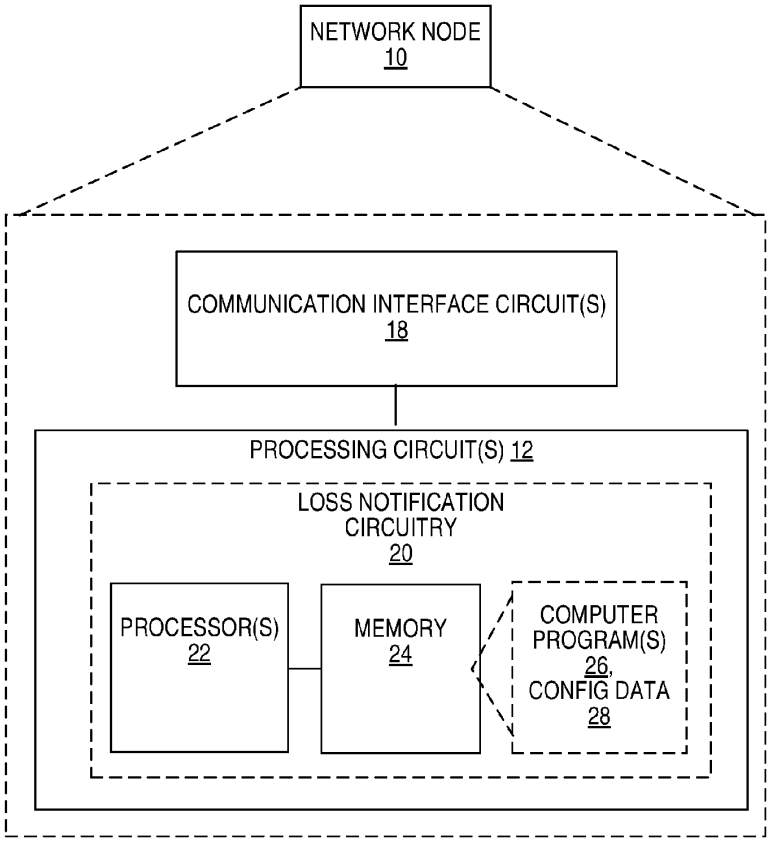

NETWORK NODE
10
COMMUNICATION INTERFACE CIRCUIT(S)
18
PROCESSING CIRCUIT(S) 12
LOSS NOTIFICATION
CIRCUITRY
20
PROCESSOR(S)
22
MEMORY
24
COMPUTER
PROGRAM(S)
26,
CONFIG DATA
28

FIG. 4

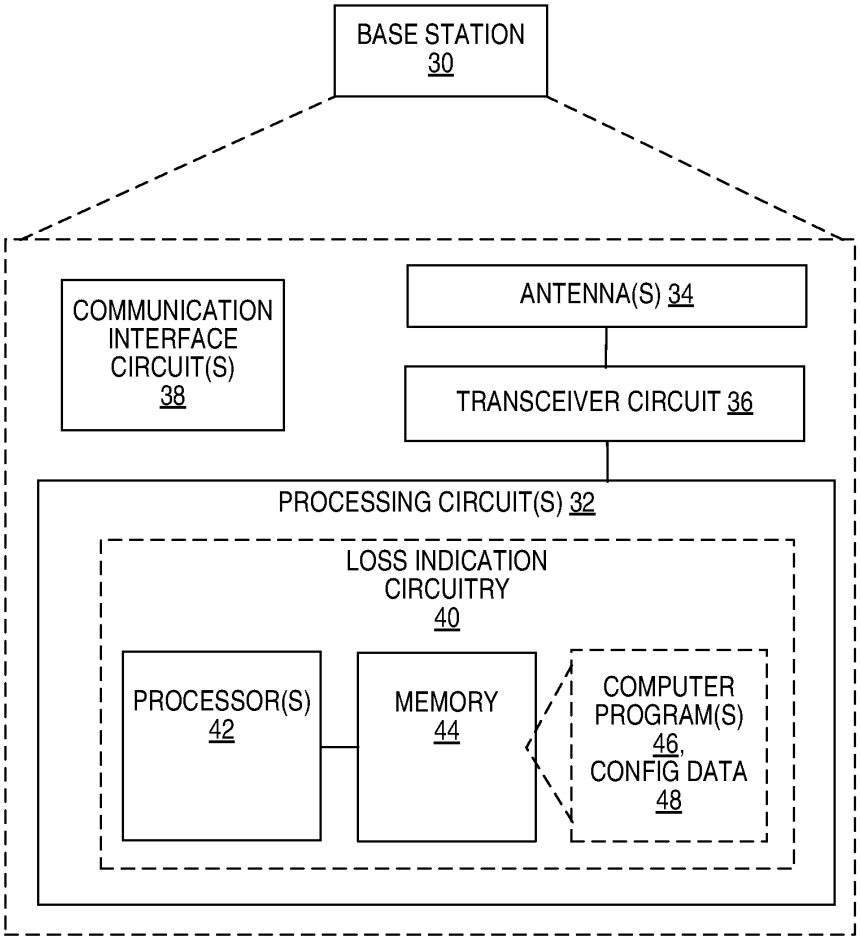

BASE STATION
30
COMMUNICATION INTERFACE CIRCUIT(S)
38
ANTENNA(S) 34
TRANSCEIVER CIRCUIT 36
PROCESSING CIRCUIT(S) 32
LOSS INDICATION CIRCUITRY
40
PROCESSOR(S)
42
MEMORY
44
COMPUTER PROGRAM(S)
46,
CONFIG DATA
48

FIG. 5

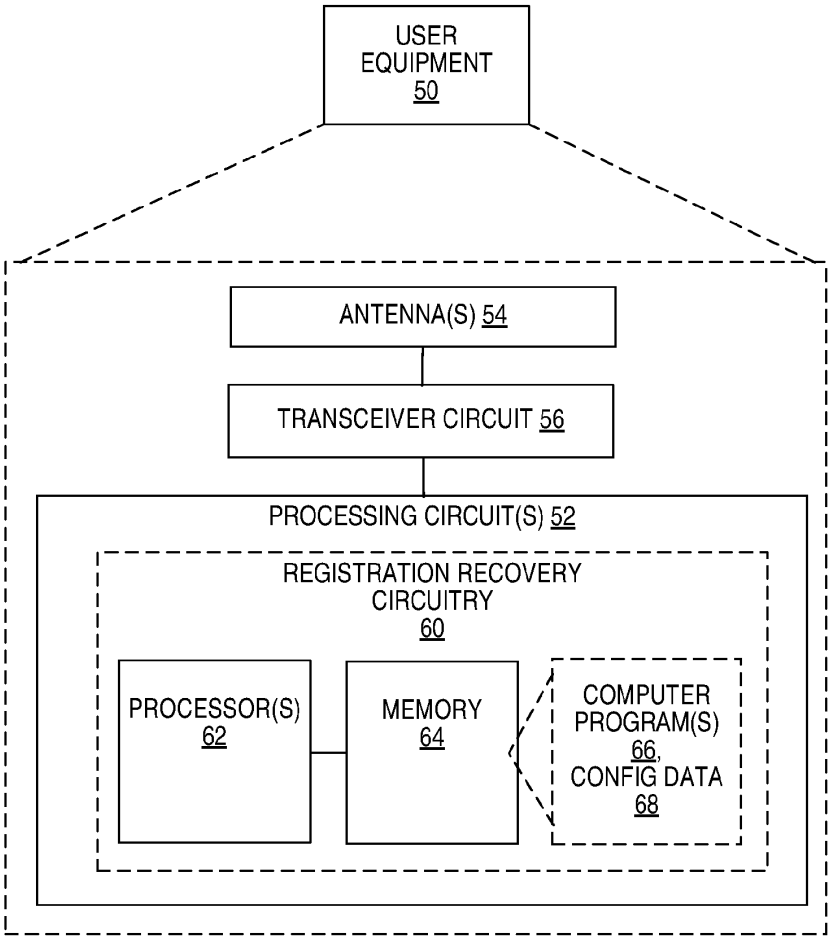

USER EQUIPMENT 50
ANTENNA(S) 54
TRANSCEIVER CIRCUIT 56
PROCESSING CIRCUIT(S) 52
REGISTRATION RECOVERY CIRCUITRY 60
PROCESSOR(S) 62
MEMORY 64
COMPUTER PROGRAM(S) 66, CONFIG DATA 68

FIG. 6

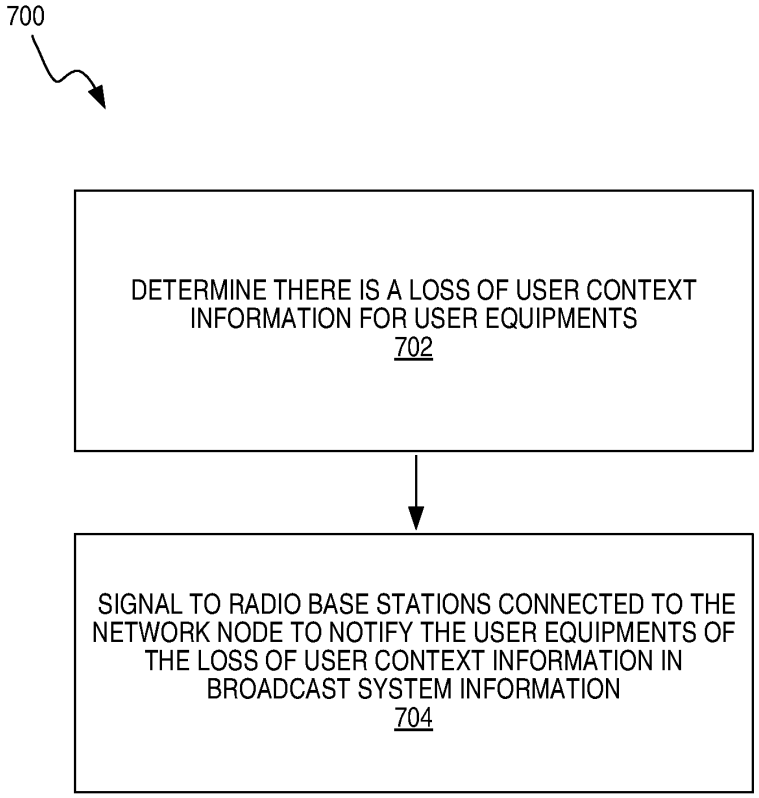

700
DETERMINE THERE IS A LOSS OF USER CONTEXT INFORMATION FOR USER EQUIPMENTS
702
SIGNAL TO RADIO BASE STATIONS CONNECTED TO THE NETWORK NODE TO NOTIFY THE USER EQUIPMENTS OF THE LOSS OF USER CONTEXT INFORMATION IN BROADCAST SYSTEM INFORMATION
704

FIG. 7

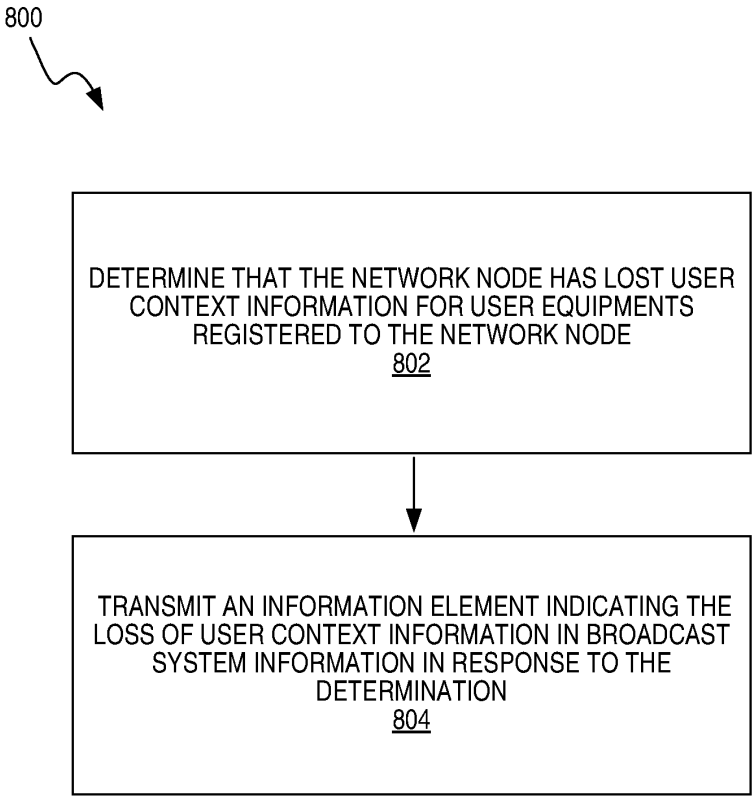

800
DETERMINE THAT THE NETWORK NODE HAS LOST USER CONTEXT INFORMATION FOR USER EQUIPMENTS REGISTERED TO THE NETWORK NODE
802
TRANSMIT AN INFORMATION ELEMENT INDICATING THE LOSS OF USER CONTEXT INFORMATION IN BROADCAST SYSTEM INFORMATION IN RESPONSE TO THE DETERMINATION
804

FIG. 8

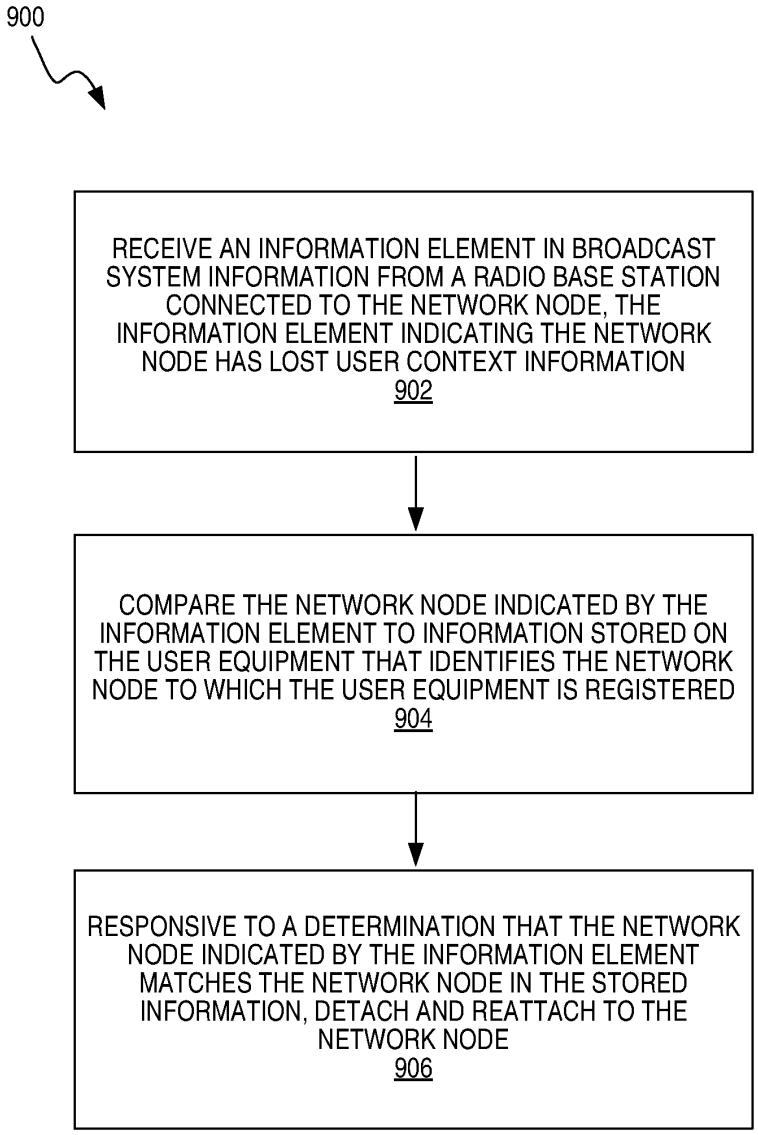

900
RECEIVE AN INFORMATION ELEMENT IN BROADCAST SYSTEM INFORMATION FROM A RADIO BASE STATION CONNECTED TO THE NETWORK NODE, THE INFORMATION ELEMENT INDICATING THE NETWORK NODE HAS LOST USER CONTEXT INFORMATION
902
COMPARE THE NETWORK NODE INDICATED BY THE INFORMATION ELEMENT TO INFORMATION STORED ON THE USER EQUIPMENT THAT IDENTIFIES THE NETWORK NODE TO WHICH THE USER EQUIPMENT IS REGISTERED
904
RESPONSIVE TO A DETERMINATION THAT THE NETWORK NODE INDICATED BY THE INFORMATION ELEMENT MATCHES THE NETWORK NODE IN THE STORED INFORMATION, DETACH AND REATTACH TO THE NETWORK NODE
906

FIG. 9

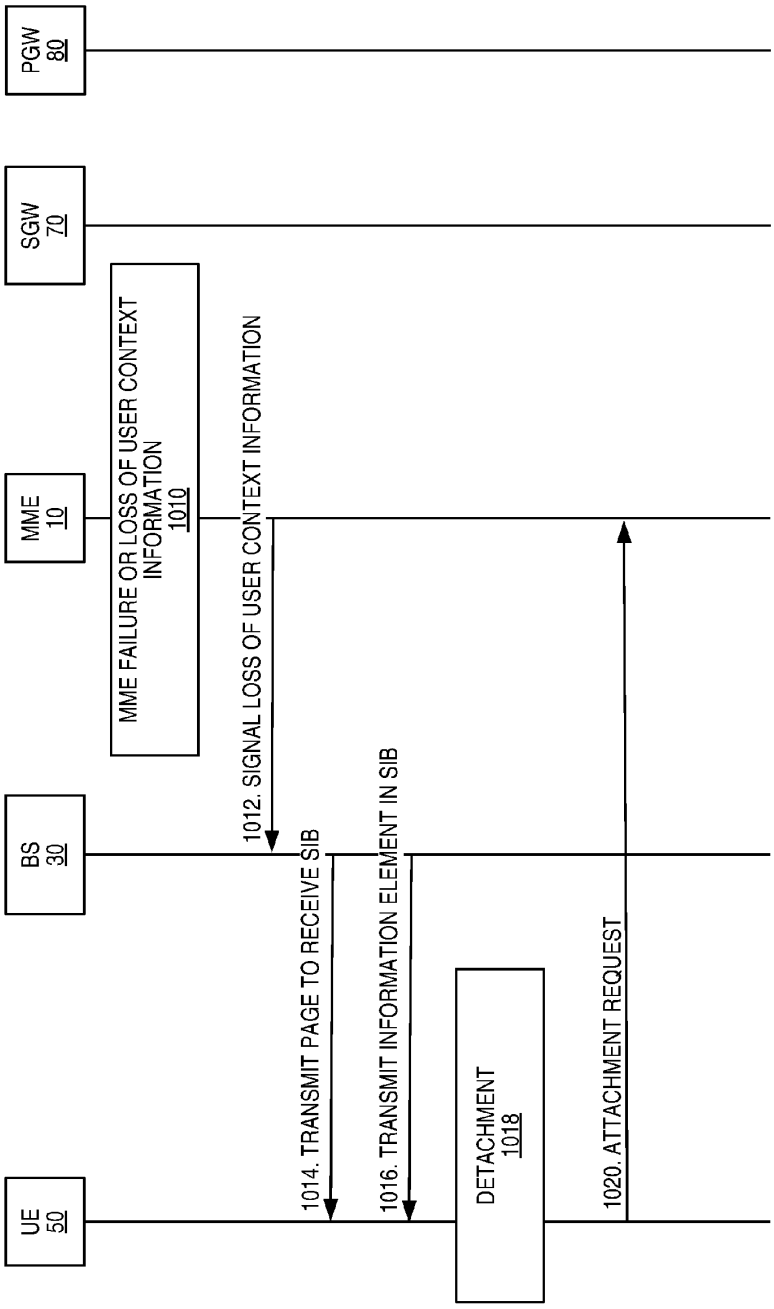

PGW 80
SGW 70
MME 10
BS 30
UE 50
MME FAILURE OR LOSS OF USER CONTEXT INFORMATION 1010
1012. SIGNAL LOSS OF USER CONTEXT INFORMATION
1014. TRANSMIT PAGE TO RECEIVE SIB
1016. TRANSMIT INFORMATION ELEMENT IN SIB
DETACHMENT 1018
1020. ATTACHMENT REQUEST

FIG. 10

IE/Group Name	Presence	Range	IE type and reference	Semantics description	Criticality	Assigned Criticality
Message Type	M		9.2.1.1		YES	reject
MME Name	O		PrintableString (1..150,...)		YES	ignore
Served GUMMEIs		*1..<maxnoofRATs>*		The LTE related pool configuration is included on the first place in the list.	GLOBAL	reject
>Served PLMNs		*1..<maxnoofPLMNsPer MME>*			-	
>>PLMN Identity	M		9.2.3.8		-	
>Served GroupIDs	M	*1..<maxnoofGroupIDs>*			-	
>>MME Group ID	M		OCTET STRING (2)		-	
>Served MMECs		*1..<maxnoofMMECs>*			-	
>>MME Code	M		9.2.3.12		-	
Relative MME Capacity	M		9.2.3.17		YES	ignore
MME Relay Support Indicator	O		9.2.1.82		YES	ignore
• **MME Failure Indicator**	• O		• **BOOLEAN**		• **YES**	• **ignore**
Criticality Diagnostics	O		9.2.1.21		YES	ignore

Range bound	Explanation
maxnoofPLMNsPer MME	Maximum no. of PLMNs per MME. Value is 32.
maxnoofRATs	Maximum no. of RATs. Value is 8.
maxnoofGroupIDs	Maximum no. of GroupIDs per node per RAT. Value is 65536.
maxnoofMMECs	Maximum no. of MMECs per node per RAT. Value is 256.

FIG. 11

IE/Group Name	Presence	Range	IE type and reference	Semantics description	Criticality	Assigned Criticality
Message Type	M		9.2.1.1		YES	reject
MME Name	O		PrintableString(1..150,...)		YES	ignore
Served GUMMEIs		0..<maxnoofRATs>		The LTE related pool configuration is included on the first place in the list.	GLOBAL	reject
>Served PLMNs		1..<maxnoofPLMNsPer MME>			-	
>>PLMN Identity	M		9.2.3.8		-	
>Served GroupIDs		1..<maxnoofGroupIDs>			-	
>>MME GroupID	M		OCTET STRING (2)		-	
>Served MMECs		1..<maxnoofMMECs>			-	
>>MME Code	M		9.2.3.12		-	
Relative MME Capacity	O		9.2.3.17		YES	reject
MME Failure Indicator	**O**		**BOOLEAN**		**YES**	**ignore**

Range bound	Explanation
maxnoofPLMNsPer MME	Maximum no. of PLMNs per MME. Value is 32.
maxnoofRATs	Maximum no. of RATs. Value is 8.
maxnoofGroupIDs	Maximum no. of GroupIDs per node per RAT. Value is 65535.
maxnoofMMECs	Maximum no. of MMECs per node per RAT. Value is 256.

FIG. 12

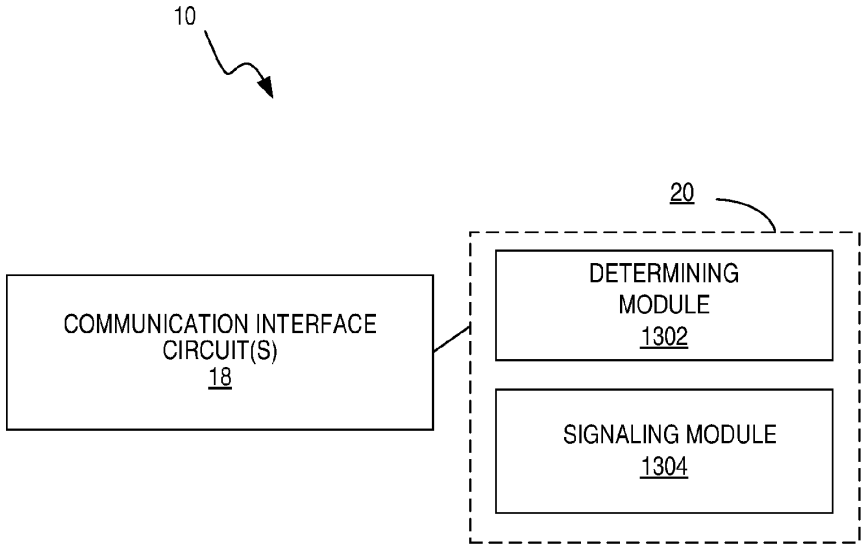

10
20
COMMUNICATION INTERFACE CIRCUIT(S) 18
DETERMINING MODULE 1302
SIGNALING MODULE 1304

FIG. 13

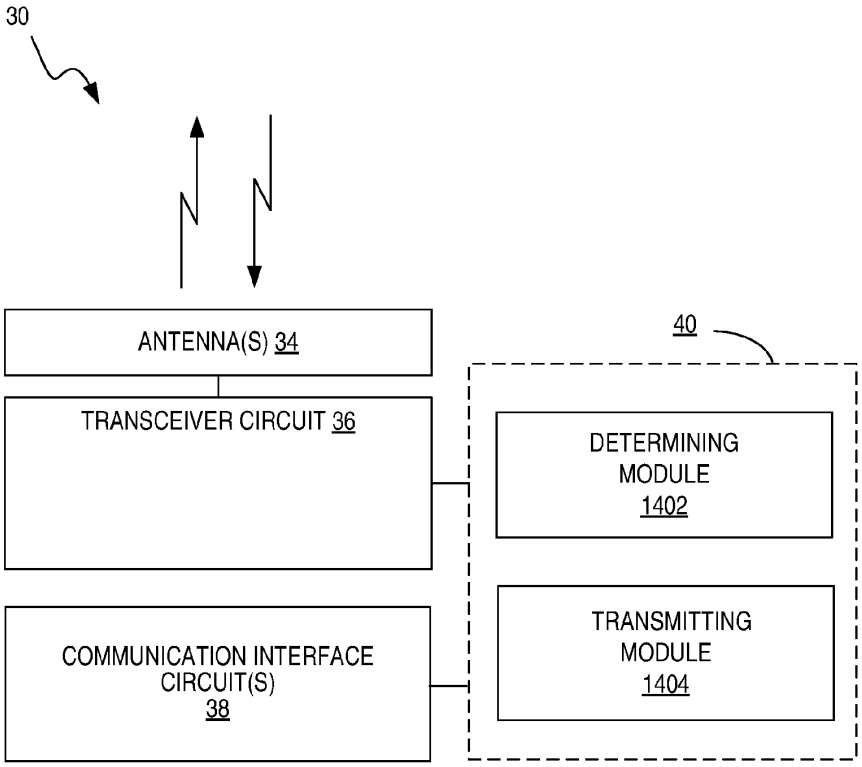

30
ANTENNA(S) 34
TRANSCEIVER CIRCUIT 36
COMMUNICATION INTERFACE CIRCUIT(S) 38
40
DETERMINING MODULE 1402
TRANSMITTING MODULE 1404

FIG. 14

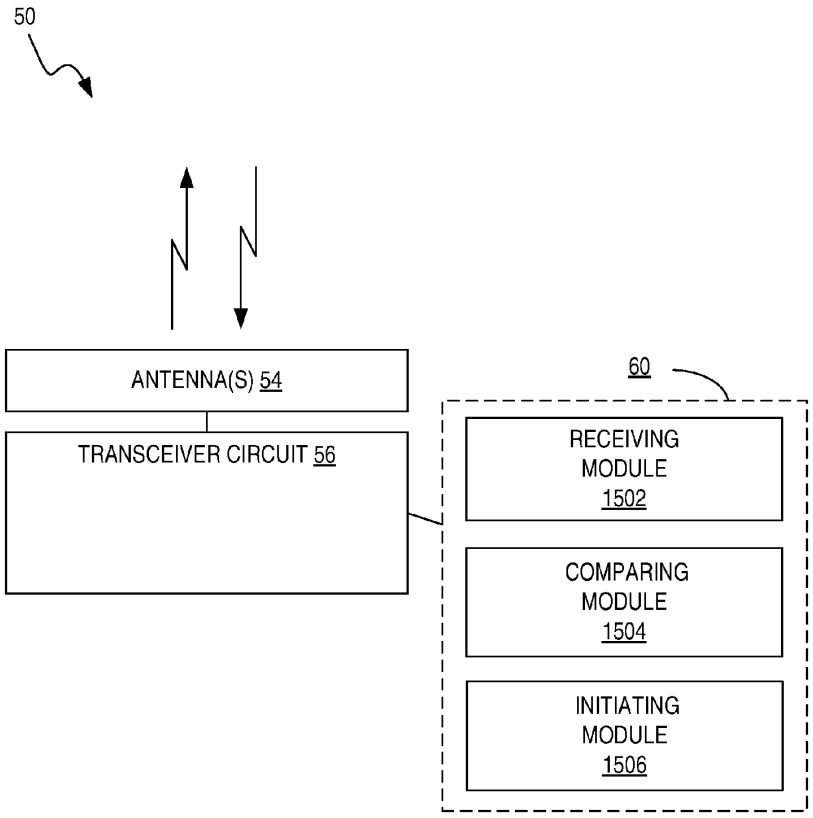

50
ANTENNA(S) 54
TRANSCEIVER CIRCUIT 56
60
RECEIVING MODULE 1502
COMPARING MODULE 1504
INITIATING MODULE 1506

FIG. 15

USER EQUIPMENT REGISTRATION RECOVERY UPON CORE NODE FAILURE

TECHNICAL FIELD

[0001] The present invention generally relates to wireless communication networks, and particularly relates to registration of wireless devices with core network entities.

BACKGROUND

[0002] An increasing number of machines or other autonomous devices communicate with each other (or with an application server) without human interaction over cellular networks. A typical scenario is to have sensors sending measurements infrequently, where each of the transmissions consists of only small amounts of data. This type of communication is referred to as machine to machine (M2M) communications or machine-type communication (MTC). Devices in cellular systems (such as Evolved Universal Terrestrial Radio Access or E-UTRA) are often battery driven and the power consumption is therefore an important factor. Sensors and other similar devices may reside in remote locations and the number of deployed devices could be so large that it would be practically infeasible to replace the batteries of such devices. Thus, it is important to reduce the amount of power consumption.

[0003] An existing means to reduce the battery power consumption is to use discontinuous reception (DRX), a feature in which the device receiver is switched off except during configured intervals. Currently the longest specified DRX cycle length is 2.56 seconds for E-UTRA. However, it would be beneficial to extend the DRX cycles beyond currently specified values to reduce the battery power consumption further especially for such (MTC type of) devices. Extended DRX cycles naturally cause larger delays to reach the user equipment (UE) in the downlink, however this is typically not considered a problem due to the delay insensitive traffic on such devices.

[0004] MTC devices can sometimes be placed in challenging locations, for which E-UTRA network deployments were not dimensioned for full coverage. For example, smart meters are often placed in building basements and are sometimes even contained in metal enclosures. Similarly, devices may be located in rural and isolated areas to address smart agriculture scenarios. As a consequence, long-range coverage extensions are defined so that the coverage for (low data-rate) MTC devices can be extended.

[0005] To enhance the radio coverage and reduce the power consumption for these MTC devices, there are ongoing efforts in the wireless community. For the former, it is essential to reduce the signaling overhead since repetition is one of the main techniques for those UEs to access the network, e.g. ensuring that the message sizes are kept small. While for the latter, it is essential to minimize the UE activity periods, e.g. by introducing extended DRX cycles.

[0006] The Evolved UMTS Terrestrial Radio Access Network (E-UTRAN), standardized by members of the 3rd Generation Partnership Project (3GPP), includes radio base stations called enhanced NodeBs (eNBs or eNodeBs), providing the E-UTRA user plane and control plane protocol terminations towards the user equipment or UE. The eNBs are interconnected with each other using the X2 interface. The eNBs are also connected using the S1 interface to the EPC (Evolved Packet Core), more specifically to the MME (Mobility Management Entity) by means of the S1-MME interface and to the Serving Gateway (S-GW) by means of the S1-U interface. The S1 interface supports a many-to-many relation between MMEs/S-GWs and eNBs. A simplified view of the E-UTRAN architecture is illustrated in FIG. **1**.

[0007] The eNB hosts functionalities such as Radio Resource Management (RRM), radio bearer control, admission control, header compression of user plane data towards serving gateway, and/or routing of user plane data towards the serving gateway. The MME is the control node that processes the signaling between the UE and the CN (core network). Significant functions of the MME are related to connection management and bearer management, which are handled via Non Access Stratum (NAS) protocols. The S-GW is the anchor point for UE mobility, and also includes other functionalities such as temporary DL (downlink) data buffering while the UE is being paged, packet routing and forwarding to the right eNB, and/or gathering of information for charging and lawful interception. The PDN Gateway (P-GW, not shown in FIG. **1**) is the node responsible for UE IP address allocation, as well as Quality of Service (QoS) enforcement (as further discussed below). The reader is referred to 3GPP TS 36.300 and the references therein for further details of functionalities of the different nodes.

[0008] FIG. **2** gives a summary of the functionalities of the different nodes, and the reader is referred to the 3GPP document "Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall Description; Stage 2," 3GPP TS 36.300, v. 11.3.0 (September 2012), available at 3gpp.org, and the references therein for the details of the functionalities of the different nodes. In FIG. **2**, the boxes labeled "eNB," "MME," "S-GW," and "P-GW" depict the logical nodes, the unshaded white boxes within the larger boxes depict the functional entities of the control plane, and the shaded boxes within the box labeled "eNB" depict the radio protocol layers.

[0009] In E-UTRA, a UE attached to the network has a UE context in the MME, see 3GPP TS 23.401. In this UE context, data essential for the communication is stored. One example is the temporary mobile subscriber identity (S-TMSI), which is used to address the UE over the radio interface. Another example is the tracking area identity (TAI) List, which describes the set of cells, one of which were UE is located. In case of an MME failure, user context information such as the UE context and data like S-TMSI and TAI List is lost. Section 5.6.2.2.2 of 3GPP TS 24.301 defines the following procedure to take place as a recovery measure, to reach and notify the UE of terminating call/data.

[0010] Paging for Evolved Packet System (EPS) services using International Mobile Subscriber Identity (IMSI) is an abnormal procedure used for error recovery in the network. The network may initiate paging for EPS services using IMSI with core network (CN) domain indicator set to "PS" if the S-TMSI is not available due to a network failure (see example in FIG. **3**).

[0011] In S1 mode, to initiate the procedure, the EPS Mobility Management (EMM) entity in the network requests the lower layer to start paging. If the TAI list is not available due to a network failure, the network may perform the paging within all tracking areas served by the MME (see 3GPP TS 36.331 and 3GPP TS 36.413). When a UE receives a page for EPS services using IMSI from the network before

a UE initiated EMM specific procedure has been completed, the UE then aborts the EMM specific procedure and proceeds according to the description in subclause 5.6.2.2.2 of 3GPP TS 24.301. Upon reception of paging for EPS services using IMSI, the UE shall stop timer T3346, if it is running, locally deactivate any EPS bearer context(s) and locally detach from EPS. Additionally, the UE shall delete the following parameters: last visited registered TAI, TAI list, Globally Unique Temporary ID (GUTI) and Key Selection Identifier Access Security Management Entity (KSIASME). The UE shall set the EPS update status to EU2 NOT UPDATED and change the state to EMM-DEREGISTERED. The UE shall stop all timers T3396 that are running.

[0012] If A/Gb mode or Iu mode is supported by the UE, the UE shall, in addition, handle the General Packet Radio System (GPRS) Mobility Management (GMM) parameters, GMM state, GPRS update status, P-TMSI, P-TMSI signature, RAI, and GPRS ciphering key sequence number as specified in 3GPP TS 24.008 for the case when a paging for GPRS services using IMSI is received.

[0013] After performing the local detach, the UE shall then perform an attach procedure as described in subclause 5.5.1.2 of 3GPP TS 24.301. If the UE is operating in CS/PS mode 1 or CS/PS mode 2 of operation, then the UE shall perform a combined attach procedure as described in subclause 5.5.1.3. In some cases, user interaction can be required, thus the UE cannot activate the dedicated bearer context(s) automatically. Also, the UE does not respond to the paging except with the attach request, hence timer T3413 in the network is not used when paging with IMSI.

[0014] It is recognized herein that the procedure described above results in a massive paging load over a large number of cells ("all tracking areas served by the MME") using the IMSI that requires more encoding bits in the paging message compared to a paging message where S-TMSI is used. The sum of these impacts would consume substantial radio resources used for paging, and even increase the risk of congestion.

[0015] For UEs that are in a position that requires coverage enhancement techniques, the paging message will be repeated several hundreds of times for successful UE reception. The procedure described above would introduce even higher risk of radio resource congestion. Given that the information that a particular UE may support and need coverage enhancement techniques is lost at the MME failure, the procedure described above will fail as such devices will not be reached.

[0016] In this case, UE-specific DRX cycle lengths (previously negotiated between the MME and the UE) are lost in the network due to the MME failure. As a result, the network may not be able to reach the UE until next time UE triggers registration procedure. This will disable the recovery procedure described above.

SUMMARY

[0017] Embodiments of the present invention comprise apparatuses and methods for registration recovery of wireless devices upon a loss of user context information by a network node for which the devices are registered. For example, an MME may lose user context information, such as S-TMSIs, TAI lists, DRX cycle length or use of coverage enhancement techniques. Of course, lost user context information may include other data, including but not limited to, coverage level, etc. The loss of user context information may be caused by a failure of the MME.

[0018] According to some embodiments, the MME determines there is a loss of user context information for wireless devices such as UEs, and signals to radio base stations (e.g., eNBs) connected, or communicatively coupled, to the MME to notify the UEs of the loss of user context information in, for example, broadcast system information (SIB). The MME failure is indicated to radio eNBs connected to the MME using a procedure, message or information element. For example, a new information element may be transmitted in S1 Management procedures, such as in the S1 messages S1 SETUP RESPONSE and/or MME CONFIGURATION UPDATE.

[0019] As for the eNB, the eNB determines that the MME has lost user context information for UEs registered to the network node. In response to the determination, an information element indicating the loss of user context information is transmitted in broadcast system information. For instance, the connected eNBs will start to transmit a new information element in broadcast system information identifying the affected/failed MMES. The information element may contain: alt1 (List of) Global Unique Mobility Management Entity Identifiers (GUMMEIs) of the Failure MME; alt2 (List of) MME Identifiers (MMEIs) of the Failure MME and/or alt3 (List of) MME codes (MMECs) of the failure MME.

[0020] UEs in a cell of the connected eNB will be triggered to receive broadcast system information in the cell. This can be achieved by transmitting paging messages in all cells of the connected eNB, indicating that all UEs (i.e. not only UEs addressed in the paging message) shall start to receive broadcast system information. This can also be achieved by UEs regularly (i.e. according to a preconfigured time interval) and autonomously starting to receive broadcast system information in the cell.

[0021] A UE located in the cell controlled by the connected eNBs receives the new information element in broadcast system information and compares to its locally stored information identifying its registered MME (Globally Unique Temporary ID (GUTI) that contains the MMEC). In the case there is a match (which means the UE is registered to the failed MME), the UE detaches (and releases the bearers locally) and re-attaches to the network (**3**), which means a new UE context (including S-TMSI, TAI List, DRX cycle length, use of coverage enhancement techniques, etc.) is created in the MME.

[0022] In some embodiments, to make sure the UE does not detach and re-attach multiple times as triggered by the same MME failure, a counter (sequence number) can be added to the S1 sequence management procedure (**1**) and the broadcast system information (**2**). This counter is stepped by one at MME failure. When the UE triggers detach and re-attach (**4**), the UE memorizes the counter value, and will trigger yet another detach/re-attach only in case the counter value broadcast in system information is different from the UE-stored count value.

[0023] The discussions of the solutions are based on E-UTRA; however, these aspects can also be considered valid for other technologies.

[0024] According to some embodiments, a method, in a radio base station connected to a network node in a wireless communication network, for indicating a loss of user context information stored by the network node, includes determin-

ing that the network node has lost user context information for one or more user equipments registered to the network node. The method also includes, in response to said determining, transmitting an information element indicating the loss of user context information in broadcast system information.

[0025] According to some embodiments, a method, in a user equipment registered to a network node in a wireless communication network, for reattaching to the network node upon loss of user context information stored by the network node, includes receiving an information element in broadcast system information from a radio base station connected to the network node, the information element indicating the network node has lost user context information. The method also includes comparing the network node indicated by the information element to information stored on the user equipment that identifies the network node to which the user equipment is registered. The method further includes, responsive to a determination that the network node indicated by the information element matches the network node in the stored information, detaching and reattaching to the network node.

[0026] According to some embodiments, a method, in a network node storing user context information for user equipments for which the network node is registered, for recreating new user context information upon a loss of user context information, includes determining there is a loss of user context information for one or more user equipments and signaling to radio base stations connected to the network node to notify the one or more user equipments of the loss of user context information in broadcast system information.

[0027] According to some embodiments, a radio base station connected to a network node in a wireless communication network and configured to indicate a loss of user context information stored by the network node, includes a transceiver circuit and a processing circuit operatively connected to the transceiver circuit. The processing circuit is configured to determine that the network node has lost user context information for one or more user equipments registered to the network node, and, in response to the determination, transmit, via the transceiver circuit, an information element indicating the loss of user context information in broadcast system information.

[0028] According to some embodiments, a user equipment registered to a network node in a wireless communication network and configured to reattach to the network node upon loss of user context information stored by the network node, includes a transceiver circuit and a processing circuit operatively connected to the transceiver circuit. The processing circuit is configured to receive an information element in broadcast system information from a radio base station connected to the network node, the information element indicating the network node has lost user context information. The processing circuit is configured to compare the network node indicated by the information element to information stored on the user equipment that identifies the network node to which the user equipment is registered, and, responsive to a determination that the network node indicated by the information element matches the network node in the stored information, initiate detachment and reattachment to the network node.

[0029] According to some embodiments, a network node storing user context information for user equipments for which the network node is registered and configured to recreate new user context information upon a loss of user context information, includes a communication interface circuit and a processing circuit operatively connected to the communication interface circuit. The processing circuit is configured to determine there is a loss of user context information for one or more user equipments and signal, via the communication interface circuit, to radio base stations connected to the network node to notify the one or more user equipments of the loss of user context information in broadcast system information.

[0030] Variations of the above-described methods, as well as corresponding apparatuses, computer program products, computer readable medium and functional implementations are described in detail below.

[0031] Of course, the present invention is not limited to the above features and advantages. Those of ordinary skill in the art will recognize additional features and advantages upon reading the following detailed description, and upon viewing the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] FIG. **1** is a diagram of a simplified view of E-UTRAN architecture.

[0033] FIG. **2** illustrates functionalities of the different nodes in the E-UTRAN architecture.

[0034] FIG. **3** illustrates paging for an attachment request.

[0035] FIG. **4** illustrates a block diagram of a network node configured to recreate new user context information upon a loss of user context information, according to some embodiments.

[0036] FIG. **5** illustrates a block diagram of a radio base station configured to indicate a loss of user context information stored by the network node, according to some embodiments.

[0037] FIG. **6** illustrates a block diagram of a user equipment configured to reattach and recover registration to the network node upon loss of user context information stored by the network node, according to some embodiments.

[0038] FIG. **7** illustrates a method for recreating new user context information upon a loss of user context information, according to some embodiments.

[0039] FIG. **8** illustrates a method for indicating a loss of user context information stored by the network node, according to some embodiments.

[0040] FIG. **9** illustrates a method for reattaching to the network node upon loss of user context information stored by the network node, according to some embodiments.

[0041] FIG. **10** illustrates an overview of a network performing registration recovery of user equipments upon loss of user context information by a network node, according to some embodiments.

[0042] FIG. **11** illustrates information elements in an example S1 SETUP RESPONSE message, according to some embodiments.

[0043] FIG. **12** illustrates information elements in an example MME CONFIGURATION UPDATE message, according to some embodiments.

[0044] FIG. **13** illustrates an example functional implementation of recreating new user context information upon a loss of user context information, according to some embodiments.

[0045] FIG. **14** illustrates an example functional implementation of indicating a loss of user context information stored by the network node, according to some embodiments.

[0046] FIG. **15** illustrates an example functional implementation of indicating a loss of user context information stored by the network node, according to some embodiments.

DETAILED DESCRIPTION

[0047] FIG. **4** illustrates a diagram of a network node **10**, according to some embodiments. The network node **10** resides in the core network and facilitates communication between access networks and the Internet using communication interface circuit **18**. The communication interface circuit **18** includes circuitry for communicating with other nodes in the core network, radio nodes, and/or other types of nodes in the network for the purposes of providing data and cellular communication services. According to various embodiments, cellular communication services may be operated according to any one or more of the 3GPP cellular standards, GSM, GPRS, WCDMA, HSDPA, LTE and LTE-Advanced.

[0048] The network node **10** also includes one or more processing circuits **12** that are operatively associated with the communication interface circuit **18**. For ease of discussion, the one or more processing circuits **12** are referred to hereafter as "the processing circuit **12**". The processing circuit **12** comprises one or more digital processors **22**, e.g., one or more microprocessors, microcontrollers, Digital Signal Processors (DSPs), Field Programmable Gate Arrays (FPGAs), Complex Programmable Logic Devices (CPLDs), Application Specific Integrated Circuits (ASICs), or any mix thereof. More generally, the processing circuit **12** may comprise fixed circuitry, or programmable circuitry that is specially configured via the execution of program instructions implementing the functionality taught herein, or may comprise some mix of fixed and programmed circuitry. The processor **22** may be multi-core having two or more processor cores utilized for enhanced performance, reduced power consumption, and more efficient simultaneous processing of multiple tasks.

[0049] The processing circuit **12** also includes a memory **24**. The memory **24**, in some embodiments, stores one or more computer programs **26** and, optionally, configuration data **28**. The memory **24** provides non-transitory storage for the computer program **26** and it may comprise one or more types of computer-readable media, such as disk storage, solid-state memory storage, or any mix thereof. By way of non-limiting example, the memory **24** comprises any one or more of SRAM, DRAM, EEPROM, and FLASH memory, which may be in the processing circuit **12** and/or separate from the processing circuit **12**.

[0050] In general, the memory **24** comprises one or more types of computer-readable storage media providing non-transitory storage of the computer program **26** and any configuration data **28** used by the network node **10**. Here, "non-transitory" means permanent, semi-permanent, or at least temporarily persistent storage and encompasses both long-term storage in non-volatile memory and storage in working memory, e.g., for program execution.

[0051] The processor **22** of the processing circuit **12** may execute a computer program **26** stored in the memory **24** that configures the processor **22** to determine there is a loss of user context information for one or more user equipments and signal, via the communication interface **18**, to radio base stations connected to the network node **10** to notify the one or more user equipments of the loss of user context information in broadcast system information. This structure and functionality may be referred to as loss notification circuitry **20** in the processing circuit **12**.

[0052] FIG. **5** illustrates a diagram of a radio base station **30**, according to some embodiments. The base station **30** provides an air interface to wireless devices, e.g., an LTE air interface for downlink transmission and uplink reception, which is implemented via antennas **34** and a transceiver circuit **36**. The transceiver circuit **36** may include transmitter circuits, receiver circuits, and associated control circuits that are collectively configured to transmit and receive signals according to a radio access technology, for the purposes of providing cellular communication services. According to various embodiments, cellular communication services may be operated according to any one or more of the 3GPP cellular standards, GSM, general packet radio service (GPRS), wideband code division multiple access (WCDMA), high-speed downlink packet access (HSDPA), LTE and LTE-Advanced. The base station **30** may also include a communication interface circuit **38** for communicating with nodes in the core network such as the network node **10**, other peer radio nodes, and/or other types of nodes in the network. The base station **30** may be, for example, an eNodeB.

[0053] The base station **30** also includes one or more processing circuits **32** that are operatively associated with the communication interface circuit **38** and transceiver circuit **36**. The processing circuit **32** comprises one or more digital processors **42**, e.g., one or more microprocessors, microcontrollers, DSPs, FPGAs, CPLDs, ASICs, or any mix thereof. More generally, the processing circuit **32** may comprise fixed circuitry, or programmable circuitry that is specially configured via the execution of program instructions implementing the functionality taught herein, or may comprise some mix of fixed and programmed circuitry. The processor **32** may be multi-core.

[0054] The processing circuit **32** also includes a memory **44**. The memory **44**, in some embodiments, stores one or more computer programs **46** and, optionally, configuration data **48**. The memory **44** provides non-transitory storage for the computer program **46** and it may comprise one or more types of computer-readable media, such as disk storage, solid-state memory storage, or any mix thereof. By way of non-limiting example, the memory **44** comprises any one or more of SRAM, DRAM, EEPROM, and FLASH memory, which may be in the processing circuit **32** and/or separate from the processing circuit **32**. In general, the memory **44** comprises one or more types of computer-readable storage media providing non-transitory storage of the computer program **46** and any configuration data **48** used by the base station **30**.

[0055] The processor **42** may execute a computer program **46** stored in the memory **44** that configures the processor **42** to determine that the network node **10** has lost user context information for one or more user equipments registered to the network node **10**, and, in response to the determination, transmit, via the transceiver circuit **36**, an information element indicating the loss of user context information in

broadcast system information. This structure and functionality may be referred to as loss indication circuitry **40** in the processing circuit **52**.

[0056] FIG. **6** illustrates a diagram of a wireless device, such as a user equipment **50**, according to some embodiments. To ease explanation, the user equipment **50** may also be considered to represent any wireless devices that perform machine to machine (M2M) communications or machine-type communication (MTC). The user equipment **50** communicates with a radio node or base station, such as base station **30**, via antennas **54** and a transceiver circuit **56**. The transceiver circuit **56** may include transmitter circuits, receiver circuits, and associated control circuits that are collectively configured to transmit and receive signals according to a radio access technology, for the purposes of providing cellular communication services. According to various embodiments, cellular communication services may be operated according to any one or more of the 3GPP cellular standards, GSM, GPRS, WCDMA, HSDPA, LTE and LTE-Advanced.

[0057] The user equipment **50** also includes one or more processing circuits **52** that are operatively associated with the radio transceiver circuit **56**. The processing circuit **52** comprises one or more digital processing circuits, e.g., one or more microprocessors, microcontrollers, DSPs, FPGAs, CPLDs, ASICs, or any mix thereof. More generally, the processing circuit **52** may comprise fixed circuitry, or programmable circuitry that is specially adapted via the execution of program instructions implementing the functionality taught herein, or may comprise some mix of fixed and programmed circuitry. The processing circuit **52** may be multi-core.

[0058] The processing circuit **52** also includes a memory **64**. The memory **64**, in some embodiments, stores one or more computer programs **66** and, optionally, configuration data **68**. The memory **64** provides non-transitory storage for the computer program **66** and it may comprise one or more types of computer-readable media, such as disk storage, solid-state memory storage, or any mix thereof. By way of non-limiting example, the memory **64** comprises any one or more of SRAM, DRAM, EEPROM, and FLASH memory, which may be in the processing circuit **52** and/or separate from processing circuit **52**. In general, the memory **64** comprises one or more types of computer-readable storage media providing non-transitory storage of the computer program **66** and any configuration data **68** used by the user equipment **50**.

[0059] The processor **62** of the processor circuit **52** may execute a computer program **66** stored in the memory **64** that configures the processor **62** to receive an information element in broadcast system information from a radio base station, such as base station **30** connected to the network node **10**, the information element indicating the network node **10** has lost user context information. The processing circuit **52** is also configured to compare the network node **10** indicated by the information element to information stored on the user equipment **50** that identifies the network node to which the user equipment **50** is registered. Responsive to a determination that the network node **10** indicated by the information element matches the network node in the stored information, the processing circuit **52** initiates detachment and reattachment of the user equipment **50** to the network node **10**. The user equipment **50** may also perform any other procedure to recover registration upon receiving one or more information elements in the broadcast system information. This functionality may be performed by registration recovery circuitry **60** in processing circuit **52**.

[0060] FIG. **10** illustrates an example overview of the registration recovery of the user equipment **50** upon a loss of user context information by the network node **10** (block **1010**), shown as MME **10** in this example. The network may also include a serving gateway **70** and a packet data network gateway **80**. FIG. **10** will be used as context to explain methods **700**-**900** of FIGS. **7**-**9**.

[0061] Process **1012** of FIG. **10** shows the MME **10** signaling loss of user context information to the base station **30**. The processing circuit **12** of the MME **10** is configured to perform a method, such as method **700** of FIG. **7**. The method **700** includes determining there is a loss of user context information for user equipments like the user equipment **50** (block **702**). The MME **10** then signals to the base station **30** connected to the MME **10** to notify user equipments, including the user equipment **50**, of the loss of user context information in broadcast system information (block **704**). The user context information lost by the MME **10** may include one or more temporary mobile subscriber identifiers, one or more tracking area identifiers, and/or DRX cycle length information for the user equipments **50**.

[0062] In some cases, the MME **10** signals an information element indicating the loss of user context information during an S1 management procedure. For example, the information element is transmitted in an S1 SETUP RESPONSE message and/or an MME CONFIGURATION UPDATE message. FIG. **11** shows a suggested change to the S1 SETUP RESPONSE. This message is sent by the MME **10** to transfer information for a Transport Network Layer (TNL) association. The direction is from the MME **10** to an eNB. FIG. **12** shows suggested changes to the MME CONFIGURATION UPDATE. This message is sent by the MME **10** to transfer updated information for a TNL association. The direction is from the MME **10** to an eNB.

[0063] At process **1014**, the base station **30** transmits a page to user equipments to receive system broadcast information (SIB). The page may be sent to all user equipments in all cells of the base station **30**.

[0064] At process **1016**, an information element indicating the MME **10** lost user context information is transmitted to user equipments in broadcast system information. The processing circuit **32** of the base station **30** is configured to perform a method, such as method **800** of FIG. **8**. The method **800** includes determining that the MME **10** has lost user context information for one or more user equipments registered to the MME **10** (block **802**). This determination may be made in response to receiving signaling or an information element from the MME **10** indicating the loss of user context information.

[0065] In response to the determination, the base station **30** transmits an information element indicating the loss of user context information in broadcast system information (block **804**). The information element may identify the MME **10**. For example, an information element includes one or more Global Unique Mobility Management Entity Identifiers (GUMMEIs) of the MME, one or more MME Identifiers (MMEIs) of the MME, one or more MME Group Identities (MMEGIs), and/or one or more MME codes (MMECs) of the MME.

[0066] The user equipment **50** receives the page notifying the user equipment **50** to receive the broadcast system

information and initiates reception of the broadcast system information responsive to receiving the page. Alternatively, rather than receiving the page, the user equipment **50** receives the information element in broadcast system information during a periodic monitoring of the broadcast system information. This may involve autonomously starting to receive broadcast system information during periodic intervals.

[0067] The processing circuit **52** of the user equipment **50** is configured to perform a method, such as method **900** of FIG. **9**. The method **900** includes receiving an information element in broadcast system information from the base station **30** connected to the MME **10**, the information element indicating the MME **10** has lost user context information (block **902**). The method **900** also includes comparing the MME **10** indicated by the information element to information stored on the user equipment **50** that identifies the network node or MME to which the user equipment is registered (block **904**).

[0068] The method **900** further includes, responsive to a determination that the MME **10** indicated by the information element matches the network node in the stored information, initiating detachment (process **1018**) and reattachment (attachment request **1020**) to the network node (block **906**). The MME **10** may also recreate new user context information for the user equipment **50** or other user equipments that reattach to the MME **10**.

[0069] To prevent unnecessary detachment and reattachment, the user equipment **50**, according to some embodiments, compares a stored counter value, previously received from the network and representing, directly or indirectly, a number of times the MME **10** has lost user context information, to a loss counter value indicated in the broadcast system information. The processing circuit **52** of the user equipment **50** controls the user equipment to detach and reattach to the MME **10** based on whether the stored counter value matches the loss counter value. For example, when the values match, detachment and reattachment are not performed. If the values are different, then detachment and reattachment are performed. The MME **10** may increment a counter value upon a loss of user context information by the MME **10** and transmit the counter value. While the MME **10** is used as an example network node, the methods are not limited to MMES.

[0070] FIG. **13** illustrates an example functional module or circuit architecture as may be implemented in the network node **10**, e.g., based on the processing circuitry **20**. The illustrated embodiment at least functionally includes a determining module **1302** for determining there is a loss of user context information for one or more user equipments. The embodiment also includes a signaling module **1304** for signaling to radio base stations connected to the network node to notify the one or more user equipments of the loss of user context information in broadcast system information.

[0071] FIG. **14** illustrates an example functional module or circuit architecture as may be implemented in the base station **30**, e.g., based on the processing circuitry **40**. The illustrated embodiment at least functionally includes a determining module **1402** for determining that a network node has lost user context information for one or more user equipments registered to the network node. The embodiment also includes a transmitting module **1404** for, in response to said determining, transmitting an information element indicating the loss of user context information in broadcast system information.

[0072] FIG. **15** illustrates an example functional module or circuit architecture as may be implemented in the user equipment **50**, e.g., based on the processing circuitry **60**. The illustrated embodiment at least functionally includes a receiving module **1502** for receiving an information element in broadcast system information from a radio base station connected to a network node, the information element indicating the network node has lost user context information. The embodiment also includes a comparing module **1504** for comparing the network node indicated by the information element to information stored on the user equipment that identifies the network node to which the user equipment is registered. The embodiment also includes a signaling module **1506** for, responsive to a determination that the network node indicated by the information element matches the network node in the stored information, detaching and reattaching to the network node.

[0073] Notably, modifications and other embodiments of the disclosed invention(s) will come to mind to one skilled in the art having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the invention(s) is/are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of this disclosure. Although specific terms may be employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

1-43. (canceled)

44. A method, in a radio base station connected to a network node in a wireless communication network, for indicating a loss of user context information stored by the network node, the method comprising:

determining that the network node has lost user context information for one or more user equipments registered to the network node; and,

in response to said determining, transmitting an information element indicating the loss of user context information in broadcast system information.

45. The method of claim **44**, wherein the user context information lost by the network node comprises one or more temporary mobile subscriber identifiers, one or more tracking area identifiers, and/or discontinuous reception (DRX) cycle length information for the one or more user equipments.

46. The method of claim **44**, further comprising transmitting a paging message that indicates that all user equipments of the cells are to receive broadcast system information.

47. The method of claim **44**, wherein determining that the network node has lost user context information comprises receiving an information element from the network node indicating that the loss of user context information has occurred.

48. The method of claim **44**, wherein the information element comprises an identifier of the network node.

49. A method, in a user equipment registered to a network node in a wireless communication network, for reattaching to the network node upon loss of user context information stored by the network node, the method comprising:

receiving an information element in broadcast system information from a radio base station connected to the

network node, the information element indicating the network node has lost user context information;

comparing the network node indicated by the information element to information stored on the user equipment that identifies the network node to which the user equipment is registered; and

responsive to a determination that the network node indicated by the information element matches the network node in the stored information, detaching and reattaching to the network node.

50. The method of claim **49**, further comprising:

receiving a page notifying the user equipment to receive the broadcast system information; and

initiating reception of the broadcast system information responsive to receiving the page.

51. The method of claim **49**, wherein the information element is received during a periodic monitoring of the broadcast system information.

52. A method, in a network node storing user context information for user equipments for which the network node is registered, for recreating new user context information upon a loss of user context information, comprising:

determining there is a loss of user context information for one or more user equipments; and

signaling to radio base stations connected to the network node to notify the one or more user equipments of the loss of user context information in broadcast system information.

53. A radio base station connected to a network node in a wireless communication network and configured to indicate a loss of user context information stored by the network node, the radio base station comprising:

a transceiver circuit; and

a processing circuit operatively connected to the transceiver circuit and configured to:

determine that the network node has lost user context information for one or more user equipments registered to the network node; and

in response to the determination, transmit, via the transceiver circuit, an information element indicating the loss of user context information in broadcast system information.

54. The radio base station of claim **53**, wherein the user context information lost by the network node comprises one or more temporary mobile subscriber identifiers, one or more tracking area identifiers, and/or discontinuous reception (DRX) cycle length information for the one or more user equipments.

55. The radio base station of claim **53**, wherein the processing circuit is configured to transmit a page message, via the transceiver circuit, that indicates that all user equipments of the cells are to receive broadcast system information.

56. The radio base station of claim **53**, wherein the processing circuit is configured to determine that the network node has lost user context information by receiving, via the transceiver circuit, an information element from the network node indicating that the loss of user context information has occurred.

57. The radio base station of claim **53**, wherein the information element comprises an identifier of the network node.

58. A user equipment, registered to a network node in a wireless communication network and configured to reattach to the network node upon loss of user context information stored by the network node, the user equipment comprising:

a transceiver circuit; and

a processing circuit operatively connected to the transceiver circuit and configured to:

receive an information element in broadcast system information from a radio base station connected to the network node, the information element indicating the network node has lost user context information;

compare the network node indicated by the information element to information stored on the user equipment that identifies the network node to which the user equipment is registered; and

responsive to a determination that the network node indicated by the information element matches the network node in the stored information, initiate detachment and reattachment to the network node.

59. The user equipment of claim **58**, wherein the processing circuit is configured to:

receive, via the transceiver circuit, a page notifying the user equipment to receive the broadcast system information; and

initiate reception of the broadcast system information responsive to receiving the page.

60. The user equipment of claim **58**, wherein the information element is received during a periodic monitoring of the broadcast system information.

61. A network node storing user context information for user equipments for which the network node is registered and configured to recreate new user context information upon a loss of user context information, the network node comprising:

a communication interface circuit; and

a processing circuit operatively connected to the communication interface circuit and configured to:

determine there is a loss of user context information for one or more user equipments; and

signal, via the communication interface circuit, to radio base stations connected to the network node to notify the one or more user equipments of the loss of user context information in broadcast system information.

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