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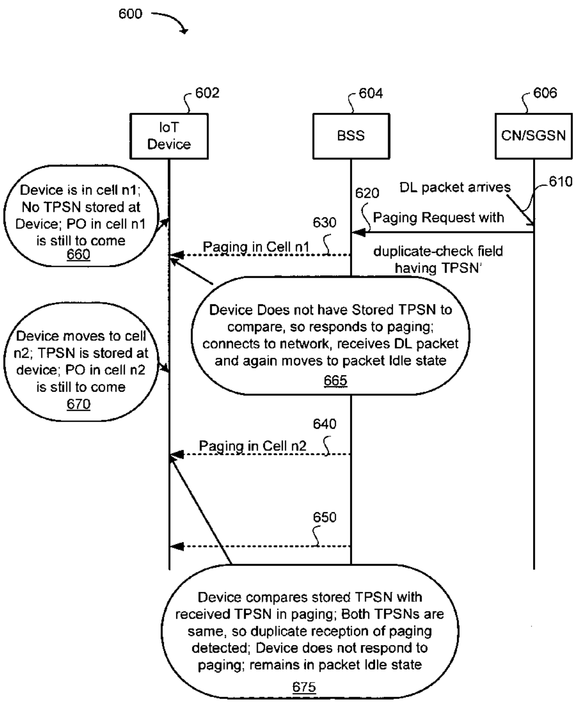

FIG. 6

(57) Abstract: Technology for efficient paging with extended discontinuous reception (eDRX) of multiple cells in a routing area is disclosed. In an example, an apparatus of a user equipment (UE) having circuitry configured to identify a missed paging request message by: receiving at the UE a pending paging request and downlink (DL) packet notification included in a routing area update (RAU) accept message delivered by a core network (CN) when the UE fails to respond to a paging request message previously delivered by the CN to a plurality unsynchronized cells of a routing area (RA); determining by the UE the RAU accept message includes the pending paging request and downlink (DL) packet notification; and receiving a DL packet prior to entering a packet idle state.

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EFFICIENT PAGING WITH EXTENDED DISCONTINUOUS RECEPTION (eDRX) OF MULTIPLE CELLS IN A ROUTING AREA

BACKGROUND

[0001] Wireless mobile communication technology uses various standards and protocols to transmit data between a node (e.g., a transmission station) and a wireless device (e.g., a mobile device). Some wireless devices communicate using orthogonal frequency-division multiple access (OFDMA) in a downlink (DL) transmission and single carrier frequency division multiple access (SC-FDMA) in an uplink (UL) transmission. Standards and protocols that use orthogonal frequency-division multiplexing (OFDM) for signal transmission include the third generation partnership project (3GPP) long term evolution (LTE), the Institute of Electrical and Electronics Engineers (IEEE) 802.16 standard (e.g., 802.16e, 802.16m), which is commonly known to industry groups as WiMAX (Worldwide interoperability for Microwave Access), and the IEEE 802.11 standard, which is commonly known to industry groups as WiFi.

[0002] In 3rd Generation Partnership Project (3GPP) radio access network (RAN) Long Term Evolution (LTE) systems, a node can be a combination of Universal Terrestrial Radio Access Network (UTRAN) Node Bs (also commonly denoted as Node Bs) and Radio Network Controllers (RNCs), which communicate with the wireless device, known as a user equipment (UE). The downlink (DL) transmission can be a communication from the node (e.g., NodeB) to the wireless device (e.g., UE), and the uplink (UL) transmission can be a communication from the wireless device to the node.

[0003] In a Global System for Mobile communications (GSM) Enhanced Data rates for GSM Evolution (EDGE) Radio Access Network (GERAN), data can be transmitted from the NodeB to the UE via a physical downlink shared channel (PDSCH). A physical uplink control channel (PUCCH) can be used to acknowledge that data was received. Downlink and uplink channels or transmissions can use time-division duplexing (TDD) or frequency-division duplexing (FDD). GERAN based cellular Internet of things (CIoT) solutions are being developed in 3GPP. GPRS EDGE is one of the major solutions proposed to develop a GERAN based CIoT communication system, referred to as extended coverage (EC) GSM. In the proposed EC-GSM, the GPRS frame/channel structures have been adopted in the downlink to keep the backward compatibility to coexist with legacy GPRS.

[0004] The GERAN based CIoT communication systems can be configured to significantly reduce the energy usage for CIoT devices to communicate with the EC-GSM network. For example, extended discontinuous receive (DRX) cycles may be used to allow the CIoT devices to communicate more infrequently, thereby reducing energy usage. However, the extended DRX cycles can cause additional problems within the communications network.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Features and advantages of the disclosure can be apparent from the detailed description which follows, taken in conjunction with the accompanying drawings, which together illustrate, by way of example, features of the disclosure; and, wherein:

[0006] FIG. 1 illustrates a mobile communication network within a cell in accordance with an example;

[0007] FIG. 2 illustrates a diagram illustrating a wireless network arrangement having a plurality of cells in accordance with an example;

[0008] FIG.s 3-4 illustrates block diagrams of a system having either missed paging request messages or duplicate reception of a paging request message in unsynchronized cells in a Routing Area (RA) in accordance with an example;

[0009] FIG. 5 illustrates block diagram of a system to identify a missed paging request message by a user equipment (UE) in accordance with an example;

[0010] FIG. 6 illustrates block diagram of a system to identify duplicate reception of paging and avoid multiple responses to the same paging in accordance with an example;

[0011] FIG. 7 depicts a flow chart of a method to identify a missed paging request message by a user equipment (UE) in accordance with an example;

[0012] FIG. 8 depicts a flow chart of a method to identify a duplicate reception of a paging request message by a user equipment (UE) in accordance with an example;

[0013] FIG. 9 depicts a flow chart of an additional method for achieving efficient paging with extended discontinuous reception (eDRX) with a user equipment (UE) in accordance with an example;

[0014] FIG. 10 depicts a flow chart of an additional method for achieving efficient paging requests with extended discontinuous reception (eDRX) by a base station system with a user equipment (UE) in accordance with an example;

[0015] FIG. 11 illustrates a diagram of a wireless device (e.g., UE) in accordance with an example;

[0016] FIG. 12 illustrates a diagram of example components of a wireless device (e.g. User Equipment "UE") device in accordance with an example; and

[0017] FIG. 13 illustrates a diagram of a node (e.g., eNB) and wireless device (e.g., UE) in accordance with an example.

[0018] Reference can now be made to the exemplary embodiments illustrated, and specific language can be used herein to describe the same. It can nevertheless be understood that no limitation of the scope of the technology is thereby intended.

DETAILED DESCRIPTION

[0019] Before the present technology is disclosed and described, it is to be understood that this technology is not limited to the particular structures, process actions, or materials disclosed herein, but is extended to equivalents thereof as would be recognized by those ordinarily skilled in the relevant arts. It should also be understood that terminology employed herein is used for the purpose of describing particular examples only and is not intended to be limiting. The same reference numerals in different drawings represent the same element. Numbers provided in flow charts and processes are provided for clarity in illustrating actions and operations and do not necessarily indicate a particular order or sequence.

EXAMPLE EMBODIMENTS

[0020] An initial overview of technology embodiments are provided below and then specific technology embodiments are described in further detail later. This initial summary is intended to aid readers in understanding the technology more quickly but is not intended to identify key features or essential features of the technology nor is it intended to limit the scope of the claimed subject matter.

[0021] In one aspect, the technology described herein applies to 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE) systems (e.g., wireless communication systems). In one aspect, within the 3GPP LTE systems, user equipment (UE), also known as mobile terminals and/or wireless terminals can communicate via a Radio Access Network (RAN) to one or more core networks. The UE can be a mobile station or user equipment units such as mobile telephones also known as "cellular" telephones, and laptops with wireless capability, e.g., mobile terminals, and thus may be, for example, portable, pocket, hand-held, computer-included, or car-mounted mobile devices which communicate voice and/or data with radio access network.

[0022] The radio access network can cover a geographical area, which can be divided into cell areas, with each cell area being served by a radio network node referred to as a base station, e.g., a Radio Base Station (RBS), which can be referred to as "eNB", "eNodeB", "NodeB" or "B node". The 3GPP specifications can define the function for reducing location registration procedures when a mobile station makes reselection between different RANs (Radio Access Networks) provided by different RATs (Radio Access Technologies). Specific examples of RAN include UTRAN (Universal Terrestrial Radio Access Network), GERAN (GSM EDGE Radio Access Network) and E-UTRAN (Evolved Universal Terrestrial Radio Access Network). In one aspect, as described herein, a (GERAN) system can have a base station (BS), a base transceiver station (BTS), a base station system (BSS), and a base station controller, and other components used by a GERAN system.

[0023] Moreover, a radio network controller (RNC) in the RAN can control radio resources and user mobility. Resource control includes admission control, congestion control, and channel switching which corresponds to changing the data rate of a connection. The base stations, (e.g., the "eNB", "eNodeB", "NodeB" or "B node") can be connected to the RNC and orchestrate radio communications with mobile radio stations over an air interface. The RNC controls what system information the eNodeB can broadcast and can also be the control plane protocol termination point towards the UE. RNCs can also be connected to nodes in the core network, i.e., Serving GPRS Support

Node (SGSN), Gateway GPRS Support Node (GGSN), mobile switching center (MSC), etc. The core network can provide various services to mobile radio users who are connected by the radio access network such as authentication, call routing, charging, service invocation, and access to other networks like the Internet, public switched telephone network (PSTN), Integrated Services Digital Network (ISDN), etc. In one aspect, the UE can report a network resource identifier (Network Resource Identifier, NRI) to the RNC in an initial direct transfer message, which can be used for sending a routing area update (Routing Area Update, RAU) request message. The RNC can report a routing area identifier (Routing Area Identifier, RAI) and the NRI to a mobile switching center (Mobile Switching Center, MSC). The MSC can send the NRI and the RAI to a target mobility management entity (Mobility Management Entity, MME) or a target SGSN, so that the target MME or the target SGSN can determine, according to the RAI and the NRI, a source SGSN where the UE is located, and obtains a context of the UE from the source SGSN.

[0024] In one aspect, a cell can be a geographical area where radio coverage is provided by the radio base station equipment at a base station site. The base stations can communicate over the air interface operating on radio frequencies with the UE units within range of the base stations. That is, a base station can be located in each cell to provide the radio coverage. A UE in each cell can receive information and data from the base station and transmit information and data to the base station. Information and data transmitted by the base station to the user equipment can occur on channels of radio carriers known as downlink carriers. Information and data transmitted by the UE to the base station can occur on uplink data channels of radio carriers, which can be referred to as uplink carriers.

[0025] Once a UE synchronizes and attaches itself to a base station, the UE can gain a radio resource control (RRC) connection, which can be referred to as being in connected mode. A UE maintaining a connected mode with a Node can consume a significant amount of energy. In order to limit the amount of energy used, the UE can be placed into an "idle mode". The UE in idle mode does not have a Radio Resource Control (RRC) connection.

[0026] The core network can locate the UE within each cell. That is, the core network can keep track of the location of the UE in units of a location registration area. The location registration area can be called a RA (Routing Area) or TA (Tracking Area).

[0027] In order to move a UE in idle mode into a connected mode, a paging operation can be performed by the core network with the UE. The paging operation can include the process of notifying the UE in idle mode by the core network, about an incoming data session, such as a downlink (DL) packet transmission.

[0028] In EC-GSM, devices, such as the UE, can enter into a packet idle state to save device power after data transfer. The UE can monitor paging channels periodically at specific time instants called paging occasions (PO) in the idle state. The UE can be paged for any downlink (DL) packet transmission when the UE is in the idle state.

[0029] In one aspect, discontinuous reception (DRX) can be used to enable a reduced power consumption of the UE. In idle mode, the UE and the core network can be coordinated in terms of having the same information about how and in what phases the data transfer occurs. In phases in which no data transfer occurs, the UE receiver functionality can be switched off and can thus enter a low power state. The paging operation can be used to switch the UE receiver functionality back to an on state. The paging periodicity can be determined by a discontinuous reception (DRX) cycle. Typical DRX cycles can be on the order of milliseconds to several seconds. A large value of a DRX cycle (i.e. a longer period) provides more device power saving for the UE. However, the device power savings occur at a cost of increased latency for DL traffic.

[0030] An extension of DRX cycles can be used to increase the UE power saving in the packet idle state for UEs, including cellular internet of things (CIoT) devices, by increasing the DRX cycles to minutes, tens of minutes, or longer. This can be particularly effective for CIoT devices with low mobility. However, certain types of CIoT devices may roam and move within each Cell with a relatively high mobility. For example, a CIoT device configured for fleet management or parcel tracking may have high mobility. The longer eDRX cycles can bring challenges for efficient handling of a paging operation, especially for mobile CIoT devices. As the eDRX assists to save power, an additional challenge arising upon the UE moving between cells during the lengthy eDRX idle mode (i.e. 54 minutes). In this case, the UE may miss the paging message if the UE moves between unsynchronized cells while in the power saving packet idle state. As such, the next time the UE voluntarily wakes up (e.g., exits the packet idle state) to check in with the cell more a time greater than the lengthy eDRX idle mode (e.g., the 54 minutes) may have lapsed if no paging message is received. As such, the present technology provides a solution to allow the UE to be able to receive paging message without a delay of the lengthy eDRX idle mode (e.g., the 54 minutes). In this way, the UE is able to conserve battery life by receiving multiple duplicate paging messages and responding to each one.

[0031] In a 3GPP Cellular Networks, Point-to-Point (PtP) and Point-to-Multipoint (PtM) paging mechanisms can provide efficient use of radio paging resources while maintaining low User Equipment (UE) power consumption. Paging can be used to establish connections and initiate transmissions. For example, a paging signal that is transmitted to a UE can be associated with a unique identity assigned to the UE. In one aspect, the UEs can be in an inactive paging state (e.g., "paging idle state") for considerable time periods while awaiting paging indications. Power consumption can be significantly reduced while the UEs are in such a paging state. To accomplish this, paging occasions can be predetermined in the UE and network. This can allow the UE to minimize transmit and receive processing between paging occasions, which results in reduced power consumption and correspondingly increased battery life. A paging occasion (PO) can be calculated in terms of time division multiple access (TDMA) frame numbers.

[0032] If different cells in a routing area (RA) are not synchronized in frame timing (i.e., if the cells have different frame numbers at a time instant), the POs in the cells can occur at various time instants to transmit a paging message in response to a paging request from core network (CN)/SGSN. As such, within the unsynchronized cells, a UE moving between the cells may miss a paging message or the UE may undesirably respond multiple times to the same paging due to duplicate receptions of a paging message within the cells. Since DRX cycles can be of several minutes (such as 54 minutes) in eDRX, it is highly likely that even low mobility devices may move to one or more new cells in a time interval equal to an eDRX cycle.

[0033] As such, the present technology described herein provides a solution for a UE that does not receive, or receives multiple issued paging messages in a RA with unsynchronized cells. The SGSN or core network (CN) may broadcast the paging messaging (e.g., paging request) in the RA only once. That is, the CN does not retransmit the paging request for the same paging trigger (such as for the same DL packet arrival at the CN).

[0034] If the UE does not respond to the paging message, the SGSN can store the paging message (e.g., a paging message request) for a time period equal to a periodic RA Update (RAU) timer. Since the UE typically contacts the core network within this RAU time period for the RAU, the CN can indicate to the UE that a suspended paging message exists. The paging message may include a DL packet transmission notification. In one example, the RAU response message (such as RAU accept and/or RAU reject message) from the CN/SGSN can be used to communicate the paging message notification.

[0035] In one aspect, the present technology provides a solution for preventing a UE from responding multiple times to the same paging message due to duplicate receptions of the paging message as the UE moves between cells. In one aspect, a short temporary paging sequence number (TPSN) for each UE can be included in the paging message as a duplicate-check field. The UE can check the duplicate-check field of the paging message. If the TPSN is the same as a previous paging TPSN stored at the UE, the UE can ignore the paging message and can ignore the request to connect to the core network.

[0036] In an alternative aspect, the present technology provides for efficient paging with extended discontinuous reception (eDRX) of multiple cells in a routing area. In an example, an apparatus of a user equipment (UE) having circuitry comprising one or more processors and memory that is configured to identify a missed paging request message by: receiving at the UE a pending paging request and downlink (DL) packet notification included in a routing area update (RAU) accept message delivered by a core network (CN) when the UE fails to respond to a paging request message previously delivered by the CN to a plurality unsynchronized cells of a routing area (RA); determine, at the UE, the RAU accept message includes the pending paging request and downlink (DL) packet notification; and receive a DL packet prior to entering a packet idle state.

[0037] In one aspect, the present technology provides for efficient paging with extended discontinuous reception (eDRX) of multiple cells in a routing area. In an example, an apparatus of a user equipment (UE) having circuitry, comprising one or more processors and memory, configured to identify duplicate reception of a paging request message by:

receiving a paging message having a duplicate paging message check field including a short temporary paging sequence number (TPSN), wherein the paging request message is delivered by a core network (CN) to a plurality cells of a routing area (RA); determine that the UE includes a stored TPSN of an alternative paging message previously delivered to the UE by the CN to the plurality cells of the RA; determine that the TPSN matches the stored TPSN when the UE includes the stored TPSN; and/or ignore the paging message by the UE when the TPSN matches the alternative TPSN.

[0038] In one aspect, the present technology provides for efficient paging with extended discontinuous reception (eDRX) of multiple cells in a routing area. In an example, an apparatus of a base station system having circuitry, comprising one or more processors and memory, configured to provide efficient paging requests with extended discontinuous reception (eDRX) with a user equipment (UE) by: receiving a paging message and a short temporary paging sequence number (TPSN) delivered by a core network (CN) to a plurality cells of a routing area (RA); including the TPSN in the paging message received from the CN when the paging message is delivered by the CN; and/or transmitting the paging message having the duplicate paging message check field including the TPSN to the UE to allow the UE to identify duplicate reception of a paging request message.

[0039] In one aspect, the present technology provides for efficient paging with extended discontinuous reception (eDRX) of multiple cells in a routing area. In an example, an apparatus of a user equipment (UE) having circuitry configured to identify duplicate reception of a paging request message by: receiving a first paging message having a duplicate paging message check field including a first short temporary paging sequence number (TPSN) delivered by a core network (CN) to a plurality cells of a routing area (RA); receiving a second paging message having a second TPSN in the duplicate paging message check field delivered by the CN to a plurality cells of a routing area (RA); comparing the first TPSN to the second TPSN; and/or ignoring the second paging message by the UE when the second TPSN matches the first TPSN.

[0040] FIG. 1 illustrates an mobile communication network within a cell 100 having an evolved node B (eNB) with a mobile device. FIG. 1 illustrates an eNB 104 that can be associated with an anchor cell, macro cell or primary cell. Also, the cell 100 can include mobile device, such as, for example, a User equipment (UE or UEs) 108 that can be in communication with the eNB 104. The eNB 104 may be a station that communicates with the UE 108 and may also be referred to as a base station, a node B, an access point, and the like. The eNB 104 can be a high transmission power eNB, such as a macro eNB, for coverage and connectivity. The eNB 104 can be responsible for mobility and can also be responsible for radio resource control (RRC) signaling. User equipment (UE or UEs) 108 can be supported by the macro eNB 104.

[0041] The eNB 104 may provide communication coverage for a particular geographic area. In 3GPP, the term "cell" can refer to a particular geographic coverage area of eNB and/or an eNB subsystem serving the coverage area, depending on the context in which the term is used.

[0042] In FIG. 2 a wireless communication system, in particular a telecommunication network 100 comprising a wireless access subsystem, is schematically disclosed. It should be noted that the descriptions and embodiments of FIG. 1 can be used in FIG. 2.

[0043] In one aspect, telecommunication network 200 comprises an access subsystem 210 (also named UTRAN or E-UTRAN) and a core network 220. Access subsystem 210 comprises access apparatuses 211 in wireless communication with user equipment (UEs) 212. In one embodiment, the access subsystem 210 comprises also apparatuses for cable connection of a user equipment 212 to the network. In one aspect, telecommunication network 200 can be a 3GPP LTE network and access apparatuses 211 can be an eNodeB apparatuses and/or base station subsystems (BSS), nevertheless the example is not limited to this type of network. As an example, telecommunication network 200 can be an LTE or UMTS or GSM or GPRS or EDGE network. Depending on the type of network, access apparatuses 211 can be of different types and can be interconnected in different ways. These apparatuses therefore are not limited to eNodeBs and can comprise any device suitable to provide a wireless connection to UE 212; as an example access apparatuses can comprise access points, radio base stations, remote radio heads (RRH) and radio network controllers controlling the radio base stations.

[0044] Access subsystem 210 can be divided in cells (e.g., cells 213) with each cell comprising at least an access apparatus 211 communicating with UEs 212 in a corresponding coverage area. Each access apparatus 211 can comprises equipment and one or more antennas. In case the equipment can receive and transmit signals from different antennas, each cell 213 can be logically divided into a plurality of sub cells, each covered by a given antenna controlled by a common equipment

[0045] In one aspect, eNodeBs 211 can be connected via an interface 215 to the core network 220, which comprises server(s) and databases for providing services (such as data communications, voice calls, or VoIP calls) to the UE 212 connected via the access subsystem 210. In particular, core network 220 comprises MMEs (Mobility Management Entities) and Gateways for connection with other networks.

[0046] Turning now to FIG.s 3-4, a block diagram of a system 300 and 400 having either missed paging request messages or received duplicate reception of a paging request message in unsynchronized cells in a Routing Area (RA) is depicted. It should be noted that the descriptions and embodiments of FIGs. 1-2 can be used in FIG.s 3-4. As shown in (a) of FIG. 3-4, a device, such as a UE 312, may miss a paging message. The UE 312 can be a moving device, such as a CIoT device, that can miss receiving the paging message as the UE 312 moves from cell to cell (e.g., such as from cell A to cell B of the cells A-D in FIG.s3-4). In this example, the UE 312 can move out of a cell (e.g., cell A) before a PO in cell A occurs, and/or the UE 312 can enter a cell (such as cell B) after a PO has already occurred in that cell (e.g., cell B). The probability of missing the reception of a paging message for the UE 412 can be highly probable (e.g., greater than 50%) due to a separation distance (several minutes) of the POs where the cells (e.g., cells A-D) are unsynchronized in a RA when longer DRX cycles are used, such as DRX cycles longer than several seconds. If the cells are small, such as femto cells or home eNBs, a PO may be missed or repeated, even with relatively short DRX cycles, as a UE moves between the cells. It is because for a given speed of UE, the time to stay in a cell is lower for smaller cell. DRX cycles can be in the range of up to a few seconds when not using an extended DRX system.

[0047] In one aspect, a device moving out of cell can be totally independent of DRX cycle or eDRX cycle, depending on the speed and/or velocity of device. Occurrence of a PO depends on DRX cycle. A PO can be calculated as an absolute frame and subframe numbers based on DRX/eDRX cycles, such as, for example, a PO can occur in a frame, such as X, X+320, X+640, ... if DRX/eDRX cycle is 320 frames (i.e. 3200 ms in LTE).

In one aspect, if cells are not synchronized, frame numbers of different cells can not be synchronized. That is, frame X can occur at time "t1", time "t2",...,time "tn" in cells "C1", cell "C2", ..., or cell 'Cn'.. However, the time (t) difference between time t1, t2, can always be less than DRX/eDRX cycle value. In legacy systems, a maximum value of DRX cycle is 2.54s, so the paging will come in any cell (after CN request for paging) within 2.54s, and the device is less likely to move out of a cell in 2.54s. In this scenario there is no problem of missed or duplicate paging. In eDRX case, a maximum value of DRX cycle can be 54mins, so the paging can come in a cell (after CN request for paging) from 0s to 54 mins (within 54 mins). Even a low mobility device can move out of a cell within 54 mins. As such, the challenge of missed or duplicate paging occurs.

[0048] As shown in (b) of FIG. 4, a device, such as a UE 412, can receive the same paging message multiple times in different cells (e.g., cells A-D) as the UE moves from cell to cell (such as from cell A to cell B and to cell C, as illustrated in FIG. 4. The UE 412 can receive a paging message, such as a paging message for a DL packet transmission notification. The UE 412 can connect to the network, such as a core network, receive the DL packet transmission, and then return to a packet idle state.

[0049] It can be assumed that the UE 412 moves to a new cell (e.g., from cell A to cell B) before the PO occurs in the new cell (e.g., cell B). As a result, the UE 412 can receive the paging message for same a DL packet transmission, which the UE 412 has already received (e.g., such as receiving the paging message in a previous cell, such as in cell A). Such a duplicate reception of the paging message may occur one or more time(s) in different cells (e.g., cells A-D). If the UE 412 connects to the core network in response to each paging message reception, there can be a significant waste of radio resources and increased signaling overhead in the system. In addition, the UE can use significantly more energy to connect to the core network multiple times.

[0050] Thus, the use of extended DRX (eDRX) cycles can be used to increase the UE 412 power saving in the packet idle state for cellular IoT (CIoT). Extended DRX (eDRX) cycles can be up to several minutes. However, if a paging message is missed when a UE moves between cells, the use of eDRX can significantly increase the amount of time (based on the eDRX period) until the UE moves to an RRC connected state to receive a DL transmission. For example, using eDRX, the UE may wait approximately 54 minutes if the UE has recently entered the eDRX idle mode. It may be desirable for the UE to receive data in a DL transmission without a significant delay. It should be noted that eDRX can maximizes a device's power saving by causing the device to "wake up" less frequently to check for paging.

[0051] FIG. 5 illustrates a block diagram of a system 500 that is configured to identify a missed paging request message by a user equipment (UE) in accordance with an example. It should be noted that the descriptions and embodiments of FIGS. 1-4 can be used in FIG. 5. FIG. 5 depicts sending an indication to the UE about a DL packet arrival in case a paging message communicated in unsynchronized cells in a routing area (RA) is missed. In one aspect, the CN or SGSN 506 can send a paging message 510 (e.g., paging request or paging trigger) to all cells in the RA only once. The paging retransmission timer can be started, as in action 565.

[0052] In one aspect, the paging message 510 can be first sent to the base station subsystem (BSS) 504, and the BSS 504 can send the paging message 510 to the UE via a paging operation 520 in an "nth" cell (e.g., n1 cell). The BSS 504 can send the paging message 510 again illustrated in FIG. 5 as the paging message 520 to an nth cell (e.g., n2 cell).

[0053] If the UE 502 (e.g., IoT device) responds to the paging message 510, then the paging message 510 reception is successful with the core network and recognized by the core network. That is, the UE 502 can respond to the paging message 510 and does not miss the paging message. The CN/SGSN 502 does not take any further action other than any prior defined procedures of a paging operation.

[0054] However, if the UE 502 (e.g., IoT device) does not respond to the paging message 510, then the CN/SGSN 506 can recognize the paging message as "missed" and can store the paging request for a period up to periodic RAU timer, as in action 570. Since the UE 502 typically attempts to make contact the CN/SGSN 506 within at least the RAU time period, the CN/SGSN 506 indicates to the UE 502 about pending paging/DL packet notification (i.e., due to the missed paging message) during a RAU process. That is, the paging message 510 can be sent to various cells as paging message 520, paging message 530, and paging message 540. The UE 502 may miss (i.e. not receive) each of these paging messages, such as paging message 520, 530, and 540.

[0055] However, the UE can transmit to the BSS 504 a RAU message 550, which is forwarded to the CN/SGSN 506. The CN/SGSN 506 can send a "pending paging/DL packet notification" message in the RAU accept message 560. The RAU accept message 560 can be sent from the CN/SGSN 506 to the BSS 504, which can be forwarded to the UE 502 by the BSS 504.

[0056] As such, within the RAU accept message 560, a new field can be included, which can be referred to as a 'eDRX-Pending-Paging-DL-Packet" field for sending "pending paging/DL packet notification" message in the RAU accept message 560.

[0057] The UE 502 can check and determine if the RAU accept message 506 include the new field that can be labeled as "eDRX-Pending-Paging-DL-Packet", or another desired label, for sending a "pending paging/DL packet notification" message in the RAU accept message 560. The new field "eDRX-Pending-Paging-DL-Packet" can indicate to the UE 502 that the UE 502 has missed a paging message (such as paging message 510, 530, 540) and there is DL packet for the UE 502 to receive. The UE 502 can then enter a wait stage or wait to receive the DL packet prior to entering into the idle state (e.g., the packet idle state) for up to a predetermined time, such as a maximum waiting time, which can be referred to as "eDRX-Pending-Paging-DL-Packet-Wait-Time", which allows sufficient time for the DL packet to be transmitted to the UE 502. That is, the UE 502 can wait for a start of a DL packet transmission/reception for at least a time period equal to the predetermined time, such as a maximum waiting time, which can be referred to as "eDRX-Pending-Paging-DL-Packet-Wait-Time", before entering into the idle state, such as the packet idle state, as in action 580.

[0058] In this way, FIG. 5 provides a solution to ensure the UE 502 can be informed about a DL packet notification or paging message attempt failure from the CN/SGSN 506. Also, the paging message resources can be saved, which would have been previously wasted in multiple attempts of retransmission of paging from CN/SGSN 506 to the UE 502.

[0059] Thus, FIG. 5 illustrates a solution for a UE that does not receive an issued paging message in a RA with unsynchronized cells, when the paging message is communicated by the SGSN or core network (CN) by broadcasting the paging messaging (e.g., paging request) in the RA only once meaning the core network (CN) does not retransmit the paging request for the same paging trigger (such as for the same DL packet arrival at CN). If the UE does not respond to the paging message, the SGSN can store the paging message (e.g., a paging message request) for a time period equal to a periodic RA Update (RAU) timer. Since the UE can contact the core network within this RAU time period, the CN can indicate to the UE about a suspended paging message and DL packet transmission notification using the RAU response message (such as RAU accept and/or RAU reject message) from the CN/SGSN.

[0060] FIG. 6 illustrates a block diagram of a system 600 configured to identify duplicate reception of a paging message and to avoid multiple responses to the same paging message in accordance with an example. It should be noted that the descriptions and embodiments of FIGS. 1-5 can be used in FIG. 6. A moving device, such as UE 602 (e.g., an IoT device) can receive a paging message multiple times in different, unsynchronized cells in a Routing Area, if the PO is communicated at different times in different cells in which the UE travels. The UE 602 can be configured to respond only to the first reception of the paging message at the UE. Responding to duplicate receptions of the paging message by the UE can add signaling overhead and resource wastage without any gain. As such, the UE 602 can be configured to identify a duplicate paging reception so that the UE can cease responding multiple times for the same paging message. As such, as depicted in FIG. 6, the present example adds a duplicate-check field in the paging message. A short temporary paging sequence number (TPSN), that is defined per device (e.g., UE 602), can be included in the paging message.

[0061] For example, a CN/SGSN 606 can send a paging request with a duplicate-check field having a short temporary paging sequence number (TPSN) per UE 602 (i.e. IoT device). The TPSN can be included in the paging message 620 as a duplicate-check field. The paging message 620, having the duplicate-check field with the TPSN, can be sent from the CN/SGSN 606 to the BSS 604. The BSS 604 can then forward the paging message to one of a plurality of cells, such as paging message 630 in cell n1. As depicted in FIG. 6, the UE 602 can be in cell n1 with no previous TPSN stored in the UE 602.The PO in cell n1 can still be pending, as in action 660. The UE 602 can check to see if the UE 602 has a previously stored TPSN sent from a previous paging message when the paging message 630 is sent to the UE 602 (e.g., the paging message 620 can be forwarded from BSS 604 as paging message 630). When the UE 602 does not have a stored TPSN to compare with the current TPSN included in the paging message 630, the UE 602 can connect to the core network, receive a DL packet transmission, and then reenter an idle state (e.g., packet idle state), as in action 665. The UE 602 can save the TPSN sent in the paging message 620, which was forwarded by the BSS as paging message 630.

[0062] Assume now the UE 602 moves from cell n1 to cell n2 (and the TPSN sent with the paging message 620 is already stored in the UE 602) and the PO in cell n2 is still pending (e.g., has not occurred in cell n2), as in action 670. At a later time, the paging message 620, sent to the BSS 604, can be forwarded by the BSS 604 as paging message 640 to the UE 602 in the cell n2. At action 675, the UE 602 can compare the stored TPSN with the received TPSN sent in the paging message 640 and can determine that the currently received TPSN (e.g., the TPSN included in the paging message 640) is identical to, or the same as, the TPSN sent in the paging message 630. That is, both the paging message 630 sent to the UE 602 in cell n1 and the paging message 640 sent to the UE 602 in cell n2 have the same TPSN, indicating they are duplicate paging messages. As such, the UE 602 can be configured to not respond to the paging message 640 since it is identified as a duplicate paging message based on identical TPSNs.

[0063] In one aspect, whenever the BSS 604 receives a paging request with a new TPSN from the CN/SGSN 606 while a previous paging for the same UE 602 is pending (i.e. waiting for next PO), the BSS 604 can cancel a pending paging message and transmit a paging message with a new TPSN over the air-interface. This can allow the TPSN to always have a defined size of one (1) bit. That, is the TPSN can be defined as a single bit such that the only possible values of TPSN are either a zero (0) or a one (1). In one aspect, the TPSN values can roll over after 2 values such as 0, 1, 0, 1, 0, ..., in case the CN/SGSN 606 makes more than two paging requests during an eDRX cycle.

[0064] For example, assume a DL packet arrives for a UE. A CN/SGSN can then send a paging request with TPSN that is equal to zero (0). The UE can respond to this paging request after receiving a paging message from a cell with the nearest PO. The UE can connect to network, receive the DL packet, and return back to packet Idle in a time less than an eDRX cycle. It should be noted that other cells in the RA may send a paging message with a TPSN equal to zero (0) as POs in each of the other cells. That is, although a CN can send the paging request to a BSS (i.e. many cells in that BSS) at the same time, actual transmission of paging message from network to UE depends on the cell's frame numbers/timing. As cells have different frame timing, PO occurs at different times in different cells.

[0065] Next, assume that a next packet arrives at the CN before an eDRX cycle passes (e.g., completes), since the paging request with TPSN equal to zero (0) was sent. The paging message operation with TPSN equal to zero (0) can be previously completed for a CN/SGSN, although some cells in the RA can continue to send paging messages with TPSN equal to zero (0). The CN/SGSN can now send a new paging messaging request with TPSN equal to one (1). Each of the BSSs can now schedule transmission of the new paging message with TPSN equal to one (1). When some cells still have a pending paging message with TPSN equal to zero (0), the cells can cancel the pending paging message with TPSN equal to zero (0) and schedule a paging message with TPSN equal to one (1). Since the UE can have a stored TPSN equal to zero (0), the UE can know that this paging message (with TPSN equal to one (1)) is a new paging message initiation from CN/SGSN and the UE can respond to this new paging message to receive the DL packet.

[0066] In one aspect, the UE can check for the duplicate-check field upon receiving a paging message. If the TPSN in a duplicate-check field is the same as a previous paging TPSN stored at the UE, the UE can ignore the paging message and does not try to connect to the core network. If the UE has does not have a stored TPSN, the UE can consider the received paging message as a new paging message and can store the TPSN received in the paging message. If a UE is paged (e.g., in case of a new DL packet arrival), an SGSN can generate a new TPSN for that UE to be included in the paging message sent to the BSSs. The SGSN can store this newly assigned TPSN for the UE.

[0067] In one aspect, the CN/SGSN can keep the stored TPSN for at least a time period equal to both an extended discontinuous reception (eDRX) cycle and T_{delta} , where T_{delta} represents a time lapse between a generation of a paging message at the CN/SGSN and reception of the paging message by the BSSs. That is the T_{delta} can be a time period between generation at the CN/SGSN of the paging message delivered to the BSS and the reception at the BSS of the paging message.

[0068] If there is no new paging message for that UE for a time period of both the eDRX cycle and the T_{delta} (e.g., eDRX cycle + T_{delta}), the SGSN can clear any stored TPSN. If UE moves to a new RA (as can be identified at the CN/SGSN upon reception of non-periodic RAU message from device), the CN/SGSN can immediately clear any stored TPSN for the UE. Similarly, whenever the UE receives a paging in a cell with a new TPSN, the UE can store the TPSN for the period of an eDRX cycle. If UE does not receive a new paging for an eDRX cycle period, the UE can clear the stored TPSN.

[0069] Thus, FIG. 6 provides for efficient paging with extended discontinuous reception (eDRX) of multiple cells in a routing area. In one aspect, a short temporary paging sequence number (TPSN) per UE can be included in the paging message as a duplicate-check field. The UE can check the duplicate-check field of the paging message. If the TPSN is same as a previous paging TPSN stored at the UE, the UE can ignore the paging message and can ignore the request to connect to the core network. The ability to ignore duplicate paging messages at the UE can reduce power usage at the UE and also reduce network traffic.

[0070] Another example provides functionality 700 of a user equipment (UE) operable to identify a missed paging request message, as shown in the flow chart in FIG. 7. It should be noted that the descriptions and embodiments of FIG. 7 can be used, applied to, provide additional functionality, and/or used in conjunction with the embodiments described in FIGS. 1-6. For example, the functionality of the UE can be implemented as the method 700 or the functionality can be executed as instructions on a machine, where the instructions are included on at least one computer readable medium or one non-transitory machine readable storage medium. The one or more processors can be configured to receive at the UE a pending paging request and downlink (DL) packet notification included in a routing area update (RAU) accept message delivered by a core network (CN) when the UE fails to respond to a paging request message previously delivered by the CN to a plurality unsynchronized cells of a routing area (RA), as in block 710. The one or more processors can be configured to determine by the UE the RAU accept message includes the pending paging request and downlink (DL) packet notification, as in block 720. The one or more processors can be configured to receive a DL packet prior to entering a packet idle state, as in block 730.

[0071] Another example provides functionality 800 of a user equipment (UE) operable to identify duplicate reception of a paging message by a user equipment (UE), as shown in the flow chart in FIG. 8. It should be noted that the descriptions and embodiments of FIG. 8 can be used, applied to, provide additional functionality, and/or used in conjunction with the embodiments described in FIGS. 1-7. For example, the functionality of the UE can be implemented as the method 800 or the functionality can be executed as instructions on a machine, where the instructions are included on at least one computer readable medium or one non-transitory machine readable storage medium. The one or more processors can be configured to receive a paging message (e.g., a paging request message) having a duplicate paging message check field including a short temporary paging sequence number (TPSN) delivered by a core network (CN) to a plurality cells of a routing area (RA), as in block 810. The one or more processors can be configured to determine that the UE includes a stored TPSN of an alternative paging message previously delivered to the UE by the CN to the plurality cells of the RA, as in block 820. The one or more processors can be configured to determine that the TPSN matches the stored TPSN when the UE includes the stored TPSN, as in action 830. The one or more processors can be configured to ignore the paging message by the UE when the TPSN matches the alternative TPSN, as in block 840.

[0072] It should be noted that each of the following may be included in FIG. 8. In other words, each of the following may be included in each of the actions and/or in conjunction with one or more of the actions described in FIG. 8.

[0073] Another example provides functionality 900 of a user equipment (UE) operable to for achieving efficient paging with eDRX with a user equipment (UE), as shown in the flow chart in FIG. 9. It should be noted that the descriptions and embodiments of FIG. 9 can be used, applied to, provide additional functionality, and/or used in conjunction with the embodiments described in FIGS. 1-8. For example, the functionality of the UE can be implemented as the method 900 or the functionality can be executed as instructions on a machine, where the instructions are included on at least one computer readable medium or one non-transitory machine readable storage medium. The one or more processors can be configured to receive a first paging message having a duplicate paging message check field including a first short temporary paging sequence number (TPSN) delivered by a core network (CN) to a plurality cells of a routing area (RA), as in block 910. The one or more processors can be configured to receive a second paging message having a second TPSN in the duplicate paging message check field delivered by the CN to a plurality cells of a routing area (RA), as in block 920. The one or more processors can be configured to compare the first TPSN to the second TPSN, as in action 930. The one or more processors can be configured to ignore the second paging message by the UE when the second TPSN matches the first TPSN, as in action 940.

[0074] Another example provides functionality 100 of a base station system operable to provide efficient paging requests with extended discontinuous reception (eDRX) by a base station system with a user equipment (UE), as shown in the flow chart in FIG. 10. For example, the functionality of the BSS can be implemented as the method 1000 or the functionality can be executed as instructions on a machine, where the instructions are included on at least one computer readable medium or one non-transitory machine readable storage medium. The one or more processors can be configured to receive by the BSS a paging message and a short temporary paging sequence number (TPSN) delivered by a core network (CN) to a plurality cells of a routing area (RA), as in block 1010. The one or more processors can be include by the BSS the TPSN in the paging message received from the CN when the paging message is delivered by the CN, as in block 1020. The one or more processors can be configured to transmit the paging message having the duplicate paging message check field including the TPSN to the UE to allow the UE to identify duplicate reception of a paging request message, as in action 1030.

[0075] It should be noted that each of the following can be included in FIGs. 7-10, depending on system specifications, system design, capacity, and/or a user preference. In other words, each of the following may be included in each of the actions and/or in conjunction with one or more of the actions described in FIGs. 7-9. For example, one or more processors can be configured to issue a RAU message to contact the CN within an RAU time period and/or respond to the paging request message when the UE received the paging request message previously delivered by the CN in one of the plurality unsynchronized cells. In one aspect, the pending paging request and downlink (DL) packet notification can indicate to the UE that the UE has missed the paging request message previously delivered by the CN in one of the plurality unsynchronized cells and a DL packet is waiting for the UE. In one aspect, the one or more processors can be configured to wait to receive the DL packet for a predefined time period prior to entering the packet idle state.

[0076] In one aspect, the one or more processors can be configured to store for a time period the stored TPSN of the alternative paging message previously delivered to the UE, and/or clear the stored TPSN from the UE if the paging message is not received during the time period. In one aspect, the time period is equal to an extended discontinuous reception (eDRX) cycle.

[0077] In one aspect, the one or more processors can be configured to respond to the paging message when the TPSN in the duplicate paging message check field does not match the alternative TPSN of the alternative paging message previously delivered to the UE by the CN, respond to the paging message when the UE determines the TPSN in the duplicate paging message check field does not match the alternative TPSN of the alternative paging message previously delivered to the UE by the CN, wait to receive the DL packet for a predefined time period prior to entering the packet idle state, and/or clear the stored TPSN when the UE transfers from one of the plurality cells of the RA to an alternative one of the plurality cells of the RA. In one aspect, the TPSN can be a single bit consisting of either a zero (0) or a one (1)

[0078] In one aspect, the one or more processors can be configured to cancel the paging message that was transmitted to the UE and is currently pending when the base station system receives an alternative paging message having an alternative TPSN, and/or transfer the alternative paging message having an alternative TPSN when the paging message is canceled. The time period can be equal to an extended discontinuous reception (eDRX) cycle and T_{delta} , where T_{delta} can be a time period between generation at the CN of the paging message delivered to the base station system and the reception at the base station system of the paging message.

[0079] In one aspect, the one or more processors can be configured to cause the UE to determine that the second TPSN matches the first TPSN, and/or store for a time period the first TPSN. In one aspect, the time period can be equal to an extended discontinuous reception (eDRX) cycle.

[0080] In one aspect, the one or more processors can be configured to cause the UE to clear the first TPSN from the UE if the second paging message is not received during the time period, respond to the paging message when the TPSN in the duplicate paging message check field does not match the alternative TPSN of the alternative paging message previously delivered to the UE by the CN, respond to the paging message when the UE determines the TPSN in the duplicate paging message check field does not match the alternative TPSN of the alternative paging message previously delivered to the UE by the CN, wait to receive the DL packet for a predefined time period prior to entering the packet idle state, and/or clear the stored TPSN when the UE transfers from one of the plurality cells of the RA to an alternative one of the plurality cells of the RA. In one aspect, the TPSN is a single bit consisting of either a zero (0) or a one (1).

[0081] FIG. 11 provides an example illustration of the wireless device 1100, such as a user equipment (UE), a mobile station (MS), a mobile wireless device, a mobile communication device, a tablet, a handset, or other type of wireless device. In one aspect, the wireless device can include at least one of an antenna, a touch sensitive display screen, a speaker, a microphone, a graphics processor, a baseband processor, an application processor, internal memory, a non-volatile memory port, and combinations thereof.

[0082] The wireless device can include one or more antennas configured to communicate with a node or transmission station, such as a base station (BS), an evolved Node B (eNB), a baseband unit (BBU), a remote radio head (RRH), a remote radio equipment (RRE), a relay station (RS), a radio equipment (RE), a remote radio unit (RRU), a central processing module (CPM), or other type of wireless wide area network (WWAN) access point. The wireless device can be configured to communicate using at least one wireless communication standard including 3GPP LTE, WiMAX, High Speed Packet Access (HSPA), Bluetooth, and WiFi. The wireless device can communicate using separate antennas for each wireless communication standard or shared antennas for multiple wireless communication standards. The wireless device can communicate in a wireless local area network (WLAN), a wireless personal area network (WPAN), and/or a WWAN. The mobile device can include a storage medium. In one aspect, the storage medium can be associated with and/or communication with the application processor, the graphics processor, the display, the non-volatile memory port, and/or internal memory. In one aspect, the application processor and graphics processor are storage mediums.

[0083] FIG. 12 provides an example illustration of a user equipment (UE) device 1200, such as a wireless device, a mobile station (MS), a mobile wireless device, a mobile communication device, a tablet, a handset, or other type of wireless device. The UE device 1200 can include one or more antennas configured to communicate with a node or transmission station, such as a base station (BS), an evolved Node B (eNB), a baseband unit (BBU), a remote radio head (RRH), a remote radio equipment (RRE), a relay station (RS), a radio equipment (RE), a remote radio unit (RRU), a central processing module (CPM), or other type of wireless wide area network (WWAN) access point. The UE device 1200 can be configured to communicate using at least one wireless communication standard including 3GPP LTE, WiMAX, High Speed Packet Access (HSPA), Bluetooth, and WiFi. The UE device 1200 can communicate using separate antennas for each wireless communication standard or shared antennas for multiple wireless communication standards. The UE device 1200 can communicate in a wireless local area network (WLAN), a wireless personal area network (WPAN), and/or a WWAN.

[0084] In some embodiments, the UE device 1200 may include application circuitry 1202, baseband circuitry 1204, Radio Frequency (RF) circuitry 1206, front-end module (FEM) circuitry 1208 and one or more antennas 1210, coupled together at least as shown.

[0085] The application circuitry 1202 may include one or more application processors. For example, the application circuitry 1202 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 a storage medium 1212, and may be configured to execute instructions stored in the storage medium 1212 to enable various applications and/or operating systems to run on the system.

[0086] The baseband circuitry 1204 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 1204 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 1206 and to generate baseband signals for a transmit signal path of the RF circuitry 1206. Baseband processing circuity 1204 may interface with the application circuitry 1202 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 1206. For example, in some embodiments, the baseband circuitry 1204 may include a second generation (2G) baseband processor 1204a, third generation (3G) baseband processor 1204b, fourth generation (4G) baseband processor 1204c, and/or other baseband processor(s) 1204d for other existing generations, generations in development or to be developed in the future (e.g., fifth generation (5G), 6G, etc.). The baseband circuitry 1204 (e.g., one or more of baseband processors 1204a-d) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 1206. 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 1204 may include Fast-Fourier Transform (FFT), precoding, and/or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 1204 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.

[0087] In some embodiments, the baseband circuitry 1204 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) 1204e of the baseband circuitry 1204 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) 1204f. The audio DSP(s) 104f may be 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 1204 and the application circuitry 1202 may be implemented together such as, for example, on a system on a chip (SOC).

[0088] In some embodiments, the baseband circuitry 1204 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 1204 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 1204 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

[0089] The RF circuitry 1206 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 1206 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 1206 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 1208 and provide baseband signals to the baseband circuitry 1204. RF circuitry 1206 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 1204 and provide RF output signals to the FEM circuitry 1208 for transmission.

[0090] In some embodiments, the RF circuitry 1206 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 1206 may include mixer circuitry 1206a, amplifier circuitry 1206b and filter circuitry 1206c. The transmit signal path of the RF circuitry 1206 may include filter circuitry 1206c and mixer circuitry 1206a. RF circuitry 1206 may also include synthesizer circuitry 1206d for synthesizing a frequency for use by the mixer circuitry 1206a of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 1206a of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 1208 based on the synthesized frequency provided by synthesizer circuitry 1206d. The amplifier circuitry 1206b may be configured to amplify the down-converted signals and the filter circuitry 1206c 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 1204 for further processing. In some embodiments, the output baseband signals may be zero-frequency baseband signals, although this can be optional. In some embodiments, mixer circuitry 1206a of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[0091] In some embodiments, the mixer circuitry 1206a of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 1206d to generate RF output signals for the FEM circuitry 1208. The baseband signals may be provided by the baseband circuitry 1204 and may be filtered by filter circuitry 1206c. The filter circuitry 1206c may include a low-pass filter (LPF), although the scope of the embodiments is not limited in this respect.

[0092] In some embodiments, the mixer circuitry 1206a of the receive signal path and the mixer circuitry 1206a of the transmit signal path may include two or more mixers and may be arranged for quadrature down-conversion and/or up-conversion respectively. In some embodiments, the mixer circuitry 1206a of the receive signal path and the mixer circuitry 1206a 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 1206a of the receive signal path and the mixer circuitry 1206a may be arranged for direct down-conversion and/or direct up-conversion, respectively. In some embodiments, the mixer circuitry 1206a of the receive signal path and the mixer circuitry 1206a of the transmit signal path may be configured for super-heterodyne operation.

[0093] 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 1206 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 1204 may include a digital baseband interface to communicate with the RF circuitry 1206.

[0094] 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.

[0095] In some embodiments, the synthesizer circuitry 1206d 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 1206d may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[0096] The synthesizer circuitry 1206d may be configured to synthesize an output frequency for use by the mixer circuitry 1206a of the RF circuitry 1206 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 1206d may be a fractional N/N+1 synthesizer.

[0097] In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although this can be optional. Divider control input may be provided by either the baseband circuitry 1204 or the applications processor 1202 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 1202.

[0098] Synthesizer circuitry 1206d of the RF circuitry 1206 may include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider may be a dual modulus divider (DMD) and the phase accumulator may be a digital phase accumulator (DPA). In some embodiments, the DMD may be configured to divide the input signal by either N or N+1 (e.g., based on a carry out) to provide a fractional division ratio. In some example embodiments, the DLL may include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-flop. In these embodiments, the delay elements may be configured to break a VCO period up into Nd equal packets of phase, where Nd is the number of delay elements in the delay line. In this way, the DLL provides negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

[0099] In some embodiments, synthesizer circuitry 1206d may be configured to generate a carrier frequency as the output frequency, while in other embodiments, the output frequency may be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency) and used in conjunction with quadrature generator and divider circuitry to generate multiple signals at the carrier frequency with multiple different phases with respect to each other. In some embodiments, the output frequency may be a LO frequency (fLO). In some embodiments, the RF circuitry 1206 may include an IQ/polar converter.

[00100] FEM circuitry 1208 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 1210, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 1206 for further processing. FEM circuitry 1208 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 1206 for transmission by one or more of the one or more antennas 1210.

[00101] In some embodiments, the FEM circuitry 1208 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 1206). The transmit signal path of the FEM circuitry 1208 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 1206), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 1210.

[00102] In some embodiments, the UE device 1200 can include additional elements such as, for example, memory/storage, display, camera, sensor, and/or input/output (I/O) interface.

[00103] FIG. 13 illustrates a diagram 1300 of a node 1310 (e.g., eNB and/or a base station system) and wireless device (e.g., UE) in accordance with an example. The node can include a base station (BS), a Node B (NB), an evolved Node B (eNB), a baseband unit (BBU), a remote radio head (RRH), a remote radio equipment (RRE), a remote radio unit (RRU), or a central processing module (CPM). In one aspect, the node can be a base station system. The node 1310 can include a node device 1312. The node device 1312 or the node 1310 can be configured to communicate with the wireless device 1320. The node device 1312 can be configured to implement the technology described. The node device 1312 can include a processing module 1314 and a transceiver module 1316. In one aspect, the node device 1312 can include the transceiver module 1316 and the processing

module 1314 forming a circuitry 1318 for the node 1310. In one aspect, the transceiver module 1316 and the processing module 1314 can form a circuitry of the node device 1312. The processing module 1314 can include one or more processors and memory. In one embodiment, the processing module 1322 can include one or more application processors. The transceiver module 1316 can include a transceiver and one or more processors and memory. In one embodiment, the transceiver module 1316 can include a baseband processor.

[00104] The wireless device 1320 can include a transceiver module 1324 and a processing module 1322. The processing module 1322 can include one or more processors and memory. In one embodiment, the processing module 1322 can include one or more application processors. The transceiver module 1324 can include a transceiver and one or more processors and memory. In one embodiment, the transceiver module 1324 can include a baseband processor. The wireless device 1320 can be configured to implement the technology described. The node 1310 and the wireless devices 1320 can also include one or more storage mediums, such as the transceiver module 1316, 1324 and/or the processing module 1314, 1322.

Examples

[00105] The following examples pertain to specific technology embodiments and point out specific features, elements, or steps that can be used or otherwise combined in achieving such embodiments.

[00106] Example 1 includes an apparatus of a user equipment (UE) operable to identify a missed paging request message, the apparatus comprising one or more processors and memory configured to: process at the UE a pending paging request and downlink (DL) packet notification included in a routing area update (RAU) accept message delivered by a core network (CN) when the UE fails to respond to a paging request message previously delivered by the CN to a plurality unsynchronized cells of a routing area (RA); determine by the UE the RAU accept message includes the pending paging request and downlink (DL) packet notification; and process a DL packet prior to entering a packet idle state.

[00107] Example 2 includes the apparatus of Example 1, further configured to issue a RAU message to contact the CN within an RAU time period.

[00108] Example 3 includes the apparatus of Example 1 or 2, further configured to respond to the paging request message when the UE received the paging request message previously delivered by the CN in one of the plurality unsynchronized cells.

[00109] Example 4 includes the apparatus of Example 1, wherein the pending paging request and downlink (DL) packet notification indicates to the UE that the UE has missed the paging request message previously delivered by the CN in one of the plurality unsynchronized cells and a DL packet is waiting for the UE.

[00110] Example 5 includes the apparatus of Example 4, further configured to wait to receive the DL packet for a predefined time period prior to entering the packet idle state.

[00111] Example 6 includes an apparatus of a user equipment (UE) operable to identify duplicate reception of a paging request message, the apparatus comprising one or more processors and memory configured to: process a paging message having a duplicate paging message check field including a short temporary paging sequence number (TPSN) delivered by a core network (CN) to a plurality cells of a routing area (RA); determine that the UE includes a stored TPSN of an alternative paging message previously delivered to the UE by the CN to the plurality cells of the RA; determine that the TPSN matches the stored TPSN when the UE includes the stored TPSN; and ignore the paging message by the UE when the TPSN matches the alternative TPSN.

[00112] Example 7 includes the apparatus of Example 6, further configured to store for a time period the stored TPSN of the alternative paging message previously delivered to the UE.

[00113] Example 8 includes the apparatus of Example 7, further configured to clear the stored TPSN from the UE if the paging message is not received during the time period.

[00114] Example 9 includes the apparatus of Example 6 or 7, wherein the time period is equal to an extended discontinuous reception (eDRX) cycle.

[00115] Example 10 includes the apparatus of Example 6, further configured to respond to the paging message when the TPSN in the duplicate paging message check field does not match the alternative TPSN of the alternative paging message previously delivered to the UE by the CN.

[00116] Example 11 includes the apparatus of Example 6 or 10, further configured to

respond to the paging message when the UE determines the TPSN in the duplicate paging message check field does not match the alternative TPSN of the alternative paging message previously delivered to the UE by the CN.

[00117] Example 12 includes the apparatus of Example 6, further configured to wait to receive the DL packet for a predefined time period prior to entering the packet idle state.

[00118] Example 13 includes the apparatus of Example 6 or 12, further configured to clear the stored TPSN when the UE transfers from one of the plurality cells of the RA to an alternative one of the plurality cells of the RA.

[00119] Example 14 includes the apparatus of Example 6, wherein the TPSN is a single bit consisting of either a zero (0) or a one (1).

[00120] Example 15 includes a base station system operable to provide efficient paging requests with extended discontinuous reception (eDRX) with a user equipment (UE), the base station system, having a base station device, comprising one or more processors and memory configured to: process a paging message and a short temporary paging sequence number (TPSN) delivered by a core network (CN) to a plurality cells of a routing area (RA); include the TPSN in the paging message received from the CN when the paging message is delivered by the CN; and process, for transmission, the paging message having the duplicate paging message check field including the TPSN to the UE to allow the UE to identify duplicate reception of a paging request message.

[00121] Example 16 includes the base station system of example 15, further configured to: cancel the paging message that was transmitted to the UE and is currently pending when the base station system receives an alternative paging message having an alternative TPSN; or cancel a pending paging message when the TPSN equals zero (0) and schedule the paging message when the TPSN equals one (1).

[00122] Example 17 includes the base station system of example 16, further configured transfer the alternative paging message having an alternative TPSN when the paging message is canceled.

[00123] Example 18 includes the base station system of example 15 or 16, wherein the time period is equal to an extended discontinuous reception (eDRX) cycle and T_{delta}, where T_{delta} is a time period between generation at the CN of the paging message

delivered to the base station system and the reception at the base station system of the paging message.

[00124] Example 19 includes at least one computer-readable storage medium, on a user equipment (UE) having at least one processor, comprising instructions for identifying duplicate reception of a paging request message, the instructions, when executed, cause the UE to: process a first paging message having a duplicate paging message check field including a first short temporary paging sequence number (TPSN) delivered by a core network (CN) to a plurality cells of a routing area (RA); process a second paging message having a second TPSN in the duplicate paging message check field delivered by the CN to a plurality cells of a routing area (RA); compare the first TPSN to the second TPSN; and ignore the second paging message by the UE when the second TPSN matches the first TPSN.

[00125] Example 20 includes the computer-readable storage medium of example 19, comprising further instructions that, when executed, cause the UE to determine that the second TPSN matches the first TPSN.

[00126] Example 21 includes the computer-readable storage medium of example 19 or 20, comprising further instructions that, when executed, cause the UE to store for a time period the first TPSN.

[00127] Example 22 includes the computer-readable storage medium of example 20 or 21, wherein the time period is equal to an extended discontinuous reception (eDRX) cycle.

[00128] Example 23 includes the computer-readable storage medium of example 20, comprising further instructions that, when executed, cause the UE to clear the first TPSN from the UE if the second paging message is not received during the time period.

[00129] Example 24 includes the computer-readable storage medium of example 19 or 23, comprising further instructions that, when executed, cause the UE to respond to the paging message when the TPSN in the duplicate paging message check field does not match the alternative TPSN of the alternative paging message previously delivered to the UE by the CN.

[00130] Example 25 includes the computer-readable storage medium of example 19, comprising further instructions that, when executed, cause the UE to respond to the

paging message when the UE determines the TPSN in the duplicate paging message check field does not match the alternative TPSN of the alternative paging message previously delivered to the UE by the CN.

[00131] Example 26 includes the computer-readable storage medium of example 19 or 25, comprising further instructions that, when executed, cause the UE to wait to receive the DL packet for a predefined time period prior to entering the packet idle state.

[00132] Example 27 includes the computer-readable storage medium of example 19, comprising further instructions that, when executed, cause the UE to clear the stored TPSN when the UE transfers from one of the plurality cells of the RA to an alternative one of the plurality cells of the RA.

[00133] Example 28 includes the computer-readable storage medium of example 19 or 27, wherein the TPSN is a single bit consisting of either a zero (0) or a one (1).

[00134] Example 29 includes an apparatus of a user equipment (UE) operable to identify a missed paging request message, the apparatus comprising one or more processors and memory configured to: process at the UE a pending paging request and downlink (DL) packet notification included in a routing area update (RAU) accept message delivered by a core network (CN) when the UE fails to respond to a paging request message previously delivered by the CN to a plurality unsynchronized cells of a routing area (RA); determine by the UE the RAU accept message includes the pending paging request and downlink (DL) packet notification; and receive a DL packet prior to entering a packet idle state.

[00135] Example 30 includes the apparatus of Example 29, further configured to issue a RAU message to contact the CN within an RAU time period.

[00136] Example 31 includes the apparatus of Example 29, further configured to respond to the paging request message when the UE received the paging request message previously delivered by the CN in one of the plurality unsynchronized cells.

[00137] Example 32 includes the apparatus of Example 29, wherein the pending paging request and downlink (DL) packet notification indicates to the UE that the UE has missed the paging request message previously delivered by the CN in one of the plurality unsynchronized cells and a DL packet is waiting for the UE.

[00138] Example 33 includes the apparatus of Example 32, further configured to wait to

receive the DL packet for a predefined time period prior to entering the packet idle state.

[00139] Example 34 includes an apparatus of a user equipment (UE) operable to identify duplicate reception of a paging request message, the apparatus comprising one or more processors and memory configured to: process a paging message having a duplicate paging message check field including a short temporary paging sequence number (TPSN) delivered by a core network (CN) to a plurality cells of a routing area (RA); determine that the UE includes a stored TPSN of an alternative paging message previously delivered to the UE by the CN to the plurality cells of the RA; determine that the TPSN matches the stored TPSN when the UE includes the stored TPSN; and ignore the paging message by the UE when the TPSN matches the alternative TPSN.

[00140] Example 35 includes the apparatus of Example 34, further configured to store for a time period the stored TPSN of the alternative paging message previously delivered to the UE.

[00141] Example 36 includes the apparatus of Example 35, further configured to clear the stored TPSN from the UE if the paging message is not received during the time period.

[00142] Example 37 includes the apparatus of Example 35, wherein the time period is equal to an extended discontinuous reception (eDRX) cycle.

[00143] Example 38 includes the apparatus of Example 34, further configured to respond to the paging message when the TPSN in the duplicate paging message check field does not match the alternative TPSN of the alternative paging message previously delivered to the UE by the CN.

[00144] Example 39 includes the apparatus of Example 34, further configured to respond to the paging message when the UE determines the TPSN in the duplicate paging message check field does not match the alternative TPSN of the alternative paging message previously delivered to the UE by the CN.

[00145] Example 40 includes the apparatus of Example 34, further configured to wait to receive the DL packet for a predefined time period prior to entering the packet idle state.

[00146] Example 41 includes the apparatus of Example 34, further configured to clear the stored TPSN when the UE transfers from one of the plurality cells of the RA to an alternative one of the plurality cells of the RA.

[00147] Example 42 includes the apparatus of Example 34, wherein the TPSN is a single bit consisting of either a zero (0) or a one (1).

[00148] Example 43 includes an base station system operable to provide efficient paging requests with extended discontinuous reception (eDRX) with a user equipment (UE), the base station system, having a base station device, comprising one or more processors and memory configured to: process a paging message and a short temporary paging sequence number (TPSN) delivered by a core network (CN) to a plurality cells of a routing area (RA); include the TPSN in the paging message received from the CN when the paging message is delivered by the CN; and transmit the paging message having the duplicate paging message check field including the TPSN to the UE to allow the UE to identify duplicate reception of a paging request message.

[00149] Example 44 includes the base station system of example 43, further configured to: cancel the paging message that was transmitted to the UE and is currently pending when the base station system receives an alternative paging message having an alternative TPSN; or cancel a pending paging message when the TPSN equals zero (0) and schedule the paging message when the TPSN equals one (1).

[00150] Example 45 includes the base station system of example 44, further configured transfer the alternative paging message having an alternative TPSN when the paging message is canceled.

[00151] Example 46 includes the base station system of example 43, wherein the time period is equal to an extended discontinuous reception (eDRX) cycle and T_{delta} , where T_{delta} is a time period between generation at the CN of the paging message delivered to the base station system and the reception at the base station system of the paging message.

[00152] Example 47 includes at least one non-transitory computer-readable storage medium, on a user equipment (UE) having at least one processor, comprising instructions for identifying duplicate reception of a paging request message, the instructions, when executed, cause the UE to: process a first paging message having a duplicate paging message check field including a first short temporary paging sequence number (TPSN) delivered by a core network (CN) to a plurality cells of a routing area (RA); receive a second paging message having a second TPSN in the duplicate paging message check

field delivered by the CN to a plurality cells of a routing area (RA); compare the first TPSN to the second TPSN; and ignore the second paging message by the UE when the second TPSN matches the first TPSN.

[00153] Example 48 includes the computer-readable storage medium of example 47, comprising further instructions that, when executed, cause the UE to determine that the second TPSN matches the first TPSN.

[00154] Example 49 includes the computer-readable storage medium of example 48, comprising further instructions that, when executed, cause the UE to store for a time period the first TPSN.

[00155] Example 50 includes the computer-readable storage medium of example 47, wherein the time period is equal to an extended discontinuous reception (eDRX) cycle.

[00156] Example 51 includes the computer-readable storage medium of example 47, comprising further instructions that, when executed, cause the UE to clear the first TPSN from the UE if the second paging message is not received during the time period.

[00157] Example 52 includes the computer-readable storage medium of example 47, comprising further instructions that, when executed, cause the UE to respond to the paging message when the TPSN in the duplicate paging message check field does not match the alternative TPSN of the alternative paging message previously delivered to the UE by the CN.

[00158] Example 53 includes the computer-readable storage medium of example 47, comprising further instructions that, when executed, cause the UE to respond to the paging message when the UE determines the TPSN in the duplicate paging message check field does not match the alternative TPSN of the alternative paging message previously delivered to the UE by the CN.

[00159] Example 54 includes the computer-readable storage medium of example 47, comprising further instructions that, when executed, cause the UE to wait to receive the DL packet for a predefined time period prior to entering the packet idle state.

[00160] Example 55 includes the computer-readable storage medium of example 47, comprising further instructions that, when executed, cause the UE to clear the stored TPSN when the UE transfers from one of the plurality cells of the RA to an alternative one of the plurality cells of the RA.

[00161] Example 56 includes the computer-readable storage medium of example 47, wherein the TPSN is a single bit consisting of either a zero (0) or a one (1).

[00162] Example 57 includes an apparatus of a user equipment (UE) operable to identify a missed paging request message, the apparatus comprising one or more processors and memory configured to: process, at the UE, a pending paging request and downlink (DL) packet notification included in a routing area update (RAU) accept message delivered by a core network (CN) when the UE fails to respond to a paging request message previously delivered by the CN to a plurality unsynchronized cells of a routing area (RA); determine by the UE the RAU accept message includes the pending paging request and downlink (DL) packet notification; and receive a DL packet prior to entering a packet idle state.

[00163] Example 58 includes the apparatus of Example 57, further configured to: issue a RAU message to contact the CN within an RAU time period; or respond to the paging request message when the UE received the paging request message previously delivered by the CN in one of the plurality unsynchronized cells, wherein the pending paging request and downlink (DL) packet notification indicates to the UE that the UE has missed the paging request message previously delivered by the CN in one of the plurality unsynchronized cells and a DL packet is waiting for the UE.

[00164] Example 59 includes the apparatus of Example 57 or 58, further configured to wait to receive the DL packet for a predefined time period prior to entering the packet idle state.

[00165] Example 60 includes an apparatus of a user equipment (UE) operable to identify duplicate reception of a paging request message, the apparatus comprising one or more processors and memory configured to: receive a paging message having a duplicate paging message check field including a short temporary paging sequence number (TPSN) delivered by a core network (CN) to a plurality cells of a routing area (RA); determine that the UE includes a stored TPSN of an alternative paging message previously delivered to the UE by the CN to the plurality cells of the RA; determine that the TPSN matches the stored TPSN when the UE includes the stored TPSN; and ignore the paging message by the UE when the TPSN matches the alternative TPSN.

[00166] Example 61 includes the apparatus of Example 60, further configured to: store for a time period the stored TPSN of the alternative paging message previously delivered to the UE, wherein the time period is equal to an extended discontinuous reception (eDRX) cycle; clear the stored TPSN from the UE if the paging message is not received during the time period; or respond to the paging message when the TPSN in the duplicate paging message check field does not match the alternative TPSN of the alternative paging message previously delivered to the UE by the CN.

[00167] Example 62 includes the subject matter of Example 60 or any of the subject matter described herein, further configured to respond to the paging message when the UE determines the TPSN in the duplicate paging message check field does not match the alternative TPSN of the alternative paging message previously delivered to the UE by the CN.

[00168] Example 63 includes the subject matter of Example 60 or any of the subject matter described herein, further configured to: wait to receive the DL packet for a predefined time period prior to entering the packet idle state; or clear the stored TPSN when the UE transfers from one of the plurality cells of the RA to an alternative one of the plurality cells of the RA, wherein the TPSN is a single bit consisting of either a zero (0) or a one (1).

[00169] Example 64 includes a base station system operable to provide efficient paging requests with extended discontinuous reception (eDRX) with a user equipment (UE), the base station system, having a base station device, comprising one or more processors and memory configured to: process a paging message and a short temporary paging sequence number (TPSN) delivered by a core network (CN) to a plurality cells of a routing area (RA); include the TPSN in the paging message received from the CN when the paging message is delivered by the CN; and transmit the paging message having the duplicate paging message check field including the TPSN to the UE to allow the UE to identify duplicate reception of a paging request message.

[00170] Example 65 includes the base station system of example 64, further configured to: cancel the paging message that was transmitted to the UE and is currently pending when the base station system receives an alternative paging message having an alternative TPSN; cancel a pending paging message when the TPSN equals zero (0) and schedule the

paging message when the TPSN equals one (1); or transfer the alternative paging message having an alternative TPSN when the paging message is canceled.

[00171] Example 66 includes at least one non-transitory computer-readable storage medium, on a user equipment (UE) having at least one processor, comprising instructions for identifying duplicate reception of a paging request message, the instructions, when executed, cause the UE to: process a first paging message having a duplicate paging message check field including a first short temporary paging sequence number (TPSN) delivered by a core network (CN) to a plurality cells of a routing area (RA); receive a second paging message having a second TPSN in the duplicate paging message check field delivered by the CN to a plurality cells of a routing area (RA): compare the first TPSN to the second TPSN; and ignore the second paging message by the UE when the second TPSN matches the first TPSN.

[00172] Example 67 includes the computer-readable storage medium of example 66, comprising further instructions that, when executed, cause the UE to: determine that the second TPSN matches the first TPSN; or store for a time period the first TPSN, wherein the time period is equal to an extended discontinuous reception (eDRX) cycle and T_{delta}, where T_{delta} is a time period between generation at the CN of the paging message delivered to the base station system and the reception at the base station system of the paging message.

[00173] Example 68 includes computer-readable storage medium of claim 66 or 67, comprising further instructions that, when executed, cause the UE to: clear the first TPSN from the UE if the second paging message is not received during the time period; or respond to the paging message when the TPSN in the duplicate paging message check field does not match the alternative TPSN of the alternative paging message previously delivered to the UE by the CN.

[00174] Example 69 includes the subject matter of Example 66 or any of the subject matter described herein, comprising further instructions that, when executed, cause the UE to wait to receive the DL packet for a predefined time period prior to entering the packet idle state.

[00175] Example 70 includes the subject matter of Example 60 or any of the subject matter described herein, comprising further instructions that, when executed, cause the UE to

clear the stored TPSN when the UE transfers from one of the plurality cells of the RA to an alternative one of the plurality cells of the RA.

[00176] Example 71 includes the subject matter of Example 60 or any of the subject matter described herein, wherein the TPSN is a single bit consisting of either a zero (0) or a one (1).

[00177] Example 72 includes a device for identifying duplicate reception of a paging request message, the device comprising: means for processing a first paging message having a duplicate paging message check field including a first short temporary paging sequence number (TPSN) delivered by a core network (CN) to a plurality cells of a routing area (RA); means for processing a second paging message having a second TPSN in the duplicate paging message check field delivered by the CN to a plurality cells of a routing area (RA); means for comparing the first TPSN to the second TPSN; and means for ignoring the second paging message by the UE when the second TPSN matches the first TPSN.

[00178] Example 73 includes device of claim 72, further comprising: means for determining that the second TPSN matches the first TPSN; or means for storing for a time period the first TPSN, wherein the time period is equal to an extended discontinuous reception (eDRX) cycle and T_{delta} , where T_{delta} is a time period between generation at the CN of the paging message delivered to the base station system and the reception at the base station system of the paging message.

[00179] Example 74 includes the device of claim 72, further comprising: means for clearing the first TPSN from the UE if the second paging message is not received during the time period; or means for responding to the paging message when the TPSN in the duplicate paging message check field does not match the alternative TPSN of the alternative paging message previously delivered to the UE by the CN.

[00180] Various techniques, or certain aspects or portions thereof, may take the form of program code (i.e., instructions) embodied in tangible media, such as floppy diskettes, compact disc-read-only memory (CD-ROMs), hard drives, non-transitory computer readable storage medium, or any other machine-readable storage medium wherein, when the program code is loaded into and executed by a machine, such as a computer, the machine becomes an apparatus for practicing the various techniques. Circuitry can include hardware, firmware, program code, executable code, computer instructions, and/or software. A non-transitory computer readable storage medium can be a computer readable storage medium that does not include signal. In the case of program code execution on programmable computers, the computing device may include a processor, a storage medium readable by the processor (including volatile and non-volatile memory and/or storage elements), at least one input device, and at least one output device. The volatile and non-volatile memory and/or storage elements may be a random-access memory (RAM), erasable programmable read only memory (EPROM), flash drive, optical drive, magnetic hard drive, solid state drive, or other medium for storing electronic data. The node and wireless device may also include a transceiver module (i.e., transceiver), a counter module (i.e., counter), a processing module (i.e., processor), and/or a clock module (i.e., clock) or timer module (i.e., timer). One or more programs that may implement or utilize the various techniques described herein may use an application programming interface (API), reusable controls, and the like. Such programs may be implemented in a high level procedural or object oriented programming language to communicate with a computer system. However, the program(s) may be implemented in assembly or machine language, if desired. In any case, the language may be a compiled or interpreted language, and combined with hardware implementations.

[00181] As used herein, the term processor can include general purpose processors, specialized processors such as VLSI, FPGAs, or other types of specialized processors, as well as base band processors used in transceivers to send, receive, and process wireless communications.

[00182] It should be understood that many of the functional units described in this specification have been labeled as modules, in order to more particularly emphasize their implementation independence. For example, a module may be implemented as a hardware circuit comprising custom very-large-scale integration (VLSI) circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. A module may also be implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices or the like.

[00183] Modules may also be implemented in software for execution by various types of

processors. An identified module of executable code may, for instance, comprise one or more physical or logical blocks of computer instructions, which may, for instance, be organized as an object, procedure, or function. Nevertheless, the executables of an identified module may not be physically located together, but may comprise disparate instructions stored in different locations which, when joined logically together, comprise the module and achieve the stated purpose for the module.

[00184] Indeed, a module of executable code may be a single instruction, or many instructions, and may even be distributed over several different code segments, among different programs, and across several memory devices. Similarly, operational data may be identified and illustrated herein within modules, and may be embodied in any suitable form and organized within any suitable type of data structure. The operational data may be collected as a single data set, or may be distributed over different locations including over different storage devices, and may exist, at least partially, merely as electronic signals on a system or network. The modules may be passive or active, including agents operable to perform desired functions.

[00185] As used herein, the term "circuitry" can 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 aspects, the circuitry can be implemented in, or functions associated with the circuitry can be implemented by, one or more software or firmware modules . In some aspects, circuitry can include logic, at least partially operable in hardware.

[00186] Aspects described herein can be implemented into a system using any suitably configured hardware and/or software.

[00187] As used herein, the term processor can include general purpose processors, specialized processors such as VLSI, FPGAs, or other types of specialized processors, as well as base band processors used in transceivers to send, receive, and process wireless communications.

[00188] It should be understood that many of the functional units described in this specification have been labeled as modules, in order to more particularly emphasize their implementation independence. For example, a module can be implemented as a hardware circuit comprising custom very-large-scale integration (VLSI) circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. A module can also be implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices or the like.

[00189] Modules can also be implemented in software for execution by various types of processors. An identified module of executable code can, for instance, comprise one or more physical or logical blocks of computer instructions, which can, for instance, be organized as an object, procedure, or function. Nevertheless, the executables of an identified module may not be physically located together, but can comprise disparate instructions stored in different locations which, when joined logically together, comprise the module and achieve the stated purpose for the module.

[00190] Indeed, a module of executable code can be a single instruction, or many instructions, and can even be distributed over several different code segments, among different programs, and across several memory devices. Similarly, operational data can be identified and illustrated herein within modules, and can be embodied in any suitable form and organized within any suitable type of data structure. The operational data can be collected as a single data set, or can be distributed over different locations including over different storage devices, and can exist, at least partially, merely as electronic signals on a system or network. The modules can be passive or active, including agents operable to perform desired functions.

[00191] Reference throughout this specification to "an example" or “exemplary” means that a particular feature, structure, or characteristic described in connection with the example is included in at least one embodiment of the present technology. Thus, appearances of the phrases "in an example" or the word “exemplary” in various places throughout this specification are not necessarily all referring to the same embodiment.

[00192] As used herein, a plurality of items, structural elements, compositional elements, and/or materials can be presented in a common list for convenience. However, these lists should be construed as though each member of the list is individually identified as a separate and unique member. Thus, no individual member of such list should be construed as a de facto equivalent of any other member of the same list solely based on their presentation in a common group without indications to the contrary. In addition, various embodiments and example of the present technology can be referred to herein along with alternatives for the various components thereof. It is understood that such embodiments, examples, and alternatives are not to be construed as defacto equivalents of one another, but are to be considered as separate and autonomous representations of the present technology.

[00193] Furthermore, the described features, structures, or characteristics can be combined in any suitable manner in one or more embodiments. In the following description, numerous specific details are provided, such as examples of layouts, distances, network examples, etc., to provide a thorough understanding of embodiments of the technology. One skilled in the relevant art can recognize, however, that the technology can be practiced without one or more of the specific details, or with other methods, components, layouts, etc. In other instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of the technology.

[00194] While the forgoing examples are illustrative of the principles of the present technology in one or more particular applications, it can be apparent to those of ordinary skill in the art that numerous modifications in form, usage and details of implementation can be made without the exercise of inventive faculty, and without departing from the principles and concepts of the technology. Accordingly, it is not intended that the technology be limited, except as by the claims set forth below.

CLAIMS

What is claimed is:

1. An apparatus of a user equipment (UE) operable to identify a missed paging request message, the apparatus comprising one or more processors and memory configured to:

process at the UE a pending paging request and downlink (DL) packet notification included in a routing area update (RAU) accept message delivered by a core network (CN) when the UE fails to respond to a paging request message previously delivered by the CN to a plurality unsynchronized cells of a routing area (RA);

determine by the UE the RAU accept message includes the pending paging request and downlink (DL) packet notification; and

process a DL packet, received from an eNodeB, prior to entering a packet idle state.

2. The apparatus of claim 1, further configured to issue a RAU message to contact the CN within an RAU time period.

3. The apparatus of claim 1 or 2, further configured to respond to the paging request message when the UE received the paging request message previously delivered by the CN in one of the plurality unsynchronized cells.

4. The apparatus of claim 1, wherein the pending paging request and downlink (DL) packet notification indicates to the UE that the UE has missed the paging request message previously delivered by the CN in one of the plurality unsynchronized cells and a DL packet is waiting for the UE.

5. The apparatus of claim 4, further configured to wait to receive the DL packet for a predefined time period prior to entering the packet idle state.

6. An apparatus of a user equipment (UE) operable to identify duplicate reception of a paging request message, the apparatus comprising one or more processors and memory configured to:

process a paging message having a duplicate paging message check field including a short temporary paging sequence number (TPSN) delivered by a core network (CN) to a plurality cells of a routing area (RA);

determine that the UE includes a stored TPSN of an alternative paging message previously delivered to the UE by the CN to the plurality cells of the RA;

determine that the TPSN matches the stored TPSN when the UE includes the stored TPSN; and

ignore the paging message by the UE when the TPSN matches the alternative TPSN.

7. The apparatus of claim 6, further configured to store for a time period the stored TPSN of the alternative paging message previously delivered to the UE.

8. The apparatus of claim 7, further configured to clear the stored TPSN from the UE if the paging message is not received during the time period.

9. The apparatus of claim 6 or 7, wherein the time period is equal to an extended discontinuous reception (eDRX) cycle.

10.The apparatus of claim 6, further configured to respond to the paging message when the TPSN in the duplicate paging message check field does not match the alternative TPSN of the alternative paging message previously delivered to the UE by the CN.

11.The apparatus of claim 6 or 10, further configured to respond to the paging message when the UE determines the TPSN in the duplicate paging message check field does not match the alternative TPSN of the alternative paging message previously delivered to the UE by the CN.

12.The apparatus of claim 6, further configured to wait to receive the DL packet for a predefined time period prior to entering the packet idle state.

13.The apparatus of claim 6 or 12, further configured to clear the stored TPSN when the UE transfers from one of the plurality cells of the RA to an alternative one of the plurality cells of the RA.

14.The apparatus of claim 6, wherein the TPSN is a single bit consisting of either a zero (0) or a one (1).

15. An base station system operable to provide efficient paging requests with extended discontinuous reception (eDRX) with a user equipment (UE), the base station system, having a base station device, comprising one or more processors and memory configured to:

process a paging message and a short temporary paging sequence number (TPSN) delivered by a core network (CN) to a plurality cells of a routing area (RA);

include the TPSN in the paging message received from the CN when the paging message is delivered by the CN; and

process, for transmission, the paging message having the duplicate paging message check field including the TPSN to the UE to allow the UE to identify duplicate reception of a paging request message.

16.The base station system of claim 15, further configured to:

cancel the paging message that was transmitted to the UE and is currently pending when the base station system receives an alternative paging message having an alternative TPSN; or

cancel a pending paging message when the TPSN equals zero (0) and schedule the paging message when the TPSN equals one (1).

17.The base station system of claim 16, further configured transfer the alternative paging message having an alternative TPSN when the paging message is canceled.

18.The base station system of claim 15 or 16, wherein the time period is equal to an extended discontinuous reception (eDRX) cycle and T_{delta} , where T_{delta} is a time period between generation at the CN of the paging message delivered to the base station system and the reception at the base station system of the paging message.

19.At least one computer-readable storage medium, on a user equipment (UE) having at least one processor, comprising instructions for identifying duplicate reception of a paging request message, the instructions, when executed, cause the UE to:

process a first paging message having a duplicate paging message check field including a first short temporary paging sequence number (TPSN) delivered by a core network (CN) to a plurality cells of a routing area (RA);

process a second paging message having a second TPSN in the duplicate paging message check field delivered by the CN to a plurality cells of a routing area (RA);

compare the first TPSN to the second TPSN; and

ignore the second paging message by the UE when the second TPSN matches the first TPSN.

20.The computer-readable storage medium of claim 19, comprising further instructions that, when executed, cause the UE to determine that the second TPSN matches the first TPSN.

21.The computer-readable storage medium of claim 19 or 20, comprising further instructions that, when executed, cause the UE to store for a time period the first TPSN.

22.The computer-readable storage medium of claim 20 or 21, wherein the time period is equal to an extended discontinuous reception (eDRX) cycle.

23.The computer-readable storage medium of claim 20, comprising further instructions that, when executed, cause the UE to clear the first TPSN from the UE if the second paging message is not received during the time period.

24.The computer-readable storage medium of claim 19 or 23, comprising further instructions that, when executed, cause the UE to respond to the paging message when the TPSN in the duplicate paging message check field does not match the alternative TPSN of the alternative paging message previously delivered to the UE by the CN.

25.The computer-readable storage medium of claim 19, comprising further instructions that, when executed, cause the UE to respond to the paging message when the UE determines the TPSN in the duplicate paging message check field does not match the alternative TPSN of the alternative paging message previously delivered to the UE by the CN.

26.The computer-readable storage medium of claim 19 or 25, comprising further instructions that, when executed, cause the UE to wait to receive the DL packet for a predefined time period prior to entering the packet idle state.

27.The computer-readable storage medium of claim 19, comprising further instructions that, when executed, cause the UE to clear the stored TPSN when the UE transfers from one of the plurality cells of the RA to an alternative one of the plurality cells of the RA.

28.The computer-readable storage medium of claim 19 or 27, wherein the TPSN is a single bit consisting of either a zero (0) or a one (1).

100

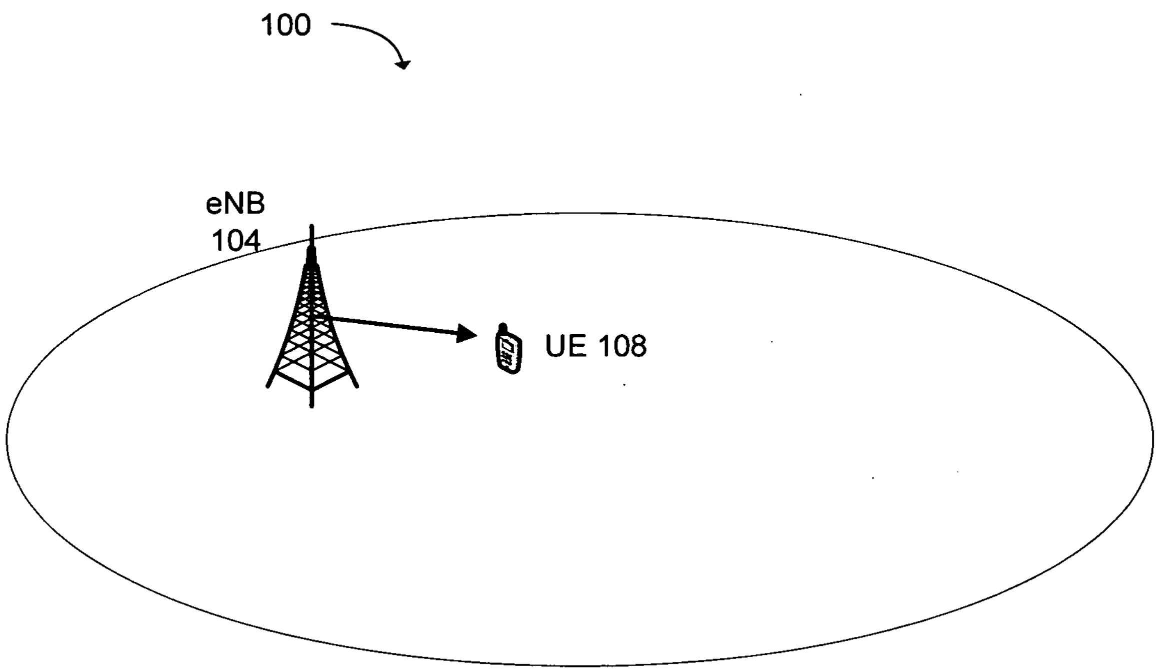


FIG. 1

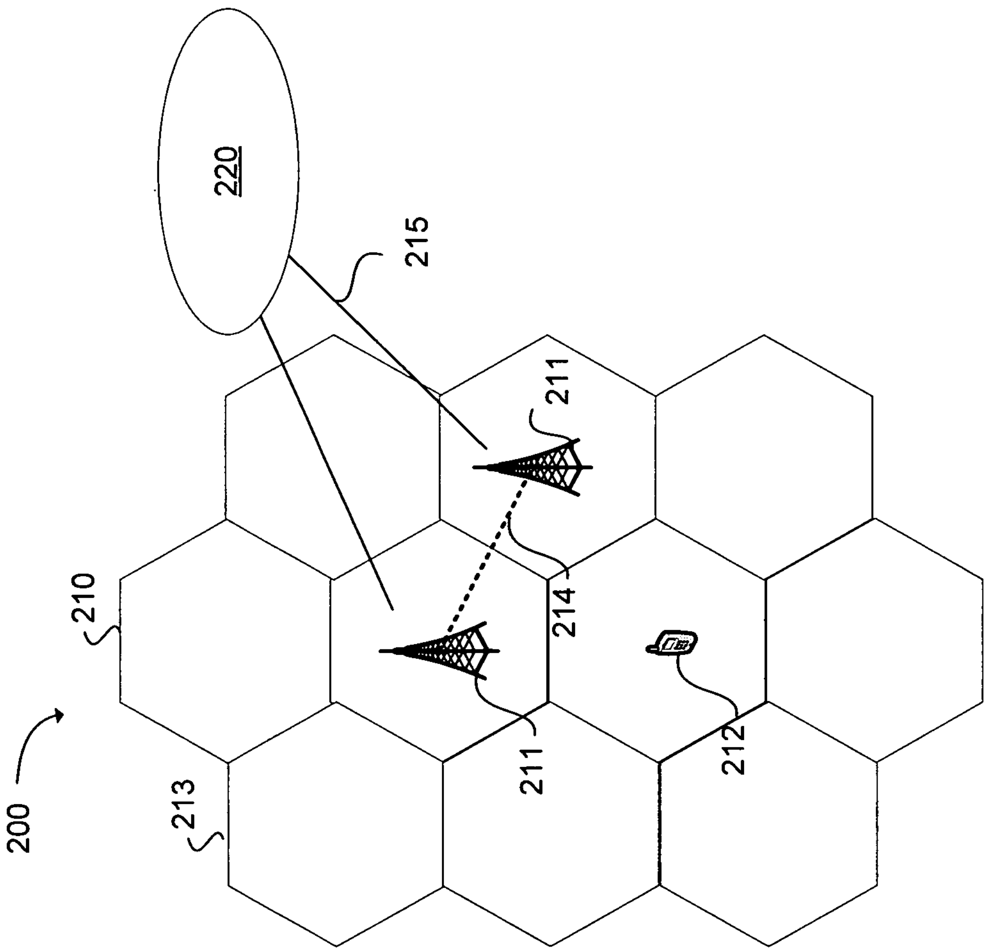
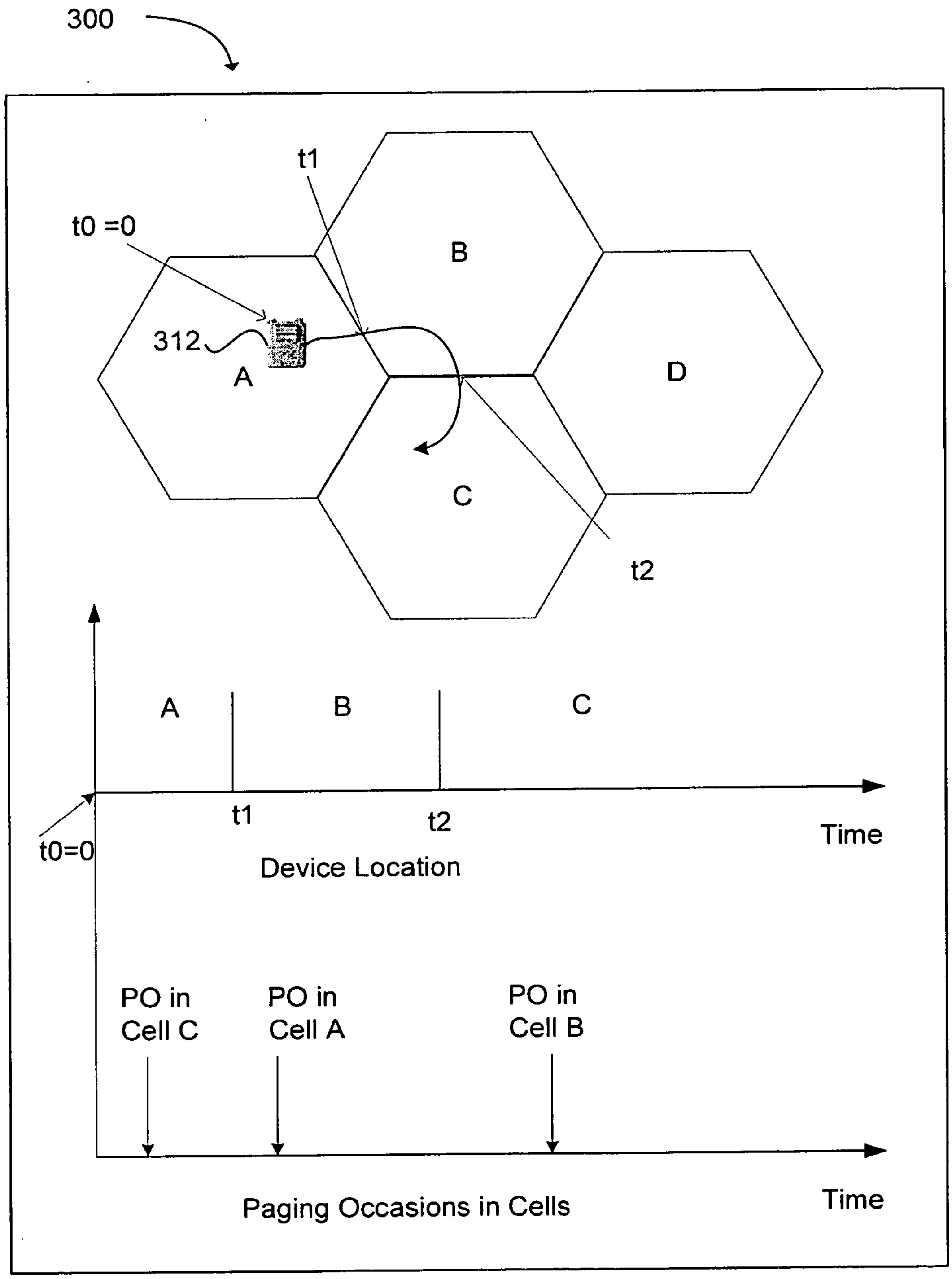
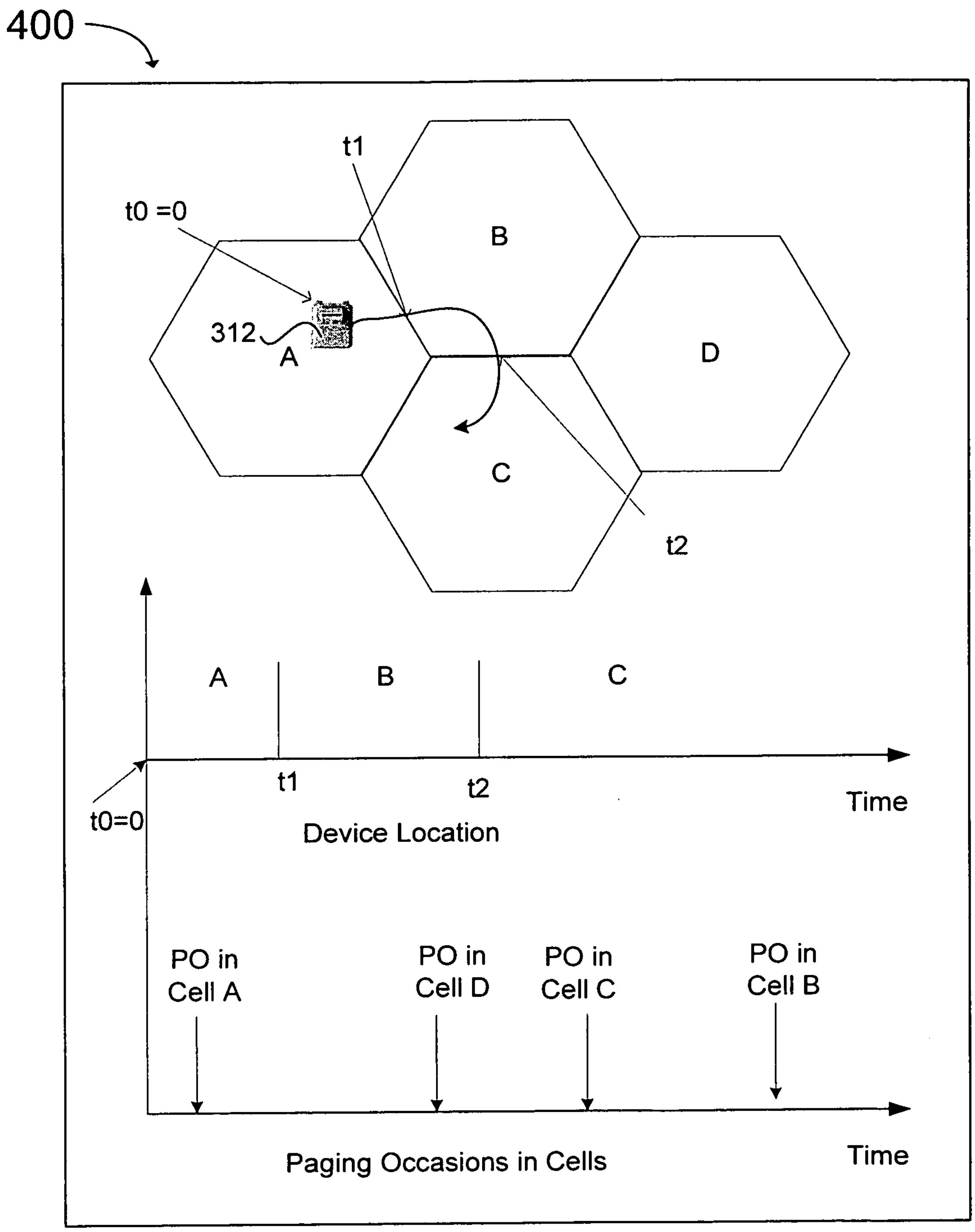


FIG. 2



Device missed Paging

FIG. 3



Device received multiple Pagings in Cells A and C

FIG. 4

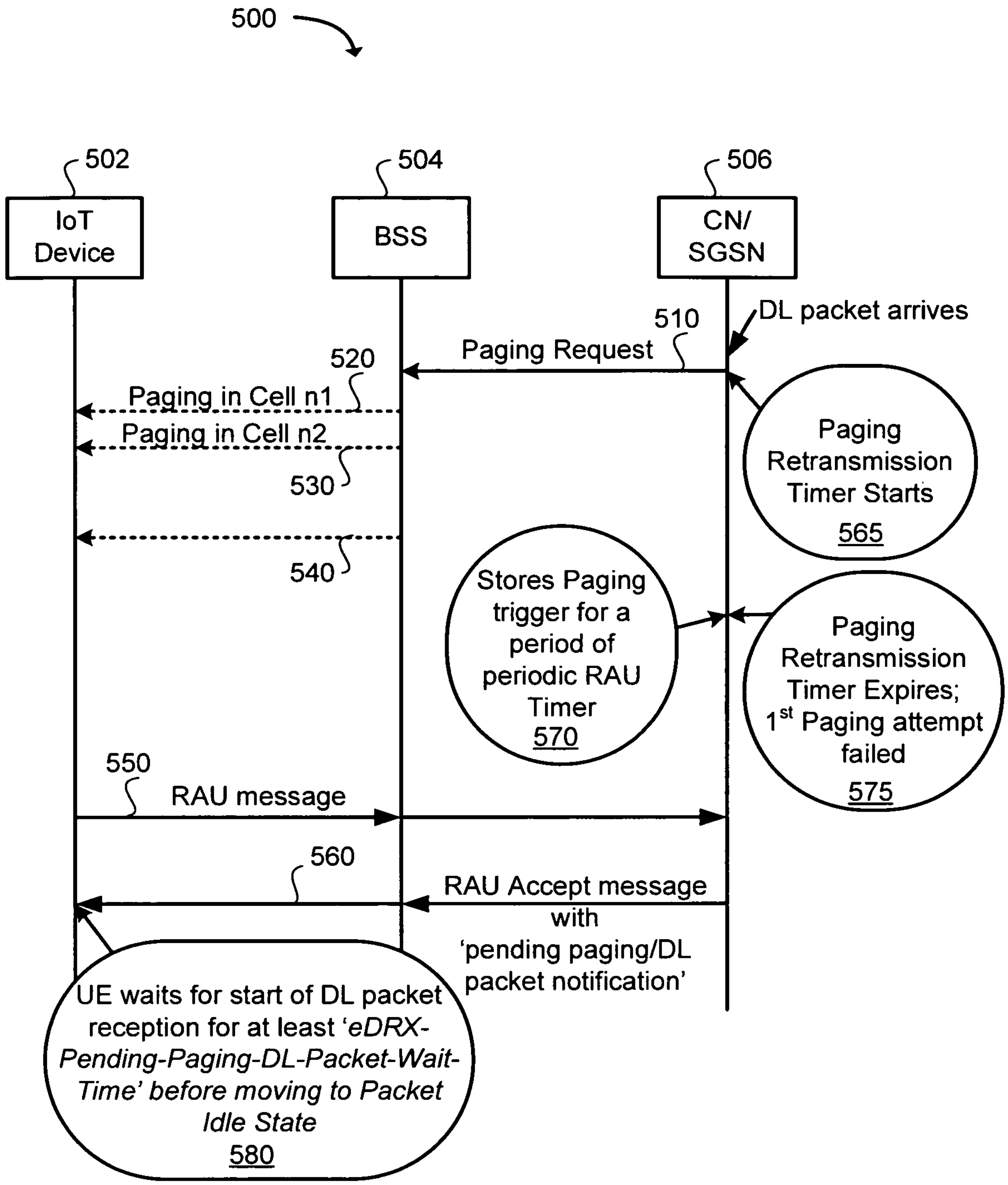
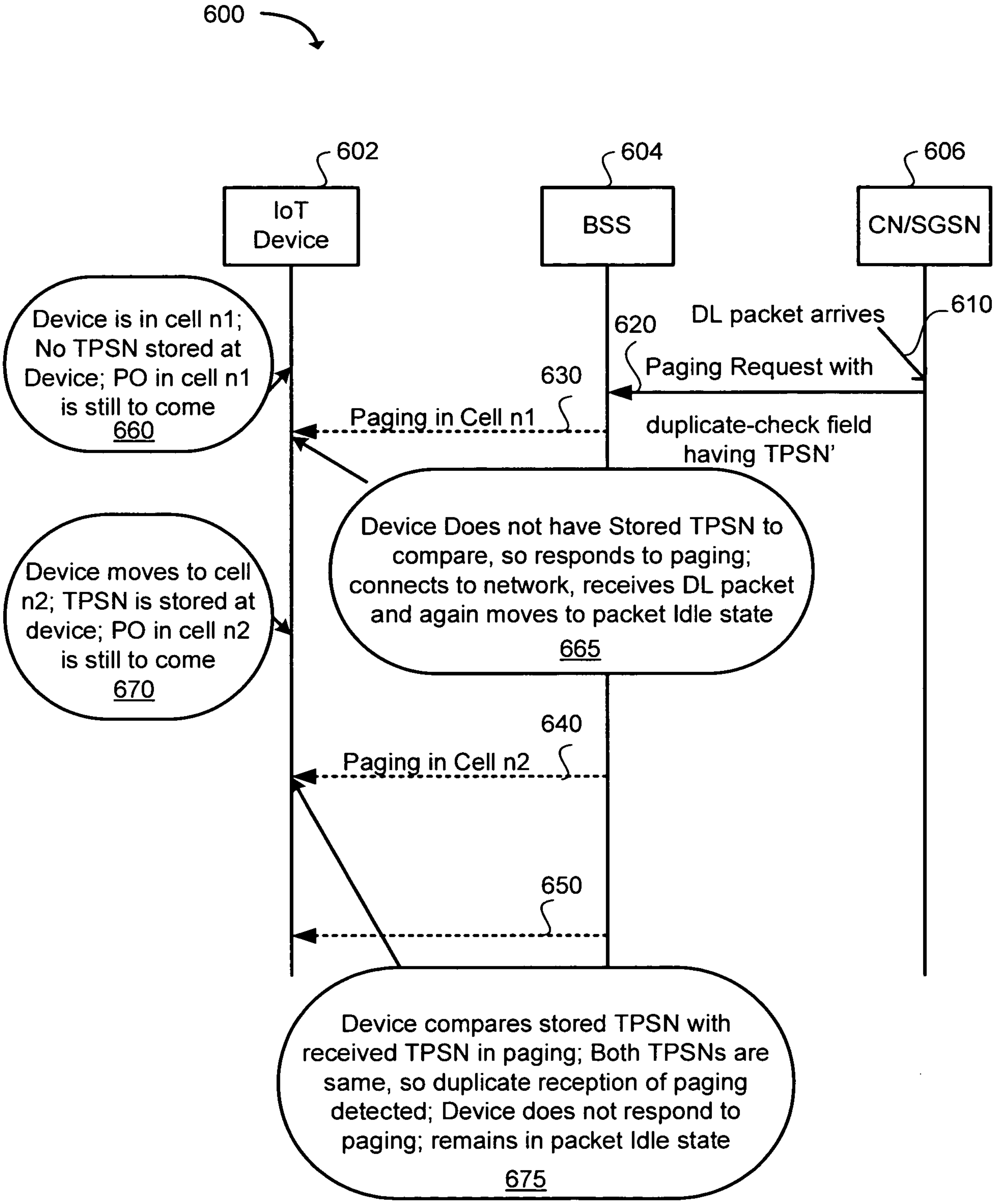

500
502
IoT Device
504
BSS
506
CN/ SGSN
DL packet arrives
510
Paging Request
520
Paging in Cell n1
Paging in Cell n2
530
540
Paging Retransmission Timer Starts
565
Stores Paging trigger for a period of periodic RAU Timer
570
Paging Retransmission Timer Expires; 1st Paging attempt failed
575
550
RAU message
560
RAU Accept message with 'pending paging/DL packet notification'
UE waits for start of DL packet reception for at least 'eDRX-Pending-Paging-DL-Packet-Wait-Time' before moving to Packet Idle State
580

FIG. 5



600
602
IoT Device
604
BSS
606
CN/SGSN
610
DL packet arrives
620
Paging Request with duplicate-check field having TPSN'
630
Paging in Cell n1
Device is in cell n1; No TPSN stored at Device; PO in cell n1 is still to come
660
Device Does not have Stored TPSN to compare, so responds to paging; connects to network, receives DL packet and again moves to packet Idle state
665
Device moves to cell n2; TPSN is stored at device; PO in cell n2 is still to come
670
640
Paging in Cell n2
650
Device compares stored TPSN with received TPSN in paging; Both TPSNs are same, so duplicate reception of paging detected; Device does not respond to paging; remains in packet Idle state
675

FIG. 6

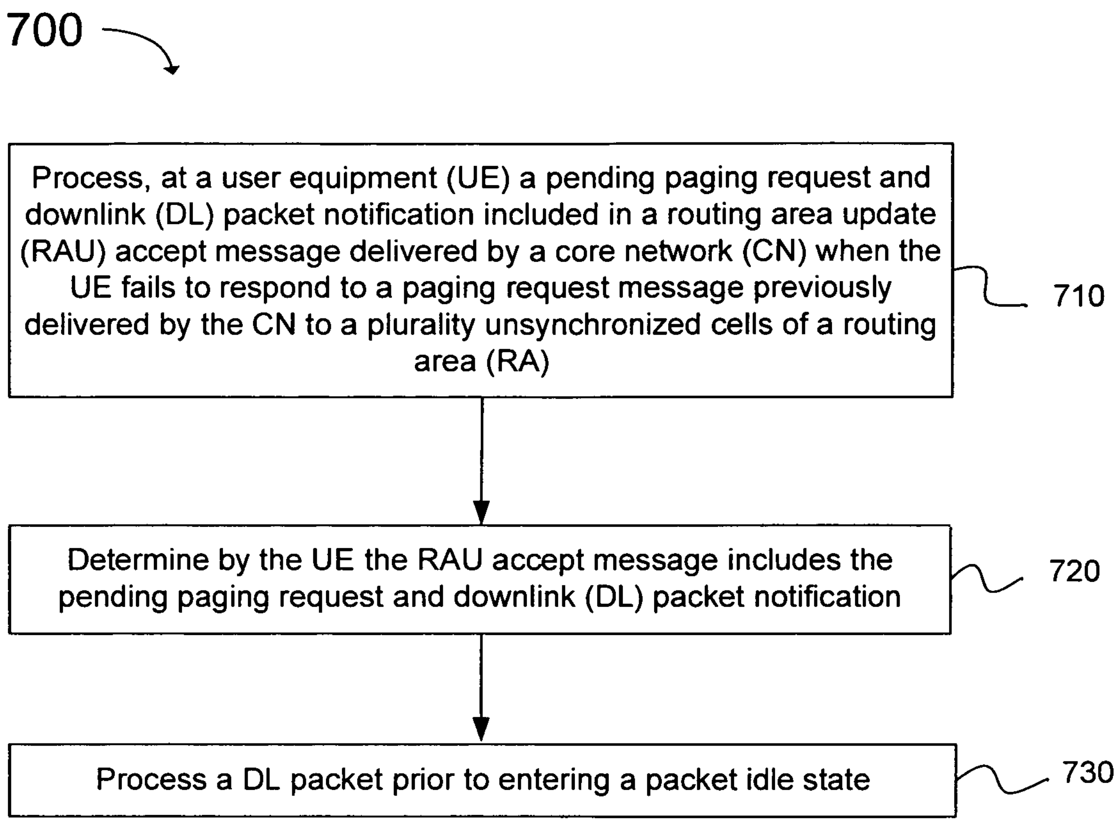

700
Process, at a user equipment (UE) a pending paging request and downlink (DL) packet notification included in a routing area update (RAU) accept message delivered by a core network (CN) when the UE fails to respond to a paging request message previously delivered by the CN to a plurality unsynchronized cells of a routing area (RA)
710
Determine by the UE the RAU accept message includes the pending paging request and downlink (DL) packet notification
720
Process a DL packet prior to entering a packet idle state
730

FIG. 7

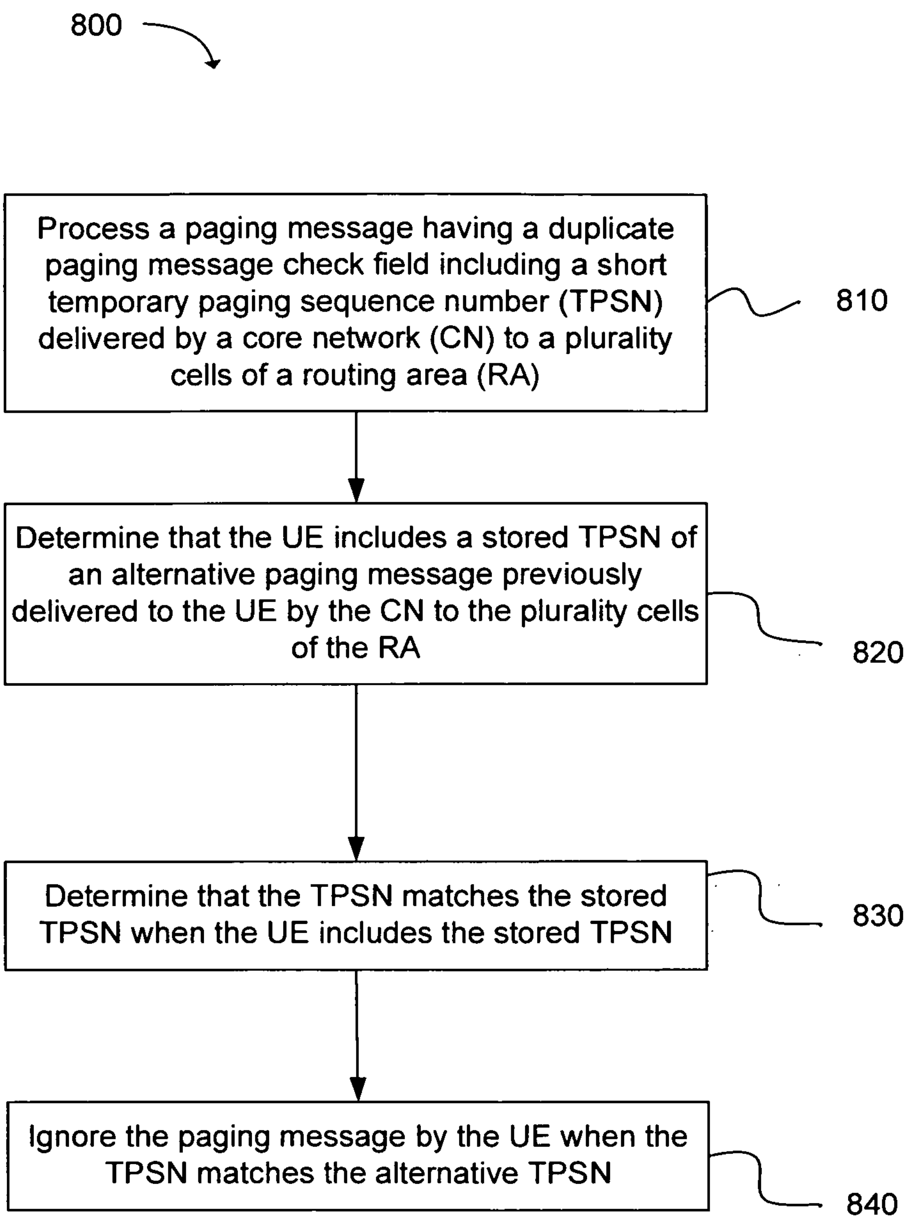

800
Process a paging message having a duplicate paging message check field including a short temporary paging sequence number (TPSN) delivered by a core network (CN) to a plurality cells of a routing area (RA)
810
Determine that the UE includes a stored TPSN of an alternative paging message previously delivered to the UE by the CN to the plurality cells of the RA
820
Determine that the TPSN matches the stored TPSN when the UE includes the stored TPSN
830
Ignore the paging message by the UE when the TPSN matches the alternative TPSN
840

FIG. 8

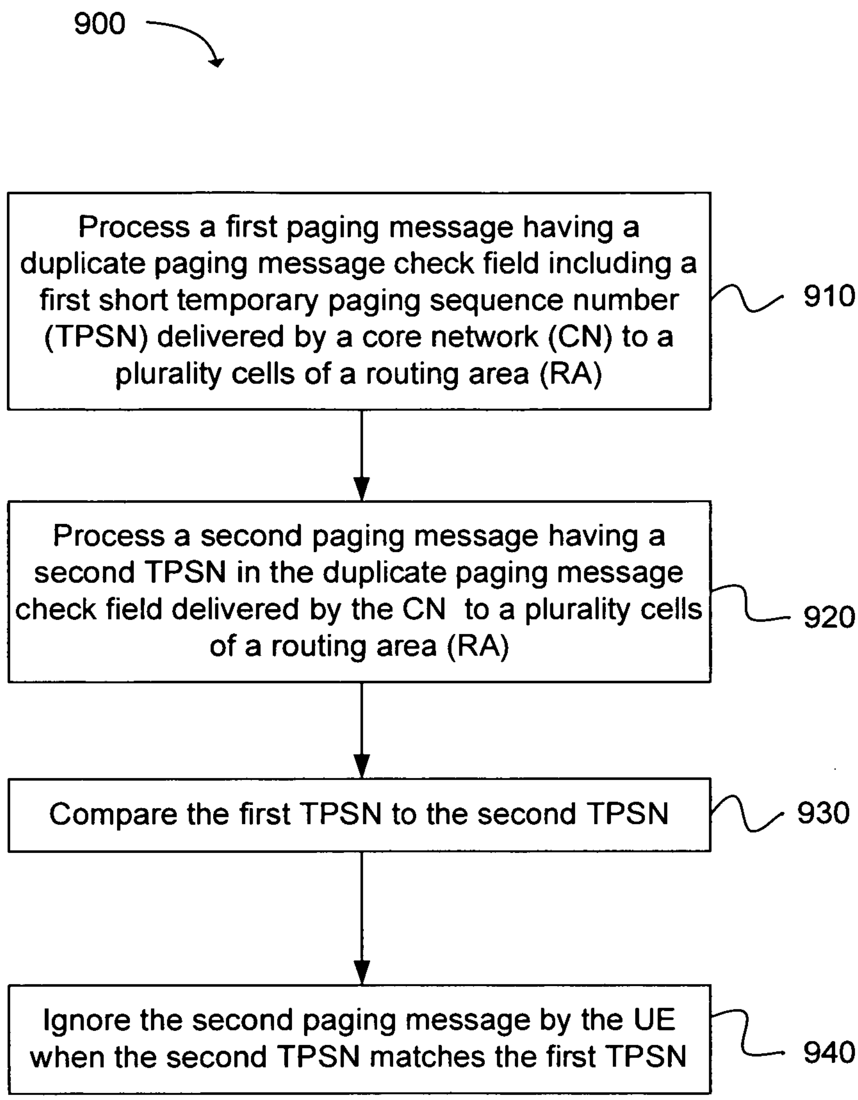

900
Process a first paging message having a duplicate paging message check field including a first short temporary paging sequence number (TPSN) delivered by a core network (CN) to a plurality cells of a routing area (RA)
910
Process a second paging message having a second TPSN in the duplicate paging message check field delivered by the CN to a plurality cells of a routing area (RA)
920
Compare the first TPSN to the second TPSN
930
Ignore the second paging message by the UE when the second TPSN matches the first TPSN
940

FIG. 9

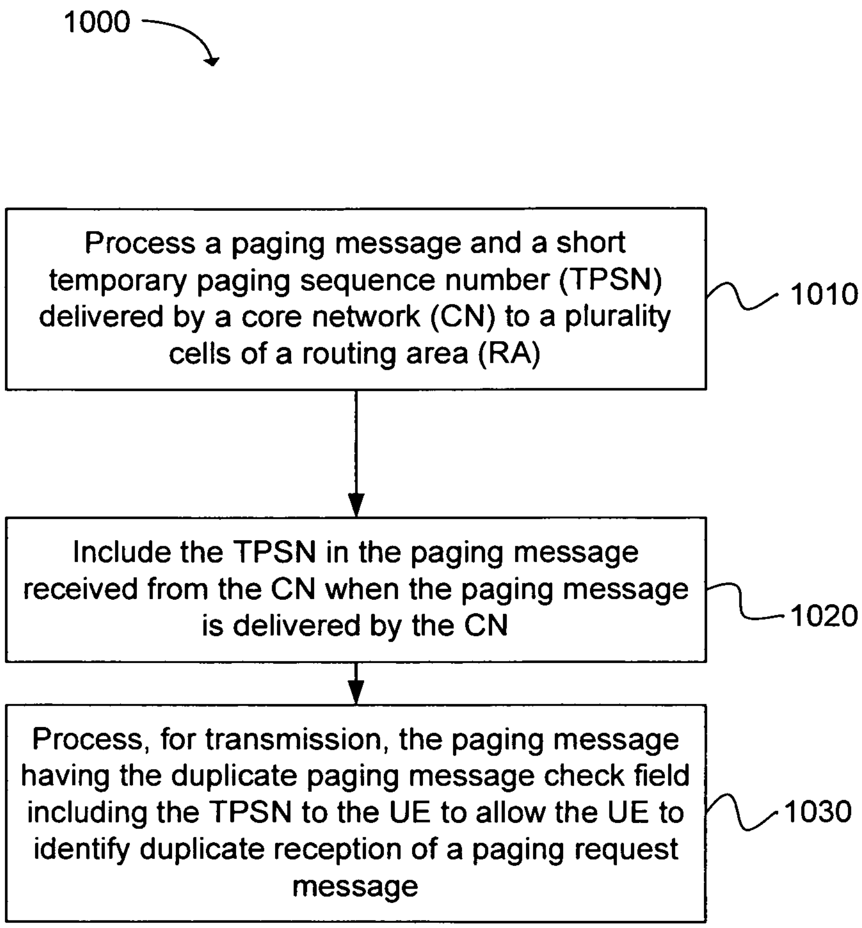

1000
Process a paging message and a short temporary paging sequence number (TPSN) delivered by a core network (CN) to a plurality cells of a routing area (RA)
1010
Include the TPSN in the paging message received from the CN when the paging message is delivered by the CN
1020
Process, for transmission, the paging message having the duplicate paging message check field including the TPSN to the UE to allow the UE to identify duplicate reception of a paging request message
1030

FIG. 10

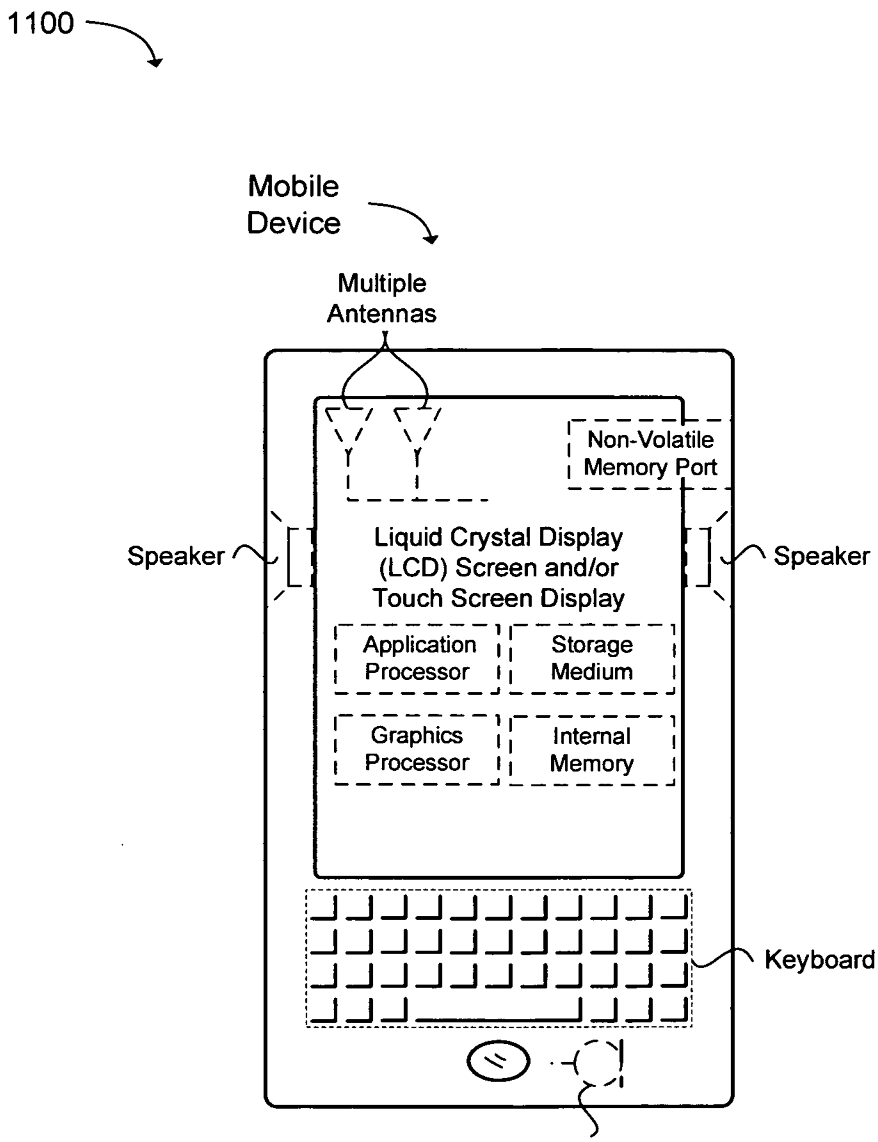

1100
Mobile Device
Multiple Antennas
Non-Volatile Memory Port
Speaker
Liquid Crystal Display (LCD) Screen and/or Touch Screen Display
Speaker
Application Processor
Storage Medium
Graphics Processor
Internal Memory
Keyboard

FIG. 11

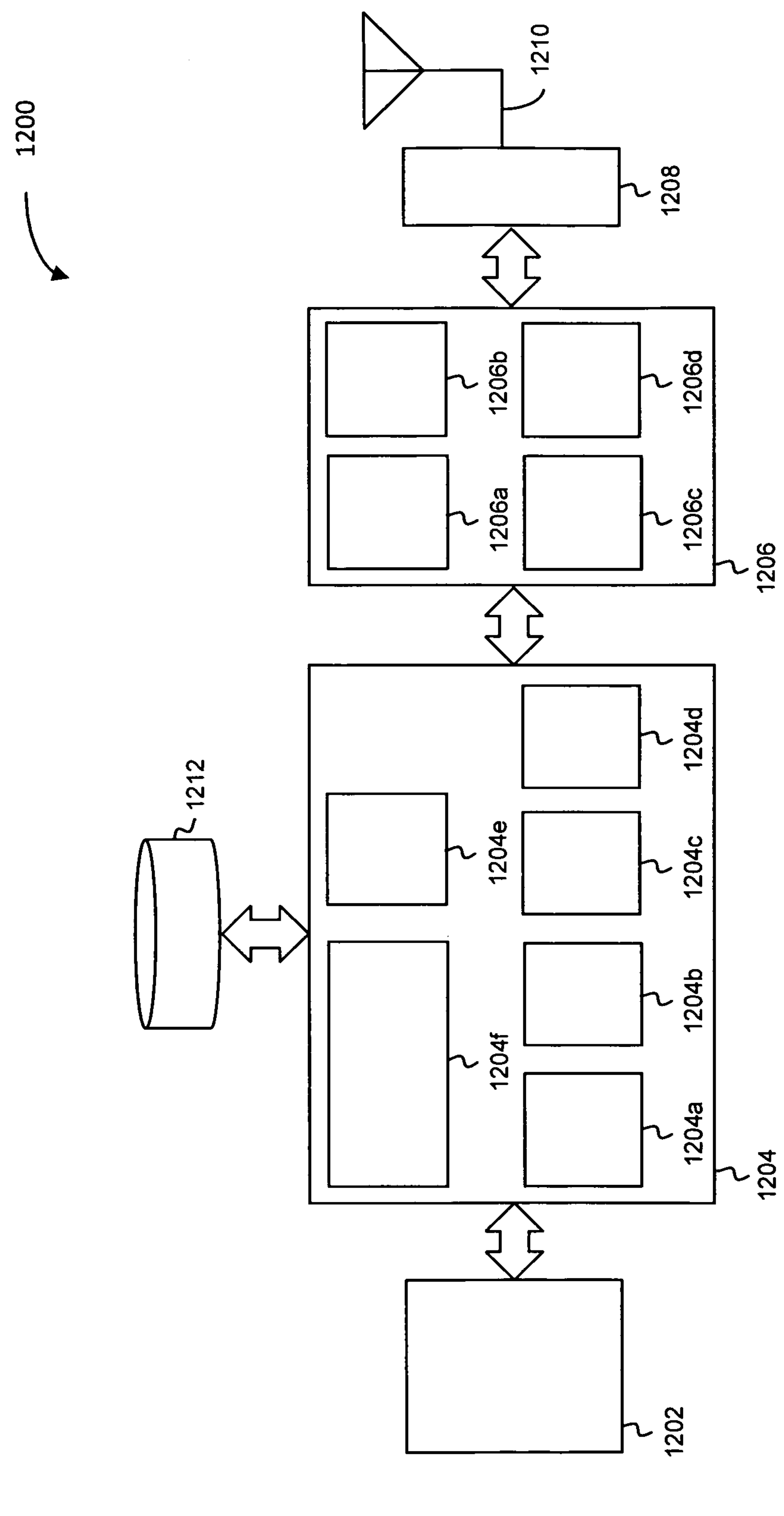

1200
1210
1208
1206b
1206d
1206a
1206c
1206
1212
1204e
1204d
1204c
1204b
1204f
1204a
1204
1202

FIG. 12

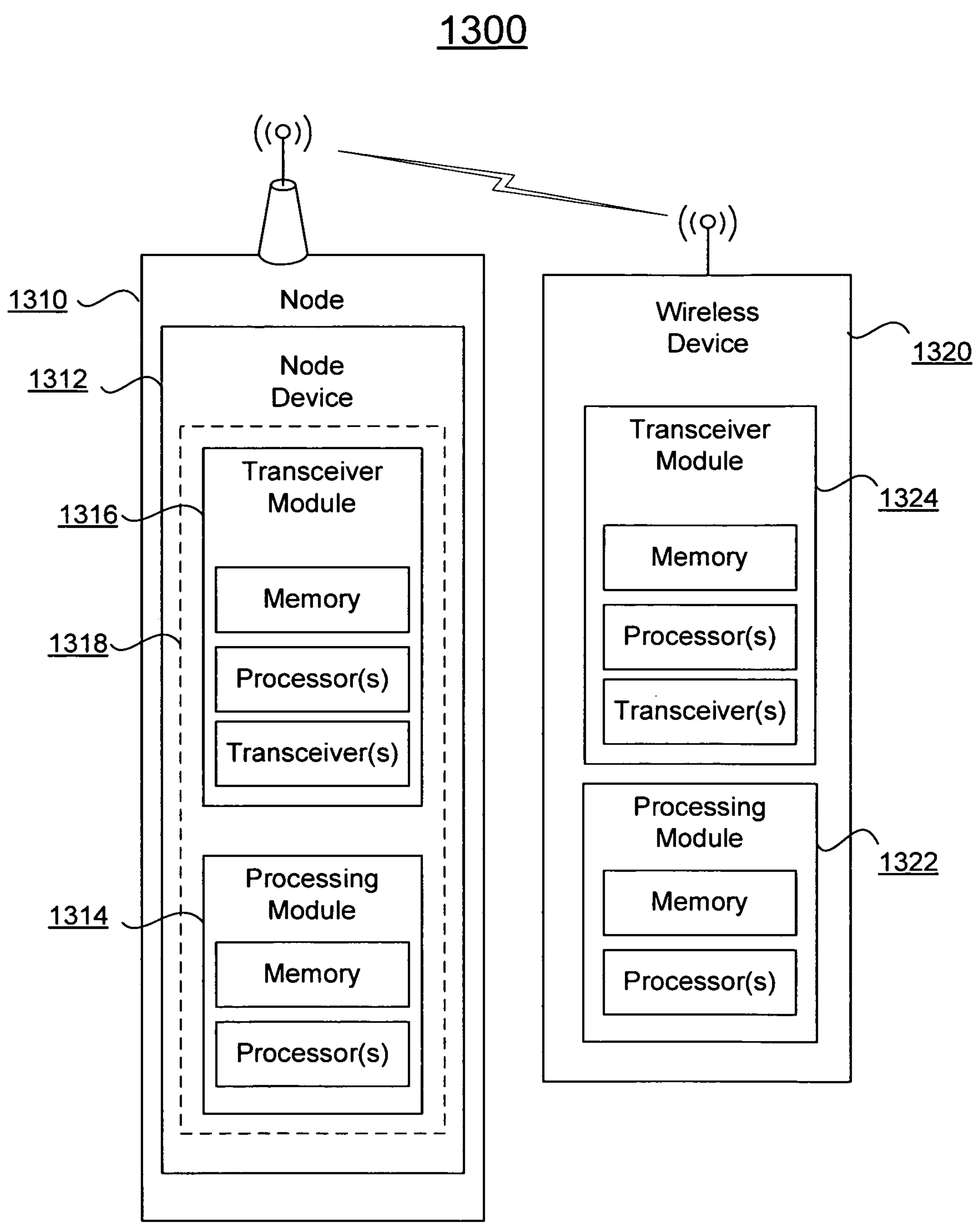

1300
1310
Node
1312
Node Device
1316
Transceiver Module
Memory
1318
Processor(s)
Transceiver(s)
1314
Processing Module
Memory
Processor(s)
Wireless Device
1320
Transceiver Module
1324
Memory
Processor(s)
Transceiver(s)
Processing Module
1322
Memory
Processor(s)

FIG. 13

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/000426

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W68/02 H04W60/04 H04W84/04 H04W88/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04W

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2014/256319 A1 (LEE KANG-GYU [KR]) 11 September 2014 (2014-09-11) abstract paragraphs [0007], [0023], [0025], [0061] - [0064], [0079] - [0082], [0086], [0087], [0098] figures 2,4,6 -----	1-5

-/--

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

[X] See patent family annex.

* Special categories of cited documents :

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 March 2016	13/06/2016

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

2

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

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	INTEL CORPORATION: "Impacts of Unsynchronized Cells in a Routing Area on Paging with eDRX", 3GPP DRAFT; GP-150404-IMPACTS OF UNSYNCHRONIZED CELLS IN A RA ON PAGING WITH EDRX, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPO , vol. TSG GERAN, no. Vilnius, Lithuania; 20150525 - 20150529 22 May 2015 (2015-05-22), pages 1-9, XP050977227, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/GERAN/Docs/ [retrieved on 2015-05-22] page 1, line 1 - page 5, line 13 figure 1 -----	1-5
Y	ERICSSON LM: "Pseudo CR 45.820 Synchronized Cells for eDRX", 3GPP DRAFT; GPC150264 - PCR SYNCHRONIZED CELLS FOR EDRX, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. TSG GERAN, no. Sophia Antipolis; 20150420 - 20150423 22 April 2015 (2015-04-22), pages 1-2, XP050945373, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/SA6/GERAN/Docs/ [retrieved on 2015-04-22] Par. 1.1 Par. 1.2 -----	1-5
A	"3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Study on System Impacts of Extended DRX Cycle for Power Consumption Optimization; (Release 13)", 3GPP STANDARD; 3GPP TR 23.770, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. SA WG2, no. V0.2.0, 4 May 2015 (2015-05-04), pages 1-33, XP050966447, Par. 4 Par. 5.2 - Par. 5.2.2.1 Annex A -----	1-5

2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/000426

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-5

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-5

   Delivering a paging request message by the CN to a plurality unsynchronized cells of a routing area, RA, and process a DL packet, received from an eNodeB.

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2. claims: 6-28

   Processing a paging message having a duplicate paging message check field including a short temporary paging sequence number, TPSN, delivered by a CN to a plurality cells of a routing area, RA; determining that the UE includes a stored TPSN of an alternative paging message previously delivered to the UE by the CN to the plurality cells of the RA; determining that the TPSN matches the stored TPSN when the UE includes the stored TPSN; and ignoring the paging message by the UE when the TPSN matches the alternative TPSN.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2015/000426

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2014256319 A1	11-09-2014	EP 2974486 A1	20-01-2016
		KR 20140111428 A	19-09-2014
		US 2014256319 A1	11-09-2014
		WO 2014142390 A1	18-09-2014