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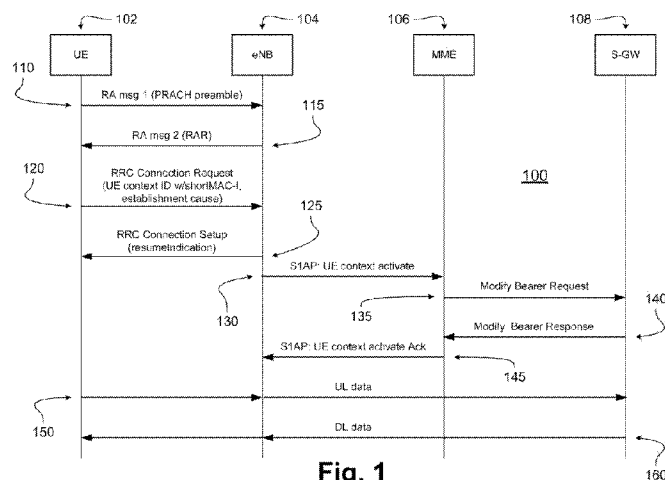


Fig. 1

(57) **Abstract:** Described is an apparatus of an Evolved Node-B (eNB) operable to communicate with a User Equipment (UE) on a wireless network. The apparatus may comprise a first circuitry, a second circuitry, and a third circuitry. The first circuitry may be operable to store a resume identification comprising one or more UE identification bits for the UE and one or more cell identification bits. The second circuitry may be operable to store an access stratum (AS) context for the UE. The third circuitry may be operable to associate the resume identification with the AS context for the UE.

RADIO RESOURCE CONTROL ENHANCEMENTS FOR ACCESS STRATUM CONTEXT REUSE

CLAIM OF PRIORITY

[0001] The present application claims priority under 35 U.S.C. § 119(e) to United States Provisional Patent Application Serial Number 62/277,830 filed January 12, 2016 and entitled “Radio Resource Control Enhancements To Support Access Stratum Context Reuse For Narrowband Internet Of Things Devices,” which is herein incorporated by reference in its entirety.

BACKGROUND

[0002] Various wireless cellular communication systems have been implemented or are being proposed, including a 3rd Generation Partnership Project (3GPP) Universal Mobile Telecommunications System (UMTS), a 3GPP Long-Term Evolution (LTE) system, a 3GPP LTE-Advanced (LTE-A) system, and a 5th Generation wireless / 5th Generation mobile networks (5G) system. Next-generation wireless cellular communication systems may provide support for massive numbers of user devices like Narrowband Internet-of-Things (NB-IoT) devices, Cellular Internet-of-Things (CIoT) devices, or Machine-Type Communication (MTC) devices. Such devices may have very low device complexity, may be latency-tolerant, and may be designed for low throughput and very low power consumption.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] The embodiments of the disclosure will be understood more fully from the detailed description given below and from the accompanying drawings of various embodiments of the disclosure. However, while the drawings are to aid in explanation and understanding, they are only an aid, and should not be taken to limit the disclosure to the specific embodiments depicted therein.

[0004] **Fig. 1** illustrates a Radio Resource Control (RRC) Resume procedure for Solution 18, in accordance with some embodiments of the disclosure.

[0005] **Fig. 2** illustrates an RRC Suspend procedure for Solution 18, in accordance with some embodiments of the disclosure.

[0006] **Fig. 3** illustrates connection release procedures to suspend connections, in accordance with some embodiments of the disclosure.

- [0007] **Figs. 4A-4B** illustrates Abstract Syntax Notation (ASN) messages and Information Elements (IEs) for connection release procedures, in accordance with some embodiments of the disclosure.
- [0008] **Fig. 5** illustrates conditional definitions for connection release procedures, in accordance with some embodiments of the disclosure.
- [0009] **Fig. 6** illustrates connection request procedures to resume connections, in accordance with some embodiments of the disclosure.
- [0010] **Fig. 7** illustrates ASN messages and IEs for connection request procedures, in accordance with some embodiments of the disclosure.
- [0011] **Fig. 8** illustrates a field definition for connection request procedures, in accordance with some embodiments of the disclosure.
- [0012] **Fig. 9** illustrates connection setup procedures to respond to resumption requests, in accordance with some embodiments of the disclosure.
- [0013] **Fig. 10** illustrates ASN messages and IEs for connection setup procedures, in accordance with some embodiments of the disclosure.
- [0014] **Fig. 11** illustrates connection rejection procedures, in accordance with some embodiments of the disclosure.
- [0015] **Figs. 12A-12B** illustrates ASN messages and IEs for connection rejection procedures, in accordance with some embodiments of the disclosure.
- [0016] **Fig. 13** illustrates an Evolved Node B (eNB) and a User Equipment (UE), in accordance with some embodiments of the disclosure.
- [0017] **Fig. 14** illustrates hardware processing circuitries for an eNB for employing new Identifications (IDs) incorporating UE IDs and cell IDs, in accordance with some embodiments of the disclosure.
- [0018] **Fig. 15** illustrates hardware processing circuitries for a UE for employing new IDs incorporating UE IDs and cell IDs, in accordance with some embodiments of the disclosure.
- [0019] **Fig. 16** illustrates methods for an eNB for new IDs incorporating UE IDs and cell IDs, in accordance with some embodiments of the disclosure.
- [0020] **Fig. 17** illustrates methods for a UE for new IDs incorporating UE IDs and cell IDs, in accordance with some embodiments of the disclosure.
- [0021] **Fig. 18** illustrates example components of a UE device, in accordance with some embodiments of the disclosure.

DETAILED DESCRIPTION

[0022] Narrow Band Internet-of-Things (IoT), or NB-IOT, aims to define a clean-slate (CS) solution based on 3rd Generation Partnership Project (3GPP) Long-Term Evolution (LTE), which might not be backward-compatible, in order to address specific Cellular Internet of Things (C-IoT) features. C-IoT features may include improved indoor coverage, support for massive number of low throughput devices, low delay sensitivity, ultra-low device cost, low device power consumption, and optimized network architecture.

[0023] Radio Resource Control (RRC) procedures based on existing LTE protocols and relevant optimizations to facilitate a selected physical layer may be supported for NB-IoT. Service and System Access Working Group 2 (SA2) has agreed, for normative work, to pursue a Solution 2 (e.g., a Control Plane solution for Data over Non-Access-Stratum (NAS)) as a desirable feature for User Equipments (UEs) and Networks. SA2 has also agreed to pursue a Solution 18 (e.g., a User Plane solution with keeping Access Stratum (AS) context in an Evolved Node-B (eNB)) as an optional feature.

[0024] In Solution 18, a UE may be disposed to perform an initial connection setup to establish a NAS signaling connection and to provide the UE and the network with an initial AS context. A NAS layer may be aware that subsequently no Service Requests may be required as long as a valid AS context in the network may be found by the AS layer. If for any reason the AS layer context is missing in the network while the UE attempts a resume procedure, the resume procedure may fail, and the AS layer may trigger a NAS layer service request, which may establish a new initial AS layer context.

[0025] When a UE transitions from an RRC-Connected state to an RRC-IDLE state, the connection may be suspended and may cause the UE and the network to retain the context in RRC-IDLE mode, which may then be used for future connections.

[0026] Disclosed herein are mechanisms and methods for addressing RRC impacts to Technical Specification 36.331 and related enhancements due to the introduction of the User Plane solutions in which AS context of a UE may be stored for subsequent connection usage as part of NB-IoT design and backward compatibility with LTE. In some embodiments, mechanisms and methods may relate to state-3 specifications for RRC enhancements to support User Plane solutions for small data transmissions as part of NB-IoT. Some mechanisms and methods may comprise new UE Identifications (IDs), which may be forward-compatible.

[0027] In the following description, numerous details are discussed to provide a more thorough explanation of embodiments of the present disclosure. It will be apparent to one

skilled in the art, however, that embodiments of the present disclosure may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form, rather than in detail, in order to avoid obscuring embodiments of the present disclosure.

[0028] Note that in the corresponding drawings of the embodiments, signals are represented with lines. Some lines may be thicker, to indicate a greater number of constituent signal paths, and/or have arrows at one or more ends, to indicate a direction of information flow. Such indications are not intended to be limiting. Rather, the lines are used in connection with one or more exemplary embodiments to facilitate easier understanding of a circuit or a logical unit. Any represented signal, as dictated by design needs or preferences, may actually comprise one or more signals that may travel in either direction and may be implemented with any suitable type of signal scheme.

[0029] Throughout the specification, and in the claims, the term "connected" means a direct electrical, mechanical, or magnetic connection between the things that are connected, without any intermediary devices. The term "coupled" means either a direct electrical, mechanical, or magnetic connection between the things that are connected or an indirect connection through one or more passive or active intermediary devices. The term "circuit" or "module" may refer to one or more passive and/or active components that are arranged to cooperate with one another to provide a desired function. The term "signal" may refer to at least one current signal, voltage signal, magnetic signal, or data/clock signal. The meaning of "a," "an," and "the" include plural references. The meaning of "in" includes "in" and "on."

[0030] The terms "substantially," "close," "approximately," "near," and "about" generally refer to being within +/- 10% of a target value. Unless otherwise specified the use of the ordinal adjectives "first," "second," and "third," etc., to describe a common object, merely indicate that different instances of like objects are being referred to, and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

[0031] It is to be understood that the terms so used are interchangeable under appropriate circumstances such that the embodiments of the invention described herein are, for example, capable of operation in other orientations than those illustrated or otherwise described herein.

[0032] The terms "left," "right," "front," "back," "top," "bottom," "over," "under," and the like in the description and in the claims, if any, are used for descriptive purposes and not necessarily for describing permanent relative positions.

[0033] For purposes of the embodiments, the transistors in various circuits, modules, and logic blocks are Tunneling FETs (TFETs). Some transistors of various embodiments may comprise metal oxide semiconductor (MOS) transistors, which include drain, source, gate, and bulk terminals. The transistors may also include Tri-Gate and FinFET transistors, Gate All Around Cylindrical Transistors, Square Wire, or Rectangular Ribbon Transistors or other devices implementing transistor functionality like carbon nanotubes or spintronic devices. MOSFET symmetrical source and drain terminals i.e., are identical terminals and are interchangeably used here. A TFET device, on the other hand, has asymmetric Source and Drain terminals. Those skilled in the art will appreciate that other transistors, for example, Bi-polar junction transistors-BJT PNP/NPN, BiCMOS, CMOS, etc., may be used for some transistors without departing from the scope of the disclosure.

[0034] For the purposes of the present disclosure, the phrases "A and/or B" and "A or B" mean (A), (B), or (A and B). For the purposes of the present disclosure, the phrase "A, B, and/or C" means (A), (B), (C), (A and B), (A and C), (B and C), or (A, B and C).

[0035] In addition, the various elements of combinatorial logic and sequential logic discussed in the present disclosure may pertain both to physical structures (such as AND gates, OR gates, or XOR gates), or to synthesized or otherwise optimized collections of devices implementing the logical structures that are Boolean equivalents of the logic under discussion.

[0036] In addition, for purposes of the present disclosure, the term "eNB" may refer to a legacy LTE capable Evolved Nod-B (eNB), a Narrowband Internet-of-Things (NB-IoT) capable eNB, a Cellular Internet-of-Things (CIoT) capable eNB, a Machine-Type Communication (MTC) capable eNB, and/or another base station for a wireless communication system. For purposes of the present disclosure, the term "UE" may refer to a legacy LTE capable User Equipment (UE), an NB-IoT capable UE, a CIoT capable UE, an MTC capable UE, and/or another mobile equipment for a wireless communication system.

[0037] Various embodiments of eNBs and/or UEs discussed below may process one or more transmissions of various types. Some processing of a transmission may comprise demodulating, decoding, detecting, parsing, and/or otherwise handling a transmission that has been received. In some embodiments, an eNB or UE processing a transmission may determine or recognize the transmission's type and/or a condition associated with the transmission. For some embodiments, an eNB or UE processing a transmission may act in accordance with the transmission's type, and/or may act conditionally based upon the transmission's type. An eNB or UE processing a transmission may also recognize one or

more values or fields of data carried by the transmission. Processing a transmission may comprise moving the transmission through one or more layers of a protocol stack (which may be implemented in, e.g., hardware and/or software-configured elements), such as by moving a transmission that has been received by an eNB or a UE through one or more layers of a protocol stack.

[0038] Various embodiments of eNBs and/or UEs discussed below may also generate one or more transmissions of various types. Some generating of a transmission may comprise modulating, encoding, formatting, assembling, and/or otherwise handling a transmission that is to be transmitted. In some embodiments, an eNB or UE generating a transmission may establish the transmission's type and/or a condition associated with the transmission. For some embodiments, an eNB or UE generating a transmission may act in accordance with the transmission's type, and/or may act conditionally based upon the transmission's type. An eNB or UE generating a transmission may also determine one or more values or fields of data carried by the transmission. Generating a transmission may comprise moving the transmission through one or more layers of a protocol stack (which may be implemented in, e.g., hardware and/or software-configured elements), such as by moving a transmission to be sent by an eNB or a UE through one or more layers of a protocol stack.

[0039] In some embodiments, in a user plane such as Solution 18, a UE may be disposed to performing an initial connection setup to establish a NAS signaling connection and/or to provide the UE and a network with an initial AS context. When the UE transitions from an RRC-Connected state to an RRC-IDLE state, the connection may be suspended and may cause the UE and/or the network to retain the AS Context in an RRC-IDLE mode to be used for future connections. If, for any reason, the AS layer context is missing in the network while the UE attempts a resume procedure, the resume procedure may fail, and the AS may inform a NAS layer to trigger a NAS layer service request to establish a new initial AS layer context. Discussed herein are RRC impacts and advantageous enhancements due to the introduction of these methods and mechanisms.

[0040] **Fig. 1** illustrates an RRC Resume procedure for Solution 18, in accordance with some embodiments of the disclosure. A procedure 100 may take place between a UE 102, an eNB 104, a Mobility Management Entity (MME) 106, and a Serving Gateway (S-GW) 108. Procedure 100 may have a plurality of portions.

[0041] In a portion 110, UE 102 may transmit a Random Access (RA) message to eNB 104 (e.g., via a Physical Random Access Channel (PRACH)). In a portion 115, eNB 104 may transmit an RA message (e.g., a RA Response (RAR)) to UE 102.

[0042] In a portion 120, UE 102 may transmit an RRC Connection Request message to eNB 104. The RRC Connection Request message may carry a UE context Identification (ID) with a short Medium Access Control (MAC) information for Integrity (MAC-I), and/or an establishment cause. In a portion 125, eNB 104 may transmit an RRC Connection Setup message to UE 102. The RRC Connection Setup message may contain a resume indication.

[0043] In a portion 130, eNB 104 may transmit to MME 106 an UE context activation indicator (e.g., via an S1 interface Application Protocol (S1AP)). In a portion 135, MME 106 may transmit to S-GW 108 a Modify Bearer Request.

[0044] In a portion 140, S-GW 108 may transmit a Modify Bearer Response to MME 106. In a portion 145, MME 106 may transmit a UE context activate acknowledgement to eNB 104 (e.g., via an S1AP).

[0045] In a portion 150, UE 102 may transmit UL data to eNB 104, which may in turn transmit the UL data to MME 106 and/or S-GW 108. In a portion 160, S-GW 108 and/or MME 106 may transmit DL data to eNB 104, which may in turn transmit the DL data to UE 102. UE 102 may accordingly be connected to eNB 104 for ordinary UL and/or DL data traffic.

[0046] Regarding RRC Resume procedure details, in a connection resumption procedure, a connection request may be disposed to being sent to the eNB referring to the UE's stored context. Consideration of legacy LTE connection request and connection setup messages with relevant changes for the resume process may advantageously facilitate LTE reuse. Since solution 18 may be used by both NB-IoT and non-NB-IoT UEs, the impact to UEs might be reduced if existing messages are reused. Also, to allow use by both NB-IOT and non-NB-IOT UEs, avoiding increases to the message size of message 3 in the RACH procedure may be advantageous.

[0047] The legacy RRC Connection Request message may allow 48 bits of RRC payload, which may include a 5-byte UE ID and/or an establishment cause. If a critical extension is used for RRC Connection Request to support the resume procedure, a useful payload may advantageously be smaller, which may facilitate support for future extensions.

[0048] During legacy RRC establishment procedure, when a UE enters Connected state from Idle state, it may be assigned a C-RNTI by an eNB in order to assign radio resources to the UE. If the C-RNTI is included as part of a context, then the C-RNTI may be used as a way of referring to the context. However, this may place a limit on a number of suspended-state UEs that may be supported in a cell. This may be similar to an RRC connection re-establishment procedure.

[0049] However, in order to be more future-proof, it may be advantageous to introduce a new ID that is a combination of a UE ID and a cell ID (noting that the cell ID may not necessarily be the PCI as used in RRC Connection Re-establishment Request in, e.g., legacy LTE). A split between the UE ID and the cell ID may be left to network implementation and/or deployment, and may not have to be visible to the UE. The new ID may be decided by the network and shared with the UE during a connection suspend procedure. The cell ID within the new ID may be advantageously facilitate consideration of mobility for future releases.

[0050] RRC connection setup may also be re-utilized to resume a suspended connection in response to a received connection request. A setup complete message might not be sent in response to this message, as there may be no need to send a NAS message to the network. For the NB-IoT case, as there may be only one radio bearer, it may be unnecessary to provide any bearer indication specifically. In the future, if there are multiple bearers, suspension of the connection to puts all the bearers in suspend mode may even be considered as a baseline. Finally, it may be noted that a UE may still continue to perform idle mode procedures while in suspended mode, which may provide another motivation for assuming legacy RRC connection establishment messages for moving the UE from idle to connected mode.

[0051] In the event that the eNB is unable to find the UE context, or the context is deemed no longer valid, the eNB may reject the UE's connection request. On receipt of the rejection message, the RRC may delete its stored context and either inform an upper layer of the failure of the connection establishment, or send out the original service request procedure received from the NAS. In the former case, the NAS may then try the service request procedure again, whereupon the AS may perform a normal RRC Connection Request. Use of this method may mean that the UE is disposed to performing the RACH procedure again. However, in some embodiments, it may be best to restart the whole procedure. In a future release, an optimization to avoid the RACH procedure may be considered.

[0052] In some embodiments, a short-MAC-I used within an RRC connection re-establishment procedure may also be utilized for support of Solution 18 as well, as the UE is returning to the eNB where the context is kept. The UE may calculate the short-MAC-I using the security configuration of the eNB that it was previously connected to (and through which the connection was suspended) and provide it as part of the request message.

[0053] **Fig. 2** illustrates an RRC Suspend procedure for Solution 18, in accordance with some embodiments of the disclosure. A procedure 200 may take place between a UE

202, an eNB 204, an MME 206, and an S-GW 208. Procedure 200 may have a plurality of portions.

[0054] In a portion 210, UE 202 may transmit UL data to eNB 204, which may in turn transmit the UL data to MME 206 and/or S-GW 208. In a portion 220, S-GW 208 and/or MME 206 may transmit DL data to eNB 204, which may in turn transmit the DL data to UE 202. UE 202 may accordingly be connected to eNB 204 for ordinary UL and/or DL data traffic.

[0055] In a portion 235, eNB 204 may decide to suspend the connection with UE 202. In a portion 240, eNB 204 may transmit to MME 206 a UE context deactivation indicator (e.g., via an S1AP). In a portion 245, MME 206 may transmit to S-GW 208 a Release Access Bearer Request.

[0056] In a portion 250, S-GW 208 may transmit a Release Access Bearer Response to MME 206. In a portion 255, MME 206 may transmit a UE context deactivate acknowledgement to eNB 204 (e.g., via an S1AP).

[0057] In a portion 260, MME 206 may enter an Evolved Packet System (EPS) Connection Management (ECM) Idle state. In a portion 270, eNB 204 may transmit an RRC Connection Release message to UE 202. The RRC Connection Release message may carry a UE Context Storage Indication and/or a UE context ID. IN portion 280, UE 202 may enter an RRC Idle state and/or an ECM Idle state.

[0058] An RRC Connection release procedure may be preceded by S1 UE context release procedure as per legacy, and may move the UE to RRC_IDLE mode. An RRC Suspend procedure may move a UE to idle mode as well. Thus, if the RRC Connection Release procedure is maintained for NB-IOT, it is preferred that the release procedure is also used for the suspending of the RRC Connection using for e.g. a context storage and suspend indication IE or the release cause value along with the UE context ID.

[0059] In some embodiments, a legacy LTE connection release procedure may be modified such that the context can be stored if notified by the eNB.

[0060] **Fig. 3** illustrates connection release procedures to suspend connections, in accordance with some embodiments of the disclosure. A procedure 300 may comprise a first portion 310 and a second portion 320. First portion 310 may relate to an RRC Connection Release procedure in general. In first portion 310, for NB-IoT UEs supporting small data transmission using AS context reuse, a release may carry an indication to suspend one or more radio bearers and to store a UE context.

[0061] Second portion 320 may relate to reception of an RRC Connection Release message by a UE. In second portion 320, if an RRC Connection Release message includes a UE Context Storage Indication and a UE Context ID, a UE may store UE context information and a UE Context Identity, and may consider the connection suspended.

[0062] In some embodiments, for NB-IoT UEs supporting small data transmission using AS context reuse, a release may carry an indication to suspend one or more radio bearers and store a UE context.

[0063] For some embodiments, if an RRC Connection Release message includes a UE Context Storage Indication and a UE Context ID, a UE may store the UE context information and the UE Context Identity, and may consider the connection suspended.

[0064] **Figs. 4A-4B** illustrates Abstract Syntax Notation (ASN) messages and Information Elements (IEs) for connection release procedures, in accordance with some embodiments of the disclosure. A set of ASN elements 400 may comprise a set of RRC Connection Release IEs 410, which may comprise a UE Context Storage Indication and/or a UE Context Identity 420. In some embodiments, the UE Context Identity may be a bit string, which may comprise 24 bits.

[0065] **Fig. 5** illustrates conditional definitions for connection release procedures, in accordance with some embodiments of the disclosure. A set of conditional definitions 500 may comprise a Suspend conditional 510. In some embodiments, Suspend conditional 510 may optionally be present (e.g., as a “Need ON”) when a UE Context Storage Indication is present. In some embodiments, Suspend conditional 510 may optionally not be present, and a UE may delete any existing value for the Suspend conditional 510 field.

[0066] **Fig. 6** illustrates connection request procedures to resume connections, in accordance with some embodiments of the disclosure. A procedure 600 may comprise a portion 610, which may relate to transmission of an RRC Connection Request message.

[0067] In portion 610, if a UE Context Identity is stored along with UE context information from a previous connection release, a UE may set various contents of an RRC Connection Request message. For example, in some embodiments, a UE may set a UE Identity to a received UE Context Identity. For some embodiments, a UE may set a short MAC-I to a least-significant 16 bits of a MAC-I. The MAC-I may be calculated over an ASN.1 encoded as per a Section 8 (e.g., as a multiple of 8 bits) VarShortMAC-Input. The MAC-I may be calculated with a K_{RRCint} key and integrity protection algorithm used in a source PCell. The MAC-I may be calculated with all input bits for COUNT, BEARER, and/or DIRECTION set to binary ones.

[0068] Notably, in some embodiments, upper layers may provide a System Architecture Evaluation (SAE) Temporary Mobile Subscriber Identity (S-TMSI) if a UE is registered in a Tracking Area (TA) of a current cell.

[0069] **Fig. 7** illustrates ASN messages and IEs for connection request procedures, in accordance with some embodiments of the disclosure. A set of ASN elements 700 may comprise an RRC Connection Request message 710, a set of RRC Connection Request IEs 720, and/or a UE Resume Identity 730.

[0070] In some embodiments, RRC Connection Request message 710 may relate to RRC Connection Request IEs 720 (and may also relate to one or more critical extension future IEs). RRC Connection Request IEs 720 may include a sequence comprising UE Resume Identity 730. In turn, UE Resume Identity 730 may include a sequence comprising a UE Context Identity and a short MAC-I.

[0071] **Fig. 8** illustrates a field definition for connection request procedures, in accordance with some embodiments of the disclosure. A set of field definitions 800 may comprise a UE Resume Identity 810. In some embodiments, UE Resume Identity 810 may be a 24-bit UE Identity. For some embodiments, UE Resume Identity 810 may comprise a combination of a UE identifier and a cell identifier, as determined by a network. In some embodiments, UE Resume Identity 810 may be included to facilitate contention resolution by lower layers, and may identify a UE and its stored context in a given cell and/or eNB.

[0072] **Fig. 9** illustrates connection setup procedures to respond to resumption requests, in accordance with some embodiments of the disclosure. A procedure 900 may comprise a portion 910, which may relate to reception of an RRC Connection Setup message by a UE. In portion 910, if a Resume Indication is included, a UE may consider a resume connection request to be successful, and may resume a suspended connection with its existing configuration.

[0073] Notably, in some embodiments, prior to portion 910, lower layer signaling may be used to allocate a Cell Radio Network Temporary Identifier (C-RNTI)

[0074] **Fig. 10** illustrates ASN messages and IEs for connection setup procedures, in accordance with some embodiments of the disclosure. A set of ASN elements 1000 may comprise a set of RRC Connection Setup IEs 1010. In some embodiments, a RRC Connection Setup IE's 1010 may include a sequence comprising a Resume Indication.

[0075] **Fig. 11** illustrates connection rejection procedures, in accordance with some embodiments of the disclosure. A procedure 1100 may comprise a portion 1110, which may relate to reception of an RRC Connection Reject message by a UE. In portion 1110, in some

embodiments, if a UE Resume Reject is included, a UE may delete a stored configuration and a UE Context Identity, and/or may initiate an RRC Connection Request procedure.

[0076] Notably, in some embodiments, a UE may store a deprioritisation request irrespective of any cell reselection absolute priority assignments (e.g., by dedicated signaling or by common signaling), and regardless of RRC connections in an Evolved Universal Mobile Telecommunication System (UMTS) Terrestrial Radio Access Network (E-UTRAN) or in another Radio Access Technology (RAT), unless otherwise specified.

[0077] **Figs. 12A-12B** illustrates ASN messages and IEs for connection rejection procedures, in accordance with some embodiments of the disclosure. A set of ASN elements 1200 may comprise a set of RRC Connection Reject IEs 1210.

[0078] In some embodiments, RRC Connection Reject IEs 1210 may include a sequence comprising a UE Resume Reject.

[0079] **Fig. 13** illustrates an eNB and a UE, in accordance with some embodiments of the disclosure. **Fig. 13** includes block diagrams of an eNB 1310 and a UE 1330 which are operable to co-exist with each other and other elements of an LTE network. High-level, simplified architectures of eNB 1310 and UE 1330 are described so as not to obscure the embodiments. It should be noted that in some embodiments, eNB 1310 may be a stationary non-mobile device.

[0080] eNB 1310 is coupled to one or more antennas 1305, and UE 1330 is similarly coupled to one or more antennas 1325. However, in some embodiments, eNB 1310 may incorporate or comprise antennas 1305, and UE 1330 in various embodiments may incorporate or comprise antennas 1325.

[0081] In some embodiments, antennas 1305 and/or antennas 1325 may comprise one or more directional or omni-directional antennas, including monopole antennas, dipole antennas, loop antennas, patch antennas, microstrip antennas, coplanar wave antennas, or other types of antennas suitable for transmission of RF signals. In some MIMO (multiple-input and multiple output) embodiments, antennas 1305 are separated to take advantage of spatial diversity.

[0082] eNB 1310 and UE 1330 are operable to communicate with each other on a network, such as a wireless network. eNB 1310 and UE 1330 may be in communication with each other over a wireless communication channel 1350, which has both a downlink path from eNB 1310 to UE 1330 and an uplink path from UE 1330 to eNB 1310.

[0083] As illustrated in **Fig. 13**, in some embodiments, eNB 1310 may include a physical layer circuitry 1312, a MAC (media access control) circuitry 1314, a processor 1316,

a memory 1318, and a hardware processing circuitry 1320. A person skilled in the art will appreciate that other components not shown may be used in addition to the components shown to form a complete eNB.

[0084] In some embodiments, physical layer circuitry 1312 includes a transceiver 1313 for providing signals to and from UE 1330. Transceiver 1313 provides signals to and from UEs or other devices using one or more antennas 1305. In some embodiments, MAC circuitry 1314 controls access to the wireless medium. Memory 1318 may be, or may include, a storage media/medium such as a magnetic storage media (e.g., magnetic tapes or magnetic disks), an optical storage media (e.g., optical discs), an electronic storage media (e.g., conventional hard disk drives, solid-state disk drives, or flash-memory-based storage media), or any tangible storage media or non-transitory storage media. Hardware processing circuitry 1320 may comprise logic devices or circuitry to perform various operations. In some embodiments, processor 1316 and memory 1318 are arranged to perform the operations of hardware processing circuitry 1320, such as operations described herein with reference to logic devices and circuitry within eNB 1310 and/or hardware processing circuitry 1320.

[0085] Accordingly, in some embodiments, eNB 1310 may be a device comprising an application processor, a memory, one or more antenna ports, and an interface for allowing the application processor to communicate with another device.

[0086] As is also illustrated in **Fig. 13**, in some embodiments, UE 1330 may include a physical layer circuitry 1332, a MAC circuitry 1334, a processor 1336, a memory 1338, a hardware processing circuitry 1340, a wireless interface 1342, and a display 1344. A person skilled in the art would appreciate that other components not shown may be used in addition to the components shown to form a complete UE.

[0087] In some embodiments, physical layer circuitry 1332 includes a transceiver 1333 for providing signals to and from eNB 1310 (as well as other eNBs). Transceiver 1333 provides signals to and from eNBs or other devices using one or more antennas 1325. In some embodiments, MAC circuitry 1334 controls access to the wireless medium. Memory 1338 may be, or may include, a storage media/medium such as a magnetic storage media (e.g., magnetic tapes or magnetic disks), an optical storage media (e.g., optical discs), an electronic storage media (e.g., conventional hard disk drives, solid-state disk drives, or flash-memory-based storage media), or any tangible storage media or non-transitory storage media. Wireless interface 1342 may be arranged to allow the processor to communicate with another device. Display 1344 may provide a visual and/or tactile display for a user to interact with UE 1330, such as a touch-screen display. Hardware processing circuitry 1340 may comprise

logic devices or circuitry to perform various operations. In some embodiments, processor 1336 and memory 1338 may be arranged to perform the operations of hardware processing circuitry 1340, such as operations described herein with reference to logic devices and circuitry within UE 1330 and/or hardware processing circuitry 1340.

[0088] Accordingly, in some embodiments, UE 1330 may be a device comprising an application processor, a memory, one or more antennas, a wireless interface for allowing the application processor to communicate with another device, and a touch-screen display.

[0089] Elements of **Fig. 13**, and elements of other figures having the same names or reference numbers, can operate or function in the manner described herein with respect to any such figures (although the operation and function of such elements is not limited to such descriptions). For example, **Fig. 14** also depicts embodiments of eNBs, hardware processing circuitry of eNBs, UEs, and/or hardware processing circuitry of UEs, and the embodiments described with respect to **Fig. 13** and **Fig. 14** can operate or function in the manner described herein with respect to any of the figures.

[0090] In addition, although eNB 1310 and UE 1330 are each described as having several separate functional elements, one or more of the functional elements may be combined and may be implemented by combinations of software-configured elements and/or other hardware elements. In some embodiments of this disclosure, the functional elements can refer to one or more processes operating on one or more processing elements. Examples of software and/or hardware configured elements include Digital Signal Processors (DSPs), one or more microprocessors, DSPs, Field-Programmable Gate Arrays (FPGAs), Application Specific Integrated Circuits (ASICs), Radio-Frequency Integrated Circuits (RFICs), and so on.

[0091] **Fig. 14** illustrates hardware processing circuitries for an eNB for new IDs incorporating UE IDs and cell IDs, in accordance with some embodiments of the disclosure. With reference to **Fig. 13**, an eNB may include various hardware processing circuitries discussed below (such as hardware processing circuitry 1400 of **Fig. 14**), which may in turn comprise logic devices and/or circuitry operable to perform various operations. For example, in **Fig. 13**, eNB 1310 (or various elements or components therein, such as hardware processing circuitry 1320, or combinations of elements or components therein) may include part of, or all of, these hardware processing circuitries.

[0092] In some embodiments, one or more devices or circuitries within these hardware processing circuitries may be implemented by combinations of software-configured elements and/or other hardware elements. For example, processor 1316 (and/or one or more

other processors which eNB 1310 may comprise), memory 1318, and/or other elements or components of eNB 1310 (which may include hardware processing circuitry 1320) may be arranged to perform the operations of these hardware processing circuitries, such as operations described herein with reference to devices and circuitry within these hardware processing circuitries. In some embodiments, processor 1316 (and/or one or more other processors which eNB 1310 may comprise) may be a baseband processor.

[0093] Returning to **Fig. 14**, an apparatus of eNB 1310 (or another eNB or base station), which may be operable to communicate with one or more UEs on a wireless network, may comprise hardware processing circuitry 1400. In some embodiments, hardware processing circuitry 1400 may comprise one or more antenna ports 1405 operable to provide various transmissions over a wireless communication channel (such as wireless communication channel 1350). Antenna ports 1405 may be coupled to one or more antennas 1407 (which may be antennas 1305). In some embodiments, hardware processing circuitry 1400 may incorporate antennas 1407, while in other embodiments, hardware processing circuitry 1400 may merely be coupled to antennas 1407.

[0094] Antenna ports 1405 and antennas 1407 may be operable to provide signals from an eNB to a wireless communications channel and/or a UE, and may be operable to provide signals from a UE and/or a wireless communications channel to an eNB. For example, antenna ports 1405 and antennas 1407 may be operable to provide transmissions from eNB 1310 to wireless communication channel 1350 (and from there to UE 1330, or to another UE). Similarly, antennas 1407 and antenna ports 1405 may be operable to provide transmissions from a wireless communication channel 1350 (and beyond that, from UE 1330, or another UE) to eNB 1310.

[0095] Hardware processing circuitry 1400 may comprise various circuitries operable in accordance with the various embodiments discussed herein. With reference to **Fig. 14**, hardware processing circuitry 1400 may comprise a first circuitry 1410, a second circuitry 1420, a third circuitry 1430, and/or a fourth circuitry 1440. First circuitry 1410 may be operable to store a resume identification comprising one or more UE identification bits for the UE and one or more cell identification bits. First circuitry 1410 may also be operable to store an AS context for the UE. Second circuitry 1420 may be operable to associate the resume identification with the AS context for the UE. First circuitry 1410 may communicate the resume identification to second circuitry 1420 over an interface 1412.

[0096] In some embodiments, the UE may be one of: a C-IoT capable UE, or a MTC capable UE. For some embodiments, the UE may be one of: a NB-IoT capable UE, or a 3GPP LTE capable UE.

[0097] In some embodiments, third circuitry 1430 may be operable to generate a RRC connection release message for the UE, the RRC connection release message carrying the resume identification. First circuitry 1410 may provide the resume identification to third circuitry 1430 via an interface 1413. For some embodiments, fourth circuitry 1440 may be operable to process a RRC connection request message carrying a second resume identification comprising one or more UE identification bits and one or more cell identification bits. Second circuitry 1420 may be operable to provide the resume identification to fourth circuitry 1440 via an interface 1425.

[0098] In some embodiments, the RRC connection request message may carry a short MAC-I value associated with at least one of: the resume identification, and the AS context. For some embodiments, the RRC connection request message may carry a critical extension for resumption of suspended connection.

[0099] In some embodiments, second circuitry 1420 may be operable to determine whether the second resume identification matches another stored resume identification. For some embodiments, third circuitry 1430 may be operable to generate an RRC connection setup message in response to the RRC connection request message, the RRC connection setup message carrying an indication of successful resumption of the AS context. In some embodiments, third circuitry 1430 may be operable to generate an RRC rejection request message in response to the RRC connection request message.

[00100] For some embodiments, second circuitry 1420 may be operable to delete the AS context, and third circuitry 1430 may be operable to communicate a connection-establishment failure to an upper layer. In some embodiments, second circuitry 1420 may be operable to delete the AS context, and third circuitry 1430 may be operable to send a service request procedure received from a NAS.

[00101] In some embodiments, first circuitry 1410, second circuitry 1420, third circuitry 1430, and/or fourth circuitry 1440 may be implemented as separate circuitries. In other embodiments, first circuitry 1410, second circuitry 1420, third circuitry 1430, and/or fourth circuitry 1440 may be combined and implemented together in a circuitry without altering the essence of the embodiments.

[00102] **Fig. 15** illustrates hardware processing circuitries for a UE for new IDs incorporating UE IDs and cell IDs, in accordance with some embodiments of the disclosure.

With reference to **Fig. 13**, a UE may include various hardware processing circuitries discussed below (such as hardware processing circuitry 1500 of **Fig. 15**), which may in turn comprise logic devices and/or circuitry operable to perform various operations. For example, in **Fig. 13**, UE 1330 (or various elements or components therein, such as hardware processing circuitry 1340, or combinations of elements or components therein) may include part of, or all of, these hardware processing circuitries.

[00103] In some embodiments, one or more devices or circuitries within these hardware processing circuitries may be implemented by combinations of software-configured elements and/or other hardware elements. For example, processor 1336 (and/or one or more other processors which UE 1330 may comprise), memory 1338, and/or other elements or components of UE 1330 (which may include hardware processing circuitry 1340) may be arranged to perform the operations of these hardware processing circuitries, such as operations described herein with reference to devices and circuitry within these hardware processing circuitries. In some embodiments, processor 1336 (and/or one or more other processors which UE 1330 may comprise) may be a baseband processor.

[00104] Returning to **Fig. 15**, an apparatus of UE 1330 (or another UE or mobile handset), which may be operable to communicate with one or more eNBs on a wireless network, may comprise hardware processing circuitry 1500. In some embodiments, hardware processing circuitry 1500 may comprise one or more antenna ports 1505 operable to provide various transmissions over a wireless communication channel (such as wireless communication channel 1350). Antenna ports 1505 may be coupled to one or more antennas 1507 (which may be antennas 1325). In some embodiments, hardware processing circuitry 1500 may incorporate antennas 1507, while in other embodiments, hardware processing circuitry 1500 may merely be coupled to antennas 1507.

[00105] Antenna ports 1505 and antennas 1507 may be operable to provide signals from a UE to a wireless communications channel and/or an eNB, and may be operable to provide signals from an eNB and/or a wireless communications channel to a UE. For example, antenna ports 1505 and antennas 1507 may be operable to provide transmissions from UE 1330 to wireless communication channel 1350 (and from there to eNB 1310, or to another eNB). Similarly, antennas 1507 and antenna ports 1505 may be operable to provide transmissions from a wireless communication channel 1350 (and beyond that, from eNB 1310, or another eNB) to UE 1330.

[00106] Hardware processing circuitry 1500 may comprise various circuitries operable in accordance with the various embodiments discussed herein. With reference to **Fig. 15**,

hardware processing circuitry 1500 may comprise a first circuitry 1510 and/or a second circuitry 1520. First circuitry 1510 may be operable to process a RRC connection release message from the eNB carrying a resume identification comprising one or more UE identification bits and one or more cell identification bits. Second circuitry 1520 may be operable to generate an RRC connection request message carrying the resume identification. First circuitry 1510 may provide the resume identification to second circuitry 1520 via an interface 1515.

[00107] In some embodiments, the UE may be one of: a C-IoT capable UE, or a MTC capable UE. For some embodiments, the UE may be one of: a NB-IoT capable UE, or a 3GPP LTE capable UE. In some embodiments, the RRC connection request message may carry a short MAC-I value associated with at least one of: the resume identification, and the AS context. For some embodiments, the RRC connection request message may carry a critical extension for resumption of suspended connection.

[00108] In some embodiments, first circuitry 1510 may be operable to process an RRC connection setup message corresponding to the RRC connection request message, the RRC connection setup message carrying an indication of successful resumption of the AS context and. For some embodiments, first circuitry 1510 may be operable to process an RRC rejection request message corresponding to the RRC connection request message.

[00109] In some embodiments, first circuitry 1510 and/or second circuitry 1520 may be implemented as separate circuitries. In other embodiments, first circuitry 1510 and second circuitry 1520 may be combined and implemented together in a circuitry without altering the essence of the embodiments.

[00110] **Fig. 16** illustrates methods for an eNB for new IDs incorporating UE IDs and cell IDs, in accordance with some embodiments of the disclosure. With reference to **Fig. 13**, various methods that may relate to eNB 1310 and hardware processing circuitry 1320 are discussed below. Although the actions in method 1600 of **Fig. 16** are shown in a particular order, the order of the actions can be modified. Thus, the illustrated embodiments can be performed in a different order, and some actions may be performed in parallel. Some of the actions and/or operations listed in **Fig. 16** are optional in accordance with certain embodiments. The numbering of the actions presented is for the sake of clarity and is not intended to prescribe an order of operations in which the various actions must occur. Additionally, operations from the various flows may be utilized in a variety of combinations.

[00111] Moreover, in some embodiments, machine readable storage media may have executable instructions that, when executed, cause eNB 1310 and/or hardware processing

circuitry 1320 to perform an operation comprising the methods of **Fig. 16**. Such machine readable storage media may include any of a variety of storage media, like magnetic storage media (e.g., magnetic tapes or magnetic disks), optical storage media (e.g., optical discs), electronic storage media (e.g., conventional hard disk drives, solid-state disk drives, or flash-memory-based storage media), or any other tangible storage media or non-transitory storage media.

[00112] In some embodiments, an apparatus may comprise means for performing various actions and/or operations of the methods of **Fig. 16**.

[00113] Returning to **Fig. 16**, various methods may be in accordance with the various embodiments discussed herein. A method 1600 may comprise a storing 1610, a storing 1615, and/or an associating 1620. Method 1600 may also comprise a generating 1630, a processing 1640, a determining 1650, a generating 1660, and/or a generating 1670.

[00114] In storing 1610, a resume identification comprising one or more UE identification bits for the UE and one or more cell identification bits may be stored. In storing 1615, an AS context for the UE may be stored. In associating 1620, the resume identification may be associated with the AS context for the UE.

[00115] In some embodiments, the UE may be one of: a C-IoT capable UE, or a MTC capable UE. For some embodiments, the UE may be one of: a NB-IoT capable UE, or a 3GPP LTE capable UE.

[00116] In generating 1630, an RRC connection release message may be generated for the UE, the RRC connection release message carrying the resume identification. In processing 1640, an RRC connection request message carrying a second resume identification comprising one or more UE identification bits and one or more cell identification bits may be processed.

[00117] In some embodiments, the RRC connection request message may carry a short MAC-I value associated with at least one of: the resume identification, and the AS context. For some embodiments, the RRC connection request message may carry a critical extension for resumption of suspended connection.

[00118] In determining 1650, whether the second resume identification matches another stored resume identification may be determined. In generating 1660, an RRC connection setup message carrying an indication of successful resumption of the AS context in response to the RRC connection request message may be generated.

[00119] In generating 1670, an RRC rejection request message may be generated in response to the RRC connection request message. For some embodiments, in a deleting, an

AS context may be deleted, and in a communicating, a connection-establishment failure may be communicated to an upper layer. In some embodiments, in a deleting, an AS context may be deleted, and in a sending, a service request procedure received from a NAS may be sent.

[00120] **Fig. 17** illustrates methods for a UE for new IDs incorporating UE IDs and cell IDs, in accordance with some embodiments of the disclosure. With reference to **Fig. 13**, methods that may relate to UE 1330 and hardware processing circuitry 1340 are discussed below. Although the actions in the method 1700 of **Fig. 17** are shown in a particular order, the order of the actions can be modified. Thus, the illustrated embodiments can be performed in a different order, and some actions may be performed in parallel. Some of the actions and/or operations listed in **Fig. 17** are optional in accordance with certain embodiments. The numbering of the actions presented is for the sake of clarity and is not intended to prescribe an order of operations in which the various actions must occur. Additionally, operations from the various flows may be utilized in a variety of combinations.

[00121] Moreover, in some embodiments, machine readable storage media may have executable instructions that, when executed, cause UE 1330 and/or hardware processing circuitry 1340 to perform an operation comprising the methods of **Fig. 17**. Such machine readable storage media may include any of a variety of storage media, like magnetic storage media (e.g., magnetic tapes or magnetic disks), optical storage media (e.g., optical discs), electronic storage media (e.g., conventional hard disk drives, solid-state disk drives, or flash-memory-based storage media), or any other tangible storage media or non-transitory storage media.

[00122] In some embodiments, an apparatus may comprise means for performing various actions and/or operations of the methods of **Fig. 17**.

[00123] Returning to **Fig. 17**, various methods may be in accordance with the various embodiments discussed herein. A method 1700 may comprise a processing 1710 and/or a generating 1715. Method 1700 may also comprise a processing 1720 and/or a processing 1730.

[00124] In processing 1710, a RRC connection release message from the eNB carrying a resume identification comprising one or more UE identification bits and one or more cell identification bits may be processed. In generating 1715, an RRC connection request message carrying the resume identification may be generated.

[00125] In some embodiments, the UE may be one of: a C-IoT capable UE, or a MTC capable UE. For some embodiments, the UE may be one of: a NB-IoT capable UE, or a 3GPP LTE capable UE. In some embodiments, the RRC connection request message may

carry a short MAC-I value associated with at least one of: the resume identification, and the AS context. For some embodiments, the RRC connection request message may carry a critical extension for resumption of suspended connection.

[00126] In processing 1720, an RRC connection setup message corresponding to the RRC connection request message may be processed, the RRC connection setup message carrying an indication of successful resumption of the AS context and. In processing 1730, an RRC rejection request message corresponding to the RRC connection request message may be processed.

[00127] **Fig. 18** illustrates example components of a UE device, in accordance with some embodiments of the disclosure. In some embodiments, a UE device 1800 may include application circuitry 1802, baseband circuitry 1804, Radio Frequency (RF) circuitry 1806, front-end module (FEM) circuitry 1808, a low-power wake-up receiver (LP-WUR), and one or more antennas 1810, coupled together at least as shown. In some embodiments, the UE device 1800 may include additional elements such as, for example, memory/storage, display, camera, sensor, and/or input/output (I/O) interface.

[00128] The application circuitry 1802 may include one or more application processors. For example, the application circuitry 1802 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) may include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors may be coupled with and/or may include memory/storage and may be configured to execute instructions stored in the memory/storage to enable various applications and/or operating systems to run on the system.

[00129] The baseband circuitry 1804 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 1804 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 1806 and to generate baseband signals for a transmit signal path of the RF circuitry 1806. Baseband processing circuitry 1804 may interface with the application circuitry 1802 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 1806. For example, in some embodiments, the baseband circuitry 1804 may include a second generation (2G) baseband processor 1804A, third generation (3G) baseband processor 1804B, fourth generation (4G) baseband processor 1804C, and/or other baseband processor(s) 1804D for other existing generations, generations in development or to be developed in the future (e.g., fifth generation (5G), 6G, etc.). The baseband circuitry 1804 (e.g., one or more of baseband

processors 1804A-D) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 1806. 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 1804 may include Fast-Fourier Transform (FFT), precoding, and/or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 1804 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.

[00130] In some embodiments, the baseband circuitry 1804 may include elements of a protocol stack such as, for example, elements of an EUTRAN protocol including, for example, physical (PHY), media access control (MAC), radio link control (RLC), packet data convergence protocol (PDCP), and/or RRC elements. A central processing unit (CPU) 1804E of the baseband circuitry 1804 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) 1804F. The audio DSP(s) 1804F may include elements for compression/decompression and echo cancellation and may include other suitable processing elements in other embodiments. Components of the baseband circuitry may be suitably combined in a single chip, a single chipset, or disposed on a same circuit board in some embodiments. In some embodiments, some or all of the constituent components of the baseband circuitry 1804 and the application circuitry 1802 may be implemented together such as, for example, on a system on a chip (SOC).

[00131] In some embodiments, the baseband circuitry 1804 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 1804 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 1804 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

[00132] RF circuitry 1806 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various

embodiments, the RF circuitry 1806 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 1806 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 1808 and provide baseband signals to the baseband circuitry 1804. RF circuitry 1806 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 1804 and provide RF output signals to the FEM circuitry 1808 for transmission.

[00133] In some embodiments, the RF circuitry 1806 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 1806 may include mixer circuitry 1806A, amplifier circuitry 1806B and filter circuitry 1806C. The transmit signal path of the RF circuitry 1806 may include filter circuitry 1806C and mixer circuitry 1806A. RF circuitry 1806 may also include synthesizer circuitry 1806D for synthesizing a frequency for use by the mixer circuitry 1806A of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 1806A of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 1808 based on the synthesized frequency provided by synthesizer circuitry 1806D. The amplifier circuitry 1806B may be configured to amplify the down-converted signals and the filter circuitry 1806C 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 1804 for further processing. In some embodiments, the output baseband signals may be zero-frequency baseband signals, although this is not a requirement. In some embodiments, mixer circuitry 1806A of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[00134] In some embodiments, the mixer circuitry 1806A of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 1806D to generate RF output signals for the FEM circuitry 1808. The baseband signals may be provided by the baseband circuitry 1804 and may be filtered by filter circuitry 1806C. The filter circuitry 1806C may include a low-pass filter (LPF), although the scope of the embodiments is not limited in this respect.

[00135] In some embodiments, the mixer circuitry 1806A of the receive signal path and the mixer circuitry 1806A 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 1806A of the receive signal path and the mixer

circuitry 1806A 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 1806A of the receive signal path and the mixer circuitry 1806A may be arranged for direct down-conversion and/or direct up-conversion, respectively. In some embodiments, the mixer circuitry 1806A of the receive signal path and the mixer circuitry 1806A of the transmit signal path may be configured for super-heterodyne operation.

[00136] 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 1806 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 1804 may include a digital baseband interface to communicate with the RF circuitry 1806.

[00137] 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.

[00138] In some embodiments, the synthesizer circuitry 1806D 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 1806D may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[00139] The synthesizer circuitry 1806D may be configured to synthesize an output frequency for use by the mixer circuitry 1806A of the RF circuitry 1806 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 1806D may be a fractional $N/N+1$ synthesizer.

[00140] In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although that is not a requirement. Divider control input may be provided by either the baseband circuitry 1804 or the applications processor 1802 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 1802.

[00141] Synthesizer circuitry 1806D of the RF circuitry 1806 may include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider may be a dual modulus divider (DMD) and the phase accumulator may be a digital

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

[00142] In some embodiments, synthesizer circuitry 1806D 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 1806 may include an IQ/polar converter.

[00143] FEM circuitry 1808 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 1810, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 1806 for further processing. FEM circuitry 1808 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 1806 for transmission by one or more of the one or more antennas 1810.

[00144] In some embodiments, the FEM circuitry 1808 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 1806). The transmit signal path of the FEM circuitry 1808 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 1806), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 1810).

[00145] In some embodiments, the UE 1800 comprises a plurality of power saving mechanisms. If the UE 1800 is in an RRC_Connected state, where it is still connected to the eNB as it expects to receive traffic shortly, then it may enter a state known as Discontinuous

Reception Mode (DRX) after a period of inactivity. During this state, the device may power down for brief intervals of time and thus save power.

[00146] If there is no data traffic activity for an extended period of time, then the UE 1800 may transition off to an RRC_Idle state, where it disconnects from the network and does not perform operations such as channel quality feedback, handover, etc. The UE 1800 goes into a very low power state and it performs paging where again it periodically wakes up to listen to the network and then powers down again. Since the device might not receive data in this state, in order to receive data, it should transition back to RRC_Connected state.

[00147] An additional power saving mode may allow a device to be unavailable to the network for periods longer than a paging interval (ranging from seconds to a few hours). During this time, the device is totally unreachable to the network and may power down completely. Any data sent during this time incurs a large delay and it is assumed the delay is acceptable.

[00148] In addition, in various embodiments, an eNB device may include components substantially similar to one or more of the example components of UE device 1800 described herein.

[00149] It is pointed out that elements of any of the Figures herein having the same reference numbers and/or names as elements of any other Figure herein may, in various embodiments, operate or function in a manner similar those elements of the other Figure (without being limited to operating or functioning in such a manner).

[00150] Reference in the specification to "an embodiment," "one embodiment," "some embodiments," or "other embodiments" means that a particular feature, structure, or characteristic described in connection with the embodiments is included in at least some embodiments, but not necessarily all embodiments. The various appearances of "an embodiment," "one embodiment," or "some embodiments" are not necessarily all referring to the same embodiments. If the specification states a component, feature, structure, or characteristic "may," "might," or "could" be included, that particular component, feature, structure, or characteristic is not required to be included. If the specification or claim refers to "a" or "an" element, that does not mean there is only one of the elements. If the specification or claims refer to "an additional" element, that does not preclude there being more than one of the additional element.

[00151] Furthermore, the particular features, structures, functions, or characteristics may be combined in any suitable manner in one or more embodiments. For example, a first embodiment may be combined with a second embodiment anywhere the particular features,

structures, functions, or characteristics associated with the two embodiments are not mutually exclusive.

[00152] While the disclosure has been described in conjunction with specific embodiments thereof, many alternatives, modifications and variations of such embodiments will be apparent to those of ordinary skill in the art in light of the foregoing description. For example, other memory architectures e.g., Dynamic RAM (DRAM) may use the embodiments discussed. The embodiments of the disclosure are intended to embrace all such alternatives, modifications, and variations as to fall within the broad scope of the appended claims.

[00153] In addition, well known power/ground connections to integrated circuit (IC) chips and other components may or may not be shown within the presented figures, for simplicity of illustration and discussion, and so as not to obscure the disclosure. Further, arrangements may be shown in block diagram form in order to avoid obscuring the disclosure, and also in view of the fact that specifics with respect to implementation of such block diagram arrangements are highly dependent upon the platform within which the present disclosure is to be implemented (i.e., such specifics should be well within purview of one skilled in the art). Where specific details (e.g., circuits) are set forth in order to describe example embodiments of the disclosure, it should be apparent to one skilled in the art that the disclosure can be practiced without, or with variation of, these specific details. The description is thus to be regarded as illustrative instead of limiting.

[00154] The following examples pertain to further embodiments. Specifics in the examples may be used anywhere in one or more embodiments. All optional features of the apparatus described herein may also be implemented with respect to a method or process.

[00155] Example 1 provides an apparatus of an Evolved Node B (eNB) operable to communicate with a User Equipment (UE) on a wireless network, comprising: a memory to store at least one of: a resume identification, or an access stratum (AS) context; and one or more processors to: store the resume identification comprising one or more UE identification bits for the UE and one or more cell identification bits; store the access stratum (AS) context for the UE; and associate the resume identification with the AS context for the UE

[00156] In example 2, the apparatus of example 1, wherein the UE is one of: a Cellular Internet-of-Things (C-IoT) capable UE, or a Machine-Type Communication (MTC) capable UE.

[00157] In example 3, the apparatus of example 1, wherein the UE is one of: a Narrow-Band Internet-of-Things (NB-IoT) capable UE, or a 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE) capable UE.

[00158] In example 4, the apparatus of any of examples 1 through 3, wherein the one or more processors are to: generate a Radio Resource Control (RRC) connection release message for the UE, the RRC connection release message carrying the resume identification.

[00159] In example 5, the apparatus of any of examples 1 through 4, wherein the one or more processors are to: process a Radio Resource Control (RRC) connection request message carrying a second resume identification comprising one or more UE identification bits and one or more cell identification bits.

[00160] In example 6, the apparatus of example 5, wherein the RRC connection request message carries a short MAC-I value associated with at least one of: the resume identification, and the AS context.

[00161] In example 7, the apparatus of either of examples 5 or 6, wherein the RRC connection request message carries a critical extension for resumption of suspended connection.

[00162] In example 8, the apparatus of any of examples 5 through 7, wherein the one or more processors are to: determine whether the second resume identification matches another stored resume identification.

[00163] In example 9, the apparatus of any of examples 5 through 8, wherein the one or more processors are to: generate an RRC connection setup message in response to the RRC connection request message, the RRC connection setup message carrying an indication of successful resumption of the AS context.

[00164] In example 10, the apparatus of any of examples 5 through 9, wherein the one or more processors are to: generate an RRC rejection request message in response to the RRC connection request message.

[00165] In example 11, the apparatus of any of examples 5 through 10, wherein the one or more processors are to: delete the AS context; and communicate a connection-establishment failure to an upper layer.

[00166] In example 12, the apparatus of any of examples 5 through 10, wherein the one or more processors are to: delete the AS context; and send a service request procedure received from a Non-Access Stratum (NAS).

[00167] Example 13 provides an Evolved Node B (eNB) device comprising an application processor, a memory, one or more antenna ports, and an interface for allowing the

application processor to communicate with another device, the eNB device including the apparatus of any of examples 1 through 12.

[00168] Example 14 provides a method comprising: storing a resume identification comprising one or more UE identification bits for the UE and one or more cell identification bits; storing an access stratum (AS) context for the UE; and associating the resume identification with the AS context for the UE

[00169] In example 15, the method of example 14, wherein the UE is one of: a Cellular Internet-of-Things (C-IoT) capable UE, or a Machine-Type Communication (MTC) capable UE.

[00170] In example 16, the method of example 14, wherein the UE is one of: a Narrow-Band Internet-of-Things (NB-IoT) capable UE, or a 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE) capable UE.

[00171] In example 17, the method of any of examples 14 through 16, comprising: generating a Radio Resource Control (RRC) connection release message for the UE, the RRC connection release message carrying the resume identification.

[00172] In example 18, the method of any of examples 14 through 17, comprising: processing a Radio Resource Control (RRC) connection request message carrying a second resume identification comprising one or more UE identification bits and one or more cell identification bits.

[00173] In example 19, the method of example 18, wherein the RRC connection request message carries a short MAC-I value associated with at least one of: the resume identification, and the AS context.

[00174] In example 20, the method of examples 18 or 19, wherein the RRC connection request message carries a critical extension for resumption of suspended connection.

[00175] In example 21, the method of any of examples 18 through 20, comprising: determining whether the second resume identification matches another stored resume identification.

[00176] In example 22, the method of any of examples 18 through 21, comprising: generating an RRC connection setup message carrying an indication of successful resumption of the AS context in response to the RRC connection request message.

[00177] In example 23, the method of any of examples 18 through 22, comprising: generating an RRC rejection request message in response to the RRC connection request message.

[00178] In example 24, the method of any of examples 18 through 22, comprising: deleting the AS context; and communicating a connection-establishment failure to an upper layer.

[00179] In example 25, the method of any of examples 18 through 22, comprising: deleting the AS context; and sending a service request procedure received from a Non-Access Stratum (NAS).

[00180] Example 26 provides machine readable storage media having machine executable instructions stored thereon that, when executed, cause one or more processors to perform a method according to method of any of examples 14 through 25.

[00181] Example 27 provides an apparatus of an Evolved Node B (eNB) operable to communicate with a User Equipment (UE) on a wireless network, comprising: means for storing a resume identification comprising one or more UE identification bits for the UE and one or more cell identification bits; means for storing an access stratum (AS) context for the UE; and means for associating the resume identification with the AS context for the UE

[00182] In example 28, the apparatus of example 27, wherein the UE is one of: a Cellular Internet-of-Things (C-IoT) capable UE, or a Machine-Type Communication (MTC) capable UE.

[00183] In example 29, the apparatus of example 27, wherein the UE is one of: a Narrow-Band Internet-of-Things (NB-IoT) capable UE, or a 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE) capable UE.

[00184] In example 30, the apparatus of any of examples 27 through 29, comprising: means for generating a Radio Resource Control (RRC) connection release message for the UE, the RRC connection release message carrying the resume identification.

[00185] In example 31, the apparatus of any of examples 27 through 30, comprising: means for processing a Radio Resource Control (RRC) connection request message carrying a second resume identification comprising one or more UE identification bits and one or more cell identification bits.

[00186] In example 32, the apparatus of example 31, wherein the RRC connection request message carries a short MAC-I value associated with at least one of: the resume identification, and the AS context.

[00187] In example 33, the apparatus of examples 31 or 32, wherein the RRC connection request message carries a critical extension for resumption of suspended connection.

[00188] In example 34, the apparatus of any of examples 31 through 33, comprising: means for determining whether the second resume identification matches another stored resume identification.

[00189] In example 35, the apparatus of any of examples 31 through 34, comprising: means for generating an RRC connection setup message carrying an indication of successful resumption of the AS context in response to the RRC connection request message.

[00190] In example 36, the apparatus of any of examples 31 through 35, comprising: means for generating an RRC rejection request message in response to the RRC connection request message.

[00191] In example 37, the apparatus of any of examples 31 through 35, comprising: means for deleting the AS context; and means for communicating a connection-establishment failure to an upper layer.

[00192] In example 38, the apparatus of any of examples 31 through 35, comprising: means for deleting the AS context; and means for sending a service request procedure received from a Non-Access Stratum (NAS).

[00193] Example 39 provides machine readable storage media having machine executable instructions that, when executed, cause one or more processors of an Evolved Node B (eNB) to perform an operation comprising: store a resume identification comprising one or more UE identification bits for the UE and one or more cell identification bits; store an access stratum (AS) context for the UE; and associate the resume identification with the AS context for the UE

[00194] In example 40, the machine readable storage media of example 39, wherein the UE is one of: a Cellular Internet-of-Things (C-IoT) capable UE, or a Machine-Type Communication (MTC) capable UE.

[00195] In example 41, the machine readable storage media of example 39, wherein the UE is one of: a Narrow-Band Internet-of-Things (NB-IoT) capable UE, or a 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE) capable UE.

[00196] In example 42, the machine readable storage media of any of examples 39 through 41, the operation comprising: generate a Radio Resource Control (RRC) connection release message for the UE, the RRC connection release message carrying the resume identification.

[00197] In example 43, the machine readable storage media of any of examples 39 through 42, the operation comprising: process a Radio Resource Control (RRC) connection

request message carrying a second resume identification comprising one or more UE identification bits and one or more cell identification bits.

[00198] In example 44, the machine readable storage media of example 43, wherein the RRC connection request message carries a short MAC-I value associated with at least one of: the resume identification, and the AS context.

[00199] In example 45, the machine readable storage media of examples 43 or 44, wherein the RRC connection request message carries a critical extension for resumption of suspended connection.

[00200] In example 46, the machine readable storage media of any of examples 43 through 45, the operation comprising: determine whether the second resume identification matches another stored resume identification.

[00201] In example 47, the machine readable storage media of any of examples 43 through 46, the operation comprising: generate an RRC connection setup message carrying an indication of successful resumption of the AS context in response to the RRC connection request message.

[00202] In example 48, the machine readable storage media of any of examples 43 through 47, the operation comprising: generate an RRC rejection request message in response to the RRC connection request message.

[00203] In example 49, the machine readable storage media of any of examples 43 through 47, the operation comprising: delete the AS context; and communicate a connection-establishment failure to an upper layer.

[00204] In example 50, the machine readable storage media of any of examples 43 through 47, the operation comprising: delete the AS context; and send a service request procedure received from a Non-Access Stratum (NAS).

[00205] Example 51 provides an apparatus of a User Equipment (UE) operable to communicate with an Evolved Node B (eNB) on a wireless network, comprising: one or more processors to: process a Radio Resource Control (RRC) connection release message from the eNB carrying a resume identification comprising one or more UE identification bits and one or more cell identification bits; and generate an RRC connection request message carrying the resume identification.

[00206] In example 52, the apparatus of example 51, wherein the UE is one of: a Cellular Internet-of-Things (C-IoT) capable UE, or a Machine-Type Communication (MTC) capable UE.

[00207] In example 53, the apparatus of example 51, wherein the UE is one of: a Narrow-Band Internet-of-Things (NB-IoT) capable UE, or a 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE) capable UE.

[00208] In example 54, the apparatus of any of examples 51 through 53, wherein the RRC connection request message carries a short MAC-I value associated with at least one of: the resume identification, and the AS context.

[00209] In example 55, the apparatus of any of examples 51 through 54, wherein the RRC connection request message carries a critical extension for resumption of suspended connection.

[00210] In example 56, the apparatus of any of examples 51 through 55, wherein the one or more processors are to: process an RRC connection setup message corresponding to the RRC connection request message, the RRC connection setup message carrying an indication of successful resumption of the AS context and.

[00211] In example 57, the apparatus of any of examples 51 through 56, wherein the one or more processors are to: process an RRC rejection request message corresponding to the RRC connection request message.

[00212] Example 58 provides a User Equipment (UE) device comprising an application processor, a memory, one or more antennas, a wireless interface for allowing the application processor to communicate with another device, and a touch-screen display, the UE device including the apparatus of any of examples 51 through 57.

[00213] Example 59 provides a method comprising: processing a Radio Resource Control (RRC) connection release message from the eNB carrying a resume identification comprising one or more UE identification bits and one or more cell identification bits; and generating an RRC connection request message carrying the resume identification.

[00214] In example 60, the method of example 59, wherein the UE is one of: a Cellular Internet-of-Things (C-IoT) capable UE, or a Machine-Type Communication (MTC) capable UE.

[00215] In example 61, the method of example 59, wherein the UE is one of: a Narrow-Band Internet-of-Things (NB-IoT) capable UE, or a 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE) capable UE. 62, the method of any of examples 59 through 61, wherein the RRC connection request message carries a short MAC-I value associated with at least one of: the resume identification, and the AS context.

[00216] In example 63, the method of any of examples 59 through 62, wherein the RRC connection request message carries a critical extension for resumption of suspended connection.

[00217] In example 64, the method of any of examples 59 through 63, comprising: processing an RRC connection setup message corresponding to the RRC connection request message, the RRC connection setup message carrying an indication of successful resumption of the AS context and.

[00218] In example 65, the method of any of examples 59 through 64, comprising: processing an RRC rejection request message corresponding to the RRC connection request message.

[00219] Example 66 provides machine readable storage media having machine executable instructions stored thereon that, when executed, cause one or more processors to perform a method according to any of examples 59 through 65.

[00220] Example 67 provides an apparatus of a User Equipment (UE) operable to communicate with an Evolved Node B (eNB) on a wireless network, comprising: means for processing a Radio Resource Control (RRC) connection release message from the eNB carrying a resume identification comprising one or more UE identification bits and one or more cell identification bits; and means for generating an RRC connection request message carrying the resume identification.

[00221] In example 68, the apparatus of example 67, wherein the UE is one of: a Cellular Internet-of-Things (C-IoT) capable UE, or a Machine-Type Communication (MTC) capable UE.

[00222] In example 69, the apparatus of example 67, wherein the UE is one of: a Narrow-Band Internet-of-Things (NB-IoT) capable UE, or a 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE) capable UE. 70, the apparatus of any of examples 67 through 69, wherein the RRC connection request message carries a short MAC-I value associated with at least one of: the resume identification, and the AS context.

[00223] In example 71, the apparatus of any of examples 67 through 70, wherein the RRC connection request message carries a critical extension for resumption of suspended connection.

[00224] In example 72, the apparatus of any of examples 67 through 71, comprising: means for processing an RRC connection setup message corresponding to the RRC connection request message, the RRC connection setup message carrying an indication of successful resumption of the AS context and.

[00225] In example 73, the apparatus of any of examples 67 through 72, comprising: means for processing an RRC rejection request message corresponding to the RRC connection request message.

[00226] Example 74 provides machine readable storage media having machine executable instructions that, when executed, cause one or more processors of a User Equipment (UE) to perform an operation comprising: process a Radio Resource Control (RRC) connection release message from the eNB carrying a resume identification comprising one or more UE identification bits and one or more cell identification bits; and generate an RRC connection request message carrying the resume identification.

[00227] In example 75, the machine readable storage media of example 74, wherein the UE is one of: a Cellular Internet-of-Things (C-IoT) capable UE, or a Machine-Type Communication (MTC) capable UE.

[00228] In example 76, the machine readable storage media of example 74, wherein the UE is one of: a Narrow-Band Internet-of-Things (NB-IoT) capable UE, or a 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE) capable UE. 77, the machine readable storage media of any of examples 74 through 76, wherein the RRC connection request message carries a short MAC-I value associated with at least one of: the resume identification, and the AS context.

[00229] In example 78, the machine readable storage media of any of examples 74 through 77, wherein the RRC connection request message carries a critical extension for resumption of suspended connection.

[00230] In example 79, the machine readable storage media of any of examples 74 through 78, the operation comprising: process an RRC connection setup message corresponding to the RRC connection request message, the RRC connection setup message carrying an indication of successful resumption of the AS context and.

[00231] In example 80, the machine readable storage media of any of examples 74 through 79, the operation comprising: process an RRC rejection request message corresponding to the RRC connection request message.

[00232] In example 81, the apparatus of any of examples 1 through 12, and 51 through 57, wherein the one or more processors comprise a baseband processor.

[00233] In example 82, the apparatus of any of examples 1 through 12, and 51 through 57, comprising a transceiver circuitry for at least one of: generating transmissions, encoding transmissions, processing transmissions, or decoding transmissions.

[00234] In example 83, the apparatus of any of examples 1 through 12, and 51 through 57, comprising a transceiver circuitry for generating transmissions and processing transmissions.

[00235] An abstract is provided that will allow the reader to ascertain the nature and gist of the technical disclosure. The abstract is submitted with the understanding that it will not be used to limit the scope or meaning of the claims. The following claims are hereby incorporated into the detailed description, with each claim standing on its own as a separate embodiment.

CLAIMS

We claim:

1. An apparatus of an Evolved Node-B (eNB) operable to communicate with a User Equipment (UE) on a wireless network, comprising:
 - a memory to store at least one of: a resume identification, or an access stratum (AS) context; and
 - one or more processors to:
 - store the resume identification comprising one or more UE identification bits for the UE and one or more cell identification bits;
 - store the access stratum (AS) context for the UE; and
 - associate the resume identification with the AS context for the UE
2. The apparatus of claim 1,
 - wherein the UE is one of: a Cellular Internet-of-Things (C-IoT) capable UE, or a Machine-Type Communication (MTC) capable UE.
3. The apparatus of either of claims 1 or 2, wherein the one or more processors are to:
 - generate a Radio Resource Control (RRC) connection release message for the UE, the RRC connection release message carrying the resume identification.
4. The apparatus of either of claims 1 or 2, wherein the one or more processors are to:
 - process a Radio Resource Control (RRC) connection request message carrying a second resume identification comprising one or more UE identification bits and one or more cell identification bits.
5. The apparatus of claim 4,
 - wherein the RRC connection request message carries a short MAC-I value associated with at least one of: the resume identification, and the AS context.
6. The apparatus of claim 4,
 - wherein the RRC connection request message carries a critical extension for resumption of suspended connection.

7. Machine readable storage media having machine executable instructions that, when executed, cause one or more processors of an Evolved Node-B (eNB) to perform an operation comprising:
 - store a resume identification comprising one or more UE identification bits for the UE and one or more cell identification bits;
 - store an access stratum (AS) context for the UE; and
 - associate the resume identification with the AS context for the UE
8. The machine readable storage media of claim 7,
 - wherein the UE is one of: a Cellular Internet-of-Things (C-IoT) capable UE, or a Machine-Type Communication (MTC) capable UE.
9. The machine readable storage media of either of claims 7 or 8, the operation comprising:
 - generate a Radio Resource Control (RRC) connection release message for the UE, the RRC connection release message carrying the resume identification.
10. The machine readable storage media of either of claims 7 or 8, the operation comprising:
 - process a Radio Resource Control (RRC) connection request message carrying a second resume identification comprising one or more UE identification bits and one or more cell identification bits.
11. The machine readable storage media of claim 10,
 - wherein the RRC connection request message carries a short MAC-I value associated with at least one of: the resume identification, and the AS context.
12. The machine readable storage media of claim 10,
 - wherein the RRC connection request message carries a critical extension for resumption of suspended connection.
13. An apparatus of a User Equipment (UE) operable to communicate with an Evolved Node-B (eNB) on a wireless network, comprising:
 - one or more processors to:

process a Radio Resource Control (RRC) connection release message from the eNB carrying a resume identification comprising one or more UE identification bits and one or more cell identification bits; and
generate an RRC connection request message carrying the resume identification.

14. The apparatus of claim 13,
wherein the UE is one of: a Cellular Internet-of-Things (C-IoT) capable UE, or a Machine-Type Communication (MTC) capable UE.
15. The apparatus of either of claims 13 or 14,
wherein the RRC connection request message carries a short MAC-I value associated with at least one of: the resume identification, and the AS context.
16. The apparatus of either of claims 13 or 14,
wherein the RRC connection request message carries a critical extension for resumption of suspended connection.
17. The apparatus of either of claims 13 or 14, wherein the one or more processors are to:
process an RRC connection setup message corresponding to the RRC connection request message, the RRC connection setup message carrying an indication of successful resumption of the AS context and.
18. The apparatus of either of claims 13 or 14, wherein the one or more processors are to:
process an RRC rejection request message corresponding to the RRC connection request message.
19. Machine readable storage media having machine executable instructions that, when executed, cause one or more processors of a User Equipment (UE) to perform an operation comprising:
process a Radio Resource Control (RRC) connection release message from the eNB carrying a resume identification comprising one or more UE identification bits and one or more cell identification bits; and
generate an RRC connection request message carrying the resume identification.

20. The machine readable storage media of claim 19,
wherein the UE is one of: a Cellular Internet-of-Things (C-IoT) capable UE, or a
Machine-Type Communication (MTC) capable UE.
21. The machine readable storage media of either of claims 19 or 20,
wherein the RRC connection request message carries a short MAC-I value associated
with at least one of: the resume identification, and the AS context.
22. The machine readable storage media of either of claims 19 or 20,
wherein the RRC connection request message carries a critical extension for
resumption of suspended connection.
23. The machine readable storage media of either of claims 19 or 20, the operation
comprising:
process an RRC connection setup message corresponding to the RRC connection
request message, the RRC connection setup message carrying an indication of
successful resumption of the AS context and.
24. The machine readable storage media of either of claims 19 or 20, the operation
comprising:
process an RRC rejection request message corresponding to the RRC connection
request message.

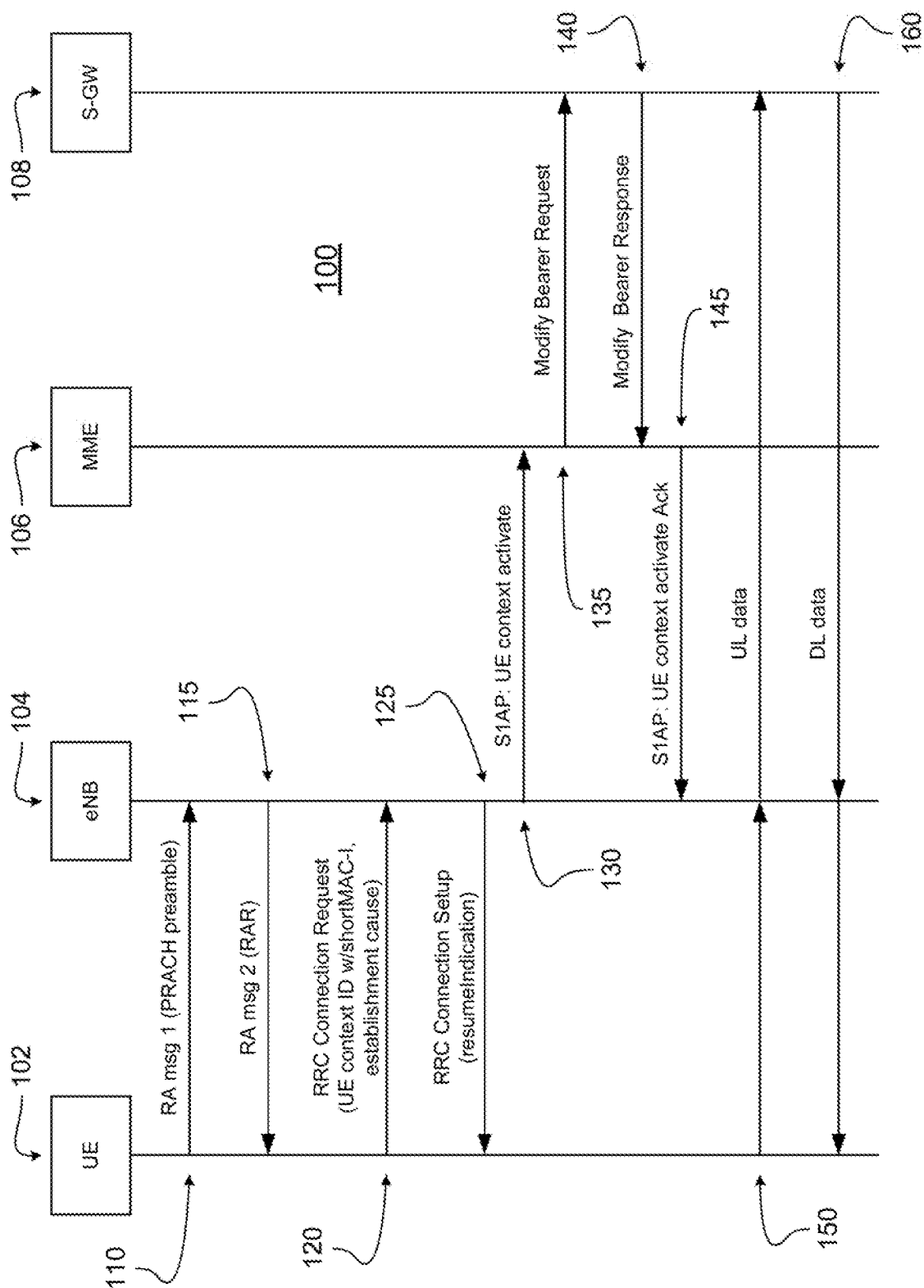


Fig. 1

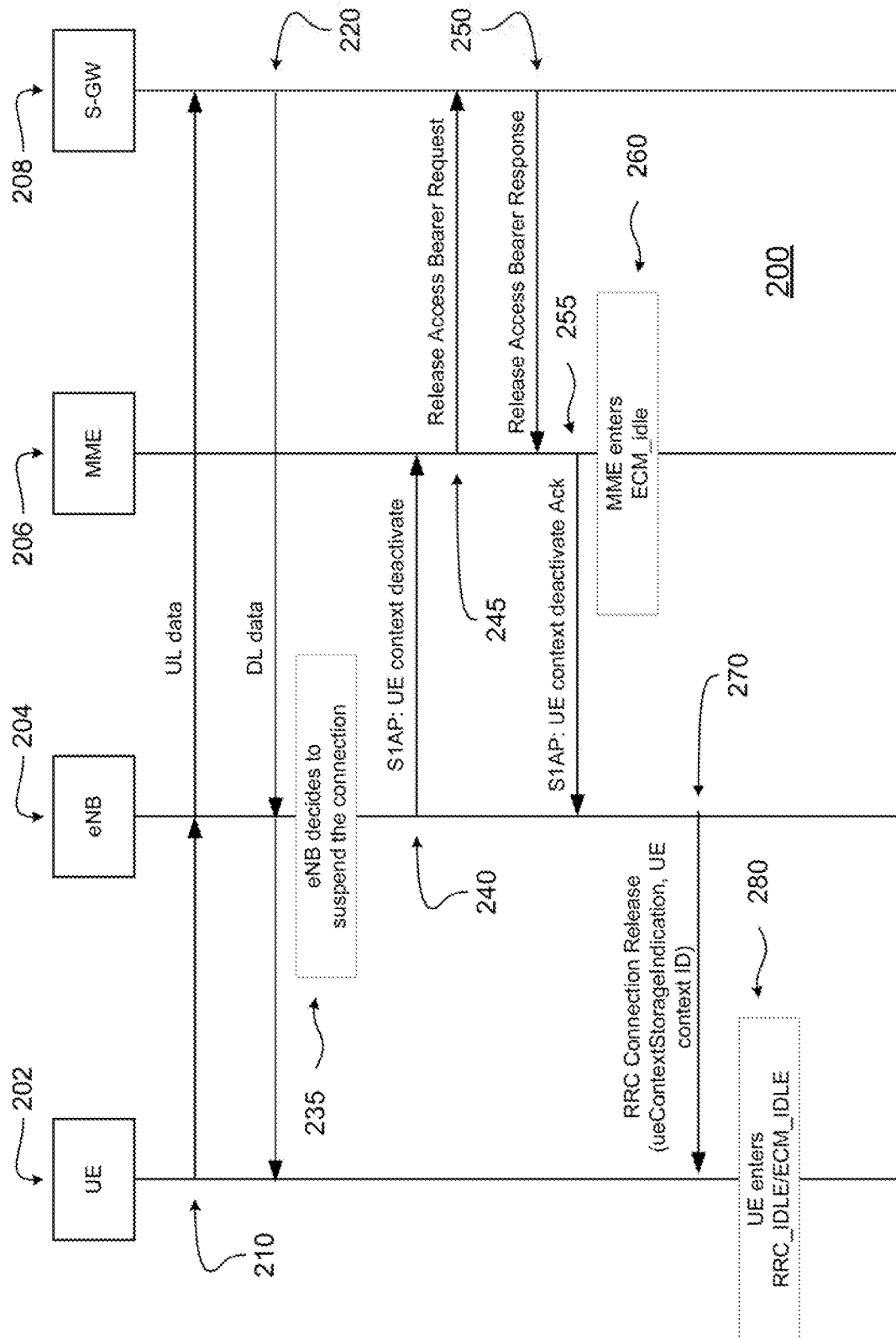


Fig. 2

5.3.8.1 General

The purpose of this procedure is to release the RRC connection, which includes the release of the established radio bearers as well as all radio resources. For NB-IOT UEs supporting small data transmission using AS context reuse, the release could carry an indication to suspend the radio bearers and store the UE context.

5.3.8.2 Initiation

E-UTRAN initiates the RRC connection release procedure to a UE in RRC_CONNECTED.

5.3.8.3 Reception of the RRCConnectionRelease by the UE

The UE shall:

- 1> delay the following actions defined in this sub-clause 60 ms from the moment the *RRCConnectionRelease* message was received or optionally when lower layers indicate that the receipt of the *RRCConnectionRelease* message has been successfully acknowledged, whichever is earlier;
- 1> if the *RRCConnectionRelease* message includes the *UEContextStorageIndication* and *UE Context ID*:
 - 2> store the UE context information, the *UEContextIdentity* and consider the connection suspended;
- 1> else if the *RRCConnectionRelease* message includes the *idleModeMobilityControlInfo*:
 - 2> store the cell reselection priority information provided by the *idleModeMobilityControlInfo*;
 - 2> if the *t320* is included:
 - 3> start timer T320, with the timer value set according to the value of *t320*;
- 1> else:
 - 2> apply the cell reselection priority information broadcast in the system information;

– RRCConnectionRelease

The *RRCConnectionRelease* message is used to command the release of an RRC connection.

Signalling radio bearer: SRB1
 RLC-SAP: AM
 Logical channel: DCCH
 Direction: E-UTRAN to UE

300

Fig. 3

RRCConnectionRelease message400

```

-- ASN1START

RRCConnectionRelease ::=
  rrc-TransactionIdentifier
  criticalExtensions
  c1 rrcConnectionRelease-r8
  },
  criticalExtensionsFuture
  }
}

RRCConnectionRelease-r8-IEs ::=
  releaseCause
  redirectedCarrierInfo
  idleModeMobilityControlInfo
  nonCriticalExtension
  }

RRCConnectionRelease-v890-IEs ::=
  SEQUENCE {
    releaseCause,
    redirectedCarrierInfo
    IdleModeMobilityControlInfo
    RRCConnectionRelease-v890-IEs
  }
  -- Need ON
  -- Need OF

RRCConnectionRelease-v9a0-IEs ::=
  lateNonCriticalExtension
  nonCriticalExtension
  }

RRCConnectionRelease-v9a0-IEs ::=
  SEQUENCE {
    OCTET STRING (CONTAINING RRCConnectionRelease-v9a0-IEs)
    RRCConnectionRelease-v920-IEs
  }
  OPTIONAL,
  OPTIONAL

-- Late non critical extensions
RRCConnectionRelease-v9a0-IEs ::=
  redirectedCarrierInfo-v9a0
  idleModeMobilityControlInfo-v9a0
  nonCriticalExtension
  }
  SEQUENCE {
    redirectedCarrierInfo-v9a0
    IdleModeMobilityControlInfo-v9a0
    SEQUENCE {
      RRCConnectionRelease-v9a0-IEs
    }
  }
  -- Cond NoRedirect-r8
  -- Cond IdleInfoEUTRA
  ...

```

Fig. 4A

RRCConnectionRelease message (cont'd)

```

...
-- Regular non critical extensions
RRCConnectionRelease-v920-IEs ::=
    cellInfoList-r9
        geran-r9
        utra-FDD-r9
        utra-TDD-r9
        ...
        utra-TDD-r10
    }
    nonCriticalExtension
}

RRCConnectionRelease-v1020-IEs ::=
    extendedWaitTime-r10
    nonCriticalExtension
}

RRCConnectionRelease-v13x0-IEs ::=
    ueContextStorageIndication-r13
    ueContextIdentity-r13
    nonCriticalExtension
}

...
UEContextIdentity-r13 ::=
    BIT STRING (SIZE (24))
    ---- ASN1STOP

```

410

400

420

Fig. 4B

500

Conditional presence	Explanation
<i>EARFCN-max</i>	The field is mandatory present if the corresponding <i>carrierFreq</i> (i.e. without suffix) is set to <i>maxEARFCN</i> . Otherwise the field is not present.
<i>IdleInfoEUTRA</i>	The field is optionally present, need OP, if the <i>IdleModeMobilityControlInfo</i> (i.e. without suffix) is included and includes <i>freqPriorityListEUTRA</i> ; otherwise the field is not present.
<i>NoRedirect-r8</i>	The field is optionally present, need OP, if the <i>redirectedCarrierInfo</i> (i.e. without suffix) is not included; otherwise the field is not present.
<i>Redirection</i>	The field is optionally present, need ON, if the <i>redirectedCarrierInfo</i> is included and set to <i>geran</i> , <i>utra-FDD</i> , <i>utra-TDD</i> or <i>utra-TDD-r10</i> ; otherwise the field is not present.
<i>Suspend</i>	The field is optionally present, Need ON, when <i>ueContextStorageIndication</i> is present. Otherwise it is not present and UE shall delete any existing value for this field.

510

Fig. 5

5.3.3.3 Actions related to transmission of *RRCCConnectionRequest* message
 The UE shall set the contents of *RRCCConnectionRequest* message as follows:

600

- 1> if *UEContextIdentity* was stored along with UE context information from previous connection release:
 - 2> set the *ue-Identity* to the received *UEContextIdentity*
 - 2> set the *shortMAC-I* to the 16 least significant bits of the MAC-I calculated:
 - 3> over the ASN.1 encoded as per section 8 (i.e., a multiple of 8 bits) *VarShortMAC-Input*;
 - 3> with the K_{RRCint} key and integrity protection algorithm that was used in the source PCell; and
 - 3> with all input bits for COUNT, BEARER and DIRECTION set to binary ones;
- 1> else set the *ue-Identity* as follows:
 - 2> if upper layers provide an S-TMSI:
 - 3> set the *ue-Identity* to the value received from upper layers;
 - 2> else:
 - 3> draw a random value in the range $0 \dots 2^{40} - 1$ and set the *ue-Identity* to this value;
 - 1> set the *establishmentCause* in accordance with the information received from upper layers;

610

The UE shall submit the *RRCCConnectionRequest* message to lower layers for transmission.

- *RRCCConnectionRequest*
- The *RRCCConnectionRequest* message is used to request the establishment of an RRC connection.
 - Signalling radio bearer: SRB0
 - RLC-SAP: TM
 - Logical channel: CCCH
 - Direction: UE to E-UTRAN

Fig. 6

RRCConnectionRequest message700

```

-- ASN1START
RRCConnectionRequest ::=
    criticalExtensions
        rrcConnectionRequest-r8
        criticalExtensionsFuture
            rrcConnectionRequest-r13
            criticalExtensionsFuture-r13
        )
    )
RRCConnectionRequest-r8-IEs ::=
    ue-Identity
    establishmentCause
    spare
    )
RRCConnectionRequest-r13-IEs ::=
    SEQUENCE {
        InitialUE-Identity,
        EstablishmentCause,
        BIT STRING (SIZE (1))
    }
RRCConnectionRequest-r13-IEs ::=
    ue-resumeIdentity-r13
    establishmentCause-r13
    spare
    )
InitialUE-Identity ::=
    s-TMSI
    randomValue
    )
EstablishmentCause ::=
    CHOICE {
        s-TMSI,
        BIT STRING (SIZE (40))
    }
ENUMERATED {
    emergency, highPriorityAccess, mt-Access, mo-Signalling,
    mo-Data, delayTolerantAccess-v1020, mo-VoiceCall-v1260, spare1
}
UE-ResumeIdentity-r13 ::=
    ueContextIdentity-r13
    shortMAC-I-r13
    )
-- ASN1STOP

```

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720

730

Fig. 7

800

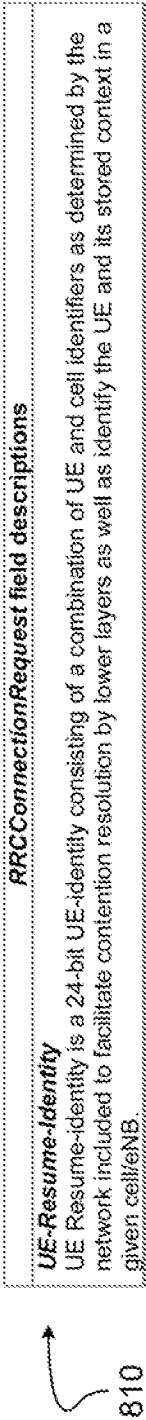


Fig. 8

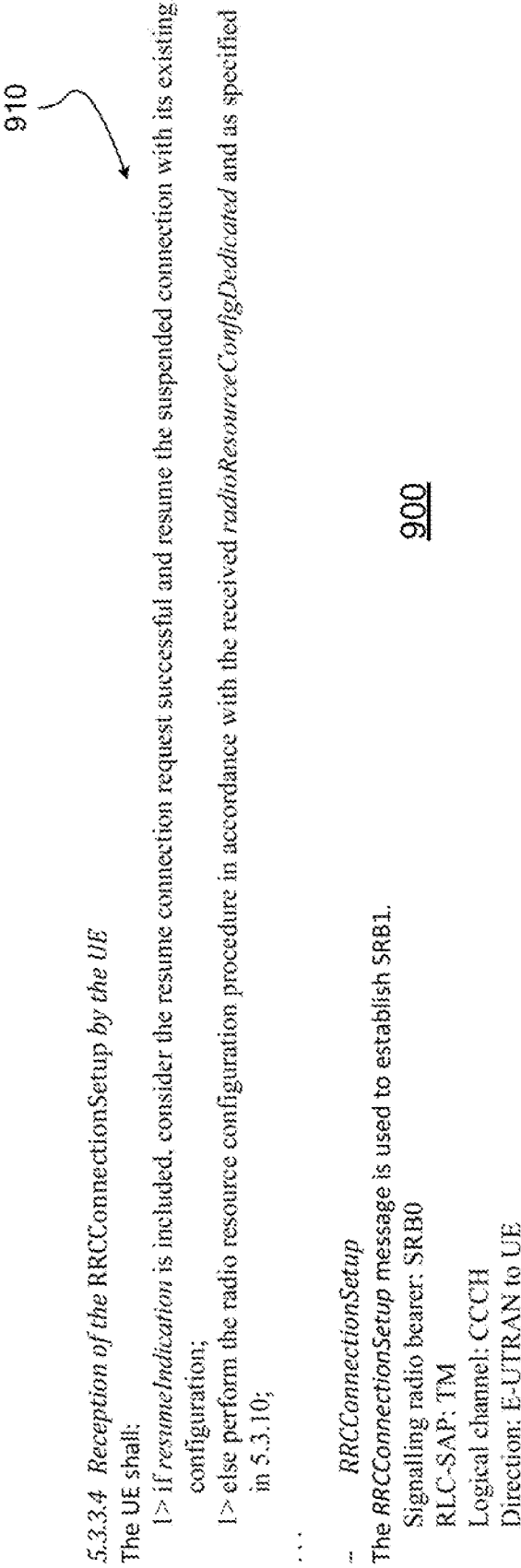


Fig. 9

RRCConnectionSetup message1000

```

-- ASN1START

RRCConnectionSetup ::=
  rrc-TransactionIdentifier
  criticalExtensions
  c1
    rrcConnectionSetup-r8
    spare7 NULL,
    spare6 NULL, spare5 NULL, spare4 NULL,
    spare3 NULL, spare2 NULL, spare1 NULL
  },
  criticalExtensionsFuture
  SEQUENCE {}
}

RRCConnectionSetup-r8-IEs ::=
  radioResourceConfigDedicated
  nonCriticalExtension
  SEQUENCE {
    radioResourceConfigDedicated,
    RRCConnectionSetup-v8a0-IEs
  } OPTIONAL

RRCConnectionSetup-v8a0-IEs ::=
  lateNonCriticalExtension
  nonCriticalExtension
  SEQUENCE {
    OCTET STRING
    RRCConnectionSetup-v13x0-IEs
  } OPTIONAL,
  OPTIONAL

RRCConnectionSetup-v13x0-IEs ::=
  resumeIndication-r13
  nonCriticalExtension
  SEQUENCE {
    ENUMERATED {true}
    SEQUENCE {}
  } OPTIONAL,
  OPTIONAL

-- ASN1STOP

```

1010

--- Need ON

Fig. 10

5.3.3.8 Reception of the RRCConnectionReject by the UE

The UE shall:

- 1> stop timer T300;
- 1> reset MAC and release the MAC configuration;
- 1> start timer T302, with the timer value set to the *waitTime*;
- 1> if the *extendedWaitTime* is present and the UE supports delay tolerant access:
 - 2> forward the *extendedWaitTime* to upper layers;
- 1> if *deprioritisationReq* is included and the UE supports RRC Connection Reject with deprioritisation:
 - 2> start or restart timer T325 with the timer value set to the *deprioritisationTimer* signalled;
- 1> store the *deprioritisationReq* until T325 expiry;
- 1> if ue-resumeReject is included:
 - 2> delete the stored configuration and *UEContextIdentity*
 - 2> initiate the *RRCConnectionRequest* procedure in accordance with 5.3.3.3;
- 1> inform upper layers about the failure to establish the RRC connection and that access barring for mobile originating calls, mobile originating signalling, mobile terminating access and mobile originating CS fallback is applicable, upon which the procedure ends;

– *RRCConnectionReject*

The *RRCConnectionReject* message is used to reject the RRC connection establishment.

Signalling radio bearer: SRB0

RLC-SAP: TM

Logical channel: CCCH

Direction: E-UTRAN to UE

Fig. 11

RRCConnectionReject message

1200

```
-- ASN1START
RRCConnectionReject ::=
  criticalExtensions
    c1
      rrcConnectionReject-r8
      rrcConnectionReject-r13
    },
    criticalExtensionsFuture
      SEQUENCE {}
  }
RRCConnectionReject-r8-IEs ::=
  waitTime
  nonCriticalExtension
  SEQUENCE {
    INTEGER (1..16),
    RRCConnectionReject-v8a0-IEs OPTIONAL
  }
RRCConnectionReject-v8a0-IEs ::=
  lateNonCriticalExtension
  nonCriticalExtension
  SEQUENCE2 {
    OCTET STRING
    RRCConnectionReject-v1020-IEs OPTIONAL,
    OPTIONAL
  }
...
```

Fig. 12A

RRCConnectionReject message (cont'd)

```

...
RRCConnectionReject-v1020-IEs ::=
    extendedWaitTime-r10
    nonCriticalExtension
}

RRCConnectionReject-v1130-IEs ::=
    deprioritisationReq-r11
    deprioritisationType-r11
    deprioritisationTimer-r11
}
nonCriticalExtension
}

RRCConnectionReject-r13-IEs ::=
    ue-resumeReject-r13
    nonCriticalExtension
}
-- ASN1STOP

```

--- Need ON

OPTIONAL,
OPTIONAL

OPTIONAL,
OPTIONAL

OPTIONAL,
OPTIONAL

OPTIONAL

1210

1200

Fig. 12B

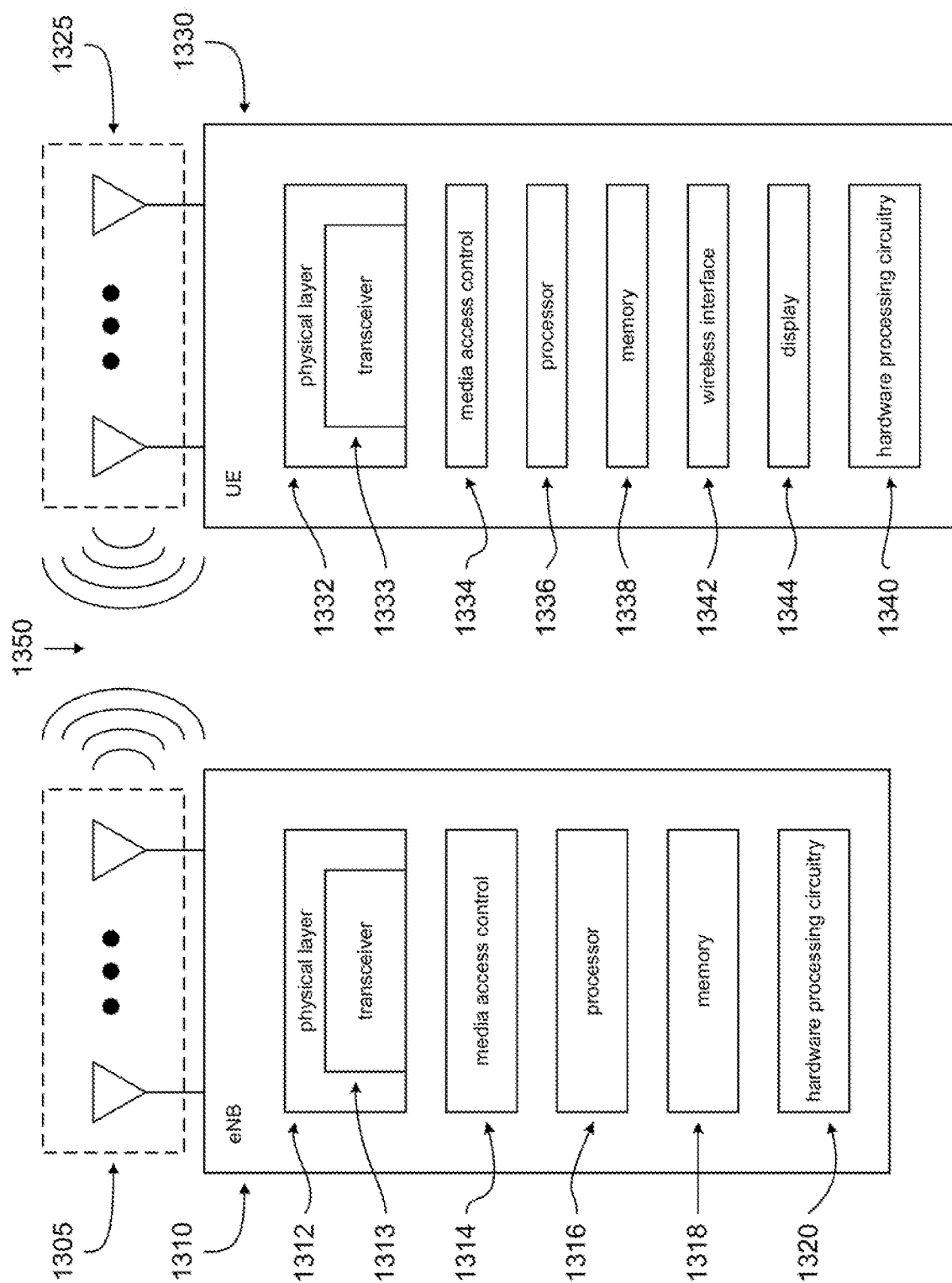


Fig. 13

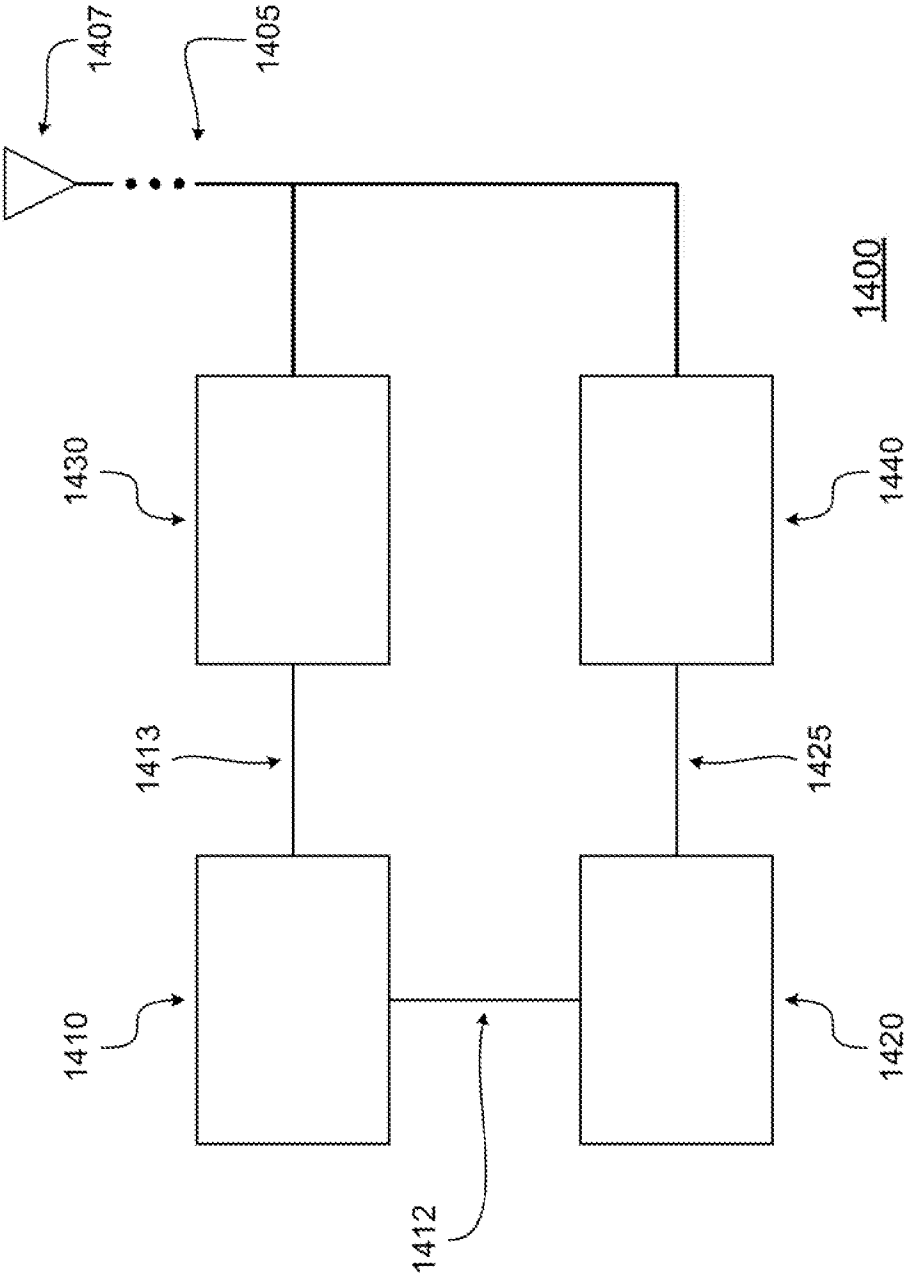


Fig. 14

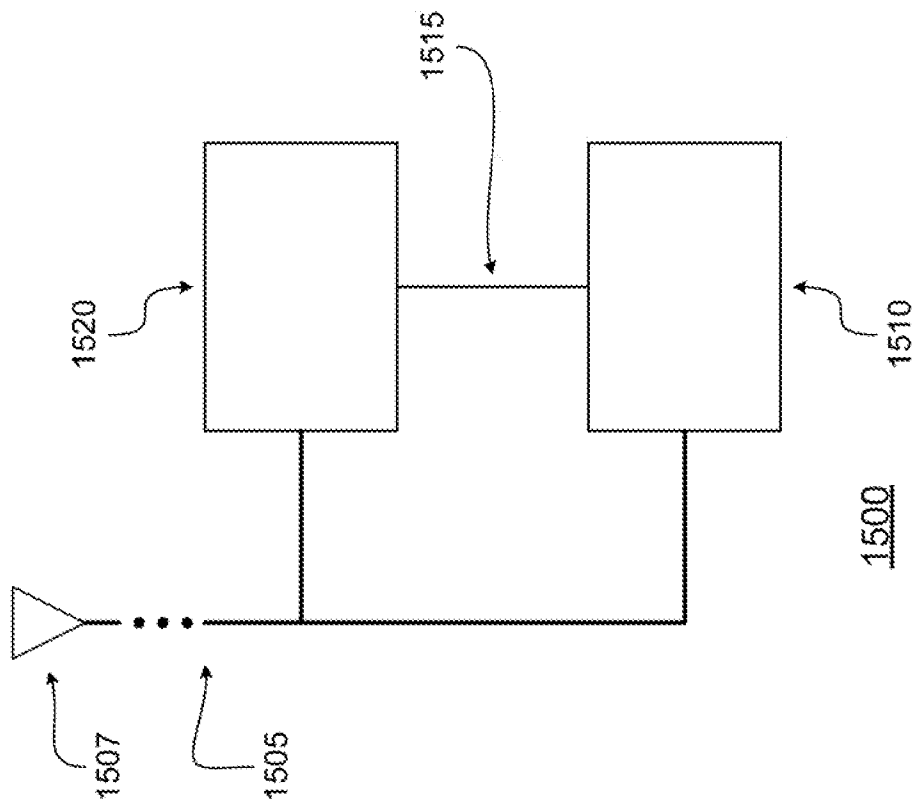
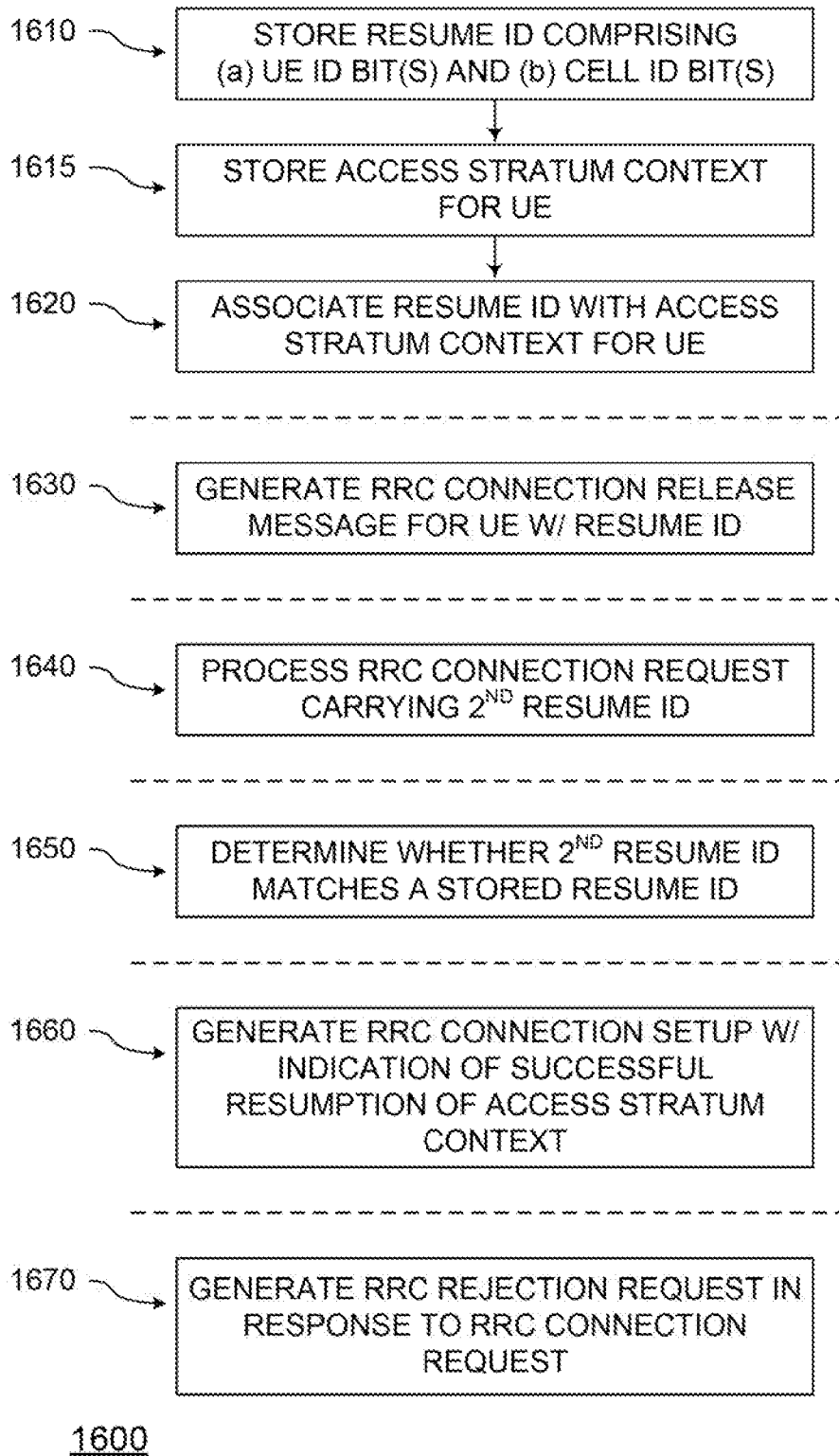
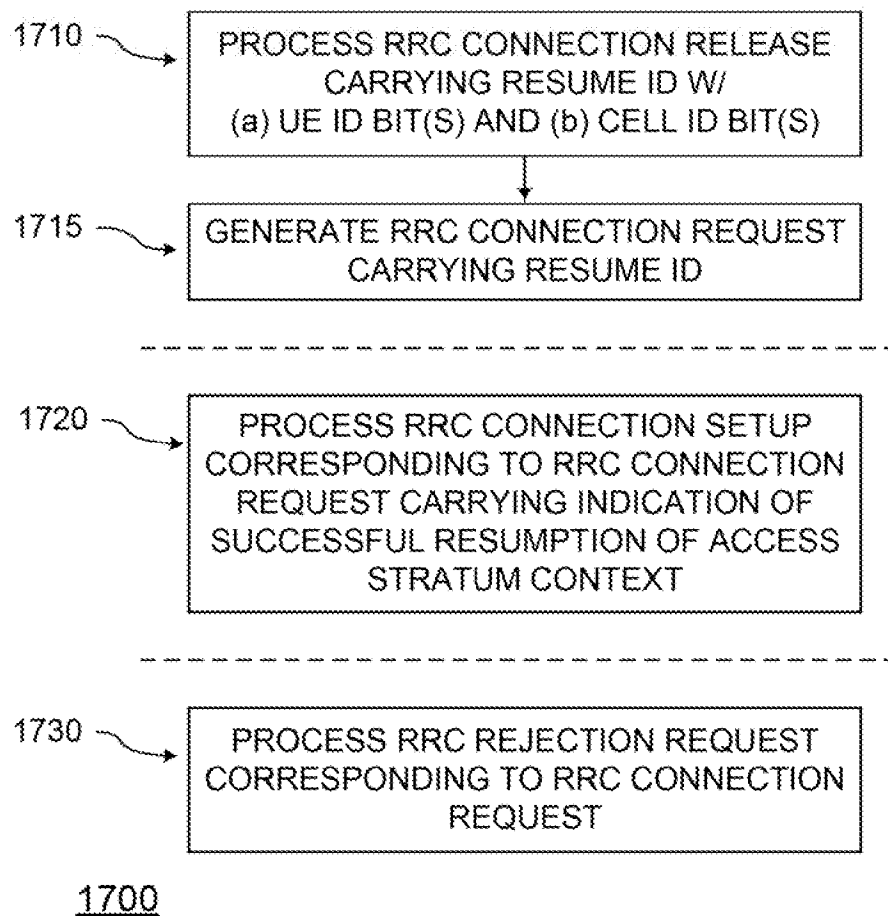


Fig. 15

**Fig. 16**

**Fig. 17**

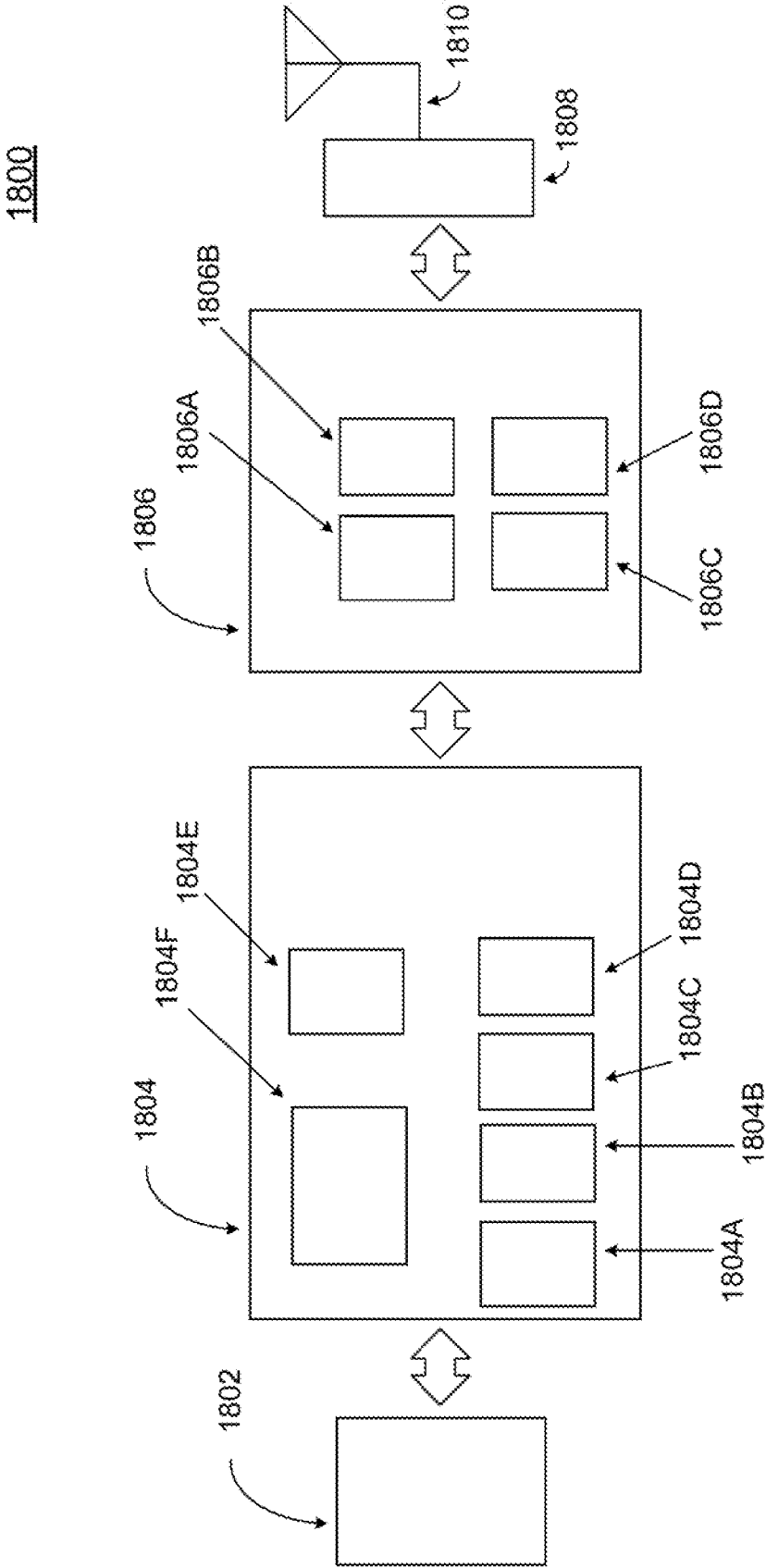


Fig. 18

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/069582

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W76/04 H04W76/02
ADD. H04W76/06

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, COMPENDEX, INSPEC, IBM-TDB, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	NOKIA NETWORKS: "Signaling details for UP based solution", 3GPP DRAFT; R3-160057 DISC UP SOLUTION, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG3, no. Budapest, HU; 20160120 - 20160122 11 January 2016 (2016-01-11), XP051067016, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG3_Iu /TSGR3_AHGs/R3_AHG_NB-IOT/Docs/ [retrieved on 2016-01-11]	1,2,7,8
A	* chapter 2.2.3 * * chapters 1, 2 * ----- -/-	3-6,9-24

☒ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

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

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Date of the actual completion of the international search

16 March 2017

Date of mailing of the international search report

22/03/2017

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Authorized officer

Rosken, Wilfried

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2016/069582

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	"3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2 (Release 13)", 3GPP STANDARD; 3GPP TS 36.300, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. RAN WG2, no. V13.2.0, 11 January 2016 (2016-01-11), pages 1-290, XP051047745, [retrieved on 2016-01-11]	1,2,7,8
A	* chapter 10.1.6 * * chapter 10.1.5.1 *	3-6,9-24
A	----- NTT DOCOMO ET AL: "Work on user plane based solution with AS information stored in RAN", 3GPP DRAFT; R2-156424, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG2, no. Anaheim, USA; 20151116 - 20151120 16 November 2015 (2015-11-16), XP051005843, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN2/Docs/ [retrieved on 2015-11-16] * chapters 2, 3 * * Annex A, B * ----- -/--	1-24

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2016/069582

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	ERICSSON: "Support of UE mobility for Solution 18 - User Plane CIOT Optimisations", 3GPP DRAFT; R3-160094, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG3, no. Budapest, HU; 20160120 - 20160122 11 January 2016 (2016-01-11), XP051067046, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG3_Iu/TSGR3_AHGs/R3_AHG_NB-IOT/Docs/ [retrieved on 2016-01-11] * chapter 2 *	1-24
A	----- "3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Architecture enhancements for Cellular Internet of Things (Release 13)", 3GPP STANDARD; 3GPP TR 23.720, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. SA WG2, no. V1.2.0, 23 November 2015 (2015-11-23), pages 1-96, XP051046270, [retrieved on 2015-11-23] * chapters 6.5, 6.18 *	1-24
A	----- "3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification (Release 13)", 3GPP STANDARD; 3GPP TS 36.331, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. RAN WG2, no. V13.0.0, 6 January 2016 (2016-01-06), pages 1-507, XP051047501, [retrieved on 2016-01-06] * chapters 5.3.3, 5.3.3.3, 5.3.7, 5.3.7.4, 5.3.8 * pages 210-216 -----	1-24