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(54) Title: CONTROL PLANE ARCHITECTURE FOR LTE-NR TIGHT INTERWORKING

(57) Abstract: Systems, methods, apparatuses, and computer program products supporting LTE- new radio (NR) interworking and/or control plane architecture for LTE-NR tight interworking for 5G networks are provided.

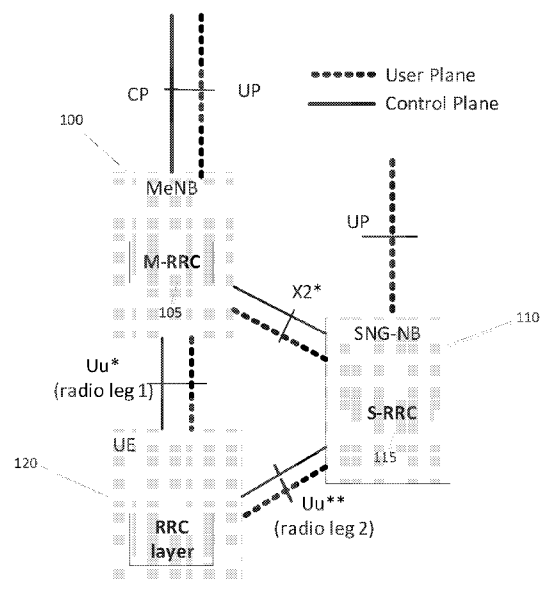


Fig. 1

CONTROL PLANE ARCHITECTURE FOR LTE-NR TIGHT INTERWORKING

5

CROSS REFERENCE TO RELATED APPLICATION:

[0001] This application claims the benefit of U.S. Provisional Application No. 62/374,385 entitled "CONTROL PLANE ARCHITECTURE FOR LONG TERM EVOLUTION (LTE)-NEW RADIO ACCESS TECHNOLOGY (NR) TIGHT
10 INTERWORKING" filed on August 12, 2016.

BACKGROUND:

Field:

[0002] Embodiments of the invention generally relate to wireless or mobile
15 communications networks, such as, but not limited to, the Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (UTRAN), Long Term Evolution (LTE) Evolved UTRAN (E-UTRAN), LTE-Advanced (LTE-A), LTE-A Pro, and/or 5G radio access technology or new radio access technology (NR). Some embodiments may generally relate to control plane architecture or design for LTE-NR tight
20 interworking.

Description of the Related Art:

[0003] Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (UTRAN) refers to a communications network including base stations, or
25 Node Bs, and for example radio network controllers (RNC). UTRAN allows for connectivity between the user equipment (UE) and the core network. The RNC provides control functionalities for one or more Node Bs. The RNC and its corresponding Node Bs are called the Radio Network Subsystem (RNS). In case of E-UTRAN (enhanced UTRAN), no RNC exists and radio access functionality is provided by an evolved Node B (eNodeB or eNB) or many eNBs. Multiple eNBs are involved for a single UE connection, for example, in case of Coordinated Multipoint Transmission (CoMP) and in dual connectivity.

[0004] Long Term Evolution (LTE) or E-UTRAN refers to improvements of the UMTS through improved efficiency and services, lower costs, and use of new spectrum opportunities. In particular, LTE is a 3GPP standard that provides for uplink peak rates of
35 at least, for example, 75 megabits per second (Mbps) per carrier and downlink peak rates of

at least, for example, 300 Mbps per carrier. LTE supports scalable carrier bandwidths from 20 MHz down to 1.4 MHz and supports both Frequency Division Duplexing (FDD) and Time Division Duplexing (TDD).

[0005] As mentioned above, LTE may also improve spectral efficiency in networks, allowing carriers to provide more data and voice services over a given bandwidth. Therefore, LTE is designed to fulfill the needs for high-speed data and media transport in addition to high-capacity voice support. Advantages of LTE include, for example, high throughput, low latency, FDD and TDD support in the same platform, an improved end-user experience, and a simple architecture resulting in low operating costs.

10 [0006] Certain releases of 3GPP LTE (e.g., LTE Rel-10, LTE Rel-11, LTE Rel-12, LTE Rel-13) are targeted towards international mobile telecommunications advanced (IMT-A) systems, referred to herein for convenience simply as LTE-Advanced (LTE-A).

[0007] LTE-A is directed toward extending and optimizing the 3GPP LTE radio access technologies. A goal of LTE-A is to provide significantly enhanced services by means of higher data rates and lower latency with reduced cost. LTE-A is a more optimized radio system fulfilling the international telecommunication union-radio (ITU-R) requirements for IMT-Advanced while maintaining backward compatibility. One of the key features of LTE-A, introduced in LTE Rel-10, is carrier aggregation, which allows for increasing the data rates through aggregation of two or more LTE carriers.

20 [0008] 5th generation wireless systems (5G) refers to the new generation of radio systems and network architecture. 5G is expected to provide higher bitrates and coverage than the current LTE systems. Some estimate that 5G will provide bitrates one hundred times higher than LTE offers. 5G is also expected to increase network expandability up to hundreds of thousands of connections. The signal technology of 5G is anticipated to be improved for greater coverage as well as spectral and signaling efficiency.

SUMMARY:

[0009] Various aspects of examples of the invention are set out in the claims.

30 [00010] According to a first aspect of the present invention, a method, apparatus and software program product are disclosed for formatting at a network node operating in accordance with a first of a long term evolution and a new radio access technology a radio resource control message for a user equipment comprising at least one of a message or procedure type; for transferring the radio resource control message to a master network node

35 operating in accordance with a second of the long term evolution and new radio access

technology, different from said first access technology; for transferring a second radio resource control message directly to the user equipment; and wherein the transferring the radio resource control message indicates the transferring the second radio resource control message.

- 5 [00011] According to a first aspect of the present invention, a method, apparatus and software program product are disclosed for receiving at a master network node operating in accordance with a first of a long term evolution and a new radio access technology a radio resource control message for a user equipment comprising at least one of a message or procedure type, wherein the radio resource control message received from a network node
- 10 operating in accordance with a second of the long term evolution and new radio access technology, different from said first access technology; for formatting a master radio resource control message for a user equipment comprising at least a master cell related configuration and transaction identifiers and failure handling information associated with the master radio resource control message and the resource control message; and for
- 15 transferring a message comprising the master radio resource control message and the radio resource control message to the user equipment.

BRIEF DESCRIPTION OF THE DRAWINGS:

- 20 [00012] For proper understanding of the invention, reference should be made to the accompanying drawings, wherein:
- [00013] Fig. 1 illustrates an example system diagram, according to an embodiment;
- [00014] Fig. 2 illustrates an example signaling diagram, according to one embodiment;
- [00015] Fig. 3a illustrates an example block diagram of an apparatus, according to an
- 25 embodiment;
- [00016] Fig. 3b illustrates an example block diagram of an apparatus, according to another embodiment;
- [00017] Fig. 4a illustrates an example flow diagram of a method, according to an embodiment; and
- 30 [00018] Fig. 4b illustrates an example flow diagram of a method, according to another embodiment.

DETAILED DESCRIPTION:

[00019] It will be readily understood that the components of the invention, as generally described and illustrated in the figures herein, may be arranged and designed in a wide variety of different configurations. Thus, the following detailed description of embodiments of systems, methods, apparatuses, and computer program products supporting LTE-new
5 radio (NR) interworking and/or control plane architecture for LTE-NR tight interworking, for instance, for 5G networks, as represented in the attached figures, is not intended to limit the scope of the invention, but is merely representative of some selected embodiments of the invention.

[00020] The features, structures, or characteristics of the invention described throughout this
10 specification may be combined in any suitable manner in one or more embodiments. For example, the usage of the phrases “certain embodiments,” “some embodiments,” or other similar language, throughout this specification refers to the fact that a particular feature, structure, or characteristic described in connection with the embodiment may be included in
15 at least one embodiment of the present invention. Thus, appearances of the phrases “in certain embodiments,” “in some embodiments,” “in other embodiments,” or other similar language, throughout this specification do not necessarily all refer to the same group of embodiments, and the described features, structures, or characteristics may be combined in any suitable manner in one or more embodiments.

[00021] Additionally, if desired, the different functions discussed below may be performed
20 in a different order and/or concurrently with each other. Furthermore, if desired, one or more of the described functions may be optional or may be combined. As such, the following description should be considered as merely illustrative of the principles, teachings and embodiments of this invention, and not in limitation thereof.

[00022] Some embodiments of the invention are directed to control plane architecture
25 aspects with respect to LTE-NR tight interworking for 5G networks. Fig. 1 illustrates a system diagram depicting NR control plane architecture options for LTE-NR tight interworking (e.g., between a LTE node and NR node) or NR-NR tight interworking (e.g., between two NR nodes), according to certain embodiments. In an embodiment, NR may refer to 5G radio access networks or systems.

[00023] As illustrated in Fig. 1, a master radio resource control (M-RRC) unit 105 may be
30 included in a master eNB (MeNB) 100, and a secondary radio resource control (S-RRC) unit 115 may be included in a secondary node B (SNG-NB) 110. In one embodiment, the master eNB 100 may be an LTE node. However, in other embodiments, the master eNB 100 may be a new radio access technology (NR) node (e.g., 5G access node). In an embodiment,
35 the SNG-NB 110 may be a secondary eNB (SeNB), for example. In one embodiment, the

secondary eNB may be a new radio access technology (NR) node (e.g., 5G access node). In other embodiments, the secondary eNB may be an LTE node.

[00024] According to one embodiment, after an initial configuration, NR RRC protocol messages may be transported between the SNG-NB 110 and the UE 120 in different ways including, for example, semi-independent or fully independent modes. In the semi-independent operation, M-RRC 105 transfers the configuration of S-RRC 115 in a transparent container to the UE 120 in a LTE RRC message. In the fully independent operation, S-RRC 115 prepares the NR RRC message and sends it to the UE 120, independent of the MeNB 100. It is noted that, in both the semi-independent and fully independent modes of operation, MeNB 100 hosts the M-RRC 105 and SNG-NB 110 hosts the S-RRC 115. In certain embodiments, the MeNB 100 may be unaware of the RRC message generated by the S-RRC 115 towards the UE 120.

[00025] Certain embodiments provide improvements in control plane design, for example, when dealing with dual-connectivity signalling in LTE-NR tight interworking. As mentioned above, NR may refer to 5G radio access networks or systems or vice versa.

[00026] Dual connectivity is a LTE feature for small cell enhancement where more than one eNB or access point may simultaneously serve a UE. In dual connectivity, a given UE may consume radio resources provided by at least two different network access points, which are referred to as a master node or master eNB (MeNB) and secondary node or secondary eNBs (SeNBs), connected with non-ideal backhaul while in RRC_CONNECTED. The Master Cell Group (MCG) is the group of serving cells associated with the MeNB. The MeNB is the node that terminates at least S1-MME and therefore acts as mobility anchor towards the core network (CN). The Secondary Cell Group (SCG) is the group of serving cells associated with the SeNB. The SeNB is the eNB providing additional radio resources for the UE, which is not the Master eNB. Similar to carrier aggregation, dual connectivity aims to utilize the radio resource within multiple carriers to improve UE throughput.

[00027] For LTE-NR interworking, dual connectivity has been agreed for inter-RAT resource aggregation due to the fact that this option provides reliability of radio resource control (RRC) connection (from LTE macro cell) along with increased per user throughput small cell NR node(s). Typically, the LTE macro cell carries the control plane while the NR small cell carries the user plane.

[00028] According to an embodiment, it may be desirable that the secondary node is able to format full RRC messages and send them independently to the UE (without the master node having to involve itself in the inspection and decoding). Certain embodiments are directed to such an approach and improvements in the RRC protocol for LTE and NR (e.g., 5G),

such as secondary node RRC message formatting, new message processing rules at the UE when receiving RRC messages from master and secondary nodes, and/or failure reporting when messages are processed for LTE-NR tight interworking.

[00029] Additionally, some embodiments provide rules on how the master and secondary nodes communicate the formatting of RRC protocol data units (PDUs) and transactions. For example, according to certain embodiments, master and secondary nodes may cooperate and issue master and secondary node RRC ASN.1 messages, a secondary node has the freedom to format the secondary node configuration to make its operation in semi/fully independent manner (this is an important consideration since LTE and NR network infrastructure may not necessarily come from the same vendor). Also, some embodiments provide procedures at the UE side to ensure that messages may be handled at the UE with clear behavior and not cause race conditions or procedural clashes.

[00030] In one embodiment, coordination rules for the combinations of RRC transaction identifiers used by the master and secondary nodes are provided, which allows a UE to always differentiate the different RRC procedures even within one RRC message or when RRC diversity/multi-connectivity scheme is configured (UE may be able to receive/transmit NR RRC messages via LTE/master leg or directly via NR/secondary leg).

[00031] Furthermore, some embodiments provide methods for UE reporting in case of configuration failure where the UE can independently or together report the configuration failure to master and secondary procedures. In an embodiment, it is possible that the master/secondary configuration fails and the secondary/master configuration is successful.

[00032] Certain embodiments of the invention provide various options/sub-options for master and secondary node message formatting and processing with coordination rules. Table 1 below illustrates examples of usage of combinations of transaction identifiers for different combinations of master and secondary node RRC procedures.

Combination of Master and Secondary node procedure	Transaction ID filled by Secondary node (also implies that the secondary node is using RRC diversity/multi-connectivity i.e. secondary node message may be sent to UE via. both master and secondary leg)	Transaction ID not filled by Secondary node (also implies that the secondary node is using master node to route the message and not directly sending this to UE via. secondary leg)	Comments
0,0 → invalid	N/A	N/A	N/A

combination			
0,1 → Secondary node configuration only	Use secondary node transaction identifier (Note 1)	Use a new master node transaction identifier (Note 1)	<u>Note 1:</u> UL response message for Secondary only.
1,0 → Master only configuration	N/A	N/A	N/A
1,1 → Master node receives Secondary node configuration just in time to combine both messages	Add parallel processing flag, use new master node transaction identifier for master configuration and secondary node identifier for secondary configuration (Note 2)	Add parallel processing flag, use new master node transaction identifier for both configurations (Note 3)	<u>Note 2:</u> For UL response UE always sends RRC reconfiguration complete for the Master and Secondary as and when the procedures are completed. <u>Note 3:</u> For UL response UE always sends RRC reconfiguration complete when both procedures are completed.
1,1 → Master node receives Secondary node configuration just after triggering Master only configuration	Add parallel processing flag, use secondary node identifier for secondary configuration (Note 4)	Add parallel processing flag, use new master node transaction identifier (Note 5)	<u>Note 4:</u> - If parallel processing flag is not set to TRUE, the UE serially processes RRC messages. - For UL response UE always sends RRC reconfiguration complete for the Master and Secondary as and when the procedures are completed. <u>Note 5:</u> For UL response UE always sends RRC reconfiguration complete when both procedures are completed.

TABLE 1

[00033] Fig. 2 illustrates an example signaling message flow diagram, according to one embodiment. It is noted that Fig. 2 illustrates one possible example of a message flow, but the messages may take different forms in other embodiments. According to an embodiment, the secondary node may format a full RRC message. The RRC message may include, for example, a RRC PDU containing message/procedure type and optional secondary node transaction identifier. In the example of Fig. 2, this RRC message is referred to as “S-Msg1,” but other labels may be used for this message (as well as the other messages in Fig. 2) according to other embodiments. The secondary node may optionally encrypt S-Msg1.

[00034] As further illustrated in Fig. 2, the secondary node may transfer the S-Msg1 to a master node using, for example, the X2* interface. Optionally, the secondary node may transfer a S-Msg2 to the UE directly via a secondary leg (i.e., a link between the secondary node and the UE). This option may require a secondary node packet data convergence protocol (PDCP) and signaling radio bearer (SRB) between Secondary node and UE capable of carrying direct RRC messages, and may need X2* level coordination either as part of X2* setup or on a per UE basis.

[00035] In an embodiment, if the secondary node includes a transaction identifier in the S-Msg1, it may indicate it to the master node on the X2* interface. Additionally, the secondary node may indicate to the master node the type or summarizing contents of the RRC message, e.g., initial measurement configuration, initial secondary node configuration, measurement reconfiguration, data radio bearer (DRB) addition, etc. In an embodiment, the secondary node may indicate to the master node that it has encrypted the S-Msg1 and/or the secondary node may indicate to the master node that the S-Msg1 is transparent and the master node may encrypt it with a master node key. According to one embodiment, the secondary node may indicate to the master node that it requires a separate failure cause to be reported from the UE. When the secondary node has transferred the S-Msg2 to the UE directly via the secondary leg, the secondary node may indicate to the master node that it has already dispatched S-Msg1 to the UE via the secondary leg. The secondary node may indicate to the master node whether it expects the UE to send replies or failure causes via secondary (another) leg. In Fig. 2, this would indicate whether the UE is to reply in UE-Msg1 or UE-Msg2 or both, and whether the master node should inform the secondary node via M-Msg2.

[00036] In an embodiment, if S-Msg2 is being sent, the S-Msg2 may contain a copy of S-Msg1 with the additional information added as described above, or may contain the additional info only (in this case the M-Msg1 is not being sent).

[00037] Continuing with Fig. 2, the master node may receive the S-Msg1 described above. The master node may then format a M-Msg1 containing the master cell(s) related

configuration. The master node indicates in the M-Msg1 message header information about M-Msg1 and S-Msg1 failure handling and transaction identifiers. In this case, in Fig. 2, M-Msg1 comprises M-Msg1 header information and M-Msg1 and S-Msg1. In an embodiment, the master node may encrypt M-Msg1 separately. In this case, in Fig. 2, M-Msg1 may
 5 comprise separately encrypted {M-Msg1 header and M-msg1} and separately encrypted S-Msg1. In another embodiment, the Master node may append S-Msg1 to M-Msg1 and then encrypt jointly. In this case, in Fig. 2, M-Msg1 encrypts jointly {M-Msg1 message part and S-Msg1}.

[00038] According to one embodiment, the master node may indicate how the UE should
 10 process these messages at UE. For example, the indication of how the UE should process the messages may include at least one of: the order of M-Msg1 and S-Msg1 processing (serialized or independent and even could be simultaneous), response message format options (separate or joint response), failure handling (joint or separate failure), and/or the route or routes over which the UE shall reply with a response or failure indication. In Fig.
 15 2, this would indicate whether the UE is to reply in UE-Msg1 or UE-Msg2 or both.

[00039] In certain embodiments, the master node may add additional information to the RRC PDU about RRC diversity used. According to an embodiment, the message from master node containing M-Msg1 and S-Msg1 may be sent via the master leg (link between master node and UE). In another embodiment, the message from the master node may contain only
 20 M-Msg1 sent via the secondary leg only.

[00040] In an embodiment, at the UE side, the master node PDCP and the secondary node PDCP will decrypt the containers and the master node RRC will pass the S-Msg to the secondary node RRC ASN.1 handling layer. Also, at the UE side, if the secondary node PDCP layer is not instantiated, then the master node PDCP will decrypt the master node
 25 message and the RRC layer will separate M-Msg1 and S-Msg1. It is noted that the UE can implicitly know this if there is a single transaction identifier in the RRC message or there are separate ones. Otherwise, specific information may be added in the RRC message from the master node.

[00041] Fig. 3a illustrates an example of an apparatus 10 according to an
 30 embodiment. In an embodiment, apparatus 10 may be a node, host, or server in a communications network or serving such a network. For example, apparatus 10 may be a network node or access node for a radio access network, such as a base station, node B or eNB, or an access node or access point of NR or 5G radio access technology. Thus, in certain embodiments, apparatus 10 may include a base station, access node, access point,
 35 node B or eNB serving a cell. For instance, in some embodiments, apparatus 10 may

correspond to the master node or secondary node illustrated in Fig. 2. It should be noted that one of ordinary skill in the art would understand that apparatus 10 may include components or features not shown in Fig. 3a.

[00042] As illustrated in Fig. 3a, apparatus 10 may include a processor 22 for processing
5 information and executing instructions or operations. Processor 22 may be any type of general or specific purpose processor. While a single processor 22 is shown in Fig. 3a, multiple processors may be utilized according to other embodiments. In fact, processor 22 may include one or more of general-purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs), field-programmable gate arrays
10 (FPGAs), application-specific integrated circuits (ASICs), and processors based on a multi-core processor architecture, as examples.

[00043] Processor 22 may perform functions associated with the operation of apparatus 10 which may include, for example, precoding of antenna gain/phase parameters, encoding and decoding of individual bits forming a communication message, formatting of information,
15 and overall control of the apparatus 10, including processes related to management of communication resources.

[00044] Apparatus 10 may further include or be coupled to a memory 14 (internal or external), which may be coupled to processor 22, for storing information and instructions that may be executed by processor 22. Memory 14 may be one or more memories and of
20 any type suitable to the local application environment, and may be implemented using any suitable volatile or nonvolatile data storage technology such as a semiconductor-based memory device, a magnetic memory device and system, an optical memory device and system, fixed memory, and removable memory. For example, memory 14 can be comprised of any combination of random access memory (RAM), read only memory (ROM), static
25 storage such as a magnetic or optical disk, or any other type of non-transitory machine or computer readable media. The instructions stored in memory 14 may include program instructions or computer program code that, when executed by processor 22, enable the apparatus 10 to perform tasks as described herein.

[00045] In some embodiments, apparatus 10 may also include or be coupled to one or more
30 antennas 25 for transmitting and receiving signals and/or data to and from apparatus 10. Apparatus 10 may further include or be coupled to a transceiver 28 configured to transmit and receive information. The transceiver 28 may include, for example, a plurality of radio interfaces that may be coupled to the antenna(s) 25. The radio interfaces may correspond to a plurality of radio access technologies including one or more of LTE, WLAN, Bluetooth,
35 BT-LE, NFC, radio frequency identifier (RFID), ultrawideband (UWB), and the like. The

radio interface may include components, such as filters, converters (for example, digital-to-analog converters and the like), mappers, a Fast Fourier Transform (FFT) module, and the like, to generate symbols for a transmission via one or more downlinks and to receive symbols (for example, via an uplink). As such, transceiver 28 may be configured to

5 modulate information on to a carrier waveform for transmission by the antenna(s) 25 and demodulate information received via the antenna(s) 25 for further processing by other elements of apparatus 10. In other embodiments, transceiver 28 may be capable of transmitting and receiving signals or data directly.

[00046] In an embodiment, memory 14 may store software modules that provide

10 functionality when executed by processor 22. The modules may include, for example, an operating system that provides operating system functionality for apparatus 10. The memory may also store one or more functional modules, such as an application or program, to provide additional functionality for apparatus 10. The components of apparatus 10 may be implemented in hardware, or as any suitable combination of hardware and software.

[00047] According to one embodiment, apparatus 10 may be a secondary node or SeNB. In this embodiment, apparatus 10 may be controlled by memory 14 and processor 22 to format a full RRC message, referred to as S-Msg1. The RRC message may include, for example, a RRC PDU containing a message/procedure type and optional secondary node transaction identifier. Apparatus 10 may optionally be controlled by memory 14 and processor 22 to

20 encrypt S-Msg1. Then, apparatus 10 may be controlled by memory 14 and processor 22 to transfer or transmit the S-Msg1 to a master node using, for example, the X2* interface. Optionally, in one embodiment, apparatus 10 may be controlled by memory 14 and processor 22 to transfer or transmit S-Msg2 to a UE directly via a secondary leg (i.e., a link between the apparatus 10 and the UE).

[00048] In an embodiment, if a transaction identifier is included in the S-Msg1, apparatus 10 may be controlled by memory 14 and processor 22 to indicate the transaction identifier to the master node on the X2* interface. Additionally, apparatus 10 may be controlled by memory 14 and processor 22 to indicate to the master node the type or summarizing contents of the S-Msg1, e.g., initial measurement configuration, initial secondary node configuration,

30 measurement reconfiguration, data radio bearer (DRB) addition, etc. In an embodiment, apparatus 10 may be controlled by memory 14 and processor 22 to indicate to the master node that it has encrypted the S-Msg1 and/or to indicate to the master node that the S-Msg1 is transparent and the master node may encrypt it with a master node key. According to one embodiment, apparatus 10 may be controlled by memory 14 and processor 22 to indicate to

35 the master node that it requires a separate failure cause to be reported from the UE. When

the apparatus 10 has transferred the S-Msg2 to the UE directly via the secondary leg, the apparatus 10 may indicate to the master node that it has already dispatched S-Msg1 to the UE via the secondary leg. In an embodiment, apparatus 10 may be controlled by memory 14 and processor 22 to indicate to the master node whether it expects the UE to send replies or failure causes via secondary (another) leg. This would indicate whether the UE is to reply in UE-Msg1 or UE-Msg2 or both, and whether the master node should inform the apparatus 10 via M-Msg2.

[00049] In an embodiment, if S-Msg2 is being sent, the S-Msg2 may be one of the following: a copy of S-Msg1 with the additional information added as described above or containing the additional info only (in this case the M-Msg1 is not being sent).

[00050] Fig. 3b illustrates an example of an apparatus 20 according to another embodiment. In an embodiment, apparatus 20 may be a node, host, or server in a communications network or serving such a network. For example, apparatus 20 may be a network node or access node for a radio access network, such as a base station, node B or eNB, or an access node or access point of NR or 5G radio access technology. Thus, in certain embodiments, apparatus 20 may include a base station, access node, access point, node B or eNB serving a cell. For instance, in some embodiments, apparatus 20 may correspond to the master node or secondary node illustrated in Fig. 2. It should be noted that one of ordinary skill in the art would understand that apparatus 20 may include components or features not shown in Fig. 3b.

[00051] As illustrated in Fig. 3b, apparatus 20 may include a processor 32 for processing information and executing instructions or operations. Processor 32 may be any type of general or specific purpose processor. While a single processor 32 is shown in Fig. 3b, multiple processors may be utilized according to other embodiments. In fact, processor 32 may include one or more of general-purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs), field-programmable gate arrays (FPGAs), application-specific integrated circuits (ASICs), and processors based on a multi-core processor architecture, as examples.

[00052] Processor 32 may perform functions associated with the operation of apparatus 20 including, without limitation, precoding of antenna gain/phase parameters, encoding and decoding of individual bits forming a communication message, formatting of information, and overall control of the apparatus 20, including processes related to management of communication resources.

[00053] Apparatus 20 may further include or be coupled to a memory 34 (internal or external), which may be coupled to processor 32, for storing information and instructions

that may be executed by processor 32. Memory 34 may be one or more memories and of any type suitable to the local application environment, and may be implemented using any suitable volatile or nonvolatile data storage technology such as a semiconductor-based memory device, a magnetic memory device and system, an optical memory device and system, fixed memory, and removable memory. For example, memory 34 can be comprised of any combination of random access memory (RAM), read only memory (ROM), static storage such as a magnetic or optical disk, or any other type of non-transitory machine or computer readable media. The instructions stored in memory 34 may include program instructions or computer program code that, when executed by processor 32, enable the apparatus 20 to perform tasks as described herein.

[00054] In some embodiments, apparatus 20 may also include or be coupled to one or more antennas 35 for receiving a downlink or signal and for transmitting via an uplink from apparatus 20. Apparatus 20 may further include a transceiver 38 configured to transmit and receive information. The transceiver 38 may also include a radio interface (e.g., a modem) coupled to the antenna 35. The radio interface may correspond to a plurality of radio access technologies including one or more of LTE, LTE-A, 5G, WLAN, Bluetooth, BT-LE, NFC, RFID, UWB, and the like. The radio interface may include other components, such as filters, converters (for example, digital-to-analog converters and the like), symbol demappers, signal shaping components, an Inverse Fast Fourier Transform (IFFT) module, and the like, to process symbols, such as OFDMA symbols, carried by a downlink or an uplink. For instance, transceiver 38 may be configured to modulate information on to a carrier waveform for transmission by the antenna(s) 35 and demodulate information received via the antenna(s) 35 for further processing by other elements of apparatus 20. In other embodiments, transceiver 38 may be capable of transmitting and receiving signals or data directly. Apparatus 20 may further include a user interface.

[00055] In an embodiment, memory 34 stores software modules that provide functionality when executed by processor 32. The modules may include, for example, an operating system that provides operating system functionality for apparatus 20. The memory may also store one or more functional modules, such as an application or program, to provide additional functionality for apparatus 20. The components of apparatus 20 may be implemented in hardware, or as any suitable combination of hardware and software.

[00056] According to one embodiment, apparatus 20 may be a master node or MeNB. In this embodiment, apparatus 20 may be controlled by memory 34 and processor 32 to receive the S-Msg1 described above. Apparatus 20 may then be controlled by memory 34 and processor 32 to format an M-Msg1 containing the master cell(s) related configuration. In an

- embodiment, apparatus 20 may be controlled by memory 34 and processor 32 to indicate, in the M-Msg1, message header information about M-Msg1 and S-Msg1 failure handling and transaction identifiers. In this case, M-Msg1 comprises M-Msg1 header information and M-Msg1 and S-Msg1. In an embodiment, apparatus 20 may be controlled by memory 34 and processor 32 to encrypt M-Msg1 separately. In this case, M-Msg1 may comprise separately encrypted {M-Msg1 header and M-msg1} and separately encrypted S-Msg1. In another embodiment, apparatus 20 may be controlled by memory 34 and processor 32 to append S-Msg1 to M-Msg1 and then encrypt jointly. In this case, M-Msg1 encrypts jointly {M-Msg1 message part and S-Msg1}.
- 10 **[00057]** According to one embodiment, apparatus 20 may be controlled by memory 34 and processor 32 to indicate how the UE should process these messages at the UE. For example, the indication of how the UE should process the messages may include at least one of: the order of M-Msg1 and S-Msg1 processing (serialized or independent and even could be simultaneous), response message format options (separate or joint response), failure
- 15 handling (joint or separate failure), and/or the route or routes over which the UE shall reply with a response or failure indication. This may indicate whether the UE is to reply in UE-Msg1 or UE-Msg2 or both.
- [00058]** In certain embodiments, apparatus 20 may be controlled by memory 34 and processor 32 to add additional information to the RRC PDU about RRC diversity used.
- 20 According to an embodiment, the message from apparatus 20 containing M-Msg1 and S-Msg1 may be sent via the master leg (link between apparatus 20 and UE). In another embodiment, the message from the apparatus 20 may contain only M-Msg1 sent via the secondary leg only.
- [00059]** Fig. 4a illustrates an example flow diagram of a method, according to one
- 25 embodiment. The method may be performed by a base station, eNB, or access node, for example. More specifically, in some embodiments, the method of Fig. 4a may be executed by an eNB or NR node acting as a secondary eNB (SeNB). The method of Fig. 4a may include, at 400, formatting a full RRC message, which may be referred to as S-Msg1. The RRC message may include, for example, a RRC PDU containing a message/procedure type
- 30 and optional secondary node transaction identifier. In certain embodiments, the method may optionally include encrypting S-Msg1. Then, the method may include, at 410, transferring or transmitting the S-Msg1 to a master node using, for example, the X2* interface. Optionally, in one embodiment, the method may include, at 420, transferring or transmitting S-Msg2 to a UE directly via a secondary leg (i.e., a link between the apparatus 10 and the
- 35 UE).

[00060] In an embodiment, if a transaction identifier is included in the S-Msg1, the method may include indicating the transaction identifier to the master node on the X2* interface. Additionally, in an embodiment, the method may include indicating to the master node the type or summarizing contents of the S-Msg1, e.g., initial measurement configuration, initial
 5 secondary node configuration, measurement reconfiguration, data radio bearer (DRB) addition, etc. In an embodiment, the method may include indicating to the master node that it has encrypted the S-Msg1 and/or indicating to the master node that the S-Msg1 is transparent and the master node may encrypt it with a master node key. According to one embodiment, the method may include indicating to the master node that it requires a separate
 10 failure cause to be reported from the UE. When the S-Msg2 has been transmitted to the UE directly via the secondary leg, the method may include, at 430, indicating to the master node that it has already dispatched S-Msg1 to the UE via the secondary leg.

[00061] In an embodiment, the method may include indicating to the master node whether it expects the UE to send replies or failure causes via secondary (another) leg. This would
 15 indicate whether the UE is to reply in UE-Msg1 or UE-Msg2 or both, and whether the master node should inform the secondary node via M-Msg2. In an embodiment, if S-Msg2 is being sent, the S-Msg2 may contain a copy of S-Msg1 with the additional information added as described above or may contain the additional information only (in this case the M-Msg1 is not being sent).

[00062] Fig. 4b illustrates an example flow diagram of a method, according to one
 20 embodiment. The method may be performed by a base station, eNB, or access node, for example. More specifically, in some embodiments, the method of Fig. 4b may be executed by an eNB acting as a master eNB (MeNB). The method of Fig. 4b may include, at 450, receiving the S-Msg1 described above from a secondary node. The method may then
 25 include, at 460, formatting an M-Msg1 containing at least the master cell(s) related configuration. In an embodiment, the method may include indicating, in the M-Msg1, message header information about M-Msg1 and S-Msg1 failure handling and transaction identifiers. In this case, M-Msg1 comprises M-Msg1 header information and M-Msg1 and S-Msg1. In an embodiment, the method may include encrypting M-Msg1 separately. In this
 30 case, M-Msg1 may comprise separately encrypted {M-Msg1 header and M-msg1} and separately encrypted S-Msg1. In another embodiment, the method may include appending S-Msg1 to M-Msg1 and then encrypting jointly. In this case, M-Msg1 encrypts jointly {M-Msg1 message part and S-Msg1}.

[00063] According to one embodiment, the method may include indicating how the UE
 35 should process these messages at the UE. For example, the indication of how the UE should

process the messages may include at least one of: the order of M-Msg1 and S-Msg1 processing (serialized or independent and even could be simultaneous), response message format options (separate or joint response), failure handling (joint or separate failure), and/or the route or routes over which the UE shall reply with a response or failure indication. This
5 may indicate whether the UE is to reply in UE-Msg1 or UE-Msg2 or both.

[00064]In certain embodiments, the method may further include adding additional information to the RRC PDU about RRC diversity used. According to an embodiment, the method may then include, at 470, transferring or transmitting a message containing M-
10 Msg1, or containing M-Msg1 and S-Msg1, for example via the master leg, to the UE.

[00065]Embodiments of the invention provide several advantages, technical improvements, and/or technical effects. For example, embodiments of the invention can improve performance and throughput of network nodes including, for example, access points, eNBs, and UEs. As a result, the use of embodiments of the invention result in improved functioning of communications networks and their nodes.

[00066]In some embodiments, the functionality of any of the methods, processes, signaling diagrams, or flow charts described herein may be implemented by software and/or computer program code or portions of code stored in memory or other computer readable or tangible media, and executed by a processor. In some embodiments, the apparatus may be, included or be associated with at least one software application, module, unit or entity configured as
15 arithmetic operation(s), or as a program or portions of it (including an added or updated software routine), executed by at least one operation processor. Programs, also called program products or computer programs, including software routines, applets and macros, may be stored in any apparatus-readable data storage medium and they include program instructions to perform particular tasks. A computer program product may comprise one or
20 more computer-executable components which, when the program is run, are configured to carry out embodiments. The one or more computer-executable components may be at least one software code or portions of it. Modifications and configurations required for implementing functionality of an embodiment may be performed as routine(s), which may be implemented as added or updated software routine(s). Software routine(s) may be
25 downloaded into the apparatus.

[00067]Software or a computer program code or portions of it may be in a source code form, object code form, or in some intermediate form, and it may be stored in some sort of carrier, distribution medium, or computer readable medium, which may be any entity or device capable of carrying the program. Such carriers include a record medium, computer memory,
30 read-only memory, photoelectrical and/or electrical carrier signal, telecommunications

signal, and software distribution package, for example. Depending on the processing power needed, the computer program may be executed in a single electronic digital computer or it may be distributed amongst a number of computers. The computer readable medium or computer readable storage medium may be a non-transitory medium.

- 5 [00068] In other embodiments, the functionality may be performed by hardware, for example through the use of an application specific integrated circuit (ASIC), a programmable gate array (PGA), a field programmable gate array (FPGA), or any other combination of hardware and software. In yet another embodiment, the functionality may be implemented as a signal, a non-tangible means that can be carried by an electromagnetic
10 signal downloaded from the Internet or other network.

- [00069] According to an embodiment, an apparatus, such as a node, device, or a corresponding component, may be configured as a computer or a microprocessor, such as single-chip computer element, or as a chipset, including at least a memory for providing storage capacity used for arithmetic operation and an operation processor for executing the
15 arithmetic operation.

- [00070] One having ordinary skill in the art will readily understand that the invention as discussed above may be practiced with steps in a different order, and/or with hardware elements in configurations which are different than those which are disclosed. Therefore, although the invention has been described based upon these preferred embodiments, it
20 would be apparent to those of skill in the art that certain modifications, variations, and alternative constructions would be apparent, while remaining within the spirit and scope of the invention.

We Claim:

1. A method comprising:
formatting (400) at a network node operating in accordance with a first of a long term evolution and a new radio access technology a radio resource control message (S-Msg1) for a user equipment comprising at least one of a message or procedure type;
transferring (410) the radio resource control message (S-Msg1) to a master network node operating in accordance with a second of the long term evolution and new radio access technology, different from said first access technology;
transferring (420) a second radio resource control message (S-Msg2) directly to the user equipment; and
wherein the transferring the radio resource control message indicates (430) the transferring the second radio resource control message.
2. The method of claim 1, wherein the radio resource control message comprises at least one of a copy of the second radio resource control message and information descriptive of the second radio resource control message.
3. The method of claim 2, wherein the information descriptive of the second radio resource control message comprises at least one of a transaction type and a summarizing content.
4. The method of any of claims 1-3, further comprising indicating to the master network node at least one of whether the radio resource control message is encrypted or whether the radio resource control message is transparent or whether the master network node may encrypt the radio resource control message with a master node key.
5. The method of any of claims 1-4, further comprising indicating to the second network node at least one of whether the user equipment is to report a failure cause directly to the network node and whether the second network node is to report a failure cause from the user equipment.
6. A method comprising:
receiving (450) at a master network node operating in accordance with a first of a long term evolution and a new radio access technology a radio resource control message (S-

Msg1) for a user equipment comprising at least one of a message or procedure type, wherein the radio resource control message (S-Msg1) received from a network node operating in accordance with a second of the long term evolution and new radio access technology, different from said first access technology;

formatting (460) a master radio resource control message (M-Msg1) for a user equipment comprising at least a master cell related configuration and transaction identifiers and failure handling information associated with the master radio resource control message and the resource control message; and

transferring (470) a message comprising the master radio resource control message and the radio resource control message to the user equipment.

7. The method of claim 6, wherein the master radio resource control message and the radio resource control message encrypted separately.

8. The method of claim 6 or 7, further comprising:
indicating to the user equipment a processing order for the master radio resource control message and the radio resource control message.

9. The method of claim 8, wherein the processing order comprises one of serialized, independent or simultaneous.

10. The method of any of claims 6-9, further comprising:
indicating to the user equipment a response message format option, comprising one of separate or joint response.

11. The method any of claims 6-10, wherein the failure handling information indicates at least one of joint or separate failure handling and failure routing information.

12. The method of claim 11, wherein the failure routing information comprises one of a route from the user equipment to the network node, a route from the user equipment to the master network node and routes from the user equipment to both of the network node and the master network node.

13. An apparatus, comprising:
at least one processor; and

at least one memory including computer program code
the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to perform at least the method in accordance with any of claims 1-5 or any of claims 6-12.

14. An apparatus, comprising means for performing at least the method in accordance with any of claims 1-5 or any of claims 6-12.

15. A computer program, comprising code for executing the method of any of claims 1-5 or any of claims 6-12 when the computer program is run on a processor.

16. A non-transitory computer-readable medium encoded with instructions that, when executed by a processor, perform the method according to any of claims 1-5 or any of claims 6-12.

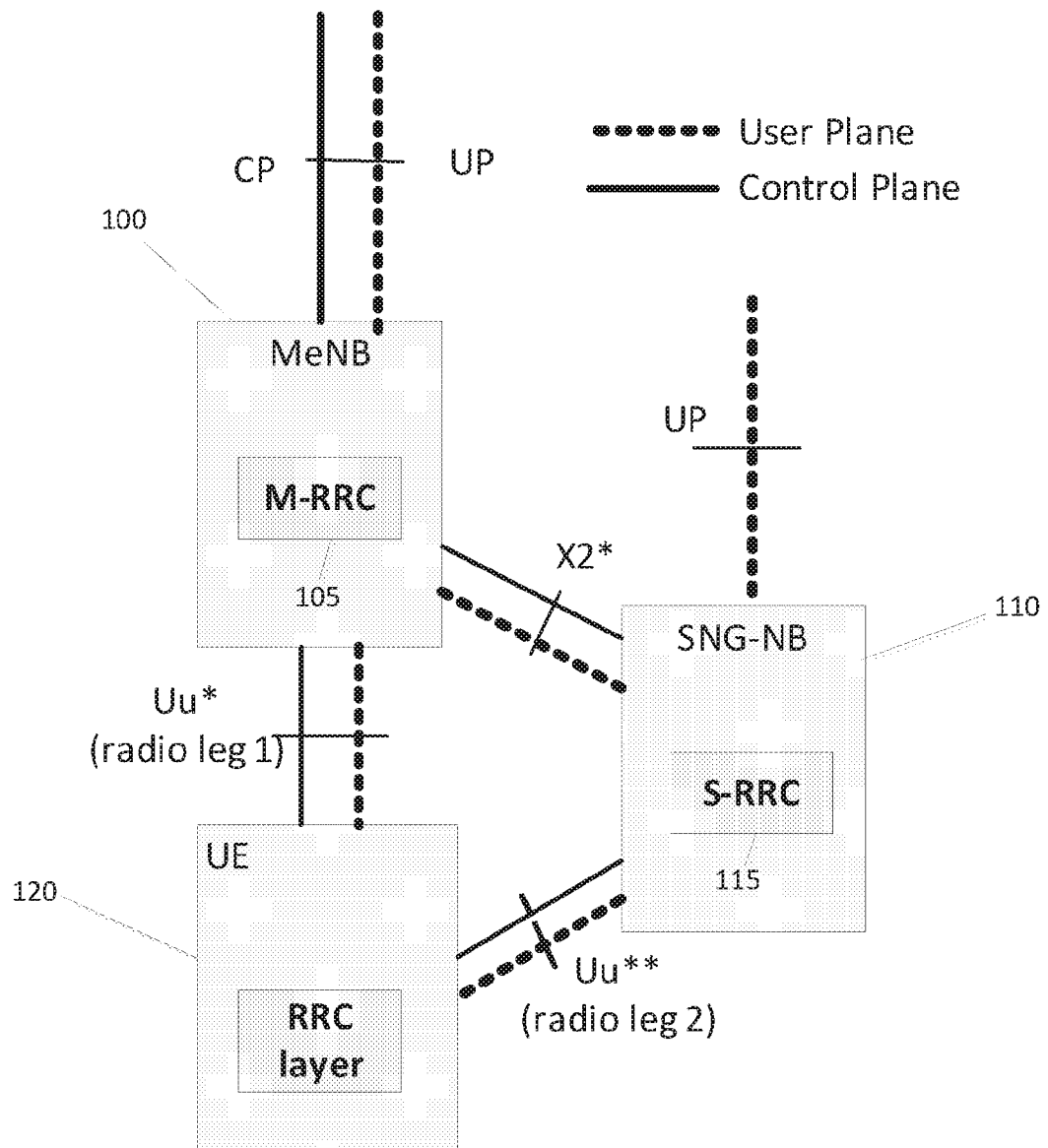


Fig. 1

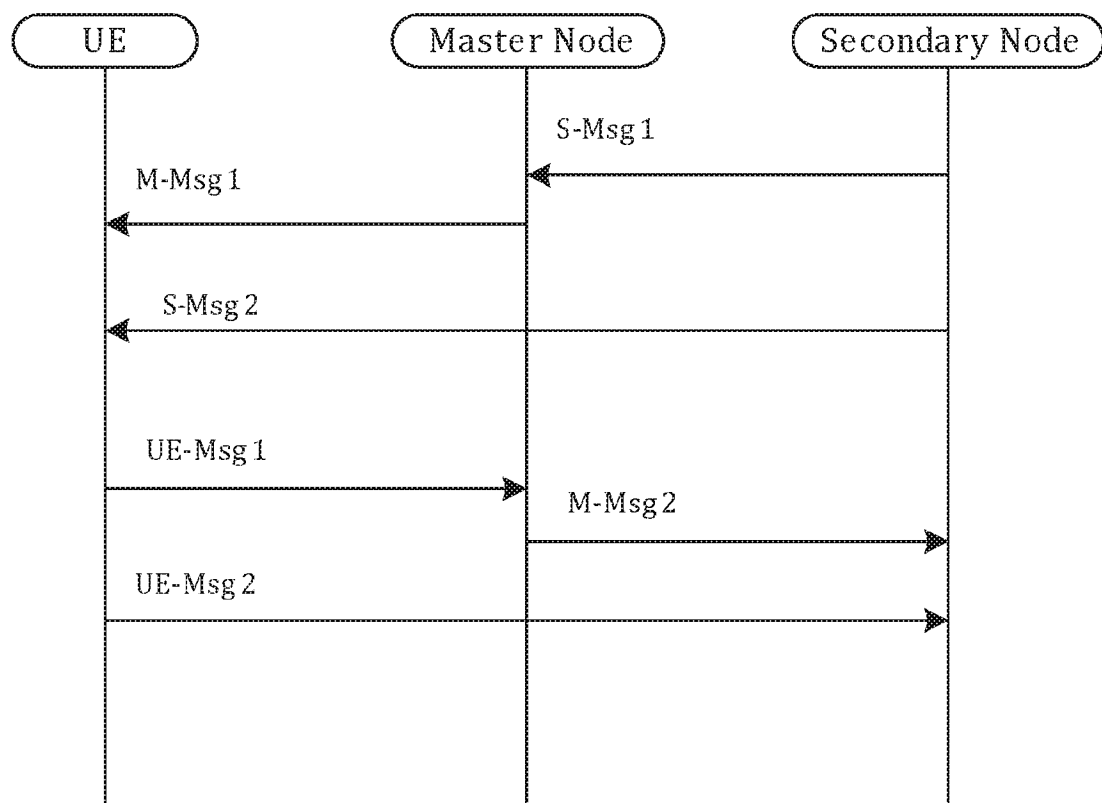


Fig. 2

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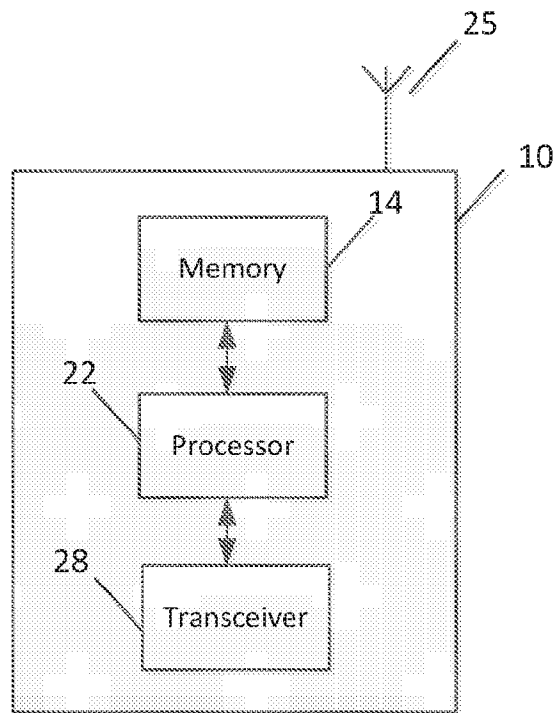


Fig. 3a

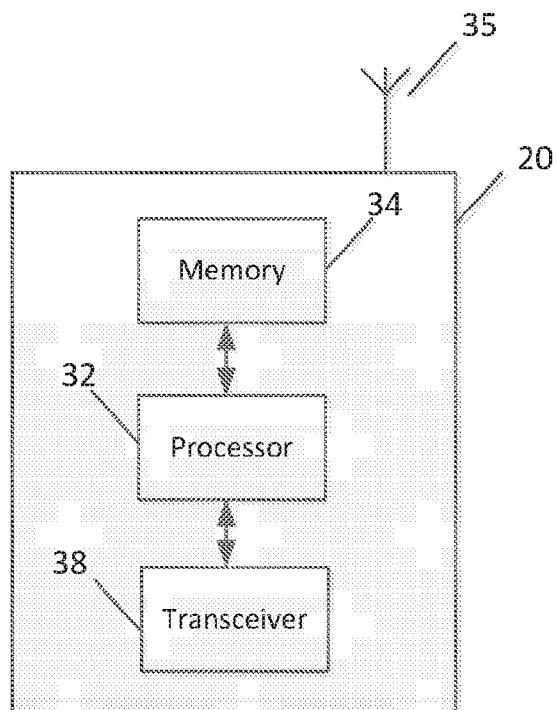


Fig. 3b

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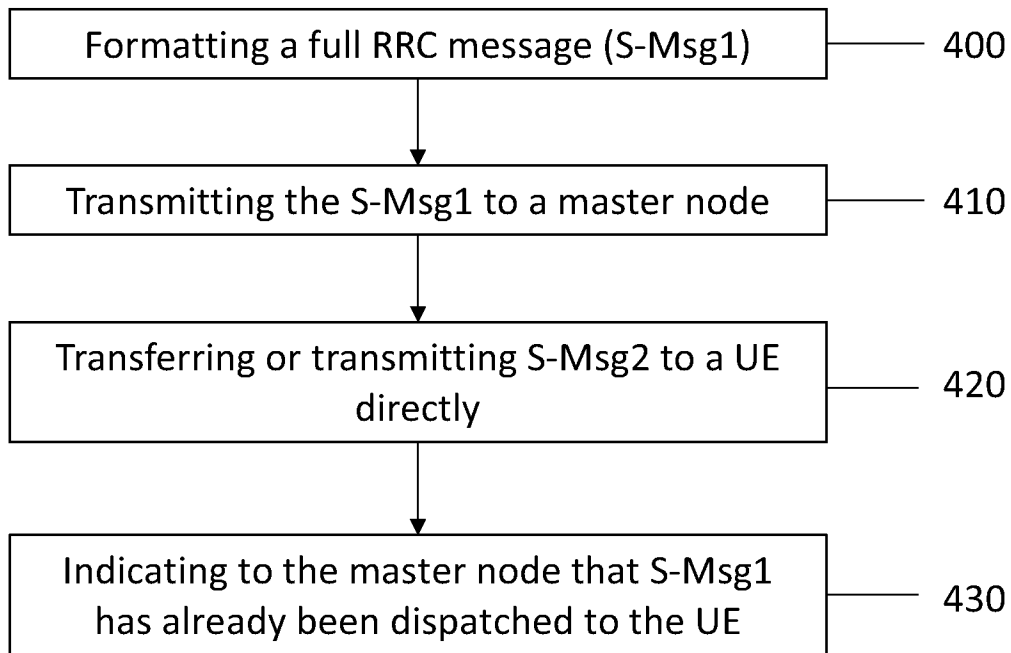


Fig. 4a

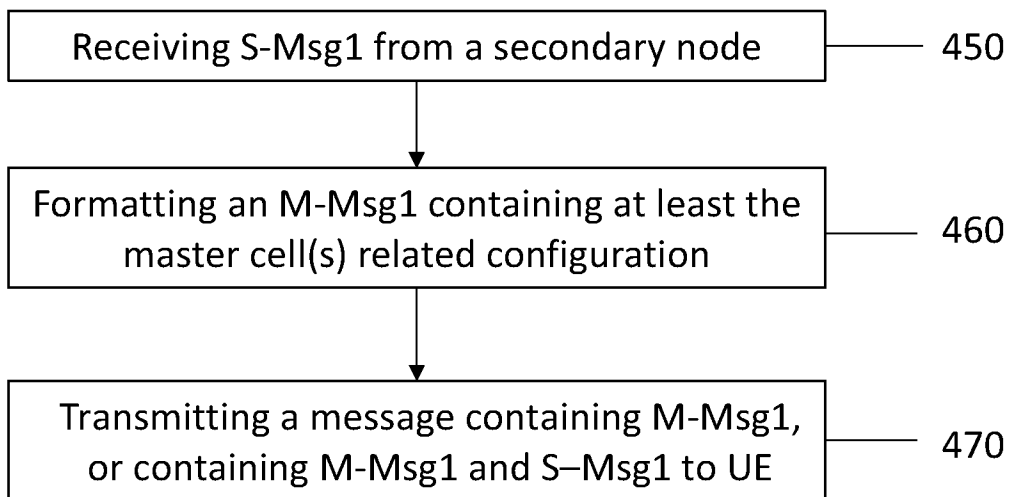


Fig. 4b

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2017/054826

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: H04W

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

SE, DK, FI, NO classes as above

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

EPO-Internal, PAJ, WPI data, COMPENDEX, INSPEC, IBM-TDB

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	"3GPP Draft; R2-163511 NR control plane architectural options for LTE-NR tight interworking", Nokia; Alcatel-Lucent Shanghai Bell, 2016-05-22, 3rd Generation Partnership Project (3GPP), Mobile Competence Centre ; 650, route des Lucioles ; F-06921 Sophia-Antipolis Cedex ; France; whole document --	1-16
P, X	"3GPP Draft; R2-1701677; Control plane issues for LTE-NR interworking", KT Corp, 2017-02-12, 3rd Generation Partnership Project (3GPP), Mobile Competence Centre ; 650, route des Lucioles ; F-06921 Sophia-Antipolis Cedex ; France; whole document --	1-16



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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

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

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

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

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

"T"

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

"X"

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

"Y"

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

"&"

document member of the same patent family

Date of the actual completion of the international search

27-11-2017

Date of mailing of the international search report

27-11-2017

Name and mailing address of the ISA/SE

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INTERNATIONAL SEARCH REPORT

 International application No.
 PCT/IB2017/054826

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	"3GPP Standard; 3GPP TR 38.804 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Study on New Radio Access Technology; Radio Interface Protocol Aspects (Release 14)", 3rd Generation Partnership Project (3GPP), Mobile Competence Centre ; 650, route des Lucioles ; F-06921 Sophia-Antipolis Cedex ; France, 2016-06-20; whole document; especially "Annex A" --	1-16
A	WO 2015060860 A1 (ERICSSON TELEFON AB L M ET AL), 30 April 2015 (2015-04-30); abstract; page 1, line 1 - page 6, line 7 --	1-16
A	"3GPP Draft; R2-163739 Consideration on the Dual RRC for LTE NR tight interworking", ZTE, 2016-05-22, 3rd Generation Partnership Project (3GPP), Mobile Competence Centre ; 650, route des Lucioles ; F-06921 Sophia-Antipolis Cedex ; France; whole document --	1-16
A	"3GPP Draft; R2-164268 LTE-NR tight interworking control plane", Huawei; HiSilicon, 2016-05-22, 3rd Generation Partnership Project (3GPP), Mobile Competence Centre ; 650, route des Lucioles ; F-06921 Sophia-Antipolis Cedex ; France; whole document -- -----	1-16

Continuation of: second sheet

International Patent Classification (IPC)

H04W 76/04 (2009.01)

H04W 92/02 (2009.01)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2017/054826

WO 2015060860 A1 30/04/2015 US 20160269982 A1 15/09/2016