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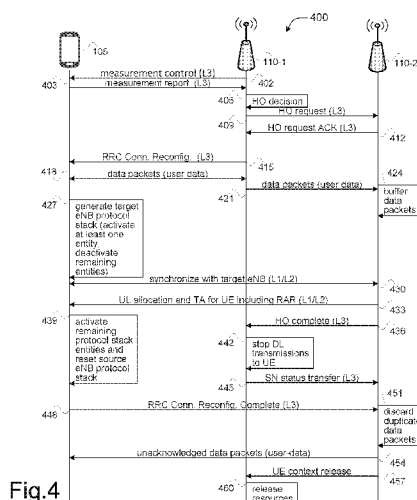


Fig.4

(57) Abstract: Methods, systems, and storage media for reducing interruptions in data transmission/reception during handover (HO) operations in wireless communications networks are described. In embodiments, a user equipment (UE) may receive an HO command from a source evolved nodeB (eNB). The UE may establish and activate a medium access control (MAC) entity for a connection with a target eNB based on the HO command. The UE may establish and activate a packet data convergence protocol (PDCP) entity and a radio link control (RLC) entity for the connection with the target eNB upon completion (or prior to completion) of an HO operation with the target eNB. The UE may continue to receive downlink transmissions from the source eNB until the HO operation is complete. Other embodiments may be described and/or claimed.



SYSTEMS AND METHODS FOR REDUCING INTERRUPTIONS IN DATA TRANSMISSIONS DUE TO HANDOVER OPERATIONS

RELATED APPLICATIONS

The present application claims priority under 35 U.S.C. § 119 to U.S. Provisional
5 Application No. 62/294,618 filed on February 12, 2016, which is hereby incorporated by
reference in its entirety.

FIELD

Implementations of the claimed invention generally relate to the field of wireless
communications, and in particular, to reducing interruptions in data transmission/reception
10 during handover operations in Long Term Evolution (LTE) wireless communications
networks.

BACKGROUND

In cellular communications networks, a user equipment (UE) may undergo a
handover (HO) operation to transfer an ongoing voice call or data session from a source
15 evolved nodeB (eNB) to a target eNB. The source eNB may initiate the HO operation
based on a measurement report received from the UE. The source eNB may send an HO
command to the UE after receiving an HO request acknowledgement (ACK) from the
target eNB in response to an HO request. At this point, the source eNB stops data
transmission to the UE since the UE detaches from the source eNB and synchronizes with
20 the target eNB. If the source eNB still has data intended for the UE, the source eNB may
send a sequence number (SN) status transfer and forward the data packets intended for the
UE to the target eNB so that the target eNB can transmit such data to UE once the HO
operation is complete. However, the UE will likely have an interruption in data reception
during the time between reception of the HO command and completion of the HO
25 operation due to detaching from the source eNB. This interruption in data reception during
the HO operation may degrade UE experience.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments will be readily understood by the following detailed description
in conjunction with the accompanying drawings. To facilitate this description, like
30 reference numerals designate like structural elements. Embodiments are illustrated by way
of example and not by way of limitation in the figures of the accompanying drawings.

FIG. 1 illustrates a cellular communications network in accordance with various
example embodiments;

FIG. 2 illustrates example components of an electronic device for wireless communication, in accordance with various example embodiments;

FIG. 3 illustrates an interface scheme between elements of a cellular communications network, in accordance with various embodiments;

5 FIG. 4 illustrates a process for performing a handover operation performed by various elements of the cellular communications network of FIG. 1, in accordance with various embodiments;

10 FIG. 5 illustrates a process that may be performed by a UE to receive downlink transmissions during a handover operation, in accordance with a first type of example embodiments;

FIG. 6 illustrates a process that may be performed by a UE to receive downlink transmissions during a handover operation according to the first type of example embodiments;

15 FIG. 7 illustrates a process that may be performed by a UE to receive downlink transmissions during a handover operation, in accordance with a second type of example embodiments;

FIG. 8 illustrates a process that may be performed by a UE to receive downlink transmissions during a handover operation, in accordance with a third type of example embodiments;

20 FIG. 9 illustrates a process that may be performed by a UE to receive downlink transmissions during a handover operation, in accordance with a fourth type of example embodiments;

FIG. 10 illustrates a process that may be performed by a target eNB during a handover operation, in accordance with various embodiments; and

25 FIG. 11 illustrates a process that may be performed by a source eNB during a handover operation, in accordance with various embodiments.

DETAILED DESCRIPTION

30 The following detailed description refers to the accompanying drawings. The same reference numbers may be used in different drawings to identify the same or similar elements. In the following description, for purposes of explanation and not limitation, specific details are set forth such as particular structures, architectures, interfaces, techniques, etc., in order to provide a thorough understanding of the various aspects of the claimed invention. However, it will be apparent to those skilled in the art having the benefit of the present disclosure that the various aspects of the invention claimed may be

practiced in other examples that depart from these specific details. In certain instances, descriptions of well-known devices, circuits, and methods are omitted so as not to obscure the description of the present invention with unnecessary detail.

Various aspects of the illustrative embodiments will be described using terms
5 commonly employed by those skilled in the art to convey the substance of their work to others skilled in the art. However, it will be apparent to those skilled in the art that alternate embodiments may be practiced with only some of the described aspects. For purposes of explanation, specific numbers, materials, and configurations are set forth in order to provide a thorough understanding of the illustrative embodiments. However, it
10 will be apparent to one skilled in the art that alternate embodiments may be practiced without the specific details. In other instances, well-known features are omitted or simplified in order not to obscure the illustrative embodiments.

Further, various operations will be described as multiple discrete operations, in turn, in a manner that is most helpful in understanding the illustrative embodiments;
15 however, the order of description should not be construed as to imply that these operations are necessarily order dependent. In particular, these operations need not be performed in the order of presentation.

The phrase “in various embodiments,” “in some embodiments,” and the like are used repeatedly. The phrase generally does not refer to the same embodiments; however, it
20 may. The terms “comprising,” “having,” and “including” are synonymous, unless the context dictates otherwise. The phrase “A and/or B” means (A), (B), or (A and B). The phrases “A/B” and “A or B” mean (A), (B), or (A and B), similar to the phrase “A and/or B.” For the purposes of the present disclosure, the phrase “at least one of A and B” means (A), (B), or (A and B). The description may use the phrases “in an embodiment,” “in
25 embodiments,” “in some embodiments,” and/or “in various embodiments,” which may each refer to one or more of the same or different embodiments. Furthermore, the terms “comprising,” “including,” “having,” and the like, as used with respect to embodiments of the present disclosure, are synonymous.

Example embodiments may be described as a process depicted as a flowchart, a
30 flow diagram, a data flow diagram, a structure diagram, or a block diagram. Although a flowchart may describe the operations as a sequential process, many of the operations may be performed in parallel, concurrently, or simultaneously. In addition, the order of the operations may be re-arranged. A process may be terminated when its operations are completed, but may also have additional steps not included in the figure(s). A process may

correspond to a method, a function, a procedure, a subroutine, a subprogram, and the like. When a process corresponds to a function, its termination may correspond to a return of the function to the calling function and/or the main function.

As used herein, the term “circuitry” refers to, is part of, or includes hardware components such as an Application Specific Integrated Circuit (ASIC), an electronic circuit, a logic circuit, a processor (shared, dedicated, or group) and/or memory (shared, dedicated, or group) that are configured to provide the described functionality. In some embodiments, the circuitry may execute one or more software or firmware programs to provide at least some of the described functionality. Example embodiments may be described in the general context of computer-executable instructions, such as program code, software modules, and/or functional processes, being executed by one or more of the aforementioned circuitry. The program code, software modules, and/or functional processes may include routines, programs, objects, components, data structures, etc., that perform particular tasks or implement particular data types. The program code, software modules, and/or functional processes discussed herein may be implemented using existing hardware in existing communication networks. For example, program code, software modules, and/or functional processes discussed herein may be implemented using existing hardware at existing network elements or control nodes.

As used herein, the term “processor circuitry” refers to, is part of, or includes circuitry capable of sequentially and automatically carrying out a sequence of arithmetic or logical operations; recording, storing, and/or transferring digital data. The term “processor circuitry” may refer to one or more application processors, one or more baseband processors, a physical central processing unit (CPU), a single-core processor, a dual-core processor, a triple-core processor, a quad-core processor, and/or any other device capable of executing or otherwise operating computer-executable instructions, such as program code, software modules, and/or functional processes. As used herein, the term “interface circuitry” refers to, is part of, or includes circuitry providing for the exchange of information between two or more components or devices. The term “interface circuitry” may refer to one or more hardware interfaces (for example, buses, input/output (I/O) interfaces, peripheral component interfaces, and the like).

As used herein, the term “user equipment” may be considered synonymous to, and may hereafter be occasionally referred to, as a client, mobile, mobile device, mobile terminal, user terminal, mobile unit, mobile station, mobile user, UE, subscriber, user, remote station, access agent, user agent, receiver, etc., and may describe a remote user of

network resources in a communications network. Furthermore, the term “user equipment” may include any type of wireless/wired device such as consumer electronics devices, cellular phones, smartphones, tablet personal computers, wearable computing devices, personal digital assistants (PDAs), desktop computers, and laptop computers, for example.

5 As used herein, the term “network element” may be considered synonymous to and/or referred to as a networked computer, networking hardware, network equipment, router, switch, hub, bridge, radio network controller, radio access network device, gateway, server, and/or any other like device. The term “network element” may describe a physical computing device of a wired or wireless communication network and be
10 configured to host a virtual machine. Furthermore, the term “network element” may describe equipment that provides radio baseband functions for data and/or voice connectivity between a network and one or more users. The term “network element” may be considered synonymous to and/or referred to as a “base station.” As used herein, the term “base station” may be considered synonymous to and/or referred to as a node B, an
15 enhanced or evolved node B (eNB), base transceiver station (BTS), access point (AP), etc., and may describe equipment that provides the radio baseband functions for data and/or voice connectivity between a network and one or more users.

It should also be noted that the term “channel” as used herein may refer to any transmission medium, either tangible or intangible, which is used to communicate data or
20 a data stream. Additionally, the term “channel” may be synonymous with and/or equivalent to “communications channel,” “data communications channel,” “transmission channel,” “data transmission channel,” “access channel,” “data access channel,” “link,” “data link,” “carrier,” “radiofrequency carrier,” and/or any other like term denoting a pathway or medium through which data is communicated.

25 Embodiments herein relate to facilitating continuous downlink transmissions during handover operations. In typical wireless networks, a UE may not receive downlink transmissions during a handover operation, which may degrade UE experience. The example embodiments provide systems and methods which allow a UE to receive downlink transmissions from a source base station while completing a handover operation
30 with a target base station. The example embodiments may reduce interruptions in downlink transmissions due to handover operations. In embodiments, a UE may receive an HO command from a source evolved nodeB (eNB), and may generate a protocol stack associated with a target eNB. The UE may establish a medium access control (MAC) entity for the connection with the target eNB based on the HO command, and the UE may

establish a packet data convergence protocol (PDCP) entity for the connection with the target eNB and a radio link control (RLC) entity for the connection with the target eNB upon completion (or prior to completion) of the HO operation with the target eNB. Other embodiments may be described and/or claimed.

FIG. 1 illustrates an example of a cellular communications network 100 (also referred to as “network 100” and the like), according to an example embodiment. Network 100 includes UEs 105, two eNBs 110 (eNB 110-1 and eNB 110-2 are collectively referred to as “eNB 110” or “eNBs 110”), and to cells 115 (cell 115-1 and cell 115-2 are collectively referred to as “cell 115” or “cells 115”). The following description is provided for an example network 100 that operates in conjunction with the Long Term Evolution (LTE) standard as provided by 3rd Generation Partnership Project (3GPP) technical specifications (TS). However, the example embodiments are not limited in this regard and the described embodiments may apply to other networks that benefit from the principles described herein.

Referring to FIG. 1, UE 105 may be a physical hardware device capable of running one or more applications and capable of accessing network services via one or more radio links 120 (radio link 120-1 and radio link 120-2 are collectively referred to as “radio links 120” or “links 120”) with corresponding eNBs 110. A link 120 may allow the UE 105 to transmit and receive data from an eNB 110 that provides the link 120. To transmit/receive data to/from one or more eNBs 110, UE 105 may include a transmitter/receiver (or alternatively, a transceiver), memory, one or more processors, and/or other like components that enable UE 105 to operate in accordance with one or more wireless communications protocols and/or one or more cellular phone communications protocols. In various embodiments, UE 105 may have multiple antenna elements that enable the UE 105 to maintain multiple links 120 to transmit/receive data to/from multiple eNBs 110. For example, as shown in FIG. 1, UE 105 may connect with eNB 110-1 via link 120-1 and simultaneously connect with eNB 110-2 via link 120-2. Furthermore, UE 105 may be capable of measuring various cell-related criteria, such as channel conditions and signal quality (for example, reference signal received power (RSRP), reference signal received quality (RSRQ), and the like), and provide a measurement report including this information to an eNB 110. Examples of UE 105 may include a wireless phone or smartphone, a laptop personal computer (PC), a tablet PC, a wearable computing device, an autonomous sensor or other like machine type communication (MTC) device, and/or any other physical device capable of recording, storing, and/or transferring digital data

to/from eNB 110 and/or any other like network element.

The eNBs 110 are hardware computing devices configured to provide wireless communication services to mobile devices (for example, UE 105) within a coverage area or cell 115 associated with an eNB 110 (for example, cell 115-1 associated with eNB 110-1). A cell 115 providing services to UE 105 may also be referred to as a “serving cell,” “cell coverage area,” and the like. As discussed previously, eNBs 110 may provide wireless communication services to UE 105 via links 120. The links 120 between the eNBs 110 and the UE 105 may include one or more downlink (or forward) channels for transmitting information from eNB 110 to UE 105. Although not shown by FIG. 1, links 120 may also include one or more uplink (or reverse) channels for transmitting information from UE 105 to an eNB 110. The channels may include the physical downlink shared channel (PDSCH), physical downlink control channel (PDCCH), physical hybrid automatic repeat request (HARQ) indicator channel (PHICH), physical control format indicator channel (PCFICH), physical broadcast channel (PBCH), physical uplink shared channel (PUSCH), physical uplink control channel (PUCCH), physical random access channel (PRACH), and/or any other like communications channels or links used to transmit/receive data.

In various embodiments, eNBs 110 include a transmitter/receiver (or alternatively, a transceiver) connected to one or more antennas, one or more memory devices, one or more processors, and/or other like components. The one or more transmitters/receivers may be configured to transmit/receive data signals to/from one or more UEs 105 within its cell 115 via one or more links that may be associated with a transmitter and a receiver. In embodiments where network 100 employs the LTE or LTE-A standard, eNBs 110 may employ Evolved Universal Terrestrial Radio Access (E-UTRA) protocols, for example, using orthogonal frequency-division multiple access (OFDMA) for scheduling and transmitting downlink communications and single carrier frequency-division multiple access (SC-FDMA) for scheduling and receiving uplink communications from UE 105. Furthermore, eNBs 110 may be capable of communicating with one another over a backhaul connection 125 and may communicate with one or more servers 135 within a core network (CN) 140 over another backhaul connection 130. In embodiments where network 100 employs the LTE or LTE-A standard, backhaul connection 125 may include a wired connection employing an X2 interface, which defines an interface for communicating data packets directly between eNBs 110. Furthermore, in such embodiments the backhaul connection 130 may include a wired connection employing an

S1 interface, which defines a protocol for the forwarding of packets indirectly between eNBs 110 by way of one or more mobility management entities (MMEs), one or more Serving Gateways (SGWs), and/or other like core network elements. In embodiments, various HO-related messages may be communicated directly between the eNBs 110 over the X2 interface (for example, during an X2-HO operation or an Intra-MME HO) or indirectly between the eNBs 110 over the S1 interface (for example, during an S1-HO operation or an Inter-MME HO).

In many deployment scenarios, the UE 105 may undergo a handover (HO) operation when moving between cells 115. For example, when UE 105 moves from cell 115-1 to cell 115-2, eNB 110-1 may handover UE 105 to eNB 110-2. In this case, eNB 110-2 may be considered a “source cell” or a “source eNB” and eNB 110-2 may be considered a “target cell” or a “target eNB.” Typically, the source eNB 110-1 may send a measurement configuration to the UE to request a measurement report from the UE 105 when certain configured event(s) triggered, and the UE 105 may perform signal quality or cell power measurements for channels or links 120 of the target eNB 110-2 and/or other neighboring cells (not shown). Based on the results of the measurement, some configured events may trigger the UE to send the measurement report to the source eNB. The source eNB 110-1 may decide to handover the UE to the target eNB by initiating the HO operation. To initiate the HO operation, the source eNB 110-1 may transmit an HO request message to the target eNB 110-2, and in response, the source eNB 110-1 may receive an HO request acknowledgement (ACK) from the target eNB 110-2. Once the HO request ACK is received, the source eNB 110-1 may send an HO command to the UE to begin an attachment process with the target eNB 110-2. At this point, the source eNB 110-1 stops data transmission to the UE since the UE detaches from the source eNB 110-1 and starts synchronization with the target eNB 110-2. If the source eNB 110-1 still has data intended for the UE, the source eNB 110-1 may send a sequence number (SN) status transfer to the target eNB 110-2 and forward data to the target eNB 110-2 so that the target eNB 110-2 can transmit such data to UE 105 once the HO operation is complete. However, because the UE 105 detaches from the source eNB 110-1 during the typical HO operation, the UE 105 will likely experience an interruption in data reception during the time between reception of the HO command and completion of the HO operation.

According to various embodiments, the UE 105 may continue to receive downlink transmissions from a source eNB (for example, source eNB 110-1) while a HO operation occurs with a target eNB (for example, target eNB 110-2). In embodiments, in order to

reduce the HO interruption time, the UE 105 may receive downlink data from source eNB 110-1 after receiving the HO command and before receiving a random access message from target eNB 110-2, such as a random access response (RAR). Example embodiments also provide a new UE protocol stack architecture in order to enable the UE 105 to receive
5 downlink receptions and transmit uplink transmissions from/to the source eNB 110-1 after receiving the HO command and before completion of the HO operation. Typically, the UE 105 will generate or create a protocol stack for communicating with an eNB 110. During conventional HO operations, a UE 105 will reset the protocol stack created for communicating with the source eNB 110 and prepare the protocol stack for
10 communicating with the target eNB 110 prior to attaching to the target eNB. In embodiments, the UE 105 may create or generate the target eNB 110 protocol stack without resetting the source eNB 110 protocol stack. In some embodiments, the UE 105 may activate the target eNB 110 protocol stack, or portions thereof, after receiving an RAR from target eNB 110-2. In other embodiments, the UE 105 may generate or create
15 the target eNB 110 protocol stack, or portions thereof, after receiving an RAR from target eNB 110-2. In other embodiments, the UE 105 may activate the target eNB 110 protocol stack, or portions thereof, once the protocol stack is generated. The various example embodiments are described in detail with regard to FIGS. 3-9.

Although not shown by FIG. 1, each eNB 110 may be part of a radio access
20 network (RAN) or associated with a radio access technology (RAT). In embodiments where communications network 100 employs the LTE standard, the RAN may be referred to as an evolved universal terrestrial radio access network (E-UTRAN). RANs and their typical functionality are generally well-known, and thus, a further detailed description of the typical functionality of RAN is omitted.

25 The network 100 may include CN 140, which may include one or more hardware devices, such as the one or more servers 135. These servers may provide various telecommunications services to the UEs 105. In embodiments where network 100 employs the LTE standards, the one or more servers 135 of the CN 140 may comprise components of the System Architecture Evolution (SAE) with an Evolved Packet
30 Core (EPC) as described by 3GPP technical specifications. In such embodiments, the one or more servers 135 of the CN 140 may include components such as one or more MMEs and/or Serving General Packet Radio Service Support Nodes (SGSNs) (which may be referred to as an “SGSN/MME”), a serving gateway (SGW), packet data network (PDN) gateway (PGW), home subscriber server (HSS), access network discovery and selection

function (ANDSF), evolved packet data gateway (ePDG), an MTC interworking function (IWF), and/or other like components as are known. The various elements of the CN 140 may route phone calls from UE 105 to other mobile phones or landline phones, or provide the UE 105 with a connection to the internet 145 for communication with one or more other computer devices. Because the components of the SAE core network and their functionality are generally well-known, a further detailed description of the SAE core network is omitted. It should also be noted that the aforementioned functions may be provided by the same physical hardware device or by separate components and/or devices.

Although FIG. 1 shows two cell coverage areas (for example, cells 115), two base stations (for example, eNBs 110), and one mobile device (for example, UE 105), it should be noted that in various example embodiments, network 100 may include many more eNBs serving many more UEs than those shown in FIG. 1. However, it is not necessary that all of these generally conventional components be shown in order to understand the example embodiments as described herein.

FIG. 2 illustrates, for one embodiment, example components of an electronic device 200. In various embodiments, the electronic device 200 may be implemented in or by UE 105 and/or an eNB 110 as described previously with regard to FIG. 1. In some embodiments, the electronic device 200 may include application circuitry 202, baseband circuitry 204, radio frequency (RF) circuitry 206, front-end module (FEM) circuitry 208 and one or more antennas 210, coupled together at least as shown. In embodiments where the electronic device 200 is implemented in or by an eNB 110, the electronic device 200 may also include network interface circuitry (not shown) for communicating over a wired interface (for example, an X2 interface, an S1 interface, and the like).

The application circuitry 202 may include one or more application processors. For example, the application circuitry 202 may include circuitry such as, but not limited to, one or more single-core or multi-core processors 202a. The processor(s) 202a 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 202b (also referred to as “memory 202b” or “computer-readable medium 202b”) and may be configured to execute instructions stored in the memory/storage 202b to enable various applications and/or operating systems to run on the system.

The baseband circuitry 204 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 204 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 206 and to generate baseband signals for a transmit signal path of the RF circuitry 206. Baseband circuitry 204 may interface with the application circuitry 202 for generation and processing of the baseband signals and for
5 controlling operations of the RF circuitry 206. For example, in some embodiments, the baseband circuitry 204 may include a second generation (2G) baseband processor 204a, third generation (3G) baseband processor 204b, fourth generation (4G) baseband processor 204c, and/or other baseband processor(s) 204d for other existing generations, generations in development or to be developed in the future (e.g., fifth generation (5G), 6G, etc.). The
10 baseband circuitry 204 (e.g., one or more of baseband processors 204a-d) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 206. The radio control functions may include, but are not limited to, signal modulation/demodulation, encoding/decoding, radio frequency shifting, and the like. In some embodiments, modulation/demodulation circuitry of the baseband
15 circuitry 204 may include Fast-Fourier Transform (FFT), precoding, and/or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 204 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
20 limited to these examples and may include other suitable functionality in other embodiments.

In some embodiments, the baseband circuitry 204 may include elements of a protocol stack such as, for example, elements of an evolved universal terrestrial radio access network (E-UTRAN) protocol including, for example, physical (PHY), media
25 access control (MAC), radio link control (RLC), packet data convergence protocol (PDCP), and/or radio resource control (RRC) elements. A central processing unit (CPU) 204e of the baseband circuitry 204 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
30 processor(s) (DSP) 204f. The audio DSP(s) 204f may include elements for compression/decompression and echo cancellation and may include other suitable processing elements in other embodiments. The baseband circuitry 204 may further include memory/storage 204g (also referred to as “memory 204g” or “computer-readable medium 204g”). The memory/storage 204g may be used to load and store data and/or

instructions for operations performed by the processors of the baseband circuitry 204. Memory/storage for one embodiment may include any combination of suitable volatile memory and/or non-volatile memory. The memory/storage 204g may include any combination of various levels of memory/storage including, but not limited to, read-only memory (ROM) having embedded software instructions (e.g., firmware), random access memory (e.g., dynamic random access memory (DRAM)), cache, buffers, etc. The memory/storage 204g may be shared among the various processors or dedicated to particular processors. Components of the baseband circuitry 204 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 204 and the application circuitry 202 may be implemented together, such as, for example, on a system on a chip (SOC).

In some embodiments, the baseband circuitry 204 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 204 may support communication with an E-UTRAN 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 204 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

RF circuitry 206 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 206 may include switches, filters, amplifiers, etc., to facilitate the communication with the wireless network. RF circuitry 206 may include a receive signal path that may include circuitry to down-convert RF signals received from the FEM circuitry 208 and provide baseband signals to the baseband circuitry 204. RF circuitry 206 may also include a transmit signal path that may include circuitry to up-convert baseband signals provided by the baseband circuitry 204 and provide RF output signals to the FEM circuitry 208 for transmission.

In some embodiments, the RF circuitry 206 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 206 may include mixer circuitry 206a, amplifier circuitry 206b and filter circuitry 206c. The transmit signal path of the RF circuitry 206 may include filter circuitry 206c and mixer circuitry 206a. RF circuitry 206 may also include synthesizer circuitry 206d for synthesizing a frequency for use by the mixer circuitry 206a of the receive signal path and the transmit signal path. In

some embodiments, the mixer circuitry 206a of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 208 based on the synthesized frequency provided by synthesizer circuitry 206d. The amplifier circuitry 206b may be configured to amplify the down-converted signals and the filter circuitry 206c 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 204 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 206a of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

In some embodiments, the mixer circuitry 206a of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 206d to generate RF output signals for the FEM circuitry 208. The baseband signals may be provided by the baseband circuitry 204 and may be filtered by filter circuitry 206c. The filter circuitry 206c may include a low-pass filter (LPF), although the scope of the embodiments is not limited in this respect.

In some embodiments, the mixer circuitry 206a of the receive signal path and the mixer circuitry 206a of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and/or upconversion, respectively. In some embodiments, the mixer circuitry 206a of the receive signal path and the mixer circuitry 206a 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 206a of the receive signal path and the mixer circuitry 206a of the transmit signal path may be arranged for direct downconversion and/or direct upconversion, respectively. In some embodiments, the mixer circuitry 206a of the receive signal path and the mixer circuitry 206a of the transmit signal path may be configured for super-heterodyne operation.

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 206 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 204 may include a digital baseband

interface to communicate with the RF circuitry 206.

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.

5 In some embodiments, the synthesizer circuitry 206d 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 206d may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider. The
10 synthesizer circuitry 206d may be configured to synthesize an output frequency for use by the mixer circuitry 206a of the RF circuitry 206 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 206d may be a fractional $N/N+1$ synthesizer.

 In some embodiments, frequency input may be provided by a voltage controlled
15 oscillator (VCO), although that is not a requirement. Divider control input may be provided by either the baseband circuitry 204 or the application circuitry 202 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 application circuitry 202.

20 Synthesizer circuitry 206d of the RF circuitry 206 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
25 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
30 delay line is one VCO cycle.

 In some embodiments, synthesizer circuitry 206d 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 206 may include an IQ/polar converter.

5 FEM circuitry 208 may include a receive signal path that may include circuitry configured to operate on RF signals received from one or more antennas 210, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 206 for further processing. FEM circuitry 208 may also include a transmit signal path that may include circuitry configured to amplify signals for transmission provided by
10 the RF circuitry 206 for transmission by one or more of the one or more antennas 210. In some embodiments, the FEM circuitry 208 may include a TX/RX switch to switch between transmit mode and receive mode operation. The FEM circuitry 208 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
15 amplified received RF signals as an output (e.g., to the RF circuitry 206). The transmit signal path of the FEM circuitry 208 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 206), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 210).

20 In some embodiments, the electronic device 200 may include additional elements such as, for example, memory/storage, display, camera, sensor, and/or interface circuitry (for example, input/output (I/O) interfaces or buses) (not shown). In embodiments where the electronic device is implemented in or by an eNB 110, the electronic device may include network interface circuitry. The network interface circuitry may be one or more
25 computer hardware components that connect electronic device 200 to one or more network elements, such as one or more servers within the CN 140 or another eNB 110, via a wired connection. To this end, the network interface circuitry may include one or more dedicated processors and/or FPGAs to communicate using one or more wired communications protocol. The wired communications protocols may include a serial communications
30 protocol (e.g., the Universal Serial Bus (USB), FireWire, Serial Digital Interface (SDI), and/or other like serial communications protocols), a parallel communications protocol (e.g., IEEE 1284, Computer Automated Measurement And Control (CAMAC), and/or other like parallel communications protocols), and/or a network communications protocol (e.g., Ethernet, token ring, Fiber Distributed Data Interface (FDDI), and/or other like

network communications protocols). The network interface circuitry may also include one or more virtual network interfaces configured to operate with one or more applications.

In embodiments where the electronic device 200 is a UE 105 or is incorporated into or otherwise part of a UE 105, the baseband circuitry 204 (or processor circuitry) may
5 detect an HO command based on one or more signals received from a source eNB; establish a MAC entity for a connection with a target eNB based on the HO command; establish a PDCP entity for the connection with the target eNB and an RLC entity for the connection with the target eNB upon completion of an HO operation with the target eNB; and maintain another PDCP entity for a connection with the source eNB, another RLC
10 entity for the connection with the source eNB, and another MAC entity for the connection with the source eNB until completion of the HO operation. Furthermore, the baseband circuitry 204 may be configured to perform the processes described herein (or parts thereof), such as processes 500-900 described with respect to FIGS. 5-9.

In embodiments where the electronic device 200 is an eNB 110 or is incorporated
15 into or otherwise part of an eNB 110, the baseband circuitry 204 (or processor circuitry) may control receipt of an HO request from a source eNB, wherein the HO request is to indicate an HO operation to occur between a UE and the eNB; establish a MAC entity for a connection with the UE indicated by the HO request; control receipt of data packets from the source eNB that are to be provided to the UE during the HO operation; and establish a
20 PDCP entity for the connection with the UE and an RLC entity for the connection with the UE. Furthermore, the baseband circuitry 204 may be configured to perform the processes described herein, such as process 1000 described with respect to FIG. 10.

In other embodiments where the electronic device 200 is an eNB 110 or is incorporated into or otherwise part of an eNB 110, the baseband circuitry 204 (or
25 processor circuitry) may control transmission of an HO command to the UE based on a determination that the UE should perform an HO operation with a target eNB; control transmission of one or more data packets to the UE after transmission of the HO command; control receipt of an HO complete message from the target eNB; and terminate transmission of the one or more data packets to the UE in response to receipt of the HO
30 complete message. Furthermore, the baseband circuitry 204 may be configured to perform the processes described herein, such as process 1100 described with regard to FIG. 11.

FIG. 3 illustrates example interface scheme 300 between elements of a cellular communications network 100, in accordance with various embodiments. As shown, the UE 105 includes a protocol stack 305 and eNBs 110-1 and 110-2 may include a protocol

stack 310. Each of the protocol stacks 305-310 include a Radio Resource Control (RRC) entity or layer, a Packet Data Convergence Protocol (PDCP) entity/layer, a Radio Link Control (RLC) entity/layer, a Medium Access Control (MAC) entity/layer, and Physical layer (PHY) entity/layer. The protocol stacks 305-310 may be used in a control plane
5 protocol stack for establishing radio-specific functionality. In some embodiments, the protocol stacks 305-310, without the RRC entities, may be used in a user plane protocol stack, which is used for communicating data between the UE 105 and the eNB 110 over an air interface, such as the LTE-Uu interface or the PC5 interface.

The main functions of the RRC entity may include RRC connection control; Inter-
10 RAT mobility including security activation and transfer of RRC context information; measurement configuration and reporting; transfer of dedicated non-access stratum (NAS) information and non-LTE dedicated information; transfer of UE radio access capability information; support for E-UTRAN sharing (multiple PLMN identities); generic protocol error handling; support of self-configuration and self-optimisation; and support of
15 measurement logging and reporting for network performance optimisation. The broadcast of system information may include NAS common information; cell (re-)selection parameters, neighbouring cell information and information, and common channel configuration information. RRC connection control may include establishment/modification/release of RRC connections, initial security activation such as
20 initial configuration of access stratum (AS) integrity protection (SRBs) and AS ciphering (for SRBs and DRBs), establishment/modification/release of resource blocks (RBs) carrying user data (for example, DRBs); radio configuration control; RN-specific radio configuration control for the radio interface; cell management; quality of service (QoS) control; and recovery from radio link failures (RLFs).

The main functions of the PDCP layer may include header compression and
25 decompression of Internet Protocol (IP) data flows using the Robust Header Compression (ROHC) protocol; transfer of data (user plane or control plane); maintenance of PDCP sequence numbers (SNs); in-sequence delivery of upper layer protocol data units (PDUs) at re-establishment of lower layers; duplicate elimination of lower layer service data units
30 (SDUs) at re-establishment of lower layers for radio bearers mapped on the RLC layer; ciphering and deciphering of user plane data and control plane data; integrity protection and integrity verification of control plane data; integrity protection and integrity verification of user plane data for relay nodes (RNs); timer based discard; duplicate discarding; and or split bearers, routing and reordering.

The main functions of the RLC layer may include transfer of upper layer PDUs; error correction through automatic repeat request (ARQ); concatenation, segmentation and reassembly of RLC SDUs; re-segmentation of RLC data PDUs; reordering of RLC data PDUs; duplicate detection; RLC SDU discard; RLC re-establishment; and protocol error
5 detection.

The main functions of the MAC layer may include mapping between logical channels and transport channels; multiplexing of MAC SDUs from one or different logical channels onto transport blocks (TB) to be delivered to the physical layer on transport channels; demultiplexing of MAC SDUs from one or different logical channels from
10 transport blocks (TB) delivered from the physical layer on transport channels; scheduling information reporting; error correction through Hybrid Automatic Repeat Request (HARQ); priority handling between UEs by means of dynamic scheduling; priority handling between logical channels of one MAC entity; Logical Channel prioritisation; transport format selection; radio resource selection for sidelink connections.

15 The main functions of the PHY layer may include carrying information from the MAC transport channels over the air interface. Takes care of the link adaptation (AMC), power control, cell search (for initial synchronization and handover purposes) and other measurements (inside the LTE system and between systems) for the RRC layer.

Some of the functions listed above may be applicable to both the UE 105 and the
20 eNB 110, while some of the functions may only be applicable to only the UE 105 or the eNB 110. Further, although FIG. 3 shows the UE 105 including a single protocol stack 305, in various example embodiments, the UE 105 may generate or create multiple protocol stacks 305 for communicating with multiple eNBs 110, wherein each protocol stack 305 includes a corresponding RRC entity, PDCP entity, RLC entity, MAC entity,
25 and PHY entity.

FIG. 4 illustrates a process 400 for performing an HO operation performed by various elements of the cellular communications network 100 of FIG. 1 using the interface scheme 300 of FIG. 3. For illustrative purposes, the operations of process 400 will be described as being performed by the UE 105, the eNB 110-1 acting as a source eNB or
30 source cell, and the eNB 110-2 acting as a target eNB or target cell. While particular examples and orders of operations are illustrated in FIG. 4, in various embodiments, these operations may be re-ordered, broken into additional operations, combined, and/or omitted altogether. In some embodiments, the operations illustrated in FIG. 4 may be combined with operations described with regard to other embodiments, such as those illustrated by

one or more of FIGS. 5-11 and/or one or more operations described with regard to the non-limiting examples provided herein.

Referring to FIG. 4, at operation 402, UE 105 may receive a measurement control message from the source eNB 110-1, and at operation 403, the UE 105 may provide a measurement report to source eNB 110-1 based on some event trigger. The measurement control message and the measurement report may be signaled using layer 3 (L3) signaling, for example, RRC layer or non-access stratum (NAS) layer signaling. In embodiments, the measurement control message may be based on a configuration measurement provided by an RRC entity of the source eNB 110-1. The configuration message may instruct the UE 105 to configure itself to perform one or more carrier frequency measurements for one or more listed cells. Such measurements may include intra-frequency measurements (for example, measurements of one or more downlink carrier frequency(ies) of the serving cell(s)), inter-frequency (for example, measurements of one or more carrier frequencies that differ from any of the downlink carrier frequency(ies) of the serving cell(s)), and/or inter-radio access technology (RAT) measurements (for example, measurements of UTRA frequencies, GERAN frequencies, and/or CDMA2000 frequencies). This configuration may be done during an initial RRC connection establishment procedure with the source eNB 110-1. The measurements to be taken may include reception-transmission time difference measurements, Received Signal Strength Indicator (RSSI) measurements, channel occupancy measurements, RSRP/RSRQ measurements, Signal-to-Noise Ratio (SNR) measurements, Signal-to-Interference-plus-Noise Ratio (SINR) measurements, and/or other like measurements. After the UE 105 performs these measurements, the UE 105 may generate the measurement report, and transmit the measurement report to the source eNB 110-1 at operation 403.

At operation 406, the source eNB 110-1 may make an HO decision based on the measurements in the measurement report. At operation, 409, the source eNB 110-1 may transmit an HO request to the target eNB 110-2, and at operation 412, the target eNB 110-2 may transmit an HO request acknowledgement (ACK) to the source eNB 110-1. The HO request and the HO request ACK may be communicated using L3 signaling, for example, using X2 signaling when a direct connection between the source eNB 110-1 and the target eNB 110-2 is available. At operation 415, the source eNB 110-1 may transmit an RRC Connection Reconfiguration message to the UE 105. The RRC Connection Reconfiguration message may be an HO command, which instructs the UE 105 to perform an HO operation with the target eNB 110-2. The RRC Connection Reconfiguration

message may indicate communications resources from the target eNB 110-2 that are available for the UE 105, a Cell Radio Network Temporary Identifier (C-RNTI) associated with the target eNB 110-2, a selected security algorithm to use for encrypting/decrypting messages, a Random Access Channel (RACH) preamble assignment, access parameters, and/or other like information. The information indicated by the RRC Connection Reconfiguration message may be used by the UE 105 to synchronize with the target eNB 110-2 during RACH procedure in the HO operation. Additionally, at least some of the information indicated by the RRC Connection Reconfiguration message may be information that was contained in the HO request ACK message.

Furthermore, in embodiments where the RRC Connection Reconfiguration message is the HO command, the RRC Connection Reconfiguration message may include a mobility control information, information element (IE) (also referred to as “mobilityControlInformation” or “mobilityControlInfo”). The mobilityControlInfo IE may indicate a value for an HO timer, such as timer T304. Expiration of the timer T304 may indicate an HO failure, and the UE 105 may revert back to a configuration used in the source cell 110-1, and/or store handover failure information (such as, RSRP and/or RSRQ measurements, location information, a horizontal velocity, and the like) for reporting. The mobilityControlInfo IE may also include other information that the UE 105 may use for performing the HO operation.

After providing the HO command to the UE 105, the source eNB 110-1 at operation 418 may continue to provide one or more downlink transmissions (data packets) to the UE 105 while the UE 105 performs the HO operation with the target eNB 110-2. The data packets may be transmitted to the UE 105 over the user-plane. In some embodiments, the UE 105 may continue to provide user data to the source eNB 110-1. Furthermore, the UE 105 may begin to synchronize with the target eNB 110-2 while the UE 105 continues to receive downlink transmissions from the source eNB 110-1. At operation 421 the source eNB 110-1 may provide copies of the data packets to the target eNB 110-2, which may be referred to as a packet forwarding operation. The packet forwarding operation may take place directly from source eNB 110-1 to target eNB 110-2 (for example, over the X2 interface). At operation 424, the target eNB 110-2 may buffer the data packets.

Meanwhile, at operation 427, the UE 105 may generate a protocol stack for communicating with the target eNB 110-2 (also referred to as a “target protocol stack,” “target eNB protocol stack,” and the like) and/or activate at least one target protocol stack

entity for communicating with the target eNB 110-2. Furthermore, operation 427 may also include deactivating some target protocol stack entities. For example, in some embodiments the UE 105 may generate the target protocol stack, activate the MAC entity of the target protocol stack, and deactivate the PDCP and RLC entities of the target protocol stack (see for example, processes 500 and 600 shown and described with regard to FIGS. 5 and 6, respectively). In other embodiments, the UE 105 may activate the PDCP entity, the RLC entity, and the MAC entity of the target protocol stack (see for example process 900 shown and described with regard to FIG. 9). In other embodiments, the UE 105 may only create and establish a MAC entity for the target eNB 110-2 without generating/creating an entire target protocol stack (see for example process 700 shown and described with regard to FIG. 7). In other embodiments, the UE 105 may activate the PDCP and/or RLC entities by performing PDCP and/or RLC re-establishment procedures for one or more signaling radio bearers (SRBs) without generating/creating an entire target protocol stack (see for example process 800 shown and described with regard to FIG. 8). Additionally, the UE 105 should have already established a protocol stack for communicating with the source eNB 110-1 (also referred to as a “source protocol stack”) during an attachment procedure with the source eNB 110-1 (not shown). In embodiments, the UE 105 may maintain (or not reset) the source protocol stack while generating/creating the target protocol stack.

At operation 430, the UE 105 performs a cell synchronization procedure with the target eNB 110-2, which may include layer 1 (L1) and/or layer 2 (L2) signaling between the UE 105 and the target eNB 110-2, for example PDCP, RLC, MAC, and/or PHY signaling. The cell synchronization procedure may include, for example, locating a primary synchronization signal (PSS) and a secondary synchronization signal (SSS) to obtain a physical cell identifier (PCI) of the target eNB 110-2, using the PCI to locate one or more reference signals (RSs) to perform channel estimation, and reading a master information block (MIB) and one or more system information blocks (SIBs) associated with the target eNB 110-2. The synchronization operation may also include performing a RACH procedure, which may include the UE 105 generating and transmitting a RACH Request (also referred to as a “Random Access (RA) Preamble” message) to the target eNB 110-2. In some embodiments, the RACH Request may trigger the target eNB 110-2 to generate and/or activate a MAC entity for communicating with the UE 105.

After synchronization with the target eNB 110-2, at operation 433 the target eNB 110-2 may provide the UE 105 with an uplink (UL) allocation and a timing advance (TA),

which may include a RA Response (RAR). The UL allocation, TA, and RAR may be provided to the UE 105 using L1/L2 signaling. In response to receipt of the RAR, at operation 439 the UE 105 activates the PDCP entity and the RLC entity in the target protocol stack (if this was not done at operation 427), and resets the source protocol stack.

5 In some embodiments, the PDCP entity and the RLC entity may have been activated at operation 427, and in such embodiments, operation 439 may only include resetting the source eNB protocol stack.

Meanwhile, at operation 436, the target eNB 110-2 transmits an HO complete message to the source eNB 110-2. The HO complete message may be communicated to
10 the source eNB 110-1 using L3 signaling. In response to receipt of the HO complete message, at operation 442 the source eNB 110-1 terminates downlink (DL) transmissions to the UE 105, and at operation 445 the source eNB 110-1 transmits an SN status transfer message to the target eNB 110-2 using L3 signaling.

At operation 448, the UE 105 transmits an RRC Connection Reconfiguration
15 Complete message to the target eNB 110-2. In embodiments, the RRC Connection Reconfiguration Complete message may include a PDCP status report, which may indicate data packets that were not properly received or properly decompressed during the HO operation. For example, the PDCP status report may indicate data packets that were intended to be delivered to the UE 105 at operation 418. Data packets that are not properly
20 received and/or properly decompressed by the UE 105 may be referred to as “unacknowledged data packets.” In some embodiments, operation 448 may be performed in parallel with operations 442-445. Alternatively, operations 442-445 may occur after operation 448.

At operation 451, the target eNB 110-2 may discard any duplicate packets that
25 were properly received and/or properly decompressed by the UE 105, and at operation 454, the target eNB 110-2 may (re-)transmit unacknowledged data packets to the UE 105, which were buffered at operation 424.

Meanwhile, the target eNB 110-2 and source eNB 110-1 may perform various HO-related operations with one or more core network elements (not shown by FIG. 4). These
30 operations may include the target eNB 110-2 providing copies of the data packets to an SGW over the user-plane, and transmitting a path switch request to an MME using L3 signaling. In response to the path switch request, the MME may transmit a modify bearer request to the SGW using L3 signaling. In response to the modify bearer request, the SGW may switch a downlink path associated with the UE 105, provide an end marker to the

source eNB 110-1 over the user-plane, and provide a modify bearer response to the MME. The target eNB 110-2 may receive, from the MME using L3 signaling, a path switch request ACK based on the modify bearer response. In response to the path switch request ACK, at operation 457 the target eNB 110-2 may transmit a UE context release message
5 to the source eNB 110-1. At operation 460, the source eNB 110-1 may release and reallocate resources that were previously allocated to the UE 105 in response to the UE context release message. In various embodiments, operations 457 and 460 may occur any time after operation 448.

FIGS. 5-9 illustrate processes 500-900, respectively, which may be performed by
10 the UE 105 to receive downlink transmissions during a handover operation, in accordance with a first type of example embodiments. In some embodiments, the UE 105 may include one or more non-transitory computer-readable media having instructions, stored thereon, that when executed by the UE 105, cause the UE 105 to perform the one or more of processes 500-900. For illustrative purposes, the operations of processes 500-900 are
15 described as being performed by the UE 105 or components/protocol stack entities of the UE 105, which are described with respect to FIGS. 1-3. However, it should be noted that other similar devices/entities may operate the processes 500-900. While particular examples and orders of operations are illustrated in FIGS. 5-9, in various embodiments, these operations may be re-ordered, broken into additional operations, combined, and/or
20 omitted altogether. In some embodiments, the operations illustrated in one of FIGS. 5-9 may be combined with operations described with regard to other example embodiments and/or one or more operations described with regard to the non-limiting examples provided herein.

FIG. 5 illustrates a process 500 that may be performed by a UE 105 to receive
25 downlink transmissions during a handover operation, in accordance with a first type of example embodiments. At operation 505, the processor circuitry of the UE 105 may control receipt of signaling from the source eNB 110-1. In embodiments, the RF circuitry 206 may receive RF signaling from the source eNB 110-1, and the RF circuitry 206 may pass data representative of the signaling to processor circuitry of the UE 105 via interface
30 circuitry of the UE 105. At operation 510, the processor circuitry of the UE 105 may detect an HO command based on the signaling received from the source eNB 110-1. In various embodiments, the HO command may be an RRC Connection Reconfiguration message, which may also include the mobilityControlInfo IE. Operations 505 and 510 may be performed at operation 415 in the example embodiment shown and described with

regard to FIG. 4.

At operation 515, processor circuitry of the UE 105 may establish a new MAC entity for a connection with the target eNB 110-2 based on the HO command. At operation 520, processor circuitry of the UE 105 may, upon completion of an HO operation with the target eNB 110-2, establish a new PDCP entity for the connection with the target eNB 110-2 and a new RLC entity for the connection with the target eNB 110-2. At operation 525, the processor circuitry of the UE 105 may maintain an existing PDCP entity for a connection with the source eNB, an existing RLC entity for the connection with the source eNB, and an existing MAC entity for the connection with the source eNB until completion of the HO operation.

In various embodiments, to perform operations 515 and 520, the processor circuitry may generate a new protocol stack including a new PDCP entity, a new RLC entity, and a new MAC entity. The new protocol stack may be a target eNB protocol stack for communicating with the target eNB 110-2. In such embodiments, the processor circuitry may maintain an existing protocol stack until completion of the HO operation. The existing protocol stack may be a source eNB protocol stack established with the source eNB 110-1, and may be used to receive one or more downlink transmissions during the HO operation. The existing protocol stack may include an existing PDCP entity, an existing RLC entity, and an existing MAC entity. These operations may correspond with operation 427 as shown and described with regard to FIG. 4.

In some embodiments, to perform operation 515, the processor circuitry may activate the new MAC entity in after receiving or detecting the HO command. The processor circuitry may implement an RRC entity to provide an RRC Connection Reconfiguration Complete message to the new MAC entity. Passing the RRC Connection Reconfiguration Complete message to the new MAC entity may trigger the new MAC entity to initiate a RACH procedure. These operations may correspond to operation 427 shown and described with regard to FIG. 4.

To perform the RACH procedure, the processor circuitry implementing the new MAC entity may determine one or more subframes and an available set of physical RACH (PRACH) resources for the transmission of a RACH request to the target eNB 110-2. The new MAC entity may also determine an RA preamble index, an RA Radio Network Temporary Identity (RA-RNTI), and an amount of power to be used for transmitting the RACH request. The new MAC entity may then generate the RACH request including the RA preamble index, the RA-RNTI, and the preamble transmission power. These

operations may correspond to operation 430 shown and described with regard to FIG. 4.

Once the RA request message is received by the target eNB 110-2, the target eNB 110-2 may generate a RACH response (also referred to as a “Random Access Response” or “RAR”) indicating a temporary RNTI allocated to the UE 105, a timing advance (TA) for uplink (UL) transmissions, and an UL grant indicating an allocation of UL resources for the UE 105 to transmit data to the target eNB 110-2. The target eNB 110-2 may then transmit the RAR to the UE 105. These operations may correspond to operation 433 shown and described with regard to FIG. 4.

Receipt of the RAR may cause the processor circuitry to perform operation 520 by activating the new PDCP entity and the new RLC entity, and perform operation 525 by resetting the existing protocol stack. This operation may be performed at operation 439 shown and described with regard to FIG. 4.

After activation of the new PDCP entity and the new RLC entity, the processor circuitry may control transmission of an RRC Connection Reconfiguration Complete message to the target eNB 110-2. This operation may be performed at operation 448 shown and described with regard to FIG. 4.

FIG. 6 illustrates a process 600 that may be performed by a UE 105 to receive downlink transmissions during a handover operation according to the first type of example embodiments. At operation 605 processor circuitry of the UE 105 may obtain or detect an HO command from source eNB 110-1. In various embodiments, the HO command may be included in an RRC Connection Reconfiguration message, which may also include the mobilityControlInfo IE. Operation 605 may be performed at operation 415 in the example embodiment shown and described with regard to FIG. 4.

At operation 610, the processor circuitry of UE 105 may generate a new protocol stack that may be used for communicating with a target eNB 110-2. The new protocol stack may include a new PDCP entity to be used for a new connection with the target eNB 110-2, a new RLC entity to be used for the new connection, and a new MAC entity to be used for the new connection. Operation 610 may be performed at operation 427 in the example embodiment shown and described with regard to FIG. 4.

At operation 615, the processor circuitry of the UE 105 may activate the new MAC entity while maintaining entities of an existing protocol stack for an existing connection with the source eNB 11-1. The existing protocol stack may include an existing PDCP entity, an existing RLC entity, and an existing MAC entity. In some embodiments, operation 615 may also include deactivating the other entities of the new protocol stack

(for example, the new PDCP and new RLC entities). The existing protocol stack may be established with the source eNB 110-1 for receipt of one or more downlink transmissions prior to and during the HO operation. Operation 615 may be performed at operation 427 in the example embodiment shown and described with regard to FIG. 4.

5 At operation 620, the processor circuitry of the UE 105 may provide an RRC Connection Reconfiguration Complete message to the new MAC entity. When the new MAC entity receives the RRC Connection Reconfiguration Message, the processor circuitry implementing the new MAC entity may initiate an RA procedure with the target eNB 110-2 by controlling transmission of a RA request to the target eNB 110-2. Operation
10 620 may be performed at operation 430 in the example embodiment shown and described with regard to FIG. 4.

 At operation 625, the processor circuitry of the UE 105 may control receipt of an RAR from the target eNB 110-2 based on the RA request. Operation 625 may be performed at operation 433 in the example embodiment shown and described with regard
15 to FIG. 4.

 Upon receipt of the RAR, at operation 630 the processor circuitry of the UE 105 may reset the existing protocol stack. At operation 635, the processor circuitry of the UE 105 may activate the new PDCP entity and the new RLC entity in the new protocol stack. Operations 630 and 635 may be performed at operation 439 in the example embodiment
20 shown and described with regard to FIG. 4. In some embodiments, process 600 may also include the processor circuitry controlling transmission of the RRC Connection Reconfiguration Complete message to the target eNB 110-2 after the new PDCP entity and the new RLC entity are activated. Such an operation may correspond with operation 448 in the example embodiment shown and described with regard to FIG. 4.

25 FIG. 7 illustrates a process 700 that may be performed by a UE 105 to receive downlink transmissions during a handover operation, in accordance with a second type of example embodiments. At operation 705 the processor circuitry of the UE 105 may obtain or detect an HO command. In various embodiments, the HO command may be an RRC Connection Reconfiguration message, which may also include the mobilityControlInfo IE.
30 Operation 705 may be performed at operation 415 in the example embodiment shown and described with regard to FIG. 4.

 At operation 710, the processor circuitry of the UE 105 may activate a new MAC entity for communicating with the target eNB 110-2 while maintaining an existing protocol stack for communicating with the source eNB 110-1. In embodiments, the

processor circuitry of the UE 105 may generate and activate the new MAC entity in response to receipt or detection of the HO command without generating the new protocol stack. Operation 710 may be performed at operation 427 as shown and described with regard to FIG. 4. At operation 715, the processor circuitry of the UE 105 may request
5 activation of another new MAC entity at the target eNB 110-2. In embodiments, the processor circuitry may control the RF circuitry 206, via the interface circuitry, to transmit a RACH message (for example, the RACH request described previously) to the target eNB 110-2 to initiate the RACH procedure. Operation 715 may be performed at operation 430 as shown and described with regard to FIG. 4.

10 At operation 720, the processor circuitry of the UE 105 may control receipt of an RAR from the target eNB 110-1 via interface circuitry of the UE 105. The processor circuitry may control receipt of an RAR from the target eNB 110-2 in a same or similar manner as discussed previously. Operation 720 may be performed at operation 433 as shown and described with regard to FIG. 4.

15 At operation 725, the processor circuitry of the UE 105 may perform a PDCP re-establishment procedure for both data radio bearers (DRBs) and signaling radio bearers (SRBs)) and perform an RLC re-establishment procedure. The PDCP re-establishment procedure for uplink DRBs may include resetting a header compression protocol for uplink transmissions, applying an integrity protection algorithm and key provided by
20 upper layers if the UE 105 is connected as a relay node, applying a ciphering algorithm and key provided by upper layers, and performing retransmission or transmission of all the PDCP SDUs already associated with PDCP SNs in ascending order of count values associated to the PDCP SDU prior to the PDCP re-establishment. The PDCP re-establishment procedure for uplink SRBs may include discarding all stored PDCP SDUs
25 and PDCP PDUs, and applying the ciphering and integrity protection algorithms and keys provided by upper layers. The PDCP re-establishment procedure for downlink DRBs may include processing the PDCP Data PDUs that are received from lower layers due to the re-establishment of the lower layers, resetting the header compression protocol for downlink transmissions, applying the ciphering algorithm and key provided by upper layers, and
30 applying the integrity protection algorithm and key provided by upper layers if the UE is connected as a relay node. The PDCP re-establishment procedure for downlink SRBs may include discarding the PDCP Data PDUs that are received from lower layers, discarding all stored PDCP SDUs and PDCP PDUs, and applying the ciphering and integrity protection algorithms and keys provided by upper layers. The PDCP re-establishment

procedure may include any other operations delineated by any relevant standards. Furthermore, the processor circuitry may also use a new security key for performing the PDCP re-establishment procedure. This new security key may have been generated for ciphering and deciphering messages associated with the target eNB 110-2

5 The RLC re-establishment procedure may include discarding all RLC SDUs; reassembling RLC SDUs from PDUs, removing RLC headers when doing so and delivering all reassembled RLC SDUs to upper layers in ascending order of the RLC SN, if not delivered before; discarding all remaining PDUs; discarding all RLC SDUs; stop and reset all timers; and reset all state variables to their initial values. The RLC re-
10 establishment procedure may include any other operations delineated by any relevant standards. Furthermore, the processor circuitry may also use the new security key for performing the RLC re-establishment procedure.

Referring back to FIG. 7, at operation 730, the processor circuitry of the UE 105 may control transmission of an RRC Reconfiguration Complete message to the target eNB
15 110-1. In embodiments, transmission of the RRC Connection Reconfiguration Complete message to the target eNB 110-2 may indicate completion of the HO operation. At operation 735, the UE 105 may reset the existing protocol stack. Operations 730 and 735 may be performed at operation 448 shown and described with regard to FIG. 4.

FIG. 8 illustrates a process 800 that may be performed by a UE 105 to receive
20 downlink transmissions during a handover operation, in accordance with a third type of example embodiments. At operation 805 the processor circuitry of the UE 105 may obtain or detect an HO command from the source eNB 110-1. In various embodiments, the HO command may be an RRC Connection Reconfiguration message, which may also include the mobilityControlInfo IE. Operation 805 may be performed at operation 415 in the
25 example embodiment shown and described with regard to FIG. 4.

At operation 810, the processor circuitry of the UE 105 may perform re-establishment procedures for one or more SRBs with the target eNB 110-2. An SRB is a radio bearer that carries downlink control channel (DCCH) signaling data for the establishment of Radio Access Bearers (RABs), and may be used to provide signaling to
30 the UE 105 during the connection with the target eNB 110-2. In embodiments, to perform operation 810 the processor circuitry of the UE 105 may perform the PDCP and/or the RLC re-establishment procedures discussed previously for one or more SRBs. In some embodiments, the one or more SRBs may include both SRB1 and SRB2, while in other embodiments the one or more SRBs may only include SRB1. In some embodiments, the

processor circuitry may use a security key for communicating with the target eNB 110-2 for the PDCP and/or RLC re-establishment procedures. Operation 810 may be performed at operation 427 in the example embodiment shown and described with regard to FIG. 4.

After the processor circuitry performs the PDCP and/or RLC re-establishment procedures, at operation 815, the UE 105 may create a new MAC entity for a connection with the target eNB 110-2. In embodiments, once the new MAC entity is created, an RRC entity implemented by processor circuitry may provide the new MAC entity with an RRC Reconfiguration message to initiate or trigger the RA procedure. The RA procedure may be performed in a same or similar manner as discussed previously, and at operation 820, the processor circuitry of the UE 105 may control receipt of an RAR from the target eNB 110-2. Operations 815 and 820 may be performed at operations 430 and 433 in the example embodiment shown and described with regard to FIG. 4.

In response to receipt of the RAR, at operation 825, the processor circuitry of the UE 105 may perform re-establishment procedures for DRBs and any remaining SRBs. In embodiments, to perform operation 825 the processor circuitry of the UE 105 may perform the PDCP and/or the RLC re-establishment procedures discussed previously for the one or more DRBs and/or any remaining SRBs that were not re-established at operation 810. In some embodiments, the processor circuitry may use a security key for communicating with the target eNB 110-2 for the PDCP and/or RLC re-establishment procedures. Operation 825 may be performed at operation 439 in the example embodiment shown and described with regard to FIG. 4.

At operation 830, the processor circuitry of the UE 105 may control transmission of the RRC Reconfiguration Complete message to the target eNB 110-1. In embodiments, transmission of the RRC Connection Reconfiguration Complete message to the target eNB 110-2 may indicate completion of the HO operation. Operation 830 may be performed at operation 448 shown and described with regard to FIG. 4.

FIG. 9 illustrates a process 900 that may be performed by a UE 105 to receive downlink transmissions during a handover operation, in accordance with a fourth type of example embodiments. At operation 905 the processor circuitry of the UE 105 may obtain or detect an HO command from source eNB 110-1. In various embodiments, the HO command may be an RRC Connection Reconfiguration message, which may also include the mobilityControlInfo IE.

At operation 910, the processor circuitry of the UE 105 may generate new protocol stack. The new protocol stack may be the same or similar to the new protocol stack

discussed with regard to operation 605 of FIG. 6, and may include a new PDCP entity to be used for a new connection with the target eNB 110-2, a new RLC entity to be used for the new connection with the target eNB 110-2, and a new MAC entity to be used for the new connection with the target eNB 110-2. Operation 910 may be performed at operation 5 427 in the example embodiment shown and described with regard to FIG. 4.

At operation 915, the processor circuitry of the UE 105 may activate an entirety of the new protocol stack while maintaining an existing protocol stack. The existing protocol stack may be the same or similar to the existing protocol stack as discussed with regard to operation 605 of FIG. 6, and may include an existing PDCP entity, an existing RLC entity, 10 and an existing MAC entity. Operation 915 may be performed at operation 427 in the example embodiment shown and described with regard to FIG. 4.

At operation 920, the processor circuitry of the UE 105 may provide an RRC Connection Reconfiguration Complete message to the new MAC entity of the new protocol stack. When the new MAC entity receives the RRC Connection Reconfiguration 15 Message, the new MAC entity may initiate a RA procedure with the target eNB 110-2 by controlling transmission of an RA request to the target eNB 110-2. Operation 920 may be performed at operation 430 in the example embodiment shown and described with regard to FIG. 4.

At operation 925, the processor circuitry of the UE 105 may control receipt of an 20 RAR from the target eNB 110-2 based on the RA request. Operation 925 may be performed at operation 433 in the example embodiment shown and described with regard to FIG. 4. Upon receipt of the RAR, at operation 930 the processor circuitry of the UE 105 may reset the existing protocol stack. Operation 930 may be performed at operation 439 in the example embodiment shown and described with regard to FIG. 4. In some 25 embodiments, process 900 may also include processor circuitry controlling transmission of an RRC Connection Reconfiguration Complete message to the target eNB 110-2 after the existing protocol stack is deactivated. Such an operation may correspond with operation 448 in the example embodiment shown and described with regard to FIG. 4.

FIGS. 10-11 illustrate processes 1000-1100, respectively, which may be performed 30 by an eNB 110 during a handover operation, in accordance with various embodiments. In some embodiments, the eNB 110 may include one or more non-transitory computer-readable media having instructions, stored thereon, which when executed by the eNB 110, cause the eNB 110 to perform the processes 1000 and/or 1100. For illustrative purposes, the operations of processes 1000-1100 will be described as being performed by one of the

eNBs 110 and/or or components/protocol stack entities of the eNBs 110, which are described with respect to FIGS. 1-3. However, it should be noted that other similar devices and/or network elements may operate the processes 1000-1100. While particular examples and orders of operations are illustrated in FIGS. 10-11, in various embodiments, these operations may be re-ordered, broken into additional operations, combined, and/or omitted altogether. In some embodiments, the operations illustrated in one of FIGS. 10-11 may be combined with operations described with regard to other embodiments and/or one or more operations described with regard to the non-limiting examples provided herein.

FIG. 10 illustrates the process 1000 that may be performed by an eNB 110-2 operating as a target eNB during a handover operation, in accordance with various embodiments. At operation 1005 the processor circuitry of the eNB 110 may control receipt of an HO request from source eNB 110-1. The HO request may include context information associated with the UE 105, such as a security context and radio bearer context, which may be used to prepare the eNB 110-2 for the HO operation. In embodiments, the processor circuitry of the eNB 110-2 control transmission of an HO request ACK to the source eNB 110-1. The HO request ACK may indicate communications resources that are available for the UE 105, a C-RNTI, selected security algorithms to use for encrypting/decrypting and integrity protecting messages, a RACH preamble, access parameters, and/or other like information. In embodiments, the source eNB 110-1 may include this information in an RRC message, which may then be provided to the UE 105 as the HO command. The HO request and the HO request ACK messages may be communicated directly between the eNB 110-1 and eNB 110-2 over an X2 interface. These operations may be performed at operations 406-415 as shown and described with regard to FIG. 4.

At operation 1010, the processor circuitry of the eNB 110-2 may control receipt of a first copy of data packets from the source eNB 110-1. In embodiments, the source eNB 110-1 may buffer the data packets intended for the UE 105, create duplicate or copies of those data packets, and may forward a copy of the data packets to the eNB 110-2. The source eNB 110-1 transmit the original data packets, or another copy of the data packets, to the UE 105 while the UE 105 performs the HO operation with the eNB 110-2. Furthermore, the processor circuitry of the eNB 110-2 may also buffer or otherwise control storage of the received data packets. These operations may be performed at operations 418-422 as shown and described with regard to FIG. 4.

At operation 1015, the processor circuitry of the eNB 110-2 may establish a MAC

entity for a connection with the UE 105. At operation 1020, the eNB 110 may establish a PDCP entity and an RLC entity for the connection with the UE 105. The MAC, PDCP, and RLC entities may be established and/or activated according to any of the example embodiments discussed with regard to FIGS. 5-9. These operations may be performed at operations 406-415 as shown and described with regard to FIG. 4.

At operation 1025, the processor circuitry of the eNB 110-2 may control transmission of an HO complete message to the source eNB 110-1. The HO complete message may indicate to the source eNB 110-1 to release and reallocate resources that were allocated to the UE 105 prior to the HO operation. Operation 1025 may be performed at operation 436 as shown and described with regard to FIG. 4.

At operation 1030, the processor circuitry of the eNB 110-2 may control receipt of a PDCP status report from the UE 105. The PDCP status report is used to notify the target eNB 110-2 of any data packets that may have been lost due to the PDCP and/or RLC re-establishment procedures discussed previously. The PDCP status report may indicate any PDCP SDUs that are missing after the PDCP re-establishment procedure. The PDCP status report may include a bitmap with a field of length in bits equal to the number of PDCP SNs. Fields in the bitmap may include a '0' value in a corresponding position in the bitmap field for all PDCP SDUs that have not been received as indicated by lower layers, and optionally any PDCP SDUs for which decompression has failed. A value of '1' in the bitmap fields may indicate properly received and/or properly decompresses PDCP SDUs. In various embodiments, the PDCP status report may be included in an RRC Connection Reconfiguration Complete message. Operation 1030 may be performed at operation 448 as shown and described with regard to FIG. 4.

At operation 1035, the processor circuitry of the eNB 110-2 may control transmission, to the UE 105, of data packets indicated by the PDCP status report as being missing or improperly decompressed. In embodiments, the processor circuitry of the eNB 110-2 may discard or delete data packets indicated by the PDCP status report as properly received and/or properly decompressed. Operation 1035 may be performed at operations 451-454 as shown and described with regard to FIG. 4.

FIG. 11 illustrates the process 1100 that may be performed by an eNB 110-1 operating as a source eNB during a handover operation, in accordance with various embodiments. At operation 1105 the processor circuitry of the eNB 110-1 may control transmission of an HO command to the UE 105. In various embodiments the HO command may be an RRC Connection Reconfiguration message. In embodiments, the

source eNB 110-1 may receive an HO request ACK from the target eNB 110-2, and the source eNB 110-1 may include or insert information from the HO request ACK message into the HO command. The HO request ACK message may be the same or similar to the HO request ACK message discussed with regard to operation 1005 of FIG. 10. Operation 1105 may be performed at operation 415 as shown and described with regard to FIG. 4.

At operation 1110, the processor circuitry of the eNB 110-1 may transmit one or more data packets to the UE 105 after transmission of the HO command. At operation 1115, the eNB 110-1 may transmit copies of the one or more data packets to the target eNB 110-2. The eNB 110-1 may forward copies of the data packets to the target eNB 110-2 for bearers subject to data forwarding. The forwarding may be either direct forwarding (for example, over an X2 interface between the eNB 110-1 and the target eNB 110-2) according to known data forwarding procedures. In embodiments, the eNB 110-1 may continue to transmit the one or more data packets to the UE 105, and continue to forward copies of the one or more data packets to the target eNB 110-2 until receipt of an HO complete message from the target eNB 110-2 at operation 1120. Operations 1110 and 1115 may be performed at operations 418-424 as shown and described with regard to FIG. 4.

At operation 1120, the processor circuitry of the eNB 110-1 may control receipt of an HO complete message from the target eNB 110-2. In response to receipt of the HO complete message, at operation 1125 the processor circuitry of the eNB 110-1 may terminate downlink transmissions to the UE 105, and at operation 1130 the processor circuitry of the eNB 110-1 may release and reallocate resources that were previously allocated to the UE 105. Operations 1120-1130 may be performed at operations 436-442 as shown and described with regard to FIG. 4.

Some non-limiting examples of changes to 3GPP TS 36.331 version 13.1.0 (2016-04) that may implement the various example embodiments are provided in the table 1 below.

5.3.5.4 Reception of an *RRCCConnectionReconfiguration* including the *mobilityControlInfo* by the UE (handover)

If the *RRCCConnectionReconfiguration* message includes the *mobilityControlInfo* and the UE is able to comply with the configuration included in this message, the UE shall:

1> stop timer T310, if running;

1> stop timer T312, if running;

1> start timer T304 with the timer value set to *t304*, as included in the *mobilityControlInfo*;

1> if the *carrierFreq* is included:

2> consider the target PCell to be one on the frequency indicated by the *carrierFreq* with a physical cell identity indicated by the *targetPhysCellId*;

1> else:

2> consider the target PCell to be one on the frequency of the source PCell with a physical cell identity indicated by the *targetPhysCellId*;

1> start synchronising to the DL of the target PCell;

NOTE 1: The UE should perform the handover as soon as possible following the reception of the RRC message triggering the handover, which could be before confirming successful reception (HARQ and ARQ) of this message.

1> maintain mcg mac, if configured;

1> reset scg mac, if configured;

NOTE 2: The handling of the radio bearers after the successful completion of the PDCP re-establishment, e.g. the re-transmission of unacknowledged PDCP SDUs (as well as the associated status reporting), the handling of the SN and the HFN, is specified in 3GPP TS 36.323 version 13.1.0 (2016-04).

1> configure lower layers to consider the SCell(s) other than the PSCell, if configured, to be in deactivated state;

1> apply the value of the *newUE-Identity* as the C-RNTI;

1> if the *RRCCConnectionReconfiguration* message includes the *fullConfig*:

2> perform the radio configuration procedure as specified in section 5.3.5.8;

1> configure lower layers in accordance with the received *radioResourceConfigCommon*;

1> configure lower layers in accordance with any additional fields, not covered in the previous, if included in the received *mobilityControlInfo*;

1> if the *RRCCConnectionReconfiguration* message includes the *radioResourceConfigDedicated*:

2> perform the radio resource configuration procedure as specified in 5.3.10;

1> if the *keyChangeIndicator* received in the *securityConfigHO* is set to *TRUE*:

2> generate new $k_{\text{enb-target}}$ key based on the k_{asme} key taken into use with the latest successful nas smc procedure, as specified in 3GPP TS 33.401 version 13.2.0 (2016-03-17);

1> else:

2> generate the $k_{\text{enb-target}}$ key based on the current k_{enb} or the nh , using the *nextHopChainingCount* value indicated in the *securityconfigho*, as specified in ts 33.401;

Note X: use k_{enb} until handover complete, update k_{enb} with $k_{\text{enb-target}}$

1> store the *nextHopChainingCount* value;

1> if the *securityAlgorithmConfig* is included in the *securityConfigHO*:

2> derive the K_{RRCint} key associated with the *integrityProtAlgorithm*, as specified in TS 33.401 ;

2> if connected as an RN:

3> derive the K_{UPint} key associated with the *integrityProtAlgorithm*, as specified in TS 33.401 ;

2> derive the K_{RRCenc} key and the K_{UPenc} key associated with the *cipheringAlgorithm*, as specified in TS 33.401;

1> else:

2> derive the K_{RRCint} key associated with the current integrity algorithm, as specified in TS 33.401;

2> if connected as an RN:

3> derive the K_{UPint} key associated with the current integrity algorithm, as specified in TS 33.401;

2> derive the K_{RRCenc} key and the K_{UPenc} key associated with the current ciphering algorithm, as specified in TS 33.401;

1> configure lower layers to apply the integrity protection algorithm and the K_{RRCint} key, i.e. the integrity protection configuration shall be applied to all subsequent messages received and sent by the UE, including the message used to indicate the successful completion of the procedure;

1> configure lower layers to apply the ciphering algorithm, the K_{RRCenc} key and the K_{UPenc} key, i.e. the ciphering configuration shall be applied to all subsequent messages received and sent by the UE, including the message used to indicate the successful completion of the procedure;

1> if connected as an RN:

2> configure lower layers to apply the integrity protection algorithm and the K_{UPint} key, for current or subsequently established DRBs that are configured to apply integrity protection, if any;

1> if the received *RRCCConnectionReconfiguration* includes the *sCellToReleaseList*:

2> perform SCell release as specified in 5.3.10.3a;

1> if the received *RRCCConnectionReconfiguration* includes the *sCellToAddModList*:

2> perform SCell addition or modification as specified in 5.3.10.3b;

1> if the received *RRCCConnectionReconfiguration* includes the *scg-Configuration*; or

1> if the current UE configuration includes one or more split DRBs and the received *RRCCConnectionReconfiguration* includes *radioResourceConfigDedicated* including *drb-ToAddModList*:

2> perform SCG reconfiguration as specified in 5.3.10.10;

1> if the received *RRCCConnectionReconfiguration* includes the *systemInformationBlockType1Dedicated*:

2> perform the actions upon reception of the *SystemInformationBlockType1* message as specified in 5.2.2.7;

1> perform the measurement related actions as specified in 5.5.6.1;

1> if the *RRCCConnectionReconfiguration* message includes the *measConfig*:

2> perform the measurement configuration procedure as specified in 5.5.2;

1> perform the measurement identity autonomous removal as specified in 5.5.2.2a;

1> release *reportProximityConfig* and clear any associated proximity status reporting timer;

1> if the *RRCCConnectionReconfiguration* message includes the *otherConfig*:

2> perform the other configuration procedure as specified in 5.3.10.9;

1> if the *RRCCConnectionReconfiguration* message includes the *continuesourcetrans*:

2> perform the sidelink dedicated configuration procedure as specified in 5.3.10.x;

1> if the *RRCCConnectionReconfiguration* message includes *wlan-OffloadInfo*:

2> perform the dedicated WLAN offload configuration procedure as specified in 5.6.12.2;

1> set the content of *RRCCConnectionReconfigurationComplete* message as follows:

2> if the UE has radio link failure or handover failure information available in *VarRLF-Report* and if the RPLMN is included in *plmn-IdentityList* stored in *VarRLF-Report*:

3> include *rlf-InfoAvailable*;

2> if the UE has MBSFN logged measurements available for E-UTRA and if the RPLMN is included in *plmn-IdentityList* stored in *VarLogMeasReport* and if T330 is not running:

3> include *logMeasAvailableMBSFN*;

2> else if the UE has logged measurements available for E-UTRA and if the RPLMN is included in *plmn-IdentityList* stored in *VarLogMeasReport*:

3> include the *logMeasAvailable*;

2> if the UE has connection establishment failure information available in *VarConnEstFailReport* and if the RPLMN is equal to *plmn-Identity* stored in *VarConnEstFailReport*:

3> include *connEstFailInfoAvailable*;

1> submit the *RRCCConnectionReconfigurationComplete* message to lower layers for transmission;

1> if MAC successfully completes the random access procedure:

2> the ue shall re-establish pdcp for all rbs that are established; re-establish mcg rlc, if configured, for all rbs that are established;

2> stop timer T304;

2> apply the parts of the CQI reporting configuration, the scheduling request configuration and the sounding RS configuration that do not require the UE to know the SFN of the target PCell, if any;

2> apply the parts of the measurement and the radio resource configuration that require the UE to know the SFN of the target PCell (e.g. measurement gaps, periodic CQI reporting, scheduling request configuration, sounding RS configuration), if any, upon acquiring the SFN of the target PCell;

NOTE 3: Whenever the UE shall setup or reconfigure a configuration in accordance with a field that is received it applies the new configuration, except for the cases addressed by the above statements.

2> if the UE is configured to provide IDC indications:

3> if the UE has transmitted an *InDeviceCoexIndication* message during the last 1 second preceding reception of the *RRCCofigurationReconfiguration* message including *mobilityControlInfo*:

4> initiate transmission of the *InDeviceCoexIndication* message in accordance with 5.6.9.3;

2> if the UE is configured to provide power preference indications:

3> if the UE has transmitted a *UEAssistanceInformation* message during the last 1 second preceding reception of the *RRCCofigurationReconfiguration* message including *mobilityControlInfo*:

4> initiate transmission of the *UEAssistanceInformation* message in accordance with 5.6.10.3;

2> if *SystemInformationBlockType15* is broadcast by the PCell:

3> if the UE has transmitted a *MBMSInterestIndication* message during the last 1 second preceding reception of the *RRCCofigurationReconfiguration* message including *mobilityControlInfo*:

4> ensure having a valid version of *SystemInformationBlockType15* for the PCell;

4> determine the set of MBMS frequencies of interest in accordance with 5.8.5.3;

4> initiate transmission of the *MBMSInterestIndication* message in accordance with 5.8.5.4;

2> if *SystemInformationBlockType18* is broadcast by the target PCell; and the UE transmitted a *SidelinkUEInformation* message including *commRxInterestedFreq* or *commTxResourceReq* during the last 1 second preceding reception of the *RRCCofigurationReconfiguration* message including *mobilityControlInfo*; or

2> if *SystemInformationBlockType19* is broadcast by the target PCell; and the UE transmitted a *SidelinkUEInformation* message including *discRxInterest* or *discTxResourceReq* during the last 1 second preceding reception of the

RRCConnectionReconfiguration message including *mobilityControlInfo*:

3> initiate transmission of the *SidelinkUEInformation* message in accordance with 5.10.2.3;

2> the procedure ends;

NOTE 4: The UE is not required to determine the SFN of the target PCell by acquiring system information from that cell before performing RACH access in the target PCell.

Table 1: Reception of an *RRCConnectionReconfiguration* not including the *mobilityControlInfo* by the UE

Some non-limiting examples are provided below.

5 Example 1 may include a user equipment, “UE”, comprising: interface circuitry to receive, from radio frequency, “RF”, circuitry, data representative of signaling from a source eNB; and processor circuitry coupled with the interface circuitry, the processor circuitry to: detect, based on the data representative of the signaling, a handover, “HO”, command, establish a new media access control, “MAC”, entity for a new connection with
10 a target evolved nodeB, “eNB”, based on the HO command, establish, upon completion of an HO operation with the target eNB, a new packet data convergence protocol, “PDCP”, entity for the new connection with the target eNB and a new radio link control, “RLC”, entity for the new connection with the target eNB, and maintain, until completion of the HO operation, an existing PDCP entity for an existing connection with the source eNB, an
15 existing RLC entity for the existing connection with the source eNB, and an existing MAC entity for the existing connection with the source eNB.

Example 2 may include the apparatus of example 1 and/or some other examples herein, wherein the HO command is a radio resource control, “RRC”, Connection Reconfiguration message, and the processor circuitry is to control transmission of an RRC
20 Connection Reconfiguration Complete message to the target eNB to indicate completion of the HO operation.

Example 3 may include the apparatus of example 1 and/or some other examples herein, wherein the processor circuitry is to: generate a new protocol stack including the new PDCP entity, the new RLC entity, and the new MAC entity, wherein the processor
25 circuitry is to maintain an existing protocol stack established with the source eNB for receipt of one or more downlink transmissions during the HO operation, wherein the existing protocol stack includes the existing PDCP entity, the existing RLC entity, and the

existing MAC entity.

Example 4 may include the apparatus of example 3 and/or some other examples herein, wherein to establish the MAC entity, the processor circuitry is further to: activate the new MAC entity in response to receipt of the HO command; and provide an RRC
5 Connection Reconfiguration Complete message to the new MAC entity to trigger activation of another new MAC entity in the target eNB.

Example 5 may include the apparatus of example 3 and/or some other examples herein, wherein to trigger activation of the other new MAC entity, the processor circuitry is to: control transmission of a random access channel, "RACH", message to the target
10 eNB to trigger initiation of a RACH procedure by the target eNB.

Example 6 may include the apparatus of example 5 and/or some other examples herein, wherein to establish the new PDCP entity and the new RLC entity the processor circuitry is to: control receipt of a random access response, "RAR", from the target eNB; activate the new PDCP entity and the new RLC entity after receipt of the RAR; and
15 control transmission of the RRC Connection Reconfiguration Complete message to the target eNB.

Example 7 may include the apparatus of example 3 and/or some other examples herein, wherein the processor circuitry is further to: perform re-establishment of the new PDCP entity and the new RLC entity for one or more signal radio bearers, "SRBs"; trigger
20 initiation of a RACH procedure at the target eNB; and perform re-establishment of the new PDCP entity and the new RLC entity for one or more data resource bearers, "DRBs", in response to receipt of a RAR.

Example 8 may include the apparatus of example 7 and/or some other examples herein, wherein to trigger initiation of the RACH procedure at the target eNB, the
25 processor circuitry is to: provide a RRC Connection Reconfiguration Complete message to the new MAC entity; and control transmission of a RACH message to the target eNB.

Example 9 may include the apparatus of examples 7-8 and/or some other examples herein, wherein the one or more SRBs include only SRB1 or SRB1 and SRB2.

Example 10 may include the apparatus of examples 7-9 and/or some other
30 examples herein, wherein to perform re-establishment of the one or more SRBs, the processor circuitry is to use one or more security keys associated with the target eNB to cipher or decipher a message including the one or more SRBs.

Example 11 may include the apparatus of example 3 and/or some other examples herein, wherein to establish the MAC entity, and to establish the new PDCP entity and the

new RLC entity, the processor circuitry is further to: activate the new MAC entity, the new PDPCP entity, and the new RLC entity in response to receipt of the HO command while activation of the existing MAC entity, the existing PDPCP entity, and the existing RLC entity are maintained; control receipt of a RAR from the target eNB; provide an RRC
5 Connection Reconfiguration Complete message to the new MAC entity to trigger activation of another new MAC entity in the target eNB, another new PDPCP entity in the target eNB, and another new RLC entity in the target eNB; and reset the existing protocol stack.

Example 12 may include the apparatus of any one of examples 2, 4, 6, 8-11 and/or
10 some other examples herein, wherein a PDPCP status report is included in the RRC Connection Reconfiguration Complete message, wherein the PDPCP status report is to indicate one or more packets that have not been successfully received from the source eNB during the HO operation, and the processor circuitry is further to: control receipt of copies of the one or more packets indicated by the PDPCP status report.

Example 13 may include the apparatus of any one of examples 1-12 and/or some
15 other examples herein, wherein establishment of the new MAC entity, establishment of the new PDPCP entity, and establishment of the new RLC entity is to occur during a synchronization operation with the target eNB during the HO operation.

Example 14 may include the apparatus of any one of examples 1-13 and/or some
20 other examples herein, wherein the processor circuitry is to: control transmission of a measurement report to the source eNB, wherein, the HO command is based in part on the measurement report, and the source eNB is to deliver one or more buffered packets to the target eNB; and control receipt of one or more downlink transmissions from the source eNB until completion of the HO operation.

Example 15 may include the apparatus of any of examples 1-14 and/or some other
25 examples herein, wherein the RRC Connection Reconfiguration message includes mobility control information.

Example 16 may include one or more computer-readable storage media having
instructions that, when executed by one or more processors, cause an evolved nodeB,
30 "eNB", to: receive a handover, "HO", request from a source eNB, wherein the HO request is to indicate an HO operation to occur between a user equipment, "UE", and the eNB; establish a medium access control, "MAC", entity for a connection with the UE indicated by the HO request; receive copies of data packets from the source eNB that are to be provided to the UE during the HO operation; and establish a packet data convergence

protocol, “PDCP”, entity and a radio link control, “RLC”, entity for the connection with the UE. The computer-readable media may include non-transitory computer-readable media.

5 Example 17 may include the one or more computer-readable storage media of example 16 and/or some other examples herein, wherein a Radio Resource Control, “RRC”, Connection Reconfiguration Complete message including a PDCP status report is to indicate completion of the HO operation, and wherein the instructions, when executed, further cause the eNB to: transmit data packets of the copies of data packets indicated in the PDCP status report; and discard other data packets of the copies of data packets not
10 indicated in the PDCP status report.

Example 18 may include the one or more computer-readable storage media of example 16 and/or some other examples herein, wherein the PDCP entity is a new PDCP entity, the RLC entity is a new RLC entity, and the MAC entity is a new MAC entity, and wherein the instructions, when executed, further cause the eNB to: generate a new
15 protocol stack including the new PDCP entity, the new RLC entity, and the new MAC entity.

Example 19 may include the one or more computer-readable storage media of example 18 and/or some other examples herein, wherein the instructions, when executed, further cause the eNB to: receive a Random Access Channel, “RACH”, message from the
20 UE; and activate the new MAC entity based on receipt of the RACH message.

Example 20 may include the one or more computer-readable storage media of example 19 and/or some other examples herein, wherein to activate the new MAC entity, the one or more processors are to execute the instructions to: transmit a Random Access response, “RAR”, to the UE upon activation of the new MAC entity.

25 Example 21 may include the one or more computer-readable storage media of example 20 and/or some other examples herein, wherein the instructions, when executed, further cause the eNB to: activate the new PDCP entity and the new RLC entity prior to transmission of the RAR; or activate the new PDCP entity and the new RLC entity after transmission of the RAR.

30 Example 23 may include the one or more computer-readable storage media of example 18 and/or some other examples herein, wherein execution of the instructions further cause the eNB to: perform re-establishment of the new PDCP entity and the new RLC entity for one or more signal radio bearers, “SRBs”; receive a RACH message from the UE to trigger initiation of a RACH procedure; transmit a RAR to the UE; and perform

re-establishment of the new PDCP entity and the new RLC entity for one or more data resource bearers, “DRBs”, upon transmission of the RAR.

Example 24 may include the one or more computer-readable storage media of example 23 and/or some other examples herein, wherein one or more security keys associated with the target eNB are used for re-establishment of the new PDCP entity and the new RLC entity for the one or more SRBs and for re-establishment of the new PDCP entity and the new RLC entity for the one or more DRBs.

Example 25 may include the one or more computer-readable storage media of examples 23-24 and/or some other examples herein, wherein the one or more SRBs include only SRB1 or SRB1 and SRB2.

Example 26 may include the one or more computer-readable storage media of example 18 and/or some other examples herein, wherein the instructions, when executed, further cause the eNB to: activate the new MAC entity, the new PDCP entity, and the new RLC entity based on receipt of a RACH message; transmit a RAR to the UE; and receive an RRC Connection Reconfiguration Complete message from the UE.

Example 27 may include the one or more computer-readable storage media of any one of examples 16, 18-19, 23, or 26 and/or some other examples herein, wherein the HO request and an HO request acknowledgment, “ACK”, are to be communicated between the eNB and the source eNB over an X2 interface.

Example 28 may include an apparatus to be implemented in an evolved nodeB, “eNB”, the apparatus comprising: one or more processors coupled with a memory, the one or more processors to execute instructions to: control transmission of a handover, “HO”, command to a user equipment, “UE”, based on a determination that the UE should perform a HO operation with a target eNB, control transmission of one or more data packets to the UE after transmission of the HO command, control receipt of an HO complete message from the target eNB, and terminate transmission of the one or more data packets to the UE in response to receipt of the HO complete message.

Example 29 may include the apparatus of example 28 and/or some other examples herein, wherein the one or more processors are to execute the instructions to: control transmission of a copy of the one or more data packets to a target eNB until receipt of the HO complete message.

Example 30 may include the apparatus of example 28 and/or some other examples herein, wherein the HO command is a radio resource control, “RRC”, Connection Reconfiguration message.

Example 31 may include the apparatus of example 29 and/or some other examples herein, wherein the RRC Connection Reconfiguration message includes mobility control information.

5 Example 32 may include the apparatus of examples 28-31 and/or some other examples herein, wherein the one or more processors are to execute the instructions to: maintain, until receipt of the HO complete message, a protocol stack established for the UE, wherein the protocol stack is for the transmission of the one or more data packets to the UE during the HO operation, wherein the protocol stack includes a packet data convergence protocol, "PDCP", entity, a radio link control, "RLC", entity, and a medium
10 access control, "MAC", entity.

Example 33 may include the apparatus of examples 28-31 and/or some other examples herein, wherein the one or more processors are to execute the instructions to: control transmission of an HO request to the target eNB; receive an HO request acknowledgment, "ACK", from the target eNB; and control transmission of a downlink
15 allocation to the UE based on the HO request ACK.

Example 34 may include the apparatus of examples 28-31 and/or some other examples herein, wherein the one or more processors are to execute the instructions to: control transmission of an instruction to the UE, wherein the instruction is to instruct the UE to perform one or more signal quality measurements; control receipt of a measurement
20 report from the UE based on the one or more signal quality measurements; and determine whether the UE should perform the HO operation with the target eNB based on the measurement report.

Example 35 may include an apparatus to be implemented in a user equipment, "UE", the apparatus comprising: first means for receiving one or more signals; and second
25 means for: detecting, based on the one or more signals, a handover, "HO", command, establishing a new media access control, "MAC", entity for a new connection with a target evolved nodeB, "eNB", based on the HO command, establishing, upon completion of an HO operation with the target eNB, a new packet data convergence protocol, "PDCP", entity for the new connection with the target eNB and a new radio link control, "RLC",
30 entity for the new connection with the target eNB, and maintaining, until completion of the HO operation, an existing PDCP entity for an existing connection with a source eNB, an existing RLC entity for the existing connection with the source eNB, and an existing MAC entity for the existing connection with the source eNB.

Example 36 may include the apparatus of example 35 and/or some other examples

herein, wherein the first means is for performing one or more signal measurements.

Example 37 may include the apparatus of example 35 and/or some other examples herein, wherein the HO command is a radio resource control, “RRC”, Connection Reconfiguration message, and the second means is for controlling transmission of an RRC
5 Connection Reconfiguration Complete message to the target eNB to indicate completion of the HO operation.

Example 38 may include the apparatus of example 35 and/or some other examples herein, wherein the second means is for: generating a new protocol stack including the new PDCP entity, the new RLC entity, and the new MAC entity, wherein the second
10 means is for maintaining an existing protocol stack established with the source eNB for receipt of one or more downlink transmissions during the HO operation, wherein the existing protocol stack includes the existing PDCP entity, the existing RLC entity, and the existing MAC entity.

Example 39 may include the apparatus of example 38 and/or some other examples
15 herein, wherein to establish the MAC entity, the second means is for: activating the new MAC entity in response to receipt of the HO command; and providing an RRC Connection Reconfiguration Complete message to the new MAC entity to trigger activation of another new MAC entity in the target eNB.

Example 40 may include the apparatus of example 39 and/or some other examples
20 herein, wherein to trigger activation of the other new MAC entity, the second means is for: transmitting a random access channel, “RACH”, message to the target eNB to trigger initiation of a RACH procedure by the target eNB.

Example 41 may include the apparatus of example 40 and/or some other examples herein, wherein to establish the new PDCP entity and the new RLC entity the second
25 means is for: receiving a random access response, “RAR”, from the target eNB; activating the new PDCP entity and the new RLC entity after receipt of the RAR; and transmit the RRC Connection Reconfiguration Complete message to the target eNB.

Example 42 may include the apparatus of example 38 and/or some other examples herein, wherein the second means is for: performing re-establishment of the new PDCP
30 entity and the new RLC entity for one or more signal radio bearers, “SRBs”; triggering initiation of a RACH procedure at the target eNB; and performing re-establishment of the new PDCP entity and the new RLC entity for one or more data resource bearers, “DRBs”, in response to receipt of a RAR.

Example 43 may include the apparatus of example 42 and/or some other examples

herein, wherein to trigger initiation of the RACH procedure at the target eNB, the second means is for: providing a RRC Connection Reconfiguration Complete message to the new MAC entity; and transmitting a RACH message to the target eNB.

5 Example 44 may include the apparatus of examples 43-43 and/or some other examples herein, wherein the one or more SRBs include only SRB1 or SRB1 and SRB2.

Example 45 may include the apparatus of examples 42-44 and/or some other examples herein, wherein to perform re-establishment of the one or more SRBs, the second means is for using one or more security keys associated with the target eNB to cipher or decipher a message including the one or more SRBs.

10 Example 46 may include the apparatus of example 38 and/or some other examples herein, wherein to establish the MAC entity and to establish the new PDCP entity and the new RLC entity, the second means is for: activating the new MAC entity, the new PDCP entity, and the new RLC entity in response to receipt of the HO command while activation of the existing MAC entity, the existing PDCP entity, and the existing RLC entity are
15 maintained; receiving a RAR from the target eNB; providing an RRC Connection Reconfiguration Complete message to the new MAC entity to trigger activation of another new MAC entity in the target eNB, another new PDCP entity in the target eNB, and another new RLC entity in the target eNB; and resetting the existing protocol stack.

Example 47 may include the apparatus of any one of examples 37-46 and/or some
20 other examples herein, wherein a PDCP status report is included in the RRC Connection Reconfiguration Complete message, wherein the PDCP status report is to indicate one or more packets that have not been successfully received from the source eNB during the HO operation, and the second means is for: receiving copies of the one or more packets indicated by the PDCP status report.

25 Example 48 may include the apparatus of any one of examples 35-47 and/or some other examples herein, wherein establishment of the new MAC entity, establishment of the new PDCP entity, and establishment of the new RLC entity is to occur during a synchronization operation with the target eNB during the HO operation.

Example 49 may include the apparatus of any one of examples 35-48 and/or some
30 other examples herein, wherein the second means is for: transmitting a measurement report to the source eNB, wherein, the HO command is based in part on the measurement report, and the source eNB is to deliver one or more buffered packets to the target eNB; and receiving one or more downlink transmissions from the source eNB until completion of the HO operation.

Example 50 may include the apparatus of any of examples 35-49 and/or some other examples herein, wherein the RRC Connection Reconfiguration message includes mobility control information.

Example 51 may include an apparatus to be implemented in an evolved nodeB, “eNB”, the apparatus comprising: means for receiving a handover, “HO”, request from a source eNB, wherein the HO request is to indicate an HO operation to occur between a user equipment, “UE”, and the eNB; means for establishing a medium access control, “MAC”, entity for a connection with the UE indicated by the HO request; means for receiving a first copy of data packets from the source eNB, wherein a second copy of the data packets are to be provided to the UE during the HO operation; and means for establishing a packet data convergence protocol, “PDCP”, entity and a radio link control, “RLC”, entity for the connection with the UE.

Example 52 may include the apparatus of example 51 and/or some other examples herein, wherein a Radio Resource Control, “RRC”, Connection Reconfiguration Complete message including a PDCP status report is to indicate completion of the HO operation, and the apparatus further comprises: means for transmitting data packets of the first copy of data packets indicated in the PDCP status report; and means for discarding other data packets of the first copy of data packets not indicated in the PDCP status report.

Example 53 may include the apparatus of example 51 and/or some other examples herein, wherein the PDCP entity is a new PDCP entity, the RLC entity is a new RLC entity, and the MAC entity is a new MAC entity, and wherein the apparatus further comprises: means for generating a new protocol stack including the new PDCP entity, the new RLC entity, and the new MAC entity.

Example 54 may include the apparatus of example 53 and/or some other examples herein, wherein the apparatus further comprises: means for receiving a Random Access Channel, “RACH”, message from the UE; and means for activating the new MAC entity based on receipt of the RACH message.

Example 55 may include the apparatus of example 54 and/or some other examples herein, wherein the apparatus further comprises: means for transmitting a Random Access response, “RAR”, to the UE upon activation of the new MAC entity.

Example 56 may include the apparatus of example 55 and/or some other examples herein, wherein the apparatus further comprises: means for activating the new PDCP entity and the new RLC entity prior to transmission of the RAR; or means for activating the new PDCP entity and the new RLC entity after transmission of the RAR.

Example 57 may include the apparatus of example 53 and/or some other examples herein, wherein the apparatus further comprises: means for performing re-establishment of the new PDCP entity and the new RLC entity for one or more signal radio bearers, “SRBs”; means for receiving a RACH message from the UE to trigger initiation of a RACH procedure; means for transmitting a RAR to the UE; and means for performing re-establishment of the new PDCP entity and the new RLC entity for one or more data resource bearers, “DRBs”, upon transmission of the RAR.

Example 58 may include the apparatus of example 57 and/or some other examples herein, wherein one or more security keys associated with the target eNB are used for re-establishment of the new PDCP entity and the new RLC entity for the one or more SRBs and for re-establishment of the new PDCP entity and the new RLC entity for the one or more DRBs.

Example 59 may include the apparatus of examples 57-58 and/or some other examples herein, wherein the one or more SRBs include only SRB1 or SRB1 and SRB2.

Example 60 may include the apparatus of example 53 and/or some other examples herein, wherein the apparatus further comprises: means for activating the new MAC entity, the new PDCP entity, and the new RLC entity based on receipt of a RACH message; means for transmitting a RAR to the UE; and means for receiving an RRC Connection Reconfiguration Complete message from the UE.

Example 61 may include the apparatus of any one of examples 51-60 and/or some other examples herein, wherein the HO request and an HO request acknowledgment, “ACK”, are to be communicated between the eNB and the source eNB over an X2 interface.

Example 62 may include an apparatus to be implemented in an evolved nodeB, “eNB”, the apparatus comprising: means for transmitting an handover, “HO”, command to a user equipment, “UE”, based on a determination that the UE should perform a HO operation with a target eNB, means for transmitting one or more data packets to the UE after transmission of the HO command, means for receiving an HO complete message from the target eNB, and means for terminating transmission of the one or more data packets to the UE in response to receipt of the HO complete message.

Example 63 may include the apparatus of example 62 and/or some other examples herein, wherein the apparatus further comprises: means for transmitting a copy of the one or more data packets to a target eNB until receipt of the HO complete message.

Example 64 may include the apparatus of example 63 and/or some other examples

herein, wherein the HO command is a radio resource control, "RRC", Connection Reconfiguration message.

Example 65 may include the apparatus of example 63 and/or some other examples herein, wherein the RRC Connection Reconfiguration message includes mobility control
5 information.

Example 66 may include the apparatus of examples 64-65 and/or some other examples herein, wherein the apparatus further comprises: means for maintaining a protocol stack established for the UE until receipt of the HO complete message, wherein the protocol stack is for the transmission of the one or more data packets to the UE during
10 the HO operation, wherein the protocol stack includes a packet data convergence protocol, "PDCP", entity, a radio link control, "RLC", entity, and a medium access control, "MAC", entity.

Example 67 may include the apparatus of examples 62-66 and/or some other examples herein, wherein the apparatus further comprises: means for transmitting an HO
15 request to the target eNB; means for receiving an HO request acknowledgment, "ACK", from the target eNB; and means for transmitting a downlink allocation to the UE based on the HO request ACK.

Example 68 may include the apparatus of examples 62-66 and/or some other examples herein, wherein the apparatus further comprises: means for transmitting an
20 instruction to the UE, wherein the instruction is to instruct the UE to perform one or more signal quality measurements; means for receiving a measurement report from the UE based on the one or more signal quality measurements; and means for determining whether the UE should perform the HO operation with the target eNB based on the measurement report.

Example 69 may include a method to be performed by a user equipment, "UE", the method comprising: receiving one or more signals detecting, based on the one or more signals, a handover, "HO", command; establishing a new media access control, "MAC", entity for a new connection with a target evolved nodeB, "eNB", based on the HO command; establishing, upon completion of an HO operation with the target eNB, a new
25 packet data convergence protocol, "PDCP", entity for the new connection with the target eNB and a new radio link control, "RLC", entity for the new connection with the target eNB; and maintaining, until completion of the HO operation, an existing PDCP entity for an existing connection with a source eNB, an existing RLC entity for the existing connection with the source eNB, and an existing MAC entity for the existing connection
30

with the source eNB.

Example 70 may include the method of example 69 and/or some other examples herein, wherein the HO command is a radio resource control, "RRC", Connection Reconfiguration message, and the method comprises: transmitting an RRC Connection Reconfiguration Complete message to the target eNB to indicate completion of the HO operation.

Example 71 may include the method of example 69 and/or some other examples herein, further comprising: generating a new protocol stack including the new PDCP entity, the new RLC entity, and the new MAC entity; and maintaining an existing protocol stack established with the source eNB for receipt of one or more downlink transmissions during the HO operation, wherein the existing protocol stack includes the existing PDCP entity, the existing RLC entity, and the existing MAC entity.

Example 72 may include the method of example 71 and/or some other examples herein, wherein establishing the MAC entity comprises: activating the new MAC entity in response to receipt of the HO command; and providing an RRC Connection Reconfiguration Complete message to the new MAC entity to trigger activation of another new MAC entity in the target eNB.

Example 73 may include the method of example 72 and/or some other examples herein, wherein triggering activation of the other new MAC entity comprises: transmitting a random access channel, "RACH", message to the target eNB to trigger initiation of a RACH procedure by the target eNB.

Example 74 may include the method of example 73 and/or some other examples herein, wherein establishing the PDCP entity and the RLC entity comprises: receiving a random access response, "RAR", from the target eNB; activating the new PDCP entity and the new RLC entity after receipt of the RAR; and transmit the RRC Connection Reconfiguration Complete message to the target eNB.

Example 75 may include the method of example 72 and/or some other examples herein, further comprising: performing re-establishment of the new PDCP entity and the new RLC entity for one or more signal radio bearers, "SRBs"; triggering initiation of a RACH procedure at the target eNB; and performing re-establishment of the new PDCP entity and the new RLC entity for one or more data resource bearers, "DRBs", in response to receipt of a RAR.

Example 76 may include the method of example 75 and/or some other examples herein, wherein triggering initiation of the RACH procedure at the target eNB comprises:

providing a RRC Connection Reconfiguration Complete message to the new MAC entity; and transmitting a RACH message to the target eNB.

Example 77 may include the method of examples 75-76 and/or some other examples herein, wherein the one or more SRBs include only SRB1 or SRB1 and SRB2.

5 Example 78 may include the method of examples 75-77 and/or some other examples herein, wherein performing re-establishment of the one or more SRBs, includes using one or more security keys associated with the target eNB to cipher or decipher a message including the one or more SRBs.

10 Example 79 may include the method of example 71 and/or some other examples herein, wherein establishing the MAC entity, and establishing the PDCP entity and the RLC entity comprises: activating the new MAC entity, the new PDCP entity, and the new RLC entity in response to receipt of the HO command while activation of the existing MAC entity, the existing PDCP entity, and the existing RLC entity are maintained; receiving a RAR from the target eNB; providing an RRC Connection Reconfiguration
15 Complete message to the new MAC entity to trigger activation of another new MAC entity in the target eNB, another new PDCP entity in the target eNB, and another new RLC entity in the target eNB; and resetting the existing protocol stack.

20 Example 80 may include the method of any one of examples 69-79 and/or some other examples herein, wherein a PDCP status report is included in the RRC Connection Reconfiguration Complete message, wherein the PDCP status report is to indicate one or more packets that have not been successfully received from the source eNB during the HO operation, and the method comprises: receiving copies of the one or more packets indicated by the PDCP status report.

25 Example 81 may include the method of any one of examples 69-80 and/or some other examples herein, wherein establishment of the MAC entity, establishment of the PDCP entity, and establishment of the RLC entity is to occur during a synchronization operation with the target eNB during the HO operation.

30 Example 82 may include the method of any one of examples 69-81 and/or some other examples herein, further comprising: transmitting a measurement report to the source eNB, wherein, the HO command is based in part on the measurement report, and the source eNB is to deliver one or more buffered packets to the target eNB; and receiving, from the interface circuitry, one or more downlink transmissions from the source eNB until completion of the HO operation.

Example 84 may include the method of any of examples 69-83 and/or some other

examples herein, wherein the RRC Connection Reconfiguration message includes mobility control information.

Example 85 may include a method to be performed by an evolved nodeB, “eNB”, the method comprising: receiving a handover, “HO”, request from a source eNB, wherein
5 the HO request is to indicate an HO operation to occur between a user equipment, “UE”, and the eNB; establishing a medium access control, “MAC”, entity for a connection with the UE indicated by the HO request; receiving a first copy of data packets from the source eNB, wherein a second copy of the data packets are to be provided to the UE during the HO operation; and establishing a packet data convergence protocol, “PDCP”, entity and a
10 radio link control, “RLC”, entity for the connection with the UE.

Example 86 may include the method of example 85 and/or some other examples herein, wherein a Radio Resource Control, “RRC”, Connection Reconfiguration Complete message including a PDCP status report is to indicate completion of the HO operation, and the method further comprises: transmitting data packets of the first copy of data packets
15 indicated in the PDCP status report; and discarding other data packets of the first copy of data packets not indicated in the PDCP status report.

Example 87 may include the method of example 85 and/or some other examples herein, wherein the PDCP entity is a new PDCP entity, the RLC entity is a new RLC entity, and the MAC entity is a new MAC entity, and the method further comprises:
20 generating a new protocol stack including the new PDCP entity, the new RLC entity, and the new MAC entity.

Example 88 may include the method of example 87 and/or some other examples herein, further comprising: receiving a Random Access Channel, “RACH”, message from the UE; and activating the new MAC entity based on receipt of the RACH message.

Example 89 may include the method of example 88 and/or some other examples herein, further comprising: transmitting a Random Access response, “RAR”, to the UE upon activation of the new MAC entity.

Example 90 may include the method of example 89 and/or some other examples herein, further comprising: activating the new PDCP entity and the new RLC entity prior
30 to transmission of the RAR; or activating the new PDCP entity and the new RLC entity after transmission of the RAR.

Example 97 may include the method of example 87 and/or some other examples herein, further comprising: performing re-establishment of the new PDCP entity and the new RLC entity for one or more signal radio bearers, “SRBs”; receiving a RACH message

from the UE to trigger initiation of a RACH procedure; transmitting a RAR to the UE; and performing re-establishment of the new PDCP entity and the new RLC entity for one or more data resource bearers, “DRBs”, upon transmission of the RAR.

5 Example 98 may include the method of example 97 and/or some other examples herein, wherein one or more security keys associated with the target eNB are used for re-establishment of the new PDCP entity and the new RLC entity for the one or more SRBs and for re-establishment of the new PDCP entity and the new RLC entity for the one or more DRBs.

10 Example 99 may include the method of examples 97-98 and/or some other examples herein, wherein the one or more SRBs include only SRB1 or SRB1 and SRB2.

Example 100 may include the method of example 87 and/or some other examples herein, further comprising: activating the new MAC entity, the new PDCP entity, and the new RLC entity based on receipt of a RACH message; transmitting a RAR to the UE; and receiving an RRC Connection Reconfiguration Complete message from the UE.

15 Example 101 may include the method of any one of examples 85-100 and/or some other examples herein, wherein the HO request and an HO request acknowledgment, “ACK”, are to be communicated between the eNB and the source eNB over an X2 interface.

20 Example 102 may include a method to be performed by an evolved nodeB, “eNB”, the method comprising: transmitting an handover, “HO”, command to a user equipment, “UE”, based on a determination that the UE should perform a HO operation with a target eNB, transmitting one or more data packets to the UE after transmission of the HO command, receiving an HO complete message from the target eNB, and terminating transmission of the one or more data packets to the UE in response to receipt of the HO
25 complete message.

Example 103 may include the method of example 102 and/or some other examples herein, further comprising: transmitting a copy of the one or more data packets to a target eNB until receipt of the HO complete message.

30 Example 104 may include the method of example 103 and/or some other examples herein, wherein the HO command is a radio resource control, “RRC”, Connection Reconfiguration message.

Example 105 may include the method of example 103 and/or some other examples herein, wherein the RRC Connection Reconfiguration message includes mobility control information.

Example 106 may include the method of examples 102-105 and/or some other examples herein, further comprising: maintaining a protocol stack established for the UE until receipt of the HO complete message, wherein the protocol stack is for the transmission of the one or more data packets to the UE during the HO operation, wherein
5 the protocol stack includes a packet data convergence protocol, "PDCP", entity, a radio link control, "RLC", entity, and a medium access control, "MAC", entity.

Example 107 may include the method of examples 102-106 and/or some other examples herein, further comprising: transmitting an HO request to the target eNB; receiving an HO request acknowledgment, "ACK", from the target eNB; and transmitting
10 a downlink allocation to the UE based on the HO request ACK.

Example 108 may include the apparatus of examples 102-106 and/or some other examples herein, further comprising: transmitting an instruction to the UE, wherein the instruction is to instruct the UE to perform one or more signal quality measurements; receiving a measurement report from the UE based on the one or more signal quality
15 measurements; and determining whether the UE should perform the HO operation with the target eNB based on the measurement report.

The foregoing description of the above Examples provides illustration and description for the example embodiments disclosed herein, but the above Examples are not intended to be exhaustive or to limit the scope of the invention to the precise form
20 disclosed. Modifications and variations are possible in light of the above teachings and/or may be acquired from practice of various implementations of the invention.

Claims

1. A user equipment, "UE", comprising:

interface circuitry to receive, from radio frequency, "RF", circuitry, data representative of signaling from a source eNB; and

5 processor circuitry coupled with the interface circuitry, the processor circuitry to:
detect, based on the data representative of the signaling, a handover, "HO", command,

establish a new media access control, "MAC", entity for a new connection with a target evolved nodeB, "eNB", based on the HO command,

10 establish, upon completion of an HO operation with the target eNB, a new packet data convergence protocol, "PDCP", entity for the new connection with the target eNB and a new radio link control, "RLC", entity for the new connection with the target eNB, and

maintain, until completion of the HO operation, an existing PDCP entity for
15 an existing connection with the source eNB, an existing RLC entity for the existing connection with the source eNB, and an existing MAC entity for the existing connection with the source eNB.

2. The apparatus of claim 1, wherein the HO command is a radio resource control, "RRC", Connection Reconfiguration message, and the processor circuitry is to control
20 transmission of an RRC Connection Reconfiguration Complete message to the target eNB to indicate completion of the HO operation.

3. The apparatus of claim 1, wherein the processor circuitry is to:

generate a new protocol stack including the new PDCP entity, the new RLC entity, and the new MAC entity,

25 wherein the processor circuitry is to maintain an existing protocol stack established with the source eNB for receipt of one or more downlink transmissions during the HO operation, wherein the existing protocol stack includes the existing PDCP entity, the existing RLC entity, and the existing MAC entity.

4. The apparatus of claim 3, wherein the processor circuitry is further to:

30 activate the new MAC entity in response to receipt of the HO command; and
provide an RRC Connection Reconfiguration Complete message to the new MAC entity to trigger activation of another new MAC entity in the target eNB.

5. The apparatus of claim 4, wherein to trigger activation of the other new MAC entity, the processor circuitry is to:

control transmission of a random access channel, "RACH", message to the target eNB to trigger initiation of a RACH procedure by the target eNB.

6. The apparatus of claim 5, wherein to establish the new PDCP entity and the new RLC entity the processor circuitry is to:

- 5 control receipt of a random access response, "RAR", from the target eNB;
 activate the new PDCP entity and the new RLC entity after receipt of the RAR;
 and

 control transmission of the RRC Connection Reconfiguration Complete message to the target eNB.

10 7. The apparatus of claim 3, wherein the processor circuitry is further to:

 perform re-establishment of the new PDCP entity and the new RLC entity for one or more signal radio bearers, "SRBs";

 trigger initiation of a RACH procedure at the target eNB; and

 perform re-establishment of the new PDCP entity and the new RLC entity for one
15 or more data resource bearers, "DRBs", in response to receipt of a RAR.

8. The apparatus of claim 7, wherein to trigger initiation of the RACH procedure at the target eNB, the processor circuitry is to:

 provide a RRC Connection Reconfiguration Complete message to the new MAC entity; and

20 control transmission of a RACH message to the target eNB.

9. The apparatus of claim 7, wherein to perform re-establishment of the one or more SRBs, the processor circuitry is to use one or more security keys associated with the target eNB to cipher or decipher a message including the one or more SRBs.

10. The apparatus of claim 3, wherein to establish the new MAC entity, and to establish
25 the new PDCP entity and the new RLC entity, the processor circuitry is further to:

 activate the new MAC entity, the new PDCP entity, and the new RLC entity in response to receipt of the HO command while activation of the existing MAC entity, the existing PDCP entity, and the existing RLC entity are maintained;

 control receipt of a RAR from the target eNB;

30 provide an RRC Connection Reconfiguration Complete message to the new MAC entity to trigger activation of another new MAC entity in the target eNB, another new PDCP entity in the target eNB, and another new RLC entity in the target eNB; and

 reset the existing protocol stack.

11. The apparatus of any one of claims 2, 4, 6, 8, or 10, wherein a PDCP status report is included in the RRC Connection Reconfiguration Complete message, wherein the PDCP status report is to indicate one or more packets that have not been successfully received from the source eNB during the HO operation, and the processor circuitry is further to:

5 control receipt of copies of the one or more packets indicated by the PDCP status report.

12. The apparatus of any one of claims 1-10 wherein the processor circuitry is to:

 control transmission of a measurement report to the source eNB, wherein,

 the HO command is based in part on the measurement report, and

10 the source eNB is to deliver one or more buffered packets to the target eNB; and

 control receipt of one or more downlink transmissions from the source eNB until completion of the HO operation.

13. One or more non-transitory computer-readable storage media having instructions that, 15 when executed by one or more processors, cause an evolved nodeB, "eNB", to:

 receive a handover, "HO", request from a source eNB, wherein the HO request is to indicate an HO operation to occur between a user equipment, "UE", and the eNB;

 establish a medium access control, "MAC", entity for a connection with the UE indicated by the HO request;

20 receive, from the source eNB, copies of data packets that are to be provided to the UE during the HO operation; and

 establish a packet data convergence protocol, "PDCP", entity and a radio link control, "RLC", entity for the connection with the UE.

14. The one or more non-transitory computer-readable storage media of claim 13, wherein 25 a Radio Resource Control, "RRC", Connection Reconfiguration Complete message including a PDCP status report is to indicate completion of the HO operation, and wherein the instructions, when executed, further cause the eNB to:

 transmit data packets of the copies of data packets indicated in the PDCP status report; and

30 discard other data packets of the copies of data packets not indicated in the PDCP status report.

15. The one or more non-transitory computer-readable storage media of claim 13, wherein the PDCP entity is a new PDCP entity, the RLC entity is a new RLC entity, and the MAC

entity is a new MAC entity, and wherein the instructions, when executed, further cause the eNB to:

generate a new protocol stack including the new PDCP entity, the new RLC entity, and the new MAC entity.

5

16. The one or more non-transitory computer-readable storage media of claim 15, wherein the instructions, when executed, further cause the eNB to:

receive a Random Access Channel, "RACH", message from the UE;

activate the new MAC entity based on receipt of the RACH message; and

10 transmit a Random Access response, "RAR", to the UE upon activation of the new MAC entity.

17. The one or more non-transitory computer-readable storage media of claim 16, wherein the instructions, when executed, further cause the eNB to:

activate the new PDCP entity and the new RLC entity prior to transmission of the

15 RAR; or

activate the new PDCP entity and the new RLC entity after transmission of the RAR.

18. The one or more non-transitory computer-readable storage media of claim 15, wherein execution of the instructions further causes the eNB to:

20 perform re-establishment of the new PDCP entity and the new RLC entity for one or more signal radio bearers, "SRBs";

receive a RACH message from the UE to trigger initiation of a RACH procedure;

transmit a RAR to the UE; and

perform re-establishment of the new PDCP entity and the new RLC entity for one

25 or more data resource bearers, "DRBs", upon transmission of the RAR.

19. The one or more non-transitory computer-readable storage media of claim 15, wherein the instructions, when executed, further cause the eNB to:

activate the new MAC entity, the new PDCP entity, and the new RLC entity based on receipt of a RACH message;

30 transmit a RAR to the UE; and

receive an RRC Connection Reconfiguration Complete message from the UE.

20. The one or more non-transitory computer-readable storage media of any one of claims 13, 15-16, 18, or 19 wherein the HO request and an HO request acknowledgment are to be communicated directly between the eNB and the source eNB over an X2 interface.

21. An apparatus to be implemented in an evolved nodeB, "eNB", the apparatus comprising:

one or more processors coupled with a memory, the one or more processors to execute instructions to:

5 control transmission of a handover, "HO", command to a user equipment, "UE", based on a determination that the UE should perform a HO operation with a target eNB,

 control transmission of one or more data packets to the UE after transmission of the HO command,

10 control receipt of an HO complete message from the target eNB, and

 terminate transmission of the one or more data packets to the UE in response to receipt of the HO complete message.

22. The apparatus of claim 21, wherein the one or more processors are to execute the instructions to:

15 control transmission of a copy of the one or more data packets to a target eNB until receipt of the HO complete message.

23. The apparatus of claim 21, wherein the HO command is a radio resource control, "RRC", Connection Reconfiguration message.

24. The apparatus of claims 21-23, wherein the one or more processors are to execute the instructions to:

 maintain, until receipt of the HO complete message, a protocol stack established for the UE, wherein the protocol stack is for the transmission of the one or more data packets to the UE during the HO operation,

25 wherein the protocol stack includes a packet data convergence protocol, "PDCP", entity, a radio link control, "RLC", entity, and a medium access control, "MAC", entity.

25. The apparatus of claims 21-23, wherein the one or more processors are to execute the instructions to:

 control transmission of an HO request to the target eNB;

 control receipt of an HO request acknowledgment, "ACK", from the target eNB;

30 and

 control transmission of a downlink allocation to the UE based on the HO request ACK.

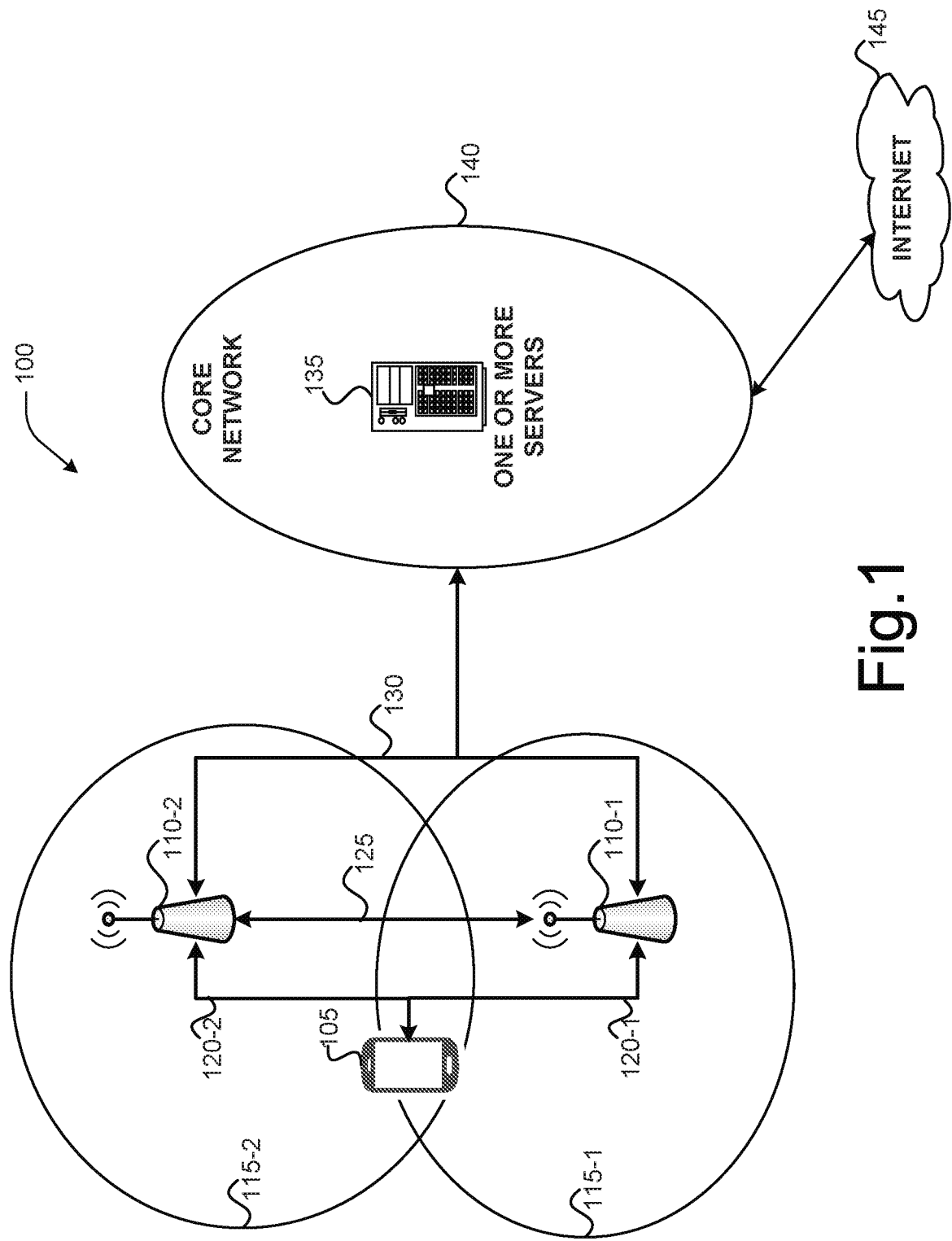


Fig.1

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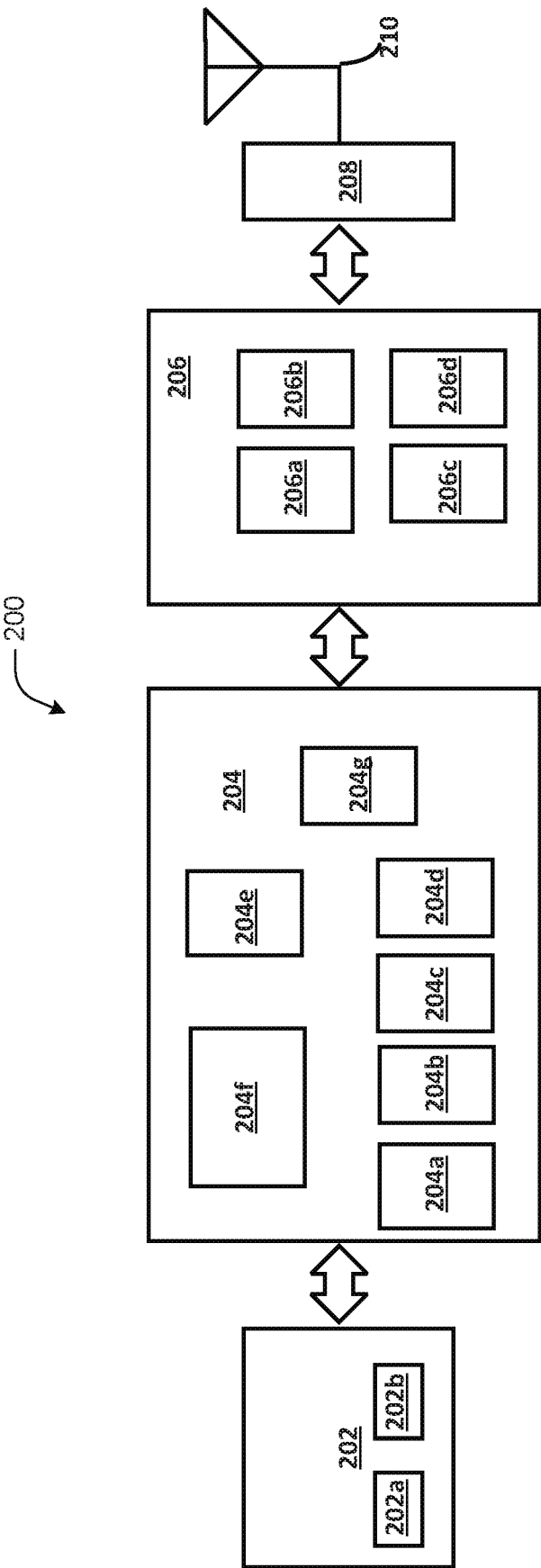


Fig.2

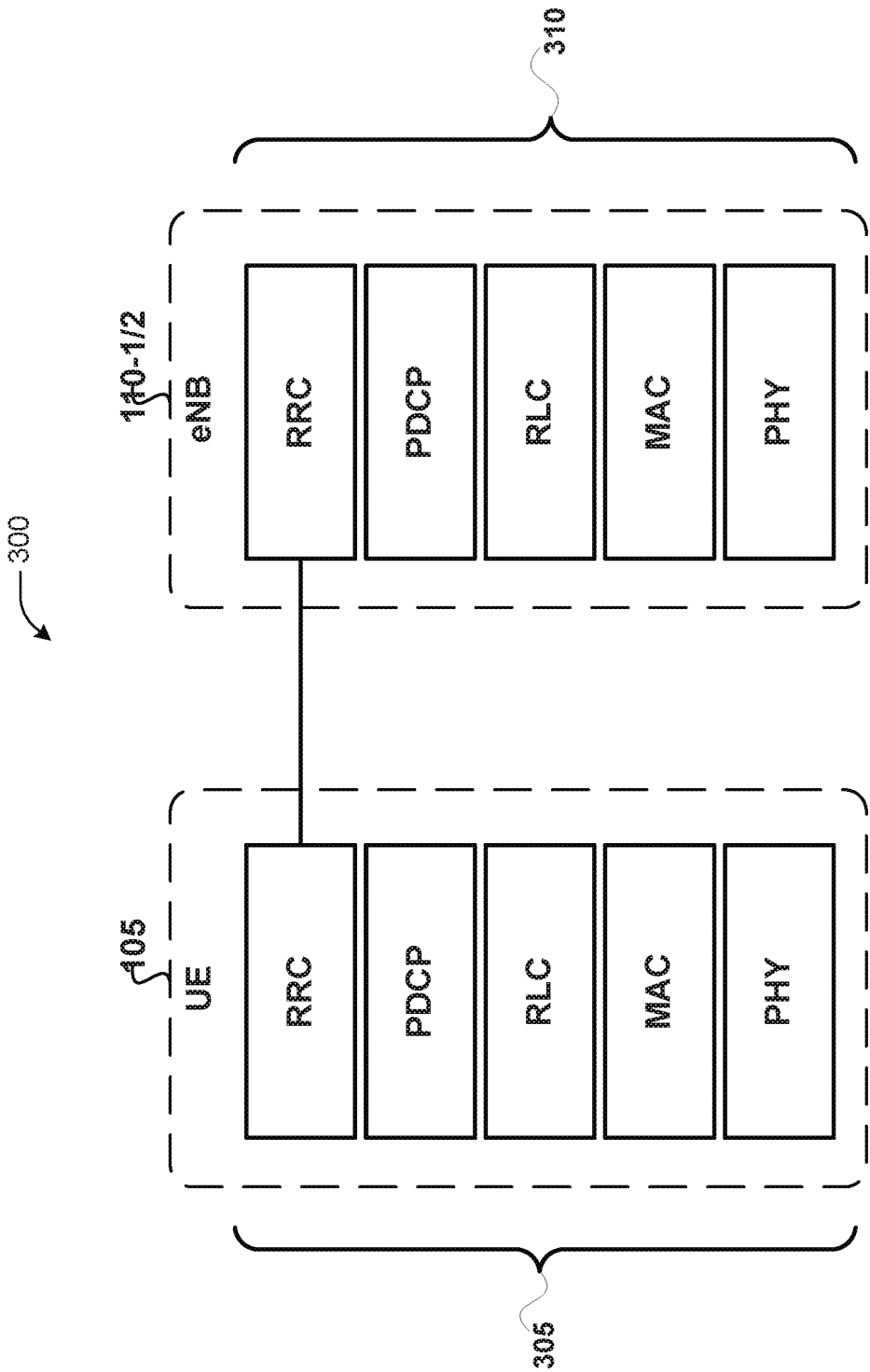


Fig.3

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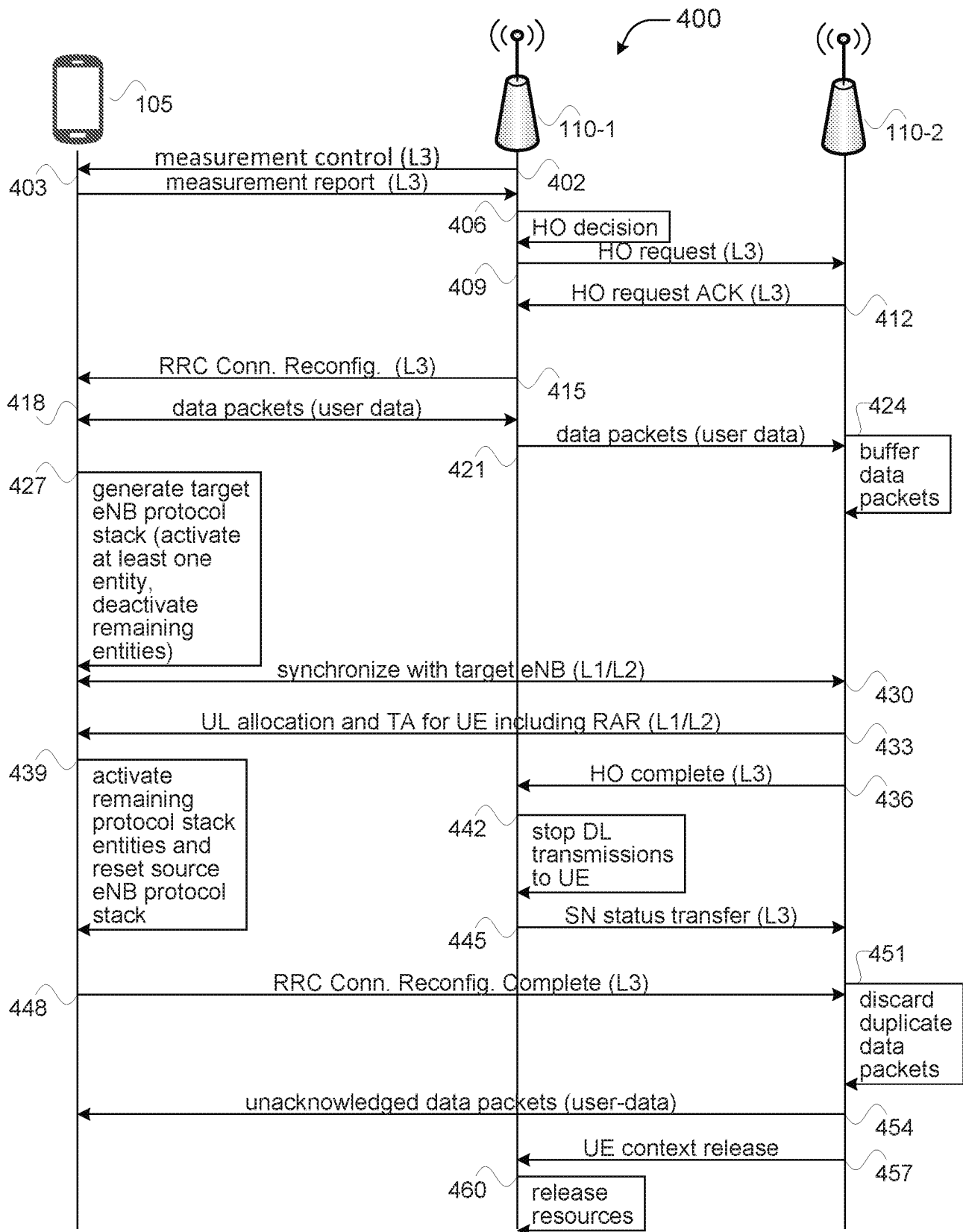


Fig.4

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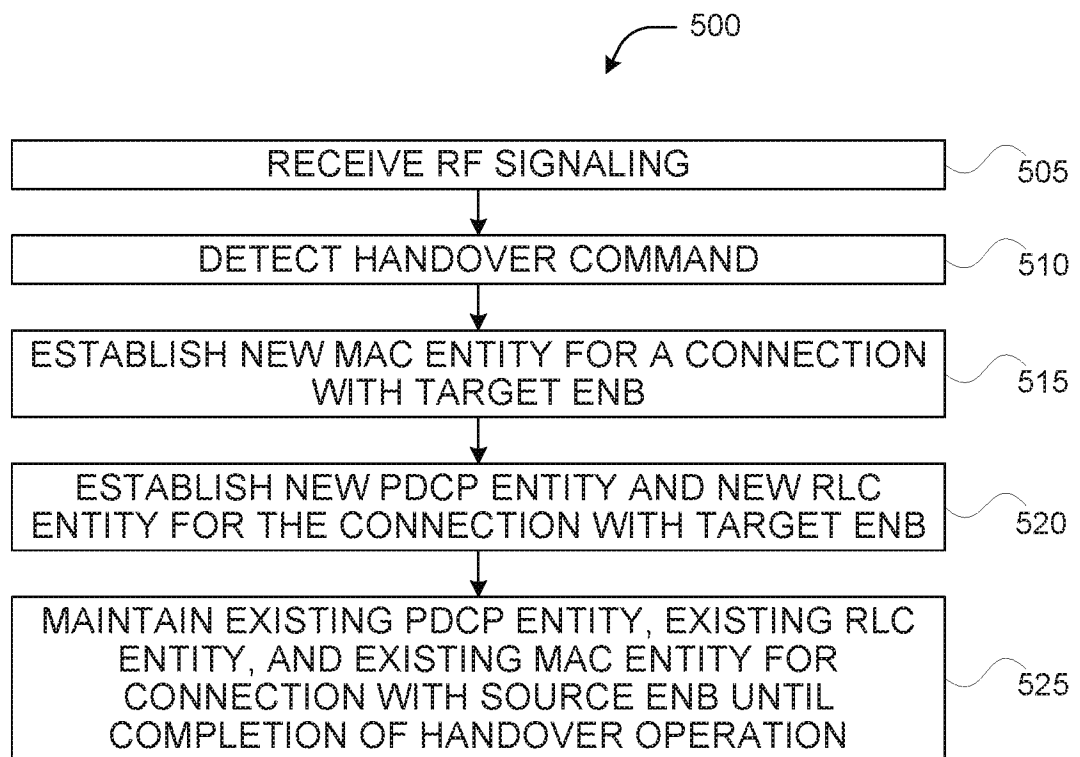


Fig.5

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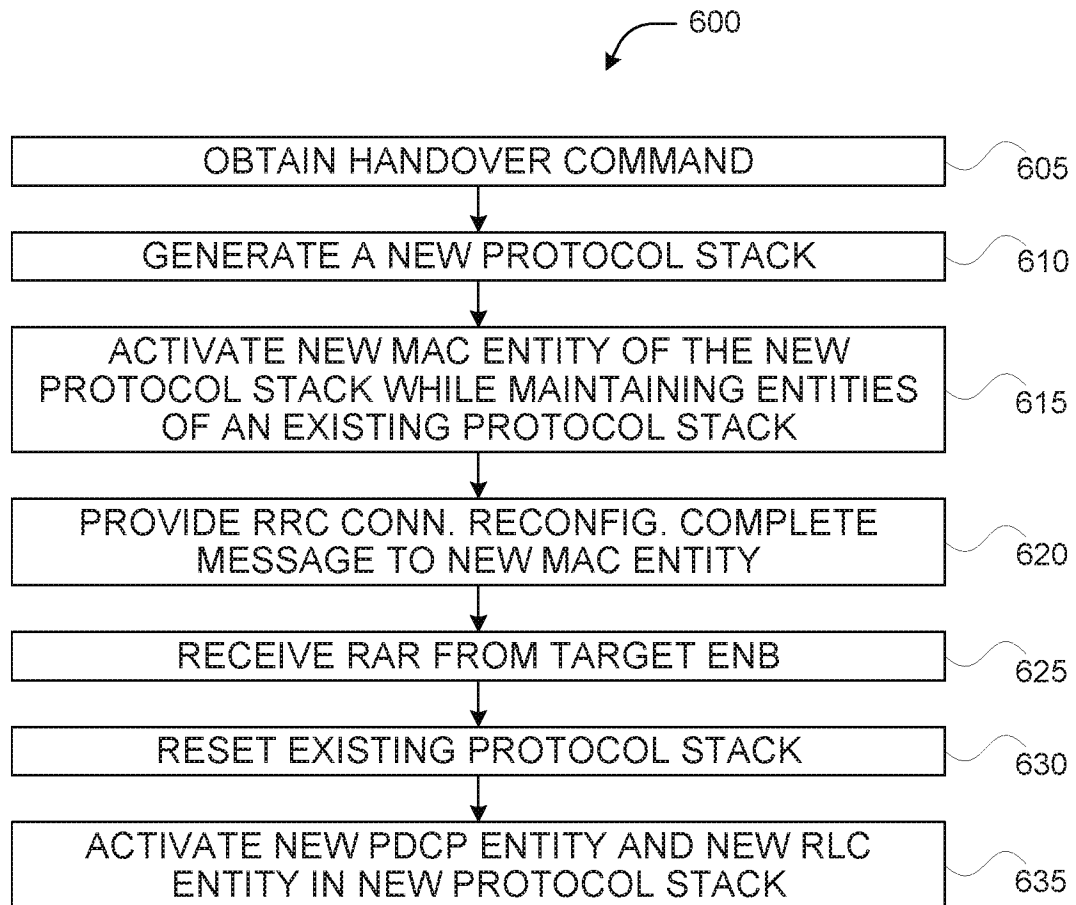


Fig.6

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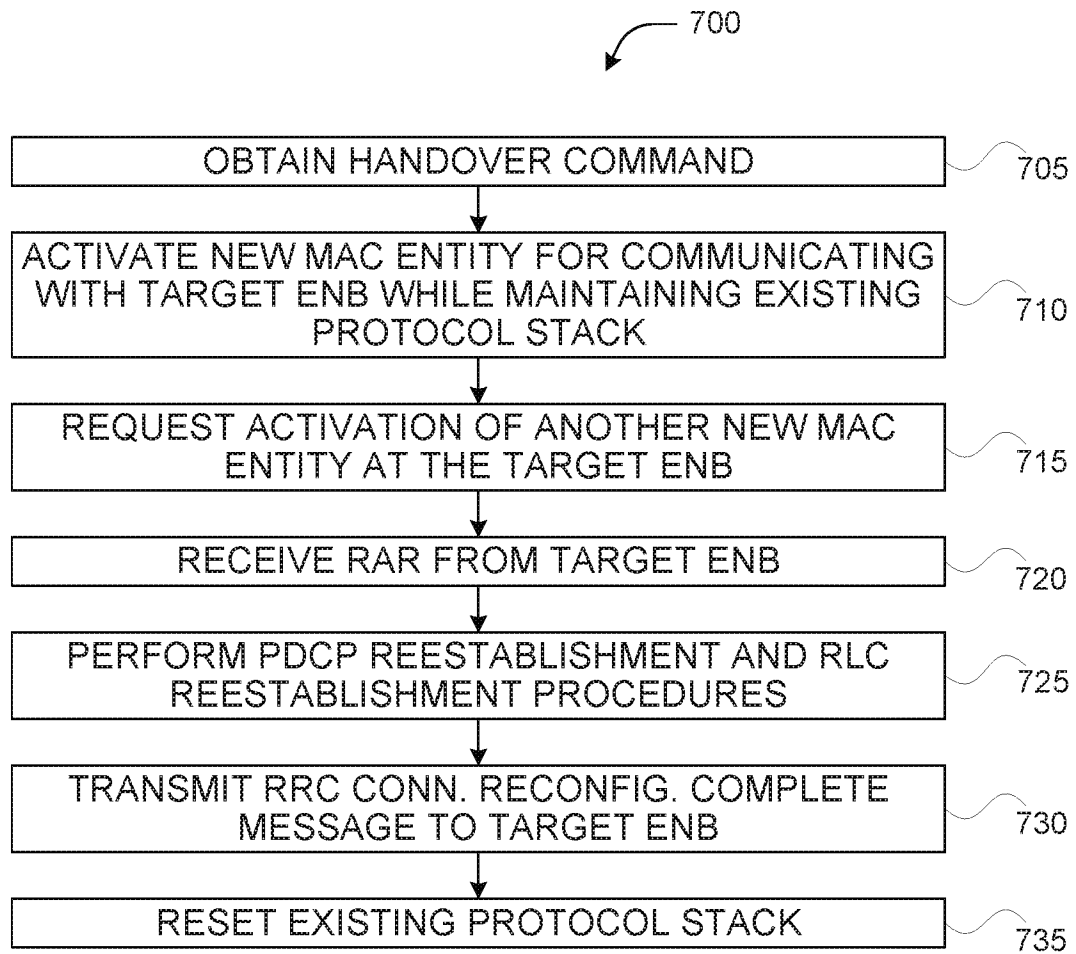


Fig.7

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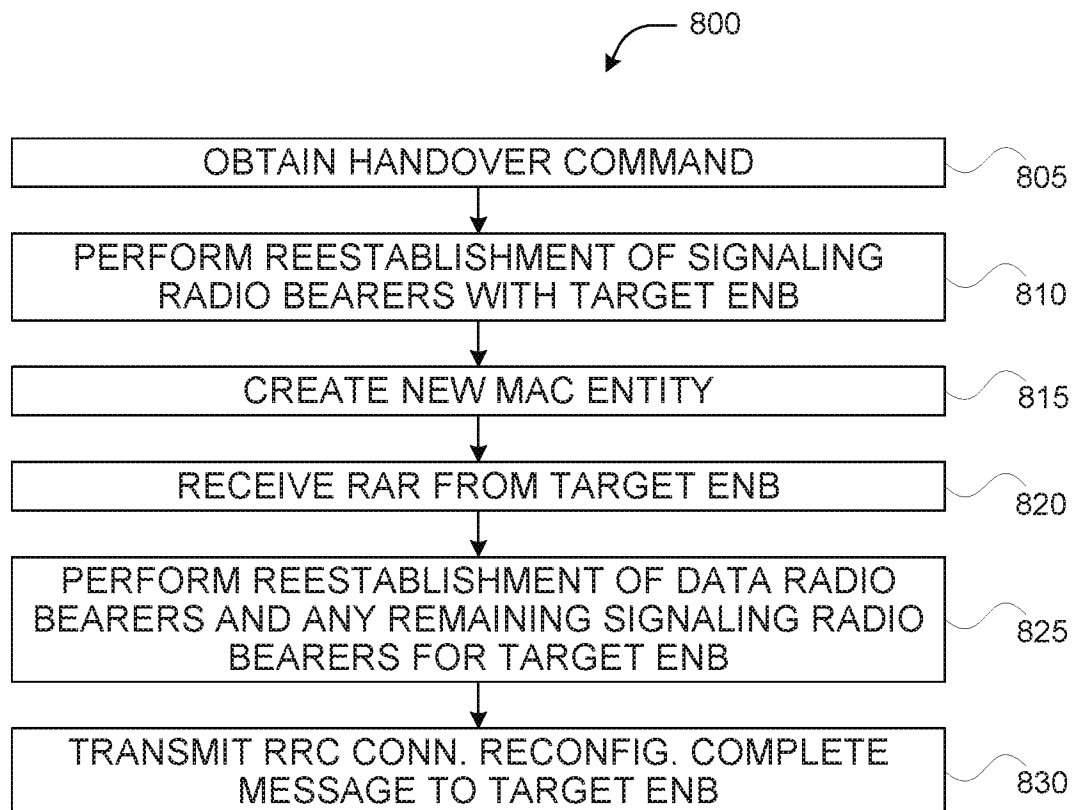


Fig.8

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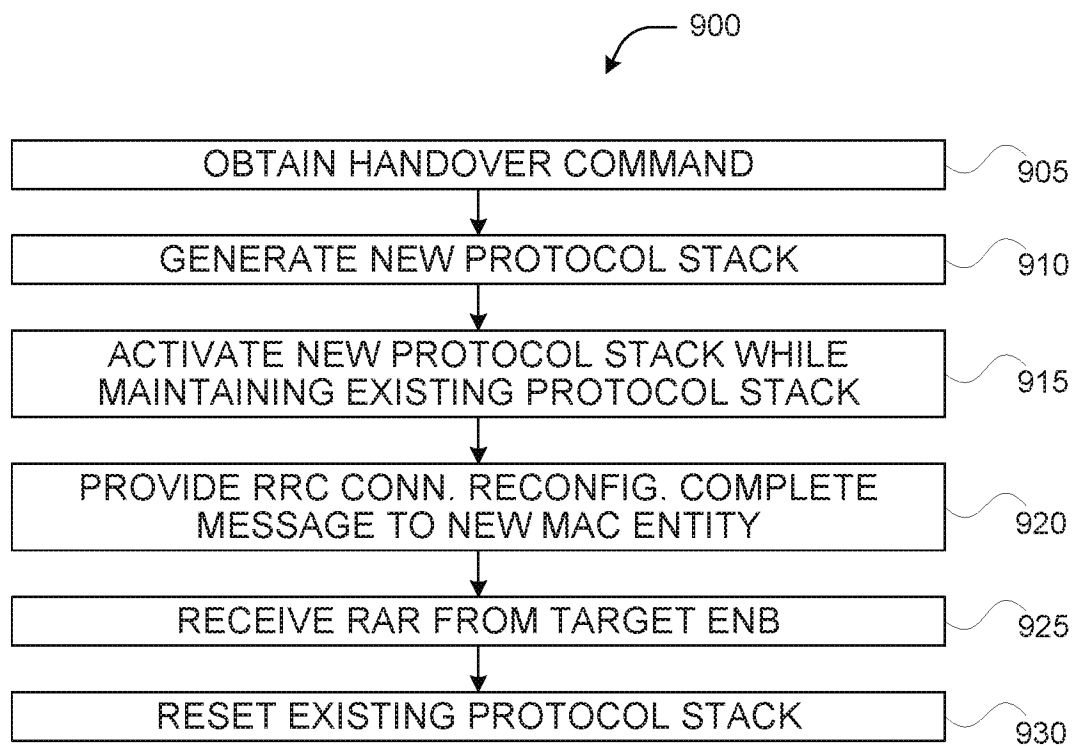


Fig.9

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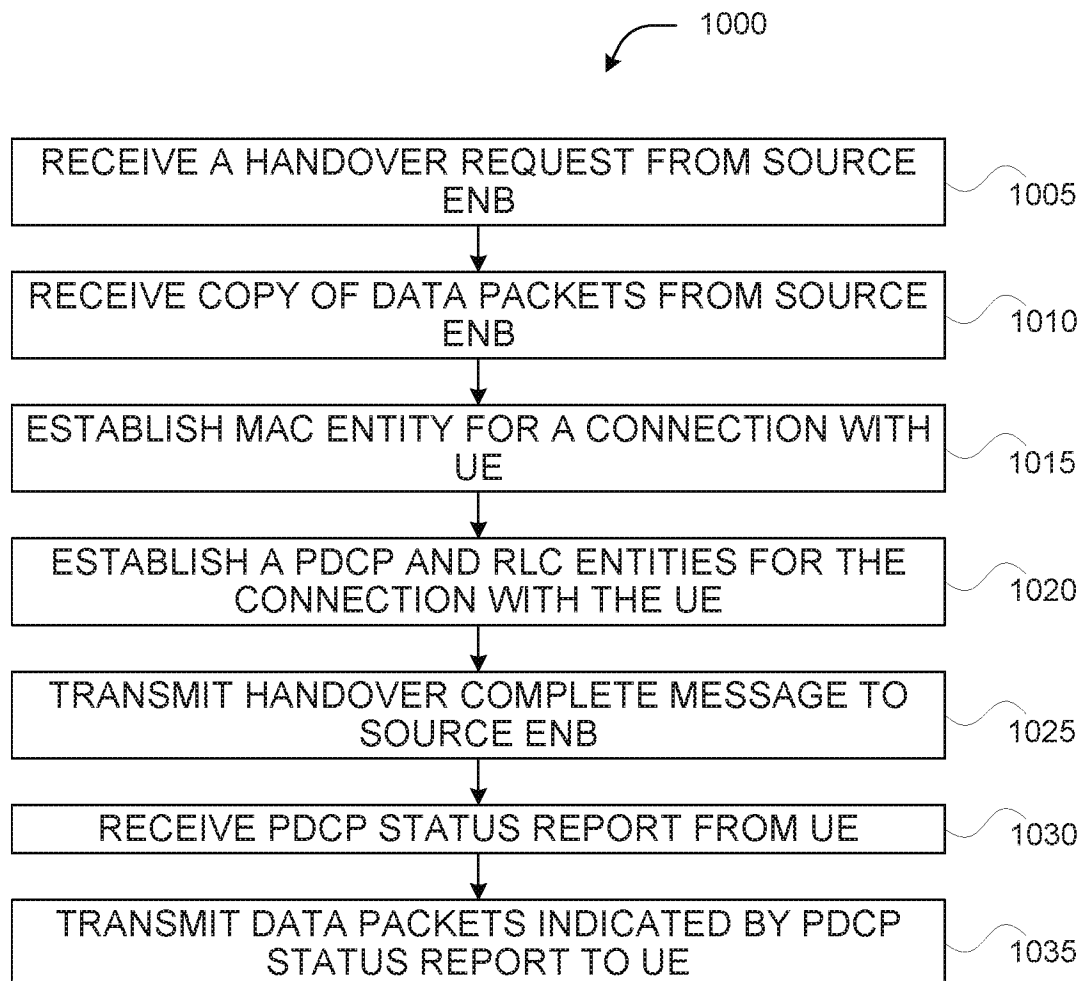


Fig.10

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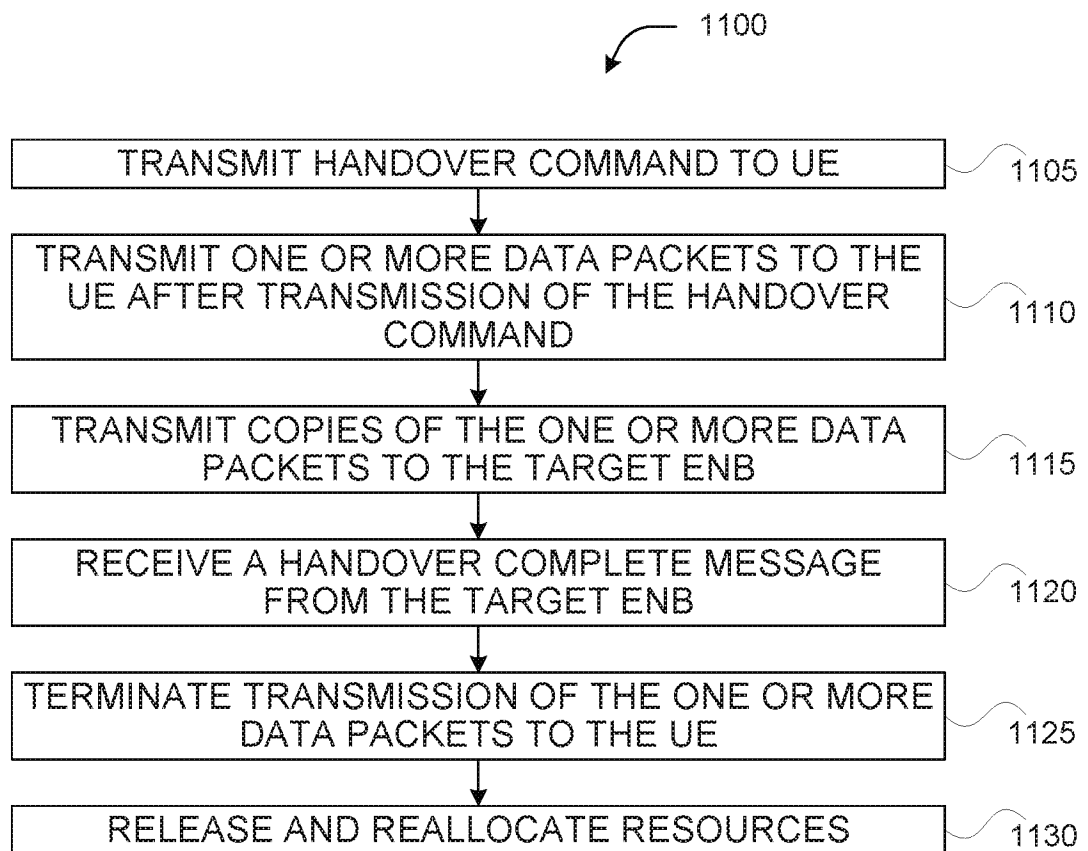


Fig.11

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/038746

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W36/18
ADD.

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

B. FIELDS SEARCHED

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

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Further documents are listed in the continuation of Box C.



See patent family annex.

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

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Date of the actual completion of the international search

17 October 2016

Date of mailing of the international search report

24/10/2016

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Authorized officer

Zembery, Peter

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/038746

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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X	"3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Study on latency reduction techniques for LTE (Release 13)", 3GPP DRAFT; R2-157181 36881-050, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , 30 November 2015 (2015-11-30), XP051065267, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG2_RL 2/TSGR2_92/LSout/ [retrieved on 2015-11-30] page 10, line 20 - page 12, line 12 page 17, line 17 - line 21 ----- -/--	1-25

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2016/038746

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	section 2 Discussion	2-12, 14-20, 22-25
A	----- INTEL CORPORATION: "Analysis on reduction of handover interruption", 3GPP DRAFT; R2-154813, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG2, no. Malmo, Sweden; 20151005 - 20151009 26 September 2015 (2015-09-26), XP051024004, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_91bis/Docs/ [retrieved on 2015-09-26] section 2.2.2 Sending data to UE from the source cell during handover	1-25
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2016/038746

Patent document cited in search report			Publication date		Patent family member(s)			Publication date	
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