

REALIZING RANDOM ACCESS CHANNEL-LESS LAYER 1/LAYER 2 TRIGGERED MOBILITY

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to Indian Patent Application No. 202221056932 entitled “Method and system to realize RACH-less HO for LLM in inter gNB-DU scenario” filed October 4, 2022, which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

[0002] In some implementations, the current subject matter relates to telecommunications systems, and in particular, to realizing random access channel layer-less (RACH-less) layer 1/layer 2 triggered mobility (LTM).

BACKGROUND

[0003] In today’s world, cellular networks provide on-demand communications capabilities to individuals and business entities. Typically, a cellular network is a wireless network that can be distributed over land areas, which are called cells. Each such cell is served by at least one fixed-location transceiver, which is referred to as a cell site or a base station. Each cell can use a different set of frequencies than its neighbor cells in order to avoid interference and provide improved service within each cell. When cells are joined together, they provide radio coverage over a wide geographic area, which enables a large number of mobile telephones, and/or other wireless devices or portable transceivers to communicate with each other and with fixed transceivers and telephones anywhere in the network. Such communications are performed through base stations and are accomplished even if the mobile transceivers are moving through more than one cell during transmission. Major wireless communications providers have deployed such cell sites throughout the world, thereby allowing communications mobile phones and mobile computing devices to be connected to the public switched telephone network and public Internet.

[0004] A mobile telephone is a portable telephone that is capable of receiving and/or making telephone and/or data calls through a cell site or a transmitting tower by using radio waves to transfer signals to and from the mobile telephone. In view of a large number of mobile telephone users, current mobile telephone networks provide a limited

and shared resource. In that regard, cell sites and handsets can change frequency and use low power transmitters to allow simultaneous usage of the networks by many callers with less interference. Coverage by a cell site can depend on a particular geographical location and/or a number of users that can potentially use the network. For example, in a city, a cell site can have a range of up to approximately $\frac{1}{2}$ mile; in rural areas, the range can be as much as 5 miles; and in some areas, a user can receive signals from a cell site 25 miles away.

[0005] The following are examples of some of the digital cellular technologies that are in use by the communications providers: Global System for Mobile Communications (“GSM”), General Packet Radio Service (“GPRS”), cdmaOne, CDMA2000, Evolution-Data Optimized (“EV-DO”), Enhanced Data Rates for GSM Evolution (“EDGE”), Universal Mobile Telecommunications System (“UMTS”), Digital Enhanced Cordless Telecommunications (“DECT”), Digital AMPS (“IS-136/TDMA”), and Integrated Digital Enhanced Network (“iDEN”). The Long Term Evolution, or 4G LTE, which was developed by the Third Generation Partnership Project (“3GPP”) standards body, is a standard for a wireless communication of high-speed data for mobile phones and data terminals. A 5G standard is currently being developed and deployed. 3GPP cellular technologies like LTE and 5G NR are evolutions of earlier generation 3GPP technologies like the GSM/EDGE and UMTS/HSPA digital cellular technologies and allows for increasing capacity and speed by using a different radio interface together with core network improvements.

[0006] Cellular networks can be divided into radio access networks and core networks. The radio access network (RAN) can include network functions that can handle radio layer communications processing. The core network can include network functions that can handle higher layer communications, e.g., internet protocol (IP), transport layer and applications layer. In some cases, the RAN functions can be split into baseband unit functions and the radio unit functions, where a radio unit connected to a baseband unit via a fronthaul network, for example, can be responsible for lower layer processing of a radio physical layer while a baseband unit can be responsible for the higher layer radio protocols, e.g., MAC, RLC, etc.

[0007] A base station for a 5G cellular network can include a centralized unit (CU), one or more distributed units (DUs) communicatively coupled to the CU, and one or more radio units (RUs) each communicatively coupled to at least one of the one or more DUs and each configured to be communicatively coupled to one or more mobile phones

and/or other user equipments (UEs). The CU can be logically split into a control plane portion CU-CP and one or more user plane portions (CU-UP). During the course of a UE's communicative coupling with the base station, the DU supporting the UE may change. Time synchronization is established in a random access channel (RACH) procedure between the UE and the new supporting DU for communications to occur properly between the UE and the new supporting DU. However, such a handover from one DU to another DU takes more time when a contention based RACH procedure must occur instead of a contention free RACH procedure. Such an increase in time to accomplish the handover increases handover latency and thereby increases user plane interruption time.

SUMMARY

[0008] In some implementations, the current subject matter relates to a computer-implemented method. The method can include receiving, at at least one layer 1/layer 2 triggered mobility (LTM) target distributed unit (DU) of a base station, information indicative of whether handover (HO) of service for a user equipment (UE) currently being served by a serving DU of the base station can be a random access channel-less (RACH-less) HO to at least one LTM target cell of the target DU or can be a RACH-based HO to the at least one LTM target cell. The method can also include preparing the at least one LTM target cell, based on the information received at the at least one LTM target cell, for one of RACH-less HO and RACH-based HO.

[0009] The method may allow for HO from one cell of a base station to another cell of the base station to take less time since HO from the serving cell to one of the at least one target cells can have been already been prepared at each of the one or more target cells to include either a contention-free RACH procedure (for RACH-less HO) or a contention-based RACH procedure (for RACH-based HO). Handover latency may thus be reduced and thereby reduce user plane interruption time.

[0010] In some implementations, the current subject matter can include one or more of the following optional features.

[0011] In some implementations, the information can includes timing advance (TA) information of the UE in the serving DU, TA information of the UE in the serving cell being either (a) a TA that is the same as a TA in the at least one LTM target cell or (b) a TA of zero can be indicative that HO to the at least one LTM target cell can be RACH-less HO, and TA information of the UE in the serving cell being neither of (a) a TA that is the same as a TA in the at least one LTM target cell and (b) a TA of zero can be indicative

that HO to the at least one LTM target cell can be RACH-based HO. Further, the at least one LTM target DU can receive the TA information of the UE in the serving DU in a message from the serving DU and the method can include the at least one LTM target DU indicating to the serving DU if the prepared LTM target cell configuration is RACH-less or RACH-based configuration, or the at least one LTM target DU can receive the TA information of the UE in the serving DU in a message from a centralized unit control plane (CU-CP) of the base station and the method can include the at least one LTM target DU indicating to the CU-CP if the prepared LTM target cell configuration is RACH-less or RACH-based configuration. Further, the CU-CP can receive the TA information of the UE in the serving DU from the serving DU during setup of an F1 communication interface between the serving DU and the CU-CP, or the CU-CP can receive the TA information of the UE in the serving DU from the serving DU after an F1 communication interface has been set up between the serving DU and the CU-CP.

[0012] In some implementations, the at least one LTM target cell can be included in at least one DU of the base station that is not the serving DU.

[0013] In some implementations, the serving DU can select one of the at least one prepared LTM target cells for handover of service for the UE from the serving DU, and the serving DU can trigger the handover of the service for the UE from the serving DU to the selected LTM target cell. Further, the serving DU can determine which one or more of the at least one LTM target cells has a radio quality above a predetermined threshold radio quality, and the selection can be among the one or more determined LTM target cells; and/or the triggering can include the serving DU transmitting to the UE a Medium Access Control (MAC) control element (CE) message.

[0014] In some implementations, the base station can have a disaggregated architecture.

[0015] In some implementations, the base station can include a Next Generation Radio Access network (NG-RAN) node. Further, the NG-RAN node can include a gNodeB or an ng-eNodeB.

[0016] In some implementations, the base station can include at least one processor and at least one non-transitory storage media storing instructions that, when executed by the at least one processor, cause the at least one processor to perform the method.

[0017] Non-transitory computer program products (i.e., physically embodied computer program products) are also described that store instructions, which when executed by one or more data processors of one or more computing systems, causes at

least one data processor to perform operations herein. Similarly, computer systems are also described that may include one or more data processors and memory coupled to the one or more data processors. The memory may temporarily or permanently store instructions that cause at least one processor to perform one or more of the operations described herein. In addition, methods can be implemented by one or more data processors either within a single computing system or distributed among two or more computing systems. Such computing systems can be connected and can exchange data and/or commands or other instructions or the like via one or more connections, including but not limited to a connection over a network (e.g., the Internet, a wireless wide area network, a local area network, a wide area network, a wired network, or the like), via a direct connection between one or more of the multiple computing systems, etc.

[0018] The details of one or more variations of the subject matter described herein are set forth in the accompanying drawings and the description below. Other features and advantages of the subject matter described herein will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The accompanying drawings, which are incorporated in and constitute a part of this specification, show certain aspects of the subject matter disclosed herein and, together with the description, help explain some of the principles associated with the disclosed implementations. In the drawings,

[0020] FIG. 1a illustrates an exemplary conventional long term evolution (“LTE”) communications system;

[0021] FIG. 1b illustrates further detail of the exemplary LTE system shown in FIG. 1a;

[0022] FIG. 1c illustrates additional detail of the evolved packet core of the exemplary LTE system shown in FIG. 1a;

[0023] FIG. 1d illustrates an exemplary evolved Node B of the exemplary LTE system shown in FIG. 1a;

[0024] FIG. 2 illustrates further detail of an evolved Node B shown in FIGS. 1a-d;

[0025] FIG. 3 illustrates an exemplary virtual radio access network, according to some implementations of the current subject matter;

[0026] FIG. 4 illustrates an exemplary 3GPP split architecture to provide its users with use of higher frequency bands;

[0027] FIG. 5a illustrates an exemplary 5G wireless communication system;

[0028] FIG. 5b illustrates an exemplary layer architecture of the split gNB and/or a split ng-eNB (e.g., next generation eNB that may be connected to 5GC);

[0029] FIG. 5c illustrates an exemplary functional split in the gNB architecture shown in FIGS. 5a-b;

[0030] FIG. 6a illustrates an exemplary system, according to some implementations of the current subject matter;

[0031] FIG. 6b illustrates an exemplary alternate configuration of the system of FIG. 6a, according to some implementations of the current subject matter;

[0032] FIG. 7 illustrates an exemplary method, according to some implementations of the current subject matter;

[0033] FIG. 8a illustrates another exemplary system, according to some implementations of the current subject matter;

[0034] FIG. 8b illustrates another exemplary system, according to some implementations of the current subject matter;

[0035] FIG. 8c illustrates yet another exemplary system, according to some implementations of the current subject matter;

[0036] FIG. 8d illustrates still another exemplary system, according to some implementations of the current subject matter;

[0037] FIG. 8e illustrates another exemplary system, according to some implementations of the current subject matter;

[0038] FIG. 9 illustrates yet another exemplary system, according to some implementations of the current subject matter; and

[0039] FIG. 10 illustrates yet another exemplary method, according to some implementations of the current subject matter.

DETAILED DESCRIPTION

[0040] The current subject matter can provide for systems and methods that can be implemented in wireless communications systems. Such systems can include various wireless communications systems, including 5G New Radio communications systems, long term evolution communication systems, etc.

[0041] In general, the current subject matter relates to realizing RACH-less LTM.

[0042] In some implementations of the current subject matter, timing advance (TA) of a serving cell of a base station of a wireless communication system can be used in

preparing at least one target cell of the base station for LTM. The at least one target cell can be informed of the serving cell's TA, e.g., by receiving the serving cell's TA from a CU-CP of the base station communicatively coupled with the serving cell and the at least one target cell. Informing the at least one target cell of the serving cell's TA can allow each of the one or more target cells to prepare itself for either RACH-less (which may also be referred to as "RACH-free") handover (HO) or for RACH-based HO from the serving cell for a user equipment (UE) communicatively coupled with the base station. The HO from one cell of the base station to another cell of the base station may therefore take less time since HO from the serving cell to one of the at least one target cells has been already been prepared at each of the one or more target cells to include either a contention-free RACH procedure (for RACH-less HO) or a contention-based RACH procedure (for RACH-based HO). Handover latency may thus be reduced and thereby reduce user plane interruption time.

[0043] Layer 1/layer 2 triggered mobility (LTM) is an updated term for lower layer mobility (LLM). RAN2 has agreed on a definition of LTM. In general, LTM is a mobility procedure that allows a network to switch a UE from a source cell to a target cell without necessarily requiring a reconfiguration with sync. In particular, the network, based on L1 measurements received, can indicate in an L2 signaling (e.g., a message such as a MAC CE) a beam belonging to an LTM candidate cell to which the UE should perform the LTM cell switch procedure. The UE is provided with at least one LTM candidate cell configuration by the network before execution of an LTM cell switch procedure.

[0044] 3GPP standards defining one or more aspects that may be related to the current subject matter include 3GPP TS 38.321 "NR; Medium Access Control (MAC) protocol specification" 3GPP TS 38.331 "NR; Radio Resource Control (RRC) protocol specification," 3GPP TS 38.463 "NG-RAN; E1 Application Protocol (E1AP)," and 3GPP TS 38.473 "NG-RAN F1 application protocol (F1AP)." Standards of the O-RAN Alliance may also be related to one or more aspects of the current subject matter.

[0045] One or more aspects of the current subject matter can be incorporated into transmitter and/or receiver components of base stations (e.g., gNodeBs, eNodeBs, etc.) in such communications systems. The following is a general discussion of long-term evolution communications systems and 5G New Radio communication systems.

I. Long Term Evolution Communications System

[0046] FIGS. 1a-c and 2 illustrate an exemplary conventional long-term evolution (“LTE”) communication system 100 along with its various components. An LTE system or a 4G LTE, as it is commercially known, is governed by a standard for wireless communication of high-speed data for mobile telephones and data terminals. The standard is an evolution of the GSM/EDGE (“Global System for Mobile Communications”/“Enhanced Data rates for GSM Evolution”) as well as UMTS/HSPA (“Universal Mobile Telecommunications System”/“High Speed Packet Access”) network technologies. The standard was developed by the 3GPP (“3rd Generation Partnership Project”).

[0047] As shown in FIG. 1a, the system 100 can include an evolved universal terrestrial radio access network (“EUTRAN”) 102, an evolved packet core (“EPC”) 108, and a packet data network (“PDN”) 101, where the EUTRAN 102 and EPC 108 provide communication between a user equipment 104 and the PDN 101. The EUTRAN 102 can include a plurality of evolved node B’s (“eNodeB” or “ENODEB” or “enodeb” or “eNB”) or base stations 106 (a, b, c) (as shown in FIG. 1b) that provide communication capabilities to a plurality of user equipment 104(a, b, c). The user equipment 104 can be a mobile telephone, a smartphone, a tablet, a personal computer, a personal digital assistant (“PDA”), a server, a data terminal, and/or any other type of user equipment, and/or any combination thereof. The user equipment 104 can connect to the EPC 108 and eventually, the PDN 101, via any eNodeB 106. Typically, the user equipment 104 can connect to the nearest, in terms of distance, eNodeB 106. In the LTE system 100, the EUTRAN 102 and EPC 108 work together to provide connectivity, mobility and services for the user equipment 104.

[0048] FIG. 1b illustrates further detail of the network 100 shown in FIG. 1a. As stated above, the EUTRAN 102 includes a plurality of eNodeBs 106, also known as cell sites. The eNodeBs 106 provides radio functions and performs key control functions including scheduling of air link resources or radio resource management, active mode mobility or handover, and admission control for services. The eNodeBs 106 are responsible for selecting which mobility management entities (MMEs, as shown in FIG. 1c) will serve the user equipment 104 and for protocol features like header compression and encryption. The eNodeBs 106 that make up an EUTRAN 102 collaborate with one another for radio resource management and handover.

[0049] Communication between the user equipment 104 and the eNodeB 106 occurs via an air interface 122 (also known as “LTE-Uu” interface). As shown in FIG. 1b,

the air interface 122 provides communication between user equipment 104b and the eNodeB 106a. The air interface 122 uses Orthogonal Frequency Division Multiple Access (“OFDMA”) and Single Carrier Frequency Division Multiple Access (“SC-FDMA”), an OFDMA variant, on the downlink and uplink respectively. OFDMA allows use of multiple known antenna techniques, such as, Multiple Input Multiple Output (“MIMO”).

[0050] The air interface 122 uses various protocols, which include a radio resource control (“RRC”) for signaling between the user equipment 104 and eNodeB 106 and non-access stratum (“NAS”) for signaling between the user equipment 104 and MME (as shown in FIG. 1c). In addition to signaling, user traffic is transferred between the user equipment 104 and eNodeB 106. Both signaling and traffic in the system 100 are carried by physical layer (“PHY”) channels.

[0051] Multiple eNodeBs 106 can be interconnected with one another using an X2 interface 130(a, b, c). As shown in FIG. 1b, X2 interface 130a provides interconnection between eNodeB 106a and eNodeB 106b; X2 interface 130b provides interconnection between eNodeB 106a and eNodeB 106c; and X2 interface 130c provides interconnection between eNodeB 106b and eNodeB 106c. The X2 interface can be established between two eNodeBs in order to provide an exchange of signals, which can include a load- or interference-related information as well as handover-related information. The eNodeBs 106 communicate with the evolved packet core 108 via an S1 interface 124(a, b, c). The S1 interface 124 can be split into two interfaces: one for the control plane (shown as control plane interface (S1-MME interface) 128 in FIG. 1c) and the other for the user plane (shown as user plane interface (S1-U interface) 125 in FIG. 1c).

[0052] The EPC 108 establishes and enforces Quality of Service (“QoS”) for user services and allows user equipment 104 to maintain a consistent internet protocol (“IP”) address while moving. It should be noted that each node in the network 100 has its own IP address. The EPC 108 is designed to interwork with legacy wireless networks. The EPC 108 is also designed to separate control plane (i.e., signaling) and user plane (i.e., traffic) in the core network architecture, which allows more flexibility in implementation, and independent scalability of the control and user data functions.

[0053] The EPC 108 architecture is dedicated to packet data and is shown in more detail in FIG. 1c. The EPC 108 includes a serving gateway (S-GW) 110, a PDN gateway (P-GW) 112, a mobility management entity (“MME”) 114, a home subscriber server (“HSS”) 116 (a subscriber database for the EPC 108), and a policy control and charging

rules function (“PCRF”) 118. Some of these (such as S-GW, P-GW, MME, and HSS) are often combined into nodes according to the manufacturer’s implementation.

[0054] The S-GW 110 functions as an IP packet data router and is the user equipment’s bearer path anchor in the EPC 108. Thus, as the user equipment moves from one eNodeB 106 to another during mobility operations, the S-GW 110 remains the same and the bearer path towards the EUTRAN 102 is switched to talk to the new eNodeB 106 serving the user equipment 104. If the user equipment 104 moves to the domain of another S-GW 110, the MME 114 will transfer all of the user equipment’s bearer paths to the new S-GW. The S-GW 110 establishes bearer paths for the user equipment to one or more P-GWs 112. If downstream data are received for an idle user equipment, the S-GW 110 buffers the downstream packets and requests the MME 114 to locate and reestablish the bearer paths to and through the EUTRAN 102.

[0055] The P-GW 112 is the gateway between the EPC 108 (and the user equipment 104 and the EUTRAN 102) and PDN 101 (shown in FIG. 1a). The P-GW 112 functions as a router for user traffic as well as performs functions on behalf of the user equipment. These include IP address allocation for the user equipment, packet filtering of downstream user traffic to ensure it is placed on the appropriate bearer path, enforcement of downstream QoS, including data rate. Depending upon the services a subscriber is using, there may be multiple user data bearer paths between the user equipment 104 and P-GW 112. The subscriber can use services on PDNs served by different P-GWs, in which case the user equipment has at least one bearer path established to each P-GW 112. During handover of the user equipment from one eNodeB to another, if the S-GW 110 is also changing, the bearer path from the P-GW 112 is switched to the new S-GW.

[0056] The MME 114 manages user equipment 104 within the EPC 108, including managing subscriber authentication, maintaining a context for authenticated user equipment 104, establishing data bearer paths in the network for user traffic, and keeping track of the location of idle mobiles that have not detached from the network. For idle user equipment 104 that needs to be reconnected to the access network to receive downstream data, the MME 114 initiates paging to locate the user equipment and re-establishes the bearer paths to and through the EUTRAN 102. MME 114 for a particular user equipment 104 is selected by the eNodeB 106 from which the user equipment 104 initiates system access. The MME is typically part of a collection of MMEs in the EPC 108 for the purposes of load sharing and redundancy. In the establishment of the user’s data bearer

paths, the MME 114 is responsible for selecting the P-GW 112 and the S-GW 110, which will make up the ends of the data path through the EPC 108.

[0057] The PCRF 118 is responsible for policy control decision-making, as well as for controlling the flow-based charging functionalities in the policy control enforcement function (“PCEF”), which resides in the P-GW 110. The PCRF 118 provides the QoS authorization (QoS class identifier (“QCI”) and bit rates) that decides how a certain data flow will be treated in the PCEF and ensures that this is in accordance with the user’s subscription profile.

[0058] As stated above, the IP services 119 are provided by the PDN 101 (as shown in FIG. 1a).

[0059] FIG. 1d illustrates an exemplary structure of eNodeB 106. The eNodeB 106 can include at least one remote radio head (“RRH”) 132 (typically, there can be three RRH 132) and a baseband unit (“BBU”) 134. The RRH 132 can be connected to antennas 136. The RRH 132 and the BBU 134 can be connected using an optical interface that is compliant with common public radio interface (“CPRI”) / enhanced CPRI (“eCPRI”) 142 standard specification either using RRH specific custom control and user plane framing methods or using O-RAN Alliance compliant Control and User plane framing methods. The operation of the eNodeB 106 can be characterized using the following standard parameters (and specifications): radio frequency band (Band4, Band9, Band17, etc.), bandwidth (5, 10, 15, 20 MHz), access scheme (downlink: OFDMA; uplink: SC-OFDMA), antenna technology (Single user and multi user MIMO; Uplink: Single user and multi user MIMO), number of sectors (6 maximum), maximum transmission rate (downlink: 150 Mb/s; uplink: 50 Mb/s), S1/X2 interface (1000Base-SX, 1000Base-T), and mobile environment (up to 350 km/h). The BBU 134 can be responsible for digital baseband signal processing, termination of S1 line, termination of X2 line, call processing and monitoring control processing. IP packets that are received from the EPC 108 (not shown in FIG. 1d) can be modulated into digital baseband signals and transmitted to the RRH 132. Conversely, the digital baseband signals received from the RRH 132 can be demodulated into IP packets for transmission to EPC 108.

[0060] The RRH 132 can transmit and receive wireless signals using antennas 136. The RRH 132 can convert (using converter (“CONV”) 140) digital baseband signals from the BBU 134 into radio frequency (“RF”) signals and power amplify (using amplifier (“AMP”) 138) them for transmission to user equipment 104 (not shown in FIG. 1d). Conversely, the RF signals that are received from user equipment 104 are amplified (using

AMP 138) and converted (using CONV 140) to digital baseband signals for transmission to the BBU 134.

[0061] FIG. 2 illustrates an additional detail of an exemplary eNodeB 106. The eNodeB 106 includes a plurality of layers: LTE layer 1 202, LTE layer 2 204, and LTE layer 3 206. The LTE layer 1 includes a physical layer (“PHY”). The LTE layer 2 includes a medium access control (“MAC”), a radio link control (“RLC”), a packet data convergence protocol (“PDCP”). The LTE layer 3 includes various functions and protocols, including a radio resource control (“RRC”), a dynamic resource allocation, eNodeB measurement configuration and provision, a radio admission control, a connection mobility control, and radio resource management (“RRM”). The RLC protocol is an automatic repeat request (“ARQ”) fragmentation protocol used over a cellular air interface. The RRC protocol handles control plane signaling of LTE layer 3 between the user equipment and the EUTRAN. RRC includes functions for connection establishment and release, broadcast of system information, radio bearer establishment/reconfiguration and release, RRC connection mobility procedures, paging notification and release, and outer loop power control. The PDCP performs IP header compression and decompression, transfer of user data and maintenance of sequence numbers for Radio Bearers. The BBU 134, shown in FIG. 1d, can include LTE layers L1-L3.

[0062] One of the primary functions of the eNodeB 106 is radio resource management, which includes scheduling of both uplink and downlink air interface resources for user equipment 104, control of bearer resources, and admission control. The eNodeB 106, as an agent for the EPC 108, is responsible for the transfer of paging messages that are used to locate mobiles when they are idle. The eNodeB 106 also communicates common control channel information over the air, header compression, encryption and decryption of the user data sent over the air, and establishing handover reporting and triggering criteria. As stated above, the eNodeB 106 can collaborate with other eNodeB 106 over the X2 interface for the purposes of handover and interference management. The eNodeBs 106 communicate with the EPC’s MME via the S1-MME interface and to the S-GW with the S1-U interface. Further, the eNodeB 106 exchanges user data with the S-GW over the S1-U interface. The eNodeB 106 and the EPC 108 have a many-to-many relationship to support load sharing and redundancy among MMEs and S-GWs. The eNodeB 106 selects an MME from a group of MMEs so the load can be shared by multiple MMEs to avoid congestion.

II. 5G NR Wireless Communications Networks

[0063] In some implementations, the current subject matter relates to a 5G new radio (“NR”) communications system. The 5G NR is a next telecommunications standard beyond the 4G/IMT-Advanced standards. 5G networks offer at higher capacity than current 4G, allow higher number of mobile broadband users per area unit, and allow consumption of higher and/or unlimited data quantities in gigabyte per month and user. This can allow users to stream high-definition media many hours per day using mobile devices, even when it is not possible to do so with Wi-Fi networks. 5G networks have an improved support of device-to-device communication, lower cost, lower latency than 4G equipment and lower battery consumption, etc. Such networks have data rates of tens of megabits per second for a large number of users, data rates of 100 Mb/s for metropolitan areas, 1 Gb/s simultaneously to users within a confined area (e.g., office floor), a large number of simultaneous connections for wireless sensor networks, an enhanced spectral efficiency, improved coverage, enhanced signaling efficiency, 1-10 ms latency, reduced latency compared to existing systems.

[0064] FIG. 3 illustrates an exemplary virtual radio access network 300. The network 300 can provide communications between various components, including a base station (e.g., eNodeB, gNodeB) 301, a radio equipment 303, a centralized unit 302, a digital unit 304, and a radio device 306. The components in the system 300 can be communicatively coupled to a core using a backhaul link 305. A centralized unit (“CU”) 302 can be communicatively coupled to a distributed unit (“DU”) 304 using a midhaul connection 308. The radio frequency (“RU”) components 306 can be communicatively coupled to the DU 304 using a fronthaul connection 310.

[0065] In some implementations, the CU 302 can provide intelligent communication capabilities to one or more DU units 304. The units 302, 304 can include one or more base stations, macro base stations, micro base stations, remote radio heads, etc. and/or any combination thereof.

[0066] In lower layer split architecture environment, a CPRI bandwidth requirement for NR can be 100s of Gb/s. CPRI compression can be implemented in the DU and RU (as shown in FIG. 3). In 5G communications systems, compressed CPRI over Ethernet frame is referred to as eCPRI and is the recommended fronthaul network. The architecture can allow for standardization of fronthaul/midhaul, which can include a higher

layer split (e.g., Option 2 or Option 3-1 (Upper/Lower RLC split architecture)) and fronthaul with L1-split architecture (Option 7).

[0067] In some implementations, the lower layer-split architecture (e.g., Option 7) can include a receiver in the uplink, joint processing across multiple transmission points (TPs) for both DL/UL, and transport bandwidth and latency requirements for ease of deployment. Further, the current subject matter's lower layer-split architecture can include a split between cell-level and user-level processing, which can include cell-level processing in remote unit ("RU") and user-level processing in DU. Further, using the current subject matter's lower layer-split architecture, frequency-domain samples can be transported via Ethernet fronthaul, where the frequency-domain samples can be compressed for reduced fronthaul bandwidth.

[0068] FIG. 4 illustrates an exemplary communications system 400 that can implement a 5G technology and can provide its users with use of higher frequency bands (e.g., greater than 10GHz). The system 400 can include a macro cell 402 and small cells 404, 406.

[0069] A mobile device 408 can be configured to communicate with one or more of the small cells 404, 406. The system 400 can allow splitting of control planes (C-plane) and user planes (U-plane) between the macro cell 402 and small cells 404, 406, where the C-plane and U-plane are utilizing different frequency bands. In particular, the small cells 404, 406 can be configured to utilize higher frequency bands when communicating with the mobile device 408. The macro cell 402 can utilize existing cellular bands for C-plane communications. The mobile device 408 can be communicatively coupled via U-plane 412, where the small cell (e.g., small cell 406) can provide higher data rate and more flexible/cost/energy efficient operations. The macro cell 402, via C-plane 410, can maintain good connectivity and mobility. Further, in some cases, LTE and NR can be transmitted on the same frequency.

[0070] FIG. 5a illustrates an exemplary 5G wireless communication system 500, according to some implementations of the current subject matter. The system 500 can be configured to have a lower layer split architecture in accordance with Option 7-2. The system 500 can include a core network 502 (e.g., 5G Core) and one or more gNodeBs (or gNBs), where the gNBs can have a centralized unit gNB-CU. The gNB-CU can be logically split into control plane portion, gNB-CU-CP, 504 and one or more user plane portions, gNB-CU-UP, 506. The control plane portion 504 and the user plane portion 506 can be configured to be communicatively coupled using an E1 communication interface

514 (as specified in the 3GPP Standard). The control plane portion 504 can be configured to be responsible for execution of the RRC and PDCP protocols of the radio stack.

[0071] The control plane and user plane portions 504, 506 of the centralized unit of the gNB can be configured to be communicatively coupled to one or more distributed units (DU) 508, 510, in accordance with the higher layer split architecture. The distributed units 508, 510 can be configured to execute RLC, MAC and upper part of PHY layers protocols of the radio stack. The control plane portion 504 can be configured to be communicatively coupled to the distributed units 508, 510 using F1-C communication interfaces 516, and the user plane portions 506 can be configured to be communicatively coupled to the distributed units 508, 510 using F1-U communication interfaces 518. The distributed units 508, 510 can be coupled to one or more remote radio units (RU) 512 via a fronthaul network 520 (which may include one or switches, links, etc.), which in turn communicate with one or more user equipment (not shown in FIG. 5a). The remote radio units 512 can be configured to execute a lower part of the PHY layer protocols as well as provide antenna capabilities to the remote units for communication with user equipments (similar to the discussion above in connection with FIGS. 1a-2).

[0072] FIG. 5b illustrates an exemplary layer architecture 530 of the split gNB. The architecture 530 can be implemented in the communications system 500 shown in FIG. 5a, which can be configured as a virtualized disaggregated radio access network (RAN) architecture, whereby layers L1, L2, L3 and radio processing can be virtualized and disaggregated in the centralized unit(s), distributed unit(s) and radio unit(s). As shown in FIG. 5b, the gNB-DU 508 can be communicatively coupled to the gNB-CU-CP control plane portion 504 (also shown in FIG. 5a) and gNB-CU-UP user plane portion 506. Each of components 504, 506, 508 can be configured to include one or more layers.

[0073] The gNB-DU 508 can include RLC, MAC, and PHY layers as well as various communications sublayers. These can include an F1 application protocol (F1-AP) sublayer, a GPRS tunneling protocol (GTPU) sublayer, a stream control transmission protocol (SCTP) sublayer, a user datagram protocol (UDP) sublayer and an internet protocol (IP) sublayer. As stated above, the distributed unit 508 may be communicatively coupled to the control plane portion 504 of the centralized unit, which may also include F1-AP, SCTP, and IP sublayers as well as radio resource control, and PDCP-control (PDCCP-C) sublayers. Moreover, the distributed unit 508 may also be communicatively coupled to the user plane portion 506 of the centralized unit of the gNB. The user plane

portion 506 may include service data adaptation protocol (SDAP), PDCP-user (PDCP-U), GTPU, UDP, and IP sublayers.

[0074] FIG. 5c illustrates an exemplary functional split in the gNB architecture shown in FIGS. 5a-b. As shown in FIG. 5c, the gNB-DU 508 may be communicatively coupled to the gNB-CU-CP 504 and gNB-CU-UP 506 using an F1-C communication interface. The gNB-CU-CP 504 and gNB-CU-UP 506 may be communicatively coupled using an E1 communication interface. The higher part of the PHY layer (or Layer 1) may be executed by the gNB-DU 508, whereas the lower parts of the PHY layer may be executed by the RUs (not shown in FIG. 5c). As shown in FIG. 5c, the RRC and PDCP-C portions may be executed by the control plane portion 504, and the SDAP and PDCP-U portions may be executed by the user plane portion 506.

[0075] Some of the functions of the PHY layer in 5G communications network can include error detection on the transport channel and indication to higher layers, FEC encoding/decoding of the transport channel, hybrid ARQ soft-combining, rate matching of the coded transport channel to physical channels, mapping of the coded transport channel onto physical channels, power weighting of physical channels, modulation and demodulation of physical channels, frequency and time synchronization, radio characteristics measurements and indication to higher layers, MIMO antenna processing, digital and analog beamforming, RF processing, as well as other functions.

[0076] The MAC sublayer of Layer 2 can perform beam management, random access procedure, mapping between logical channels and transport channels, concatenation of multiple MAC service data units (SDUs) belonging to one logical channel into transport block (TB), multiplexing/demultiplexing of SDUs belonging to logical channels into/from TBs delivered to/from the physical layer on transport channels, scheduling information reporting, error correction through HARQ, priority handling between logical channels of one UE, priority handling between UEs by means of dynamic scheduling, transport format selection, and other functions. The RLC sublayer's functions can include transfer of upper layer packet data units (PDUs), error correction through ARQ, reordering of data PDUs, duplicate and protocol error detection, re-establishment, etc. The PDCP sublayer can be responsible for transfer of user data, various functions during re-establishment procedures, retransmission of SDUs, SDU discard in the uplink, transfer of control plane data, and others.

[0077] Layer 3's RRC sublayer can perform broadcasting of system information to NAS and AS, establishment, maintenance and release of RRC connection, security,

establishment, configuration, maintenance and release of point-point radio bearers, mobility functions, reporting, and other functions.

III. REALIZING RACH-LESS LTM

[0078] In some implementations of the current subject matter, RACH-less HO from one cell to another cell can be realized for a UE communicatively coupled with a base station of a wireless communication system.

[0079] Layer 1/layer 2 triggered mobility (LTM) inter-cell handover at a base station can occur by performing Serving Cell Change (SSC) from a serving cell to a target cell. Multiple target cells may satisfy radio conditions or handover criteria needed for the UE to undergo SSC and thus be viable target cell options for HO. One or more of the viable target cells may require a RACH-based HO involving a contention-based or contention-free RACH procedure, e.g., because the UE's serving cell's timing advance (TA) and the target cell's TA are different. Timing advance refers to a time offset at a UE between a start of a received downlink subframe and a transmitted uplink subframe. This offset at the UE is necessary to ensure that the downlink and uplink subframes are synchronized at the base station. This is a Medium Access Control (MAC) layer (layer 2) control element (CE) from a base station to a UE used in controlling uplink, e.g., UE to base station, signal transmission timing. One or more of the other viable target cells may allow for RACH-less HO, e.g., because the UE's target cell's TA is zero or because the serving cell's TA is the same as the UE's target cell's TA. Realizing RACH-less HO over RACH-based HO is configured to allow for the handover to be to one of the target cells that allows for a RACH-less HO procedure.

[0080] As initial access for a UE to a wireless communication system including a base station or as a handover from one cell to another cell, the base station can receive, e.g., with one or more antennas such as the antenna(s) 136 of FIG. 1d, a signal on a communication channel, e.g., an uplink communication channel established between the base station and one or more UEs. The interface can be, for example, the air interface 122 of FIG. 1 using OFDMA and SC-FDMA, or can be another communication channel. The signal can contain a frame including a plurality of symbols that include one or more symbol groups. In general, an OFDM symbol can include a random access preamble including a cyclic prefix (CP) portion and a data symbol. A symbol group can include a

CP portion and a plurality of data symbols, which may reduce overhead by allowing one CP portion to be used with multiple data symbols instead of using one CP portion with only one data symbol. Random access is based on the UE transmitting the random access preamble on a random access channel (RACH) for access to the base station, either for initial access or for a handover. Only a certain number of random access preambles may be available for a cell. For example, under 3GPP an LTE cell can have sixty-four available preambles. It is therefore possible for multiple UEs to each randomly select the same preamble and for a cell to receive signals from the multiple UEs at a same time with each of the signals including the same preamble, thereby causing a collision, referred to as a “contention.” A contention-based RACH procedure can be performed to resolve the collision, which may delay HO since the collision has to be resolved, e.g., since each UE must have a different preamble to use, before the UEs can both properly communicate with the cell.

[0081] Conversely, in a contention-free RACH procedure, a UE does not select a preamble. Instead, a cell selects a preamble for a UE and transmits the preamble to the UE. The cell can thus ensure that collision does not occur by allocating preambles such that a particular preamble is allocated to only one UE, which may reduce HO latency as compared to a contention-based RACH procedure since it may save uplink synchronization time, which is nothing less than 20ms.

[0082] In some implementations of the current subject matter, timing advance (TA) of a UE being served by a serving cell of a base station of a wireless communication system can be used in preparing configuration of at least one target cell of at least one target DU the base station for LTM. The at least one target DU can be informed of the UE’s serving cell’s TA. Informing the at least one target cell of the serving cell’s TA can allow each of the one or more target DUs to prepare itself for either RACH-less HO or for RACH-based HO from the serving cell for a UE communicatively coupled with the base station. The HO from one cell of the base station to another cell of the base station may therefore take less time since HO from the serving cell to one of the at least one target cells has been already been prepared at each of the one or more target DUs to include either a contention-free RACH procedure (for RACH-less HO) or a contention-based RACH procedure (for RACH-based HO). Handover latency may thus be reduced and thereby reduce user plane interruption time.

[0083] In some implementations of the current subject matter, the at least one target DU can be informed of the UE’s serving cell’s TA by receiving the UE’s serving

cell's TA from a CU-CP of the base station communicatively coupled with the serving cell and the at least one target cell. TA information is layer 1 (L1) information and is thus not information used by a CU.

[0084] In some implementations of the current subject matter, a base station (e.g., the gNodeB of FIG. 5a, a next generation RAN (NG-RAN) node such as an eNodeB or a gNodeB, etc.) of a wireless communication system (e.g., a 5G wireless communication system, a 6G or later generation wireless communication system, etc.) can have a disaggregated architecture in which the base station includes one gNB-CU-CP (e.g., gNB-CU-CP 504 of FIGS. 5a-5c, etc.) and more than one CU-UP (e.g., gNB-CU-UP 506 of FIGS. 5a-5c, etc.) and gNB-DU (e.g., gNB-DUs 508, 510 of FIGS. 5a-5c, etc.). The base station can be configured to realize RACH-less LTM when a UE is handed off from one cell (serving cell) of the base station to another cell (target cell) of the base station.

[0085] FIG. 6a illustrates an exemplary system 600 configured to realize RACH-less LTM in an inter-DU scenario. A base station 624 in this illustrated implementation is a gNB configured to be in a 5G wireless communication system similar to the 5G wireless communication system 500 of FIG. 5a discussed above, but other base stations can be similarly configured and used in realizing RACH-less LTM. In the illustrated implementation of FIG. 6a, the base station 624 includes a plurality of CU-UPs 606a, 606b, 606c. The base station 624 includes three CU-UPs 606a, 606b, 606c in this illustrated implementation but can include another plural number of CU-UPs. The CU of the base station 624 that includes the plurality of CU-UPs 606a, 606b, 606c is configured to be communicatively coupled with a core network (not shown in FIG. 6a), e.g., the 5GC 502 of FIG. 5a, etc.

[0086] The CU of the base station 624 also includes a CU-CP 604 configured to be communicatively coupled to the CU's user plane portion 606a, 606b, 606c using an E1 communication interface 614. The E1 interface 614 includes three communication links in this illustrated implementation to reflect that there are three CU-Ups 606a, 606b, 606c with which the CU-CP 604 can be configured to communicate.

[0087] The base station 624 also includes a plurality of DUs 608, 610. The base station 624 includes two DUs 608, 610 in this illustrated implementation but can include another plural number of DUs. The CU-CP 604 is configured to be communicatively coupled to the DUs 608, 610 using F1-C communication interfaces 616. The CU-UPs 606a, 606b, 606c are configured to be communicatively coupled to the DUs 608, 610 using F1-U communication interfaces 618. The F1-U interface 618 associated with each of

the DUs 608, 610 includes three communication links in this illustrated implementation to reflect that there are three CU-UPs 606a, 606b, 606c with which each DU 608, 610 can be configured to communicate.

[0088] The base station 624 also includes a plurality of RUs 612. The base station 624 includes five RUs 612 in this illustrated implementation but can include another plural number of RUs. The RUs 612 are configured to be communicatively coupled to the DUs 608, 610 via a fronthaul network 620. Additionally, each of the RUs 612 is configured to be communicatively coupled to one or more UEs 622. In this illustrated implementation, two of the RUs 612 are shown communicatively coupled to one UE 622, two of the RUs 612 are shown communicatively coupled to two UEs 622, and one of the RUs 612 is shown communicatively coupled to three UEs 622, but each of the RUs 612 can be coupled to another number of UEs same or different from any of the other RUs 612.

[0089] Realization of RACH-less LTM in an inter-DU scenario can be configured to occur when one of the UEs communicatively coupled with the base station 624 is handed off from one of the DUs 608, 610 of the base station 624 to the other of the DUs 608, 610 also of the same base station 624. The one of the DUs 608, 610 currently providing service to the UE 622 is referred to as a “serving DU” due to it currently providing service to the UE 622, e.g., currently serving the UE 622. The one of the DUs 608, 610 to which the UE’s service is being handed off is referred to as a “target DU” due to it being targeted to provide service to the UE 622.

[0090] A system in which realization of RACH-less LTM in an inter-DU scenario can be configured to occur is further described with respect to FIG. 6b. FIG. 6b illustrates the CU-CP 604 and the CU-UPs 606a, 606b, 606c of FIG. 6a, but in the illustrated implementation of FIG. 6b, the base station 624 includes more than two DUs. In the illustrated implementation of FIG. 6b, the base station 624 includes sixty-six DUs. Three of the DUs 628a, 628b, 628c are macro cells (labeled macro1, macro2, and macro3 in FIG. 6b), and sixty-three of the DUs 626 small cells (nine of which are labeled in FIG. 6b as gNB-DU10, gNB-DU20, gNB-DU30, gNB-DU40, gNB-DU50, gNB-DU60, gNB-DU70, gNB-DU80, and gNB-DU90). The base station 624 can include another number of macro cells and/or another number of small cells. The macro1 DU 628a, the macro2 DU 628b, and twenty-one of the small cell DUs 626 including gNB-DU10, gNB-DU20, and gNB-DU30 are configured to be served by the first CU-UP 606a (labeled CU-UP1 in FIG. 6b). The macro1 DU 628a, macro2 DU 628b, macro3 DU 628c, and twenty-one of the small cell DUs 626 including gNB-DU40, gNB-DU50, and gNB-DU60 are configured to be

served by the second CU-UP 606b (labeled CU-UP2 in FIG. 6b). The macro2 DU 628b, macro3 DU 628c, and twenty-one of the small cell DUs 626 including gNB-DU70, gNB-DU80, and gNB-DU90 are configured to be served by the third CU-UP 606c (labeled CU-UP3 in FIG. 6b).

[0091] In the implementation shown in FIG. 6b, each CU-UP 606a, 606b, 606c is serving a subset of DUs 626, 628a, 628, 628c for all the services. However, a CU-UP can serve all the DUs of the base station for one service (e.g., enhanced mobile broadband (eMBB)), while serving a subset of the DUs for another service (e.g., vehicle-to-everything (V2X) or ultra-reliable low latency communication (URLLC)).

[0092] FIG. 7 illustrates an exemplary method 700, according to some implementations of the current subject matter. The method 700 is described with respect to an exemplary system 800 illustrated in FIG. 8a but can be implemented similarly with other systems, e.g., the system 100 of FIGS. 1a-1c and 2, the system 400 of FIG. 4, the system 500 of FIG. 5a, the systems of FIG. 6a and 6b, etc. The system 800 of FIG. 8a is a 5G system, but as mentioned above, realization of RACH-less LTM in an inter-DU scenario as described herein can be performed with other types of wireless communications systems, such as LTE wireless communications systems or 6G or later generation wireless communications systems.

[0093] In the system 800, a UE 802 (e.g., UE 104 of FIGS. 1a-1c, UE 622 of FIG. 6a, etc.) is configured 810 with LTM with one or more target cells in one or more DUs 804, 806 (e.g., DU 508 of FIGS. 5a-5c, DU 510 of FIG. 5a, DU 608 of FIG. 6a, DU 610 of FIG. 6a, DUs 626 of FIG. 6b, DUs 628a, 628b, 628c of FIG. 6b, etc.) of a base station, e.g., a gNB (e.g., gNodeB of FIG. 5a, gNodeB 624 of FIGS. 6a and 6b, etc.). For ease of explanation the system 800 is shown in FIG. 8a with one UE 802 communicatively coupled to the base station and with the base station including two DUs 804, 806, but more than one UE can be communicatively coupled to the base station and/or the base station can include more than two DUs. The base station of the system 800 also includes a CU including a CU-CP 808 (e.g., gNB-CU-CP 504 of FIGS. 5a-5c, CU-CP 604 of FIGS. 6a and 6b, etc.) and one or more CU-UPs (e.g., gNB-CU-UP 506 of FIGS. 5a-5c, CU-UPs 606a, 606b, 606c of FIGS. 6a and 6b, etc.) (not shown in FIG. 8a), and a plurality of RUs (e.g., RUs 512 of FIG. 5a, RUs 612 of FIG. 6a, etc.) (not shown in FIG. 8a). The UE 802 is currently being served by the serving DU 804. Additionally, the base station of FIG. 8a is communicatively coupled with a core network (e.g., EPC 108 of FIGS. 1a-1c and 2, 5GC 502 of FIG. 5a, etc.) (not shown in FIG. 8a).

[0094] The method 700 shows an implementation of an inter-DU LTM serving cell change scenario which includes the serving DU 804 determining 702 that a cell change for the UE 802 is needed. The serving DU's determination 702 can include the serving DU 804 analyzing 814 an intra-frequency L1 measurement report transmitted 812 by the UE 802, in accordance with 3GPP standards, to the serving DU 804. In accordance with 3GPP standards, the intra-frequency L1 measurement report can include layer 1 (L1) measurements that can be analyzed by the serving DU 804 in making resource control decisions, which can include a serving cell change in which the UE 802 is to be served by a DU, e.g., the target DU 806, other than the serving DU 804 for at least one service.

[0095] In response to determining 702 that a serving cell change should occur, the serving DU 804 notifies 704 the UE 802 of a serving cell change. As shown in FIG. 8a, the notification 704 to the UE 802 can include the serving DU 804 transmitting 816 a serving cell change command, e.g., a MAC CE, to the UE 802.

[0096] Also in response to determining 702 that a cell service change should occur, the serving DU 804 notifies 704 the CU-CP 808 that that a serving cell change for the UE 802 has occurred. The notification 704 can thus identify the UE 802 to the CU-CP 808, such as with an identifier, in accordance with 3GPP standards, known to the serving DU 804 that uniquely identifies the UE 802 to the CU-CP 808. As shown in FIG. 8a, the notification 704 to the CU-CP 808 can include the serving DU 804 transmitting 818 a Serving Cell Change Notification message to the CU-CP 808 using an F1 communication interface. As also shown in FIG. 8a, the Serving Cell Change Notification message includes a cell identification (ID) that uniquely identifies the UE 802 that underwent the serving cell change.

[0097] In response to receiving the serving cell change command 704 from the serving DU 804, the UE 802 transmits 820 a Radio Resource Control (RRC) Reconfigure Acknowledgement message to the CU-CP 808. The CU-CP 808 becomes aware from RRC Reconfigure Acknowledgement message that the UE 802, uniquely identified to the CU-CP 808 by the serving DU 804, acknowledges completion of a successful serving cell change.

[0098] Also in response to receiving a layer 3 RRC measurement configuration, the UE 802 transmits 822 an RRC measurement report to the CU-CP 808, in accordance with 3GPP standards. In accordance with 3GPP standards, the RRC measurement report can include layer 3 (L3) measurements that can be analyzed by the CU-CP 808 in making resource control decisions, which can include deciding 824 to prepare at least one target

DU cell for LTM so the at least one target cell from the target DU 806 is ready to serve the UE 802 instead of the serving DU 804 for at least one service.

[0099] In response to deciding 824 to prepare at least one target cell for LTM, the CU-CP 808 prepares 706 at least one target cell for LTM. As shown in FIG. 8a, in this illustrated implementation, each of the at least one target cells is an inter-DU target cell, e.g., is part of a different DU than the serving DU 804 where the same CU (e.g., the CU that includes the CU-CP 808) serves each DU 804, 806. Also in this illustrated implementation, the at least one target cell includes only the target DU 806 since there are only two gNB-DUs, but as mentioned above, the base station can include more than two target cells. Currently, in accordance with 3GPP standards, a maximum of eight LTM target cells can be prepared for a given UE.

[00100] Preparing 706 the at least one target cell for LTM can include notifying the at least one target DU 806 that the at least one target DU 806 may be later notified to begin providing service to the UE 802 for at least one service. The target DU 806 can thus reserve necessary resources for the UE 802. As shown in FIG. 8a, the preparation 706 of the at least one target cell, which in this illustrated implementation is only the target DU 806, can include the CU-CP 808 transmitting 832 a UE Context Setup Request message to the target DU 806, in accordance with 3GPP standards, using an F1 communication interface.

[00101] The preparation 706 of the at least one target cell can include providing to the at least one target DU 806 information indicative of whether HO can be a RACH-less HO or can be a RACH-based HO (contention free RACH (CFRA) or contention based RACH (CBRA)). In exemplary implementations, the information includes the UE's timing advance (TA) information for the serving DU 804. The UE's TA information for the serving cell 804 being either (a) a TA that is the same as a TA of the target cell that receives the TA information or (b) a TA of zero is indicative that HO to that target cell can be RACH-less HO, thereby allowing the target cell to prepare for RACH-less HO. The UE's TA information for the serving cell 804 being neither of (a) a TA that is the same as a TA of the target cell that receives the TA information and (b) a TA of zero is indicative that HO to the target cell can be RACH-based HO, thereby allowing the target cell to prepare for RACH-based HO. In instances in which the at least one target cell includes more than one target cell, RACH-less HO may be possible for zero or more of the target cells with RACH-based HO being possible for a remainder of the target cells. The

information that is indicative of whether HO can be a RACH-less HO or can be a RACH-based HO can be provided to the at least one target DU 806 in a variety of ways.

[00102] In some implementations, the CU-CP 808 transmits the information, e.g., the UE's serving cell 804 TA information, in the preparation 706 of the at least one target cell 806, e.g., as a parameter in the UE Context Setup Request message transmitted 832 to the target DU 806. The CU-CP 808 can receive TA information before the target cell preparation 706.

[00103] In some implementations, in which the CU-CP 808 receives serving cell TA information before the target cell preparation 706, the CU-CP 808 can fetch 826 the serving cell TA information from the serving cell 804 before transmitting 832 the UE Context Setup Request message to the target DU 806. The fetching 826 of the serving cell 804 TA information can thus occur after an F1 setup procedure in which an F1 communications interface is set up between the CU-CP 808 and the serving cell 804. FIG. 8a illustrates such an implementation.

[00104] As shown in FIG. 8a, the CU-CP 808 fetching 826 the serving cell 804 TA information can include the CU-CP transmitting 828 a message to the serving cell 804 requesting that the serving cell 804 provide TA information of the serving cell 804 to the CU-CP 808 and the serving cell 804 transmitting 830 in reply thereto the TA information to the CU-CP 808. The CU-CP 808 deciding 824 to prepare at least one target cell can trigger the CU-CP's transmission 828 of the message requesting TA information since the CU-CP 808 is now aware of a HO situation. Retrieving serving cell 804 TA information after a need for UE HO is known may allow the CU-CP 808 to have the most up to date TA information for the serving cell. On demand, UE-HO-associated receipt of TA information when a need for UE HO is known may ease storage requirements of the CU-CP 808 since the TA information is only received when needed and does not necessarily have to be stored for later use. As shown in FIG. 8a, the message transmitted 828 by the CU-CP 808 requesting serving cell TA information can be a UE Context Modification Request message, and the message transmitted 830 by the serving cell 804 in reply can be a UE Context Setup Response message. UE Context Modification Request messages and UE Context Setup Response messages are defined by 3GPP, so the process can take advantage of existing CU and DU functionality.

[00105] In response to receiving the UE Context Setup Request message from the CU-CP 808, the target DU 806 prepares 834 each of the at least one target cells for LTM. In this illustrated implementation the at least one target cell includes only the target DU

806 preparing 834 one target cell. As shown in FIG. 8a, the preparation 834 can include the target cell reserving necessary resources for the UE 802 and verifying RACH-less feasibility of the HO. The target DU's receipt of the serving cell TA information from the CU-CP 808 allows for such verification, as the target DU was already aware of its own cells' TA and is now aware of the serving cell's TA.

[00106] The target DU 806 notifies the CU-CP 808 that the preparation 834 has been completed. As shown in FIG. 8a, the notification to the CU-CP 808 can include the target DU 806 transmitting 836 a UE Context Setup Response message to the CU-CP 808, in accordance with 3GPP standards, using an F1 communication interface. As also shown in FIG. 8a, the UE Context Setup Response message includes consolidated cell group configuration information for the target cells prepared at the target DU 806. The consolidated cell group configuration information includes including information regarding a configuration type, e.g., RACH-based or RACH-less configuration.

[00107] The CU-CP 808 notifies 708 the serving DU 804 of the LTM-prepared at least one target cell and its configuration type by identifying each of the one or more LTM-prepared target cells and including information about each of the one or more target DUs. In an inter-DU LTM scenario, one or more of the at least one LTM-prepared target cells belong to a different DU than the serving DU 806. For example, with reference to the system of FIG. 6b, the serving DU can be a small cell 626 of macro1 DU 628a, and one or more of the target cells can be one or more small cells 626 of macro2 DU 628b and/or macro3 DU 628c.

[00108] As shown in FIG. 8a, the notification 708 to the serving DU 804 can include the CU-CP 808 transmitting 838 a UE Context Modification Request message to the serving DU 804 using an F1 communication interface. The UE Context Modification Request message can include for each of the one or more target DUs cell identification information (e.g., a unique cell ID that identifies the target DU such as a physical cell identifier (PCI)) or an index corresponding to cell ID, and priority information. The notification 708 to the serving DU 804 can include information indicative of a RACH-less HO configuration for the target DU 806. As mentioned above, the CU-CP 808 is aware of the target DU's candidacy for RACH-less handover.

[00109] The priority information provided to the serving DU 804 by the CU-CP 808 indicates a ranked order of the one or more target cells, configured for RACH-less handover, for selection by the serving DU 804 as the target DU for handover. The priority information for a particular target cell can thus include a ranking number (e.g., one, two,

three, etc.) indicating the target cell's rank in the ranking of all the target cells eligible for RACH-less handover, identified to the serving DU 804 by the CU-CP 808. The CU-CP 808 can determine the ranked order in any of a variety of ways. In some implementations, the CU-CP 808 can determine the ranked order based on resource availability, load, slice compatibility, and/or any other RRM criteria. The priority information may help the serving DU 804 select one of the one or more target cells for RACH-less HO, as discussed further below.

[00110] If there is only one target cell eligible for RACH-less handover that is a candidate for the serving cell change, as in this illustrated implementation in which the target DU 806 is the only choice, the priority information can be omitted from the message to the serving DU 804 from the CU-CP 808 since there is only one possible choice for HO identified to the serving DU 804.

[00111] In response to being notified 708 of the at least one LTM prepared target DU cell, the serving cell 804 stores the received information regarding the at least one LTM target cell, e.g., stores a list of the LTM-prepared target cell(s) and, if provided to the serving DU 804, their respective priority information. Also in response to being notified 708 of the at least one target DU, the serving cell 804 transmits 840 a UE Context Modification Response message to the CU-CP 808 using an F1 communication interface. The UE Context Modification Response message may include consolidated cell group configuration information for each the one or more target cells identified to the UE 802 by the CU-CP 808. The UE Context Modification Request message and the UE Context Modification Response message are each defined by 3GPP. The serving DU 804 can thus receive information regarding the at least one target cell from the CU-CP 808, and can acknowledge the receipt to the CU-CP 808, using messages already transmitted for HO in accordance with 3GPP standards.

[00112] In response to receiving the UE Context Modification Response message, the CU-CP 808 transmits 842 an RRC reconfiguration message to the UE 802, in accordance with 3GPP standards. As shown in FIG. 8a, the RRC reconfiguration message includes LTM target cell configuration information, e.g., as provided to the CU-CP 808 from the target DU 806 in the transmitted 830 UE Context Setup Response message. The UE may thus be informed whether or not RACH-less HO (LTM SCC) is possible. If RACH-less HO is not possible the UE can perform CBRA to the target cell 806, as a preamble is not reserved for CFRA.

[00113] In response to receiving the target cell configurations in the RRC reconfiguration message, the UE 802 transmits 844 an L1 measurement report to the serving DU 804, in accordance with 3GPP standards. The L1 measurement report provides the UE measured radio condition information of the configured target cells to the serving DU 804.

[00114] In response to receiving the L1 measurement report transmitted 844 from the UE 802, the serving cell 804 selects 710, 846 a target cell, from among the one or more LTM-prepared target cells identified to the serving DU 804, where RACH-less HO is possible. In this illustrated implementation there is only one target cell (the target DU 806) identified to the serving DU 804 by the CU-CP 808 as an LTM-prepared target cell, so the serving cell's selection 710, 846 is straightforward, with the serving DU 804 selecting 710, 846 the target DU 806. If there are multiple LTM-prepared target cells which satisfy the handover criteria at the serving DU 804, the serving DU 804 is configured to select a target cell configured for RACH-less handover, when available, as discussed herein. If there are no LTM-prepared target cells that are candidates for RACH-less HO, a target cell can be selected according to traditional procedure in accordance with 3GPP.

[00115] In implementations in which there are a plurality of target cells identified to the serving DU 804 by the CU-CP 808, the serving cell's target cell selection 710, 846 can include determining which one or more of the plurality of target cells has a radio quality above a predetermined threshold radio quality. The predetermined threshold radio quality is defined by the UE's radio condition that the serving DU 804 received from the UE 802 in the L1 measurement report. The serving DU 804 can thus take into consideration particular needs of the particular UE 802 involved in the HO when selecting 710, 846 a target cell for the HO. Additionally, the L1 measurement report transmitted 844 by the UE 802 to the serving DU 804 reports L1 measurements, which can include reference signal received power (RSRP) as defined by 3GPP, for each of the plurality of target cells, whose identities are known by the UE 802 as having been provided to the UE 802 by the CU-CP 808 in the RRC reconfiguration message. The serving DU 804 can therefore analyze the L1 measurement report received from the UE 802 to determine which one or more of the plurality of target cells has a radio quality above a predetermined threshold radio quality.

[00116] If only one of the plurality of target cells satisfies the UE's radio condition, e.g., only one of the target cells' radio qualities is above the predetermined threshold radio quality, then the serving cell 804 selects 710, 846 that target cell. If more than one of the

plurality of target cells satisfies the UE's radio condition, e.g., the target cells' radio qualities are each above the predetermined threshold radio quality, then any one of these target cells would be able to serve the UE's needs and one of these target cells can be selected according to the priority information (if received), at random, or according to another desired criteria.

[00117] Having selected 710, 846 the target cell (e.g., the target DU 806 in the illustrated implementation of FIG. 8a), the serving DU 804 triggers 712 serving cell change to the selected 710, 846 target cell. As shown in FIG. 8a, triggering 712 the serving cell change can include the serving DU 804 transmitting 848 a MAC CE to the UE 802 that includes a serving cell change command and identifies, e.g., by PCI, the selected 710, 846 target cell to the UE 802.

[00118] The UE's receipt of the MAC CE indicates to the UE 802 that LTM serving cell change (SCC) has to be performed to the identified target cell, e.g., the target DU 806 in the illustrated implementation of FIG. 8a, for the UE 802. Thus, in response to receiving the MAC CE from the serving cell 804, the UE 802 begins 714, 850 RACH-less HO to the target cell. As shown in FIG. 8a, the UE 802 beginning 714, 850 RACH-less HO to the target cell can include the UE 802 accessing 852 the target cell without a RACH procedure, in accordance with 3GPP standards, to the target DU 806 for RACH-less HO. In response to the UE 802 accessing the target cell, the target DU 806 transmits 854 a serving cell change notification to the CU-CP 808, via an F1 communications interface, that identifies the target DU 806, e.g., by unique identifier per 3GPP, as the new, current serving cell for the UE 802 for at least one service. Also in response to receiving the MAC CE from the serving cell 804, the UE 802 transmits 856 an RRC reconfiguration acknowledgment message to the CU-CP 808. The CU-CP 808 therefore receives acknowledgment from both the UE 802, via the RRC reconfiguration acknowledgment message indicating a successful RRC reconfiguration at the UE 802, and the target DU 806, via the serving cell change notification, that the target DU 806 is now serving the UE 802 for at least one service that has been handed over from the serving DU 804.

[00119] In some implementations, the serving DU 804, which has already notified by the CU-CP 808 regarding the configuration of the plurality of target cells being RACH-less or RACH-based configurations, can be configured to configure the UE 802 to perform uplink (UL) synchronization (sync) to the selected 710, 846 target cell, while still serving as serving cell and in advance to the serving cell change. The serving DU 804 can configure the UE 802 to perform the uplink sync by, for example, transmitting a command

to the UE 802 prior to the transmission 848 of the MAC CE to the UE 802 and thus before the serving cell change has occurred. The UE 802 performing UL sync prior to the serving cell change may help the UE 802 acquire the Timing Advance of the selected 710, 846 target cell and adjust, if there are any changes in the UE's serving cell TA due to further mobility of the UE 802 between the time of target cell preparation and execution of serving cell change. The UE 802 can be configured to report to the serving DU 804 the target cell TA acquired by the UE 802 during the UL sync procedure with the target DU 806. The serving DU 804 can be configured to compare the TA of the UE 802 in serving cell (determined at the serving DU 804) and the selected 710, 846 target cell (acquired during UL sync) and therefore determine if the previously configured RACH-less HO can be executed to the given target cell. In case of a change in the serving cell TA leading to infeasibility of the RACH-less HO, the serving DU 804 can be configured to indicate to the UE 802 in the transmitted 848 serving cell change command that a RACH-based HO should be performed with the target cell.

[00120] In some implementations, based on the target cell preparation request from CU-CP 808, e.g., the UE Context Setup Request transmitted 832 from the CU-CP 808, the target DU 806 can, along with preparing a RACH-less target cell configuration, be configured to reserve a RACH preamble for a RACH-based serving cell change. In a scenario of the UE 802 undergoing continuous mobility in the serving DU/cell leading to infeasibility of the RACH-less HO due to change in the UE's TA at the serving DU 804, the UE 802 can use the reserved RACH preamble for a contention less RACH access (CFRA) as a fallback solution.

[00121] As discussed above, the CU-CP 808 can receive serving cell TA information before the target cell preparation 706. In some implementations, the CU-CP 808 can receive serving cell TA information from a cell during an F1 setup procedure in which an F1 communications interface is being set up between the CU-CP 808 and the cell. This procedure may be more granular and corresponding to each beam or beam-group. A cell is divided into different beams/beam-groups or areas which may be assigned a certain TA. Later, when a UE is found to report a particular beam-group or region in its L3 measurements, a fixed TA can be mapped to the UE. Hence a single cell may have multiple TAs, each corresponding to one or more beams/beam-groups of the cell. This procedure is also feasible for smaller cells where the TA does not vary much. The CU-CP 808 can thus receive the TA information before any UE HO need is known and therefore has the TA information available and ready to transmit to a target cell. FIGS. 8b and 8c

illustrate such an implementation. FIG. 8b is similar to FIG. 8a except that instead of fetching 826 the serving cell TA information from the serving cell 804 during the HO process after the CU-CP 808 has been notified 818 of serving cell change, the CU-CP 808 checks 858 previously received serving cell TA information to identify RACH-less target cell candidates.

[00122] FIG. 8c illustrates the system of FIG. 8b configured to provide TA information to the CU-CP 808 from a cell during an F1 setup procedure, according to some implementations of the current subject matter. This can be updated using an F1:gNB-DU configuration update procedure. The F1 communications interface is setup between a DU and the CU-CP 808 in accordance with 3GPP standards.

[00123] As shown in FIG. 8c, in an F1 setup procedure in which an F1 communications interface is being set up between the CU-CP 808 and the serving DU 804, the serving DU 804 transmits 860 an F1: setup request to the CU-CP 808 including TA information of all the beams/beam-groups for each cell of the serving DU 804. The serving DU 804 is shown in FIG. 8c as having a plurality of cells, but the serving DU 804 can include a single cell. In response to receipt of the F1: setup request from the serving DU 804, the CU-CP 808 transmits 862 an F1: setup response to the serving DU 804.

[00124] As also shown in FIG. 8c, in an F1 setup procedure in which an F1 communications interface is being set up between the CU-CP 808 and the target DU 806, the target DU 806 transmits 864 an F1: setup request to the CU-CP 808 including TA information for all the beams/beam-groups of each cell of the target DU 806. The target DU 806 is shown in FIG. 8b as having a plurality of cells, but the target DU 806 can include a single cell. In response to receipt of the F1: setup request from the target DU 806, the CU-CP 808 transmits 866 an F1: setup response to the target DU 806.

[00125] FIG. 8c shows the F1 communications interface being set up between the serving DU 804 and the CU-CP 808 before the F1 communications interface is set up between the target DU 806 and the CU-CP 808, but the F1 communications interface can be set up between the target DU 806 and the CU-CP 808 before the F1 communications interface is set up between the serving DU 804 and the CU-CP 808.

[00126] In some implementations in which the CU-CP 808 receives TA information before the target cell preparation 706, the serving DU 804 can proactively provide the TA information to the CU-CP 808 without receiving a request for the TA information from the CU-CP 808. The CU-CP 808 can thus have serving cell TA information stored and on hand for later provision to the target DU 806. FIG. 8d illustrates

such an implementation. FIG. 8d is similar to FIG. 8a except that instead of fetching 826 the serving cell TA information from the serving cell 804 during the HO process after the CU-CP 808 has been notified 818 of serving cell change, the CU-CP 808 checks 876 previously received serving cell TA information to identify RACH-less target cell candidates.

[00127] As shown in FIG. 8d, in response to receiving an L1 measurement report transmitted 870 to the serving DU 804 from the UE 802 after the serving SU 804 has determined 702 that a cell change for the UE 802 is needed, the serving DU 804 identifies 872 one or more potential candidate target cells for RACH-less HO from neighboring DUs, which in the illustrated implementation of FIG. 8d only includes one DU 806. The serving DU 804 then transmits 874 a message to the CU-CP 808 via an F1 communications interface identifying the one or more potential candidate target cells. The serving DU 804 can be configured to only transmit 874 such a message to the CU-CP 808 if one or more potential candidate target cells are identified.

[00128] In some implementations, such as various implementations discussed above with respect to FIGS. 8a-8d, each of one or more candidate target cells receives a UE's serving cell TA information from a CU-CP. In other implementations, DUs of a base station can share their TA information with each other directly. Such DU-to-DU communication is not possible in a 5G wireless communications system but may be possible in a 6G or later wireless communications system. FIG. 8e illustrates such an implementation. FIG. 8e is similar to FIG. 8a except the serving DU 804 performs various functions that the CU-CP 808 is described as performing in the implementation of FIG. 8a. Functionality to realize this solution includes termination of RRC protocol at both the DU and the CU-CP, delivering intra-gNB L3 measurements to the DU, delivering inter-gNB and inter-radio access technology (RAT) measurements to the CU-CP, and the DU autonomously deciding to execute intra-gNB handovers.

[00129] As shown in FIG. 8e, in response to receiving the serving cell change command 704 from the serving DU 804, the UE 802 transmits 878 an RRC Reconfigure Acknowledgement message to the serving DU 804. The serving DU 804 becomes aware from RRC Reconfigure Acknowledgement message that the UE 802 acknowledges completion of a successful serving cell change.

[00130] Also in response to receiving a layer 3 RRC measurement configuration, the UE 802 transmits 880 an RRC measurement report to the serving DU 804. The RRC measurement report can include L3 measurements that can be analyzed by the serving DU

804 in making resource control decisions, which can include deciding 882 to prepare at least one target DU cell for LTM so the at least one target cell from the target DU 806 is ready to serve the UE 802 instead of the serving DU 804 for at least one service.

[00131] In response to deciding 882 to prepare at least one target cell for LTM, the serving DU 804 prepares at least one target cell for LTM. Preparing the at least one target cell for LTM can include notifying the at least one target DU 806 that the at least one target DU 806 may be later notified to begin providing service to the UE 802 for at least one service. The target DU 806 can thus reserve necessary resources for the UE 802. As shown in FIG. 8e, the preparation of the at least one target cell, which in this illustrated implementation is only the target DU 806, can include the serving DU 804 transmitting 884 a UE Context Setup Request message to the target DU 806.

[00132] The preparation of the at least one target cell can include providing to the at least one target DU 806 information indicative of whether HO can be a RACH-less HO or can be a RACH-based HO (CFRA or CBRA), similar to that discussed above. As shown in FIG. 8e, the information includes serving cell TA information transmitted 884 from the serving DU 804 to the target DU 806 in the UE Context Setup Request message.

[00133] In response to receiving the UE Context Setup Request message from the serving DU 804, the target DU 806 prepares 886 each of the at least one target cells for LTM, similar to the preparation 834 discussed above with respect to FIG. 8a. The target DU 806 notifies the serving DU 804 that the preparation 886 has been completed. As shown in FIG. 8e, the notification to the serving DU 804 can include the target DU 806 transmitting 888 a UE Context Setup Response message to the serving DU 804. As also shown in FIG. 8e, the UE Context Setup Response message includes consolidated cell group configuration information for the target cells prepared at the target DU 806. In response to being notified of the at least one LTM prepared target DU cell, the serving cell 804 stores the received information regarding the at least one LTM target cell, e.g., stores a list of the LTM-prepared target cell(s) and, if provided to the serving DU 804, their respective priority information.

[00134] In response to receiving the UE Context Modification Response message, the serving cell 804 transmits 890 an RRC reconfiguration message to the UE 802. As shown in FIG. 8e, the RRC reconfiguration message includes LTM target cell configuration information, e.g., as provided to the serving cell 804 from the target DU 806 in the transmitted 888 UE Context Setup Response message. The UE may thus be informed whether or not RACH-less HO (LTM SCC) is possible. If RACH-less HO is not

possible the UE can perform CBRA to the target cell 806, as a preamble is not reserved for CFRA. In response to receiving the target cell configurations in the RRC reconfiguration message, the UE 802 transmits 844 an L1 measurement report to the serving DU 804, and the process continues similar to that discussed above with respect to FIG. 8a.

[00135] In some implementations, the current subject matter can be configured to be implemented in a system 900, as shown in FIG. 9. The system 900 can include one or more of a processor 910, a memory 920, a storage device 930, and an input/output device 940. Each of the components 910, 920, 930 and 940 can be interconnected using a system bus 950. The processor 910 can be configured to process instructions for execution within the system 600. In some implementations, the processor 910 can be a single-threaded processor. In alternate implementations, the processor 910 can be a multi-threaded processor. The processor 910 can be further configured to process instructions stored in the memory 920 or on the storage device 930, including receiving or sending information through the input/output device 940. The memory 920 can store information within the system 900. In some implementations, the memory 920 can be a computer-readable medium. In alternate implementations, the memory 920 can be a volatile memory unit. In yet some implementations, the memory 920 can be a non-volatile memory unit. The storage device 930 can be capable of providing mass storage for the system 900. In some implementations, the storage device 930 can be a computer-readable medium. In alternate implementations, the storage device 930 can be a floppy disk device, a hard disk device, an optical disk device, a tape device, non-volatile solid state memory, or any other type of storage device. The input/output device 940 can be configured to provide input/output operations for the system 900. In some implementations, the input/output device 940 can include a keyboard and/or pointing device. In alternate implementations, the input/output device 940 can include a display unit for displaying graphical user interfaces.

[00136] FIG. 10 illustrates an exemplary method 1000 for realizing RACH-less LTM, according to some implementations of the current subject matter. The method 1000 may be performed, for example, using implementations shown in and described with respect to FIGS. 1-8b.

[00137] The method 1000 includes receiving 1002, at at least one LTM target cell (e.g., DUs 508, 510 of FIG. 5a, DUs 608, 610 of FIG. 6a, cells 626, 628a, 628b, 628c of FIG. 6b, target DU 806 of FIGS. 8a-8e, etc.) of a base station, information indicative of whether HO of service for a UE currently being served by a serving DU (e.g., serving DU 804 of FIGS. 8a-8e, etc.) of the base station (e.g., eNodeB 106 of FIGS. 1b-2, gNodeB of

FIG. 5a, gNodeB 624 of FIGS. 6a and 6b, base station of FIGS. 8a-8e, etc.) can be a RACH-less HO to the at least one target cell or can be a RACH-based HO to the at least one target cell. The method can also include preparing 1004 the at least one LTM target cell, based on the information received at the at least one LTM target cell, for one of RACH-less HO and RACH-based HO.

[00138] In some implementations, the current subject matter can include one or more of the following optional features.

[00139] In some implementations, the information can includes timing advance (TA) information of the UE in the serving DU, TA information of the UE in the serving cell being either (a) a TA that is the same as a TA in the at least one LTM target cell or (b) a TA of zero can be indicative that HO to the at least one LTM target cell can be RACH-less HO, and TA information of the UE in the serving cell being neither of (a) a TA that is the same as a TA in the at least one LTM target cell and (b) a TA of zero can be indicative that HO to the at least one LTM target cell can be RACH-based HO. Further, the at least one LTM target cell can receive the TA information of the UE in the serving DU (e.g., the serving DU 804 of FIG. 8e, etc.) in a message from the serving DU and the method can include the at least one LTM target cell indicating to the serving DU if the prepared LTM target cell configuration is RACH-less or RACH-based configuration, or the at least one LTM target cell can receive the TA information of the UE in the serving DU in a message from a CU-CP (e.g., gNB-CU-CP 504 of FIGS. 5a-5c, CU-CP 604 of FIGS. 6a and 6b, CU-CP 808 of FIGS. 8a-8d, etc.) of the base station and the method can include the at least one LTM target cell indicating to the CU-CP if the prepared LTM target cell configuration is RACH-less or RACH-based configuration. Further, the CU-CP can receive the TA information of the UE in the serving DU from the serving DU during setup of an F1 communication interface between the serving DU and the CU-CP, or the CU-CP can receive the TA information of the UE in the serving DU from the serving DU after an F1 communication interface has been set up between the serving DU and the CU-CP.

[00140] In some implementations, the at least one LTM target cell can be included in at least one DU of the base station that is not the serving DU.

[00141] In some implementations, the serving DU can select one of the at least one prepared LTM target cells for handover of service for the UE from the serving DU, and the serving DU can trigger the handover of the service for the UE from the serving DU to the selected LTM target cell. Further, the serving DU can determine which one or more of the at least one LTM target cells has a radio quality above a predetermined threshold radio

quality, and the selection can be among the one or more determined LTM target cells; and/or the triggering can include the serving DU transmitting to the UE a Medium Access Control (MAC) control element (CE) message.

[00142] In some implementations, the base station can have a disaggregated architecture.

[00143] In some implementations, the base station can include a Next Generation Radio Access network (NG-RAN) node. Further, the NG-RAN node can include a gNodeB (e.g., gNodeB of FIG. 5a, gNodeB 624 of FIG. 6a or FIG. 6b, gNodeB of FIGS. 8a and 8b, etc.) or an ng-eNodeB.

[00144] In some implementations, the base station can include at least one processor (e.g., processor 910 of FIG. 9, etc.) and at least one non-transitory storage media (e.g., memory 920, storage device 930, of FIG. 9, etc.) storing instructions that, when executed by the at least one processor, cause the at least one processor to perform the method 1000.

[00145] The systems and methods disclosed herein can be embodied in various forms including, for example, a data processor, such as a computer that also includes a database, digital electronic circuitry, firmware, software, or in combinations of them. Moreover, the above-noted features and other aspects and principles of the present disclosed implementations can be implemented in various environments. Such environments and related applications can be specially constructed for performing the various processes and operations according to the disclosed implementations or they can include a general-purpose computer or computing platform selectively activated or reconfigured by code to provide the necessary functionality. The processes disclosed herein are not inherently related to any particular computer, network, architecture, environment, or other apparatus, and can be implemented by a suitable combination of hardware, software, and/or firmware. For example, various general-purpose machines can be used with programs written in accordance with teachings of the disclosed implementations, or it can be more convenient to construct a specialized apparatus or system to perform the required methods and techniques.

[00146] The systems and methods disclosed herein can be implemented as a computer program product, i.e., a computer program tangibly embodied in an information carrier, e.g., in a machine readable storage device or in a propagated signal, for execution by, or to control the operation of, data processing apparatus, e.g., a programmable processor, a computer, or multiple computers. A computer program can be written in any

form of programming language, including compiled or interpreted languages, and it can be deployed in any form, including as a stand-alone program or as a module, component, subroutine, or other unit suitable for use in a computing environment. A computer program can be deployed to be executed on one computer or on multiple computers at one site or distributed across multiple sites and interconnected by a communication network.

[00147] As used herein, the term “user” can refer to any entity including a person or a computer.

[00148] Although ordinal numbers such as first, second, and the like can, in some situations, relate to an order, as used in this document ordinal numbers do not necessarily imply an order. For example, ordinal numbers can be merely used to distinguish one item from another. For example, to distinguish a first event from a second event, but need not imply any chronological ordering or a fixed reference system (such that a first event in one paragraph of the description can be different from a first event in another paragraph of the description).

[00149] The foregoing description is intended to illustrate but not to limit the scope of the invention, which is defined by the scope of the appended claims. Other implementations are within the scope of the following claims.

[00150] These computer programs, which can also be referred to as programs, software, software applications, applications, components, or code, include machine instructions for a programmable processor, and can be implemented in a high-level procedural and/or object-oriented programming language, and/or in assembly/machine language. As used herein, the term “machine-readable medium” refers to any computer program product, apparatus and/or device, such as for example magnetic discs, optical disks, memory, and Programmable Logic Devices (PLDs), used to provide machine instructions and/or data to a programmable processor, including a machine-readable medium that receives machine instructions as a machine-readable signal. The term “machine-readable signal” refers to any signal used to provide machine instructions and/or data to a programmable processor. The machine-readable medium can store such machine instructions non-transitorily, such as for example as would a non-transient solid state memory or a magnetic hard drive or any equivalent storage medium. The machine-readable medium can alternatively or additionally store such machine instructions in a transient manner, such as for example as would a processor cache or other random access memory associated with one or more physical processor cores.

[00151] To provide for interaction with a user, the subject matter described herein can be implemented on a computer having a display device, such as for example a cathode ray tube (CRT) or a liquid crystal display (LCD) monitor for displaying information to the user and a keyboard and a pointing device, such as for example a mouse or a trackball, by which the user can provide input to the computer. Other kinds of devices can be used to provide for interaction with a user as well. For example, feedback provided to the user can be any form of sensory feedback, such as for example visual feedback, auditory feedback, or tactile feedback; and input from the user can be received in any form, including, but not limited to, acoustic, speech, or tactile input.

[00152] The subject matter described herein can be implemented in a computing system that includes a back-end component, such as for example one or more data servers, or that includes a middleware component, such as for example one or more application servers, or that includes a front-end component, such as for example one or more client computers having a graphical user interface or a Web browser through which a user can interact with an implementation of the subject matter described herein, or any combination of such back-end, middleware, or front-end components. The components of the system can be interconnected by any form or medium of digital data communication, such as for example a communication network. Examples of communication networks include, but are not limited to, a local area network (“LAN”), a wide area network (“WAN”), and the Internet.

[00153] The computing system can include clients and servers. A client and server are generally, but not exclusively, remote from each other and typically interact through a communication network. The relationship of client and server arises by virtue of computer programs running on the respective computers and having a client-server relationship to each other.

[00154] The implementations set forth in the foregoing description do not represent all implementations consistent with the subject matter described herein. Instead, they are merely some examples consistent with aspects related to the described subject matter. Although a few variations have been described in detail above, other modifications or additions are possible. In particular, further features and/or variations can be provided in addition to those set forth herein. For example, the implementations described above can be directed to various combinations and sub-combinations of the disclosed features and/or combinations and sub-combinations of several further features disclosed above. In addition, the logic flows depicted in the accompanying figures and/or described herein do

not necessarily require the particular order shown, or sequential order, to achieve desirable results. Other implementations can be within the scope of the following claims.

claim

1. An apparatus, comprising:
at least one processor, and
at least one non-transitory storage media storing instructions that, when executed by the at least one processor, cause the at least one processor to perform operations comprising:
receiving, at at least one layer 1/layer 2 triggered mobility (LTM) target distributed unit (DU) of a base station, information indicative of whether handover (HO) of service for a user equipment (UE) currently being served by a serving DU of the base station can be a random access channel-less (RACH-less) HO to at least one LTM target cell of the target DU or can be a RACH-based HO to the at least one LTM target cell; and
preparing the at least one LTM target cell, based on the information received at the at least one LTM target cell, for one of RACH-less HO and RACH-based HO.
2. The apparatus of claim 1, wherein the information includes timing advance (TA) information of the UE in the serving DU;
TA information of the UE in the serving cell being either (a) a TA that is the same as a TA in the at least one LTM target cell or (b) a TA of zero is indicative that HO to the at least one LTM target cell can be RACH-less HO; and
TA information of the UE in the serving cell being neither of (a) a TA that is the same as a TA in the at least one LTM target cell and (b) a TA of zero is indicative that HO to the at least one LTM target cell can be RACH-based HO.
3. The apparatus of claim 2, wherein the at least one LTM target DU receives the TA information of the UE in the serving DU in a message from the serving DU; and
the operations further comprise the at least one LTM target DU indicating to the serving DU if the prepared LTM target cell configuration is RACH-less or RACH-based configuration.
4. The apparatus of claim 2, wherein the at least one LTM target DU receives the TA information of the UE in the serving DU in a message from a centralized unit control plane (CU-CP) of the base station; and
the operations further comprise the at least one LTM target DU indicating to the

CU-CP if the prepared LTM target cell configuration is RACH-less or RACH-based configuration.

5. The apparatus of claim 4, wherein the CU-CP receives the TA information of the UE in the serving DU from the serving DU during setup of an F1 communication interface between the serving DU and the CU-CP.

6. The apparatus of claim 4, wherein the CU-CP receives the TA information of the UE in the serving DU from the serving DU after an F1 communication interface has been set up between the serving DU and the CU-CP.

7. The apparatus of claim 1, wherein the at least one LTM target cell is included in at least one DU of the base station that is not the serving DU.

8. The apparatus of claim 1, wherein the serving DU selects one of the at least one prepared LTM target cells for handover of service for the UE from the serving DU, and the serving DU triggers the handover of the service for the UE from the serving DU to the selected LTM target cell.

9. The apparatus of claim 8, wherein the serving DU determines which one or more of the at least one LTM target cells has a radio quality above a predetermined threshold radio quality; and
the selection is among the one or more determined LTM target cells.

10. The apparatus of claim 8, wherein the triggering includes the serving DU transmitting to the UE a Medium Access Control (MAC) control element (CE) message.

11. The apparatus of claim 1, wherein the base station has a disaggregated architecture.

12. The apparatus of claim 1, wherein the base station includes a Next Generation Radio Access network (NG-RAN) node.

13. The apparatus of claim 12, wherein the NG-RAN node includes a gNodeB or an ng-eNodeB.

14. The apparatus of claim 1, wherein the base station includes the at least one processor and the at least one non-transitory storage media.

15. A computer-implemented method, comprising:

receiving, at at least one layer 1/layer 2 triggered mobility (LTM) target distributed unit (DU) of a base station, information indicative of whether handover (HO) of service for a user equipment (UE) currently being served by a serving DU of the base station can be a random access channel-less (RACH-less) HO to at least one LTM target cell of the target DU or can be a RACH-based HO to the at least one LTM target cell; and

preparing the at least one LTM target cell, based on the information received at the at least one LTM target cell, for one of RACH-less HO and RACH-based HO.

16. The method of claim 15, wherein the information includes timing advance (TA) information of the UE in the serving DU;

TA information of the UE in the serving cell being either (a) a TA that is the same as a TA in the at least one LTM target cell or (b) a TA of zero is indicative that HO to the at least one LTM target cell can be RACH-less HO; and

TA information of the UE in the serving cell being neither of (a) a TA that is the same as a TA in the at least one LTM target cell and (b) a TA of zero is indicative that HO to the at least one LTM target cell can be RACH-based HO.

17. At least one non-transitory storage media storing instructions that, when executed by at least one processor, cause the at least one processor to perform operations comprising:

receiving, at at least one layer 1/layer 2 triggered mobility (LTM) target distributed unit (DU) of a base station, information indicative of whether handover (HO) of service for a user equipment (UE) currently being served by a serving DU of the base station can be a random access channel-less (RACH-less) HO to at least one LTM target cell of the target DU or can be a RACH-based HO to the at least one LTM target cell; and

preparing the at least one LTM target cell, based on the information received at the at least one LTM target cell, for one of RACH-less HO and RACH-based HO.

18. The storage media of claim 17, wherein the information includes timing advance (TA) information of the UE in the serving DU;

TA information of the UE in the serving cell being either (a) a TA that is the same as a TA in the at least one LTM target cell or (b) a TA of zero is indicative that HO to the at least one LTM target cell can be RACH-less HO; and

TA information of the UE in the serving cell being neither of (a) a TA that is the

same as a TA in the at least one LTM target cell and (b) a TA of zero is indicative that HO to the at least one LTM target cell can be RACH-based HO.