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(54) **Title:** GROUP HANDOVER FOR MISSION CRITICAL APPLICATIONS

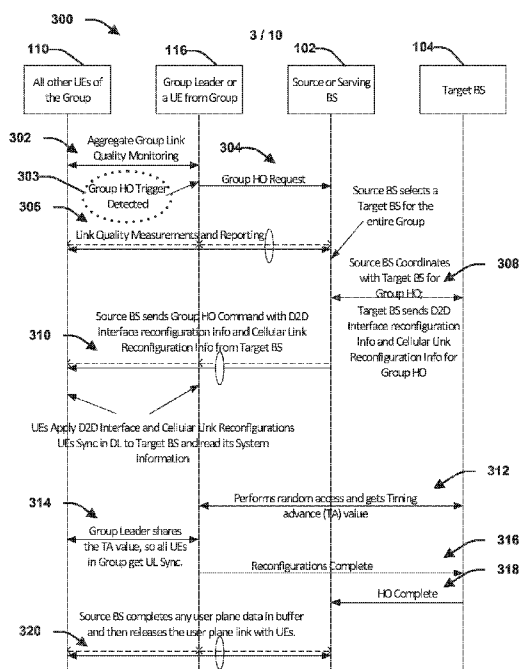


FIG. 3

(57) **Abstract:** A user equipment UE device (116), evolved NodeB or other network device can control direct device-to-device D2D or ProSe communications with UE devices (110) and control a D2D group handover with a D2D group of UEs communicatively coupled via a network channel for cellular network communications and one or more D2D or ProSe channels. The D2D/ProSe group handover can be controlled based on a set of predetermined criteria. Aggregated measurement reports (306) of channel link quality can be used to request or initiate the D2D group handover and be provided via a UE group leader (116) or individually from UE devices (110) of the D2D/ProSe group.



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GROUP HANDOVER FOR MISSION CRITICAL APPLICATIONS

REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 62/276,642 filed January 8, 2016, entitled "GROUP HANDOVER FOR MISSION CRITICAL APPLICATIONS IN 5G SYSTEMS", the contents of which are herein incorporated by reference in their entirety.

FIELD

[0002] The present disclosure relates to wireless communications, and more specifically, to group handover for mission critical applications.

BACKGROUND

[0003] Several machine-to-machine and Internet of Things (IoT) applications demand communication between devices in a group. In particular, advanced vehicular applications, such as cooperative driving, need group communication under high mobility. In cooperative driving, for example, vehicles share their intentions with other nearby vehicles. Such information is used by automated driving algorithms to enable accurate prediction of what others will do in the near future, and so optimize their own decisions. In some cases, cooperating vehicles may form a group to drive together or synchronize their operations (e.g., as a Platoon). Such higher automation and cooperation levels require data exchange between vehicles or other networked devices with lower latency and higher reliability than what existing solutions can provide.

[0004] One important characteristic of applications such as cooperative driving applications involves data (objects and sensing) and event exchanges between devices in a group within a relatively small area. Usually the group (or Platoon) will move together, eventually crossing into a new network cell at about the same time. An efficient mechanism for managing group handover (HO) is crucial to reduce the air interface network signaling, user plane (UP) HO interruption time, and provide the seamless continuation of group communication demanded by mission critical cooperative driving applications.

[0005] 3GPP standardizes device-to-device (D2D) operation/functionality to be supported in long term evolution (LTE) release specifications. Exploiting direct communication, such as in D2D communication between nearby mobile devices can

improve spectrum utilization, overall throughput, and energy efficiency, while enabling new peer-to-peer and location-based applications and services. D2D-enabled LTE devices, for example, have the potential to become competitive for fallback public safety networks that can function when cellular networks are not available or otherwise fail in connection. Introducing D2D poses many new challenges and risks to the long-standing cellular architecture, which is based on or centered on a base station (BS). One issue to be resolved is how to share or communicate resources or other communication resources in D2D communications among mobile devices (e.g., user equipment) that can communicate in both cellular and D2D communications.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] **FIG. 1** is a block diagram illustrating a wireless network communications environment for a UE or other network device (e.g., eNB) configured to form a D2D group and generate a group handover that can be utilized according to various aspects or embodiments.

[0007] **FIG. 2** is another wireless network communications environment for a UE or other network device (e.g., eNB) configured to form a D2D group and generate a group handover that can be utilized according to various aspects or embodiments.

[0008] **FIG. 3** is a process flow for wireless network for a UE or other network device (e.g., eNB) configured to form a D2D group and generate a group handover that can be utilized according to various aspects or embodiments.

[0009] **FIG. 4** is another process flow for wireless network for a UE or other network device (e.g., eNB) configured to form a D2D group and generate a group handover that can be utilized according to various aspects or embodiments.

[0010] **FIG. 5** is another process flow for wireless network for a UE or other network device (e.g., eNB) configured to form a D2D group and generate a group handover that can be utilized according to various aspects or embodiments.

[0011] **FIG. 6** is another process flow for wireless network for a UE or other network device (e.g., eNB) configured to form a D2D group and generate a group handover that can be utilized according to various aspects or embodiments.

[0012] **FIG. 7** is another wireless network communications environment for a UE or other network device (e.g., eNB) configured to form a D2D group and generate a group handover that can be utilized according to various aspects or embodiments.

[0013] **FIG. 8** is an illustration of an example network device to implement various aspects or embodiments disclosed.

[0014] **FIG. 9** is another illustration of an example network device to implement various aspects or embodiments disclosed.

[0015] **FIG. 10** is an example illustrated implementation of an architecture in which group configuration data can be transmitted to groups of User Equipment (UE) devices from an Evolved Universal Terrestrial Radio Access Network (E-UTRAN), according to one or more aspects or embodiment.

DETAILED DESCRIPTION

[0016] The present disclosure will now be described with reference to the attached drawing figures, wherein like reference numerals are used to refer to like elements throughout, and wherein the illustrated structures and devices are not necessarily drawn to scale. As utilized herein, terms “component,” “system,” “interface,” and the like are intended to refer to a computer-related entity, hardware, software (e.g., in execution), and/or firmware. For example, a component can be a processor, a process running on a processor, a controller, a circuit or a circuit element, an object, an executable, a program, a storage device, a computer, a tablet PC and/or a mobile phone with a processing device. By way of illustration, an application running on a server and the server can also be a component. One or more components can reside within a process, and a component can be localized on one computer and/or distributed between two or more computers. A set of elements or a set of other components can be described herein, in which the term “set” can be interpreted as “one or more.”

[0017] Further, these components can execute from various computer readable storage media having various data structures stored thereon such as with a module, for example. The components can communicate via local and/or remote processes such as in accordance with a signal having one or more data packets (e.g., data from one component interacting with another component in a local system, distributed system, and/or across a network, such as, the Internet, a local area network, a wide area network, or similar network with other systems via the signal).

[0018] As another example, a component can be an apparatus with specific functionality provided by mechanical parts operated by electric or electronic circuitry, in which the electric or electronic circuitry can be operated by a software application or a firmware application executed by one or more processors. The one or more processors

can be internal or external to the apparatus and can execute at least a part of the software or firmware application. As yet another example, a component can be an apparatus that provides specific functionality through electronic components or elements without mechanical parts; the electronic components can include one or more processors therein to execute software and/or firmware that confer(s), at least in part, the functionality of the electronic components.

[0019] Use of the word exemplary is intended to present concepts in a concrete fashion. As used in this application, the term “or” is intended to mean an inclusive “or” rather than an exclusive “or”. That is, unless specified otherwise, or clear from context, “X employs A or B” is intended to mean any of the natural inclusive permutations. That is, if X employs A; X employs B; or X employs both A and B, then “X employs A or B” is satisfied under any of the foregoing instances. In addition, the articles “a” and “an” as used in this application and the appended claims should generally be construed to mean “one or more” unless specified otherwise or clear from context to be directed to a singular form. Furthermore, to the extent that the terms “including”, “includes”, “having”, “has”, “with”, or variants thereof are used in either the detailed description and the claims, such terms are intended to be inclusive in a manner similar to the term “comprising”.

[0020] In consideration of the above described deficiencies, various components can operate within a cellular network having cellular and Device to Device (D2D) communication interfaces, alternatively referred to herein as Proximity-Based Services (Pro-Se). These components can reside in network devices communicatively coupled within a cellular network such as a base station (BS), evolved NodeB (eNB)), a mobile or wireless device (user equipment (UE)), or sub-system of a mobile device, which can include autonomous vehicles or other networked devices.

[0021] Furthermore, devices with reduced distance between them can form a D2D group that shares a given resource pool(s) for group communication using their D2D/ProSe (D2D, ProSe, or both) interface. The devices that members of or part of the D2D/ProSe group can be connected at all time in a connected mode via their cellular interface in order to send/receive mission critical data to/from the network (i.e. BS). By being in a connected state or being communicatively coupled within a D2D/ProSe group, implies that the device continuously or frequently monitors down link (DL) network control signaling, the eNB maintains or stores device context information, and knows the device location at the cell level. In addition, the group formation as well as

the allocation of resource pools to a D2D/ProSe group can be assisted by the network through the cellular interface. The D2D/ProSe group formation and complete management functionalities can be controlled by various components and techniques not specifically detailed herein. However, network assisted group formation methods can be used to help devices form/join and leave a group. Devices in a D2D/ProSe group can share the same resources for D2D/ProSe communications either with the assistance of the network or autonomously. A group leader can be defined to coordinate group operation. A UE device can request the network to activate a group communication mode when needed or when a nearby potential group has been detected.

[0022] Various embodiments are disclosed for D2D/ProSe group handover (HO) in order to significantly reduce network signaling, enable seamless group continuation during and after HO, and minimize user plane interruption for group communication during HO. Since all devices in the group need to perform cellular interface HO at about the same time, a group wise HO trigger can be defined. The UE devices in a group can be within a small geographical area and have similar speeds, and thus have the same timing advance (TA). In one embodiment, for example, rather than all devices performing random access (RA) to the target BS, a single device (such as UE group leader) may perform RA to get the TA and then assist other devices in the group to get UL time synchronization with target BS. Source and target eNBs can also coordinate before HO to select and assign a resource pool, which can be used by devices in the group for group communications during HO and potentially right after the HO in the new cell. The source eNB can provide D2D/ProSe interface configuration information to target BS during HO so that the D2D/ProSe group can be continued seamlessly after HO. Additional, aspects and details of the disclosure are further described below with reference to figures.

[0023] FIG. 1 illustrates an example wireless network environment 100. The wireless communications environment 100 can include one or more cellular broadcast servers, macro cell network devices 102, 104 (e.g., base stations, eNBs, access points (APs) or the like) as well as one or more small cell network devices, secondary cells, APs or the like (e.g., small eNBs, micro-eNBs, pico-eNBs, femto-eNBs, home eNBs (HeNBs), or Wi-Fi access points / nodes) 106, 108 deployed within the wireless communications environment 100 and servicing one or more UE devices 110, 112, 114, 116, 118 (e.g., a vehicle, a mobile or wireless phone, or other networked device being served by any one

of the base stations 102-108). Each wireless communications network serving device(e.g., cellular broadcast servers 102, 104 and small cell network devices 106, 108) can be referred to or comprise one or more network devices (e.g., a set of network devices (NDs)) that operate in conjunction in order to process network traffic for the one or more UE devices 110, 112, 114, 116, or 118. For example, macro cell NDs 102, 104 can comprise a set of network devices that are cellular enabled network devices. In another example, the small cell network devices 106, 108 can include a set of network devices that operate with a smaller coverage zone than the macro cell network devices 102 and 102, for example.

[0024] As illustrated, each of the one or more base stations 106, 108 can have a corresponding service area 120, 122 with a cell coverage zone. In addition, each of the one or more broadcast servers 102, 104 can have a corresponding service area 124, 126. However, the wireless communications environment 100 is not limited to this implementation and various other architectures can also be employed. For example, self-organizing network devices can deploy any number of Wi-Fi access points and respective service areas within the wireless communications environment 100. The wireless communications environment 100 can include a multitude of wireless communications networks, each having a respective coverage area or cell. The coverage area of some of the wireless communications networks can overlap such that one or more network devices can provide coverage areas or zones to UEs or mobile devices whose coverage areas from different networks of network devices overlap.

[0025] The network devices within the wireless environment 100 can also operate with one another as a Self-Organizing Network (SON), in which at least some of the network devices can be configured to provide self-configuration and self-optimizing capabilities that provide the ability to automate certain operations, management functions and system management functions. The SON incorporates self-configuration, self-optimization, monitoring, and operation management to allow the network devices to be communicatively coupled into the network and operate with little to no human intervention while taking into account application settings for applications operating on and managed by the UEs.

[0026] Although network devices (NDs) 106 and 108 are described as small cell network devices, they can also be Wi-Fi enabled devices or wireless local area network (WLAN) devices, as well as macro cell network devices, small cell network devices, or some other type of ND operable as a base station or eNB, for example. Alternatively

one or more of the macro cell NDs 102 and 104 could be small cell network devices or other NDs of a different radio access technology (RAT) that operate with different frequency carriers, for example.

[0027] Although only five UE devices 110, 112, 114, 116, 118 are illustrated, any number of UE devices can be deployed within the wireless communications environment 100 as well. A UE device can contain some or all of the functionality of a system, subscriber unit, subscriber station, mobile station, mobile, wireless terminal, device, mobile device, remote station, remote terminal, access terminal, user terminal, terminal, wireless communication device, wireless communication apparatus, user agent, user device, or other ND, for example. A mobile device can be a cellular telephone, a cordless telephone, a Session Initiation Protocol (SIP) phone, a smart phone, a feature phone, a wireless local loop (WLL) station, a networked vehicle or sub-system thereof, a personal digital assistant (PDA), a laptop, a handheld communication device, a handheld computing device, a netbook, a tablet, a satellite radio, a data card, wireless modem card and/or another processing device for communicating over a wireless system. In addition, the UE devices 110, 112, 114, 116, 118 can include functionality as more fully described herein and can also be configured as dual connected devices, in which one or more of the UE devices 110, 112, 114, 116, 118 can be connected to more than one eNB or ND of different RATs (e.g., LTE and WLAN, or other combination).

[0028] In one aspect, cellular broadcast servers or macro cell NDs 102, 104 and small cell NDs 106, 108 can monitor their surrounding radio conditions (e.g., by employing respective measurement components). For example, each of the macro cell NDs 102, 104 and small cell NDs 106, 108 can determine network traffic load on its respective network by performing a network diagnostic procedure. As an example, during a network listen procedure, macro cell NDs 102, 104, small cell NDs 106, 108 or UE devices 110, 112, 114, 116, 118 can scan their radio environment to determine network performance statistics or network parameters (e.g., frequency, SNR, signal quality, QoS, QoE, load, congestion, signal rate, etc.). Various parameters associated with macro cell NDs 102, 104 and small cell NDs 106, 108 can be detected during the network diagnostic procedure or measurements by the UE devices, such as, but not limited to, frequency bands, scrambling codes, common channel pilot power, bandwidth across respective networks, universal mobile telecommunications system terrestrial

radio access receive signal strength indicator, as well as frequency carrier priorities and so on.

[0029] In an example scenario, UE devices 110, 112, 114, 116, 118 can be serviced by networks through one of the macro cell NDs 102, 104, or small cell NDs 106, 108. As a user equipment device is moved within the wireless communications environment 100, the respective user equipment device might be moved in and out of the coverage area of the associated serving network. For example, as a user is sending/receiving communications through their respective UE device, the user might be walking, riding in a car, riding on a train, moving around a densely populated urban area (e.g., a large city), wherein the movement might cause the mobile device to be moved between various wireless communication networks. In such cases, the UE it is beneficial to route the network traffic (e.g., handover) from a serving ND to a target ND in order to continue the communication (e.g., avoid dropped calls) or facilitating offloading for load distribution or other efficiency purposes. However, with an increased number of NDs and frequency carriers to measure, UE devices 110, 112, 114, 116, 118 can have a problem being able to maintain adequate and seamless communications during handover operations.

[0030] In one embodiment, group communication can takes place through a D2D/ProSe interface 130 and uses group/cell-specific resources. For example, the BS102 can assign one or more resource pool(s) to a D2D/ProSe group 140 (e.g., UEs 110 and 116), which could be valid only in that particular cell or cell coverage area 124. Once the D2D/ProSe group 140 (e.g., UEs 110 and 116) moves to a new cell or coverage zone (e.g., coverage zone 126 served by BS 104) the new BS 104, for example, can then allocate a resource pool to the group. A resource pool can refer to a set of resources for configuring D2D/ProSe communications between a D2D/ProSe group 140, configuring the D2D/ProSe group 140, cell identifiers, channel or bandwidth specification, operating band or component carrier frequencies, channel specifications, or other network related parameters or criteria. As such, one or more mechanism can be implemented to obtain resources in the new cell or cell coverage zone (e.g., 126) while maintaining the group communications in the D2D/ProSe interface 130 with minimal overhead. This mechanism can be referred to as a D2D/ProSe Interface handover or D2D/ProSe group HO. In addition, individual handover (HO) can also be enabled in the main cellular interface to maintain connection with the network (BS) as a source BS (e.g., 102) or a target BS (e.g., 104), for example.

[0031] In a cellular interface handover, the UE devices always can be in a connected state / mode for cellular link as devices have mission critical applications and they may need to send/receive data over cellular network at any time. As a result, when the current cellular link quality of one or more UE devices (e.g., UE 116) falls below a predetermined threshold or signal link quality threshold value (e.g., a signal to noise ratio, a received channel power indicator, received signal strength indicator, or other channel quality indicator or state data), the UE devices of the D2D/ProSe group 140 can be connected to a new BS (with better cellular link quality) as a target eNB or base station. For example, when the D2D/ProSe group 140 moves toward the edges of the cell coverage zone 124 toward the cell coverage zone 126 and cellular channels are more optimal (e.g., a higher signal to noise ratio or other parameter), the UEs 116 and 110 can be handed over together in a group to a new cell (e.g., a target eNB or BS 104) to operate within the new cell coverage area 126 and continue to communicate as a D2D/ProSe group 140 having intact D2D/ProSe communications via a D2D/ProSe interface channel 130.

[0032] Given that the D2D/ProSe group 140 uses cell-specific resources, to maintain the continuity of the group, all devices of the D2D/ProSe group 140 (e.g., UE 110 and 116) can be moved to the same BS or eNB 104 at approximately the same time via operations at the respective UEs (e.g., 110 and 116), a UE group leader (e.g., 116) whether or not all devices have degraded cellular links with the current / source BS (e.g., 102). However, if the D2D/ProSe/ProSe group handover of devices is treated as a combination of several simultaneous individual HOs of devices 110, 116, this could result in significant network signaling overhead and radio resource wastage.

[0033] Additionally, the UEs 110, 116 of the D2D/ProSe group 140, individually or collectively via a UE group leader 116, or via the BS 102 can initiate, process or generate a D2D/ProSe Interface handover (D2D/ProSe group HO). In order to support mission critical applications, such as cooperative driving, the D2D/ProSe group HO can operate to continue group communications in the D2D/ProSe interface 130 during and after D2D/ProSe group HO without any interruption. How to transfer the group configuration information seamlessly to the new BS 104 and how to achieve a new resource pool(s) for group communication seamlessly from the new BS 104 can be major issues for the D2D/ProSe group HO. Furthermore, D2D/ProSe group HO can also be accompanied first by cellular interface HO of all devices in the group to the new BS 104 and as a D2D/ProSe group 140.

[0034] Direct communication between UE devices 110, 116 can further be supported by D2D communication functionality in LTE proximity services (ProSe). As such, D2D can also refer to communications between UEs or other network devices communicatively coupled to a wireless network without assistance (e.g., via an eNB/BS) and as part of or with ProSe. Here, D2D communication can be supported over dedicated resource pools, which are preconfigured or allocated by the eNB (e.g., BS 102, 104). Access to data resources within a resource pool (e.g., with a Physical Sidelink Shared Channel (PSSCH)) can be controlled or assigned by the eNB 102, 104 or acquired autonomously by the UE device using contention within control resources (Physical Sidelink Control Channel (PSCCH)). From the physical layer (PHY) perspective, UE device data transmissions can be broadcast, in which those UE devices within a geographical range can be potential receivers. Thus, both unicast and one-to-many communications can be utilized possible by the network devices (UE, eNB, etc.). UEs 110, 116, for example, can thus form groups at the application layer by exchanging application messages between UE devices over a ProSe interface circuitry as part of or in conjunction with D2D interface circuitry in D2D/ProSe communications. For example, UE devices that are members of a group can periodically broadcast group messages and other UE devices that want to join the group send a request to join the group. One of the group members can respond with a confirmation allowing the new member to enter the group. Similarly, members can broadcast a message to inform that they are leaving the group.

[0035] Based on beacons received from other UE devices, the UE device 110, 116 can maintain a neighbor list, for example, in the storage media or data store. Such a neighbor list or data set can be stored in a database table or other appropriate form. This neighbor list can record an identifier for each UE device from which a beacon was received, record a signal quality that characterizes the quality of the channel between the UE devices, as well as other information that is helpful in selecting suitable UE devices for group participation, such as the neighbor UE device's speed, trajectory, or an identifier for a group to which the neighbor UE device belongs, for example.

[0036] Referring to **FIG. 2**, illustrated is another example wireless environment 200 in accordance to various aspects being disclosed. In particular, the example wireless environment 200 illustrates a set of wireless network macro cells 202, 204, and 206. It is noted however that wireless cellular network deployments within the wireless environment 200 can encompass any number and type of cells. Coverage macro cells

202, 204, and 206 are illustrated as hexagons, but coverage cells can adopt other geometries generally dictated by a deployment configuration or floor plan, geographic areas to be covered, or other factors. Each macro cell 202, 204, and 206 can be sectorized in a $2\pi/3$ configuration, in which each macro cell includes three sectors as an example demarcated with dashed lines in **FIG. 2**. It is noted that other sectorizations are possible, and aspects or features of the disclosed subject matter can be exploited regardless of type of sectorization.

[0037] Macro cells 202, 204, and 206 are served respectively through macro cell network devices, base stations or eNodeBs (eNBs) 104, 102, and 212. It is noted that radio communication component(s) are functionally coupled through links such as cables (e.g., RF and microwave coaxial lines), ports, switches, connectors, and the like, to a set of one or more antennas that transmit and receive wireless signals (not illustrated). It is noted that a radio network controller (not shown), which can be a part of mobile network platform(s) 214, and set of base stations (e.g., eNBs 104, 102, and 212) that serve a set of macro cells; electronic circuitry or components associated with the base stations in the set of base stations; a set of respective wireless links (e.g., links 216, 218, and 220) operated in accordance with a radio technology through the base stations 104, 102, and 212, form a macro radio access network. It is further noted that, based on network features, the radio controller can be distributed among the set of base stations 104, 102, and 212 or associated radio equipment. In an aspect, for universal mobile telecommunication system-based networks, wireless links 216, 218, and 220 can embody a Uu interface (universal mobile telecommunication system air interface, or other type of air interface).

[0038] Mobile network platform(s) 214 facilitates, for example, circuit switched-based (e.g., voice and data) and packet-switched (e.g., Internet protocol, frame relay, or asynchronous transfer mode) traffic and signaling generation, as well as delivery and reception for networked telecommunication via a user equipment (UE) 116 (e.g., mobile or wireless device) or a UE 110, in accordance with various radio technologies for disparate markets. Telecommunication can be based at least in part on standardized protocols for communication determined by a radio technology utilized for communication. In addition, telecommunication can exploit various frequency bands, component carriers or carriers, which include any electromagnetic frequency bands licensed by the service provider network 222 (e.g., personal communication services, advanced wireless services, general wireless communications service, and so forth),

and any unlicensed frequency bands currently available for telecommunication. In addition, mobile network platform(s) 214 can control and manage base stations 102, 104, and 212 and radio component(s) associated thereof, in disparate macro cells 202, 204, and 206 by way of, for example, a wireless network management component (e.g., radio network controller(s), cellular gateway node(s), etc.). Moreover, wireless network platform(s) can integrate disparate networks (e.g., Wi-Fi network(s), femto cell network(s), broadband network(s), service network(s), enterprise network(s), and so on). In cellular wireless technologies (e.g., third generation partnership project universal mobile telecommunication system, global system for mobile communication, etc.), mobile network platform 214 can be embodied in the service provider network 222.

[0039] In addition, wireless backhaul link(s) 224 can include wired link components such as a T1/E1 phone line, a T3/DS3 line, a digital subscriber line either synchronous or asynchronous; an asymmetric digital subscriber line; an optical fiber backbone; a coaxial cable, etc.; and wireless link components such as line-of-sight or non-line-of-sight links which can include terrestrial air-interfaces or deep space links (e.g., satellite communication links for navigation). In an aspect, for universal mobile telecommunication system-based networks, wireless backhaul link(s) 224 embodies an IuB interface. It is noted that while an exemplary wireless environment 200 is illustrated for macro cells and macro base stations, aspects, features and advantages of the disclosed subject matter can be implemented in small cells, micro cells, pico cells, femto cells, or the like.

[0040] The wireless environment 200 illustrates further aspects comprising the UE device 116 in communication with another UE 110 via D2D/ProSe communication on the D2D/ProSe communication channel. The UE 116 is configured to switch between a cellular network mode of communication and a D2D/ProSe mode of communication. In the D2D/ProSe mode of communication, the UE 116 communicates directly with the UE 110 via a wireless communication link 130 without a BS/eNB as a constant facilitating intermediary or consistently active mediator at each communication. In the cellular network mode of communication, the cellular networks associated with the macro cells 202, 204, or 206 are utilized to facilitate a communication with the UE 110 (e.g., via the link 236 and the base station 102).

[0041] In addition, the UE 116 includes a D2D/ProSe interface component 232 and a cellular network interface component 234, while the eNB 102 comprises a D2D/ProSe interface component 240 and a cellular network interface component 242 also. The

cellular network interface component 234 of UE 116 and 242 of eNB 102 can and process cellular network communications on one or more network channels (e.g., 216, 218, 220) to enable a cellular handover in a wireless network and a formation of a device-to-device group with other UEs 110 via one or more D2D/ProSe channels 130 that communicatively couple UEs of the D2D/ProSe group. The D2D/ProSe interface component 232 of UE 116 and 240 of eNB 102, communicatively coupled to the cellular network interface components and enable D2D/ProSe communications on the one or more D2D/ProSe channels 130 among the D2D/ProSe group, and enable a D2D/ProSe group handover based on a set of predetermined criteria. The UE devices can also communicate with other UE devices in device-to-device mode (also called Peer-to-Peer (P2P) mode) over the D2D/ProSe interface component 232 as ProSe interface circuitry. Note that such ProSe interface circuitry can be an enhancement of an existing LTE ProSe PC5 interface, a new ProSe interface defined for 5G systems, a WiFi interface, Bluetooth interface, or an interface for any other version of Wireless Personal Area Networks or Wireless Local Area Networks.

[0042] The UE 116 and eNB 102 can use these components to generate and control communications directly from the UE 116 to the UE 110 while in the D2D/ProSe communication mode without the intercession of the base station 102 and handover operations that maintain D2D/ProSe communications between the D2D/ProSe group. An advantage of the D2D/ProSe communication mode by the UE 116 is that a higher data rate than a cellular network communication mode alone can be experienced due to a shorter range of communications via the link 130 than the links 218 and 236, for example. Further, the UEs 116, 110 form a D2D/ProSe group with one another or with one or more other networked devices or UEs operating within one or more macro cells 202, 204, or 206 that could benefit from D2D/ProSe communications, as the D2D/ProSe communications can help offload traffic from one or more congested cell networks (e.g. macro cells 202, 204, or 206). For example, as more D2D/ProSe configured UEs (e.g. UE 116) operate within the macro cells 202, 204, or 206, these networks could have more available spectrum for other network devices and further limit potential interference.

[0043] The D2D/ProSe interface components 132 of the UE 116 and 240 of the eNB 102 can comprise a transceiver, a transmitter, a receiver, corresponding communication circuitry or other similar components that enables a communication directly to another UE device (e.g., 110) and controlling handover of these communications as a

D2D/ProSe group. The D2D/ProSe communication component 132 can operate to switch between a D2D/ProSe communication mode and a cellular network communication mode that can be maintained via the cellular network interface components 234. The D2D/ProSe communication component 132 can transmit or receive D2D/ProSe data via the D2D/ProSe communication link 130 and process D2D/ProSe resource pools and commands received via the cellular network interface or channel 218 from eNB 102, which can control, manage and direct D2D/ProSe operations among the D2D/ProSe group by using D2D/ProSe interface component 240 and cellular network interface component 242, for example.

[0044] The D2D/ProSe communication data, for example, can comprise one or more physical parameters or predetermined criteria. These parameters / predetermined criteria can enable or facilitate the UE 110 to recognize a subsequent D2D/ProSe communication being received by UEs of the D2D/ProSe group utilizing the parameters provided as control information within the D2D/ProSe data transmission, as well as enable D2D/ProSe group handover. The D2D/ProSe communication component of each UE 116 and 110 (not shown) could likewise transmit D2D/ProSe data from the UE 116 to the UE 110 as well, in which the UE 110 could also decode subsequent transmissions based on physical parameters from the UE 116 or relayed from the UE 116 as a UE group leader of the D2D/ProSe group, which could be from the serving or source eNB 102.

[0045] These one or more parameters, can include, but not limited to, a D2D/ProSe transmitter / group identity, a position of the sub-frames message transmission in a logical resource pool, the scheduling assignment cycle or period, a number of packet data units, a number of retransmissions, time instances for initial packet data units, time instances for retransmissions, or the other D2D/ProSe communication related parameters, for example. Other predetermined criteria, for example, could be a level of complexity (e.g. in encryption, security, etc.) that a UE 116 could set for the particular D2D/ProSe link with a particular UE 110, as well as a scheduling decision, a traffic load or type, latency requirements, power consumption level desired for QoE or QoS or other criteria, for example. The predetermined criteria can further comprise a worse UE measurement of a channel link quality value, measurements from the plurality of UEs of the D2D/ProSe group, an average measurement value of measurements from the D2D/ProSe group, or one or more measurement reports from a UE group leader of the plurality of UEs of the D2D/ProSe group requesting the D2D/ProSe group handover.

[0046] Because all or most UE devices in the D2D/ProSe group need to perform cellular interface HO at the same time, a group wise HO trigger can be generated by the UE device 116 as a UE group leader, the UE 110 as a member of the D2D/ProSe group or the eNB 102. The UE devices 110 and 116 in the D2D/ProSe group can be within a small geographical area and have similar speeds; therefore they can have the same timing advance (TA). Rather than all UE devices performing random access (RA) to a target eNB or BS (e.g., eNB 104 or 212), a single UE device 116 (such as group leader) can perform RA to get the TA and then assist other devices (e.g., UE 110) in the group to get UL time synchronization with target eNB. Source and Target BSs can also coordinate before HO to select and assign a resource pool, which can be used by the UE devices in the D2D/ProSe group for group D2D/ProSe communications during HO via the D2D/ProSe link 130 or cellular interfaces 236, 216-220 and potentially right after the HO in the new cell. In the proposed solution, the source eNB 102 can provide D2D/ProSe interface configuration information to the target eNB 104 or 212 during HO so that the D2D/ProSe group can be continued seamlessly after HO in formation as a group and be communicatively coupled in real time via D2D/ProSe communication channels.

[0047] UE devices 110 and 116 as a D2D/ProSe group can be capable of communicating with the network through source eNB 102 using the cellular interface (C-interface) 218, 236, for example. This C-interface can be a new 5G or beyond interface, or it can be an enhancement of existing LTE Uu-interface. UE devices 110 and 116 can also communicate with other devices and one another in a D2D/ProSe mode over a new P-interface (e.g., interface 130). Note that the P-interface can be an enhancement of the existing LTE D2D/ProSe PC5 interface or it can be a new D2D/ProSe interface defined for 5G systems or beyond. Communications between UE devices 110 and 116 can thus operate within a D2D/ProSe group over the P-interface.

[0048] While the methods described within this disclosure are illustrated in and described herein as a series of acts or events, it will be appreciated that the illustrated ordering of such acts or events are not to be interpreted in a limiting sense. For example, some acts may occur in different orders and/or concurrently with other acts or events apart from those illustrated and/or described herein. In addition, not all illustrated acts may be required to implement one or more aspects or embodiments of the description herein. Further, one or more of the acts depicted herein may be carried out in one or more separate acts and/or phases.

[0049] Referring to **FIG. 3**, illustrates a process flow 300 for a D2D/ProSe group handover via the components of the eNBs and UEs of a D2D/ProSe group in accordance with various embodiments that will be described further in conjunction with **FIGs. 1 and 2**. A group of vehicles, network devices, or other similar UEs operating in a platoon mode with D2D/ProSe communications on a highway, for example, can reach coverage boundary of current BS (source BS) and be about to enter coverage of another BS (target BS). As a result, a D2D/ProSe group HO can be implemented according to the process flow 300 mechanisms of **FIG. 3** in order to maintain the D2D/ProSe group communications via the D2D/ProSe interface component 232 of each UE 110, 116 of the D2D/ProSe group.

[0050] Initially the one or more UEs (e.g., UE 110) of the D2D/ProSe group 140 that are not a UE group leader 116, or the UE group leader 116 can process or generate measurements of cellular quality on corresponding cell network channels. Each respective network device or UE of the D2D/ProSe group 140 can be configured to generate measurements of the network channels as well as for the one or more D2D/ProSe channels / links 130. The UEs of the D2D/ProSe group 140 can further provide the measurements to the UE group leader 116 or another UE of the D2D/ProSe group 140 via the one or more D2D/ProSe channels 130 in order to aggregate the group link measurements and quality monitoring among the D2D/ProSe group 140 at 302. In addition, the aggregate link quality measurement reporting can be generated to the eNB 102 via the one or more network channels 236 via the group leader UE 116 or from UEs individually at 306.

[0051] At 304 a UE device 110 or 116 in the D2D/ProSe group 140 can requests the source eNB 102 to initiate D2D/ProSe group HO, in which all UEs are attempted to be handed over to a target eNB 104 together, at about the same time, concurrently or simultaneously. UE devices 110, 116, for example, can frequently monitor / measure channel qualities of current cell 204 / eNB 102 in addition to neighbor cells 206, 202 of eNBs 104, 212 to decide an individual HO trigger or a group HO trigger 303.

[0052] In one example, the eNB 102 can set different thresholds for a group HO trigger 303 when UE devices are in D2D/ProSe group communication. In addition, the D2D/ProSe group HO trigger 303 can occur earlier via the UE group leader 116 or other UE than the individual HO trigger (i.e. when the device is not operating in group communication mode) so that the D2D/ProSe group 140 gets more time to complete the D2D/ProSe group handover before any cellular link 218, 236 in the group fails.

[0053] In an embodiment, the UE group leader 116 can initiate D2D/ProSe group HO based on the aggregate group trigger or D2D/ProSe group HO trigger 303 on behalf of the group via a group HO request 304. Alternatively, other UE devices in the group 140 can also trigger the D2D/ProSe group HO by using a D2D/ProSe group HO trigger 303 as a BS configurable aggregate group HO trigger as well. The group HO trigger 303 can enable or control all devices in the group to handover to the target eNB 104 at about the same time.

[0054] Group triggers for the D2D/ProSe group HO can be configurable as aggregate group HO triggers that facilitate or initiate the D2D/ProSe HO. The UE device 110 or 116 can explicitly indicate in the HO request 303 whether it is individual HO request for or a group HO request 304 for the D2D/ProSe group to be handed over together.

[0055] The group HO trigger 303 can occur or include various different triggers. For example, in an event when link quality of any one UE device in the D2D/ProSe group 140 falls below a threshold value $T_{\text{nearLinkFailureHOTrigger}}$ for a period of time T_{HO} , the D2D/ProSe group trigger could be communicated to the eNB 102. Each UE device could evaluate this trigger as a quality link threshold value, and once such an event trigger occurs, the individual UE device 110, 116 or other D2D/ProSe group member device can send the group HO request 303 to the eNB 102 directly or through the group leader 116.

[0056] In another example, the group HO trigger 303 can comprise an event when more than 50% or other percentage number of devices in the group have a channel link quality that falls below $T_{\text{GroupHOTrigger}}$ value for a time T_{HO} . Each D2D/ProSe group device can monitor for event of fulfilment of individual criteria (its link quality falling below $T_{\text{GroupHOTrigger}}$ value for a time T_{HO}) and send the occurrence of such an event to group leader 116 via a D2D/ProSe interface message exchange on one or more D2D/ProSe channels between different D2D/ProSe group UEs. The group leader 116 can further evaluate the group HO trigger 303 for the entire group and once such an event occurs, request D2D/ProSe group HO to the source eNB 102 at 303.

[0057] Another example of a D2D/ProSe group trigger 303 can include an event when the link quality with a neighbor cell (e.g., 202 or 206) for more than 50% or another percentage number of UE group member devices becomes $T_{\text{GroupHOTriggerOffset}}$ better than the current cell link 236 or 218. Each UE device 110 or 116 can monitor for event of fulfilment of individual criteria (its link quality being better than neighbor link by

$T_{\text{GroupHOTriggerOffset}}$ value for a time T_{HO}) and send the occurrence of such an event to the group leader 116 via D2D/ProSe Interface message exchange on one or more D2D/ProSe communication channels / links 130. The UE group leader 116 can then evaluate the group HO trigger 303 for the entire group and once such an event occurs, it can request the eNB 102 for group HO.

[0058] The source eNB 102 can then select the target eNB 104 at 308. The source eNB 102s can ask UE device(s) 110, 116 in the D2D/ProSe group 140 to send measurement report(s) and based on the input from other UE devices, and the source eNB 102 can select a target eNB 104 based on such reports. In another example, the source eNB 102 can ask a D2D/ProSe group leader 116 to send measurement report(s) on behalf of the D2D/ProSe group 140. The D2D/ProSe group leader 116, then, sends aggregated group measurement report at 306, which can include several measurements, such as a worst device's measurement value from among the D2D/ProSe group 140, measurement values from each UE device 110, 116 or other device from in the D2D/ProSe group 140, one or more average measurement values across the D2D/ProSe group 140 and the measurement report from the device requesting HO.

[0059] The D2D/ProSe group leader 116 can collect the measurement reports from the UE devices that are a part of, or as current members of the D2D/ProSe group via a group identifier or communicative coupled via D2D/ProSe links 130, or example, by using D2D/ProSe interface message exchange. The D2D/ProSe group leader 116 can aggregate measurement reports from other devices and send the results to the eNB 102.

[0060] At 308, the source eNB 102 can select the best eNB as target eNB 104 based on aggregate measurement report(s) from the D2D/ProSe group 140. The target eNB 104 could be selected such that none of the devices in the D2D/ProSe group 140 has link quality worse than a threshold values, such as a $T_{\text{nearLFHOTrigger}}$ or more than X% (e.g., 50%) of devices has link quality better than $T_{\text{GroupHOTrigger}}$. Other quality link threshold values can also be determined or envisioned, including the examples discussed herein as comprising the group HO trigger 303, for example.

[0061] In case the source eNB 102 does not find a suitable target eNB 104, it can ask any of the D2D/ProSe group devices (which need immediate HO) to start individual HO process via a cellular link handover without D2D/ProSe group handover. A UE device (e.g., 110) can then leave the D2D/ProSe group 140, if it completes the

handover to a different eNB, which could possibly not support D2D/ProSe group communications or support D2D/ProSe group communications in a different resource pool(s) than the current resource pool enabling D2D/ProSe communications among the D2D/ProSe group 140. However, this UE device (e.g., 110) can request the eNB (e.g., 102 or 104) to join another or second D2D/ProSe group as part of the handover process, individually as a cellular link HO or within the D2D/ProSe group as part of the D2D/ProSe group for removal to another group.

[0062] Alternately or additionally, if the eNB 102 cannot find any suitable target eNB 104, it can configure the UE group leader 116 as a relay/gateway for a period of time or indefinitely for the other UE device(s) 110 of the D2D/ProSe group 140 that need immediate HO. These UE devices with bad links with eNB 102 can then start receiving/transmitting messages via D2D/ProSe group leader 116. The eNB 102 can keep looking for suitable target eNB 104, and once it finds the suitable target eNB 104 for the D2D/ProSe group 140, it can move the D2D/ProSe group 140 to a new eNB 104.

[0063] In another aspect, the source eNB 102 can coordinates with the target eNB 104 for D2D/ProSe group HO over an eNB-to-eNB interface (such as a X2 interface in LTE). For example. The source eNB 102 can share D2D/ProSe interface configuration details and devices contexts with the target eNB 104 (e.g., group identifications, user plane and control plane attributes or configurations, addresses, operating frequencies/bands or the like). The target eNB 104 can further decide about the D2D/ProSe group 140 communication resource pool(s) and send a new resource pool info for D2D/ProSe interface communication for the D2D/ProSe group 140 to the source eNB 102 in order to coordinate the D2D/ProSe group HO. If the eNBs 102, 104 decide upon a new resource pool to be used for the D2D/ProSe group communication during D2D/ProSe group HO (and potentially for right after D2D/ProSe group HO), the source eNB 102 can send a new group resource info to the D2D/ProSe group 140 along with an HO command. Note that it can be possible in some cases that the target eNB 104 can allow the D2D/ProSe group 140 to continue using a current resource pool (e.g., an operating band for D2D/ProSe communications) for a D2D/ProSe interface communication such as in case with a dedicated band outside cellular band is being used by the D2D/ProSe interface component(s) 232 of each respective UE device 110, 116.

[0064] The source eNB 102 can further generate a D2D/ProSe group HO command or a communication command. The eNB 102 can explicitly indicate in the HO command

whether it is individual HO command or group HO Command for handing over a group of UEs specifically with cellular handover and D2D/ProSe group HO,. In one example, the source eNB 102 can send the D2D/ProSe group 140 HO command to only one device (such as D2D/ProSe group leader 116 or a UE device 110 which requested for HO). The UE device receiving the group HO from the source eNB 102, can inform all other devices in the D2D/ProSe group 140 about the D2D/ProSe group 140 HO using the D2D/ProSe interface communication, for example.

[0065] In another example, at 310 the source eNB 102 can send the HO command to all UE devices 110, 116 in the D2D/ProSe group 140 via cellular interface communication (e.g., links 236, 218). For example, if the D2D/ProSe group 140 size is big, or over a certain threshold value for a size, the source eNB 102 can use a broadcast / multicast message operations to send the D2D/ProSe group HO message, which can have the HO command or communication command to all devices. For example, a system information block (SIB) can be defined for this purpose, where the SIB message carries the HO command and corresponding group D2D/ProSe group ID (e.g., with individual IDs as well as a group ID). In another example, the source eNB 102 can also use a multimedia broadcast multicast service (MBMS) functionality to send a group HO communication message or command to one or more the UEs of the D2D/ProSe group of devices.

[0066] The group communication resource pool can comprise configurations after getting group HO command at 310 for the D2D/ProSe group HO to seamlessly enable D2D/ProSe group communications on D2D/ProSe communication channels among the D2D/ProSe group 140 with one or more eNBs operating with each UE as well. If a HO communication command comprises new group communication resource configuration(s), UE devices 110, 116 or others can start using the new resource pool for D2D/ProSe group communication immediately or after completion of the D2D/ProSe group HO according to whether the new resource is in a dedicated band (say unlicensed band for V2X) or licensed band (e.g., UL cellular band) respectively. The switching to new resource can also depend on whether D2D/ProSe communication is time aligned with cellular communication or not. If D2D/ProSe communication is time aligned with cellular communication or the eNB communication operations, the UE devices 110, 116 can switch to the new resource pool after HO completion or after achieving time synchronization (time sync) with target eNB 104. The switching to a new resource pool can also be coordinated by D2D/ProSe group leader 116 in some cases,

such as when one or more UEs of the D2D/ProSe group are using the D2D/ProSe group leader as a gateway or relay, for example. If the HO command does not contain a new resource pool configuration, a current resource pool can be validly utilized for group communication at least until D2D/ProSe group HO is completed and the group can be moved to target eNB 104. The target eNB 104 can also change the D2D/ProSe group 140 resource (e.g., a bandwidth, operating frequency range, or other resource of the resource pool) after group HO completion.

[0067] In another embodiment, synchronization can be achieved with the target eNB 104 after receiving the group HO command at 310. The UE devices of the D2D/ProSe group 140 can then sync in DL to the target eNB 104 and read the system information (SI) from the target eNB 104 at 314 based on the HO command or resources of a resource pool. The UE devices of the D2D/ProSe group 140 can further perform security updates for the target eNB 104. At first, at 312 only one UE device (which can be indicated or identified in the HO command, such as group leader 116 or the UE device 116 who initiated HO) can perform random access to get UL timing advance (TA) in order to be uplink sync with the target eNB 104. This first UE device (e.g., the UE group leader 116) at 314 can then assist all other devices in the D2D/ProSe group 140 to acquire UL sync with the target eNB 104 by communicating the TA value over D2D/ProSe interface. The UE devices of the D2D/ProSe group 140 can then use DL time synchronization and the TA value to get UL synchronized with the target eNB 104. One or more UE devices of the D2D/ProSe group 140 can then send a confirmation message to the first device (such as D2D/ProSe group leader 116) stating completion of UL time sync via group communication at 316. The first UE device, for example, can then send an air-interface message (such as radio resource control message in LTE) to the target eNB 104 on behalf of the D2D/ProSe group 140 to indicate radio reconfiguration complete for target eNB 104 at 316. The UE devices of the D2D/ProSe group 140 from now on can perform user plane UL data transmission through the target eNB 104 whenever needed.

[0068] The core network (e.g., the evolved packet core (EPC) together with or including the eNB 102 or 104) can then direct user plane DL data for the D2D/ProSe group 140 to the target eNB 104 from this point forward. The target eNB 104 can then inform the source eNB 102 about completion of group HO at 318. The source eNB 102 can keep or maintain user plane data connection with the UE devices of the D2D/ProSe group 140 until a completion of the D2D/ProSe group HO, especially if the

sub-ms latency is being utilized for the user plane. UE network devices could utilize two different RF-chains to enable this operation.

[0069] At 320, the source eNB 102 can complete any remaining user plane data transmission and then releases the user plane data connection with the devices. For example, the source eNB 102 can complete any UL plane data transmissions in a buffer or queue and release the UL connection with the UEs in the D2D/ProSe group 140.

[0070] In another embodiment, if the D2D/ProSe group 140 HO fails, in which one or more UE devices of the D2D/ProSe group 140 are not handed over to the target eNB 104 as planned different operations can be generated. For example, the source eNB 102 could run a timer or clocking component (not shown) over a certain period or duration of time to detect the D2D/ProSe group HO failure. The timer or countdown can be started once the group HO command is sent at 308 or 310. The timer can be stopped by the source eNB 102 after receiving group HO completion at 316 by a completion message from the target eNB 104 or a UE device of the D2D/ProSe group 140. Expiry of this timer can indicate a failure of group HO.

[0071] Additionally or alternatively, the target eNB 104 or the UE device 110 (who could have initiated the D2D/ProSe group HO) can inform the source eNB 102 about failure of the D2D/ProSe group HO. In case of the group HO failure additional operations can be initiated. In one example, the source eNB 102 can ask one or more UE devices (who need immediate HO) to initiate individual HO operation by sending separate regular HO commands to them specifically, in which these commands directly from the source eNB could then trigger the individual HO via the cellular link. These UE devices in this case can then move to target eNB 104 separately or independently of the D2D/ProSe group HO.

[0072] After the HO completion, if rest of the D2D/ProSe group remain with previous eNB (source eNB 102), the source eNB 102 can request these devices (with successful HO completion) to leave the D2D/ProSe group 140 in order to better preserve the D2D/ProSe communications on a quality channel link corresponding to the cellular link 236, 218, for example, or D2D/ProSe link 130.

[0073] In another example, the source eNB can attempt to form a new D2D/ProSe group (in target eNB 104) for the UE devices before moving these devices to the target eNB 104. The source eNB 102 can negotiate with the target eNB 104 to allow or enable these UE devices (who need immediate HO) to be connected to the new Group during HO or before HO. This could ensure a lower latency on D2D/ProSe interface

communications during HO. One use case for this situation is where one or more UE devices (e.g., vehicles from the D2D/ProSe group 140 take right or left turn (or take an exit from highway) at a cell boundary, while other vehicles are continuing straight on the road/highway.

[0074] Referring to **FIG. 4**, illustrated another example process flow 400 for a group handover operation within a wireless communication network environment in accordance with various aspects or embodiments described herein. The method 400 initiates at 402 with one or more UEs (e.g., UEs 110-118) initiating a group communication mode by forming a D2D/ProSe group (e.g., group 140). A serving/source eNB 102 can assign a resource pool for D2D/ProSe interface group communication between members of the group, which can be based on a resource pool including IDs of the individual members and configurations for being assisted by the source eNB 102 or other eNB. A group leader (e.g., UE 116) can be selected or designated by the eNB 102, which can then coordinate D2D/ProSe group communication among the group as a facilitator, relay, or gateway for data.

[0075] At 404, the group leader 116 can assist/coordinate monitoring of aggregate link qualities in the group 140 with source eNB 102 or neighboring eNBs 104, 212. UEs of the group 140 can send measurement reports to the group leader 116 using D2D/ProSe interface communication channel / link 130 as well as the resource pool provided for the eNB 102, for example.

[0076] At 406, a group HO trigger can be detected by a UE 110 or 116, and the UE device 110 or 116 can request source eNB 102 for a D2D/ProSe group HO.

[0077] At 408, the source eNB 102 can receive a group aggregate measurement report(s) via UE group leader 116 and select the target eNB 104 based on the report(s).

[0078] At 410, the source eNB 102 can coordinate with the target eNB 104 by sending contexts of UE devices (e.g., one or more ids, configuration data, or the like) and a D2D/ProSe interface configuration, such as group data, members of the group, or the like. A D2D/ProSe group HO can occur or be formed at the target by the target eNB 104 sending a D2D/ProSe interface reconfiguration information such as a new resource pool for D2D/ProSe interface group communications, which can be valid at least until successful completion of the D2D/ProSe group HO and possibly thereafter. A cellular interface HO occurs with the target eNB 104 sending cellular interface radio resource configuration (RRC) to one or more of the D2D/ProSe group.

[0079] At 412, the source eNB 102 can further send an HO command to the D2D/ProSe group and cellular interface radio reconfiguration information can be sent from the target eNB 104.

[0080] At 414, the UEs of D2D/ProSe group 140 can start D2D/ProSe communication on new resource pool indicated in the HO command. The UEs can then synchronize (sync) in DL with the target eNB 104 and can receive system information, as a result. The group leader 116 can perform random access, obtain a timing advance (TA) value and synchronize in the UL with the target eNB 104. The UE group leader 116 can further communicate the TA value to D2D/ProSe group UEs to enable each of them to individually synchronize with the target eNB 104 without further performing random access themselves.

[0081] At 416, the group leader 116 can send reconfiguration complete message to target eNB 104. The target eNB, in turn, can then indicate to the core network or eNB 102 about completion of the D2D/ProSe group HO.

[0082] Referring to **FIG. 5**, illustrates a process flow for the case where the completion of all UEs of the D2D/ProSe group is not a complete success, but a partial success where only some of the UEs of the D2D/ProSe group handover. FIG. 5 can further operation as an extension of FIG. 4, for example, or independently.

[0083] At 502, in response to a partial D2D/ProSe group HO failure, the group leader, the source eNB 102 or the target eNB 104 can inform at least one of the other devices of the partial failure, such as by informing the group leader, a UE device member of the D2D/ProSe group, the source eNB or the target eNB or any combination thereof.

[0084] At 504, a termination of the D2D/ProSe group HO can occur and all UEs of the D2D/ProSe group could return to the source eNB. Alternatively or additionally, successful UE devices that have been handed over to the target eNB 104 successfully can remain with the target eNB and unsuccessful UE devices could leave D2D/ProSe group, either by request or be made to. The unsuccessful UEs could then remain or return to the source eNB 102 or other more suitable eNB, at which point they can form a new second D2D/ProSe group with different members or use common resources available to both source and target eNBs to maintain the D2D/ProSe group with different serving eNBs 102 and 104, for example.

[0085] In the case of a partial group HO failure, a partial group failure message can be communicated by one or more UEs of the D2D/ProSe group such as the group

leader 116, the failing UE 110, for example, the target eNB 104 or by the source eNB 102. This can occur where some of the devices successfully complete HO after receiving the group HO command, while others fail to complete HO (e.g., say due to channel degradation with target eNB 104 after group HO initiation). If one of the UE devices indicates to the group lead 116 that it is HO failure (HOF), in one embodiment all the devices including the group leader 116 could terminate the HO and goes back to or remain connected to the source eNB 102.

[0086] In another embodiment, one of the UE devices can indicate to the group lead 116 that it is HOF, partial group HO is performed where those devices HO successfully are the only remaining member(s) in the group 140. The devices that HOF can then be forced to leave the group 140 or requested to do so. D2D/ProSe signaling can then be used for those devices to leave the group 140.

[0087] In another embodiment, the target BS 104 can inform the source BS 102 about partial group HO, as the target BS 104 finds out about the case when all devices do not move to it successfully. In that case, the options or embodiment above can apply where the eNB 104 informs one or more network devices, and either the group HO is terminate or UEs failing to complete the HO can return to the source eNB 102.

[0088] Additionally or alternately, the group leader 116 can inform the target eNB 104 as well as the source eNB 102 about the partial HO case. Particularly if all devices do not perform RA with the target eNB for UL time synchronization (as discussed earlier), the group leader 116 could assess and inform eNBs 102, 104 about the partial Group HO case.

[0089] In another embodiment, if the D2D/ProSe interface resource is common to both eNBs 102, 104, the successful UE devices and failed UE devices can continue the group communication over D2D/ProSe link as a D2D/ProSe group. Otherwise, UE devices that successfully moved to target BS can remain as a group or the target eNB 104 can ask them to join a nearby or different D2D/ProSe group. The failed UE devices can form a new group under the source eNB 102 or the source eNB 102 can ask them to join an existing nearby group under the source eNB.

[0090] **FIG. 6** illustrates another process flow in accordance with various embodiments. The method 600, for example, initiates at 602 with one or more of a UE or eNB processing cellular network communication(s) on a cell network channel or link to enable a formation of a D2D/ProSe group such as with a resource pool or one or more configuration parameters that enable a D2D/ProSe communication via D2D/ProSe

channels. At 604, the method 600 continues with controlling D2D/ProSe communications on the D2D/ProSe channels and controlling a D2D/ProSe group HO based on communications on the cell network channels, the D2D/ProSe communications on the D2D/ProSe channels, or one or more other predetermined criteria. The predetermined criteria can comprise one or more of the following: an aggregated measurement report or data therein, a worse UE measurement of a channel link quality value from the D2D/ProSe group, measurements from the plurality of UEs of the D2D/ProSe group, an average measurement value of measurements from the D2D/ProSe group, one or more measurement reports from a UE group leader of the plurality of UEs of the D2D/ProSe group requesting the D2D/ProSe group handover, a link quality threshold corresponding to one or more network channels related to the plurality of UEs in the D2D/ProSe group, a group threshold related to the link quality threshold, a neighboring cell quality threshold in a comparison with the group threshold or the link quality threshold, or one or more requests for the D2D/ProSe group handover or the cellular handover for a UE of the D2D/ProSe group.

[0091] Referring to **FIG. 7**, illustrated is another wireless network communications environment for a UE or other network device (e.g., eNB) configured to form a D2D/ProSe group and generate a group handover that can be utilized according to various aspects or embodiments. The UEs 110, 118 and 116 can comprise additional components including the D2D/ProSe interface component 232, the cellular network interface component 234, as described above, in addition to a channel quality measurement component 710 and a D2D/ProSe HO component 720. Further, the eNB 102 or any other eNB as discussed can comprise the D2D/ProSe interface component 240, the cellular network interface component 242, a channel quality measurement component 730, a D2D/ProSe HO component 740, and a HO command component 750.

[0092] The channel quality measurement components 710, 730 can generate, process, receive or transmit measurements of the cell network channels / links and D2D/ProSe channels links, and provide the measurements to a group leader UE (e.g., 116) via the one or more D2D/ProSe channels, or to an eNB 102 via the one or more network channels as the group leader UE via the cellular network interface components 234, 242.

[0093] The D2D/ProSe handover components 720, 740 can designate a UE group leader on behalf of the plurality of UEs of the D2D/ProSe group 140 to aggregate

measurements from the plurality of UEs of the D2D/ProSe group 140 and communicate one or more resource pools to other UEs of the D2D/ProSe group to enable the D2D/ProSe communications, or communicate the D2D/ProSe communications to a UE of the D2D/ProSe group requesting an individual handover via the cellular handover in response to not detecting a target eNB 102 that is suitable for the individual UE 110 or 118. Further, the D2D/ProSe handover components 720, 740 can complete any uplink (UL) plane data transmission in a buffer, release a UL connection with the plurality of UEs in the D2D/ProSe group after the D2D/ProSe group handover. The D2D/ProSe handover components 720, 740 can further determine whether the D2D/ProSe group 140 continues to utilize a current D2D/ProSe channel of the one or more D2D/ProSe channels or a new D2D/ProSe channel based on measurements of the one or more D2D/ProSe channels from the D2D/ProSe group or information from the target eNB related to the current D2D/ProSe channel within a coverage area of the target eNB.

[0094] The handover command component 750 can generate a group handover command and enable communication of the group handover command to a UE group leader 116 of the D2D/ProSe group 140 or the plurality of UEs of the D2D/ProSe group, wherein the group handover command comprises at least one of: an indication of the D2D/ProSe group handover to a target eNB, a radio resource configuration (RRC) information related to the cellular network communications, or other RRC information related to the D2D/ProSe communications, wherein the other RRC information comprises a radio resource pool allocated to the D2D/ProSe group to enable the D2D/ProSe communications via an unlicensed band or a licensed band. The handover command component 750 can also communicate the radio resource pool to the UE group leader or the plurality of UEs of the D2D/ProSe group that enables the D2D/ProSe communications after receiving the D2D/ProSe group handover from a source eNB and time synchronizing with the plurality of UEs of the D2D/ProSe group.

[0095] In some embodiments, there can be scenarios, especially with very large D2D/ProSe groups 140, that even though UE devices 110, 116, 118, or other UEs belong to the same group 140, they can also connect to the network via different cells or eNBs 102, 212 and their respective coverage areas. In this case, handover can be performed individually to each UE device 110, 116, 118 in the group, or a group handover can occur with some devices (e.g., 110 and 116) along with cellular handover, while only an individual cellular handover occurs with other UE devices 118. After the individual handover is performed, the UE devices 110, 116, 118 can continue using

the same channels for D2D/ProSe communication between them or else a new channel for group communication is provided by the network to all devices in the group 140.

[0096] In another embodiment, a UE device 118 can report a measurement indicating that a handover is needed, such as from the source eNB 102 to a target eNB 220, for example. The source eNB 102 can decide to handover the individual UE device 11. At this point in time, the source eNB 102 can also decide if the group 140 can continue using the current D2D/ProSe group channel 130 or if a new one should be formed. This decision can be based on: a. Measurements on D2D/ProSe channel 130 provided by the UE device 118 performing or initiating the handover. If channel quality is bad, a new D2D/ProSe channel can be generated for the group 140; or b. a request can be sent to the target eNB 212 to check if the channel currently used can be used in the new cell without creating too much interference or interference beyond a certain threshold, such as a signal to noise threshold, an RSSI threshold, or the like. If the same D2D/ProSe channel can be used, the UE device 118 can resume D2D/ProSe communication after individual handover. If a new channel is needed, the target eNB 212 can send a response message to the source eNB 102 with the new D2D/ProSe group channel information. The source eNB 102 then can reconfigure all the UE devices of the group 140 that are connected to that base station. In order to avoid the target eNB 212 allocating resources that cannot be agreed by the source eNB 102, the source eNB 102 can provide a list of current channel status in the source cell (e.g., cell area / zone 204 of FIG. 2), such as which bands are being used, which channels are free, or other related criteria. This could be used as a recommendation to the target eNB 212, for example, to allocate proper D2D/ProSe channels.

[0097] To provide further context for various aspects or embodiments of the disclosed subject matter, **FIG. 8** illustrates a block diagram of an embodiment of access (user) equipment 126, 130 related to access of a network (e.g., base station, wireless access point, femtocell access point, and so forth) that can enable and/or exploit features or aspects disclosed herein.

[0098] Access equipment, UE and/or software 110, 116, 102, 104 or other network device related to access of a network that can receive and transmit signal(s) from and to wireless devices, wireless ports, wireless routers, etc. through segments 802₁-802_a (where 'a' is a positive integer). Segments 802₁-802_a can be internal and/or external to access equipment and/or software 110, 116, 102, 104 related to access of a network, and can be controlled by a monitor component 804 and an antenna component 806.

Monitor component 804 and antenna component 806 can couple to communication platform 808, which can include electronic components and associated circuitry that provide for processing and manipulation of received signal(s) and other signal(s) to be transmitted.

[0099] In an aspect, communication platform 808 includes a receiver/transmitter 810 that can convert analog signals to digital signals upon reception of the analog signals, and can convert digital signals to analog signals upon transmission. In addition, receiver/transmitter 810 can divide a single data stream into multiple, parallel data streams, or perform the reciprocal operation. Coupled to receiver/transmitter 810 can be a multiplexer/demultiplexer 812 that can facilitate manipulation of signals in time and frequency space. Multiplexer/demultiplexer 812 can multiplex information (data/traffic and control/signaling) according to various multiplexing schemes such as time division multiplexing, frequency division multiplexing, orthogonal frequency division multiplexing, code division multiplexing, space division multiplexing. In addition, multiplexer/demultiplexer component 812 can scramble and spread information (e.g., codes, according to substantially any code known in the art, such as Hadamard-Walsh codes, Baker codes, Kasami codes, polyphase codes, and so forth).

[00100] A modulator/demodulator 814 is also a part of communication platform 808, and can modulate information according to multiple modulation techniques, such as frequency modulation, amplitude modulation (e.g., M-ary quadrature amplitude modulation, with M a positive integer); phase-shift keying; and so forth).

[00101] Access equipment and/or software 110, 116, 102, 104 related to access of a network also includes a processor 816 configured to confer, at least in part, functionality to substantially any electronic component in access equipment and/or software 110, 116, 102, 104. In particular, processor 816 can facilitate configuration of access equipment and/or software 110, 116, 102, 104 through, for example, monitor component 804, antenna component 806, and one or more components therein. Additionally, access equipment and/or software 110, 116, 102, 104 can include display interface 818, which can display functions that control functionality of access equipment and/or software 110, 116, 102, 104, or reveal operation conditions thereof. In addition, display interface 818 can include a screen to convey information to an end user. In an aspect, display interface 818 can be a liquid crystal display, a plasma panel, a monolithic thin-film based electrochromic display, and so on. Moreover, display interface 818 can include a component (e.g., speaker) that facilitates communication of

aural indicia, which can also be employed in connection with messages that convey operational instructions to an end user. Display interface 818 can also facilitate data entry (e.g., through a linked keypad or through touch gestures), which can cause access equipment and/or software 110, 116, 102, 104 to receive external commands (e.g., restart operation).

[00102] Broadband network interface 820 facilitates connection of access equipment and/or software 110, 116, 102, 104 to a service provider network (not shown) that can include one or more cellular technologies (e.g., third generation partnership project universal mobile telecommunication system, global system for mobile communication, and so on) through backhaul link(s) (not shown), which enable incoming and outgoing data flow. Broadband network interface 820 can be internal or external to access equipment and/or software 110, 116, 102, 104, and can utilize display interface 818 for end-user interaction and status information delivery.

[00103] Processor 816 can be functionally connected to communication platform 808 and can facilitate operations on data (e.g., symbols, bits, or chips) for multiplexing/demultiplexing, such as effecting direct and inverse fast Fourier transforms, selection of modulation rates, selection of data packet formats, inter-packet times, and so on. Moreover, processor 816 can be functionally connected, through data, system, or an address bus 822, to display interface 818 and broadband network interface 820, to confer, at least in part, functionality to each of such components.

[00104] In access equipment and/or software 110, 116, 102, 104, memory 824 can retain location and/or coverage area (e.g., macro sector, identifier(s)) access list(s) that authorize access to wireless coverage through access equipment and/or software 110, 116, 102, 104, sector intelligence that can include ranking of coverage areas in the wireless environment of access equipment and/or software 110, 116, 102, 104, radio link quality and strength associated therewith, or the like. Memory 824 also can store data structures, code instructions and program modules, system or device information, code sequences for scrambling, spreading and pilot transmission, access point configuration, and so on. Processor 816 can be coupled (e.g., through a memory bus), to memory 824 in order to store and retrieve information used to operate and/or confer functionality to the components, platform, and interface that reside within access equipment and/or software 110, 116, 102, 104.

[00105] In addition, the memory 824 can comprise one or more machine-readable medium including instructions that, when performed by a machine or component herein

cause the machine to perform acts of the method or of an apparatus or system for concurrent communication using multiple communication technologies according to embodiments and examples described herein.

[00106] As used herein, the term "circuitry" may refer to, be part of, or include an Application Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group), and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit, and/or other suitable hardware components that provide the described functionality. In some embodiments, the circuitry may be implemented in, or functions associated with the circuitry may be implemented by, one or more software or firmware modules. In some embodiments, circuitry may include logic, at least partially operable in hardware.

[00107] Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software. **FIG. 9** illustrates, for one embodiment, example components of an electronic device 900. In embodiments, the electronic device 900 may be, implement, be incorporated into, or otherwise be a part of a user equipment (UE), an evolved NodeB (eNB), or some other electronic device. In some embodiments, the electronic device 900 may include application circuitry 902, baseband circuitry 904, Radio Frequency (RF) circuitry 906, front-end module (FEM) circuitry 908 and one or more antennas 910, coupled together at least as shown. When used in a UE device, FEM circuitry 908 can also include a transmit and receive path for device-to-device communications received directly from another UE device, without traveling through the E-UTRAN (e.g. ProSe interface circuitry). When used in a UE device, FEM circuitry 808 can also include a transmit and receive path for cellular communications received from the E-UTRAN or E-UTRAN (e.g. cellular interface circuitry). In other embodiments, the above described circuitries can be included in a plurality of devices (e.g., an eNB according to a cloud-RAN (C-RAN) implementation).

[00108] The application circuitry 902 may include one or more application processors. For example, the application circuitry 902 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) may include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors may be coupled with and/or may include memory/storage and may be configured to execute instructions stored in the memory/storage to enable various applications and/or operating systems to run on the system.

[00109] The baseband circuitry 904 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 904 may include one or more baseband processors and/or control logic to process baseband signals received from a receive signal path of the RF circuitry 906 and to generate baseband signals for a transmit signal path of the RF circuitry 906. Baseband processing circuitry 904 may interface with the application circuitry 902 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 906. For example, in some embodiments, the baseband circuitry 904 may include a second generation (2G) baseband processor 904a, third generation (3G) baseband processor 904b, fourth generation (4G) baseband processor 904c, and/or other baseband processor(s) 904d for other existing generations, generations in development or to be developed in the future (e.g., fifth generation (5G), 6G, etc.). The baseband circuitry 904 (e.g., one or more of baseband processors 904a-d) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 906. The radio control functions may include, but are not limited to, signal modulation/demodulation, encoding/decoding, radio frequency shifting, etc. In some embodiments, modulation/demodulation circuitry of the baseband circuitry 904 may include Fast-Fourier Transform (FFT), precoding, and/or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 904 may include convolution, tail-biting convolution, turbo, Viterbi, and/or Low Density Parity Check (LDPC) encoder/decoder functionality. Embodiments of modulation/demodulation and encoder/decoder functionality are not limited to these examples and may include other suitable functionality in other embodiments.

[00110] In some embodiments, the baseband circuitry 904 may include elements of a protocol stack such as, for example, elements of an evolved universal terrestrial radio access network (EUTRAN) protocol including, for example, physical (PHY), media access control (MAC), radio link control (RLC), packet data convergence protocol (PDCP), and/or radio resource control (RRC) elements. A central processing unit (CPU) 904e of the baseband circuitry 904 may be configured to run elements of the protocol stack for signaling of the PHY, MAC, RLC, PDCP and/or RRC layers. In some embodiments, the baseband circuitry may include one or more audio digital signal processor(s) (DSP) 904f. The audio DSP(s) 904f may include elements for

compression/decompression and echo cancellation and may include other suitable processing elements in other embodiments.

[00111] The baseband circuitry 904 may further include memory/storage 904g. The memory/storage 904g may be used to load and store data and/or instructions for operations performed by the processors of the baseband circuitry 904. Memory/storage for one embodiment may include any combination of suitable volatile memory and/or non-volatile memory. The memory/storage 904g may include any combination of various levels of memory/storage including, but not limited to, read-only memory (ROM) having embedded software instructions (e.g., firmware), random access memory (e.g., dynamic random access memory (DRAM)), cache, buffers, etc. The memory/storage 904g may be shared among the various processors or dedicated to particular processors.

[00112] Components of the baseband circuitry may be suitably combined in a single chip, a single chipset, or disposed on a same circuit board in some embodiments. In some embodiments, some or all of the constituent components of the baseband circuitry 904 and the application circuitry 902 may be implemented together such as, for example, on a system on a chip (SOC).

[00113] In some embodiments, the baseband circuitry 904 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 904 may support communication with an evolved universal terrestrial radio access network (EUTRAN) and/or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), a wireless personal area network (WPAN). Embodiments in which the baseband circuitry 904 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

[00114] RF circuitry 906 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 906 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 906 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 908 and provide baseband signals to the baseband circuitry 904. RF circuitry 906 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 904 and provide RF output signals to the FEM circuitry 908 for transmission.

[00115] In some embodiments, the RF circuitry 906 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 906 may include mixer circuitry 906a, amplifier circuitry 906b and filter circuitry 906c. The transmit signal path of the RF circuitry 906 may include filter circuitry 906c and mixer circuitry 906a. RF circuitry 906 may also include synthesizer circuitry 906d for synthesizing a frequency for use by the mixer circuitry 906a of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 906a of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 908 based on the synthesized frequency provided by synthesizer circuitry 906d. The amplifier circuitry 906b may be configured to amplify the down-converted signals and the filter circuitry 906c may be a low-pass filter (LPF) or band-pass filter (BPF) configured to remove unwanted signals from the down-converted signals to generate output baseband signals. Output baseband signals may be provided to the baseband circuitry 904 for further processing. In some embodiments, the output baseband signals may be zero-frequency baseband signals, although this is not a requirement. In some embodiments, mixer circuitry 906a of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[00116] In some embodiments, the mixer circuitry 906a of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 906d to generate RF output signals for the FEM circuitry 908. The baseband signals may be provided by the baseband circuitry 904 and may be filtered by filter circuitry 906c. The filter circuitry 906c may include a low-pass filter (LPF), although the scope of the embodiments is not limited in this respect.

[00117] In some embodiments, the mixer circuitry 906a of the receive signal path and the mixer circuitry 906a of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and/or upconversion respectively. In some embodiments, the mixer circuitry 906a of the receive signal path and the mixer circuitry 906a of the transmit signal path may include two or more mixers and may be arranged for image rejection (e.g., Hartley image rejection). In some embodiments, the mixer circuitry 906a of the receive signal path and the mixer circuitry 906a may be arranged for direct downconversion and/or direct upconversion, respectively. In some embodiments, the mixer circuitry 906a of the receive signal path and the mixer circuitry 906a of the transmit signal path may be configured for super-heterodyne operation.

[00118] In some embodiments, the output baseband signals and the input baseband signals may be analog baseband signals, although the scope of the embodiments is not limited in this respect. In some alternate embodiments, the output baseband signals and the input baseband signals may be digital baseband signals. In these alternate embodiments, the RF circuitry 906 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 904 may include a digital baseband interface to communicate with the RF circuitry 906.

[00119] In some dual-mode embodiments, a separate radio IC circuitry may be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect.

[00120] In some embodiments, the synthesizer circuitry 906d may be a fractional-N synthesizer or a fractional $N/N+1$ synthesizer, although the scope of the embodiments is not limited in this respect as other types of frequency synthesizers may be suitable. For example, synthesizer circuitry 906d may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[00121] The synthesizer circuitry 906d may be configured to synthesize an output frequency for use by the mixer circuitry 906a of the RF circuitry 906 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 906d may be a fractional $N/N+1$ synthesizer.

[00122] In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although that is not a requirement. Divider control input may be provided by either the baseband circuitry 904 or the applications processor 902 depending on the desired output frequency. In some embodiments, a divider control input (e.g., N) may be determined from a look-up table based on a channel indicated by the applications processor 902.

[00123] Synthesizer circuitry 906d of the RF circuitry 906 may include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider may be a dual modulus divider (DMD) and the phase accumulator may be a digital phase accumulator (DPA). In some embodiments, the DMD may be configured to divide the input signal by either N or $N+1$ (e.g., based on a carry out) to provide a fractional division ratio. In some example embodiments, the DLL may include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-flop. In these embodiments, the delay elements may be configured to break a VCO period up into N_d equal packets of phase, where N_d is the number of delay elements in

the delay line. In this way, the DLL provides negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

[00124] In some embodiments, synthesizer circuitry 906d may be configured to generate a carrier frequency as the output frequency, while in other embodiments, the output frequency may be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency) and used in conjunction with quadrature generator and divider circuitry to generate multiple signals at the carrier frequency with multiple different phases with respect to each other. In some embodiments, the output frequency may be a LO frequency (fLO). In some embodiments, the RF circuitry 906 may include an IQ/polar converter.

[00125] FEM circuitry 908 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 910, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 906 for further processing. FEM circuitry 908 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 906 for transmission by one or more of the one or more antennas 910.

[00126] In some embodiments, the FEM circuitry 908 may include a TX/RX switch to switch between transmit mode and receive mode operation. The FEM circuitry may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry may include a low-noise amplifier (LNA) to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 906). The transmit signal path of the FEM circuitry 908 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 906), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 910).

[00127] In some embodiments, the electronic device 900 may include additional elements such as, for example, memory/storage, display, camera, sensor, and/or input/output (I/O) interface.

[00128] In some embodiments, the radio frequency (RF) circuitry may be to communicate with one or more UEs in a UE group via a device to device (D2D/ProSe) protocol. The baseband circuitry may be to initiate a group handover request based on aggregate link quality of the one or more UEs in the UE group.

[00129] In some embodiments, the baseband circuitry may be to identify a target BS based on aggregate link quality of one or more UEs in a UE group. The RF circuitry may be to transmit a handover command to one or more UEs in the UE group.

[00130] **FIG. 10** further illustrates an example architecture that supports group mode operation in UE devices by providing network assistance in the formation and maintenance of UE device groups. The architecture of **FIG. 10** can be adapted for use with ProSe function in both the UE device and the network as part of any D2D communications, components or operations discussed herein. The architecture includes a network 1000 that wirelessly communicates with a plurality of UE devices 110, 116, or other networked devices. The network 1000 can include E-UTRAN equipment, ProSe function circuitry 1010 as part of or comprising the D2D or ProSe interface components (e.g., 232 or 240), and an evolved packet core (EPC) network. The ProSe function circuitry 1010 functions in a manner similar to or with other components discussed herein (e.g., the group HO component or D2D labeled components), and can be an extension of the ProSe function.

[00131] The UE devices described herein can further include UE ProSe circuitry 1030. UE ProSe circuitry 1030 can be configured to interact with the group management circuitry 1010 to obtain support from the network for setting up group communication. Each UE device can include PC5 interface circuitry (not shown) that functions in a manner similar to D2D interface components as following the PC5 protocol as detailed further in TS 23.303 of 3GPP specifications.

[00132] The network (e.g., E-UTRAN or EPC network) can allocate resources on a per group basis using group information about UE devices and groups that is maintained by the ProSe function circuitry 1010. The network 1000 can utilize the group management circuitry 1010 to facilitate efficient formation and management of groups throughout the entirety of the covered region. The ProSe function circuitry 1010 can allow for the forming and managing of groups in the link layer (e.g., by the E-UTRAN) which optimizes resource allocation and access methods leading to reduced latency. This link layer based approach can address the deficiencies in handling group management in the application layer. For the purposes of this description, the example network and devices can also be considered in the context of cooperative driving or other network cooperative management operations for network devices. However, it is to be understood that the network assisted group management techniques described

herein are equally applicable to groups of UE devices that utilize D2D communication to cooperate in any way.

[00133] Several groups (1-n) of UE devices 1005 are shown. While only two or three UE devices are shown in each group in **FIG. 10**, typically multiple UE devices can be members of the same group. Each UE device can communicate with the E-UTRAN by way of an LTE-Uu interface and with other UE devices in a group by way of a PC5 interface. The UE ProSe circuitry 1030 in each UE device can be configured to generate, transmit, receive, and process group messages according to predetermined rules that apply to a UE device operating in group mode. Group messages are generated based on responsibilities that are assigned to a UE device by virtue of the UE device's membership in a group. The UE device's actions are controlled to some extent based on group messages received from other group members. Thus it can be said that group messages communicate information between group members that is used by the group members to coordinate actions of the group members. The UE devices in a group are all configured according to the same group configuration data which is generated based on group information maintained by the ProSe function circuitry 1010.

[00134] Examples of group messages can include sensor data generated by a UE device's onboard sensors (not shown). The sensor data can indicate the UE device's speed, trajectory, and other information that is useful in coordinating synchronized movement with other group members. Using device-to-device communication of sensor data enables the data to be shared in near real-time, which facilitates the synchronization effort. Event notifications can also be communicated in group messages. Event notifications can notify other group members that the UE device is going to take some action like stopping, steering, and so on. Group messages can also pertain to the UE device's membership in the group, such as alerting the group members that the UE device is joining the group or that the UE device is leaving the group and should no longer be involved in synchronization of movement between the UE devices in the group. Group messages can be exchanged between group members as prescribed by configuration data received from the ProSe function circuitry 1010.

[00135] The UE device 1005 can receive group configuration data from the E-UTRAN on the LTE-Uu interface, for example, and configure various aspects of operation of the PC5 interface or D2D interface component, for example, in order to communicate group messages within a group to which the UE device 1005 belongs. For example, the UE device 1005 can configure the PC5 interface circuitry 140 to utilize a frequency band

specified in the configuration data that is assigned to the group. The UE device can also configure the PC5 interface circuitry to use a particular transmission mode (e.g., scheduled or contention-based) specified by the configuration data that is used by the group members. The transmission mode defines the protocol that the UE device should use in order to access the allocated resources. The transmission mode may be contention-based (the UE devices listen before transmitting) or scheduled (each UE device is given a slot, such as a message slot or communication band/duration).

[00136] Recall that application layer approaches to group management do not always support the allocation of resources to a group of UE devices. In contrast, the ProSe function circuitry 1010 can initiate or enable the network 1000 to allocate resources on a group basis. This means that at its creation Group 1 is allocated a certain set of resources, such as a group of resource blocks, which can then follow Group 1. As the membership of Group 1 changes the resources allocated to Group 1 remain the same unless the resources are explicitly changed by the network 1000. This means that an individual UE device that is a member of a group and seeks to send a group message to another group member does not need to obtain, from the network 1000, the resources to do so. The UE device may use the resources allocated to all group members throughout its membership in the group. This reduces latency and improves the reliability of the communication between group members.

[00137] The ProSe function circuitry 1010 controls allocation of resources amongst various groups of UE devices. The ProSe function circuitry 1010 is illustrated as shared between the E-UTRAN and the core network because some of the functions of the ProSe function circuitry 1010 can be distributed out to individual eNBs depending on the individual eNB capabilities or desired level of core network control over group management. For example, in one embodiment, the eNB may allocate radio resources using information from the core network and also group information maintained by the ProSe function circuitry 1010. In another embodiment, the core network may determine the radio resource allocation for the group.

[00138] In general, the ProSe function circuitry 1010 generates instructions that, when executed by the core network, cause the collection and storage of “group information” 1015. Group information is information about groups of UE devices. The ProSe function circuitry 1010 generates instructions that, when executed the E-UTRAN RF circuitry, causes the E-UTRAN RF circuitry to i) communicate with the EPC network to obtain the group information for a group that can be used to define the resources to be

allocated to the group and ii) transmit the configuration data, including the allocated resources, to the LTE-Uu interface circuitry of the UE devices in a group.

[00139] As it employed in the subject specification, the term “processor” can refer to substantially any computing processing unit or device including, but not limited to including, single-core processors; single-processors with software multithread execution capability; multi-core processors; multi-core processors with software multithread execution capability; multi-core processors with hardware multithread technology; parallel platforms; and parallel platforms with distributed shared memory. Additionally, a processor can refer to an integrated circuit, an application specific integrated circuit, a digital signal processor, a field programmable gate array, a programmable logic controller, a complex programmable logic device, a discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions and/or processes described herein. Processors can exploit nano-scale architectures such as, but not limited to, molecular and quantum-dot based transistors, switches and gates, in order to optimize space usage or enhance performance of mobile devices. A processor may also be implemented as a combination of computing processing units.

[00140] In the subject specification, terms such as “store,” “data store,” data storage,” “database,” and substantially any other information storage component relevant to operation and functionality of a component and/or process, refer to “memory components,” or entities embodied in a “memory,” or components including the memory. It is noted that the memory components described herein can be either volatile memory or nonvolatile memory, or can include both volatile and nonvolatile memory.

[00141] By way of illustration, and not limitation, nonvolatile memory, for example, can be included in a memory, non-volatile memory (see below), disk storage (see below), and memory storage (see below). Further, nonvolatile memory can be included in read only memory, programmable read only memory, electrically programmable read only memory, electrically erasable programmable read only memory, or flash memory. Volatile memory can include random access memory, which acts as external cache memory. By way of illustration and not limitation, random access memory is available in many forms such as synchronous random access memory, dynamic random access memory, synchronous dynamic random access memory, double data rate synchronous dynamic random access memory, enhanced synchronous dynamic random access

memory, Synchlink dynamic random access memory, and direct Rambus random access memory. Additionally, the disclosed memory components of systems or methods herein are intended to include, without being limited to including, these and any other suitable types of memory.

[00142] Examples can include subject matter such as a method, means for performing acts or blocks of the method, at least one machine-readable medium including instructions that, when performed by a machine cause the machine to perform acts of the method or of an apparatus or system for concurrent communication using multiple communication technologies according to embodiments and examples described herein.

[00143] Example 1 is an apparatus configured to be employed by a user equipment (UE), the apparatus comprising: a cellular network interface component configured to generate and process cellular network communications on one or more network channels to enable a cellular handover in a wireless network and a formation of a device-to-device (D2D) group with one or more additional UEs via one or more D2D channels that communicatively couple the D2D group; and a ProSe interface component, communicatively coupled to the cellular network interface component, configured to generate and process D2D communications on the one or more D2D channels among the D2D group, and enable a D2D group handover based on at least one of: the cellular network communications or the D2D communications.

[00144] Example 2 includes the subject matter of Examples 2, including or omitting any elements, further comprising: a channel quality measurement component configured to generate measurements of the one or more network channels and the one or more D2D channels, and provide the measurements to a group leader UE of the one or more additional UEs via the one or more D2D channels, or to an eNB via the one or more network channels as the group leader UE via the cellular network interface component.

[00145] Example 3 includes the subject matter of any of Examples 1-2, including or omitting any elements, further comprising: a D2D handover component configured to control channel quality measurement reports from the one or more additional UEs of the D2D group and enable the D2D group handover between a source evolved NodeB (eNB) and a target eNB by processing or generating a D2D group handover trigger, wherein the D2D group handover comprises a handover operation of the cellular network communications and the D2D communications.

[00146] Example 4 includes the subject matter of any of Examples 1-3, including or omitting any elements, wherein the D2D handover component is further configured to generate a group handover request to initiate the D2D group handover in response to a channel link quality of at least one of: the one or more network channels with a source eNB or between the one or more additional UEs and the source eNB failing to satisfy a channel link quality threshold value for a period of time, in response to a determination that the channel link quality for a predetermined portion of the one or more additional UEs of the D2D group fails to satisfy the channel link quality threshold value for the period of time, or in response to another determination that the predetermined portion of the one or more additional UEs of the D2D group satisfy another channel link quality threshold value for the period of time with a neighbor network of the target eNB that is greater than the channel link quality with the source eNB.

[00147] Example 5 includes the subject matter of any of Examples 1-4, including or omitting any elements, wherein the cellular network interface component comprises a same front end module as the ProSe interface component and is further configured to process a communication command from a source eNB that identifies an individual UE handover or the D2D group handover to a target eNB, wherein the communication command includes a radio resource configuration information corresponding to at least one of: the one or more network channels via the cellular network interface component or the one or more D2D channels via the ProSe interface component for communication of a resource pool that allocates group communications to the D2D group.

[00148] Example 6 includes the subject matter of any of Examples 1-5, including or omitting any elements,, wherein the cellular network interface component is further configured to process a different resource pool that allocates a set of group communication resources to the one or more additional UEs of the D2D group, and in response to a reception of the different resource pool, or after a completion of the D2D group handover from a source eNB to a target eNB, based on whether the different resource pool comprises an unlicensed band or an unlicensed band, initiate utilizing the different resource pool to communicatively couple the one or more additional UEs of the D2D group or one or more different UEs of a different D2D group.

[00149] Example 7 includes the subject matter of any of Examples 1-6, including or omitting any elements, wherein the cellular network interface component is further configured to process a different resource pool that allocates a set of group

communication resources to the one or more additional UEs of the D2D group after a time synchronization with a target eNB.

[00150] Example 8 includes the subject matter of any of Examples 1-7, including or omitting any elements, wherein the ProSe interface component is further configured to process a communication command from a source eNB that identifies a UE of the D2D group for an individual UE handover or the D2D group for the D2D group handover to a target eNB, and in response to the communication command, perform a random access to obtain an uplink (UL) timing advance (TA) value that enables a UL synchronization with the target eNB or communicate via the one or more D2D channels to the UE of the D2D group to perform the random access, and further assist other UEs of the D2D group to acquire the UL synchronization by communicating the UL TA value via the one or more D2D channels.

[00151] Example 9 includes the subject matter of any of Examples 1-8, including or omitting any elements, wherein the ProSe interface component is further configured to communicate a failure notification to a UE group leader of the D2D group in response to failing to complete the D2D group handover to a target eNB, to terminate the D2D group handover or inform the target eNB or a source eNB of a partial D2D group handover in response to at least one of the one or more additional UEs of the D2D group failing to complete the D2D group handover to the target eNB, or form a second D2D group of UEs communicatively coupled together via the one or more D2D channels and the source eNB in response to failing to complete the D2D group handover to the target eNB.

[00152] Example 10 is an apparatus configured to be employed by evolved NodeB (eNB) comprising: a cellular network interface component configured to generate and process cellular network communications on one or more network channels to enable a cellular handover in a wireless network and a formation of a device-to-device (D2D) group with a plurality of UEs via one or more D2D channels that communicatively couple the plurality of UEs of the D2D group; and a ProSe interface component, communicatively coupled to the cellular network interface component, configured to enable D2D communications on the one or more D2D channels among the D2D group, and enable a D2D group handover based on a set of predetermined criteria.

[00153] Example 11 includes the subject matter of Example 10, including or omitting any elements, further comprising: a channel quality measurement component further configured to receive an aggregated measurement report, and a D2D group handover

request or an individual handover request for the cellular handover, from at least one UE of the plurality of UEs in the D2D group.

[00154] Example 12 includes the subject matter of any of Examples 10-11, including or omitting any elements, wherein the set of predetermined criteria comprises at least one of: a worse UE measurement of a channel link quality value, measurements from the plurality of UEs of the D2D group, an average measurement value of measurements from the D2D group, or one or more measurement reports from a UE group leader of the plurality of UEs of the D2D group requesting the D2D group handover.

[00155] Example 13 includes the subject matter of any of Examples 10-12, including or omitting any elements, further comprising: a D2D handover component configured to designate a UE group leader on behalf of the plurality of UEs of the D2D group to aggregate measurements from the plurality of UEs of the D2D group and communicate one or more resource pools to other UEs of the D2D group to enable the D2D communications, or communicate the D2D communications to a UE of the D2D group requesting an individual handover via the cellular handover in response to not detecting a target eNB that is suitable for the UE.

[00156] Example 14 includes the subject matter of any of Examples 10-13, including or omitting any elements, wherein the D2D handover component is further configured to complete any uplink (UL) plane data transmission in a buffer, release a UL connection with the plurality of UEs in the D2D group after the D2D group handover, and determine whether the D2D group continues to utilize a current D2D channel of the one or more D2D channels or a new D2D channel based on measurements of the one or more D2D channels from the D2D group or information from the target eNB related to the current D2D channel within a coverage area of the target eNB.

[00157] Example 15 includes the subject matter of any of Examples 10-14, including or omitting any elements, wherein the set of predetermined criteria comprise at least one of: a link quality threshold corresponding to the one or more network channels related to the plurality of UEs in the D2D group, a group threshold related to the link quality threshold, a neighboring cell quality threshold in a comparison with the group threshold or the link quality threshold, or one or more requests for the D2D group handover or the cellular handover for a UE of the D2D group.

[00158] Example 16 includes the subject matter of any of Examples 10-15, including or omitting any elements, further comprising: a handover command component configured to generate a group handover command and enable communication of the

group handover command to a UE group leader of the D2D group or the plurality of UEs of the D2D group, wherein the group handover command comprises at least one of: an indication of the D2D group handover to a target eNB, a radio resource configuration (RRC) information related to the cellular network communications, or other RRC information related to the D2D communications, wherein the other RRC information comprises a radio resource pool allocated to the D2D group to enable the D2D communications via an unlicensed band or a licensed band.

[00159] Example 17 includes the subject matter of any of Examples 10-16, including or omitting any elements, wherein the handover command component is further configured to communicate the radio resource pool to the UE group leader or the plurality of UEs of the D2D group that enables the D2D communications after receiving the D2D group handover from a source eNB and time synchronizing with the plurality of UEs of the D2D group.

[00160] Example 18 includes the subject matter of any of Examples 10-17, including or omitting any elements, wherein the handover command component is further configured to generate a group handover complete command to a network transmission path in response to a completion of the cellular handover for a UE of the D2D group or the D2D group handover.

[00161] Example 19 includes the subject matter of any of Examples 10-18, including or omitting any elements, wherein the cellular network interface component is further configured to enable the cellular handover with a first set of one or more UEs of the D2D group while remaining to serve a second set of one or more UEs of the D2D group, and wherein the D2D group utilizes resources of the target eNB for the D2D communications.

[00162] Example 20 includes the subject matter of any of Examples 10-19, including or omitting any elements, wherein the cellular network interface component is further configured to communicate a failure notification or a partial handover notification in response to a failure to complete the D2D group handover with one or more of the plurality of UEs of the D2D group; wherein the cellular network interface component is further configured to terminate the D2D group handover in response to at least one UE of the D2D group failing to complete the D2D group handover, or form a second D2D group with UEs communicatively coupled together via the one or more D2D channels and a source eNB in response to the failure to complete the D2D group handover to a

target eNB with a UE of the D2D group, and the second D2D group is configured to utilize resources common to another eNB as the source eNB or the target eNB.

[00163] Example 21 is a computer-readable storage medium storing executable instructions that, in response to execution, cause a processor of a user equipment (UE) to perform operations, comprising: processing a cellular network communication on a network channel to enable a formation of a device-to-device (D2D) group with a UE via one or more D2D channels that communicatively couple UEs of the D2D group; and controlling a D2D communication on the one or more D2D channels among the D2D group, and a D2D group handover based on at least one of: the cellular network communication or the D2D communication.

[00164] Example 22 includes the subject matter of Example 21, including or omitting any elements, wherein the operations further comprise: generating measurements of the network channel and the one or more D2D channels, and providing the measurements to a UE group leader of the UEs of the D2D group via the one or more D2D channels, or providing the measurements, further comprises other measurements from the D2D group, to an eNB via the network channel as the UE group leader; and processing or generating a D2D group handover trigger, wherein the D2D group handover comprises a handover operation of cellular network communications and the D2D communications for the D2D group, wherein the D2D group handover trigger is processed or generated in response to a channel link quality of at least one of: the network channel with a source eNB or between the UEs and the source eNB, failing to satisfy a channel link quality threshold value for a period of time, in response to a determination that the channel link quality for a predetermined portion of the UEs of the D2D group fails to satisfy the channel link quality threshold value for the period of time, or in response to another determination that the predetermined portion of the UEs of the D2D group satisfy another channel link quality for the period of time with a neighbor network of a target eNB that is greater than the channel link quality with the source eNB.

[00165] Example 23 includes the subject matter of any of Examples 21-22, including or omitting any elements, wherein the operations further comprise one or more of: processing a handover communication command from a source eNB that identifies an individual UE handover or the D2D group handover to a target eNB, wherein the handover communication command includes a radio resource configuration (RRC) information corresponding to at least one of: the network channel or the one or more

D2D channels for communication of a resource pool that allocates group communications to the D2D group; processing a different resource pool that allocates a set of group communication resources to the UEs of the D2D group, and in response to a reception of the different resource pool, or after a completion of the D2D group handover from the source eNB to the target eNB, based on whether the different resource pool comprises an unlicensed band or an unlicensed band, utilize the different resource pool to communicatively couple the UEs of the D2D group or one or more different UEs of a different D2D group; or performing a random access to obtain an uplink (UL) timing advance (TA) value that enables a UL synchronization with the target eNB, and initiate other UEs of the D2D group to acquire the UL synchronization by communication the UL TA value via the one or more D2D channels.

[00166] Example 24 includes the subject matter of any of Examples 21-23, including or omitting any elements, wherein the operations further comprise one or more of: communicating a failure notification to a UE group leader of the D2D group in response to a failure of the D2D group handover to a target eNB; terminating the D2D group handover, or informing at least one of the target eNB or a source eNB of a partial D2D group handover in response to at least one of the UEs of the D2D group failing to complete the D2D group handover to the target eNB; forming a second D2D group of UEs communicatively coupled together via the one or more D2D channels and the source eNB in response to failing to complete the D2D group handover to the target eNB; or communicating on the one or more D2D channels with UEs of the D2D group via common resources between the target eNB and the source eNB in response to UE of the D2D group failing to complete the D2D group handover.

[00167] Example 25 is a computer-readable storage medium storing executable instructions that, in response to execution, cause a processor of an evolved NodeB (eNB) to perform operations, comprising: processing a cellular network communication on a network channel to enable a cellular handover in a wireless network and a formation of a device-to-device (D2D) group with a plurality of UEs via one or more D2D channels that communicatively couple the plurality of UEs of the D2D group; and controlling D2D communications on the one or more D2D channels among the D2D group, and a D2D group handover based on a set of predetermined criteria.

[00168] Example 26 includes the subject matter of Examples 25, including or omitting any elements, wherein the operations further comprise: receiving an aggregated measurement report, and a D2D group handover request or an individual handover

request, from at least one UE of the plurality of UEs in the D2D group, wherein the set of predetermined criteria comprises at least one of: a worse UE measurement of a channel link quality value from the D2D group, measurements from the plurality of UEs of the D2D group, an average measurement value of measurements from the D2D group, one or more measurement reports from a UE group leader of the plurality of UEs of the D2D group requesting the D2D group handover, a link quality threshold corresponding to one or more network channels related to the plurality of UEs in the D2D group, a group threshold related to the link quality threshold, a neighboring cell quality threshold in a comparison with the group threshold or the link quality threshold, or one or more requests for the D2D group handover or the cellular handover for a UE of the D2D group.

[00169] Example 27 includes the subject matter of any of Examples 25-26, including or omitting any elements, wherein the operations further comprise: designating a UE group leader to communicate on behalf of the D2D group to aggregate measurements from the plurality of UEs of the D2D group, communicate one or more resource pools to other UEs of the D2D group to enable the D2D communications, or communicate the D2D communications to a UE of the D2D group requesting an individual handover via the cellular handover in response to failing to perform the cellular handover for the UE of the D2D group.

[00170] Example 28 includes the subject matter of any of Examples 25-27, including or omitting any elements, wherein the operations further comprise: completing one or more uplink (UL) plane data transmission in a buffer, release a UL connection with the plurality of UEs in the D2D group after the D2D group handover, and determine whether the D2D group continues to utilize a current D2D channel of the one or more D2D channels or a new D2D channel based on measurements of the one or more D2D channels from the D2D group or information from a target eNB related to the current D2D channel within a coverage area of the target eNB.

[00171] Example 29 includes the subject matter of any of Examples 25-28, including or omitting any elements, wherein the operations further comprise: generating a group handover command and enable communication of the group handover command to a UE group leader of the D2D group or the plurality of UEs of the D2D group, wherein the group handover command comprises at least one of: an indication of the D2D group handover to a target eNB, a radio resource configuration (RRC) information related to cellular network communications, or other RRC information related to the D2D

communications, wherein the other RRC information comprises a radio resource pool allocated to the D2D group to enable the D2D communications via an unlicensed band or a licensed band.

[00172] Example 30 includes the subject matter of any of Examples 25-29, including or omitting any elements, wherein the operations further comprise one or more of: communicating a failure notification or a partial handover notification in response to a failure to complete the D2D group handover with one or more of the plurality of UEs of the D2D group, a target eNB or a source eNB; terminating the D2D group handover in response to at least one UE of the D2D group failing to complete the D2D group handover; or forming a second D2D group with one or more UEs communicatively coupled together via the one or more D2D channels and the source eNB in response to the failure to complete the D2D group handover to the target eNB with a UE of the D2D group, wherein the second D2D group is configured to utilize resources common to another eNB as the source eNB or the target eNB.

[00173] Example 31 is an apparatus configured to be employed within a user equipment (UE) comprising: means for processing configured to process a cellular network communication on a network channel to enable a formation of a device-to-device (D2D) group with a UE via one or more D2D channels that communicatively couple UEs of the D2D group; and means for controlling a D2D communication on the one or more D2D channels among the D2D group, and a D2D group handover based on at least one of: the cellular network communication or the D2D communication.

[00174] Example 32 includes the subject matter of Examples 31, including or omitting any elements, further comprising: means for generating measurements of the network channel and the one or more D2D channels, and providing the measurements to a UE group leader of the UEs of the D2D group via the one or more D2D channels, or providing the measurements, further comprises other measurements from the D2D group, to an eNB via the network channel as the UE group leader; and means for processing or generating a D2D group handover trigger, wherein the D2D group handover comprises a handover operation of cellular network communications and the D2D communications for the D2D group, wherein the D2D group handover trigger is processed or generated in response to a channel link quality of at least one of: the network channel with a source eNB or between the UEs and the source eNB, failing to satisfy a channel link quality threshold value for a period of time, in response to a determination that the channel link quality for a predetermined portion of the UEs of the

D2D group fails to satisfy the channel link quality threshold value for the period of time, or in response to another determination that the predetermined portion of the UEs of the D2D group satisfy another channel link quality for the period of time with a neighbor network of a target eNB that is greater than the channel link quality with the source eNB.

[00175] Example 33 includes the subject matter of any of Examples 31-32, including or omitting any elements, wherein the means for processing is further configured to perform at least one of: process a handover communication command from a source eNB that identifies an individual UE handover or the D2D group handover to a target eNB, wherein the handover communication command includes a radio resource configuration (RRC) information corresponding to at least one of: the network channel or the one or more D2D channels for communication of a resource pool that allocates group communications to the D2D group; process a different resource pool that allocates a set of group communication resources to the UEs of the D2D group, and in response to a reception of the different resource pool, or after a completion of the D2D group handover from the source eNB to the target eNB, based on whether the different resource pool comprises an unlicensed band or an unlicensed band, utilize the different resource pool to communicatively couple the UEs of the D2D group or one or more different UEs of a different D2D group; or perform a random access to obtain an uplink (UL) timing advance (TA) value that enables a UL synchronization with the target eNB, and initiate other UEs of the D2D group to acquire the UL synchronization by communication the UL TA value via the one or more D2D channels.

[00176] Example 34 includes the subject matter of any of Examples 31-33, including or omitting any elements, further comprising one or more of: means for communicating a failure notification to a UE group leader of the D2D group in response to a failure of the D2D group handover to a target eNB; means for terminating the D2D group handover, or informing at least one of the target eNB or a source eNB of a partial D2D group handover in response to at least one of the UEs of the D2D group failing to complete the D2D group handover to the target eNB; means for forming a second D2D group of UEs communicatively coupled together via the one or more D2D channels and the source eNB in response to failing to complete the D2D group handover to the target eNB; or means for communicating on the one or more D2D channels with UEs of the D2D group via common resources between the target eNB and the source eNB in response to UE of the D2D group failing to complete the D2D group handover.

[00177] Example 35 is an apparatus configured to be employed within an evolved NodeB (eNB) comprising: means for processing a cellular network communication on a network channel to enable a cellular handover in a wireless network and a formation of a device-to-device (D2D) group with a plurality of UEs via one or more D2D channels that communicatively couple the plurality of UEs of the D2D group; and means for controlling D2D communications on the one or more D2D channels among the D2D group, and a D2D group handover based on a set of predetermined criteria.

[00178] Example 36 includes the subject matter of Example 35, including or omitting any elements, further comprising: means for receiving an aggregated measurement report, and a D2D group handover request or an individual handover request, from at least one UE of the plurality of UEs in the D2D group, wherein the set of predetermined criteria comprises at least one of: a worse UE measurement of a channel link quality value from the D2D group, measurements from the plurality of UEs of the D2D group, an average measurement value of measurements from the D2D group, one or more measurement reports from a UE group leader of the plurality of UEs of the D2D group requesting the D2D group handover, a link quality threshold corresponding to one or more network channels related to the plurality of UEs in the D2D group, a group threshold related to the link quality threshold, a neighboring cell quality threshold in a comparison with the group threshold or the link quality threshold, or one or more requests for the D2D group handover or the cellular handover for a UE of the D2D group.

[00179] Example 37 includes the subject matter of any of Examples 35-36, including or omitting any elements, further comprising: means for designating a UE group leader to communicate on behalf of the D2D group to aggregate measurements from the plurality of UEs of the D2D group, communicate one or more resource pools to other UEs of the D2D group to enable the D2D communications, or communicate the D2D communications to a UE of the D2D group requesting an individual handover via the cellular handover in response to failing to perform the cellular handover for the UE of the D2D group.

[00180] Example 38 includes the subject matter of any of Examples 35-37, including or omitting any elements, further comprising: means for completing one or more uplink (UL) plane data transmission in a buffer, release a UL connection with the plurality of UEs in the D2D group after the D2D group handover, and determine whether the D2D group continues to utilize a current D2D channel of the one or more D2D channels or a

new D2D channel based on measurements of the one or more D2D channels from the D2D group or information from a target eNB related to the current D2D channel within a coverage area of the target eNB.

[00181] Example 39 includes the subject matter of any of Examples 35-38, including or omitting any elements, further comprising: means for generating a group handover command and enable communication of the group handover command to a UE group leader of the D2D group or the plurality of UEs of the D2D group, wherein the group handover command comprises at least one of: an indication of the D2D group handover to a target eNB, a radio resource configuration (RRC) information related to cellular network communications, or other RRC information related to the D2D communications, wherein the other RRC information comprises a radio resource pool allocated to the D2D group to enable the D2D communications via an unlicensed band or a licensed band.

[00182] Example 40 includes the subject matter of any of Examples 35-38, including or omitting any elements, further comprising: means for communicating a failure notification or a partial handover notification in response to a failure to complete the D2D group handover with one or more of the plurality of UEs of the D2D group, a target eNB or a source eNB; means for terminating the D2D group handover in response to at least one UE of the D2D group failing to complete the D2D group handover; or forming a second D2D group with one or more UEs communicatively coupled together via the one or more D2D channels and the source eNB in response to the failure to complete the D2D group handover to the target eNB with a UE of the D2D group, wherein the second D2D group is configured to utilize resources common to another eNB as the source eNB or the target eNB.

[00183] Example 41 is an apparatus configured to be employed by a user equipment (UE), the apparatus comprising: a processor configured to: generate and process cellular network communications on one or more network channels to enable a cellular handover in a wireless network and a formation of a device-to-device (D2D) group with one or more additional UEs via one or more D2D channels that communicatively couple the D2D group; and generate and process D2D communications on the one or more D2D channels among the D2D group, and enable a D2D group handover based on at least one of: the cellular network communications or the D2D communications.

[00184] Example 42 is an apparatus configured to be employed by evolved NodeB (eNB) comprising: a processor configured to: generate and process cellular network

communications on one or more network channels to enable a cellular handover in a wireless network and a formation of a device-to-device (D2D) group with a plurality of UEs via one or more D2D channels that communicatively couple the plurality of UEs of the D2D group; and enable D2D communications on the one or more D2D channels among the D2D group, and enable a D2D group handover based on a set of predetermined criteria.

[00185] Example 43 includes the subject matter of any of Examples 1-20, including or omitting any elements, wherein the ProSe interface component comprises a PC5 interface.

[00186] Example 44 includes the subject matter of any of Examples 1-20, including or omitting any elements, wherein the D2D communications occur on a sidelink channel.

[00187] Example 45 includes the subject matter of any of Examples 1-20, including or omitting any elements, wherein the cellular interface component comprises an LTE-Uu interface.

[00188] It is to be understood that aspects described herein can be implemented by hardware, software, firmware, or any combination thereof. When implemented in software, functions can be stored on or transmitted over as one or more instructions or code on a computer-readable medium (e.g., the memory described herein or other storage device). Computer-readable media includes both computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A storage media or a computer readable storage device can be any available media that can be accessed by a general purpose or special purpose computer. By way of example, and not limitation, such computer-readable media can comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or other tangible and/or non-transitory medium, that can be used to carry or store desired information or executable instructions. Also, any connection is properly termed a computer-readable medium. For example, if software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and blu-ray disc where *disks* usually reproduce data magnetically, while *discs*

reproduce data optically with lasers. Combinations of the above should also be included within the scope of computer-readable media.

[00189] Various illustrative logics, logical blocks, modules, and circuits described in connection with aspects disclosed herein can be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform functions described herein. A general-purpose processor can be a microprocessor, but, in the alternative, processor can be any conventional processor, controller, microcontroller, or state machine. A processor can also be implemented as a combination of computing devices, for example, a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration. Additionally, at least one processor can comprise one or more modules operable to perform one or more of the s and/or actions described herein.

[00190] For a software implementation, techniques described herein can be implemented with modules (*e.g.*, procedures, functions, and so on) that perform functions described herein. Software codes can be stored in memory units and executed by processors. Memory unit can be implemented within processor or external to processor, in which case memory unit can be communicatively coupled to processor through various means as is known in the art. Further, at least one processor can include one or more modules operable to perform functions described herein.

[00191] Techniques described herein can be used for various wireless communication systems such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA and other systems. The terms “system” and “network” are often used interchangeably. A CDMA system can implement a radio technology such as Universal Terrestrial Radio Access (UTRA), CDMA1800, *etc.* UTRA includes Wideband-CDMA (W-CDMA) and other variants of CDMA. Further, CDMA1800 covers IS-1800, IS-95 and IS-856 standards. A TDMA system can implement a radio technology such as Global System for Mobile Communications (GSM). An OFDMA system can implement a radio technology such as Evolved UTRA (E-UTRA), Ultra Mobile Broadband (UMB), IEEE 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.18, Flash-OFDM_L, *etc.* UTRA and E-UTRA are part of Universal Mobile Telecommunication System (UMTS). 3GPP Long Term Evolution (LTE) is a release of UMTS that uses E-UTRA, which employs OFDMA on downlink and

SC-FDMA on uplink. UTRA, E-UTRA, UMTS, LTE and GSM are described in documents from an organization named "3rd Generation Partnership Project" (3GPP). Additionally, CDMA1800 and UMB are described in documents from an organization named "3rd Generation Partnership Project 2" (3GPP2). Further, such wireless communication systems can additionally include peer-to-peer (*e.g.*, mobile-to-mobile) *ad hoc* network systems often using unpaired unlicensed spectrums, 802.xx wireless LAN, BLUETOOTH and any other short- or long- range, wireless communication techniques.

[00192] Single carrier frequency division multiple access (SC-FDMA), which utilizes single carrier modulation and frequency domain equalization is a technique that can be utilized with the disclosed aspects. SC-FDMA has similar performance and essentially a similar overall complexity as those of OFDMA system. SC-FDMA signal has lower peak-to-average power ratio (PAPR) because of its inherent single carrier structure. SC-FDMA can be utilized in uplink communications where lower PAPR can benefit a mobile terminal in terms of transmit power efficiency.

[00193] Moreover, various aspects or features described herein can be implemented as a method, apparatus, or article of manufacture using standard programming and/or engineering techniques. The term "article of manufacture" as used herein is intended to encompass a computer program accessible from any computer-readable device, carrier, or media. For example, computer-readable media can include but are not limited to magnetic storage devices (*e.g.*, hard disk, floppy disk, magnetic strips, *etc.*), optical disks (*e.g.*, compact disk (CD), digital versatile disk (DVD), *etc.*), smart cards, and flash memory devices (*e.g.*, EPROM, card, stick, key drive, *etc.*). Additionally, various storage media described herein can represent one or more devices and/or other machine-readable media for storing information. The term "machine-readable medium" can include, without being limited to, wireless channels and various other media capable of storing, containing, and/or carrying instruction(s) and/or data. Additionally, a computer program product can include a computer readable medium having one or more instructions or codes operable to cause a computer to perform functions described herein.

[00194] Communications media embody computer-readable instructions, data structures, program modules or other structured or unstructured data in a data signal such as a modulated data signal, *e.g.*, a carrier wave or other transport mechanism, and includes any information delivery or transport media. The term "modulated data signal"

or signals refers to a signal that has one or more of its characteristics set or changed in such a manner as to encode information in one or more signals. By way of example, and not limitation, communication media include wired media, such as a wired network or direct-wired connection, and wireless media such as acoustic, RF, infrared and other wireless media.

[00195] Further, the actions of a method or algorithm described in connection with aspects disclosed herein can be embodied directly in hardware, in a software module executed by a processor, or a combination thereof. A software module can reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, a hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. An exemplary storage medium can be coupled to processor, such that processor can read information from, and write information to, storage medium. In the alternative, storage medium can be integral to processor. Further, in some aspects, processor and storage medium can reside in an ASIC. Additionally, ASIC can reside in a user terminal. In the alternative, processor and storage medium can reside as discrete components in a user terminal. Additionally, in some aspects, the s and/or actions of a method or algorithm can reside as one or any combination or set of codes and/or instructions on a machine-readable medium and/or computer readable medium, which can be incorporated into a computer program product.

[00196] The above description of illustrated embodiments of the subject disclosure, including what is described in the Abstract, is not intended to be exhaustive or to limit the disclosed embodiments to the precise forms disclosed. While specific embodiments and examples are described herein for illustrative purposes, various modifications are possible that are considered within the scope of such embodiments and examples, as those skilled in the relevant art can recognize.

[00197] In this regard, while the disclosed subject matter has been described in connection with various embodiments and corresponding Figures, where applicable, it is to be understood that other similar embodiments can be used or modifications and additions can be made to the described embodiments for performing the same, similar, alternative, or substitute function of the disclosed subject matter without deviating therefrom. Therefore, the disclosed subject matter should not be limited to any single embodiment described herein, but rather should be construed in breadth and scope in accordance with the appended claims below.

[00198] In particular regard to the various functions performed by the above described components (assemblies, devices, circuits, systems, *etc.*), the terms (including a reference to a "means") used to describe such components are intended to correspond, unless otherwise indicated, to any component or structure which performs the specified function of the described component (*e.g.*, that is functionally equivalent), even though not structurally equivalent to the disclosed structure which performs the function in the herein illustrated exemplary implementations of the disclosure. In addition, while a particular feature may have been disclosed with respect to only one of several implementations, such feature may be combined with one or more other features of the other implementations as may be desired and advantageous for any given or particular application.

CLAIMS

What is claimed is:

1. An apparatus configured to be employed by a user equipment (UE), the apparatus comprising:
 - a cellular network interface component configured to generate and process cellular network communications on one or more network channels to enable a cellular handover in a wireless network and a formation of a device-to-device (D2D) group with one or more additional UEs via one or more D2D channels that communicatively couple the D2D group; and
 - a ProSe interface component, communicatively coupled to the cellular network interface component, configured to generate and process D2D communications on the one or more D2D channels among the D2D group, and enable a D2D group handover based on at least one of: the cellular network communications or the D2D communications.
2. The apparatus of claim 1, further comprising:
 - a channel quality measurement component configured to generate measurements of the one or more network channels and the one or more D2D channels, and provide the measurements to a group leader UE of the one or more additional UEs via the one or more D2D channels, or to an eNB via the one or more network channels as the group leader UE via the cellular network interface component.
3. The apparatus of any of claims 1-2, further comprising:
 - a D2D handover component configured to control channel quality measurement reports from the one or more additional UEs of the D2D group and enable the D2D group handover between a source evolved NodeB (eNB) and a target eNB by processing or generating a D2D group handover trigger, wherein the D2D group handover comprises a handover operation of the cellular network communications and the D2D communications.
4. The apparatus of any of claims 1-3, wherein the D2D handover component is further configured to generate a group handover request to initiate the D2D group handover in response to a channel link quality of at least one of: the one or more

network channels with a source eNB or between the one or more additional UEs and the source eNB failing to satisfy a channel link quality threshold value for a period of time, in response to a determination that the channel link quality for a predetermined portion of the one or more additional UEs of the D2D group fails to satisfy the channel link quality threshold value for the period of time, or in response to another determination that the predetermined portion of the one or more additional UEs of the D2D group satisfy another channel link quality threshold value for the period of time with a neighbor network of the target eNB that is greater than the channel link quality with the source eNB.

5. The apparatus of any of claims 1-4, wherein the cellular network interface component comprises a same front end module as the ProSe interface component and is further configured to process a communication command from a source eNB that identifies an individual UE handover or the D2D group handover to a target eNB, wherein the communication command includes a radio resource configuration information corresponding to at least one of: the one or more network channels via the cellular network interface component or the one or more D2D channels via the ProSe interface component for communication of a resource pool that allocates group communications to the D2D group.

6. The apparatus of any of claims 1-5, wherein the cellular network interface component is further configured to process a different resource pool that allocates a set of group communication resources to the one or more additional UEs of the D2D group, and in response to a reception of the different resource pool, or after a completion of the D2D group handover from a source eNB to a target eNB, based on whether the different resource pool comprises an unlicensed band or an unlicensed band, initiate utilizing the different resource pool to communicatively couple the one or more additional UEs of the D2D group or one or more different UEs of a different D2D group.

7. The apparatus of any of claims 1-6, wherein the cellular network interface component is further configured to process a different resource pool that allocates a set of group communication resources to the one or more additional UEs of the D2D group after a time synchronization with a target eNB.

8. The apparatus of any of claims 1-7, wherein the ProSe interface component is further configured to process a communication command from a source eNB that identifies a UE of the D2D group for an individual UE handover or the D2D group for the D2D group handover to a target eNB, and in response to the communication command, perform a random access to obtain an uplink (UL) timing advance (TA) value that enables a UL synchronization with the target eNB or communicate via the one or more D2D channels to the UE of the D2D group to perform the random access, and further assist other UEs of the D2D group to acquire the UL synchronization by communication the UL TA value via the one or more D2D channels.

9. The apparatus of any of claims 1-8, wherein the ProSe interface component is further configured to communicate a failure notification to a UE group leader of the D2D group in response to failing to complete the D2D group handover to a target eNB, to terminate the D2D group handover or inform the target eNB or a source eNB of a partial D2D group handover in response to at least one of the one or more additional UEs of the D2D group failing to complete the D2D group handover to the target eNB, or form a second D2D group of UEs communicatively coupled together via the one or more D2D channels and the source eNB in response to failing to complete the D2D group handover to the target eNB.

10. An apparatus configured to be employed by evolved NodeB (eNB) comprising:
a cellular network interface component configured to generate and process cellular network communications on one or more network channels to enable a cellular handover in a wireless network and a formation of a device-to-device (D2D) group with a plurality of UEs via one or more D2D channels that communicatively couple the plurality of UEs of the D2D group; and

a ProSe interface component, communicatively coupled to the cellular network interface component, configured to enable D2D communications on the one or more D2D channels among the D2D group, and enable a D2D group handover based on a set of predetermined criteria.

11. The apparatus of claim 10, further comprising:

a channel quality measurement component further configured to receive an aggregated measurement report, and a D2D group handover request or an individual

handover request for the cellular handover, from at least one UE of the plurality of UEs in the D2D group.

12. The apparatus of any of claims 10-11, wherein the set of predetermined criteria comprises at least one of: a worse UE measurement of a channel link quality value, measurements from the plurality of UEs of the D2D group, an average measurement value of measurements from the D2D group, or one or more measurement reports from a UE group leader of the plurality of UEs of the D2D group requesting the D2D group handover.

13. The apparatus of any of claims 10-12, further comprising:

a D2D handover component configured to designate a UE group leader on behalf of the plurality of UEs of the D2D group to aggregate measurements from the plurality of UEs of the D2D group and communicate one or more resource pools to other UEs of the D2D group to enable the D2D communications, or communicate the D2D communications to a UE of the D2D group requesting an individual handover via the cellular handover in response to not detecting a target eNB that is suitable for the UE.

14. The apparatus of any of claims 10-13, wherein the D2D handover component is further configured to complete any uplink (UL) plane data transmission in a buffer, release a UL connection with the plurality of UEs in the D2D group after the D2D group handover, and determine whether the D2D group continues to utilize a current D2D channel of the one or more D2D channels or a new D2D channel based on measurements of the one or more D2D channels from the D2D group or information from the target eNB related to the current D2D channel within a coverage area of the target eNB.

15. The apparatus of any of claims 10-14, wherein the set of predetermined criteria comprise at least one of: a link quality threshold corresponding to the one or more network channels related to the plurality of UEs in the D2D group, a group threshold related to the link quality threshold, a neighboring cell quality threshold in a comparison with the group threshold or the link quality threshold, or one or more requests for the D2D group handover or the cellular handover for a UE of the D2D group.

16. The apparatus of any of claims 10-15, further comprising:

a handover command component configured to generate a group handover command and enable communication of the group handover command to a UE group leader of the D2D group or the plurality of UEs of the D2D group, wherein the group handover command comprises at least one of: an indication of the D2D group handover to a target eNB, a radio resource configuration (RRC) information related to the cellular network communications, or other RRC information related to the D2D communications, wherein the other RRC information comprises a radio resource pool allocated to the D2D group to enable the D2D communications via an unlicensed band or a licensed band.

17. The apparatus of any of claims 10-16, wherein the handover command component is further configured to communicate the radio resource pool to the UE group leader or the plurality of UEs of the D2D group that enables the D2D communications after receiving the D2D group handover from a source eNB and time synchronizing with the plurality of UEs of the D2D group.

18. The apparatus of any of claims 10-17, wherein the handover command component is further configured to generate a group handover complete command to a network transmission path in response to a completion of the cellular handover for a UE of the D2D group or the D2D group handover.

19. The apparatus of any of claims 10-18, wherein the cellular network interface component is further configured to enable the cellular handover with a first set of one or more UEs of the D2D group while remaining to serve a second set of one or more UEs of the D2D group, and wherein the D2D group utilizes resources of the target eNB for the D2D communications.

20. The apparatus of any of claims 10-19, wherein the cellular network interface component is further configured to communicate a failure notification or a partial handover notification in response to a failure to complete the D2D group handover with one or more of the plurality of UEs of the D2D group; wherein the cellular network interface component is further configured to terminate the D2D group handover in response to at least one UE of the D2D group failing to complete the D2D group

handover, or form a second D2D group with UEs communicatively coupled together via the one or more D2D channels and a source eNB in response to the failure to complete the D2D group handover to a target eNB with a UE of the D2D group, and the second D2D group is configured to utilize resources common to another eNB as the source eNB or the target eNB.

21. A computer-readable storage medium storing executable instructions that, in response to execution, cause a processor of a user equipment (UE) to perform operations, comprising:

- processing a cellular network communication on a network channel to enable a formation of a device-to-device (D2D) group with a UE via one or more D2D channels that communicatively couple UEs of the D2D group; and

- controlling a D2D communication on the one or more D2D channels among the D2D group, and a D2D group handover based on at least one of: the cellular network communication or the D2D communication.

22. The computer-readable storage medium of claim 21, wherein the operations further comprise:

- generating measurements of the network channel and the one or more D2D channels, and providing the measurements to a UE group leader of the UEs of the D2D group via the one or more D2D channels, or providing the measurements, further comprises other measurements from the D2D group, to an eNB via the network channel as the UE group leader; and

- processing or generating a D2D group handover trigger, wherein the D2D group handover comprises a handover operation of cellular network communications and the D2D communications for the D2D group, wherein the D2D group handover trigger is processed or generated in response to a channel link quality of at least one of: the network channel with a source eNB or between the UEs and the source eNB, failing to satisfy a channel link quality threshold value for a period of time, in response to a determination that the channel link quality for a predetermined portion of the UEs of the D2D group fails to satisfy the channel link quality threshold value for the period of time, or in response to another determination that the predetermined portion of the UEs of the D2D group satisfy another channel link quality for the period of time with a neighbor network of a target eNB that is greater than the channel link quality with the source

eNB.

23. The computer-readable storage medium of any of claims 21-22, wherein the operations further comprise one or more of:

processing a handover communication command from a source eNB that identifies an individual UE handover or the D2D group handover to a target eNB, wherein the handover communication command includes a radio resource configuration (RRC) information corresponding to at least one of: the network channel or the one or more D2D channels for communication of a resource pool that allocates group communications to the D2D group;

processing a different resource pool that allocates a set of group communication resources to the UEs of the D2D group, and in response to a reception of the different resource pool, or after a completion of the D2D group handover from the source eNB to the target eNB, based on whether the different resource pool comprises an unlicensed band or an unlicensed band, utilize the different resource pool to communicatively couple the UEs of the D2D group or one or more different UEs of a different D2D group; or

performing a random access to obtain an uplink (UL) timing advance (TA) value that enables a UL synchronization with the target eNB, and initiate other UEs of the D2D group to acquire the UL synchronization by communicating the UL TA value via the one or more D2D channels.

24. The computer-readable storage medium of any of claims 21-23, wherein the operations further comprise one or more of:

communicating a failure notification to a UE group leader of the D2D group in response to a failure of the D2D group handover to a target eNB;

terminating the D2D group handover, or informing at least one of the target eNB or a source eNB of a partial D2D group handover in response to at least one of the UEs of the D2D group failing to complete the D2D group handover to the target eNB;

forming a second D2D group of UEs communicatively coupled together via the one or more D2D channels and the source eNB in response to failing to complete the D2D group handover to the target eNB; or

communicating on the one or more D2D channels with UEs of the D2D group via common resources between the target eNB and the source eNB in response to UE of

the D2D group failing to complete the D2D group handover.

25. A computer-readable storage medium storing executable instructions that, in response to execution, cause a processor of an evolved NodeB (eNB) to perform operations, comprising:

processing a cellular network communication on a network channel to enable a cellular handover in a wireless network and a formation of a device-to-device (D2D) group with a plurality of UEs via one or more D2D channels that communicatively couple the plurality of UEs of the D2D group; and

controlling D2D communications on the one or more D2D channels among the D2D group, and a D2D group handover based on a set of predetermined criteria.

26. The computer-readable storage medium of claim 25, wherein the operations further comprise:

receiving an aggregated measurement report, and a D2D group handover request or an individual handover request, from at least one UE of the plurality of UEs in the D2D group, wherein the set of predetermined criteria comprises at least one of: a worse UE measurement of a channel link quality value from the D2D group, measurements from the plurality of UEs of the D2D group, an average measurement value of measurements from the D2D group, one or more measurement reports from a UE group leader of the plurality of UEs of the D2D group requesting the D2D group handover, a link quality threshold corresponding to one or more network channels related to the plurality of UEs in the D2D group, a group threshold related to the link quality threshold, a neighboring cell quality threshold in a comparison with the group threshold or the link quality threshold, or one or more requests for the D2D group handover or the cellular handover for a UE of the D2D group.

27. The computer-readable storage medium of any of claims 25-26, wherein the operations further comprise:

designating a UE group leader to communicate on behalf of the D2D group to aggregate measurements from the plurality of UEs of the D2D group, communicate one or more resource pools to other UEs of the D2D group to enable the D2D communications, or communicate the D2D communications to a UE of the D2D group requesting an individual handover via the cellular handover in response to failing to

perform the cellular handover for the UE of the D2D group.

28. The computer-readable storage medium of any of claims 25-27, wherein the operations further comprise:

completing one or more uplink (UL) plane data transmission in a buffer, release a UL connection with the plurality of UEs in the D2D group after the D2D group handover, and determine whether the D2D group continues to utilize a current D2D channel of the one or more D2D channels or a new D2D channel based on measurements of the one or more D2D channels from the D2D group or information from a target eNB related to the current D2D channel within a coverage area of the target eNB.

29. The computer-readable storage medium of any of claims 25-28, wherein the operations further comprise:

generating a group handover command and enable communication of the group handover command to a UE group leader of the D2D group or the plurality of UEs of the D2D group, wherein the group handover command comprises at least one of: an indication of the D2D group handover to a target eNB, a radio resource configuration (RRC) information related to cellular network communications, or other RRC information related to the D2D communications, wherein the other RRC information comprises a radio resource pool allocated to the D2D group to enable the D2D communications via an unlicensed band or a licensed band.

30. The computer-readable storage medium of any of claims 25-29, wherein the operations further comprise one or more of:

communicating a failure notification or a partial handover notification in response to a failure to complete the D2D group handover with one or more of the plurality of UEs of the D2D group, a target eNB or a source eNB;

terminating the D2D group handover in response to at least one UE of the D2D group failing to complete the D2D group handover; or

forming a second D2D group with one or more UEs communicatively coupled together via the one or more D2D channels and the source eNB in response to the failure to complete the D2D group handover to the target eNB with a UE of the D2D group, wherein the second D2D group is configured to utilize resources common to another eNB as the source eNB or the target eNB.

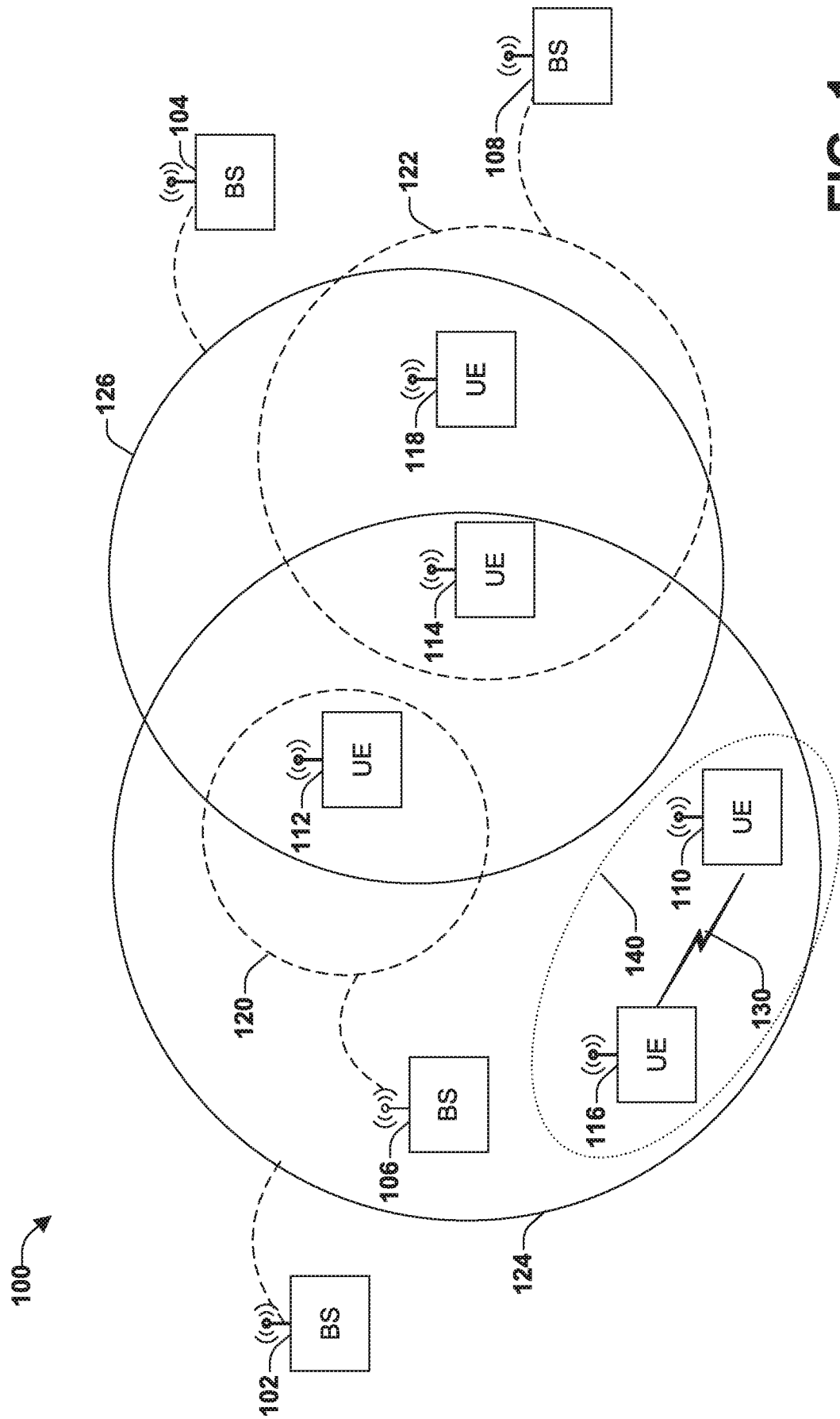


FIG. 1

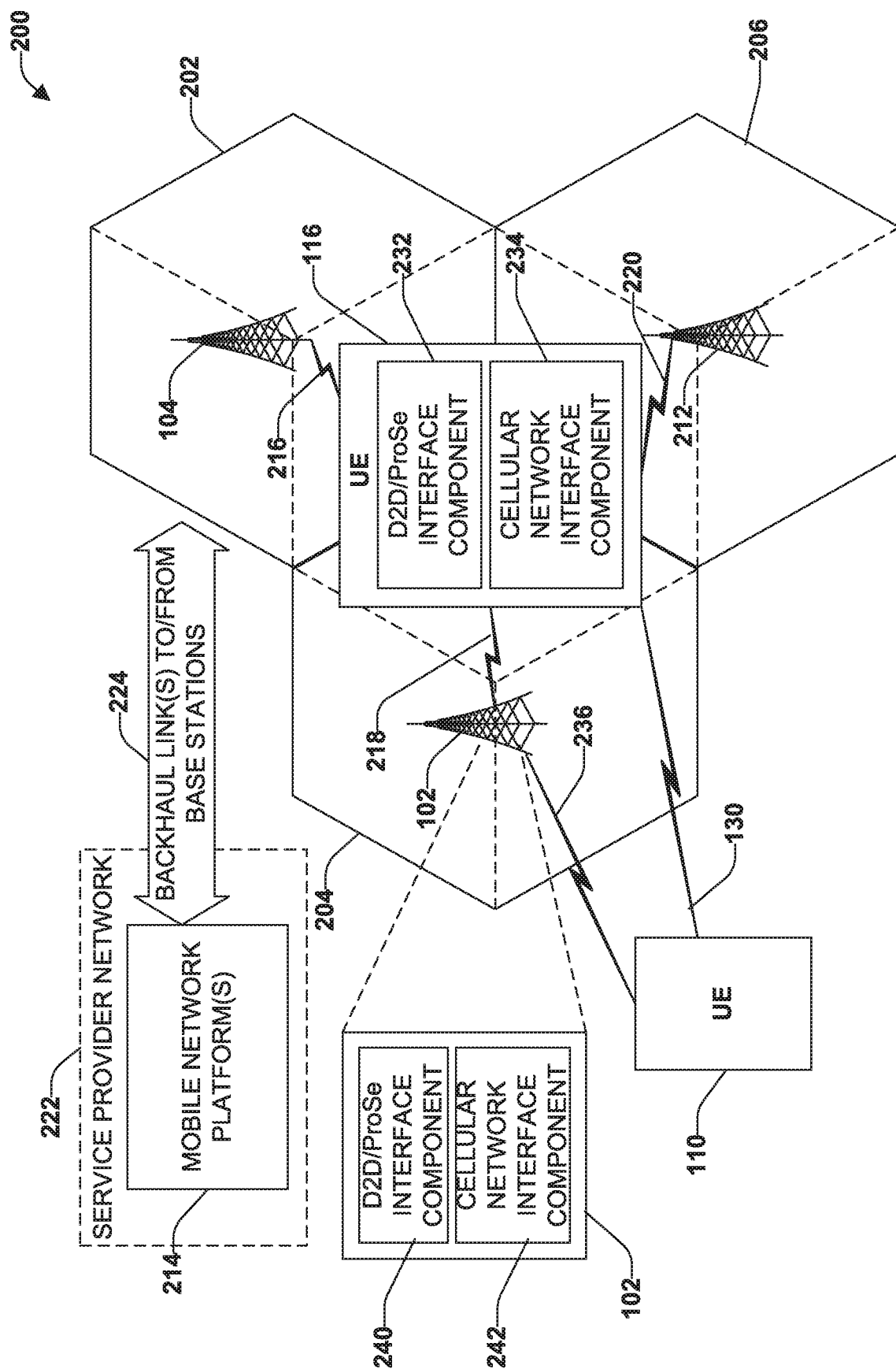
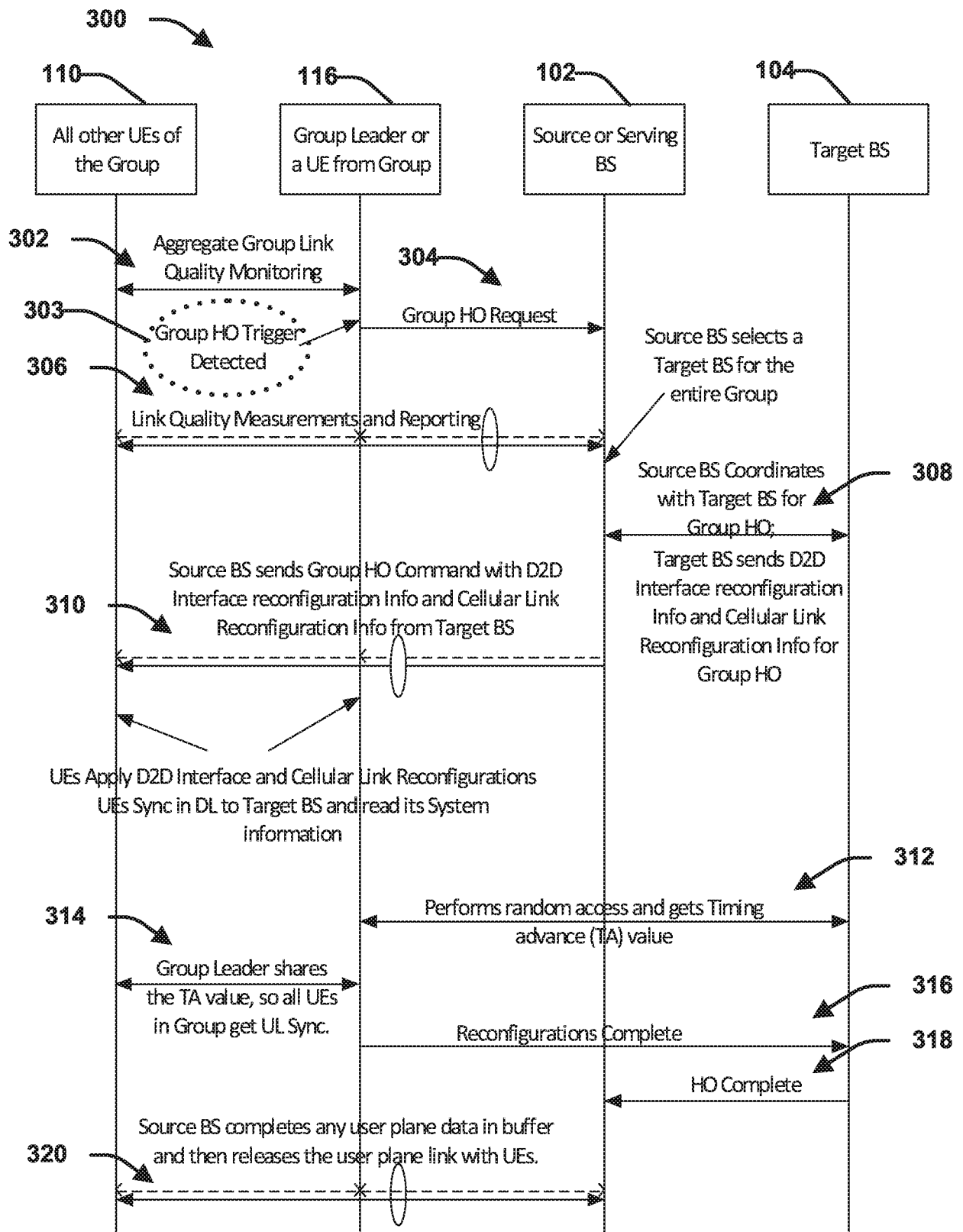
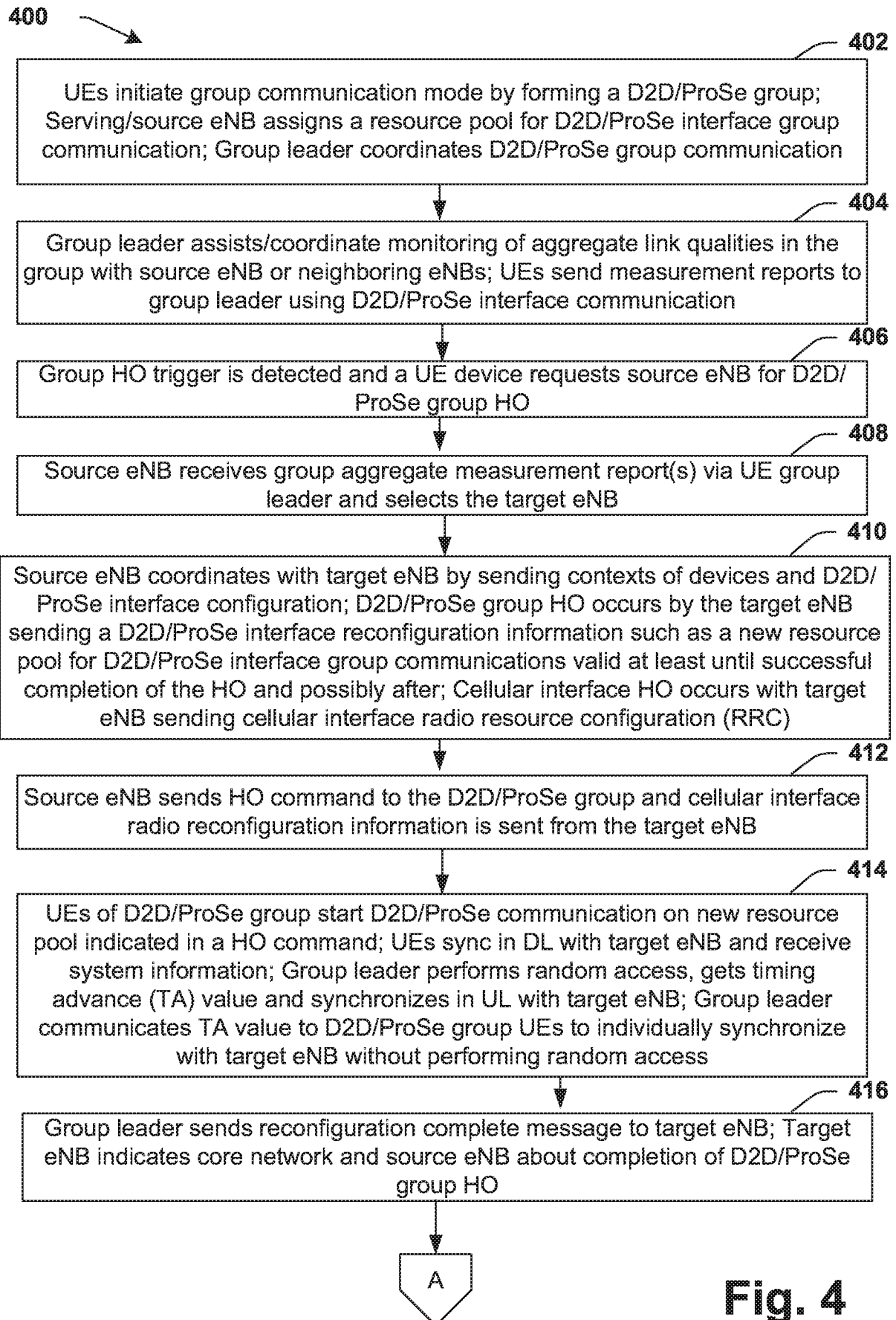
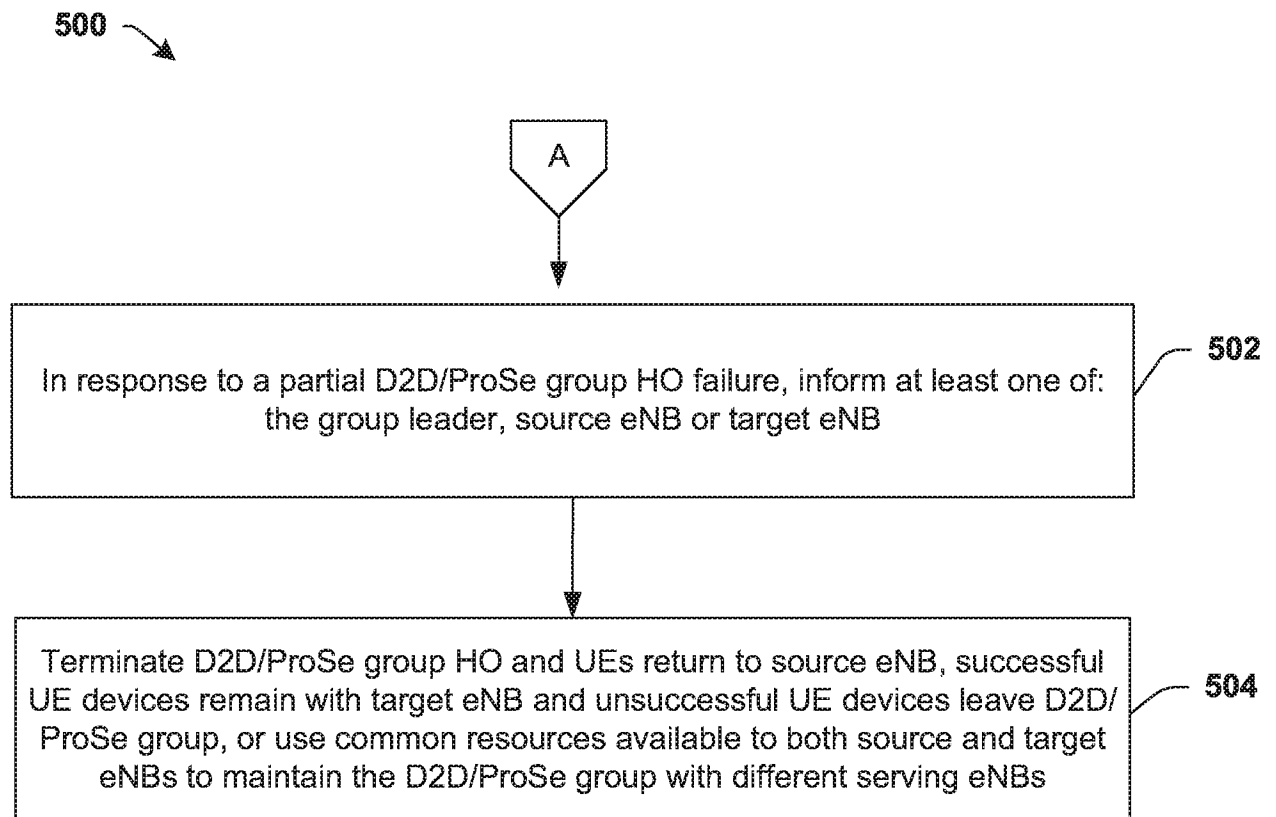
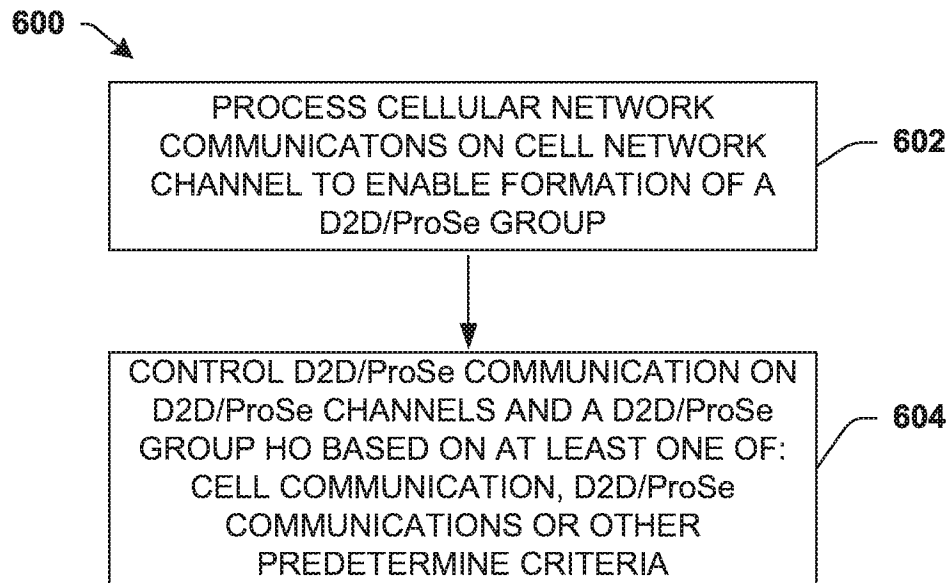


FIG. 2

**FIG. 3**

**Fig. 4**

**Fig. 5**

**Fig. 6**

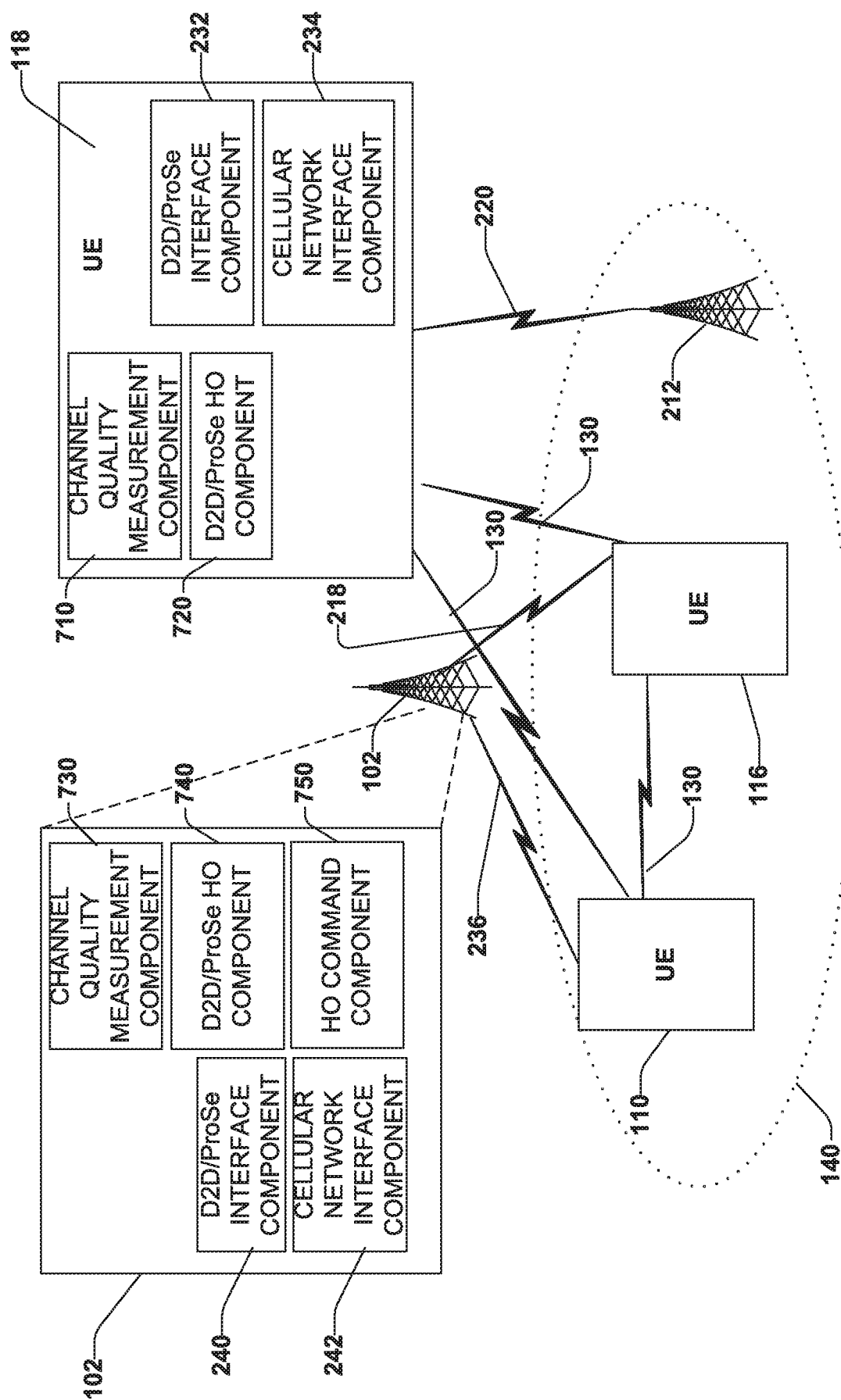
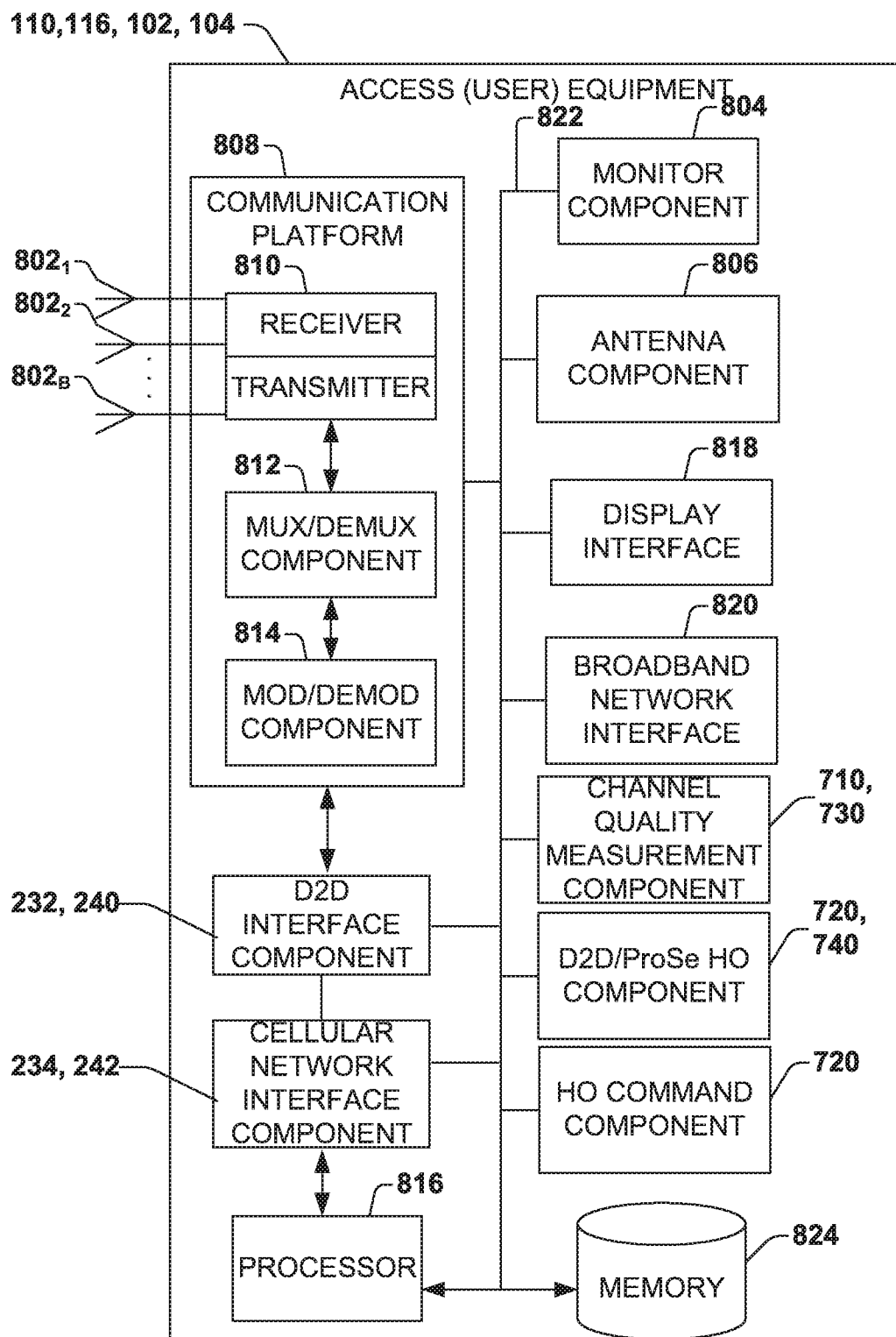


FIG. 7

**FIG. 8**

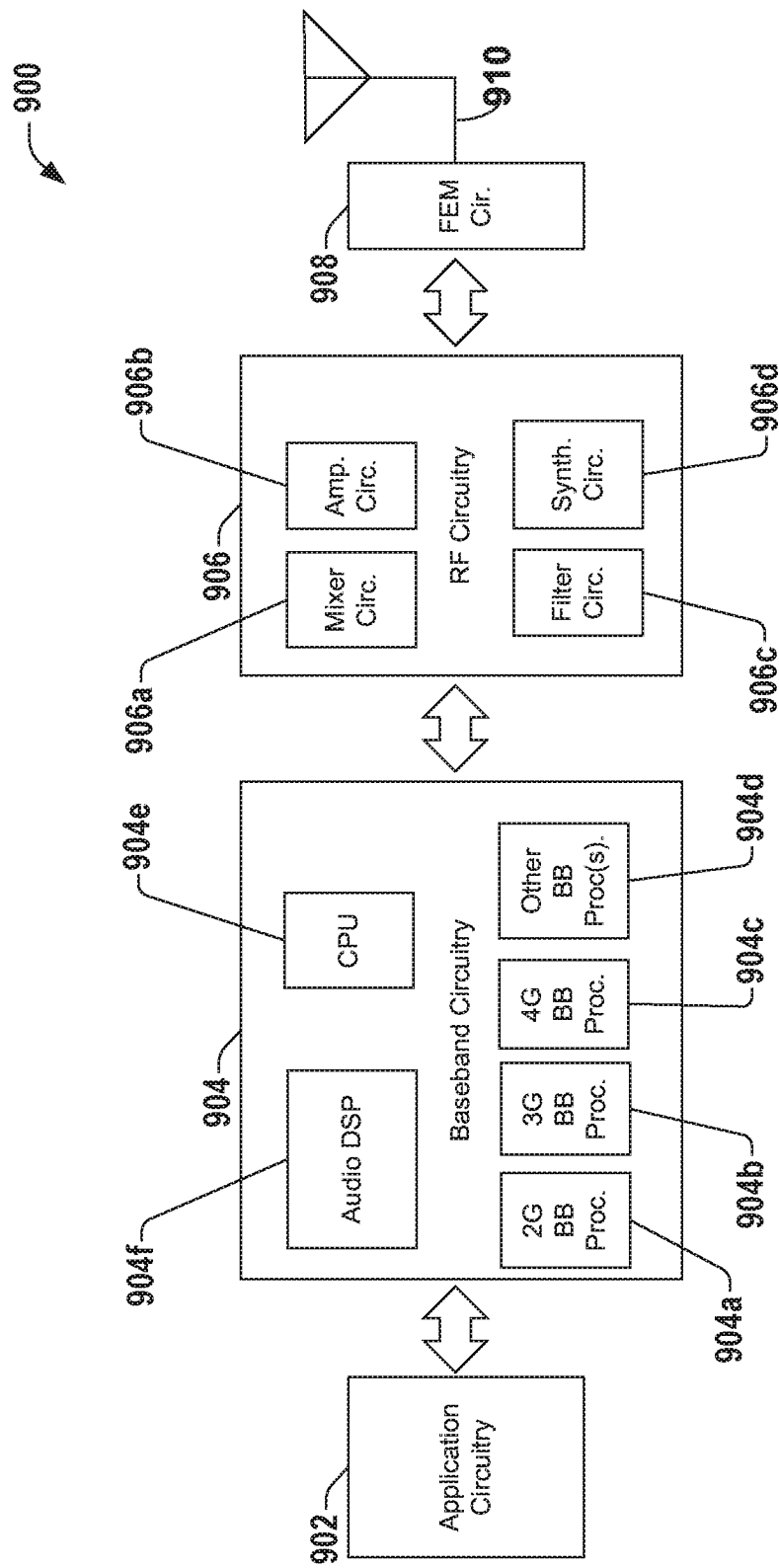


FIG. 9

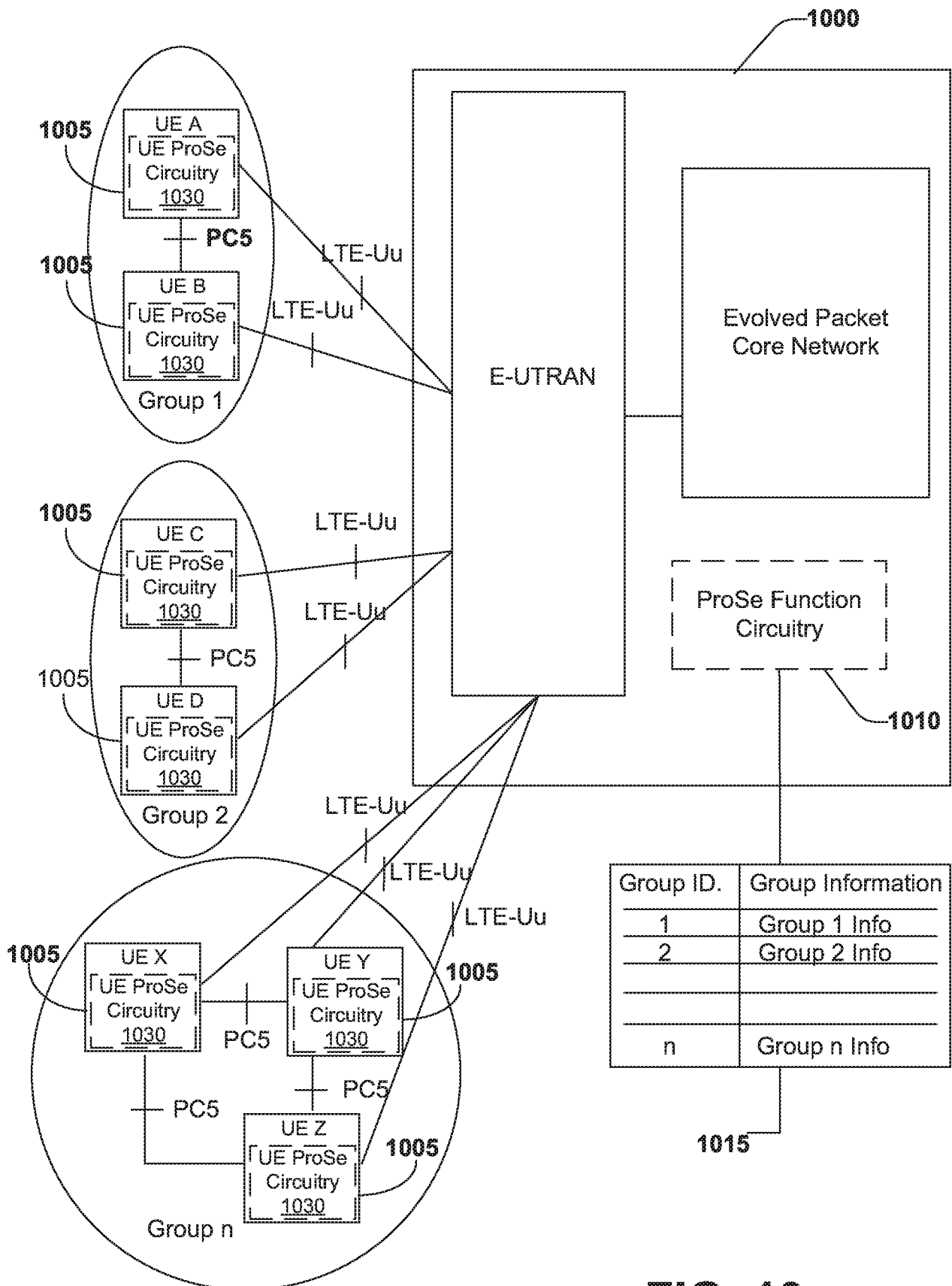


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2016/024923

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W8/00 H04W36/00
ADD. H04W24/10

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

B. FIELDS SEARCHED

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

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2014/124689 A1 (NOKIA SOLUTIONS & NETWORKS OY [FI]) 21 August 2014 (2014-08-21) abstract page 2, line 18 - line 26 page 4, line 9 - page 5, line 25 page 6, line 15 - page 11, line 24 page 12, line 33 - page 13, line 13 -----	1-30
X	WO 2015/096845 A1 (HUAWEI TECHNOLOGIES DUESSELDORF GMBH [DE]) 2 July 2015 (2015-07-02) abstract figures 5,7,10 page 21, line 17 - line 24 page 23, line 21 - page 24, line 4 page 24, line 25 - line 32 page 32, line 11 - line 26 ----- -/-	1-30



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

16 August 2016

Date of mailing of the international search report

25/08/2016

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Matt, Stefan

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2016/024923

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	SUNGKYUNG KIM ET AL: "[Group Handover on the Mobile RS] ; S80216j-06_227", IEEE DRAFT; S80216J-06_227, IEEE-SA, PISCATAWAY, NJ USA, vol. 802.16j, 14 November 2006 (2006-11-14), pages 1-6, XP017785420, [retrieved on 2006-11-14]	1,10,21, 25
A	Slide: Group HO on the MRS Slide: Group Handover Procedure Slide: Conclusions	2-9, 11-20, 22-24, 26-30
X	----- HWANG YOUSUN ET AL: "Group handover management for V2x in moving cell based LTE-Advanced system", 2015 INTERNATIONAL CONFERENCE ON INFORMATION AND COMMUNICATION TECHNOLOGY CONVERGENCE (ICTC), IEEE, 28 October 2015 (2015-10-28), pages 1054-1057, XP032830036, DOI: 10.1109/ICTC.2015.7354736 [retrieved on 2015-12-11]	1,10,21, 25
A	abstract I. introduction figures 1, 2,6 II. Group Handover mechanism for moving cell -----	2-9, 11-20, 22-24, 26,30

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2016/024923

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2014124689 A1	21-08-2014	EP 2957113 A1	23-12-2015
		US 2015382252 A1	31-12-2015
		WO 2014124689 A1	21-08-2014

WO 2015096845 A1	02-07-2015	CN 105794302 A	20-07-2016
		WO 2015096845 A1	02-07-2015
