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(71) Applicant: **QUALCOMM INCORPORATED** [US/US]; International IP Administration, 5775 Morehouse Drive, San Diego, California 92121-1714 (US).

(72) Inventors; and
(71) Applicants *(for US only)*: **WANG, Haojun** [CN/CN]; 5775 Morehouse Drive, San Diego, California 92121-1714 (US). **CUI, Zhenqing** [CN/CN]; 5775 Morehouse Drive, San Diego, California 92121-1714 (US). **CHEN, Xuesong** [CN/CN]; 5775 Morehouse Drive, San Diego, California 92121-1714 (US). **WEI, Hong** [CN/CN]; 5775 Morehouse Drive, San Diego, California 92121-1714 (US).

(74) Agent: **NTD PATENT & TRADEMARK AGENCY LTD.**; 10th Floor, Tower C, Beijing Global Trade Center, 36 North Third Ring Road East, Dongcheng District, Beijing 100013 (CN).

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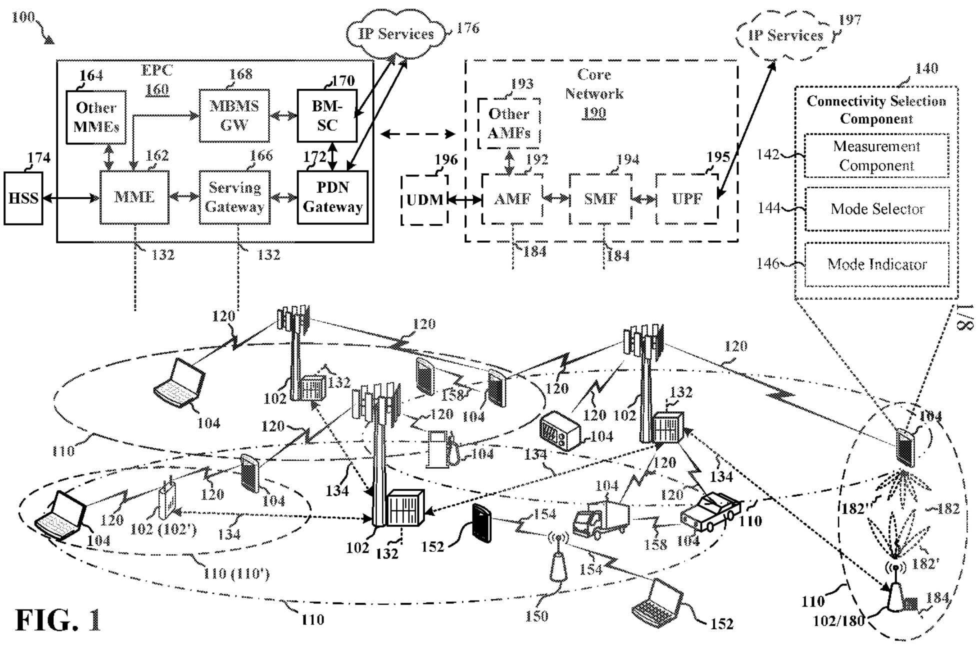

FIG. 1

(57) Abstract: A user equipment (UE) may selectively manage dual connectivity in association with network configuration messages. The UE may receive, while connected to a long term evolution (LTE) network, a request to measure a secondary cell group for a 5G new radio (NR) network. The UE may determine whether to measure the secondary cell group based on a 5G NR connection mode selected by an application processor. The UE may include the application processor, which may select the 5G NR connection mode based on one or more of: an application layer data rate, a user selected preference, a battery level of the UE, a latency requirement, a thermal mitigation, or a combination thereof.

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TECHNIQUES FOR CONNECTIVITY SELECTION FOR DUAL CONNECTIVITY DEVICE

BACKGROUND

Technical Field

[0001] The present disclosure relates generally to communication systems, and more particularly, to wireless devices with dual connectivity capability.

Introduction

[0002] Wireless communication systems are widely deployed to provide various telecommunication services such as telephony, video, data, messaging, and broadcasts. Typical wireless communication systems may employ multiple-access technologies capable of supporting communication with multiple users by sharing available system resources. Examples of such multiple-access technologies include code division multiple access (CDMA) systems, time division multiple access (TDMA) systems, frequency division multiple access (FDMA) systems, orthogonal frequency division multiple access (OFDMA) systems, single-carrier frequency division multiple access (SC-FDMA) systems, and time division synchronous code division multiple access (TD-SCDMA) systems.

[0003] These multiple access technologies have been adopted in various telecommunication standards to provide a common protocol that enables different wireless devices to communicate on a municipal, national, regional, and even global level. An example telecommunication standard is 5G New Radio (NR). 5G NR is part of a continuous mobile broadband evolution promulgated by Third Generation Partnership Project (3GPP) to meet new requirements associated with latency, reliability, security, scalability (e.g., with Internet of Things (IoT)), and other requirements. 5G NR includes services associated with enhanced mobile broadband (eMBB), massive machine type communications (mMTC), and ultra reliable low latency communications (URLLC). Some aspects of 5G NR may be based on the 4G Long Term Evolution (LTE) standard. There exists a need for further improvements in 5G NR technology. These improvements may also be applicable to other multi-access technologies and the telecommunication standards that employ these technologies.

SUMMARY

[0004] The following presents a simplified summary of one or more aspects in order to provide a basic understanding of such aspects. This summary is not an extensive overview of all contemplated aspects, and is intended to neither identify key or critical elements of all aspects nor delineate the scope of any or all aspects. Its sole purpose is to present some concepts of one or more aspects in a simplified form as a prelude to the more detailed description that is presented later.

[0005] In an aspect, the disclosure provides a method of wireless communication for a user equipment (UE). The method may include receiving, while connected to a LTE network, a request to measure a secondary cell group for a 5G NR network. The method may include determining whether to measure the secondary cell group based on a 5G NR connection mode selected by an application processor.

[0006] In another aspect, the disclosure provides an example apparatus for wireless communication. The apparatus may include a memory storing computer-executable instructions and at least one processor coupled with the memory. The at least one processor may be configured to receive, while connected to a LTE network, a request to measure a secondary cell group for a 5G NR network. The at least one processor may be configured to determine whether to measure the secondary cell group based on a 5G NR connection mode selected by an application processor.

[0007] In another aspect, the disclosure provides a second example apparatus for wireless communication. The second example apparatus may include means for receiving, while connected to a long term evolution (LTE) network, a request to measure a secondary cell group for a 5G new radio (NR) network. The second example apparatus may include means for determining whether to measure the secondary cell group based on a 5G NR connection mode selected by an application processor.

[0008] In another aspect, the disclosure provides a non-transitory computer-readable medium storing computer executable code. The code when executed by a processor may cause the processor to receive, while connected to a long term evolution (LTE) network, a request to measure a secondary cell group for a 5G new radio (NR) network. The code when executed by a processor may cause the processor to determine whether to measure the secondary cell group based on a 5G NR connection mode selected by an application processor.

[0009] To the accomplishment of the foregoing and related ends, the one or more aspects comprise the features hereinafter fully described and particularly pointed out in the claims. The following description and the annexed drawings set forth in detail certain illustrative features of the one or more aspects. These features are indicative, however, of but a few of the various ways in which the principles of various aspects may be employed, and this description is intended to include all such aspects and their equivalents.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 is a diagram illustrating an example of a wireless communications system and an access network.

[0011] FIGs. 2A, 2B, 2C, and 2D are diagrams illustrating examples of a first 5G/NR frame, DL channels within a 5G/NR subframe, a second 5G/NR frame, and UL channels within a 5G/NR subframe, respectively.

[0012] FIG. 3 is a diagram illustrating an example of a base station and user equipment (UE) in an access network.

[0013] FIG. 4 is a schematic diagram illustrating an example UE with dual connectivity capability.

[0014] FIG. 5 is a diagram of an example process for establishing dual connectivity.

[0015] FIG. 6 is a diagram of an example process for determining whether to establish dual connectivity.

[0016] FIG. 7 is a flowchart of an example method of wireless communications.

[0017] FIG. 8 is a schematic diagram of example components of the UE of FIG. 1.

DETAILED DESCRIPTION

[0018] The detailed description set forth below in connection with the appended drawings is intended as a description of various configurations and is not intended to represent the only configurations in which the concepts described herein may be practiced. The detailed description includes specific details for the purpose of providing a thorough understanding of various concepts. However, it will be apparent to those skilled in the art that these concepts may be practiced without these specific details. In some instances, well known structures and components are shown in block diagram form in order to avoid obscuring such concepts.

[0019] Dual connectivity may refer to a capability of a device to establish two or more concurrent connections using different radio access technology (RAT) types. For example, a user equipment (UE) may connect to both an LTE network (collectively referred to as Evolved Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (E-UTRA)) and a 5G NR network. An example network deployment referred to as E-UTRA-NR Dual Connectivity (EN-DC) may include both LTE base station(s) (also referred to as eNB) and 5G NR base station(s) (also referred to as gNB) and an LTE core network referred to as an evolved packet core (EPC). An EN-DC network deployment may make use of existing LTE infrastructure for rapid deployment of 5G NR access network technology.

[0020] A dual connectivity UE operating in an EN-DC deployment may consume significant amounts of power by maintaining both an LTE connection and a 5G NR connection. For example, the UE may power separate LTE and 5G NR modems or chipsets to maintain the connections. In some scenarios, a network may configure a UE to operate in dual connectivity based on the availability of a 5G NR gNB even though the UE has no particular need for a 5G NR connection. For example, a data rate of the UE may be serviced by the LTE connection. In such scenarios, an additional 5G NR connection may not improve performance of the UE.

[0021] The present disclosure provides techniques for a UE to selectively manage dual connectivity in association with network configuration messages. For example, an application processor may determine a 5G NR connectivity mode based on one or more of: an application layer data rate, a user selected preference, a battery level of the UE, a latency requirement, a thermal mitigation or a combination thereof. When the UE is connected to an LTE network and receives a request to measure a secondary cell group for a 5G NR network, the UE may determine whether to connect to a 5G NR gNB based on the 5G NR connectivity mode. Accordingly, the UE may avoid dual connectivity and associated power consumption based on determinations by the UE.

[0022] Several aspects of telecommunication systems will now be presented with reference to various apparatus and methods. These apparatus and methods will be described in the following detailed description and illustrated in the accompanying drawings by various blocks, components, circuits, processes, algorithms, etc. (collectively referred to as “elements”). These elements may be implemented using electronic hardware, computer software, or any combination thereof. Whether such elements are implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system.

[0023] By way of example, an element, or any portion of an element, or any combination of elements may be implemented as a "processing system" that includes one or more processors. Examples of processors include microprocessors, microcontrollers, graphics processing units (GPUs), central processing units (CPUs), application processors, digital signal processors (DSPs), reduced instruction set computing (RISC) processors, systems on a chip (SoC), baseband processors, field programmable gate arrays (FPGAs), programmable logic devices (PLDs), state machines, gated logic, discrete hardware circuits, and other suitable hardware configured to perform the various functionality described throughout this disclosure. One or more processors in the processing system may execute software. Software shall be construed broadly to mean instructions, instruction sets, code, code segments, program code, programs, subprograms, software components, applications, software applications, software packages, routines, subroutines, objects, executables, threads of execution, procedures, functions, etc., whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise.

[0024] Accordingly, in one or more example embodiments, the functions described may be implemented in hardware, software, or any combination thereof. If implemented in software, the functions may be stored on or encoded as one or more instructions or code on a computer-readable medium. Computer-readable media includes computer storage media. Storage media may be any available media that can be accessed by a computer. By way of example, and not limitation, such computer-readable media can comprise a random-access memory (RAM), a read-only memory (ROM), an electrically erasable programmable ROM (EEPROM), optical disk storage, magnetic disk storage, other magnetic storage devices, combinations of the aforementioned types of computer-readable media, or any other medium that can be used to store computer executable code in the form of instructions or data structures that can be accessed by a computer.

[0025] FIG. 1 is a diagram illustrating an example of a wireless communications system and an access network 100. The wireless communications system (also referred to as a wireless wide area network (WWAN)) includes base stations 102, UEs 104, an Evolved Packet Core (EPC) 160, and optionally another core network 190 (e.g., a

5G Core (5GC)). The base stations 102 may include macrocells (high power cellular base station) and/or small cells (low power cellular base station). The macrocells include base stations. The small cells include femtocells, picocells, and microcells.

[0026] In an aspect, a UE 104 may include a connectivity selection component 140 that is configured to determine whether the UE 104 establishes dual connectivity with both an LTE base station and a 5G NR base station. The connectivity selection component 140 may include a measurement component 142 that receives, while connected to the LTE network, a request to measure a secondary cell group for a 5G NR network. In an aspect, the measurement component 142 may be implemented by a 4G modem of the UE 104. The connectivity selection component 140 may include a mode selector 144 that selects a 5G NR connection mode based on one or more of: an application layer data rate, a user selected preference, a battery level of the UE, a latency requirement, a thermal mitigation or a combination thereof. In an aspect, the measurement component 142 may be implemented by an application processor (AP) of the UE 104. The connectivity selection component 140 may include a mode indicator that determines whether to measure the secondary cell group based on the 5G NR connection mode.

[0027] The base stations 102 configured for 4G LTE (collectively referred to as Evolved Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (E-UTRAN)) may interface with the EPC 160 through backhaul links 132 (e.g., S1 interface). The backhaul links 132 may be wired or wireless. The base stations 102 configured for 5G NR (collectively referred to as Next Generation RAN (NG-RAN)) may interface with core network 190 and/or EPC 160 through backhaul links 132, 134, 184, which may be wired or wireless. In an aspect, for example, an EN-DC configuration may utilize an LTE master cell group (MCG) and EPC 160 to support communications between the UE 104 and base stations 102 configured for 5G NR. The base stations 102 configured for 5G NR may establish a backhaul link (e.g., S1 bearer) directly with the serving gateway 166 of the EPC or via a master eNB (i.e., a base station 102 configured for 4G LTE). Accordingly, a UE 104 may establish a 5G NR connection with a 5G access network even if a 5GC is not deployed. Although the following description may be focused on 5G NR and LTE, the concepts described herein may be applicable to other similar areas, such as, LTE-A, CDMA, GSM, and other wireless technologies.

[0028] In addition to other functions, the base stations 102 may perform one or more of the following functions: transfer of user data, radio channel ciphering and deciphering, integrity protection, header compression, mobility control functions (e.g., handover, dual connectivity), inter-cell interference coordination, connection setup and release, load balancing, distribution for non-access stratum (NAS) messages, NAS node selection, synchronization, radio access network (RAN) sharing, multimedia broadcast multicast service (MBMS), subscriber and equipment trace, RAN information management (RIM), paging, positioning, and delivery of warning messages. The base stations 102 may communicate directly or indirectly (e.g., through the EPC 160 or core network 190) with each other over backhaul links 134 (e.g., X2 interface). The backhaul links 134 may be wired or wireless.

[0029] The base stations 102 may wirelessly communicate with the UEs 104. Each of the base stations 102 may provide communication coverage for a respective geographic coverage area 110. There may be overlapping geographic coverage areas 110. For example, the small cell 102' may have a coverage area 110' that overlaps the coverage area 110 of one or more macro base stations 102. A network that includes both small cell and macrocells may be known as a heterogeneous network. A heterogeneous network may also include Home Evolved Node Bs (eNBs) (HeNBs), which may provide service to a restricted group known as a closed subscriber group (CSG). The communication links 120 between the base stations 102 and the UEs 104 may include uplink (UL) (also referred to as reverse link) transmissions from a UE 104 to a base station 102 and/or downlink (DL) (also referred to as forward link) transmissions from a base station 102 to a UE 104. The communication links 120 may use multiple-input and multiple-output (MIMO) antenna technology, including spatial multiplexing, beamforming, and/or transmit diversity. The communication links may be through one or more carriers. The base stations 102 / UEs 104 may use spectrum up to Y MHz (e.g., 5, 10, 15, 20, 100, 400, etc. MHz) bandwidth per carrier allocated in a carrier aggregation of up to a total of Yx MHz (x component carriers) used for transmission in each direction. The carriers may or may not be adjacent to each other. Allocation of carriers may be asymmetric with respect to DL and UL (e.g., more or fewer carriers may be allocated for DL than for UL). The component carriers may include a primary component carrier and one or more secondary component carriers. A primary component carrier may be referred to as a primary cell (PCell) and a secondary component carrier may be referred to as a secondary cell (SCell).

[0030] Certain UEs 104 may communicate with each other using device-to-device (D2D) communication link 158. The D2D communication link 158 may use the DL/UL WWAN spectrum. The D2D communication link 158 may use one or more sidelink channels, such as a physical sidelink broadcast channel (PSBCH), a physical sidelink discovery channel (PSDCH), a physical sidelink shared channel (PSSCH), and a physical sidelink control channel (PSCCH). D2D communication may be through a variety of wireless D2D communications systems, such as for example, FlashLinQ, WiMedia, Bluetooth, ZigBee, Wi-Fi based on the IEEE 802.11 standard, LTE, or NR.

[0031] The wireless communications system may further include a Wi-Fi access point (AP) 150 in communication with Wi-Fi stations (STAs) 152 via communication links 154 in a 5 GHz unlicensed frequency spectrum. When communicating in an unlicensed frequency spectrum, the STAs 152 / AP 150 may perform a clear channel assessment (CCA) prior to communicating in order to determine whether the channel is available.

[0032] The small cell 102' may operate in a licensed and/or an unlicensed frequency spectrum. When operating in an unlicensed frequency spectrum, the small cell 102' may employ NR and use the same 5 GHz unlicensed frequency spectrum as used by the Wi-Fi AP 150. The small cell 102', employing NR in an unlicensed frequency spectrum, may boost coverage to and/or increase capacity of the access network.

[0033] A base station 102, whether a small cell 102' or a large cell (e.g., macro base station), may include an eNB, gNodeB (gNB), or another type of base station. Some base stations, such as gNB 180 may operate in a traditional sub 6 GHz spectrum, in millimeter wave (mmW) frequencies, and/or near mmW frequencies in communication with the UE 104. When the gNB 180 operates in mmW or near mmW frequencies, the gNB 180 may be referred to as an mmW base station. Extremely high frequency (EHF) is part of the RF in the electromagnetic spectrum. EHF has a range of 30 GHz to 300 GHz and a wavelength between 1 millimeter and 10 millimeters. Radio waves in the band may be referred to as a millimeter wave. Near mmW may extend down to a frequency of 3 GHz with a wavelength of 100 millimeters. The super high frequency (SHF) band extends between 3 GHz and 30 GHz, also referred to as centimeter wave. Communications using the mmW / near mmW radio frequency band (e.g., 3 GHz – 300 GHz) has extremely high path loss and a short range. The mmW base station 180 may utilize beamforming 182 with the UE 104 to compensate for the extremely high path loss and short range.

[0034] The base station 180 may transmit a beamformed signal to the UE 104 in one or more transmit directions 182'. The UE 104 may receive the beamformed signal from the base station 180 in one or more receive directions 182''. The UE 104 may also transmit a beamformed signal to the base station 180 in one or more transmit directions. The base station 180 may receive the beamformed signal from the UE 104 in one or more receive directions. The base station 180 / UE 104 may perform beam training to determine the best receive and transmit directions for each of the base station 180 / UE 104. The transmit and receive directions for the base station 180 may or may not be the same. The transmit and receive directions for the UE 104 may or may not be the same.

[0035] The EPC 160 may include a Mobility Management Entity (MME) 162, other MMEs 164, a Serving Gateway 166, a Multimedia Broadcast Multicast Service (MBMS) Gateway 168, a Broadcast Multicast Service Center (BM-SC) 170, and a Packet Data Network (PDN) Gateway 172. The MME 162 may be in communication with a Home Subscriber Server (HSS) 174. The MME 162 is the control node that processes the signaling between the UEs 104 and the EPC 160. Generally, the MME 162 provides bearer and connection management. All user Internet protocol (IP) packets are transferred through the Serving Gateway 166, which itself is connected to the PDN Gateway 172. The PDN Gateway 172 provides UE IP address allocation as well as other functions. The PDN Gateway 172 and the BM-SC 170 are connected to the IP Services 176. The IP Services 176 may include the Internet, an intranet, an IP Multimedia Subsystem (IMS), a PS Streaming Service, and/or other IP services. The BM-SC 170 may provide functions for MBMS user service provisioning and delivery. The BM-SC 170 may serve as an entry point for content provider MBMS transmission, may be used to authorize and initiate MBMS Bearer Services within a public land mobile network (PLMN), and may be used to schedule MBMS transmissions. The MBMS Gateway 168 may be used to distribute MBMS traffic to the base stations 102 belonging to a Multicast Broadcast Single Frequency Network (MBSFN) area broadcasting a particular service, and may be responsible for session management (start/stop) and for collecting MBMS related charging information.

[0036] The core network 190 may include a Access and Mobility Management Function (AMF) 192, other AMFs 193, a Session Management Function (SMF) 194, and a User Plane Function (UPF) 195. The AMF 192 may be in communication with a Unified Data Management (UDM) 196. The AMF 192 is the control node that processes the signaling between the UEs 104 and the core network 190. Generally, the AMF 192 provides QoS flow and session management. All user Internet protocol (IP) packets are transferred through the UPF 195. The UPF 195 provides UE IP address allocation as well as other functions. The UPF 195 is connected to the IP Services 197. The IP Services 197 may include the Internet, an intranet, an IP Multimedia Subsystem (IMS), a PS Streaming Service, and/or other IP services.

[0037] The base station may also be referred to as a gNB, Node B, evolved Node B (eNB), an access point, a base transceiver station, a radio base station, a radio transceiver, a transceiver function, a basic service set (BSS), an extended service set (ESS), a transmit reception point (TRP), or some other suitable terminology. The base station 102 provides an access point to the EPC 160 or core network 190 for a UE 104. Examples of UEs 104 include a cellular phone, a smart phone, a session initiation protocol (SIP) phone, a laptop, a personal digital assistant (PDA), a satellite radio, a global positioning system, a multimedia device, a video device, a digital audio player (e.g., MP3 player), a camera, a game console, a tablet, a smart device, a wearable device, a vehicle, an electric meter, a gas pump, a large or small kitchen appliance, a healthcare device, an implant, a sensor/actuator, a display, or any other similar functioning device. Some of the UEs 104 may be referred to as IoT devices (e.g., parking meter, gas pump, toaster, vehicles, heart monitor, etc.). The UE 104 may also be referred to as a station, a mobile station, a subscriber station, a mobile unit, a subscriber unit, a wireless unit, a remote unit, a mobile device, a wireless device, a wireless communications device, a remote device, a mobile subscriber station, an access terminal, a mobile terminal, a wireless terminal, a remote terminal, a handset, a user agent, a mobile client, a client, or some other suitable terminology.

[0038] FIG. 2A is a diagram 200 illustrating an example of a first subframe within a 5G/NR frame structure. FIG. 2B is a diagram 230 illustrating an example of DL channels within a 5G/NR subframe. FIG. 2C is a diagram 250 illustrating an example of a second subframe within a 5G/NR frame structure. FIG. 2D is a diagram 280 illustrating an example of UL channels within a 5G/NR subframe. The 5G/NR frame structure may be FDD in which for a particular set of subcarriers (carrier system bandwidth), subframes within the set of subcarriers are dedicated for either DL or UL, or may be TDD in which for a particular set of subcarriers (carrier system bandwidth), subframes within the set of subcarriers are dedicated for both DL and UL. In the examples provided by FIGs. 2A, 2C, the 5G/NR frame structure is assumed to be TDD, with subframe 4 being configured with slot format 28 (with mostly DL), where D is DL, U is UL, and X is flexible for use between DL/UL, and subframe 3 being configured with slot format 34 (with mostly UL). While subframes 3, 4 are shown with slot formats 34, 28, respectively, any particular subframe may be configured with any of the various available slot formats 0-61. Slot formats 0, 1 are all DL, UL, respectively. Other slot formats 2-61 include a mix of DL, UL, and flexible symbols. UEs are configured with the slot format (dynamically through DL control information (DCI), or semi-statically/statically through radio resource control (RRC) signaling) through a received slot format indicator (SFI). Note that the description *infra* applies also to a 5G/NR frame structure that is TDD.

[0039] Other wireless communication technologies may have a different frame structure and/or different channels. A frame (10 ms) may be divided into 10 equally sized subframes (1 ms). Each subframe may include one or more time slots. Subframes may also include mini-slots, which may include 7, 4, or 2 symbols. Each slot may include 7 or 14 symbols, depending on the slot configuration. For slot configuration 0, each slot may include 14 symbols, and for slot configuration 1, each slot may include 7 symbols. The symbols on DL may be cyclic prefix (CP) OFDM (CP-OFDM) symbols. The symbols on UL may be CP-OFDM symbols (for high throughput scenarios) or discrete Fourier transform (DFT) spread OFDM (DFT-s-OFDM) symbols (also referred to as single carrier frequency-division multiple access (SC-FDMA) symbols) (for power limited scenarios; limited to a single stream transmission). The number of slots within a subframe is based on the slot configuration and the numerology. For slot configuration 0, different numerologies μ 0 to 5 allow for 1, 2, 4, 8, 16, and 32 slots, respectively, per subframe. For slot configuration 1, different numerologies 0 to 2 allow for 2, 4, and 8 slots, respectively, per subframe. Accordingly, for slot configuration 0 and numerology μ, there are 14 symbols/slot and 2^{μ} slots/subframe. The subcarrier spacing and symbol length/duration are a function of the numerology. The subcarrier spacing may be equal to $2^{\mu} * 15$ kHz, where μ is the numerology 0 to 5. As such, the numerology μ=0 has a subcarrier spacing of 15 kHz and the numerology μ=5 has a subcarrier spacing of 480 kHz. The symbol length/duration is inversely related to the subcarrier spacing. FIGs. 2A-2D provide an example of slot configuration 0 with 14 symbols per slot and numerology μ=0 with 1 slot per subframe. The subcarrier spacing is 15 kHz and symbol duration is approximately 66.7 μs.

[0040] A resource grid may be used to represent the frame structure. Each time slot includes a resource block (RB) (also referred to as physical RBs (PRBs)) that extends 12 consecutive subcarriers. The resource grid is divided into multiple resource elements (REs). The number of bits carried by each RE depends on the modulation scheme.

[0041] As illustrated in FIG. 2A, some of the REs carry reference (pilot) signals (RS) for the UE. The RS may include demodulation RS (DM-RS) (indicated as R_x for one particular configuration, where 100x is the port number, but other DM-RS configurations are possible) and channel state information reference signals (CSI-RS) for channel estimation at the UE. The RS may also include beam measurement RS (BRS), beam refinement RS (BRRS), and phase tracking RS (PT-RS).

[0042] FIG. 2B illustrates an example of various DL channels within a subframe of a frame. The physical downlink control channel (PDCCH) carries DCI within one or more control channel elements (CCEs), each CCE including nine RE groups (REGs), each REG including four consecutive REs in an OFDM symbol. A primary synchronization signal (PSS) may be within symbol 2 of particular subframes of a frame. The PSS is used by a UE 104 to determine subframe/symbol timing and a physical layer identity. A secondary synchronization signal (SSS) may be within symbol 4 of particular subframes of a frame. The SSS is used by a UE to determine a physical layer cell identity group number and radio frame timing. Based on the physical layer identity and the physical layer cell identity group number, the UE can determine a physical cell identifier (PCI). Based on the PCI, the UE can determine the locations of the aforementioned DM-RS. The physical broadcast channel (PBCH), which carries a master information block (MIB), may be logically grouped with the PSS and SSS to form a synchronization signal (SS)/PBCH block. The MIB provides a number of RBs in the system bandwidth and a system frame number (SFN). The physical downlink shared channel (PDSCH) carries user data, broadcast system information not transmitted through the PBCH such as system information blocks (SIBs), and paging messages.

[0043] As illustrated in FIG. 2C, some of the REs carry DM-RS (indicated as R for one particular configuration, but other DM-RS configurations are possible) for channel estimation at the base station. The UE may transmit DM-RS for the physical uplink control channel (PUCCH) and DM-RS for the physical uplink shared channel (PUSCH). The PUSCH DM-RS may be transmitted in the first one or two symbols of the PUSCH. The PUCCH DM-RS may be transmitted in different configurations depending on whether short or long PUCCHs are transmitted and depending on the particular PUCCH format used. Although not shown, the UE may transmit sounding reference signals (SRS). The SRS may be used by a base station for channel quality estimation to enable frequency-dependent scheduling on the UL.

[0044] FIG. 2D illustrates an example of various UL channels within a subframe of a frame. The PUCCH may be located as indicated in one configuration. The PUCCH carries uplink control information (UCI), such as scheduling requests, a channel quality indicator (CQI), a precoding matrix indicator (PMI), a rank indicator (RI), and HARQ ACK/NACK feedback. The PUSCH carries data, and may additionally be used to carry a buffer status report (BSR), a power headroom report (PHR), and/or UCI.

[0045] FIG. 3 is a block diagram of a base station 310 in communication with a UE 350 in an access network. In the DL, IP packets from the EPC 160 may be provided to a controller/processor 375. The controller/processor 375 implements layer 3 and layer 2 functionality. Layer 3 includes a radio resource control (RRC) layer, and layer 2 includes a service data adaptation protocol (SDAP) layer, a packet data convergence protocol (PDCP) layer, a radio link control (RLC) layer, and a medium access control (MAC) layer. The controller/processor 375 provides RRC layer functionality associated with broadcasting of system information (e.g., MIB, SIBs), RRC connection control (e.g., RRC connection paging, RRC connection establishment, RRC connection modification, and RRC connection release), inter radio access technology (RAT) mobility, and measurement configuration for UE measurement reporting; PDCP layer functionality associated with header compression / decompression, security (ciphering, deciphering, integrity protection, integrity verification), and handover support functions; RLC layer functionality associated with the transfer of upper layer packet data units (PDUs), error correction through ARQ, concatenation, segmentation, and reassembly of RLC service data units (SDUs), re-segmentation of RLC data PDUs, and reordering of RLC data PDUs; and MAC layer functionality associated with mapping between logical channels and transport channels, multiplexing of MAC SDUs onto transport blocks (TBs), demultiplexing of MAC SDUs from TBs, scheduling information reporting, error correction through HARQ, priority handling, and logical channel prioritization.

[0046] The transmit (TX) processor 316 and the receive (RX) processor 370 implement layer 1 functionality associated with various signal processing functions. Layer 1, which includes a physical (PHY) layer, may include error detection on the transport channels, forward error correction (FEC) coding/decoding of the transport channels, interleaving, rate matching, mapping onto physical channels, modulation/demodulation of physical channels, and MIMO antenna processing. The TX processor 316 handles mapping to signal constellations based on various modulation schemes (e.g., binary phase-shift keying (BPSK), quadrature phase-shift keying (QPSK), M-phase-shift keying (M-PSK), M-quadrature amplitude modulation (M-QAM)). The coded and modulated symbols may then be split into parallel streams. Each stream may then be mapped to an OFDM subcarrier, multiplexed with a reference signal (e.g., pilot) in the time and/or frequency domain, and then combined together using an Inverse Fast Fourier Transform (IFFT) to produce a physical channel carrying a time domain OFDM symbol stream. The OFDM stream is spatially precoded to produce multiple spatial streams. Channel estimates from a channel estimator 374 may be used to determine the coding and modulation scheme, as well as for spatial processing. The channel estimate may be derived from a reference signal and/or channel condition feedback transmitted by the UE 350. Each spatial stream may then be provided to a different antenna 320 via a separate transmitter 318TX. Each transmitter 318TX may modulate an RF carrier with a respective spatial stream for transmission.

[0047] At the UE 350, each receiver 354RX receives a signal through its respective antenna 352. Each receiver 354RX recovers information modulated onto an RF carrier and provides the information to the receive (RX) processor 356. The TX processor 368 and the RX processor 356 implement layer 1 functionality associated with various signal processing functions. The RX processor 356 may perform spatial processing on the information to recover any spatial streams destined for the UE 350. If multiple spatial streams are destined for the UE 350, they may be combined by the RX processor 356 into a single OFDM symbol stream. The RX processor 356 then converts the OFDM symbol stream from the time-domain to the frequency domain using a Fast Fourier Transform (FFT). The frequency domain signal comprises a separate OFDM symbol stream for each subcarrier of the OFDM signal. The symbols on each subcarrier, and the reference signal, are recovered and demodulated by determining the most likely signal constellation points transmitted by the base station 310. These soft decisions may be based on channel estimates computed by the channel estimator 358. The soft decisions are then decoded and deinterleaved to recover the data and control signals that were originally transmitted by the base station 310 on the physical channel. The data and control signals are then provided to the controller/processor 359, which implements layer 3 and layer 2 functionality.

[0048] The controller/processor 359 can be associated with a memory 360 that stores program codes and data. The memory 360 may be referred to as a computer-readable medium. In the UL, the controller/processor 359 provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, and control signal processing to recover IP packets from the EPC 160. The controller/processor 359 is also responsible for error detection using an ACK and/or NACK protocol to support HARQ operations.

[0049] Similar to the functionality described in connection with the DL transmission by the base station 310, the controller/processor 359 provides RRC layer functionality associated with system information (e.g., MIB, SIBs) acquisition, RRC connections, and measurement reporting; PDCP layer functionality associated with header compression / decompression, and security (ciphering, deciphering, integrity protection, integrity verification); RLC layer functionality associated with the transfer of upper layer PDUs, error correction through ARQ, concatenation, segmentation, and reassembly of RLC SDUs, re-segmentation of RLC data PDUs, and reordering of RLC data PDUs; and MAC layer functionality associated with mapping between logical channels and transport channels, multiplexing of MAC SDUs onto TBs, demultiplexing of MAC SDUs from TBs, scheduling information reporting, error correction through HARQ, priority handling, and logical channel prioritization.

[0050] Channel estimates derived by a channel estimator 358 from a reference signal or feedback transmitted by the base station 310 may be used by the TX processor 368 to select the appropriate coding and modulation schemes, and to facilitate spatial processing. The spatial streams generated by the TX processor 368 may be provided to different antenna 352 via separate transmitters 354TX. Each transmitter 354TX may modulate an RF carrier with a respective spatial stream for transmission.

[0051] The UL transmission is processed at the base station 310 in a manner similar to that described in connection with the receiver function at the UE 350. Each receiver 318RX receives a signal through its respective antenna 320. Each receiver 318RX recovers information modulated onto an RF carrier and provides the information to a RX processor 370.

[0052] The controller/processor 375 can be associated with a memory 376 that stores program codes and data. The memory 376 may be referred to as a computer-readable medium. In the UL, the controller/processor 375 provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, control signal processing to recover IP packets from the UE 350. IP packets from the controller/processor 375 may be provided to the EPC 160. The controller/processor 375 is also responsible for error detection using an ACK and/or NACK protocol to support HARQ operations.

[0053] At least one of the TX processor 368, the RX processor 356, and the controller/processor 359 may be configured to perform aspects in connection with connectivity selection component 140 of FIG. 1.

[0054] Turning now to FIG. 4, a schematic diagram of an example network 400 includes a UE 104 connected to both an LTE eNB 440 and a 5G gNB 450, both of which may be examples of a base station 102. The network 400 also includes an EPC 160, which acts as a core network for both the LTE connection and the 5G NR connection. The LTE eNB 440 may act as a master serving cell for the UE 104. The UE 104 may establish a communication link 442 with the LTE eNB 440. The communication link 442 may, for example, carry RRC configuration messages. In an EN-DC configuration, the 5G gNB 450 may act as a secondary cell of a secondary cell group. That is, the LTE eNB 440 may configure the UE 104 to measure the 5G gNB 450 and establish a communication link 452. Accordingly, in an aspect, the communication link 442 may be a primary communication link and the communication link 452 may be a secondary communication link.

[0055] The LTE eNB 440 may connect to the EPC 160 via a backhaul link 446 (e.g., an S1 interface). A connection between the 5G gNB 450 and the EPC 160 may depend on a deployment option of the network. In a first EN-DC option, referred to as option 3, the gNB 450 may connect to the EPC 160 via the eNB 440. The gNB 450 may communicate over an X2 interface 460 with the LTE eNB 440, and the eNB 440 may forward communications via a bearer 462. In a second EN-DC option, referred to as option 3a, the gNB 450 may have an S1 interface 464 with the EPC 160, and establish a user bearer directly with the EPC 160 via the S1 interface 464. In a third EN-DC option, referred to as option 3x, the eNB 440 may connect to EPC 160 via the gNB 450, The LTE eNB 440 may communicate over an X2 interface 460 with the gNB 450, and the gNB 450 may forward communications via a bearer 464.

[0056] The UE 104 may include an application processor 410 that executes one or more applications, a 4G modem 420, and a 5G modem 430. For example, the application processor 410 may execute an operating system of the UE 104, which in turn, controls one or more user installed applications. The application processor 410 may execute the mode selector 144. The 4G modem 420 may execute 4G LTE protocols. For example, the 4G modem 420 may include the measurement component 142 configured to perform measurements of neighbor cells, which may include interfrequency LTE cells and interRAT cells (e.g., gNB 450). The 5G modem 430 may execute 5G NR protocols. In an aspect, the 4G modem 420 and 5G modem 430 may be separate chipsets and may be individually activated or deactivated.

[0057] In an aspect, the UE 104 may include the mode indicator 146. For example, the mode indicator 146 may be a flag on the 4G modem 420 and/or the 5G modem 430 that indicates a 5G NR connection mode. For example, the 5G NR connection mode may be either an allowed mode or a blocked mode. In an allowed mode, the UE 104 may establish the communication link 452 to the 5G gNB 450. In the blocked mode, the UE 104 may be prevented from establishing the communication link 452 to the 5G gNB 450.

[0058] In an aspect, the application processor 410 may include or execute a mode selector 144 configured to select a 5G NR connection mode. For example, the mode selector 144 may be configured to select the 5G NR connection mode based on one or more of an application layer data rate, a user selected preference, a battery level of the UE, a latency requirement, a thermal mitigation, or a combination thereof.

The 4G modem 420 and/or the 5G modem 430 may provide the application processor 410 with access to the mode indicator 146 via an interface (e.g., an application programming interface (API)). For example, the application processor 410 and/or mode selector 144 may set a value of the mode indicator 146. The mode indicator 146 may be checked by the 4G modem 420 when the LTE eNB 440 configures the UE 104 for measuring or connecting to the 5G gNB 450.

[0059] Turning to FIG. 5, a flow diagram 500 includes example actions of a UE 104 and network 400 for establishing dual connectivity in a EN-DC deployment. The UE 104 may include the application processor (AP) 410, 5G modem 420, and 4G modem 430, and the network 400 may include the LTE eNB 440, 5G gNB 450, and EPC 160.

[0060] At 502, the UE 104 may be powered on. For example, a user may press a power button on the UE 104 or activate a WWAN connection.

[0061] At 504, the 4G modem 420 may perform an LTE cell camping procedure. For example, the 4G modem 420 may use the measurement component 142 to find a suitable eNB 440 and acquire system information.

[0062] At 506, the 4G modem 420 may transmit an attach request message to the EPC 160 via the eNB 440. The attach request message may indicate support for dual connectivity with 5G NR. The attach request message may request that the eNB 440 be the primary serving cell for the UE 104.

[0063] At 508, the eNB 440 may transmit a UE capability enquiry asking for dual connectivity information such as 5G NR and EN-DC band combination support.

[0064] At 510, the 4G modem 420 may transmit the requested UE capability information. For example, in an aspect, the 4G modem 420 may transmit an EN-DC capability information element.

[0065] At 512, the eNB 440 may transmit an RRC connection reconfiguration message. The RRC connection reconfiguration message may specify one or more measurement objects. If the network 400 includes a gNB 450 supported by the EN-DC capability of the UE 104, the RRC connection reconfiguration message may specify a measurement object for the carrier frequency of the gNB 450. For example, the network may specify a an LTE to NR (L2NR) interRAT (IRAT) measurement.

[0066] At 514, based on the measurement object identifying a 5G NR carrier frequency, the UE 104 may activate the 5G modem 430 and start NR cell measurements. For example, the 5G modem 430 may determine whether a reference signal from the gNB 450 satisfies a threshold quality and/or a beam quality.

[0067] At 516, the 4G modem 420 may transmit a measurement report indicating one or more measurement events. For example, if the reference signal from the gNB 450 satisfies a threshold quality, the 4G modem 420 may include a B1 event identifying the corresponding carrier frequency of gNB 450 as satisfying the threshold quality.

[0068] At 518, the eNB 440 may request the gNB 450 to allocate resources for EN-DC operation for the UE 104.

[0069] At 520, the eNB 440 may transmit an RRC connection reconfiguration message configuring the UE 104 to add the measured cell of the gNB 450.

[0070] At 522, the 5G modem 430 may camp on the cell of the gNB 450 and acquire system information. The 5G modem 430 may perform a RACH procedure to communicate with the gNB 450. The UE 104 may be considered to be in an EN-DC mode with a connection to both the eNB 440 and the gNB 450.

[0071] At 524, the 4G modem 420 may transmit an RRC connection reconfiguration complete message.

[0072] At 526, the 5G modem 430 may be connected to the gNB 450. The eNB 440 may still be considered the master cell group, while the gNB 450 may be considered a secondary cell group. The UE 104 may exchange data with one or both of the eNB 440 and gNB 450. The gNB 450 may communicate with the EPC 160 according to one of the deployment options as discussed above regarding FIG. 4.

[0073] Turning to FIG. 6, a flow diagram 600 includes example actions of a UE 104 and network 400 for selectively establishing dual connectivity in a EN-DC deployment. The actions 502, 504, 506, 508, 510, and 512 may be the same as described above regarding FIG. 5.

[0074] At 602, the UE 104 may determine to ignore the RRC connection reconfiguration message if the mode indicator 146 indicates a blocked mode. For example, the value of a NR_Connect flag may be 0 or false. In an aspect, ignoring the RRC connection reconfiguration message may include refraining from performing measurements of an identified 5G NR carrier frequency. For example, the 5G modem 430 may be powered down, and the 4G modem 420 may automatically determine (e.g., without performing a measurement) that the measured quality of the 5G carrier frequency is less than a reporting threshold configured by the RRC connection reconfiguration message. Accordingly, the 4G modem 430 may determine that there is no event to report with respect to the identified 5G carrier frequency.

[0075] At 604, a data connection may be set up between the 4G modem 420 and the EPC 160 as an LTE only connection mode. That is, the UE 104 may communicate with the eNB 440, but not the gNB 450. In an aspect, using an LTE only connection may use less power than a dual connection using both LTE and 5G NR. Accordingly, when the higher data rate and/or lower latency of 5G NR are not needed, the UE 104 may save power by using an LTE only connection.

[0076] At 606, the application processor 410 may change the mode indicator 146. For example, the application processor 410 may set the NR_Connect flag to a value of 1 or true. For example, the application processor 410 may change the NR_Connect flag due to a change in applications executed by the processor 410. For instance, a new or existing application may require greater data throughput or lower latency. In an aspect, since the RRC connection reconfiguration message was previously received at 512, the UE 104 may already be configured with a 4G NR carrier frequency to measure. Accordingly, at 514, the UE 104 may activate the 5G modem 430 and measure the indicated NR carrier frequency to find an NR cell.

[0077] The actions 516, 518, 520, 522, 524, and 526 may be the same as described above regarding FIG. 5. Accordingly, the UE 104 may establish a dual connectivity with the eNB 440 and the gNB 450 in response to the application processor changing the 5G NR connection mode. For example, the UE 104 may establish dual connectivity in response to a change in a requested data rate or latency for an application executed by the application processor 410.

[0078] FIG. 7 is a flowchart of an example method 700 of wireless communications. The method 700 may be performed by the UE 104 and/or components thereof.

[0079] At block 710, the method 700 may optionally include indicating, to an LTE network, a capability of dual connectivity for LTE and 5G NR. In an aspect, for example, the 4G modem 420 of the UE 104 may indicate, to the LTE network (e.g., eNB 440), a capability of dual connectivity for LTE and 5G NR. For instance the 4G modem 420 may transmit a UE capability information element indicating an EN-DC capability.

[0080] At block 720, the method 700 may include receiving, while connected to the LTE network, a request to measure a secondary cell group for a 5G NR network. For example, the 4G modem 420 may receive, while connected to the LTE network, the request to measure a secondary cell group for a 5G NR network. For instance, the request may be an RRC Connection Reconfiguration message (e.g., at 512) indicating a carrier frequency of a 5G NR cell. That is, the RRC connection reconfiguration message may configure a measurement object for UE 104 to report a measurement of the gNB 450.

[0081] At block 730, the method 700 may optionally include selecting, by an application processor, a 5G NR connection mode based on one or more of: an application layer data rate, a user selected preference, a battery level of the UE, a latency requirement, a thermal mitigation or a combination thereof. For example, the application processor 410 may select the 5G NR connection mode based on one or more of: the application layer data rate, the user selected preference, the battery level of the UE, a latency requirement, the thermal mitigation or a combination thereof. For instance, the application processor 410 may execute the mode selector 144 to set the mode indicator 146. In an aspect, the 4G NR connection mode may be one of an allowed mode or a blocked mode. The allowed mode may allow the 5G modem 430 to establish a 5G NR connection. The blocked mode may be a mode with no 5G NR connection.

[0082] At sub-block 732, the block 730 may optionally include selecting a mode with no 5G NR connection based on an application layer data rate being less than a threshold. In an aspect, for example, the application processor 410 may execute the mode selector 144 to select the blocked mode based on the application layer data rate being less than a threshold. The application layer data rate may be, for example, a rate of downlink traffic or uplink traffic at an internet protocol (IP) layer. The mode selector 144 may aggregate data traffic for all applications at the IP layer to determine a total data throughput requested by the applications being executed. The threshold may be based on a data rate of the LTE connection. For example, the threshold may be set to approximately 50 – 80 % of an average data rate of the LTE connection, which may be calculated periodically. Accordingly, when the application layer data rate can be provided by the LTE connection, the mode selector 144 may select the blocked mode, for example, to reduce power consumption.

[0083] At sub-block 734, the block 730 may optionally include selecting a mode with no 5G NR connection based on the user selected preference. In an aspect, for example, the mode selector 144 may select the blocked mode based on the user selected preference. For instance, the application processor 410 may execute an operating system or settings application that allows a user to indicate whether to use dual connectivity. In an aspect, the operating system or settings application may allow a user to specify a preference for any of the application layer data rate, the battery level of the UE, the latency requirement, or the combination thereof. Accordingly, the mode selector 144 may consider a user preference when selecting the mode based on these properties.

[0084] At sub-block 736, the block 730 may optionally include selecting a mode with no 5G NR connection based on the battery level of the UE being less than a threshold. In an aspect, for example, the application processor 410 may execute the mode selector 144 to select the blocked mode based on the battery level of the UE being less than a threshold. For instance, the threshold may 20%, 30%, 50% or a value selected by a user. As the battery level of the UE decreases, blocking a 5G NR connection in an EN-DC scenario may reduce power consumption and extend the service time of the UE 104.

[0085] At sub-block 738, the block 730 may optionally include selecting a mode with no 5G NR connection based on the latency requirement being above a threshold. In an aspect, for example, the application processor 410 may execute the mode selector 144 to select the blocked mode based on the latency requirement being above a threshold. For instance, an application executing on the application processor 410 may specify a latency requirement. The mode selector 144 may compare a minimum latency requirement of the executing applications to a threshold value to select the 5G NR connection mode. The threshold may be based on a round trip time of the LTE connection. For example, the threshold may be set to approximately 150 - 200 % of an average round trip time of the LTE connection, which may be calculated periodically. If the minimum latency requirement of the executing applications can be provided by the LTE connection, the mode selector 144 may select the blocked mode, for example, to reduce power consumption.

[0086] At sub-block 740, the block 730 may optionally include selecting a mode with no 5G NR connection based on a surface temperature or processor temperature of the UE exceeding a threshold temperature. In an aspect, for example, the application processor 410 may execute the mode selector 144 to select the blocked mode based on the surface temperature or processor temperature of the UE 104 exceeding a threshold temperature. For instance, a threshold temperature for the surface temperature may be a temperature to prevent discomfort to a user and the threshold for the processor temperature may be a temperature where processor performance decreases. Accordingly, the mode selector 144 may select the 5G NR connection mode based on a thermal mitigation for the UE.

[0087] At block 750, the method 700 may include determining whether to measure the secondary cell group based on the 5G NR connection mode selected by an application processor. In an aspect, for example, the 4G modem 420 may execute the measurement component 142 to determine whether to measure the secondary cell group based on the mode indicator 146. For instance, the measurement component 142 may determine to measure the secondary cell group when the 5G NR connection mode is the allowed mode and may determine not to measure the secondary cell group when the 5G NR connection mode is the blocked mode.

[0088] At sub-block 752, the block 750 may optionally include determining a flag indicating the 5G NR connection mode. For example, the mode indicator 146 may be a flag indicating the 5G NR connection mode. The measurement component 142 may read a value of the flag. The flag may be set by the application processor 410.

[0089] At block 760, the method 700 may optionally include establishing a data connection with only the LTE network. In an aspect, for example, the 4G modem 420 may establish the data connection with only the LTE network after receiving the request to measure the secondary cell group for the 5G NR network. Accordingly, the 4G modem 420 may establish an LTE only connection even through the gNB 450 may be available for a 5G NR connection.

[0090] At sub-block 762, the block 760 may optionally include establishing the data connection via an LTE modem and powering down a 5G NR modem. For example, the UE 104 may establish the data connection via the 4G modem 420 and power down the 5G modem 430.

[0091] At block 770, the method 700 may optionally include activating a 5G NR modem in response to determining to measure the secondary cell group. In an aspect, for example, the UE 104 may activate the 5G modem 430 in response to determining to measure the secondary cell group. Activating the 5G modem 430 may include providing power to the 5G modem 430 or changing the 5G modem 430 from a low power state to an active state.

[0092] At block 772, the method 700 may optionally include measuring the secondary cell group using the 5G NR modem. In an aspect, for example, the 5G modem 430 may measure the secondary cell group. For example, the 5G modem 430 may be configured to measure a signal quality and beam quality of the secondary cell group. If the signal quality and beam quality satisfy the configured measurement event, the 5G modem 430 may establish a 5G NR connection with a gNB 450 and enter an EN-DC communication mode. In an aspect, the 5G NR connection may provide higher data throughput and/or lower latency than an LTE connection.

[0093] It is understood that the specific order or hierarchy of blocks in the processes / flowcharts disclosed is an illustration of example approaches. Based upon design preferences, it is understood that the specific order or hierarchy of blocks in the processes / flowcharts may be rearranged. Further, some blocks may be combined or omitted. The accompanying method claims present elements of the various blocks in a sample order, and are not meant to be limited to the specific order or hierarchy presented.

[0094] Referring to FIG. 8, one example of an implementation of UE 104 may include a variety of components, some of which have already been described above, but including components such as one or more processors 812 and memory 816 and transceiver 802 in communication via one or more buses 844, which may operate in conjunction with modem 814 and connectivity selection component 140 to enable one or more of the functions described herein related to selectively using dual connectivity. Further, the one or more processors 812, modem 814, memory 816, transceiver 802, RF front end 888 and one or more antennas 865 may be configured to support voice or data calls (simultaneously or non-simultaneously) in one or more radio access technologies.

[0095] In an aspect, the one or more processors 812 may include a modem 814 that uses one or more modem processors. The various functions related to connectivity selection component 140 may be included in modem 814 or processors 812 and, in an aspect, may be executed by a single processor, while in other aspects, different ones of the functions may be executed by a combination of two or more different processors. For example, in an aspect, the one or more processors 812 may include any one or any combination of a modem processor, or a baseband processor, or a digital signal processor, or a transmit processor, or a receiver processor, or a transceiver processor associated with transceiver 802. In other aspects, some of the features of the one or more processors 812 or modem 814 associated with connectivity selection component 140 may be performed by transceiver 802.

[0096] Also, memory 816 may be configured to store data used herein or local versions of applications 875, connectivity selection component 140 or one or more of subcomponents thereof being executed by at least one processor 812. Memory 816 may include any type of computer-readable medium usable by a computer or at least one processor 812, such as random access memory (RAM), read only memory (ROM), tapes, magnetic discs, optical discs, volatile memory, non-volatile memory, and any combination thereof. In an aspect, for example, memory 816 may be a non-transitory computer-readable storage medium that stores one or more computer-executable codes defining connectivity selection component 140 or one or more of subcomponents thereof, or data associated therewith, when UE 104 is operating at least one processor 812 to execute connectivity selection component 140 or one or more subcomponents thereof.

[0097] Transceiver 802 may include at least one receiver 806 and at least one transmitter 808. Receiver 806 may include hardware, firmware, or software code executable by a processor for receiving data, the code including instructions and being stored in a memory (such as a computer-readable medium). Receiver 806 may be, for example, a radio frequency (RF) receiver. In an aspect, receiver 806 may receive signals transmitted by at least one base station 102. Additionally, receiver 806 may process such received signals, and also may obtain measurements of the signals, such as, but not limited to, Energy per chip to Interference power ratio (Ec/Io), SNR, reference signal received power (RSRP), received signal strength indicator (RSSI), etc. Transmitter 808 may include hardware, firmware, or software code executable by a processor for transmitting data, the code including instructions and being stored in a memory (such as computer-readable medium). A suitable example of transmitter 808 may including, but is not limited to, an RF transmitter.

[0098] Moreover, in an aspect, UE 104 may include RF front end 888, which may operate in communication with one or more antennas 865 and transceiver 802 for receiving and transmitting radio transmissions, for example, wireless communications transmitted by at least one base station 102 or wireless transmissions transmitted by UE 104. RF front end 888 may be connected to one or more antennas 865 and may include one or more low-noise amplifiers (LNAs) 890, one or more switches 892, one or more power amplifiers (PAs) 898, and one or more filters 896 for transmitting and receiving RF signals.

[0099] In an aspect, LNA 890 may amplify a received signal at a desired output level. In an aspect, each LNA 890 may have a specified minimum and maximum gain values. In an aspect, RF front end 888 may use one or more switches 892 to select a particular LNA 890 and its specified gain value based on a desired gain value for a particular application.

[0100] Further, for example, one or more PA(s) 898 may be used by RF front end 888 to amplify a signal for an RF output at a desired output power level. In an aspect, each PA 898 may have specified minimum and maximum gain values. In an aspect, RF front end 888 may use one or more switches 892 to select a particular PA 898 and its specified gain value based on a desired gain value for a particular application.

[0101] Also, for example, one or more filters 896 may be used by RF front end 888 to filter a received signal to obtain an input RF signal. Similarly, in an aspect, for example, a respective filter 896 may be used to filter an output from a respective PA 898 to produce an output signal for transmission. In an aspect, each filter 896 may be connected to a specific LNA 890 or PA 898. In an aspect, RF front end 888 may use one or more switches 892 to select a transmit or receive path using a specified filter 896, LNA 890, or PA 898, based on a configuration as specified by transceiver 802 or processor 812.

[0102] As such, transceiver 802 may be configured to transmit and receive wireless signals through one or more antennas 865 via RF front end 888. In an aspect, transceiver 802 may be tuned to operate at specified frequencies such that UE 104 can communicate with, for example, one or more base stations 102 or one or more cells associated with one or more base stations 102. In an aspect, for example, modem 814 may configure transceiver 802 to operate at a specified frequency and power level based on the UE configuration of the UE 104 and the communication protocol used by modem 814.

[0103] In an aspect, modem 814 may be a multiband-multimode modem, which can process digital data and communicate with transceiver 802 such that the digital data is sent and received using transceiver 802. In an aspect, modem 814 may be multiband and be configured to support multiple frequency bands for a specific communications protocol. In an aspect, modem 814 may be multimode and be configured to support multiple operating networks and communications protocols. In an aspect, modem 814 may control one or more components of UE 104 (such as

RF front end 888, transceiver 802) to enable transmission or reception of signals from the network based on a specified modem configuration. In an aspect, the modem configuration may be based on the mode of the modem and the frequency band in use. In another aspect, the modem configuration may be based on UE configuration information associated with UE 104 as provided by the network during cell selection or cell reselection.

[0104] The previous description is provided to enable any person skilled in the art to practice the various aspects described herein. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects. Thus, the claims are not intended to be limited to the aspects shown herein, but is to be accorded the full scope consistent with the language claims, wherein reference to an element in the singular is not intended to mean “one and only one” unless specifically so stated, but rather “one or more.” The word “exemplary” is used herein to mean “serving as an example, instance, or illustration.” Any aspect described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other aspects. Unless specifically stated otherwise, the term “some” refers to one or more. Combinations such as “at least one of A, B, or C,” “one or more of A, B, or C,” “at least one of A, B, and C,” “one or more of A, B, and C,” and “A, B, C, or any combination thereof” include any combination of A, B, and/or C, and may include multiples of A, multiples of B, or multiples of C. Specifically, combinations such as “at least one of A, B, or C,” “one or more of A, B, or C,” “at least one of A, B, and C,” “one or more of A, B, and C,” and “A, B, C, or any combination thereof” may be A only, B only, C only, A and B, A and C, B and C, or A and B and C, where any such combinations may contain one or more member or members of A, B, or C. All structural and functional equivalents to the elements of the various aspects described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims. The words “module,” “mechanism,” “element,” “device,” and the like may not be a substitute for the word “means.” As such, no claim element is to be construed as a means plus function unless the element is expressly recited using the phrase “means for.”

SOME FURTHER EXAMPLE IMPLEMENTATIONS

[0105] An example method of wireless communication for a user equipment (UE), comprising: receiving, while connected to a long term evolution (LTE) network, a request to measure a secondary cell group for a 5G new radio (NR) network; and determining whether to measure the secondary cell group based on a 5G NR connection mode selected by an application processor.

[0106] The above example method, further comprising selecting, by the application processor, the 5G NR connection mode based on one or more of: an application layer data rate, a user selected preference, a battery level of the UE, a latency requirement, a thermal mitigation, or a combination thereof.

[0107] Any of the above example methods, wherein the selecting the 5G NR connection mode comprises selecting a mode with no 5G NR connection based on an application layer data rate being less than a threshold.

[0108] Any of the above example methods, wherein the selecting the 5G NR connection mode comprises selecting a mode with no 5G NR connection based on the user selected preference.

[0109] Any of the above example methods, wherein the selecting the 5G NR connection mode comprises selecting a mode with no 5G NR connection based on the battery level of the UE being less than a threshold.

[0110] Any of the above example methods, wherein the selecting the 5G NR connection mode comprises selecting a mode with no 5G NR connection based on the latency requirement being above a threshold.

[0111] Any of the above example methods, wherein the selecting the 5G NR connection mode comprises selecting a mode with no 5G NR connection based on a surface temperature or processor temperature of the UE exceeding a threshold temperature.

[0112] Any of the above example methods, wherein determining whether to measure the secondary cell group comprises determining a flag indicating the 5G NR connection mode.

[0113] Any of the above example methods, further comprising establishing a data connection with only the LTE network after receiving the request to measure the secondary cell group for the 5G NR network.

[0114] Any of the above example methods, wherein establishing a data connection with only the LTE network includes establishing the data connection via an LTE modem and powering down a 5G NR modem.

[0115] Any of the above example methods, wherein the request to measure the secondary cell group for the 5G NR network is a radio resource control (RRC) reconfiguration message indicating an inter-radio access technology (RAT) carrier frequency.

[0116] Any of the above example methods, further comprising indicating, to the LTE network, a capability of dual connectivity for LTE and 5G NR prior to receiving the request to measure the secondary cell group.

[0117] Any of the above example methods, further comprising: activating a 5G NR modem in response to the determining to measure the secondary cell group; and measuring the secondary cell group using the 5G NR modem.

[0118] The above example method, wherein determining to measure the secondary cell group is in response to a change to a value of a flag indicating the 5G NR connection mode.

[0119] A first example apparatus for wireless communication, comprising: a memory; and at least one processor coupled with the memory and configured to: receive, while connected to a long term evolution (LTE) network, a request to measure a secondary cell group for a 5G new radio (NR) network; and determine whether to measure the secondary cell group based on a 5G NR connection mode selected by an application processor.

[0120] The above first example apparatus, wherein the at least one processor is configured to select the 5G NR connection mode based on one or more of: an application layer data rate, a user selected preference, a battery level of the apparatus, a latency requirement, a thermal mitigation, or a combination thereof.

[0121] Any of the above first example apparatuses, wherein the at least one processor is configured to select a mode with no 5G NR connection based on an application layer data rate being less than a threshold.

[0122] Any of the above first example apparatuses, wherein the at least one processor is configured to select a mode with no 5G NR connection based on the user selected preference.

[0123] Any of the above first example apparatuses, wherein the at least one processor is configured to select a mode with no 5G NR connection based on the battery level of the apparatus being less than a threshold.

[0124] Any of the above first example apparatuses, wherein the at least one processor is configured to select a mode with no 5G NR connection based on the latency requirement being above a threshold.

[0125] Any of the above first example apparatuses, wherein the at least one processor is configured to select a mode with no 5G NR connection based on a surface temperature or processor temperature of the apparatus exceeding a threshold temperature.

[0126] Any of the above first example apparatuses, wherein the at least one processor is configured to determine whether to measure the secondary cell group based on a flag indicating the 5G NR connection mode.

[0127] Any of the above first example apparatuses, wherein the at least one processor is configured to establish a data connection with only the LTE network after receiving the request to measure the secondary cell group for the 5G NR network.

[0128] Any of the above first example apparatuses, wherein the at least one processor is configured to establishing the data connection via an LTE modem and powering down a 5G NR modem.

[0129] Any of the above first example apparatuses, wherein the request to measure the secondary cell group for the 5G NR network is a radio resource control (RRC) reconfiguration message indicating an inter-radio access technology (RAT) carrier frequency.

[0130] Any of the above first example apparatuses, wherein the at least one processor is configured to indicate, to the LTE network, a capability of dual connectivity for LTE and 5G NR prior to receiving the request to measure the secondary cell group.

[0131] Any of the above first example apparatuses, wherein the at least one processor is configured to: activate a 5G NR modem in response to the determining to measure the secondary cell group; and measuring the secondary cell group using the 5G NR modem.

[0132] Any of the above first example apparatuses, wherein the processor is configured to determine to measure the secondary cell group in response to a change to a value of a flag indicating the 5G NR connection mode.

[0133] A second example apparatus for wireless communication, comprising: means for receiving, while connected to a long term evolution (LTE) network, a request to measure a secondary cell group for a 5G new radio (NR) network; and means for determining whether to measure the secondary cell group based on a 5G NR connection mode selected by an application processor.

[0134] The above second example apparatus further including means for performing any of the above example methods.

[0135] An example non-transitory computer-readable medium storing computer executable code, the code when executed by a processor cause the processor to: receive, while connected to a long term evolution (LTE) network, a request to measure a secondary cell group for a 5G new radio (NR) network; and determine whether to measure the secondary cell group based on a 5G NR connection mode selected by an application processor.

[0136] The above example non-transitory computer-readable medium, wherein the code when executed by the processor causes the processor to perform any of the above example methods.

CLAIMS

WHAT IS CLAIMED IS:

1. A method of wireless communication for a user equipment (UE), comprising:

receiving, while connected to a long term evolution (LTE) network, a request to measure a secondary cell group for a 5G new radio (NR) network; and

determining whether to measure the secondary cell group based on a 5G NR connection mode selected by an application processor.

2. The method of claim 1, further comprising selecting, by the application processor, the 5G NR connection mode based on one or more of: an application layer data rate, a user selected preference, a battery level of the UE, a latency requirement, a thermal mitigation, or a combination thereof.

3. The method of claim 2, wherein the selecting the 5G NR connection mode comprises selecting a mode with no 5G NR connection based on the application layer data rate being less than a threshold.

4. The method of claim 2, wherein the selecting the 5G NR connection mode comprises selecting a mode with no 5G NR connection based on the user selected preference.

5. The method of claim 2, wherein the selecting the 5G NR connection mode comprises selecting a mode with no 5G NR connection based on the battery level of the UE being less than a threshold.

6. The method of claim 2, wherein the selecting the 5G NR connection mode comprises selecting a mode with no 5G NR connection based on the latency requirement being above a threshold.

7. The method of claim 2, wherein the selecting the 5G NR connection mode comprises selecting a mode with no 5G NR connection based on a surface temperature or processor temperature of the UE exceeding a threshold temperature.

8. The method of claim 1, wherein determining whether to measure the secondary cell group comprises determining a status of a flag indicating the 5G NR connection mode.

9. The method of claim 1, further comprising establishing a data connection with only the LTE network after receiving the request to measure the secondary cell group for the 5G NR network.

10. The method of claim 9, wherein establishing the data connection with only the LTE network includes establishing the data connection via an LTE modem and powering down a 5G NR modem.

11. The method of claim 1, wherein the request to measure the secondary cell group for the 5G NR network is a radio resource control (RRC) reconfiguration message indicating an inter-radio access technology (RAT) carrier frequency.

12. The method of claim 1, further comprising:

activating a 5G NR modem in response to the determining to measure the secondary cell group; and

measuring the secondary cell group using the 5G NR modem.

13 The method of claim 12, wherein determining to measure the secondary cell group is in response to a change to a value of a flag indicating the 5G NR connection mode.

14. An apparatus for wireless communication, comprising:

a memory storing computer-executable instructions; and

at least one processor coupled with the memory and configured to:

receive, while connected to a long term evolution (LTE) network, a request to measure a secondary cell group for a 5G new radio (NR) network; and

determine whether to measure the secondary cell group based on a 5G NR connection mode selected by an application processor.

15 The apparatus of claim 14, wherein the at least one processor is configured to select the 5G NR connection mode based on one or more of: an application layer data rate, a user selected

preference, a battery level of the apparatus, a latency requirement, a thermal mitigation, or a combination thereof.

16. The apparatus of claim 15, wherein the at least one processor is configured to select a mode with no 5G NR connection based on the application layer data rate being less than a threshold.

17. The apparatus of claim 15, wherein the at least one processor is configured to select a mode with no 5G NR connection based on the user selected preference.

18. The apparatus of claim 15, wherein the at least one processor is configured to select a mode with no 5G NR connection based on the battery level of the apparatus being less than a threshold.

19. The apparatus of claim 15, wherein the at least one processor is configured to select a mode with no 5G NR connection based on the latency requirement being above a threshold.

20. The apparatus of claim 15, wherein the at least one processor is configured to select a mode with no 5G NR connection based on a surface temperature or processor temperature of the apparatus exceeding a threshold temperature.

21. The apparatus of claim 14, wherein the at least one processor is configured to determine whether to measure the secondary cell group based on a status of a flag that indicates the 5G NR connection mode.

22. The apparatus of claim 14, wherein the at least one processor is configured to establish a data connection with only the LTE network after receiving the request to measure the secondary cell group for the 5G NR network.

23. The apparatus of claim 22, wherein the at least one processor is configured to establishing the data connection via an LTE modem and power down a 5G NR modem.

24. The apparatus of claim 14, wherein the request to measure the secondary cell group for the 5G NR network is a radio resource control (RRC) reconfiguration message indicating an inter-radio access technology (RAT) carrier frequency.

25. The apparatus of claim 14, wherein the at least one processor is configured to:

activate a 5G NR modem in response to the determining to measure the secondary cell group; and

measuring the secondary cell group using the 5G NR modem.

26. The apparatus of claim 25, wherein the at least one processor is configured to determine to measure the secondary cell group in response to a change to a value of a flag indicating the 5G NR connection mode.

27. An apparatus for wireless communication, comprising:

means for receiving, while connected to a long term evolution (LTE) network, a request to measure a secondary cell group for a 5G new radio (NR) network; and

means for determining whether to measure the secondary cell group based on a 5G NR connection mode selected by an application processor.

28. A computer-readable medium storing computer executable code, the code when executed by a processor causes the processor to:

receive, while connected to a long term evolution (LTE) network, a request to measure a secondary cell group for a 5G new radio (NR) network; and

determine whether to measure the secondary cell group based on a 5G NR connection mode selected by an application processor.

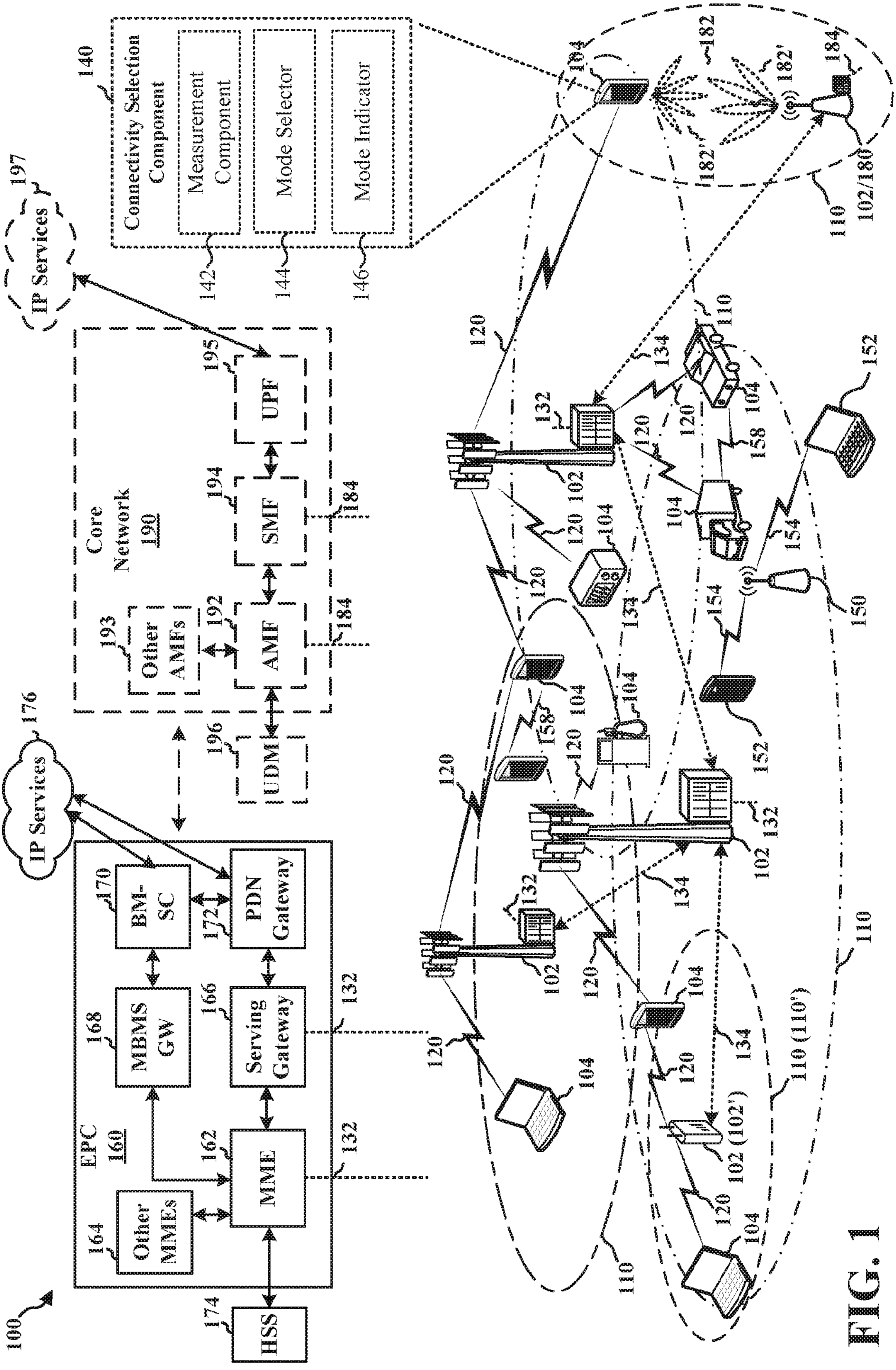

100
HSS
174
EPC
160
Other MMEs
164
MME
162
MBMS GW
168
Serving Gateway
166
BM-SC
170
PDN Gateway
172
132
IP Services
176
UDM
196
Core Network
190
Other AMFs
193
AMF
192
SMF
194
UPF
195
184
IP Services
197
Connectivity Selection Component
140
Measurement Component
142
Mode Selector
144
Mode Indicator
146
104
182
182'
182''
184
102/180
110
120
134
102
110 (110')
102 (102')
158
152
154
150

FIG. 1

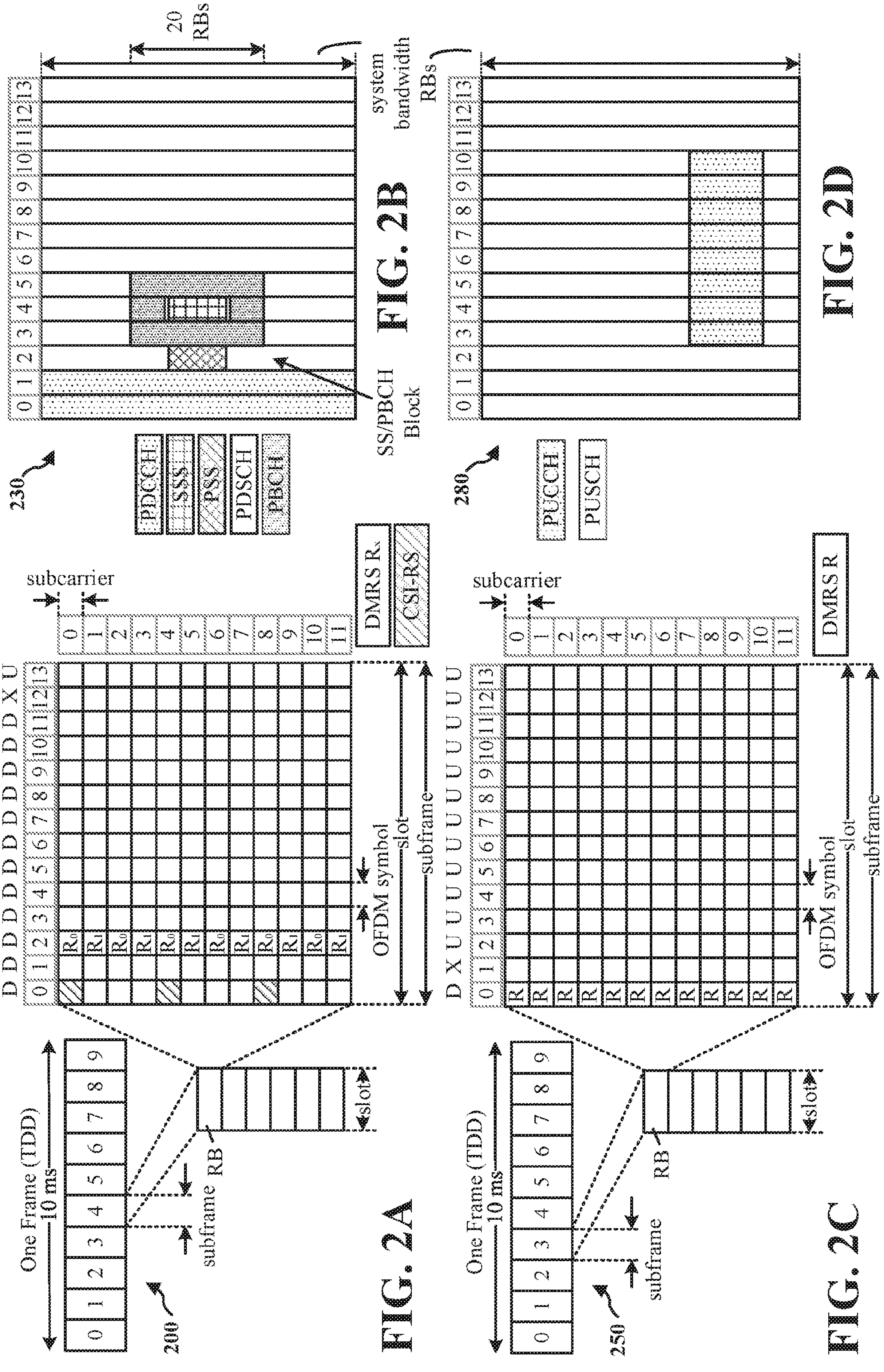


FIG. 2A

FIG. 2B

FIG. 2C

FIG. 2D

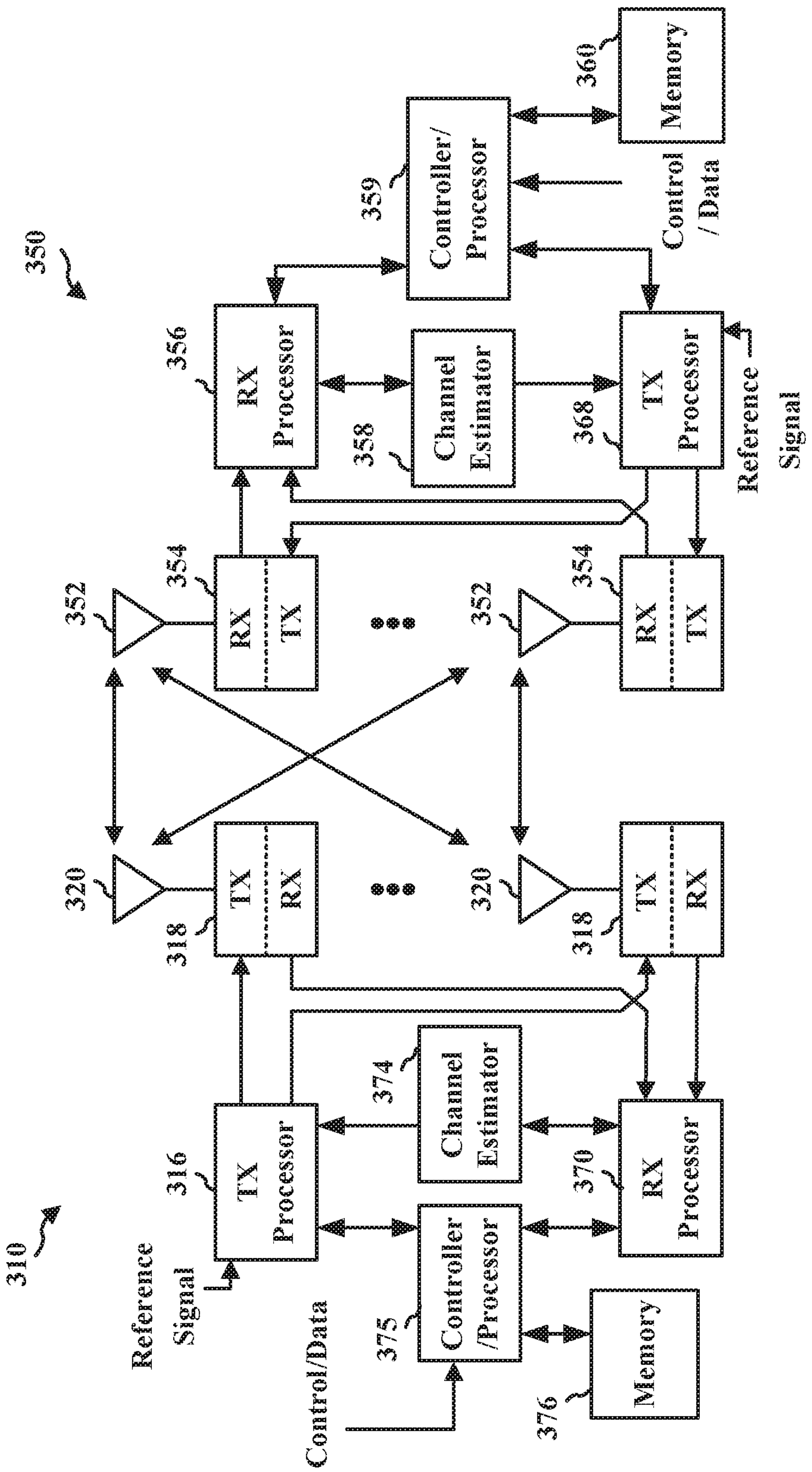

350
356
RX Processor
359
Controller/ Processor
360
Memory
Control / Data
358
Channel Estimator
368
TX Processor
Reference Signal
352
354
RX
TX
320
318
TX
RX
310
316
TX Processor
374
Channel Estimator
370
RX Processor
375
Controller /Processor
376
Memory
Reference Signal
Control/Data

FIG. 3

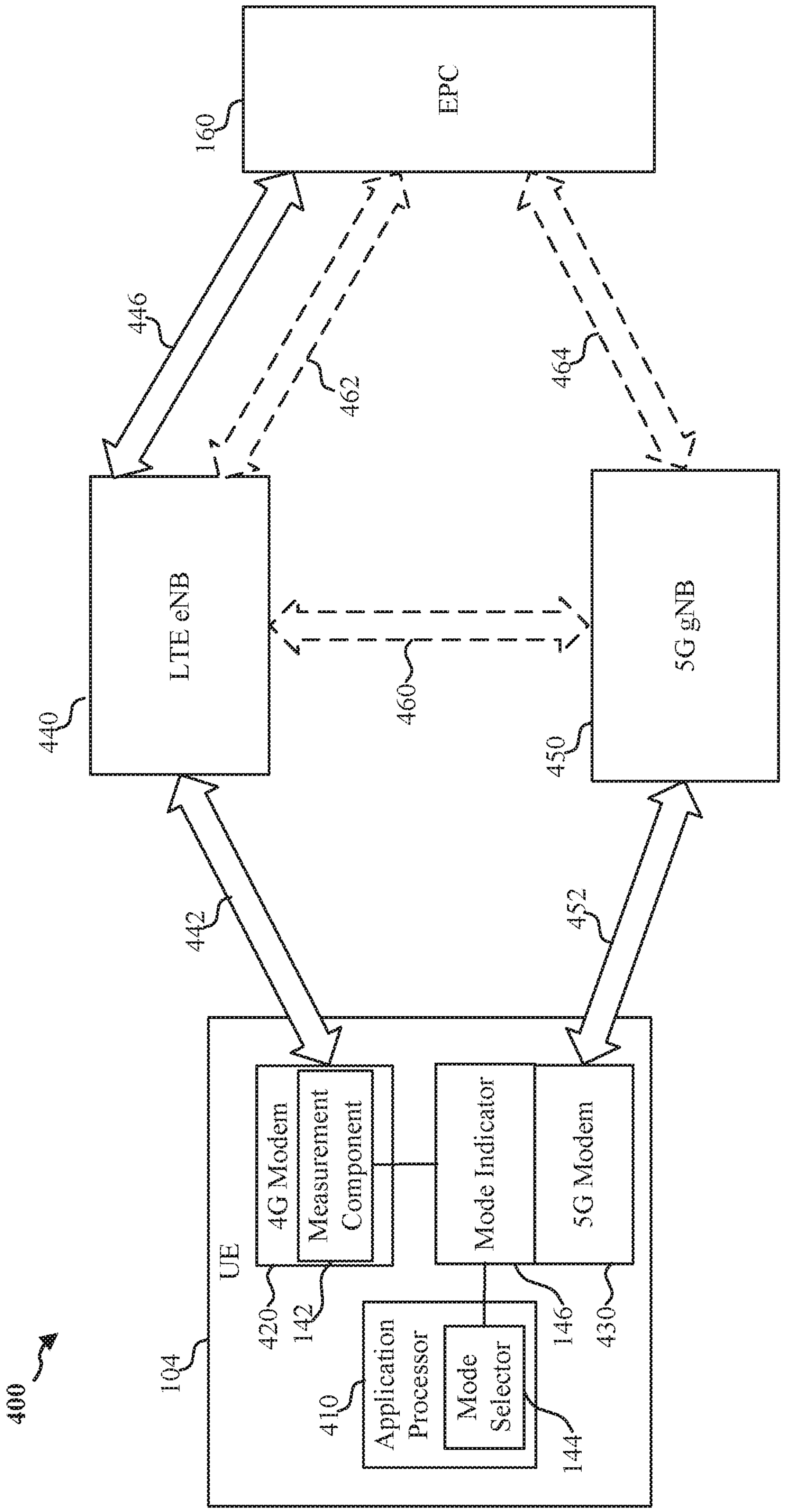

EPC
160
446
462
464
LTE eNB
440
460
5G gNB
450
442
452
UE
104
4G Modem
Measurement Component
Mode Indicator
5G Modem
420
142
146
430
Application Processor
Mode Selector
410
144
400

FIG. 4

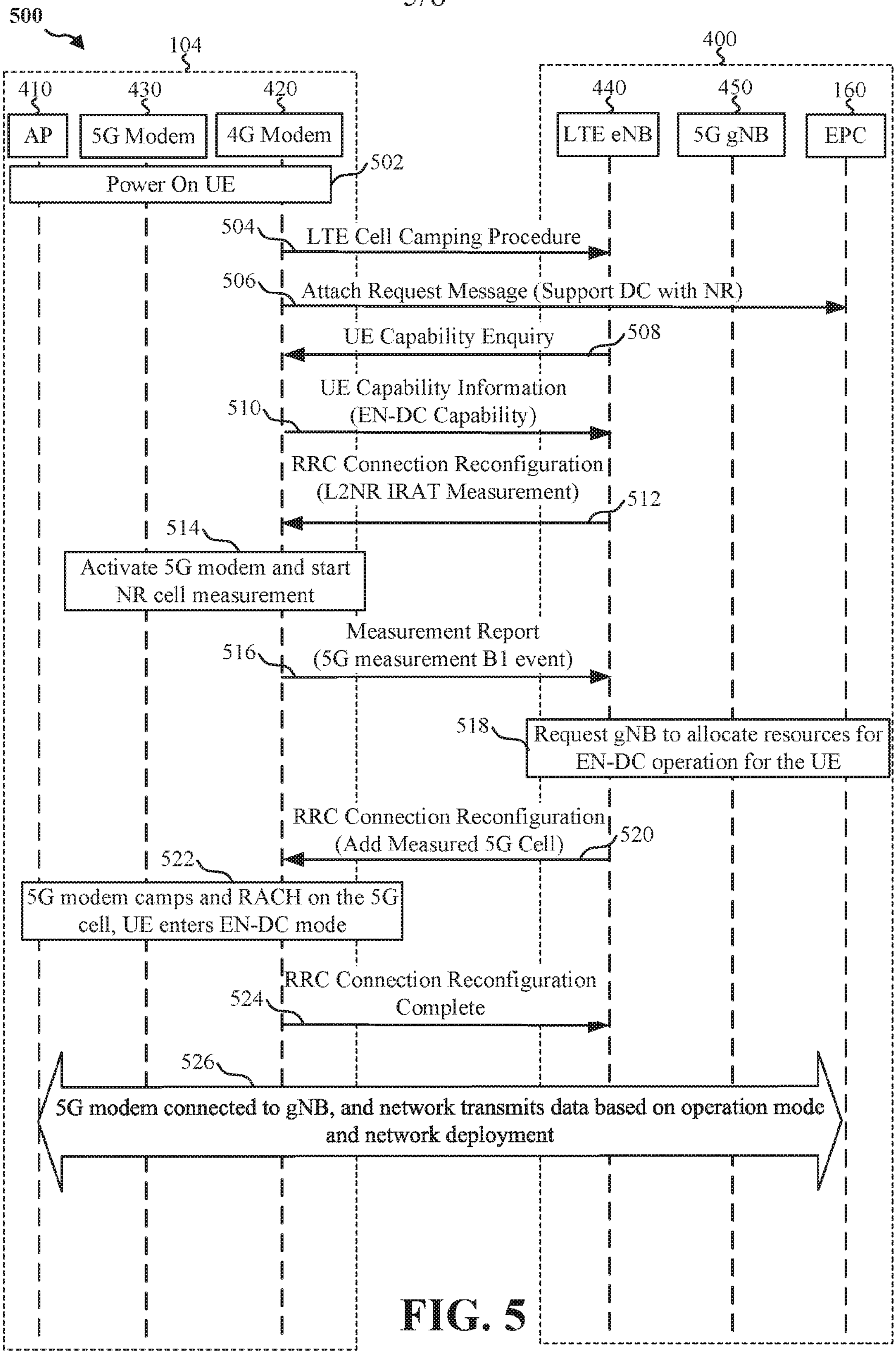
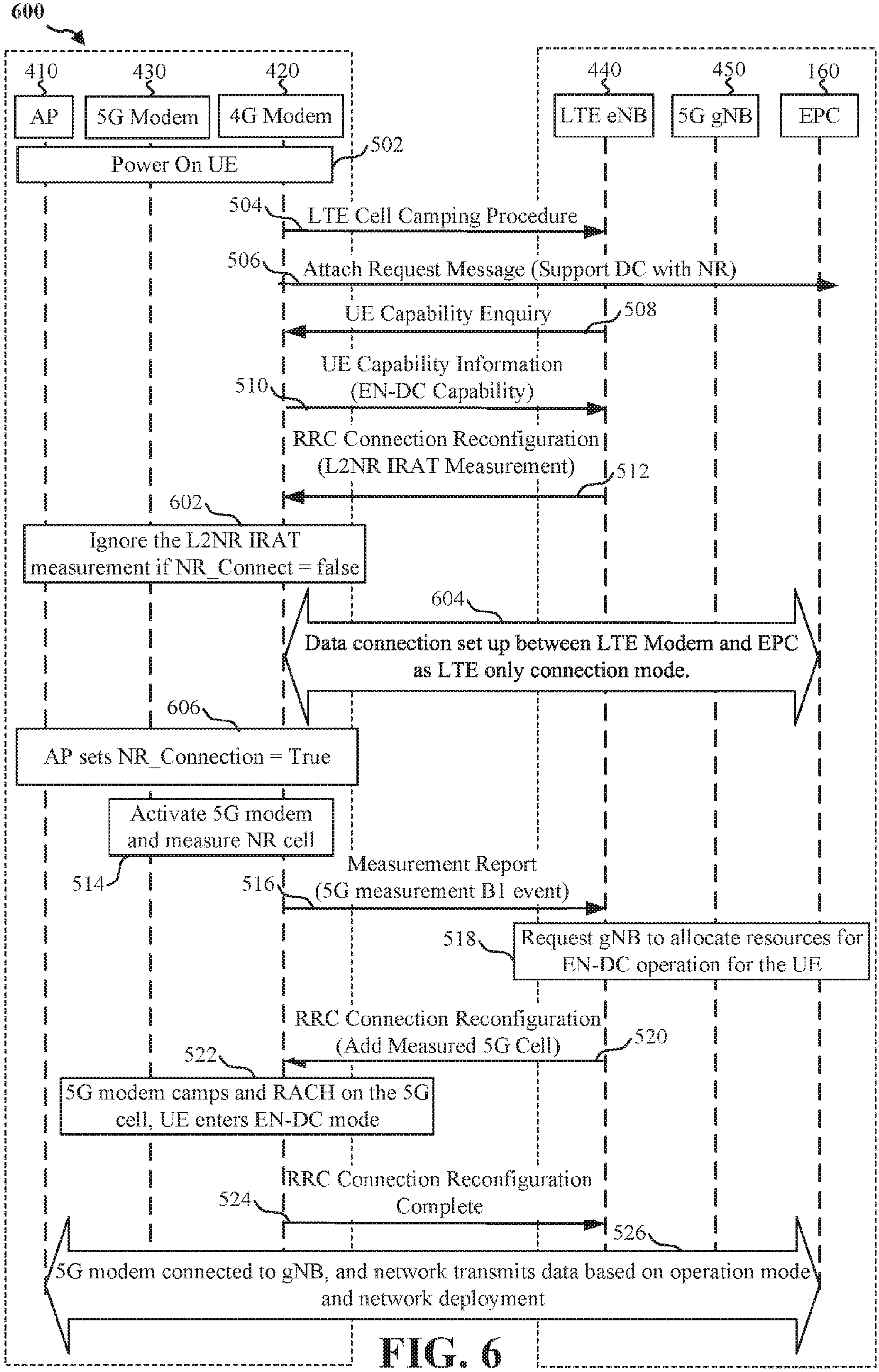

500
104
400
410
430
420
440
450
160
AP
5G Modem
4G Modem
LTE eNB
5G gNB
EPC
Power On UE
502
504
LTE Cell Camping Procedure
506
Attach Request Message (Support DC with NR)
UE Capability Enquiry
508
UE Capability Information
(EN-DC Capability)
510
RRC Connection Reconfiguration
(L2NR IRAT Measurement)
512
514
Activate 5G modem and start NR cell measurement
Measurement Report
(5G measurement B1 event)
516
518
Request gNB to allocate resources for EN-DC operation for the UE
RRC Connection Reconfiguration
(Add Measured 5G Cell)
520
522
5G modem camps and RACH on the 5G cell, UE enters EN-DC mode
RRC Connection Reconfiguration
Complete
524
526
5G modem connected to gNB, and network transmits data based on operation mode and network deployment

FIG. 5



600
410
430
420
440
450
160
AP
5G Modem
4G Modem
LTE eNB
5G gNB
EPC
Power On UE
502
504
LTE Cell Camping Procedure
506
Attach Request Message (Support DC with NR)
UE Capability Enquiry
508
UE Capability Information
(EN-DC Capability)
510
RRC Connection Reconfiguration
(L2NR IRAT Measurement)
512
602
Ignore the L2NR IRAT measurement if NR_Connect = false
604
Data connection set up between LTE Modem and EPC as LTE only connection mode.
606
AP sets NR_Connection = True
Activate 5G modem and measure NR cell
514
516
Measurement Report
(5G measurement B1 event)
518
Request gNB to allocate resources for EN-DC operation for the UE
RRC Connection Reconfiguration
(Add Measured 5G Cell)
520
522
5G modem camps and RACH on the 5G cell, UE enters EN-DC mode
RRC Connection Reconfiguration Complete
524
526
5G modem connected to gNB, and network transmits data based on operation mode and network deployment

FIG. 6

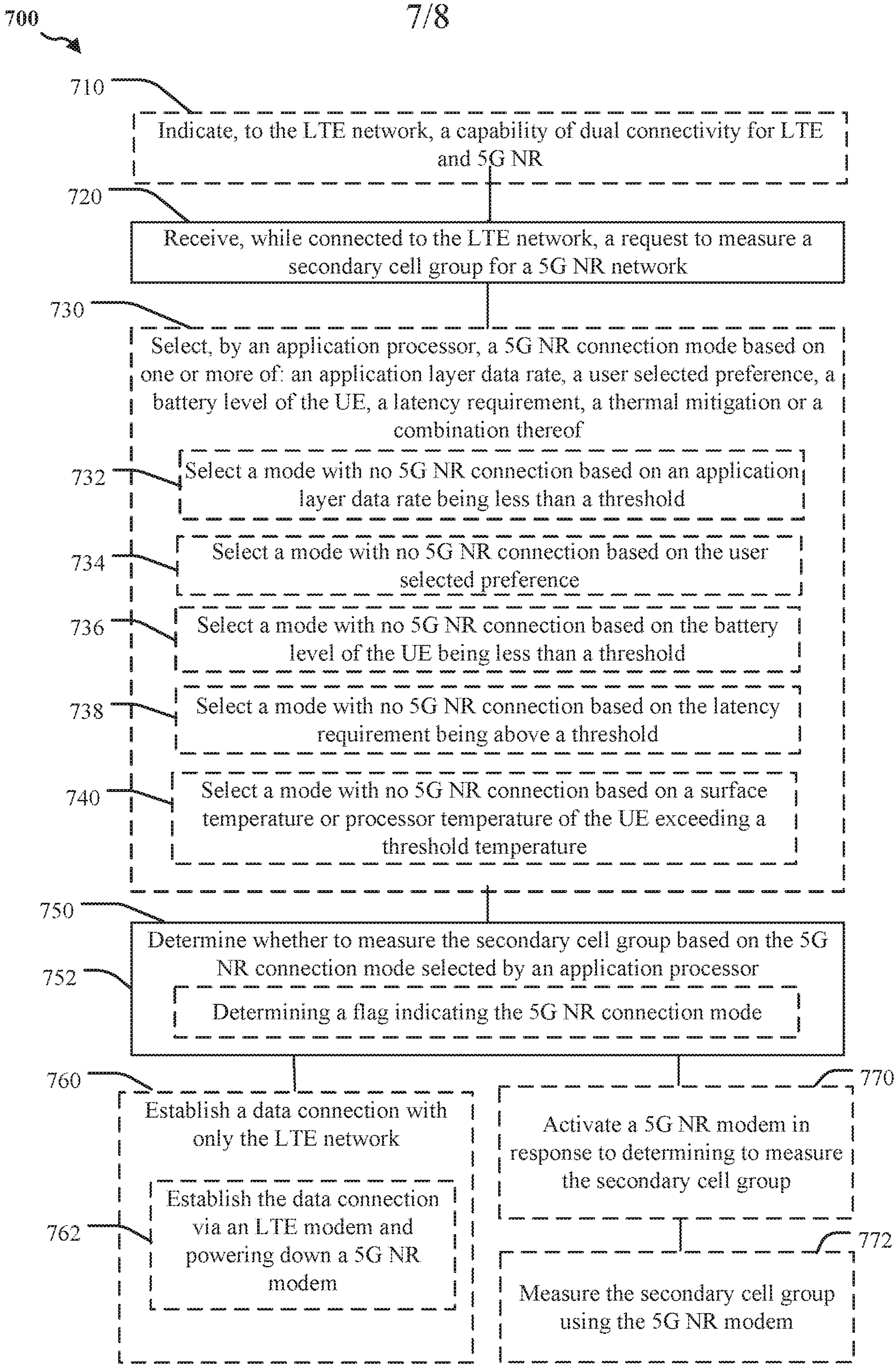

700
710
Indicate, to the LTE network, a capability of dual connectivity for LTE and 5G NR
720
Receive, while connected to the LTE network, a request to measure a secondary cell group for a 5G NR network
730
Select, by an application processor, a 5G NR connection mode based on one or more of: an application layer data rate, a user selected preference, a battery level of the UE, a latency requirement, a thermal mitigation or a combination thereof
732
Select a mode with no 5G NR connection based on an application layer data rate being less than a threshold
734
Select a mode with no 5G NR connection based on the user selected preference
736
Select a mode with no 5G NR connection based on the battery level of the UE being less than a threshold
738
Select a mode with no 5G NR connection based on the latency requirement being above a threshold
740
Select a mode with no 5G NR connection based on a surface temperature or processor temperature of the UE exceeding a threshold temperature
750
Determine whether to measure the secondary cell group based on the 5G NR connection mode selected by an application processor
752
Determining a flag indicating the 5G NR connection mode
760
Establish a data connection with only the LTE network
762
Establish the data connection via an LTE modem and powering down a 5G NR modem
770
Activate a 5G NR modem in response to determining to measure the secondary cell group
772
Measure the secondary cell group using the 5G NR modem

FIG. 7

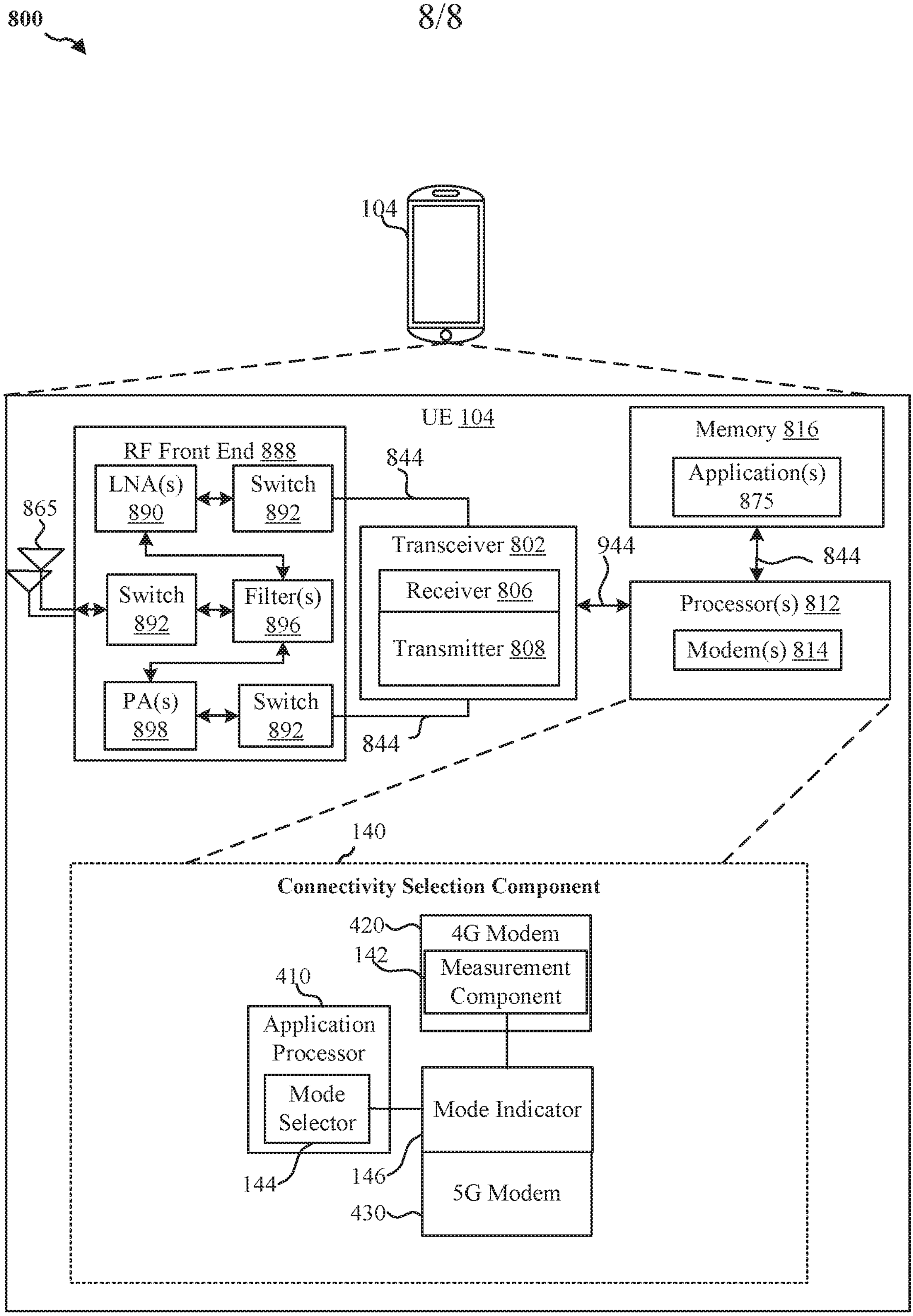

800
104
UE 104
RF Front End 888
LNA(s) 890
Switch 892
Switch 892
Filter(s) 896
PA(s) 898
Switch 892
865
844
844
Transceiver 802
Receiver 806
Transmitter 808
944
Memory 816
Application(s) 875
844
Processor(s) 812
Modem(s) 814
140
Connectivity Selection Component
420
4G Modem
142
Measurement Component
410
Application Processor
Mode Selector
Mode Indicator
144
146
5G Modem
430

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2019/081624

A. CLASSIFICATION OF SUBJECT MATTER

H04W 76/15(2018.01)i

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; H04Q

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)

CNPAT, CNKI, WPI, EPODOC, 3GPP:measure, SCG, select, cell, secondary, group, NR, EN-DC, dual, connect, mode, RAT, inter, 5G, IRAT, B1 event

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	3GPP TSG-RAN. "5GS; User Equipment (UE) conformance specification; Part 1: Protocol (Release 15)" *3GPP TS 38.523-1 V15.2.0 (2018-12),* 31 December 2018 (2018-12-31), section 8.2.3.1	1-28
X	CN 109246846 A (SPREADTRUM COMMUNICATIONS SHANGHAI CO., LTD.) 18 January 2019 (2019-01-18) description, paragraphs[0054]-[0077]	1-28
X	CN 109151921 A (BEIJING SPREADTRUM HI-TECH COMMUNICATIONS TECHNOLOGY CO., LTD.) 04 January 2019 (2019-01-04) description, paragraphs[0025]-[0067]	1-28
A	US 2019098489 A1 (QUALCOMM INCORPORATED) 28 March 2019 (2019-03-28) the whole document	1-28
A	3GPP TSG-RAN. "NR; Radio Resource Control (RRC) protocol specification(Release 15)" *3GPP TS 38.331 V15.5.0 (2019-03),* 31 March 2019 (2019-03-31), the whole document	1-28

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 December 2019	**30 December 2019**

Name and mailing address of the ISA/CN

National Intellectual Property Administration, PRC
6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088
China

Facsimile No. **(86-10)62019451**

Authorized officer

BI,Yachao

Telephone No. **86-(10)-53961777**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2019/081624

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	109246846	A	18 January 2019	CN	110381530	A	25 October 2019
				US	2018324624	A1	08 November 2018
CN	109151921	A	04 January 2019	None			
US	2019098489	A1	28 March 2019	WO	2019067926	A1	04 April 2019