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(54) Title: QUALITY OF SERVICE HANDLING FOR UPLINK TRANSMISSIONS

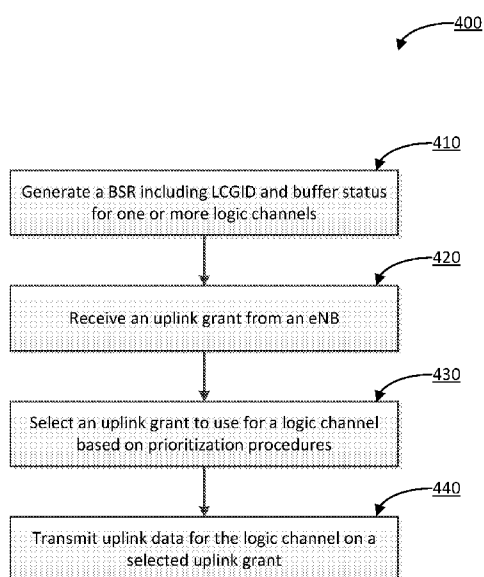


FIG. 4

(57) **Abstract:** An apparatus of a user equipment (UE) may include a memory and one or more processors coupled to the memory. The one or more processors may process a buffer status report (BSR) trigger received at the UE from an evolved nodeB (eNB) and encode, in uplink data to the eNB, a BSR including a logical control group (LCG) identification and buffer status for the logical channels associated with the LCG. The processors may further process one or more uplink grants from the eNB, wherein the uplink grants reference a licensed spectrum and an unlicensed spectrum. The processors may also encode uplink data for the logical channels associated with the LCG based on the one or more uplink grants.

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QUALITY OF SERVICE HANDLING FOR UPLINK TRANSMISSIONS

Background

[0001] The disclosure relates to the field of wireless communications, including locking of phase locked loops during wireless communications.

Brief Description of the Drawings

[0002] Various embodiments of the present disclosure will be understood more fully from the detailed description given below and from the accompanying drawings of various embodiments of the disclosure.

[0003] FIG. 1 is a block diagram illustrating components of an electronic device implementing aspects of the disclosure, according to an embodiment.

[0004] FIG. 2 is a block diagram illustrating components of a network, according to an embodiment.

[0005] FIG. 3 is a block diagram illustrating components of a network, according to an embodiment.

[0006] FIG. 4 illustrates a flowchart of an example method of transmitting uplink data, according to an embodiment.

[0007] FIG. 5 illustrates a flowchart of an example method of providing an uplink grant, according to an embodiment.

Description of Embodiments

[0008] A user equipment (UE) communicating with a network through an evolved nodeB (eNB) may use carriers at frequencies associated with licensed frequency spectrums of the network. In order to improve performance of transmissions, a UE or eNB may use unlicensed spectrum to supplement transmissions over a licensed spectrum. For example, a UE may send some uplink data transmissions over the licensed spectrum and some uplink data transmissions over the unlicensed spectrum. Unlike the licensed spectrum, the unlicensed spectrum may be used by networks and devices that are outside the control of the network. For example, the unlicensed spectrum may be used by networks and devices, such as from the same radio access technology (e.g., another operator) or a different radio access technology (e.g., WiFi), that send transmissions according to a schedule that is not set by the network. The devices out of control of the network may increase noise or interference on the unlicensed frequencies. The increased noise or interference may reduce the quality of transmissions received at the eNB.

[0009] Some transmissions from a UE may have higher priorities than others. For example, voice or video transmissions may have a higher guaranteed quality of service (QoS). In order to provide the guaranteed QoS for certain transmissions, the UE may schedule the transmissions over the licensed spectrum. In order to guarantee the QoS, the UE may transmit a buffer status for particular logical channels indicating what type of information is to be transmitted over the logical channel or a QoS for the logical channels. The eNB may transmit an uplink grant to the UE. If the uplink grant is for a cell in the licensed spectrum, the UE may transmit uplink data of the logical channels that are configured to use uplink grants for a cell in the licensed spectrum. If the uplink grant is for a cell in the unlicensed spectrum, the UE may transmit uplink data of the logical channels that are configured to use uplink grants for a cell in the unlicensed spectrum.

[0010] In some embodiments, a logical channel may be configured to use either an uplink grant for a cell from the licensed spectrum only, an uplink grant for a cell from the unlicensed spectrum only, or an uplink grant for a cell from the licensed and unlicensed spectrum. In some embodiments, a logical channel may be configured on whether it can use an uplink grant for a cell in the licensed spectrum only. Then, any logical channels that are not restricted to use only uplink grants for a cell in the licensed spectrum only are allowed to use uplink grants for cells in the licensed as well as the unlicensed spectrum. In some embodiments, the UE recognizes whether a cell is in the licensed or the unlicensed spectrum based on the frame structure configured by the eNB. For the licensed spectrum, the frame structure configured may be either Frame Structure Type 1 (FS1) for frequency division duplexing (FDD) or Frame Structure Type 2 (FS2) for time division duplexing (TDD). For the unlicensed spectrum, the frame structure configured may be Frame Structure Type 3 (FS3) for the unlicensed cell.

[0011] Long Term Evolution (LTE) systems that utilize the spectrum that is exclusively assigned to the corresponding LTE service provider (or operator) may be referred to as LTE in licensed spectrum or simply LTE. In order to provide additional services in response to an increase in demand for wireless broadband data, data throughput of an LTE system may be increased by transmitting data through an unlicensed spectrum as well as a licensed spectrum. LTE systems operating in the unlicensed spectrum may be referred to as LTE in unlicensed spectrum or LTE-U. A system integrating LTE and LTE-U using carrier aggregation technology may be referred to as licensed-assisted access (LAA) using LTE, or simply LAA. In LAA, one LTE carrier may serve as a primary serving cell and one or more LTE-U carriers serve as secondary serving cell(s).

[0012] The radio environment in the unlicensed spectrum may be quite different compared with that on the licensed spectrum. The unlicensed spectrum may include various sources for interference which are outside the control of a network operator. For example, interfering systems may include other Radio Access Technologies (RATs) (for example, wireless local area network (WLAN) technologies and the like), LAA nodes of other operators, or the like. In extreme cases, the resources of some LAA cells may be of little use due to strong interference, high signal to noise ratio, low channel availability, or the like. In addition, Listen Before Talk (LBT) and discontinuous transmission (DTX) may be supported on some unlicensed carriers to meet regulatory requirements. This may impact Quality of Service (QoS) of some bearers if the characteristics of LAA cell are not fully considered when traffic mapping is performed. For example, latency requirements might not be satisfied. In order to manage downlink data, traffic mapping may be controlled by implementations of the eNB. For example, the eNB may receive downlink data from a network to provide to the UE. The eNB may determine the buffer status for downlink logical channels based on the received downlink data. Additional information, such as QoS, or type of data, may also be provided to the eNB from the network. Therefore, the eNB may prioritize and map downlink data for transmission over a licensed or unlicensed spectrum without additional interaction with the UE. Accordingly, the UE may not have additional features to manage traffic mapping for receiving data, because the traffic mapping is handled by the eNB.

[0013] Each bearer available to a UE has a one-to-one mapping with a logical channel and is configured to provide a set QoS to the UE. In some embodiments, the UE Layer 1 (physical layer of the UE) indicates to the UE media access control (MAC) layer whether an uplink grant from the UE Layer 1 is for a serving cell in the licensed spectrum or for a serving cell in the unlicensed spectrum based on the Layer 1 frame structure type of the serving cell. A UE MAC layer application may apply a logical channel prioritization procedure when a new uplink transmission associated with an uplink grant is performed. Whether a logical channel may use an uplink grant from a serving cell in the licensed or unlicensed spectrum is configured by radio resource control (RRC) layer applications. For a new transmission on an unlicensed serving cell, a UE MAC layer application may apply the logical channel prioritization procedure on the logical channels that can use the unlicensed serving cells. Logical channels that are configured to only use uplink grants for licensed serving cells may not be considered for the new transmission on the unlicensed serving cell. For a new transmission on a licensed serving cell, a UE MAC layer application may select logical channels that can use the uplink grants for the licensed serving cells. The logical channels that

can only use the uplink grants for the licensed serving cells will not be considered for the new transmission on the unlicensed serving cell. Logical channel prioritization procedures may provide the rules in which the UE MAC entity handles traffic priority among a set of logical channels based on the priority assigned by the eNB or the higher layers such as one or more core network elements. For example, a mobility management entity (MME) of an evolved packet core (EPC) may determine the priority settings assigned to logical channels.

[0014] In LTE systems, a UE with uplink data to send may be provided with an uplink grant in a Transmission Time Interval (TTI) by an eNB. The usage of the uplink grant for a TTI may be based on the priority of the bearer or logical channel (each bearer has a 1:1 relationship with a logical channel). The UE may use a token bucket selection process or another process to determine how to use the time and frequency allocated to the UE in an uplink grant. An uplink grant in a TTI may be used by all the logical channels and MAC control signaling based on the prioritization procedure. In order to determine whether a logical channel can use the uplink grant for licensed and unlicensed cells, the UE may be configured by an eNB to use certain uplink grants exclusively for certain logical channels. For example, in order to configure the UE to use an uplink grant on unlicensed cells, an eNB may send one or more RRC signaling messages to the UE, one or more MAC signaling messages to the UE, or may send one or more Layer 1 configuration messages to configure which logical channels can use only uplink grants from licensed serving cells and which logical channels can use uplink grants from any serving cells. For example, a Layer 1 signaling may indicate the uplink grant for an unlicensed serving cell (e.g., an LAA secondary serving cell) or for a licensed serving cell (e.g. a primary serving cell or a licensed secondary serving cell) and the UE may be configured via RRC or MAC signaling with logical channels that can use an uplink grant for unlicensed serving cells or logical channels that can use only an uplink grant for licensed serving cells.

[0015] In some embodiments, logical channels may be configured to use different types of uplink grants. For example in some embodiments, there may be uplink grants to use only licensed cells, to use only unlicensed cells, or to use a combination of licensed or unlicensed cells. In an example implementation, an uplink grant provided by the network to a UE may include signaling as described with reference to the following uplink grants: (i) if, based on the QoS requirements for a bearer or logical channel, uplink data for the logical channel may be transmitted over the uplink grant either for unlicensed serving cell or licensed serving cell, then the signaling for a bearer or logical channel may be {useUnlicensedULGrant, useLicensedULGrant}; (ii) if, based on the QoS requirements for a bearer or logical channel,

uplink data for the logical channel may be transmitted over the uplink grant for both the unlicensed serving cell and the licensed serving cell, then in addition to the signaling in (i), the uplink grant may also provide signaling for the bearer or logical channel {useAllULGrant}; (iii) if based on the QoS requirements for a bearer or logical channel, uplink data for the logical channel may not be transmitted over the uplink grant for the unlicensed serving cell (e.g., voice call and/or other delay sensitive services) and otherwise the bearer or logical channel can use an uplink grant from both the unlicensed serving cell and the licensed serving cell, then the signaling for a bearer may be {notuseUnlicensedULGrant, useALLULGrant} or {onlyLicensedULGrant, useAllULGrant}. In order to provide signaling for an uplink grant, type (i) may use 1 bit per bearer. If type (ii) is added to type (i) signaling, it may use 2 bits per bearer. Type (iii) signaling may use 1 bit of signaling per bearer.

[0016] In order for the eNB to determine which type of uplink grant to provide, the UE may inform the eNB which logical channels have uplink data to send. For example, a UE sends a Buffer Status Reporting (BSR) message to the eNB including information regarding the amount of QoS for uplink data in the buffer. The BSR may include a logical channel group (LCG) ID and its corresponding uplink buffer status or buffer size field. The buffer size field may identify the total amount of data for uplink transmission across all logical channels of a logical channel group after all MAC protocol data units (PDUs) for a TTI have been generated. The LCG ID field in the BSR identifies the group of logical channel(s) for which buffer status is being reported. In some embodiments, the LCG ID field may be an eNB configured ID to group the logical channels that have the same or similar QoS expectations in one group ID. The LCG ID can be used by the eNB to differentiate a group of logical channels that can use uplink grants from licensed and unlicensed serving cells and those that can only use uplink grants from a licensed serving cell. Based on this information, the eNB can determine whether to provide the UE with uplink grants for licensed and/or unlicensed serving cells. In some embodiments, the length of the LCG ID field may be 2 bits to indicate four LCGs. In some embodiments, there may be fewer or additional LCGs. In some embodiments, the eNB may provide LCG IDs that group logical channels based on expected QoS, based on uplink grants that can be used by the logical channels, or based on other parameters. Providing LCG IDs to a plurality of UEs may allow the eNB to perform prioritization for a single UE as well as for multiple UEs. For example, the eNB may prioritize LCGs in an uplink grant to a UE based on the QoS of the logical channels associated with a LCG for the UE. In addition, the eNB may determine the demand for

particular LCGs across a plurality of UEs to determine whether to grant additional licensed or unlicensed spectrum to one or more of the UEs.

[0017] As an example implementation for setting (iii) as described above, a bearer or logical channel that uses only licensed serving cells (which may also have higher priority than other bearers or logical channels) may use LCG ID ‘N,’ wherein N is one of a plurality of available LCG IDs. In such cases, LCG ID ‘N’ may contain all the logical channels that are associated with transport delay sensitive services (i.e. voice, streaming video etc.) The other LCG IDs (grouping of other bearers and logical channels) may be considered to be able to use the uplink grant for both the licensed and unlicensed serving cells.

[0018] In some embodiments, the UE may process separate BSRs. For example, one BSR for logical channels that can use uplink grants for both unlicensed and licensed serving cells and another BSR for logical channels that can only use uplink grants for licensed serving cells. Each of the BSRs may be triggered by separate BSR procedures. For example, the UE may use a first periodic BSR timer (“periodicBSR-Timer”) to trigger periodic BSR transmissions to an eNB regarding uplink data to transmit in licensed spectrum and a second periodicBSR-Timer to trigger BSR transmissions to an eNB regarding uplink data to transmit in unlicensed spectrum. The UE may also use a first retransmission BSR timer (“retxBSR-Timer”) to trigger retransmissions of BSRs to an eNB regarding uplink data to transmit in licensed spectrum and a second retxBSR-Timer to trigger BSR retransmissions to an eNB regarding uplink data to transmit in unlicensed spectrum. The periodicBSR-Timer may trigger the UE to generate a BSR at set intervals when a timer runs out. The retxBSR-Timer may trigger a retransmission of a BSR when a BSR has been sent to the eNB, but no uplink grant was received from the eNB. In some embodiments, the eNB may send a separate explicit trigger to a UE to generate one or more BSRs for the licensed or the unlicensed spectrum or the UE may use a single periodicBSR-timer and a single retxBSR-Timer to trigger BSR transmissions.

[0019] In some embodiments, the BSRs may be provided as MAC control elements. A MAC control element may be a piece of a MAC signaling message that includes data used to control network communications. In terms of priority of the BSR MAC control element, the BSR associated with the logical channels or bearers that can only use the uplink grant for licensed serving cells will be given higher priority than the BSR associated with the logical channels or bearers that can use uplink grants for both licensed and unlicensed serving cells. In some embodiments, a UE may separate BSRs based on whether the logical channels associated with LCGs included in the BSR may use an unlicensed serving cell. For example,

an additional BSR for logical channels that can only use uplink grants for unlicensed serving cell may also be used by the UE. In some embodiments, other BSRs may be generated by the UE based on the spectrums that may be used by the associated LCGs.

[0020] In some embodiments, the UE may provide a different BSR format, or additional BSR information for the uplink grant usage for each buffer status. For example, it may provide further finer information such as the QoS, logical channel, or other information associated with the buffer status. In some embodiments, the buffer status per uplink grant in a LCG group may be of variable size to accommodate additional information in the processing of uplink grants.

[0021] In order for a UE MAC layer application to run the logical channel prioritization procedure correctly, the MAC layer application may determine whether the uplink grant is for an unlicensed serving cell or for licensed serving cell. For example, a logical channel prioritization application may perform priority handling among the logical channels. For instance, when radio resources for a new transmission are allocated, the MAC logical channel prioritization application may determine how much data from each configured logical channel should be included in each MAC PDU and may instruct a MAC multiplexing and de-multiplexing application to generate MAC PDUs from the MAC service data units (SDUs). This information may be provided by the L1/Physical layer to the MAC application. The MAC application may also use the information to decide which logical channels or bearers can use the uplink grant and run the logical channel prioritization procedure on the uplink grant for the logical channels or bearers that can use the uplink grant. For example, if the uplink grant is for a licensed serving cell, the logical channel prioritization procedure performs prioritization of the resources indicated in the uplink grant among the logical channels that are configured to use uplink grants for the licensed spectrum. If the uplink grant is for an unlicensed serving cell, the logical channel prioritization procedure performs prioritization of the resources indicated in the UL grant among the logical channels that are configured to use uplink grant for the unlicensed spectrum.

[0022] The following detailed description refers to the accompanying drawings. The same reference numbers may be used in different drawings to identify the same or similar elements. In the following description, for purposes of explanation and not limitation, specific details are set forth such as particular structures, architectures, interfaces, techniques, etc. in order to provide a thorough understanding of the various aspects of the claimed disclosure. However, various aspects of the disclosed embodiments may be practiced in other examples that depart from these specific details. In certain instances, descriptions of well-known devices, circuits,

and methods are omitted so as not to obscure the description of the present disclosure with unnecessary detail.

[0023] As used herein, the term "circuitry" may refer to, be part of, or include an Application Specific Integrated Circuit (ASIC), an electronic circuit, a processors (shared, dedicated, or group), and/or memory device (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit, and/or other suitable hardware components that provide the described functionality. In some embodiments, the circuitry may be implemented in, or functions associated with the circuitry may be implemented by, one or more software or firmware modules. In some embodiments, circuitry may include logic, at least partially operable in hardware.

[0024] Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software. Figure 1 illustrates, for one embodiment, example components of a User Equipment (UE) device 100. In some embodiments, the UE device 100 may include application circuitry 102, baseband circuitry 104, Radio Frequency (RF) circuitry 106, front-end module (FEM) circuitry 108 and one or more antennas 110, coupled together at least as shown.

[0025] The application circuitry 102 may include one or more application processors. For example, the application circuitry 102 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) may include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors may be coupled with and/or may include memory/storage and may be configured to execute instructions stored in the memory/storage to enable various applications and/or operating systems to run on the system.

[0026] The baseband circuitry 104 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 104 may include one or more baseband processors and/or control logic to process baseband signals received from a receive signal path of the RF circuitry 106 and to generate baseband signals for a transmit signal path of the RF circuitry 106. Baseband processing circuitry 104 may interface with the application circuitry 102 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 106. For example, in some embodiments, the baseband circuitry 104 may include a second generation (2G) baseband processor 104a, third generation (3G) baseband processor 104b, fourth generation (4G) baseband processor 104c, and/or other baseband processor(s) 104d for other existing generations, generations in

development or to be developed in the future (e.g., fifth generation (5G), 6G, etc.). The baseband circuitry 104 (e.g., one or more of baseband processors 104a-d) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 106. The radio control functions may include, but are not limited to, signal modulation/demodulation, encoding/decoding, radio frequency shifting, etc. In some embodiments, modulation/demodulation circuitry of the baseband circuitry 104 may include Fast-Fourier Transform (FFT), precoding, and/or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 104 may include convolution, tail-biting convolution, turbo, Viterbi, and/or Low Density Parity Check (LDPC) encoder/decoder functionality. Embodiments of modulation/demodulation and encoder/decoder functionality are not limited to these examples and may include other suitable functionality in other embodiments.

[0027] In some embodiments, the baseband circuitry 104 may include elements of a protocol stack such as, for example, elements of an evolved universal terrestrial radio access network (EUTRAN) protocol including, for example, physical (PHY), media access control (MAC), radio link control (RLC), packet data convergence protocol (PDCP), and/or radio resource control (RRC) elements. A central processing unit (CPU) 104e of the baseband circuitry 104 may be configured to run elements of the protocol stack for signaling of the PHY, MAC, RLC, PDCP and/or RRC layers. In some embodiments, the baseband circuitry may include one or more audio digital signal processor(s) (DSP) 104f. The audio DSP(s) 104f may include elements for compression/decompression and echo cancellation and may include other suitable processing elements in other embodiments. Components of the baseband circuitry may be suitably combined in a single chip, a single chipset, or disposed on a same circuit board in some embodiments. In some embodiments, some or all of the constituent components of the baseband circuitry 104 and the application circuitry 102 may be implemented together such as, for example, on a system on a chip (SOC).

[0028] In some embodiments, the baseband circuitry 104 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 104 may support communication with an evolved universal terrestrial radio access network (EUTRAN) and/or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), a wireless personal area network (WPAN). Embodiments in which the baseband circuitry 104 is configured to support radio

communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

[0029] In some embodiments, the baseband circuitry 104 may operate to send or receive transmissions in a licensed or an unlicensed spectrum. For example, the baseband circuitry 104 may use the licensed spectrum for some uplink data transmissions and the unlicensed spectrum for other uplink data transmissions. The baseband circuitry 104 may determine whether to use licensed or unlicensed spectrums based on whether the logical channel is configured to transmit on licensed or unlicensed spectrums. For example, a logical channel associated with voice or video transmissions that have a high QoS requirement may be sent over the licensed spectrum as the logical channels associated with the voice or video bearer are configured by the RRC to only transmit on a licensed spectrum. Logical channels without high QoS requirements may be sent over licensed or unlicensed spectrums depending on the availability of spectrums provided in an uplink grant and the priority of the transmissions as they are not configured to be restricted to transmit only on a licensed spectrum. For example, uplink data for some logical channels may be transmitted to the network over any uplink grant regardless of whether the uplink grant is for licensed or unlicensed spectrums. The configuration of logical channels to spectrums in uplink grants may be provided to the UE from an eNB through RRC signaling. The baseband circuitry 104 may decode the RRC signaling to determine the configuration or uplink grants received from the eNB. For example, an RRC message from the eNB may configure logical channels or bearers to use the licensed or the unlicensed spectrum based on the uplink grant. In some embodiments, the UE may provide a BSR to the network that includes an LCG ID for logical channels with uplink data to be transmit by the UE. The eNB may use the BSR to determine uplink grants (for serving cells in licensed or unlicensed spectrums) to provide to the UE.

[0030] RF circuitry 106 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 106 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 106 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 108 and provide baseband signals to the baseband circuitry 104. RF circuitry 106 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 104 and provide RF output signals to the FEM circuitry 108 for transmission.

[0031] In some embodiments, the RF circuitry 106 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 106 may include mixer circuitry 106a, amplifier circuitry 106b and filter circuitry 106c. The transmit signal path of the RF circuitry 106 may include filter circuitry 106c and mixer circuitry 106a. RF circuitry 106 may also include synthesizer circuitry 106d for synthesizing a frequency for use by the mixer circuitry 106a of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 106a of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 108 based on the synthesized frequency provided by synthesizer circuitry 106d. The amplifier circuitry 106b may be configured to amplify the down-converted signals and the filter circuitry 106c may be a low-pass filter (LPF) or band-pass filter (BPF) configured to remove unwanted signals from the down-converted signals to generate output baseband signals. Output baseband signals may be provided to the baseband circuitry 104 for further processing. In some embodiments, the output baseband signals may be zero-frequency baseband signals, although this is not a requirement. In some embodiments, mixer circuitry 106a of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[0032] In some embodiments, the mixer circuitry 106a of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 106d to generate RF output signals for the FEM circuitry 108. The baseband signals may be provided by the baseband circuitry 104 and may be filtered by filter circuitry 106c. The filter circuitry 106c may include a low-pass filter (LPF), although the scope of the embodiments is not limited in this respect.

[0033] In some embodiments, the mixer circuitry 106a of the receive signal path and the mixer circuitry 106a of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and/or upconversion respectively. In some embodiments, the mixer circuitry 106a of the receive signal path and the mixer circuitry 106a of the transmit signal path may include two or more mixers and may be arranged for image rejection (e.g., Hartley image rejection). In some embodiments, the mixer circuitry 106a of the receive signal path and the mixer circuitry 106a may be arranged for direct downconversion and/or direct upconversion, respectively. In some embodiments, the mixer circuitry 106a of the receive signal path and the mixer circuitry 106a of the transmit signal path may be configured for super-heterodyne operation.

[0034] In some embodiments, the output baseband signals and the input baseband signals may be analog baseband signals, although the scope of the embodiments is not limited in this respect. In some alternate embodiments, the output baseband signals and the input baseband signals may be digital baseband signals. In these alternate embodiments, the RF circuitry 106 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 104 may include a digital baseband interface to communicate with the RF circuitry 106.

[0035] In some dual-mode embodiments, a separate radio IC circuitry may be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect.

[0036] In some embodiments, the synthesizer circuitry 106d may be a fractional-N synthesizer or a fractional $N/N+1$ synthesizer, although the scope of the embodiments is not limited in this respect as other types of frequency synthesizers may be suitable. For example, synthesizer circuitry 106d may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[0037] The synthesizer circuitry 106d may be configured to synthesize an output frequency for use by the mixer circuitry 106a of the RF circuitry 106 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 106d may be a fractional $N/N+1$ synthesizer.

[0038] In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although that is not a requirement. Divider control input may be provided by either the baseband circuitry 104 or the applications processor 102 depending on the desired output frequency. In some embodiments, a divider control input (e.g., N) may be determined from a look-up table based on a channel indicated by the applications processor 102.

[0039] Synthesizer circuitry 106d of the RF circuitry 106 may include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider may be a dual modulus divider (DMD) and the phase accumulator may be a digital phase accumulator (DPA). In some embodiments, the DMD may be configured to divide the input signal by either N or $N+1$ (e.g., based on a carry out) to provide a fractional division ratio. In some example embodiments, the DLL may include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-flop. In these embodiments, the delay elements may be configured to break a VCO period up into Nd equal packets of phase, where

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

[0040] In some embodiments, synthesizer circuitry 106d may be configured to generate a carrier frequency as the output frequency, while in other embodiments, the output frequency may be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency) and used in conjunction with quadrature generator and divider circuitry to generate multiple signals at the carrier frequency with multiple different phases with respect to each other. In some embodiments, the output frequency may be a LO frequency (fLO). In some embodiments, the RF circuitry 106 may include an IQ/polar converter.

[0041] FEM circuitry 108 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 110, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 106 for further processing. FEM circuitry 108 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 106 for transmission by one or more of the one or more antennas 110.

[0042] In some embodiments, the FEM circuitry 108 may include a TX/RX switch to switch between transmit mode and receive mode operation. The FEM circuitry may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry may include a low-noise amplifier (LNA) to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 106). The transmit signal path of the FEM circuitry 108 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 106), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 110).

[0043] In some embodiments, the UE device 100 may include additional elements such as, for example, memory/storage, display, camera, sensor, and/or input/output (I/O) interface.

[0044] Figure 2 depicts an example network environment 200 having a UE 100 and an eNB 205. As shown in Figure 2, the UE may be in a range to receive or transmit uplink or downlink data to eNB 205. In some embodiments, the UE may be a UE as described with reference to Figure 1 above. In some embodiments, the eNB may be as described with reference to Figure 3 below. In some embodiment the eNB 205 may be connected to an EPC to provide network services to the UE 100. The eNB 205 may have a primary serving cell 210 and a secondary serving cell 215. The eNB may use the primary and secondary serving

cells with carrier aggregation to improve throughput of uplink or downlink data for the network. In some embodiments, the eNB may provide additional secondary serving cells.

[0045] In some embodiments, the primary serving cell 210 may provide all of the control signaling to the UE for configuring logical channels of the UE 100 and to provide uplink grants to the UE. The communications between the primary serving cell 210 and the UE 100 may be performed over a licensed spectrum. Accordingly, the scheduled time and frequencies for use by the UE 100 may be set by the eNB 205 to ensure QoS for the UE by reducing interference from other sources.

[0046] In some embodiments, the secondary serving cell 215 may include carriers that use an unlicensed spectrum. For example, the eNB 205 may not have an exclusive license to the time or frequencies used by the secondary serving cell 215. Accordingly, there may be transmissions producing interference on the secondary serving cell 215 that are out of control of the eNB 205. Therefore, the UE 100 may have a lower QoS when sending communications on the secondary serving cell 215. However, using the secondary serving cell for some network communications may improve the available bandwidth for transmission. For example, uplink data transmission with lower required QoS may be transmitted over the unlicensed secondary serving cell 215. In some embodiments, there may be additional secondary serving cells not shown in Figure 2. Some of the secondary serving cells may provide additional licensed spectrum for use by the network.

[0047] Figure 3 illustrates additional components of a network environment 300. For example, the network environment 200 may be similar to that discussed with reference to Figure 2 above. In Figure 3, the network environment 300 includes an evolved packet core (EPC) 310, an eNB 320, and a plurality of UEs 100. The eNB 310 may be similar to the eNB 205 discussed in reference to Figure 2 above to transmit and receive communications from one or more UEs 100 over a primary and secondary serving cell. The UEs 100 may be as described above with reference to Figure 1.

[0048] The EPC in Figure 3 may include a serving gateway 314, a packet data network (PDN) gateway 316, a mobility management entity (MME) 318, and a home subscriber server (HHS) 312. The HHS 312 may include a database that supports MME functionality. For example, the HHS 312 may include information on user and subscriber information for authentication and access authorization. For example, the HHS 312 may include information for a subscriber accessing a network through a UE 100. The subscriber information may indicate QoS that is provided for the UE 100. For example, some UEs 100 may have

subscriber information with an indication that the UE 100 is to be provided with premium service by the network. Accordingly, those UEs 100 may be provided with more uplink grants for the licensed spectrum instead of the unlicensed spectrum.

[0049] The eNodeB 320 may provide RRC signaling in the control plane for the UE. For example, the eNodeB 320 may determine whether to provide an uplink grant to a UE. The eNodeB 320 may also provide configuration messages to the UE. For example, the eNodeB 320 may generate RRC, MAC, or Layer 1 signaling to the UE to configure LCGIDs. The eNodeB 320 may also decode messages received from the UE, such as BSRs. The eNodeB 320 may use the messages from the UE to determine whether to provide uplink grants licensed or unlicensed spectrum to the UE.

[0050] The serving gateway 314 and the PDN gateway 316 may provide a gateway for connections from the UEs 100 to a network. For example, the serving gateway 314 may provide signaling to maintain connections between the UEs 100 and the EPC 310. The serving gateway 213 may route uplink and downlink packets from the EPC 310 to the UE 100 through the eNB 320. The PDN gateway 316 may provide connection from the EPC 310 to a wider network. For example, the PDN gateway 316 may provide a connection from the EPC 310 to the internet, a wide area network, a local area network, or the like. The PDN gateway 316 may route packets to and from various PDNs to the UEs 100 through the serving gateway 314. In some embodiments, the serving gateway 314 and the PDN gateway 316 may be a single component of the EPC. In addition to the components of the EPC 310 illustrated in Figure 3, the EPC 310 may include additional components. For example, the EPC 310 may include additional components to support additional access technologies. The components of the EPC 310 may include one or more processors or associated memory devices to carry out various features or functions.

[0051] The EPC 310 may be associated with one or more eNB 320 to transmit and receive signals from UEs 100. For example, the EPC 310 and eNB 320 may communicate over an x2 interface such that signals may be transmitted and received at the EPC 310 from the UE 100. In some embodiments, another wired or wireless interface between the EPC 310 and the eNB 320 may be used. The eNB 320 may include RF circuitry 325 to transmit and receive wireless signals from the UE. For example, RF circuitry 325 may include similar components to those described with reference to the UE in Figure 1 above. For example, the RF circuitry 325 may include mixer circuitry, amplifier circuitry, filter circuitry, or synthesizer circuitry. The eNB may also include one or more antennas 330 with which to transmit and receive

signals. In some embodiments, the eNB 320 may also include additional components not shown such as baseband circuitry, application circuitry, or the like. In some embodiments, the eNB may have multiple serving cells. Some of the serving cells may be in the licensed spectrum and some in the unlicensed spectrum. The eNB may use carrier aggregation the serving cells to increase throughput available to the network.

[0052] Based on network configuration settings set by the EPC 310, the eNB may provide an uplink grant to the UE 100 in response to a request from the UE 100. For example, the UE 100 may provide a BSR to the eNB 320 indicating uplink data to be transmitted to the network. The eNB may use the information in the BSR including LCGID and corresponding buffer status to determine whether to provide an uplink grant and whether such uplink grant is to provide for licensed or unlicensed spectrum. For example, the unlicensed spectrum may be provided for logical channels that have low priority or no guaranteed QoS. The unlicensed spectrum may also be provided for some UEs 100 that do not have premium service. The LCG ID provided in the BSR indicates to the eNB whether the UE has uplink data to send from logical channels for low priority, no guaranteed QoS, or for premium service. Processes used by a network or UE to provide uplink data over the licensed spectrum, the unlicensed spectrum, or a combination of the licensed and the unlicensed spectrum are described further below with reference to Figures 4 and 5.

[0053] Figure 4 illustrates an example method performed by a UE to transmit uplink data to a network over licensed or unlicensed spectrums, according to an embodiment. Beginning in block 410, the UE may generate a BSR including the buffer statuses for one or more logical channels corresponding to each LCG ID with uplink data available to transmit. For example, the UE may generate a BSR for one or more logical channels corresponding to a LCG with uplink data available to transmit. Each logical channel may be configured with a LCG ID. For example, the UE may map QoS requirements for the logical channels to the LCGIDs based on mapping provided by the eNB. The UE may then determine a buffer status for each of the LCGIDs based on the buffer status of the logical channels associated with each LCG. For example, the buffer status may indicate the amount of data accumulated in the buffer of logic channels for the LCG. The UE may transmit the generated BSR to an associated eNB. In response to receiving the BSR for the UE, the eNB may provide one or more uplink grants to the UE. For example, the eNB may determine an uplink grant to provide to a UE according to a method similar to that discussed below with reference to Figure 5.

[0054] In block 420, the UE may receive an uplink grant from the eNB. For example, the uplink grant may indicate licensed or unlicensed spectrums for the UE to use for transmitting uplink data to the network. The uplink grant may include an indication of frequency and time resources allocated to the UE by an eNB. For example, the uplink grant may include an indication for a UE to use a grant of a licensed spectrum or a grant of an unlicensed spectrum. The grant may indicate which of the spectrums indicated are licensed or unlicensed such that the UE can use the information to determine which uplink grants to use for particular logical channels or bearers. In some embodiments, the UE Layer 1 indicates to UE MAC whether the uplink grant from the eNB is for a licensed or an unlicensed carrier based on the frame structure used for the serving cell of the uplink grant.

[0055] In block 430, the UE performs logical channel prioritization to determine how the uplink data from the different logical channels shared the uplink grant based on the uplink grant received from the eNB. For example, the LCGIDs provided by the eNB may indicate whether logical channels assigned to an LCGID may use only the licensed spectrum or a combination of the licensed and the unlicensed spectrum. If the uplink grant received from the eNB is for serving a cell in an unlicensed spectrum, only those logical channels that are configured to use uplink grants for serving cell in the unlicensed spectrum, or not restricted to use only uplink grants from a licensed spectrum, will be involved in the logical channel prioritization. If the uplink grant received from the eNB is for a serving cell in a licensed spectrum, all the logical channels may be involved in the logical channel prioritization. For example, a logical channel that is in a particular LCG may use only licensed or unlicensed grants according to configuration of the group. The UE may then determine an uplink grant to use based on the available grants that meet the configuration requirements for the group. In some embodiments, the UE may perform a prioritization procedure of logical channels with uplink data to transmit in order to determine a particular logical channel that is to use an uplink grant. For example, if a first logical channel is in a higher priority LCGID and a second logical channel is in a lower priority LCGID, but both logical channels are able to use the licensed spectrum of an uplink grant based on the configuration for their LCGs the higher priority logical channel may use the uplink grant for the licensed spectrum before the lower priority logical channel. In some embodiments, additional prioritization procedures may be used to determine which logical channels are to use which uplink grants. For example, logical channels may be allocated to uplink grants based on priority, size of uplink data to send, QoS expectations, length of time data has been in an uplink buffer for a logic channel, or other information. In some embodiments, the prioritization process may be performed in the MAC

layer of the UE. The UE may determine whether a grant is for the licensed or the unlicensed spectrum based on data provided to the MAC layer from the physical layer.

[0056] In block 440, the UE may transmit uplink data for the logical channel on the selected uplink grant. For example, if based on prioritization procedures the logical channel is configured to use the uplink grant for a licensed spectrum, the UE may transmit uplink data of the logical channel on the allocated uplink grant. In some embodiments, the UE may determine that a logical channel should use uplink grants for licensed and unlicensed spectrums. The UE may then transmit some uplink data for the logical channel on a first uplink grant for the licensed spectrum and on a second uplink grant for the unlicensed spectrum.

[0057] Figure 5 illustrates an example method performed by an eNB to provide an uplink grant of the licensed or the unlicensed spectrum to a UE, according to an embodiment. Beginning in block 510, the eNB transmits a configuration message to a UE to set LCGIDs for the UE. For example the LCGIDs may indicate a prioritization level for different logical channels or bearers. In some embodiments, the LCGIDs may indicate a QoS level for logical channels in the group. The QoS level for the LCGIDs may be used by a UE such that the UE can determine a LCGID for each logical channel used by the UE. In some embodiments, the LCG IDs may be used by the eNB to group logical channels or bearers that can use an uplink grant for a licensed spectrum or an uplink grant for an unlicensed spectrum. Based on this LCG ID, the eNB can determine whether to allocate an uplink grant for a licensed serving cell, an uplink grant for unlicensed an serving cell, or uplink grants for both a licensed serving cell and an unlicensed serving cell to a UE.

[0058] The LCGIDs provided by the eNB may map a two bit indication of the LCG to a service level associated with the LCG. In some embodiments, the highest priority LCGID may be used to indicate enhanced QoS and channels associated with the highest priority LCGID may use only the licensed spectrum. For example, enhanced QoS may be provided to logical channels of a UE with uplink data for upload, or for UEs that have premium service associated with a user subscription. The lowest priority LCGID may be used to indicate logical channels that have no or low QoS requirements. The lowest priority LCGID may use only the unlicensed spectrum to reduce traffic on the licensed spectrum. The middle priority LCGIDs may be used to indicate logical channels that may use either the license spectrum or the unlicensed spectrum, or logical channels that may use both the licensed spectrum and the unlicensed spectrum. For example, the second highest priority LCGID may use both the

licensed and the unlicensed spectrum to increase the available spectrum for uplink transmissions, and the third highest priority LCGID may use only the licensed or the unlicensed spectrum depending on the available uplink grant and the prioritization procedure of the UE. In some other embodiments, the LCG ID may be configured to each logical channel depending on whether it can use uplink grants for a licensed spectrum only, an uplink grant for an unlicensed spectrum only, or an uplink grant from both licensed and unlicensed spectrums.

[0059] In some embodiments, the eNB may trigger multiple BSR reports from a UE to determine the status of licensed and unlicensed uplink grants. For example, the eNB may trigger a first BSR report from a UE to determine LCGIDs and buffer status for logical channels using licensed uplink grants and a second BSR report from the UE to determine LCGIDs and buffer status for logical channels using unlicensed uplink grants. In some embodiments, the eNB may trigger BSRs from a UE that include additional information for particular logical channels. For example, the BSR may include separate buffer status for uplink grant usage for each uplink grant used by each LCG.

[0060] In block 520, the eNB receives a BSR message from one or more UEs. For example, the BSR report may include LCGIDs and buffer statuses for one or more logical channels of the UE with uplink data for transmission associated with a LCG identified by a LCG ID. The BSR may also include an indication for each of the LCG whether uplink grant usage by the UE is over the licensed or the unlicensed spectrum. For example, the LCGIDs used by the UE, an indication in the BSR, or a MAC control element, may indicate the licensed or unlicensed status of uplink grants used by logical channels corresponding to a LCG identified by a LCGID. The eNB may decode the BSR message to determine the amount of uplink data that a UE is to transmit, QoS of the uplink data. The eNB may also determine whether to allocate one or more uplink grants for a licensed spectrum only, either uplink grants for licensed or unlicensed spectrums, or uplink grants for both licensed and unlicensed spectrums.

[0061] In block 530, the eNB generates one or more uplink grant messages for the UE based on the BSR. For example, the eNB may use the BSRs of the UE in combination with additional BSRs of other UEs to determine available spectrum to access the network. The eNB may also determine whether to provide licensed or unlicensed uplink grants to the UE based on the LCGIDs of the UE and the buffer status of each LCGID. For example, if a BSR message from a UE indicates a large amount of data to be transmitted by a UE over the

licensed spectrum, the eNB may provide an uplink grant in the licensed spectrum to the UE. The eNB may provide one or more uplink grants in licensed or unlicensed spectrums based on the BSR message from the UE.

[0062] In block 540, the eNB provides the uplink grant to the UE. For example, the uplink grant may be transmitted to the UE using a downlink control information (DCI) message on a physical downlink control channel (PDCCH). The DCI message may indicate time and frequency resources for the eNB to use to transmit the uplink data. In some embodiments, the uplink grant may be provided by the UE in another manner. In some embodiments, the uplink grant provided to a UE may include an indication that the uplink is for the licensed or the unlicensed spectrum. In some embodiments, the physical layer of the UE may indicate to the MAC layer of the UE whether an uplink grant is in the licensed or the unlicensed spectrum

[0063] In addition to providing information for the licensed and the unlicensed spectrum, the processes described herein may provide indications to UEs of whether to use different frequency bands or different types of wireless access spectrums. For example, the licensed spectrum may be available to an eNB at different strengths and interference rates.

Accordingly, the eNB may treat the high quality licensed spectrum and the lower quality licensed spectrum for different LCGs in the same manner as described above with reference to the licensed and the unlicensed spectrum.

[0064] While the present disclosure describes a number of embodiments, those skilled in the art will appreciate numerous modifications and variations therefrom. It is intended that the appended claims cover all such modifications and variations as fall within the true spirit and scope of this present disclosure.

[0065] The following examples pertain to further embodiments of the disclosure.

[0066] Example 1 is an apparatus of a user equipment comprising: a memory; and one or more processors operatively coupled to the memory, the processors to: process a buffer status report (BSR) trigger received at the UE from an evolved NodeB (eNB); encode, in uplink data to the eNB, a BSR including a logical control group (LCG) identification and a buffer status associated with a LCG identified by the LCG identification; process one or more uplink grants from the eNB, wherein the uplink grants reference a licensed spectrum and an unlicensed spectrum; and encode uplink data of a logical channel associated with the LCG based on the one or more uplink grants.

[0067] In example 2, in the apparatus of example 1, or any of the examples described herein, the one or more uplink grants comprise a frequency and a time allocation to the UE.

[0068] In example 3, in the apparatus of example 1, or any of the examples described herein, the processors are further to: determine that the logical channel is configured by the eNB to only transmit on licensed spectrum; and encode the uplink data to use a first uplink grant, of the one or more uplink grants, wherein the first uplink grant is for the licensed spectrum and a second uplink grant of the one or more uplink grants is for the unlicensed spectrum.

[0069] In example 4, in the apparatus of example 1, or any of the examples described herein, the processors are further to: determine that the logical channel is configured by the eNB to only transmit on unlicensed spectrum; and encode the uplink data to use a first uplink grant, of the one or more uplink grants, wherein the first uplink grant is for the unlicensed spectrum and a second uplink grant of the one or more uplink grants is for the unlicensed spectrum.

[0070] In example 5, in the apparatus of example 1, or any of the examples described herein, the processors are further to determine that the logical channel is configured by the eNB to transmit on licensed spectrum or unlicensed spectrum; and encode the uplink data to use a first uplink grant of the one or more uplink grants and a second uplink grant of the one or more uplink grants, wherein the first uplink grant is for the licensed spectrum and the second uplink grant is for the unlicensed spectrum.

[0071] In example 6, in the apparatus of example 1, or any of the examples described herein, the processors are further to determine that the logical channel is configured by the eNB to use an uplink grant for the licensed spectrum only, to use an uplink grant for either the licensed spectrum or the unlicensed spectrum, or to use an uplink grant for unlicensed spectrum only.

[0072] In example 7, in the apparatus of example 1, or any of the examples described herein, the BSR indicates a first buffer status of a first set of logical channels that only use licensed spectrum and a second buffer status of a second set of logical channels that only use unlicensed spectrum.

[0073] In example 8, in the apparatus of example 1, or any of the examples described herein, the BSR indicates a first buffer status of a first set of logical channels, and wherein the one or more processors are further to generate a second BSR indicating a second buffer status of a second set of logical channels.

[0074] In example 9, in the apparatus of example 1, or any of the examples described herein, the processors are further to determine the uplink data of the logical channel to encode the uplink data based on performing a prioritization procedure for the uplink grant and

whether the one or more uplink grants are for the licensed spectrum or the unlicensed spectrum.

[0075] In example 10, the apparatus of example 1, or any of the examples described herein, further comprises: radio frequency (RF) circuitry coupled to the one or more processors; front-end module circuitry coupled to the radio frequency circuitry; and an antenna coupled to the front-end module circuitry.

[0076] In example 11, in the apparatus of example 10, or any of the examples described herein, to processes a buffer status report trigger, the UE is to: process a first periodic BSR timer (periodicBSR-Timer) to trigger a first BSR regarding uplink data to transmit in the licensed spectrum; and process a second periodicBSR-Timer to trigger a second BSR regarding uplink data to transmit in the unlicensed spectrum.

[0077] In example 12, in the apparatus of example 1, or any of the examples described herein, to processes a buffer status report trigger, the UE is to: process a first retransmission BSR timer (retxBSR-Timer) to trigger a first BSR regarding uplink data to transmit in the licensed spectrum; and process a second retxBSR-Timer to trigger a second BSR regarding uplink data to transmit in the unlicensed spectrum.

[0078] Example 13 is one or more computer-readable media having instructions that, when executed, cause one or more processors of a user equipment (UE) to: process a configuration message from an evolved NodeB (eNB) comprising a logical channel group (LCG) for use by a logical channel of the UE; and determine whether the logic channel is to transmit uplink data on a licensed spectrum or an unlicensed spectrum based on the LCG for the logical channel.

[0079] In example 14, the one or more computer-readable media of example 13, or any of the examples described herein, the instructions further cause the processors to process a first uplink grant for the licensed spectrum and a second uplink grant for the unlicensed spectrum.

[0080] In example 15, the one or more computer-readable media of example 13, or any of the examples described herein, the instructions further cause the processors to process a radio resource control (RRC) message from the eNB indicating that the logical channel is to use only a first uplink grant for the licensed spectrum or only a second uplink grant for the unlicensed spectrum.

[0081] In example 16, the one or more computer-readable media of example 13, or any of the examples described herein, the instructions further cause the processors to process a RRC

message from the eNB indicating that the logical channel is to use a first uplink grant for the licensed spectrum and a second uplink grant for the unlicensed spectrum.

[0082] In example 17, the one or more computer-readable media of example 13, or any of the examples described herein, the instructions further cause the processors to generate a buffer status report (BSR) comprising a buffer status and LCG identification for the LCG.

[0083] In example 18, the one or more computer-readable media of example 13, or any of the examples described herein, the instructions further cause the processors to determine uplink data of the logical channel to transmit based on performing a prioritization procedure on the logical channel.

[0084] Example 19 is apparatus of an evolved nodeB (eNB), comprising: a memory; and one or more processors coupled to the memory, the processors to: provide a configuration message to a user equipment (UE), wherein the configuration message comprises logical channel groups (LCG) associated with a set of logical channels and an indication of spectrums available to logical channels of the set of logical channels; process a buffer status report received at the eNB from a UE, the BSR comprising a LCG identification and buffer status associated with a LCG identified by the LCG identification for a subset of logical channels associated with the LCG; and provide an uplink grant to a UE based on the BSR, wherein the uplink grant indicates to the UE whether to use a licensed spectrum or an unlicensed spectrum for the subset of logical channels.

[0085] In example 20, in the apparatus of example 19, or any of the examples described herein, the uplink grant is for the unlicensed spectrum, and the one or more processors are further to determine to provide the uplink grant in response to the LCG identification indicating the logical channel can use the unlicensed spectrum.

[0086] In example 21, in the apparatus of example 19, or any of the examples described herein, the uplink grant is for licensed spectrum, and the one or more processors are further to determine to provide the uplink grant in response to the LCG identification indicating the logical channel can use only the licensed spectrum.

[0087] In example 22, in the apparatus of example 19, or any of the examples described herein, the processors are further to provide additional uplink grants to a plurality of additional UEs based at least in part on additional BSRs received at the eNB from the additional UEs.

[0088] Example 23 is an apparatus of a user equipment, comprising: means for encoding a buffer status report (BSR) comprising a logic control group (LCG) identification and buffer status for a plurality of logical channels; means for processing an uplink grant from an

evolved nodeB (eNB), wherein the uplink grant is for an unlicensed spectrum of a secondary serving cell; and means for determining uplink data for a first logical channel of the plurality of logic channels to transmit based on the uplink grant.

[0089] In example 24, the apparatus of example 23, or any of the examples described herein, further comprises means for processing a second uplink grant from the eNB, wherein the second uplink grant is for a licensed spectrum; and means for determining second uplink data for a second logical channel of the plurality of logical channels to transmit according to the second uplink grant.

[0090] In example 25, the apparatus of example 23, or any of the examples described herein, further comprises means for determining the LCG identification for a first logical channel based on quality of service expectations for the first logical channel.

[0091] Example 26 is a method comprising: processing a buffer status report (BSR) trigger received at the UE from an evolved NodeB (eNB); generating a BSR including a logical control group (LCG) identification and a buffer status associated with a LCG identified by the LCG identification; processing one or more uplink grants from the eNB, wherein the uplink grants reference at least one of a licensed spectrum or an unlicensed spectrum; and encoding uplink data of a logical channel associated with the LCG based on the one or more uplink grants.

[0092] In example 27, in the method of example 26, or any of the examples described herein, the one or more uplink grants comprise a frequency and a time allocation to the UE.

[0093] In example 28, the method of example 26, or any of the examples described herein, further comprises: determining that the logical channel is configured by the eNB to only transmit on licensed spectrum; and using a first uplink grant, of the one or more uplink grants, to transmit the uplink data, wherein the first uplink grant is for the licensed spectrum and a second uplink grant of the one or more uplink grants is for the unlicensed spectrum.

[0094] In example 29, the method of example 26, or any of the examples described herein, further comprises: determining that the logical channel is configured by the eNB to only transmit on unlicensed spectrum; and using a first uplink grant, of the one or more uplink grants, to transmit the uplink data, wherein the first uplink grant is for the unlicensed spectrum and a second uplink grant of the one or more uplink grants is for the unlicensed spectrum.

[0095] In example 30, the method of example 26, or any of the examples described herein, further comprises: determining that the logical channel is configured by the eNB to transmit on licensed spectrum or unlicensed spectrum; and using a first uplink grant of the one or more

uplink grants and a second uplink grant of the one or more uplink grants to transmit the uplink data, wherein the first uplink grant is for the licensed spectrum and the second uplink grant is for the unlicensed spectrum.

[0096] In example 31, the method of example 26, or any of the examples described herein, further comprises determining that the logic channel is configured by the eNB to use an uplink grant for the licensed spectrum only, to use an uplink grant for either the licensed spectrum or the unlicensed spectrum, or to use an uplink grant for unlicensed spectrum only.

[0097] In example 32, in the method of example 26, or any of the examples described herein, the BSR indicates a first buffer status of a first set of logical channels that only use licensed spectrum and a second buffer status of a second set of logical channels that only use unlicensed spectrum.

[0098] In example 33, in the method of example 26, or any of the examples described herein, further comprises the BSR indicates a first buffer status of a first set of logical channels, and wherein the one or more processors are further to generate a second BSR indicating a second buffer status of a second set of logical channels.

[0099] In example 34, the method of example 26, or any of the examples described herein, further comprises determining the uplink data of the logical channel to transmit based on performing a prioritization procedure for the uplink grant and whether the one or more uplink grants are for the licensed spectrum or the unlicensed spectrum.

[0100] In example 35, the method of example 26, or any of the examples described herein, further comprises determining the logic channel is configured by the eNB to be associated with the LCG based on a quality of service indication of the logical channel or based on whether the logical channel can use the licensed spectrum or the unlicensed spectrum.

[0101] Example 36 is an apparatus comprising means to perform a method as claimed in any of examples 26 to 35.

[0102] Example 37 is a machine-readable storage including machine-instructions that, when executed, cause an apparatus to perform a method as claimed in any of claims 26 to 35.

[0103] In the description herein, numerous specific details are set forth, such as examples of specific types of processors and system configurations, specific hardware structures, specific architectural and micro architectural details, specific register configurations, specific instruction types, specific system components, specific measurements/heights, specific processor pipeline stages and operation etc. in order to provide a thorough understanding of the present disclosure. It will be apparent, however, that these specific details need not be employed to practice aspects of the present disclosure. In other instances, well known

components or methods, such as specific and alternative processor architectures, specific logic circuits/code for described algorithms, specific firmware code, specific interconnect operation, specific logic configurations, specific manufacturing techniques and materials, specific compiler implementations, specific expression of algorithms in code, specific power down and gating techniques/logic and other specific operational details of computer system have not been described in detail in order to avoid unnecessarily obscuring the present disclosure.

[0104] Instructions used to program logic to perform embodiments of the disclosure can be stored within a memory in the system, such as DRAM, cache, flash memory, or other storage. Furthermore, the instructions can be distributed via a network or by way of other computer readable media. Thus a machine-readable medium may include any mechanism for storing or transmitting information in a form readable by a machine (e.g., a computer), but is not limited to, floppy diskettes, optical disks, Compact Disc, Read-Only Memory (CD-ROMs), and magneto-optical disks, Read-Only Memory (ROMs), Random Access Memory (RAM), Erasable Programmable Read-Only Memory (EPROM), Electrically Erasable Programmable Read-Only Memory (EEPROM), magnetic or optical cards, flash memory, or a tangible, machine-readable storage used in the transmission of information over the Internet via electrical, optical, acoustical or other forms of propagated signals (e.g., carrier waves, infrared signals, digital signals, etc.). Accordingly, the computer-readable medium includes any type of tangible machine-readable medium suitable for storing or transmitting electronic instructions or information in a form readable by a machine (e.g., a computer).

[0105] A module as used herein refers to any combination of hardware, software, and/or firmware. As an example, a module includes hardware, such as a micro-controller, associated with a non-transitory medium to store code adapted to be executed by the micro-controller. Therefore, reference to a module, in one embodiment, refers to the hardware, which is specifically configured to recognize and/or execute the code to be held on a non-transitory medium. Furthermore, in another embodiment, use of a module refers to the non-transitory medium including the code, which is specifically adapted to be executed by the microcontroller to perform predetermined operations. And as can be inferred, in yet another embodiment, the term module (in this example) may refer to the combination of the microcontroller and the non-transitory medium. Often module boundaries that are illustrated as separate commonly vary and potentially overlap. For example, a first and a second module may share hardware, software, firmware, or a combination thereof, while potentially retaining some independent hardware, software, or firmware. In one embodiment, use of the term logic

includes hardware, such as transistors, registers, or other hardware, such as programmable logic devices.

[0106] Use of the phrase ‘configured to,’ in one embodiment, refers to arranging, putting together, manufacturing, offering to sell, importing and/or designing an apparatus, hardware, logic, or element to perform a designated or determined task. In this example, an apparatus or element thereof that is not operating is still ‘configured to’ perform a designated task if it is designed, coupled, and/or interconnected to perform said designated task. As a purely illustrative example, a logic gate may provide a 0 or a 1 during operation. But a logic gate ‘configured to’ provide an enable signal to a clock does not include every potential logic gate that may provide a 1 or 0. Instead, the logic gate is one coupled in some manner that during operation the 1 or 0 output is to enable the clock. Note once again that use of the term ‘configured to’ does not require operation, but instead focuses on the latent state of an apparatus, hardware, and/or element, where in the latent state the apparatus, hardware, and/or element is designed to perform a particular task when the apparatus, hardware, and/or element is operating.

[0107] Furthermore, use of the phrases ‘to,’ ‘capable of/to,’ and or ‘operable to,’ in one embodiment, refers to some apparatus, logic, hardware, and/or element designed in such a way to enable use of the apparatus, logic, hardware, and/or element in a specified manner. Note as above that use of to, capable to, or operable to, in one embodiment, refers to the latent state of an apparatus, logic, hardware, and/or element, where the apparatus, logic, hardware, and/or element is not operating but is designed in such a manner to enable use of an apparatus in a specified manner.

[0108] The embodiments of methods, hardware, software, firmware or code set forth above may be implemented via instructions or code stored on a machine-accessible, machine readable, computer accessible, or computer readable medium which are executable by a processing element. A non-transitory machine-accessible/readable medium includes any mechanism that provides (i.e., stores and/or transmits) information in a form readable by a machine, such as a computer or electronic system. For example, a non-transitory machine-accessible medium includes random-access memory (RAM), such as static RAM (SRAM) or dynamic RAM (DRAM); ROM; magnetic or optical storage medium; flash memory devices; electrical storage devices; optical storage devices; acoustical storage devices; other form of storage devices for holding information received from transitory (propagated) signals (e.g., carrier waves, infrared signals, digital signals); etc., which are to be distinguished from the non-transitory mediums that may receive information there from.

[0109] Instructions used to program logic to perform embodiments of the disclosure may be stored within a memory in the system, such as DRAM, cache, flash memory, or other storage. Furthermore, the instructions can be distributed via a network or by way of other computer readable media. Thus a machine-readable medium may include any mechanism for storing or transmitting information in a form readable by a machine (e.g., a computer), but is not limited to, floppy diskettes, optical disks, Compact Disc, Read-Only Memory (CD-ROMs), and magneto-optical disks, Read-Only Memory (ROMs), Random Access Memory (RAM), Erasable Programmable Read-Only Memory (EPROM), Electrically Erasable Programmable Read-Only Memory (EEPROM), magnetic or optical cards, flash memory, or a tangible, machine-readable storage used in the transmission of information over the Internet via electrical, optical, acoustical or other forms of propagated signals (e.g., carrier waves, infrared signals, digital signals, etc.). Accordingly, the computer-readable medium includes any type of tangible machine-readable medium suitable for storing or transmitting electronic instructions or information in a form readable by a machine (e.g., a computer).

[0110] Reference throughout this specification to “one embodiment” or “an embodiment” means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present disclosure. Thus, the appearances of the phrases “in one embodiment” or “in an embodiment” on “in some embodiments” in various places throughout this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more embodiments.

[0111] In the foregoing specification, a detailed description has been given with reference to specific exemplary embodiments. It will, however, be evident that various modifications and changes may be made thereto without departing from the broader spirit and scope of the disclosure as set forth in the appended claims. The specification and drawings are, accordingly, to be regarded in an illustrative sense rather than a restrictive sense. Furthermore, the foregoing use of embodiment and other exemplarily language does not necessarily refer to the same embodiment or the same example, but may refer to different and distinct embodiments, as well as potentially the same embodiment.

[0112] Some portions of the detailed description are presented in terms of algorithms and symbolic representations of operations on data bits within a computer memory. These algorithmic descriptions and representations are the means used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the art. An algorithm is here and generally, conceived to be a self-consistent sequence of

operations leading to a desired result. The operations are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared and otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers or the like. The blocks described herein can be hardware, software, firmware or a combination thereof.

[0113] It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the above discussion, it is appreciated that throughout the description, discussions utilizing terms such as “defining,” “receiving,” “determining,” “issuing,” “linking,” “associating,” “obtaining,” “authenticating,” “prohibiting,” “executing,” “requesting,” “communicating,” or the like, refer to the actions and processes of a computing system, or similar electronic computing device, that manipulates and transforms data represented as physical (e.g., electronic) quantities within the computing system's registers and memories into other data similarly represented as physical quantities within the computing system memories or registers or other such information storage, transmission or display devices.

[0114] The words “example” or “exemplary” are used herein to mean serving as an example, instance or illustration. Any aspect or design described herein as “example” or “exemplary” is not necessarily to be construed as preferred or advantageous over other aspects or designs. Rather, use of the words “example” or “exemplary” is intended to present concepts in a concrete fashion. As used in this application, the term “or” is intended to mean an inclusive “or” rather than an exclusive “or.” That is, unless specified otherwise, or clear from context, “X includes A or B” is intended to mean any of the natural inclusive permutations. That is, if X includes A; X includes B; or X includes both A and B, then “X includes A or B” is satisfied under any of the foregoing instances. In addition, the articles “a” and “an” as used in this application and the appended claims should generally be construed to mean “one or more” unless specified otherwise or clear from context to be directed to a singular form. Moreover, use of the term “an embodiment” or “one embodiment” or “an implementation” or “one implementation” throughout is not intended to mean the same embodiment or implementation unless described as such. Also, the terms “first,” “second,” “third,” “fourth,” etc. as used herein are meant as labels to distinguish among different

elements and may not necessarily have an ordinal meaning according to their numerical designation.

CLAIMS

What is claimed is:

1. An apparatus of a user equipment (UE) comprising:
a memory; and
5 one or more processors operatively coupled to the memory, the processors to:
process a buffer status report (BSR) trigger received at the UE from an evolved
NodeB (eNB);
encode, in uplink data to the eNB, a BSR including a logical control group
(LCG) identification and a buffer status associated with a LCG identified by the LCG
10 identification;
process one or more uplink grants from the eNB, wherein the uplink grants
reference a licensed spectrum and an unlicensed spectrum; and
encode uplink data of a logical channel associated with the LCG based on the
one or more uplink grants.
- 15 2. The apparatus of claim 1, wherein the one or more uplink grants comprise a frequency
and a time allocation to the UE.
3. The apparatus of claim 1 or 2, wherein the processors are further to:
determine that the logical channel is configured by the eNB to only transmit on
licensed spectrum; and
20 encode the uplink data to use a first uplink grant, of the one or more uplink grants,
wherein the first uplink grant is for the licensed spectrum and a second uplink grant of the one
or more uplink grants is for the unlicensed spectrum.
4. The apparatus of claim 1 or 2, wherein the processors are further to:
determine that the logical channel is configured by the eNB to only transmit on
25 unlicensed spectrum; and
encode the uplink data to use a first uplink grant, of the one or more uplink grants,
wherein the first uplink grant is for the unlicensed spectrum and a second uplink grant of the
one or more uplink grants is for the unlicensed spectrum.
5. The apparatus of claim 1 or 2, wherein the processors are further to:
30 determine that the logical channel is configured by the eNB to transmit on licensed
spectrum or unlicensed spectrum; and

encode the uplink data to use a first uplink grant of the one or more uplink grants and a second uplink grant of the one or more uplink grants, wherein the first uplink grant is for the licensed spectrum and the second uplink grant is for the unlicensed spectrum.

6. The apparatus of claim 1 or 2, wherein the processors are further to determine that the logic channel is configured by the eNB to use an uplink grant for the licensed spectrum only, to use an uplink grant for either the licensed spectrum or the unlicensed spectrum, or to use an uplink grant for unlicensed spectrum only.

7. The apparatus of claim 1, wherein the BSR indicates a first buffer status of a first set of logical channels that only use licensed spectrum and a second buffer status of a second set of logical channels that only use unlicensed spectrum.

8. The apparatus of claim 1, wherein the BSR indicates a first buffer status of a first set of logical channels, and wherein the one or more processors are further to generate a second BSR indicating a second buffer status of a second set of logical channels.

9. The apparatus of claim 1, 2, 7, or 8, wherein the processors are further to determine the uplink data of the logical channel to encode based on performing a prioritization procedure for the uplink grant and whether the one or more uplink grants are for the licensed spectrum or the unlicensed spectrum.

10. The apparatus of claim 1, 2, 7, or 8, further comprising:
radio frequency (RF) circuitry coupled to the one or more processors;
front-end module circuitry coupled to the radio frequency circuitry; and
an antenna coupled to the front-end module circuitry.

11. The apparatus of claim 1, 2, 7, or 8, wherein to processes a buffer status report trigger, the UE is to:

process a first periodic BSR timer (periodicBSR-Timer) to trigger a first BSR regarding uplink data to transmit in the licensed spectrum; and
process a second periodicBSR-Timer to trigger a second BSR regarding uplink data to transmit in the unlicensed spectrum.

12. The apparatus of claim 1, 2, 7, or 8, wherein to processes a buffer status report trigger, the UE is to:

process a first retransmission BSR timer (retxBSR-Timer) to trigger a first BSR regarding uplink data to transmit in the licensed spectrum; and

5 process a second retxBSR-Timer to trigger a second BSR regarding uplink data to transmit in the unlicensed spectrum.

13. One or more computer-readable media having instructions that, when executed, cause one or more processors of a user equipment (UE) to:

10 process a configuration message from an evolved NodeB (eNB) comprising a logical channel group (LCG) for use by a logical channel of the UE; and

determine whether the logical channel is to transmit uplink data on a licensed spectrum or an unlicensed spectrum based on the LCG for the logical channel; and

encode uplink data of the logical channel on the licensed spectrum or the unlicensed spectrum as determined for the logical channel.

15 14. The one or more computer-readable media of claim 13, wherein the instructions further cause the processors to process a first uplink grant for the licensed spectrum and a second uplink grant for the unlicensed spectrum.

15. The one or more computer-readable media of claim 13, wherein the instructions further cause the processors to process a radio resource control (RRC) message from the eNB
20 indicating that the logical channel is to use only a first uplink grant for the licensed spectrum or only a second uplink grant for the unlicensed spectrum.

16. The one or more computer-readable media of claim 13, wherein the instructions further cause the processors to process a RRC message from the eNB indicating that the logical channel is to use a first uplink grant for the licensed spectrum and a second uplink
25 grant for the unlicensed spectrum.

17. The one or more computer-readable media of claim 13, wherein the instructions further cause the processors to generate a buffer status report (BSR) comprising a buffer status and LCG identification for the LCG.

18. The one or more computer-readable media of claim 13, wherein the instructions further cause the processors to determine uplink data of the logical channel to transmit based on performing a prioritization procedure on the logical channel.

19. An apparatus of an evolved nodeB (eNB), comprising:

5 a memory; and

one or more processors coupled to the memory, the processors to:

provide a configuration message to a user equipment (UE), wherein the configuration message comprises logical channel groups (LCGs) associated with a set of logical channels and an indication of spectrums available to logical channels of the set of logical channels;

process a buffer status report (BSR) received at the eNB from the UE, the BSR comprising a LCG identification and buffer status associated with a LCG identified by the LCG identification for a subset of logical channels associated with the LCG; and

provide an uplink grant to the UE based on the BSR, wherein the uplink grant indicates to the UE whether to use a licensed spectrum or an unlicensed spectrum for the subset of logical channels.

20. The apparatus of claim 19, wherein the uplink grant is for the unlicensed spectrum, and the one or more processors are further to determine to provide the uplink grant in response to the LCG identification indicating the logical channel can use the unlicensed spectrum.

21. The apparatus of claim 19, wherein the uplink grant is for licensed spectrum, and the one or more processors are further to determine to provide the uplink grant in response to the LCG identification indicating the logical channel can use only the licensed spectrum.

22. The apparatus of claim 19, wherein the processors are further to provide additional uplink grants to a plurality of additional UEs based at least in part on additional BSRs received at the eNB from the additional UEs.

23. An apparatus of a user equipment, comprising:

means for encoding a buffer status report (BSR) comprising a logic control group (LCG) identification and buffer status for a plurality of logical channels;

means for processing an uplink grant from an evolved nodeB (eNB), wherein the uplink grant is for an unlicensed spectrum of a secondary serving cell; and

means for determining uplink data for a first logical channel of the plurality of logic channels to transmit based on the uplink grant.

24. The apparatus of claim 23, further comprising:

5 means for processing a second uplink grant from the eNB, wherein the second uplink grant is for a licensed spectrum; and

means for determining second uplink data for a second logical channel of the plurality of logical channels to transmit according to the second uplink grant.

25. The apparatus of claim 23, further comprising means for determining the LCG identification for a first logical channel based on quality of service expectations for the first

10 logical channel.

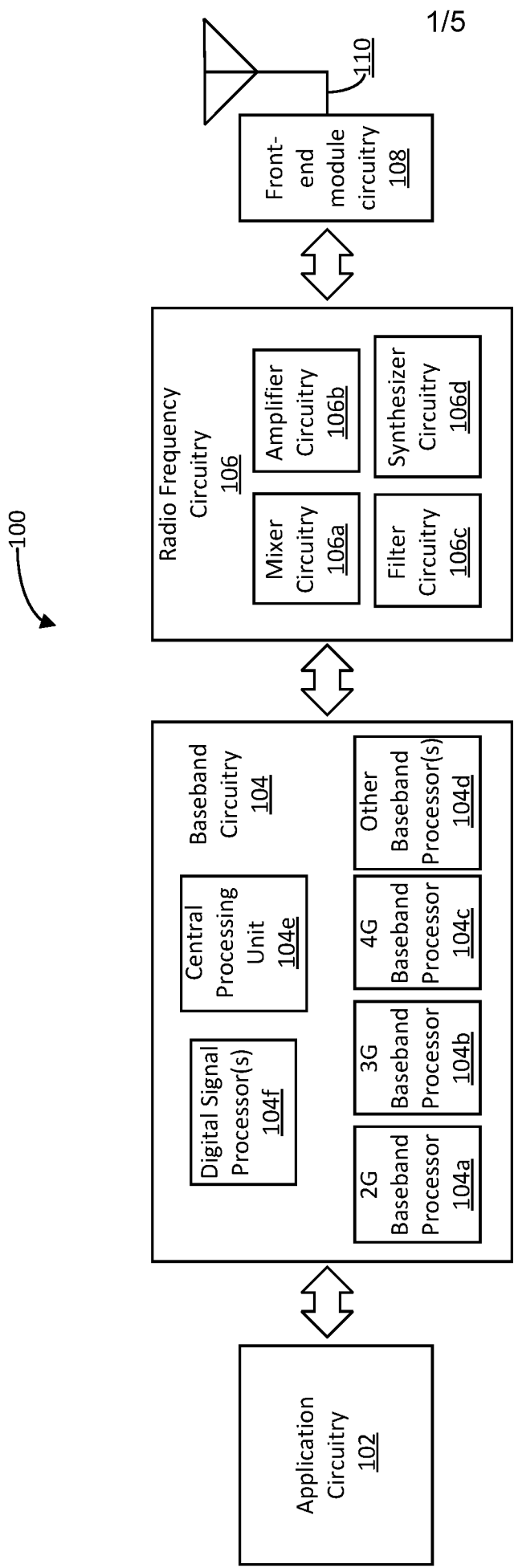


FIG. 1

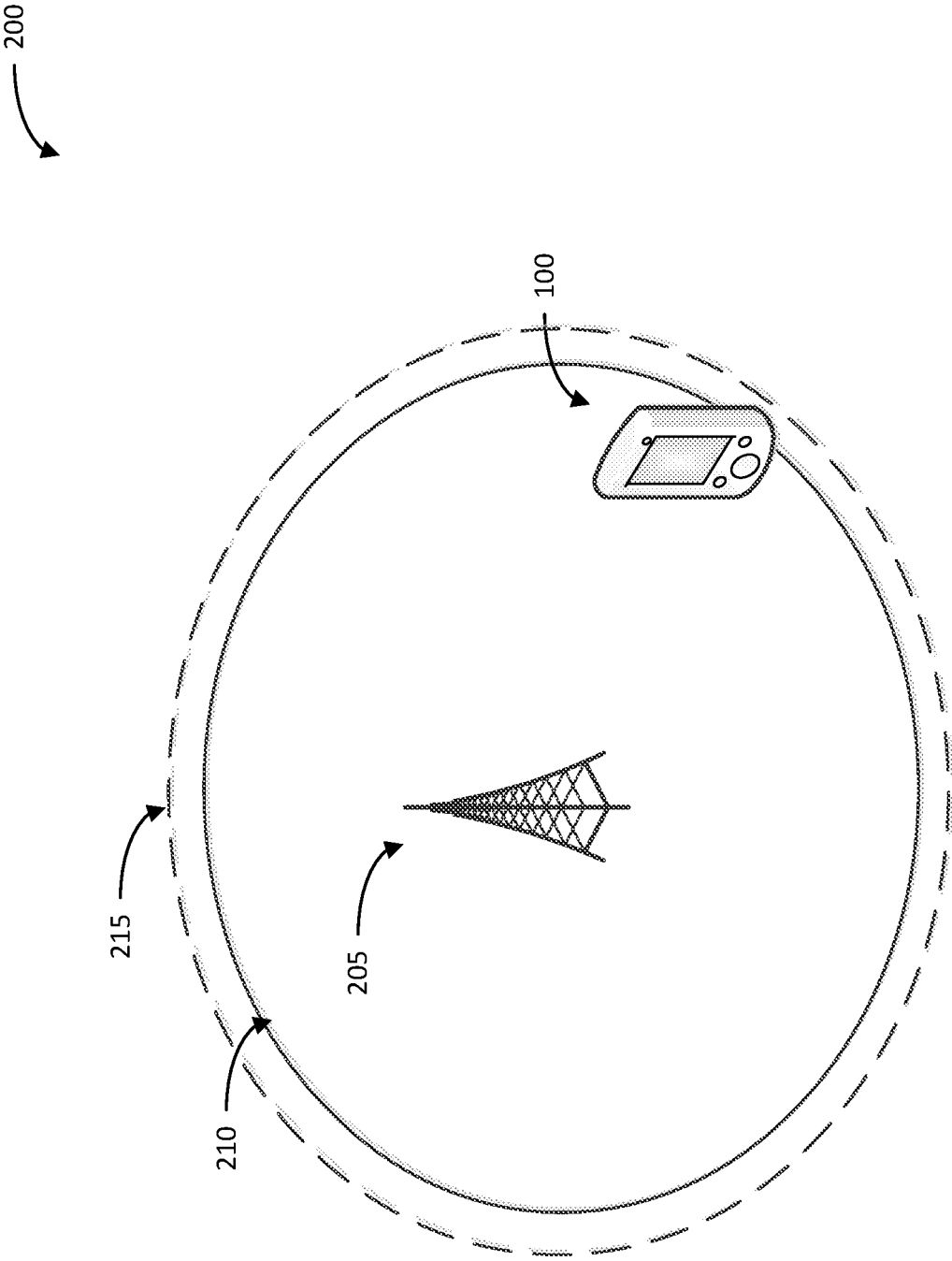


FIG. 2

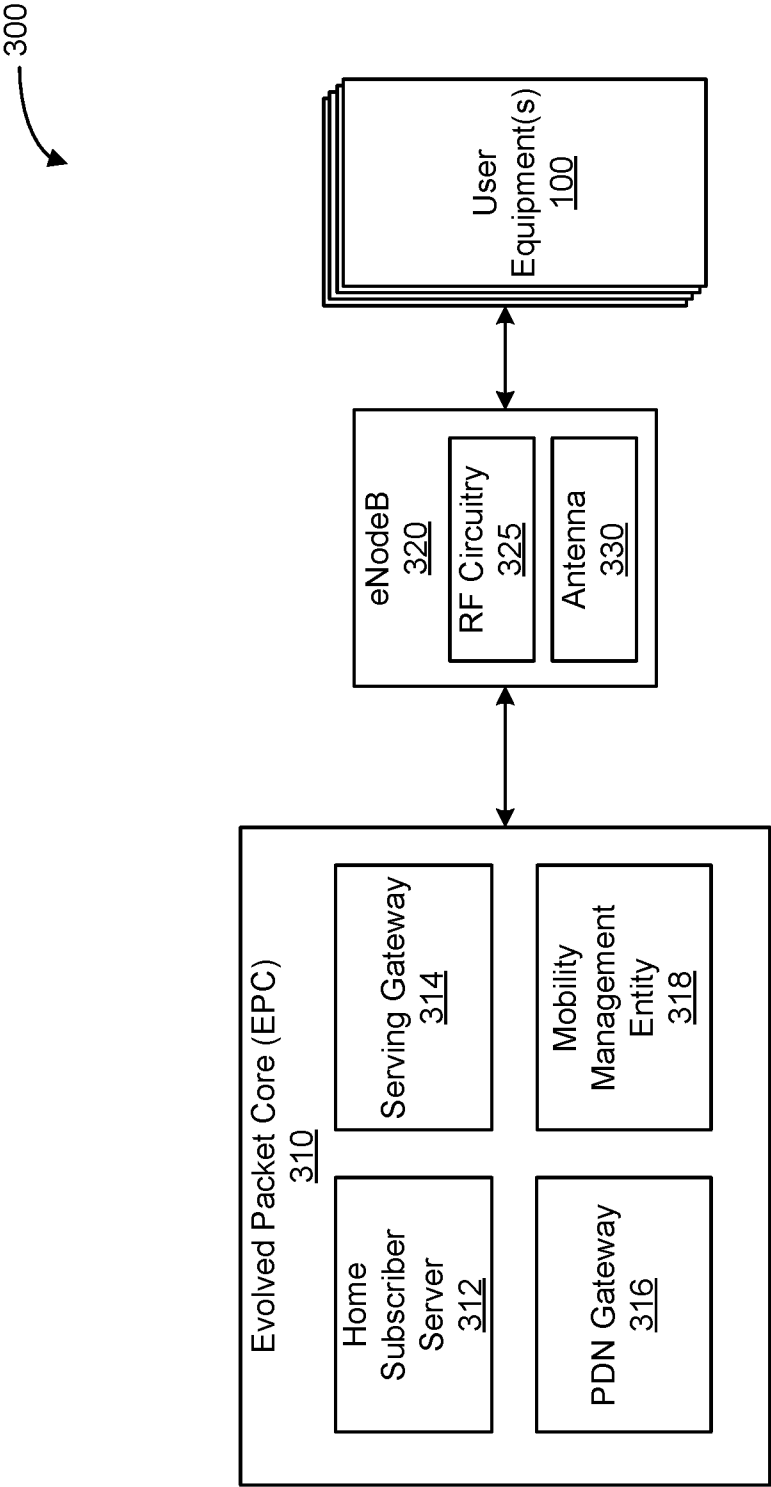


FIG. 3

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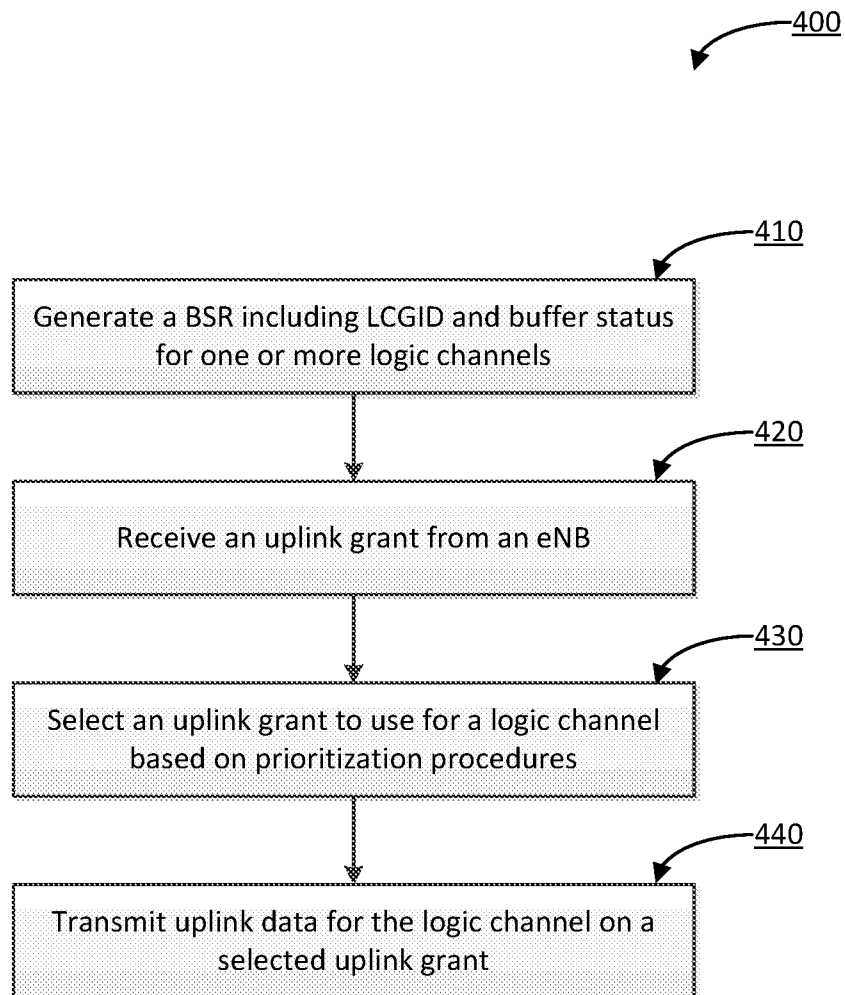


FIG. 4

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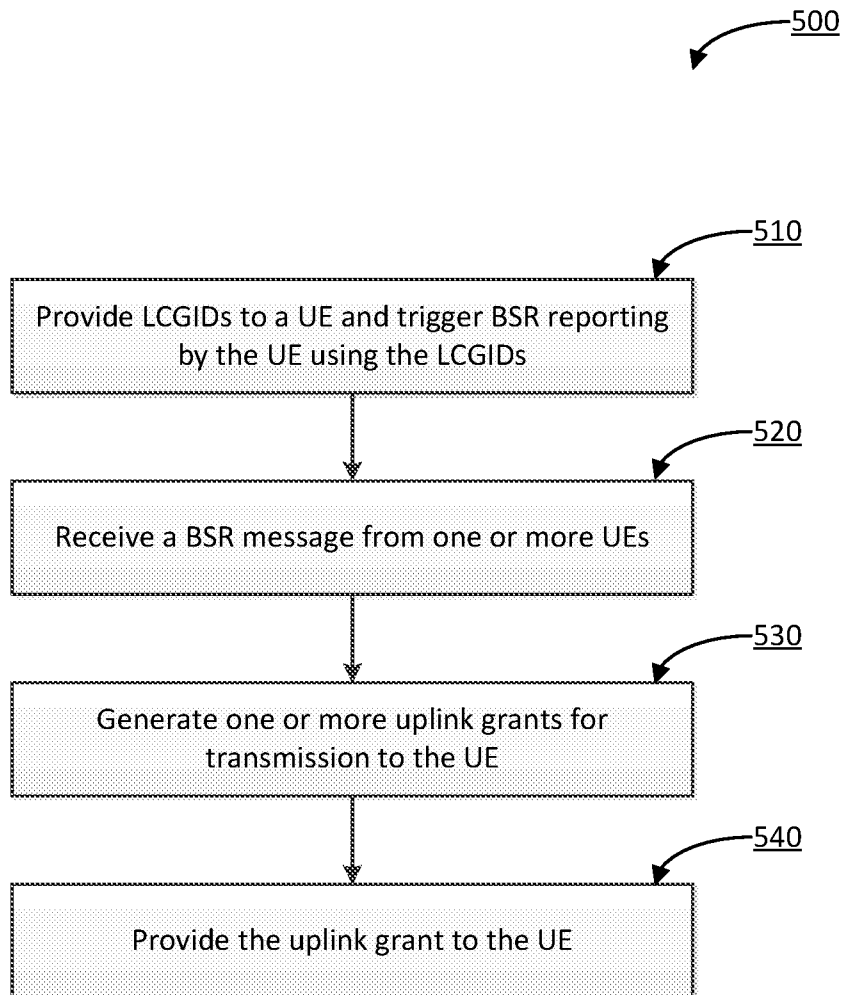


FIG. 5

A. CLASSIFICATION OF SUBJECT MATTER**H04W 28/02(2009.01)i, H04W 72/14(2009.01)i, H04W 72/12(2009.01)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 28/02; H04L 5/00; H04W 84/10; H04W 72/04; H04W 16/14; H04W 52/00; H04W 72/14; H04W 72/12

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: LCG, BSR, uplink grant, licensed spectrum, and unlicensed spectrum.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2015-0188680 A1 (FUJITSU LIMITED) 02 July 2015 See paragraphs [0009], [0044], [0047], [0061], [0101], [0128]–[0141]; and claims 1–15.	1–8, 11–17, 19–25
Y		9–10, 18
Y	US 2014-0362780 A1 (QUALCOMM INCORPORATED) 11 December 2014 See paragraphs [0113]–[0120], [0139]; claim 1; and figure 7.	9–10, 18
A	US 2015-0245349 A1 (INTEL CORPORATION) 27 August 2015 See paragraphs [0045]–[0046]; claim 1; and figure 6.	1–25
A	US 2012-0140743 A1 (GHYSLAIN PELLETIER et al.) 07 June 2012 See paragraphs [0312]–[0331]; claim 1; and figures 9–10.	1–25
A	US 2012-0289170 A1 (ZHENHONG LI et al.) 15 November 2012 See paragraphs [0065]–[0069]; claim 35; and figure 6.	1–25



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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"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

22 December 2016 (22.12.2016)

Date of mailing of the international search report

22 December 2016 (22.12.2016)

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2016/049269

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