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- (71) **Applicant:** INTEL IP CORPORATION [US/US]; 2200 Mission College Boulevard, Santa Clara, California 95054 (US).
- (72) **Inventors:** LIM, Seau S.; 15 Withering Road, Swindon South Wales SN1 4GU (GB). HEO, Youn Hyoung; 4F, 27-3, Hana Daetoo Securities Bldg., Yeouido-dong, Yeongdeungpo-gu, Seoul, Chungcheongbuk-do 150-705 (KR). HONG, He; 8F, Raycom Infotech Park A, No. 2, KeXueYuan South Road, HaiDian District, Beijing, Heilongjiang 100190 (CN).
- (74) **Agent:** ESCHWEILER, Thomas G.; Eschweiler & Associates, LLC, 629 Euclid Ave., Suite 1000, Cleveland, Ohio 44114 (US).
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[Continued on next page]

(54) **Title:** DEFINITION OF DOWNLINK SUBFRAMES FOR LICENSE ASSISTED ACCESS SECONDARY CELL FOR DISCONTINUOUS RECEPTION OPERATION

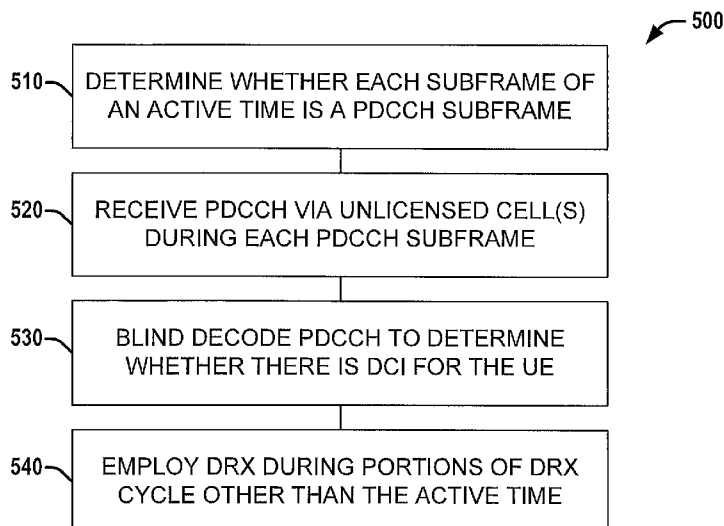


FIG. 5

(57) **Abstract:** Techniques for discontinuous reception (DRX) operation in connection with unlicensed cells are discussed. The DRX operation can be based on one of several definitions of a physical downlink control channel (PDCCH) subframe that can facilitate greater scheduling opportunities. In some aspects, PDCCH subframes can be indicated via common PDCCH. In other aspects, a time division duplexing (TDD) configuration can be employed to determine if a subframe is a PDCCH subframe. In further aspects, whether a subframe is a PDCCH subframe can be determined solely based on one or more licensed cells.



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DEFINITION OF DOWNLINK SUBFRAMES FOR LICENSE ASSISTED ACCESS
SECONDARY CELL FOR DISCONTINUOUS RECEPTION OPERATION

REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 62/316,728 filed April 1, 2016, entitled "DEFINING THE DL SUBFRAMES FOR LAA SCELL FOR DRX OPERATION", the contents of which are herein incorporated by reference in their entirety.

FIELD

[0002] The present disclosure relates to wireless technology, and more specifically to techniques for improving discontinuous reception (DRX) operation in connection with unlicensed serving cells.

BACKGROUND

[0003] Conventional LTE (Long Term Evolution) systems utilize spectrum that is exclusively assigned to the corresponding LTE service provider (or operator), referred to as LTE in Licensed Spectrum or simply LTE. In Rel-13 (3GPP (Third Generation Partnership Project) Release 13), due to an upsurge in demand for wireless broadband data, data throughput of an LTE system can be increased by transmitting data through unlicensed spectrum as well as licensed spectrum. The LTE system operating in unlicensed spectrum is often referred to as LTE in Unlicensed Spectrum or LTE-U. A system integrating LTE and LTE-U using the carrier aggregation (CA) technology is referred to as Licensed-Assisted Access (LAA) using LTE, or simply LAA. In LAA, an LTE carrier serves as the primary cell (PCell) and one or multiple LTE-U carrier serves as secondary cell(s) or SCell(s).

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] **FIG. 1** is a block diagram illustrating an example user equipment (UE) useable in connection with various aspects described herein.

[0005] **FIG. 2** is a diagram illustrating a discontinuous reception (DRX) cycle that can be employed in connection with various aspects described herein.

[0006] FIG. 3 is a block diagram illustrating a system that facilitates radio resource control (RRC) Connected state DRX operation in connection with one or more unlicensed cells at a UE, according to various aspects described herein.

[0007] FIG. 4 is a block diagram illustrating a system that facilitates RRC Connected state DRX operation by one or more UEs in connection with at least one unlicensed serving cell according to various aspects described herein.

[0008] FIG. 5 is a flow diagram illustrating a method that facilitates RRC Connected state DRX operation in connection with at least one unlicensed serving cell at a UE, according to various aspects described herein.

[0009] FIG. 6 is a flow diagram illustrating a method that facilitates communication by a base station via at least one unlicensed carrier with at least one UE implementing RRC Connected state DRX operation, according to various aspects described herein.

DETAILED DESCRIPTION

[0010] The present disclosure will now be described with reference to the attached drawing figures, wherein like reference numerals are used to refer to like elements throughout, and wherein the illustrated structures and devices are not necessarily drawn to scale. As utilized herein, terms “component,” “system,” “interface,” and the like are intended to refer to a computer-related entity, hardware, software (e.g., in execution), and/or firmware. For example, a component can be a processor (e.g., a microprocessor, a controller, or other processing device), a process running on a processor, a controller, an object, an executable, a program, a storage device, a computer, a tablet PC and/or a user equipment (e.g., mobile phone, etc.) with a processing device. By way of illustration, an application running on a server and the server can also be a component. One or more components can reside within a process, and a component can be localized on one computer and/or distributed between two or more computers. A set of elements or a set of other components can be described herein, in which the term “set” can be interpreted as “one or more.”

[0011] Further, these components can execute from various computer readable storage media having various data structures stored thereon such as with a module, for example. The components can communicate via local and/or remote processes such as in accordance with a signal having one or more data packets (e.g., data from one component interacting with another component in a local system, distributed system, and/or across a network, such as, the Internet, a local area network, a wide area network, or similar network with other systems via the signal).

[0012] As another example, a component can be an apparatus with specific functionality provided by mechanical parts operated by electric or electronic circuitry, in which the electric or electronic circuitry can be operated by a software application or a firmware application executed by one or more processors. The one or more processors can be internal or external to the apparatus and can execute at least a part of the software or firmware application. As yet another example, a component can be an apparatus that provides specific functionality through electronic components without mechanical parts; the electronic components can include one or more processors therein to execute software and/or firmware that confer(s), at least in part, the functionality of the electronic components.

[0013] Use of the word exemplary is intended to present concepts in a concrete fashion. As used in this application, the term “or” is intended to mean an inclusive “or” rather than an exclusive “or”. That is, unless specified otherwise, or clear from context, “X employs A or B” is intended to mean any of the natural inclusive permutations. That is, if X employs A; X employs B; or X employs both A and B, then “X employs A or B” is satisfied under any of the foregoing instances. In addition, the articles “a” and “an” as used in this application and the appended claims should generally be construed to mean “one or more” unless specified otherwise or clear from context to be directed to a singular form. Furthermore, to the extent that the terms “including”, “includes”, “having”, “has”, “with”, or variants thereof are used in either the detailed description and the claims, such terms are intended to be inclusive in a manner similar to the term “comprising.”

[0014] As used herein, the term “circuitry” may refer to, be part of, or include an Application Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group), and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit, and/or other suitable hardware components that provide the described functionality. In some embodiments, the circuitry may be implemented in, or functions associated with the circuitry may be implemented by, one or more software or firmware modules. In some embodiments, circuitry may include logic, at least partially operable in hardware.

[0015] Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software. **FIG. 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.

[0016] 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.

[0017] 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.

[0018] 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).

[0019] 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.

[0020] 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.

[0021] 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.

[0022] 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.

[0023] 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.

[0024] 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.

[0025] 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.

[0026] 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.

[0027] 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.

[0028] 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.

[0029] 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 N_d equal packets of phase, where N_d is the number of delay elements in the delay line. In this way, the DLL provides negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

[0030] 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.

[0031] 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.

[0032] 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).

[0033] 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.

[0034] Additionally, although the above example discussion of device 100 is in the context of a UE device, in various aspects, a similar device can be employed in connection with a base station (BS) such as an Evolved NodeB (eNB), etc.

[0035] In various aspects, techniques disclosed herein can employ one or more definitions of physical downlink control channel (PDCCH) subframes disclosed herein, which can facilitate improved discontinuous reception (DRX) operation in connection with unlicensed serving cells.

[0036] As discussed above, in Rel-13 (3GPP release 13), 3GPP defined a DL (downlink)-only design for LTE to utilize the unlicensed spectrum. To leverage the full benefits of LTE operation in unlicensed spectrum, a complete UL (uplink) access

scheme can be defined in addition to the already defined DL access scheme in Rel-13. In the MuLTEfire forum, a standalone unlicensed cell (MF cell) is also being specified.

[0037] RRC (radio resource control) Connected mode DRX has been introduced to provide for UE (user equipment) power saving in the RRC Connected state. The UE wakes up during an ON_duration of a DRX cycle (based on onDurationTimer) to monitor the control channel (e.g., PDCCH (physical downlink control channel)) to check whether there is any DL data for the UE and go to DRX when there is none. The ON_duration can be extended by a drxInactivityTimer in the case there is a burst of data for the UE. The drxInactivityTimer of a UE can be (re)started when it detects DCI (downlink control information) in PDCCH assigned to the UE in the form of UE ID (e.g., C-RNTI (cell RNTI (radio network temporary identity))). Once all the DRX timers expire, the UE goes into DRX. Referring to **FIG. 2**, illustrated is a diagram of the DRX cycle that can be employed in connection with various aspects described herein.

[0038] In Rel-13 LAA, it was agreed that common DRX would be applied when aggregating with DL LAA SCell, the same as in legacy CA (carrier aggregation). DRX timers are based on counting the number of PDCCH subframes and the definition of PDCCH subframes are provided in Rel-13 TS (Technical Specification) 36.331 as:

PDCCH-subframe: Refers to a subframe with PDCCH. For a MAC entity not configured with any TDD serving cell(s), this represents any subframe; for a MAC entity configured with at least one TDD serving cell, if a MAC entity is capable of simultaneous reception and transmission in the aggregated cells, this represents the union over all serving cells of downlink subframes and subframes including DwPTS of the TDD UL/DL configuration indicated by *tdd-Config* [8], except serving cells that are configured with *schedulingCellId* [8]; otherwise, this represents the subframes where the SpCell is configured with a downlink subframe or a subframe including DwPTS of the TDD UL/DL configuration indicated by *tdd-Config* [8].

[0039] The following DRX timers are defined:

drx-InactivityTimer. Specifies the number of consecutive PDCCH-subframe(s) after the subframe in which a PDCCH indicates an initial UL, DL or SL user data transmission for this MAC entity.

drx-RetransmissionTimer. Specifies the maximum number of consecutive PDCCH-subframe(s) until a DL retransmission is received.

onDurationTimer. Specifies the number of consecutive PDCCH-subframe(s) at the beginning of a DRX Cycle.

[0040] Due to the eNB performing LBT (listen before talk) in the DL LAA SCell, the eNB may not transmit in a DL subframe if the access medium is busy. This means that the eNB may lose a scheduling opportunity as a result of eNB LBT.

[0041] In Rel-14 UL LAA, UL LAA can be configured in the same unlicensed carrier as the DL LAA. Because of this, considering all subframes to be DL subframes (as in Rel-13 DL LAA) provides even fewer scheduling opportunities for the eNB than in Rel-13.

[0042] Various embodiments described herein can employ improved definitions of the DL subframes in a LAA SCell, which can facilitate greater scheduling opportunities.

[0043] In various aspects, which subframe is regarded as a DL subframe can be fixed/hard-coded (e.g., based on a predefined value in the specification, etc.), can be semi-statically defined via RRC or can be dynamically defined via PDCCH/MAC (medium access control) for a LAA SCell or a MF cell. Various embodiments can employ DL definitions discussed herein to ensure a more realistic DL subframe is used for defining the PDCCH subframes, which can thus provide closer to the scheduling opportunities for the eNB as configured by the eNB in terms of Active Time:

Active Time: Time related to DRX operation during which the MAC entity monitors the PDCCH.

[0044] In contrast, in Rel-13 LAA, all subframes are considered as DL subframes like in the FDD case. However due to LBT, some of the subframes may not be used, resulting in less scheduling opportunities to the eNB.

[0045] In situations in which the UL LAA SCell shares the same unlicensed carrier as the DL LAA SCell (e.g., a TDD type of configuration), the ratio of the DL and UL subframes of a transmission burst can be dynamically indicated in the Common PDCCH. In such cases, multiple options can be employed to decide on the DL subframes for a LAA SCell.

[0046] In a first option, DL subframes can be defined based on an indication in a common PDCCH of whether a subframe is a DL subframe.

[0047] In a second option, DL subframes can be defined based on an assumed DL and UL pattern for a Tx (transmit) burst as a reference TDD configuration

[0048] In a third option, DL subframes can be defined based solely on licensed cells, with no DL subframes in the LAA SCell.

[0049] For each of these three options, if the LAA SCell is self-scheduled and is aggregated with TDD cells, based on the current definition of PDCCH subframes, the PDCCH subframes are the union of the DL subframes over all serving cells which are

not cross-carrier scheduled. This can provide more scheduling opportunities for the eNB.

[0050] The first option is based on the indication of DL subframes in the common PDCCH. The common PDCCH indicates whether the next subframe is a DL subframe. This provides the most accurate picture of the DL subframes of the LAA SCell. If no common PDCCH is decoded (i.e. due to LBT) in a subframe, it considers the subframe as not a DL subframe.

[0051] The second option can assume a TDD configuration for the LAA SCell. The TDD configuration can be fixed/hardcoded (e.g., in the specification) or can be reconfigured, either per UE or for all UEs. In various aspects, the reconfiguration can be based on the traffic load of the LAA SCell.

[0052] The third option is to not consider the DL subframes in the LAA SCell in the PDCCH subframe definition, such that only the licensed serving cells are considered.

[0053] Referring to **FIG. 3**, illustrated is a block diagram of a system 300 that facilitates RRC Connected state DRX operation in connection with one or more unlicensed cells at a UE, according to various aspects described herein. System 300 can include one or more processors 310 (e.g., one or more baseband processors such as one or more of the baseband processors discussed in connection with FIG. 1), transceiver circuitry 320 (e.g., comprising one or more of transmitter circuitry or receiver circuitry, which can employ common circuit elements, distinct circuit elements, or a combination thereof), and a memory 330 (which can comprise any of a variety of storage mediums and can store instructions and/or data associated with one or more of processor(s) 310 or transceiver circuitry 320). In various aspects, system 300 can be included within a user equipment (UE). As described in greater detail below, system 300 can employ a DRX cycle and associated DRX timers based on one of the definitions for DL subframes discussed herein.

[0054] Processor(s) 310 can implement DRX operation based on a DRX cycle in connection with an RRC connected mode for at least one unlicensed serving cell (e.g., LAA SCell(s), standalone unlicensed cell(s) such as MF cell(s), etc.). During an active time of the DRX cycle, transceiver circuitry 320 can receive, and processor(s) 310 can monitor, PDCCH during PDCCH subframes to determine if there are any scheduled transmissions for the UE that comprises system 300.

[0055] Processor(s) 310 can measure the length of the active time based on an on duration timer (that specifies an on duration of the active time) and an optional DRX inactivity timer (that can extend the active time) that can be started (or restarted) based

on detected DCI (e.g., for DL, UL, or SL) associated with the UE that comprises system 300. Because these timers (and the other DRX timers discussed herein) measure the number of PDCCH subframes, processor(s) 310 can determine whether each subframe of the active time is a PDCCH subframe. Depending on the embodiment, processor(s) 310 can employ various definitions of PDCCH subframes to determine whether particular subframes are PDCCH subframes, for example, definitions according to the first, second, and third options discussed herein.

[0056] For subframe(s) of the active time that are PDCCH subframe(s), transceiver circuitry 320 can receive the PDCCH of at least one unlicensed serving cell (and, in aspects (e.g., LAA), PDCCH of any licensed serving cell(s)), and processor(s) 310 can monitor the PDCCH (e.g., via blind decoding in common and/or UE-specific search space(s)) for any DCI associated with the UE comprising system 300 (e.g., scheduling the UE for DL, UL, and/or SL transmission(s)). For each PDCCH subframe, processor(s) 310 can increment any active DRX timers (e.g., on duration timer, DRX inactivity timer, etc.) to accurately track the active time and maintain synchronization of the DRX cycle with an eNB transmitting the PDCCH.

[0057] During other portions of the DRX cycle, processor(s) 310 can implement DRX. To conserve power at the UE, transmitter circuitry 320 can avoid reception during portions of the DRX cycle when processor(s) 310 implement DRX.

[0058] In embodiments employing the first option, processor(s) 310 can determine whether each subframe is a PDCCH subframe based on a common PDCCH. For example, the common PDCCH in a first can indicate whether the first subframe is a PDCCH subframe, and, in aspects, can also indicate whether one or more future subframes will be PDCCH subframes.

[0059] In embodiments employing the second option, processor(s) 310 can determine whether each subframe is a PDCCH subframe based on a TDD (time division duplexing) configuration for the at least one unlicensed cell and/or one or more licensed serving cells. In some aspects, the TDD configuration can be a predetermined or predefined TDD configuration (e.g., defined in the specification). In other aspects, the TDD configuration can be indicated dynamically (e.g., via DCI in PDCCH) or semi-statically (e.g., via higher layer signaling (e.g., MAC (medium access control) or RRC)). For some aspects, the TDD configuration can be UE-specific, or can be common to all UEs in the cell. Additionally, in dynamic and semi-static aspects, the TDD configuration can be based on UL and/or DL traffic load(s) on the at least one unlicensed cell and/or one or more licensed cells.

[0060] In embodiments employing the third option, which can be employed in aspects involving one or more licensed cells in addition to the at least one unlicensed cell (e.g., LAA), processor(s) 310 can determine whether each subframe is a PDCCH subframe based solely on the one or more licensed cells, and independently of the at least one unlicensed cell.

[0061] Referring to **FIG. 4**, illustrated is a block diagram of a system 400 at a base station that facilitates RRC Connected state DRX operation by one or more UEs in connection with at least one unlicensed serving cell according to various aspects described herein. System 400 can include one or more processors 410 (e.g., one or more baseband processors such as one or more of the baseband processors discussed in connection with FIG. 1), transceiver circuitry 420 (e.g., which can comprise one or more of transmitter circuitry (e.g., associated with one or more transmit chains) or receiver circuitry (e.g., associated with one or more receive chains), wherein the transmitter circuitry and receiver circuitry can employ common circuit elements, distinct circuit elements, or a combination thereof), and memory 430 (which can comprise any of a variety of storage mediums and can store instructions and/or data associated with one or more of processor(s) 410 or transceiver circuitry 420). In various aspects, system 400 can be included within an Evolved Universal Terrestrial Radio Access Network (E-UTRAN) Node B (Evolved Node B, eNodeB, or eNB) or other base station in a wireless communications network. In some aspects, the processor(s) 410, transceiver circuitry 420, and the memory 430 can be included in a single device, while in other aspects, they can be included in different devices, such as part of a distributed architecture. As described in greater detail below, system 400 can facilitate UE DRX operation in connection with at least one unlicensed serving cell.

[0062] Processor(s) 410 can configure a DRX cycle for each of one or more UEs for DRX operation in connection with a RRC Connected mode. For each of the one or more UEs, the DRX cycle can be based on a set of DRX timers, which can include an on duration timer, a DRX inactivity timer, and other timers discussed herein. Each of the DRX timers measure a number of PDCCH subframes, thus, in various embodiments, different options can be employed for the definition of a PDCCH subframe.

[0063] Processor(s) 410 can generate one or more DCI messages for a UE of the one or more UEs, wherein each DCI message can schedule the UE for a DL, UL, or SL transmission in an indicated subframe. Because the UE (in RRC Connected mode) is employing a DRX cycle as discussed herein, processor(s) 410 can select one or more PDCCH subframes of an active time of the DRX cycle of the UE to schedule the one or

more DCI messages, and can schedule the one or more DCI messages in PDCCH of the at least one unlicensed cell during those PDCCH subframe(s).

[0064] Depending on the embodiment, the definition of a PDCCH subframe can vary, and thus the selection of PDCCH subframe(s) by processor(s) 410.

[0065] As discussed above, in connection with the first option, processor(s) 410 can indicate via common PDCCH whether at least one of a current subframe or one or more future subframes are PDCCH subframe(s).

[0066] In connection with the second option, processor(s) 410 can determine whether each subframe is a PDCCH subframe based on a TDD configuration that can be fixed/hardcoded/predefined (e.g., via a specification), semi-statically defined (e.g., via higher layer signaling (e.g., MAC, RRC, etc.) generated by processor(s) 410), or dynamically defined (e.g., via DCI messaging generated by processor(s) 410). In semi-statically defined and dynamically defined aspects, processor(s) 410 can determine the TDD configuration based on traffic load conditions (e.g., UL and/or DL) associated with the at least one unlicensed serving cell. Additionally, processor(s) 410 can select a common TDD configuration for the one or more UEs, or can select a UE-specific TDD configuration for each of the one or more UEs.

[0067] Referring to **FIG. 5**, illustrated is a flow diagram of a method 500 that facilitates RRC Connected state DRX operation in connection with at least one unlicensed serving cell at a UE, according to various aspects described herein. In some aspects, method 500 can be performed at a UE. In other aspects, a machine readable medium can store instructions associated with method 500 that, when executed, can cause a UE to perform the acts of method 500.

[0068] At 510, for each subframe of an active time of a DRX cycle, a determination can be made as to whether that subframe is a PDCCH subframe, which can vary between embodiments based on the definition of PDCCH subframe employed in that embodiment.

[0069] At 520, for each PDCCH subframe during the active time, PDCCH can be received via at least one unlicensed cell.

[0070] At 530, blind decoding can be performed on the received PDCCH to determine whether there is a DCI message scheduling the UE (for DL, UL, or SL, etc.) employing method 500 in the received PDCCH.

[0071] At 540, during portions of the DRX cycle other than the active time, DRX can be employed, which can reduce UE power consumption.

[0072] Additionally or alternatively, method 500 can include one or more other acts described above in connection with system 300.

[0073] Referring to **FIG. 6**, illustrated is a flow diagram of a method 600 that facilitates communication by a base station via at least one unlicensed carrier with at least one UE implementing RRC Connected state DRX operation, according to various aspects described herein. In some aspects, method 600 can be performed at an eNB. In other aspects, a machine readable medium can store instructions associated with method 600 that, when executed, can cause an eNB to perform the acts of method 600.

[0074] At 610, a UE can be configured with a DRX cycle for RRC connected mode operation, which can involve configuring one or more DRX timers.

[0075] At 620, one or more PDCCH subframes of an active time of the DRX cycle can be selected to schedule one or more DCI messages for the UE.

[0076] At 630, the one or more DCI messages can be transmitted to the UE via at least one unlicensed serving cell (e.g., LAA SCell(s), MF cell(s), etc.) during the one or more selected PDCCH subframes.

[0077] Additionally or alternatively, method 600 can include one or more other acts described above in connection with system 400.

[0078] Examples herein can include subject matter such as a method, means for performing acts or blocks of the method, at least one machine-readable medium including executable instructions that, when performed by a machine (e.g., a processor with memory, an application-specific integrated circuit (ASIC), a field programmable gate array (FPGA), or the like) cause the machine to perform acts of the method or of an apparatus or system for concurrent communication using multiple communication technologies according to embodiments and examples described.

[0079] Example 1 is an apparatus configured to be employed within a User Equipment (UE), comprising a memory; and one or more processors configured to: operate discontinuous reception (DRX) operation in a RRC (radio resource control) Connected mode with a DRX cycle in connection with one or more cells comprising at least one unlicensed cell, wherein the DRX cycle comprises an active time based on an on duration timer of a set of DRX timers and an optional DRX inactivity timer of the set of DRX timers; determine, for each subframe of the active time, whether that subframe is a physical downlink control channel (PDCCH) subframe, wherein each DRX timer of the set of DRX timers specifies a length in terms of PDCCH subframes; monitor a PDCCH of the at least one unlicensed cell during each PDCCH subframe of the active

time; and implement DRX during a portion of the DRX cycle distinct from the active time.

[0080] Example 2 comprises the subject matter of any variation of any of example(s) 1, wherein each unlicensed cell of the at least one unlicensed cell is a standalone unlicensed cell.

[0081] Example 3 comprises the subject matter of any variation of any of example(s) 1, wherein each unlicensed cell of the at least one unlicensed cell is a license assisted access (LAA) secondary cell (SCell), and wherein the one or more processors are further configured to implement the connected mode DRX operation in connection with at least one licensed cell.

[0082] Example 4 comprises the subject matter of any variation of any of example(s) 3, wherein, for each subframe of the active time, the one or more processors are configured to determine that subframe is a PDCCH subframe based solely on the at least one licensed cell.

[0083] Example 5 comprises the subject matter of any variation of any of example(s) 1-3, wherein, for each subframe of the active time, the one or more processors are configured to determine whether that subframe is a PDCCH subframe based on whether the one or more processors are capable of decoding common PDCCH associated with that subframe in the unlicensed cell.

[0084] Example 6 comprises the subject matter of any variation of any of example(s) 1-3, wherein, for each subframe of the active time, the one or more processors are configured to determine whether that subframe is a PDCCH subframe based on the information in a decoded common PDCCH indicating that subframe is a PDCCH subframe in the unlicensed cell.

[0085] Example 7 comprises the subject matter of any variation of any of example(s) 1-3, wherein, for each subframe of the active time, the one or more processors are configured to determine whether that subframe is a PDCCH subframe based on an assumption of a time division duplexing (TDD) configuration for the unlicensed cell.

[0086] Example 8 comprises the subject matter of any variation of any of example(s) 7, wherein the TDD configuration is a predetermined TDD configuration.

[0087] Example 9 comprises the subject matter of any variation of any of example(s) 7, wherein the TDD configuration is indicated via higher layer signaling for one or more UEs comprising the UE, wherein the TDD configuration is based on the uplink (UL) and downlink (DL) traffic load of the at least one unlicensed cell, and wherein the higher

layer signaling is one of MAC (medium access control) or RRC (radio resource control) signaling.

[0088] Example 10 comprises the subject matter of any variation of any of example(s) 7, wherein the TDD configuration is a UE-specific TDD configuration associated with the UE based on the uplink (UL) and downlink (DL) traffic load of the unlicensed cell.

[0089] Example 11 comprises the subject matter of any variation of any of example(s) 1-4, wherein the one or more processors are further configured to measure an on duration of the active time based on the on duration timer, wherein the on duration timer specifies a length of the on duration in PDCCH subframes.

[0090] Example 12 comprises the subject matter of any variation of any of example(s) 1-4, wherein for a first DRX cycle of the one or more DRX cycles, the one or more processors are further configured to: detect a downlink control information (DCI) message assigned to the UE in the monitored PDCCH; and extend the active time of the first DRX cycle based on the DRX inactivity timer, wherein the DRX inactivity timer specifies a length of the extension in PDCCH subframes.

[0091] Example 13 comprises the subject matter of any variation of any of example(s) 1-10, wherein the one or more processors are further configured to measure an on duration of the active time based on the on duration timer, wherein the on duration timer specifies a length of the on duration in PDCCH subframes.

[0092] Example 14 comprises the subject matter of any variation of any of example(s) 1-10 or 13, wherein for a first DRX cycle of the one or more DRX cycles, the one or more processors are further configured to: detect a downlink control information (DCI) message assigned to the UE in the monitored PDCCH; and extend the active time of the first DRX cycle based on the DRX inactivity timer, wherein the DRX inactivity timer specifies a length of the extension in PDCCH subframes.

[0093] Example 15 is a machine readable medium comprising instructions that, when executed, cause a User Equipment (UE) to: determine, for each subframe of an active time of a discontinuous reception (DRX) cycle, whether that subframe is a physical downlink control channel (PDCCH) subframe; receive PDCCH via one or more serving cells during each PDCCH subframe of the active time, wherein the one or more serving cells comprise at least one unlicensed cell; perform blind decoding on the PDCCH of each PDCCH subframe of the active time to search for one or more downlink control information (DCI) messages associated with the UE; and employ DRX during a portion of the DRX cycle distinct from the active time.

[0094] Example 16 comprises the subject matter of any variation of any of example(s) 15, wherein the one or more processors are further configured to determine, for each subframe of the DRX cycle, whether that subframe is a PDCCH subframe based on whether the UE has successfully decoded a common PDCCH during that subframe.

[0095] Example 17 comprises the subject matter of any variation of any of example(s) 15, wherein the one or more processors are further configured to determine, for each subframe of the DRX cycle, whether that subframe is the PDCCH subframe based on a pattern indicated via a time division duplexing (TDD) configuration.

[0096] Example 18 comprises the subject matter of any variation of any of example(s) 17, wherein the TDD configuration is indicated via medium access control (MAC) signaling.

[0097] Example 19 comprises the subject matter of any variation of any of example(s) 17, wherein the TDD configuration is indicated via radio resource control (RRC) signaling.

[0098] Example 20 comprises the subject matter of any variation of any of example(s) 17, wherein the TDD configuration is predefined.

[0099] Example 21 comprises the subject matter of any variation of any of example(s) 15, wherein the one or more serving cells comprise at least one licensed cell, and wherein the instructions, when executed, cause the UE to determine, for each subframe of the DRX cycle, whether that subframe is the PDCCH subframe independently of the at least one unlicensed cell.

[00100] Example 22 comprises the subject matter of any variation of any of example(s) 15-20, wherein each serving cell of the one or more serving cells is a MuLTEfire cell.

[00101] Example 23 is an apparatus configured to be employed within an Evolved NodeB (eNB), comprising a memory; and one or more processors configured to: configure a discontinuous reception (DRX) cycle for a first user equipment (UE) in a radio resource control (RRC) connected mode, wherein the DRX cycle comprises an on time that comprises a plurality of subframes; select one or more physical downlink control channel (PDCCH) subframes from the plurality of subframes; and schedule one or more downlink control information (DCI) message for the first UE in a PDCCH of at least one unlicensed serving cell during the one or more PDCCH subframes.

[00102] Example 24 comprises the subject matter of any variation of any of example(s) 23, wherein a time division duplex (TDD) configuration associated with the

first UE indicates that each of the one or more PDCCH subframes is a PDCCH subframe.

[00103] Example 25 comprises the subject matter of any variation of any of example(s) 24, wherein the TDD configuration is predefined.

[00104] Example 26 comprises the subject matter of any variation of any of example(s) 24, wherein the one or more processors are further configured to generate higher layer signaling that indicates the TDD configuration, and wherein the higher layer signaling is one of MAC (medium access control) or RRC (radio resource control) signaling.

[00105] Example 27 comprises the subject matter of any variation of any of example(s) 26, wherein the one or more processors are further configured to select the TDD configuration based at least in part on load conditions associated with the at least one unlicensed serving cell.

[00106] Example 28 comprises the subject matter of any variation of any of example(s) 26-27, wherein the one or more processors are further configured to maintain an RRC connection with a plurality of UEs in the RRC connected mode, wherein the plurality of UEs comprises the first UE, and wherein the TDD configuration is associated with each UE of the plurality of UEs.

[00107] Example 29 comprises the subject matter of any variation of any of example(s) 23, wherein, for each subframe of an active time for the first UE, the one or more processors are configured to indicate that each of the one or more PDCCH subframes is a PDCCH subframe via information in a common PDCCH.

[00108] Example 30 comprises the subject matter of any variation of any of example(s) 23, wherein, each of the one or more PDCCH is a PDCCH subframe based on only on characteristics of a licensed serving cell.

[00109] Example 31 is an apparatus configured to be employed within a User Equipment (UE), comprising means for storing instructions; and means for processing configured to execute the instructions to: determine, for each subframe of an active time of a discontinuous reception (DRX) cycle, whether that subframe is a physical downlink control channel (PDCCH) subframe; receive PDCCH via one or more serving cells during each PDCCH subframe of the active time, wherein the one or more serving cells comprise at least one unlicensed cell; perform blind decoding on the PDCCH of each PDCCH subframe of the active time to search for one or more downlink control information (DCI) messages associated with the UE; and employ DRX during a portion of the DRX cycle distinct from the active time.

[00110] Example 32 comprises the subject matter of any variation of any of example(s) 31, wherein the means for processing are further configured to execute the instructions to determine, for each subframe of the DRX cycle, whether that subframe is a PDCCH subframe based on whether the UE has successfully decoded a common PDCCH during that subframe.

[00111] Example 33 comprises the subject matter of any variation of any of example(s) 31, wherein the means for processing are further configured to execute the instructions to determine, for each subframe of the DRX cycle, whether that subframe is the PDCCH subframe based on a pattern indicated via a time division duplexing (TDD) configuration.

[00112] Example 34 comprises the subject matter of any variation of any of example(s) 33, wherein the TDD configuration is indicated via medium access control (MAC) signaling.

[00113] Example 35 comprises the subject matter of any variation of any of example(s) 33, wherein the TDD configuration is indicated via radio resource control (RRC) signaling.

[00114] Example 36 comprises the subject matter of any variation of any of example(s) 33, wherein the TDD configuration is predefined.

[00115] Example 37 comprises the subject matter of any variation of any of example(s) 31, wherein the one or more serving cells comprise at least one licensed cell, and wherein the instructions, when executed, cause the UE to determine, for each subframe of the DRX cycle, whether that subframe is the PDCCH subframe independently of the at least one unlicensed cell.

[00116] Example 38 comprises the subject matter of any variation of any of example(s) 31-36, wherein each serving cell of the one or more serving cells is a MuLTEfire cell.

[00117] The above description of illustrated embodiments of the subject disclosure, including what is described in the Abstract, is not intended to be exhaustive or to limit the disclosed embodiments to the precise forms disclosed. While specific embodiments and examples are described herein for illustrative purposes, various modifications are possible that are considered within the scope of such embodiments and examples, as those skilled in the relevant art can recognize.

[00118] In this regard, while the disclosed subject matter has been described in connection with various embodiments and corresponding Figures, where applicable, it is to be understood that other similar embodiments can be used or modifications and

additions can be made to the described embodiments for performing the same, similar, alternative, or substitute function of the disclosed subject matter without deviating therefrom. Therefore, the disclosed subject matter should not be limited to any single embodiment described herein, but rather should be construed in breadth and scope in accordance with the appended claims below.

[00119] In particular regard to the various functions performed by the above described components or structures (assemblies, devices, circuits, systems, etc.), the terms (including a reference to a “means”) used to describe such components are intended to correspond, unless otherwise indicated, to any component or structure which performs the specified function of the described component (e.g., that is functionally equivalent), even though not structurally equivalent to the disclosed structure which performs the function in the herein illustrated exemplary implementations. In addition, while a particular feature may have been disclosed with respect to only one of several implementations, such feature may be combined with one or more other features of the other implementations as may be desired and advantageous for any given or particular application.

CLAIMS

What is claimed is:

1. An apparatus configured to be employed within a User Equipment (UE), comprising:
 - a memory; and
 - one or more processors configured to:
 - operate discontinuous reception (DRX) operation in a RRC (radio resource control) Connected mode with a DRX cycle in connection with one or more cells comprising at least one unlicensed cell, wherein the DRX cycle comprises an active time based on an on duration timer of a set of DRX timers and an optional DRX inactivity timer of the set of DRX timers;
 - determine, for each subframe of the active time, whether that subframe is a physical downlink control channel (PDCCH) subframe, wherein each DRX timer of the set of DRX timers specifies a length in terms of PDCCH subframes;
 - monitor a PDCCH of the at least one unlicensed cell during each PDCCH subframe of the active time; and
 - implement DRX during a portion of the DRX cycle distinct from the active time.
2. The apparatus of claim 1, wherein each unlicensed cell of the at least one unlicensed cell is a standalone unlicensed cell.
3. The apparatus of claim 1, wherein each unlicensed cell of the at least one unlicensed cell is a license assisted access (LAA) secondary cell (SCell), and wherein the one or more processors are further configured to implement the connected mode DRX operation in connection with at least one licensed cell.
4. The apparatus of claim 3, wherein, for each subframe of the active time, the one or more processors are configured to determine that subframe is a PDCCH subframe based solely on the at least one licensed cell.
5. The apparatus of any of claims 1-3, wherein, for each subframe of the active time, the one or more processors are configured to determine whether that subframe is

a PDCCH subframe based on whether the one or more processors are capable of decoding common PDCCH associated with that subframe in the unlicensed cell.

6. The apparatus of any of claims 1-3, wherein, for each subframe of the active time, the one or more processors are configured to determine whether that subframe is a PDCCH subframe based on the information in a decoded common PDCCH indicating that subframe is a PDCCH subframe in the unlicensed cell.

7. The apparatus of any of claims 1-3, wherein, for each subframe of the active time, the one or more processors are configured to determine whether that subframe is a PDCCH subframe based on an assumption of a time division duplexing (TDD) configuration for the unlicensed cell.

8. The apparatus of claim 7, wherein the TDD configuration is a predetermined TDD configuration.

9. The apparatus of claim 7, wherein the TDD configuration is indicated via higher layer signaling for one or more UEs comprising the UE, wherein the TDD configuration is based on the uplink (UL) and downlink (DL) traffic load of the at least one unlicensed cell, and wherein the higher layer signaling is one of MAC (medium access control) or RRC (radio resource control) signaling.

10. The apparatus of claim 7, wherein the TDD configuration is a UE-specific TDD configuration associated with the UE based on the uplink (UL) and downlink (DL) traffic load of the unlicensed cell.

11. The apparatus of any of claims 1-4, wherein the one or more processors are further configured to measure an on duration of the active time based on the on duration timer, wherein the on duration timer specifies a length of the on duration in PDCCH subframes.

12. The apparatus of any of claims 1-4, wherein for a first DRX cycle of the one or more DRX cycles, the one or more processors are further configured to:

detect a downlink control information (DCI) message assigned to the UE in the monitored PDCCH; and

extend the active time of the first DRX cycle based on the DRX inactivity timer, wherein the DRX inactivity timer specifies a length of the extension in PDCCH subframes.

13. A machine readable medium comprising instructions that, when executed, cause a User Equipment (UE) to:

determine, for each subframe of an active time of a discontinuous reception (DRX) cycle, whether that subframe is a physical downlink control channel (PDCCH) subframe;

receive PDCCH via one or more serving cells during each PDCCH subframe of the active time, wherein the one or more serving cells comprise at least one unlicensed cell;

perform blind decoding on the PDCCH of each PDCCH subframe of the active time to search for one or more downlink control information (DCI) messages associated with the UE; and

employ DRX during a portion of the DRX cycle distinct from the active time.

14. The machine readable medium of claim 13, wherein the one or more processors are further configured to determine, for each subframe of the DRX cycle, whether that subframe is a PDCCH subframe based on whether the UE has successfully decoded a common PDCCH during that subframe.

15. The machine readable medium of claim 13, wherein the one or more processors are further configured to determine, for each subframe of the DRX cycle, whether that subframe is the PDCCH subframe based on a pattern indicated via a time division duplexing (TDD) configuration.

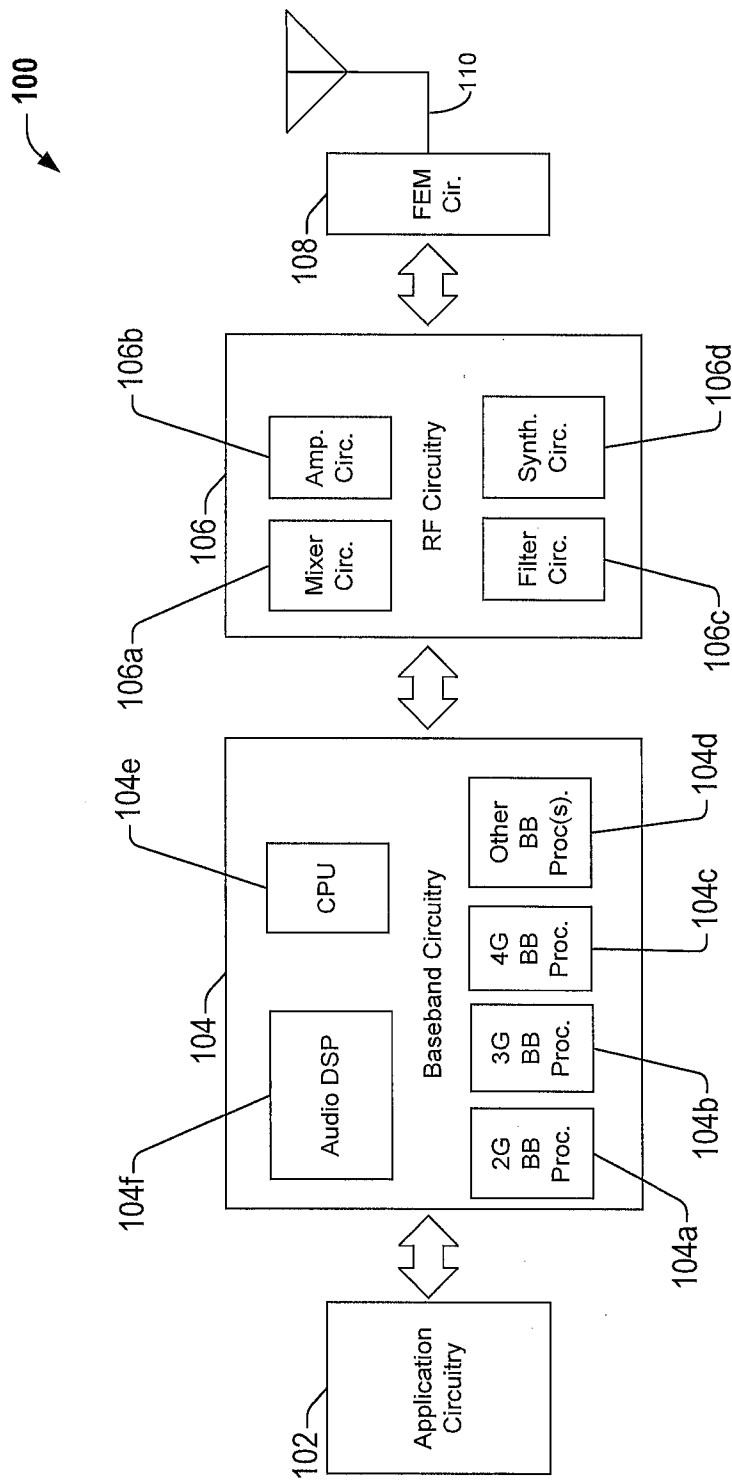
16. The machine readable medium of claim 15, wherein the TDD configuration is indicated via medium access control (MAC) signaling.

17. The machine readable medium of claim 15, wherein the TDD configuration is indicated via radio resource control (RRC) signaling.

18. The machine readable medium of claim 15, wherein the TDD configuration is predefined.

19. The machine readable medium of claim 13, wherein the one or more serving cells comprise at least one licensed cell, and wherein the instructions, when executed, cause the UE to determine, for each subframe of the DRX cycle, whether that subframe is the PDCCH subframe independently of the at least one unlicensed cell.
20. The machine readable medium of any of claims 13-18, wherein each serving cell of the one or more serving cells is a MuLTEfire cell.
21. An apparatus configured to be employed within an Evolved NodeB (eNB), comprising:
a memory; and
one or more processors configured to:
 configure a discontinuous reception (DRX) cycle for a first user equipment (UE) in a radio resource control (RRC) connected mode, wherein the DRX cycle comprises an on time that comprises a plurality of subframes;
 select one or more physical downlink control channel (PDCCH) subframes from the plurality of subframes; and
 schedule one or more downlink control information (DCI) message for the first UE in a PDCCH of at least one unlicensed serving cell during the one or more PDCCH subframes.
22. The apparatus of claim 21, wherein a time division duplex (TDD) configuration associated with the first UE indicates that each of the one or more PDCCH subframes is a PDCCH subframe.
23. The apparatus of claim 22, wherein the TDD configuration is predefined.
24. The apparatus of claim 22, wherein the one or more processors are further configured to generate higher layer signaling that indicates the TDD configuration, and wherein the higher layer signaling is one of MAC (medium access control) or RRC (radio resource control) signaling.

25. The apparatus of claim 24, wherein the one or more processors are further configured to select the TDD configuration based at least in part on load conditions associated with the at least one unlicensed serving cell.
26. The apparatus of any of claims 24-25, wherein the one or more processors are further configured to maintain an RRC connection with a plurality of UEs in the RRC connected mode, wherein the plurality of UEs comprises the first UE, and wherein the TDD configuration is associated with each UE of the plurality of UEs.
27. The apparatus of claim 21, wherein, for each subframe of an active time for the first UE, the one or more processors are configured to indicate that each of the one or more PDCCH subframes is a PDCCH subframe via information in a common PDCCH.
28. The apparatus of claim 21, wherein, each of the one or more PDCCH is a PDCCH subframe based on only on characteristics of a licensed serving cell.



Example UE

FIG. 1

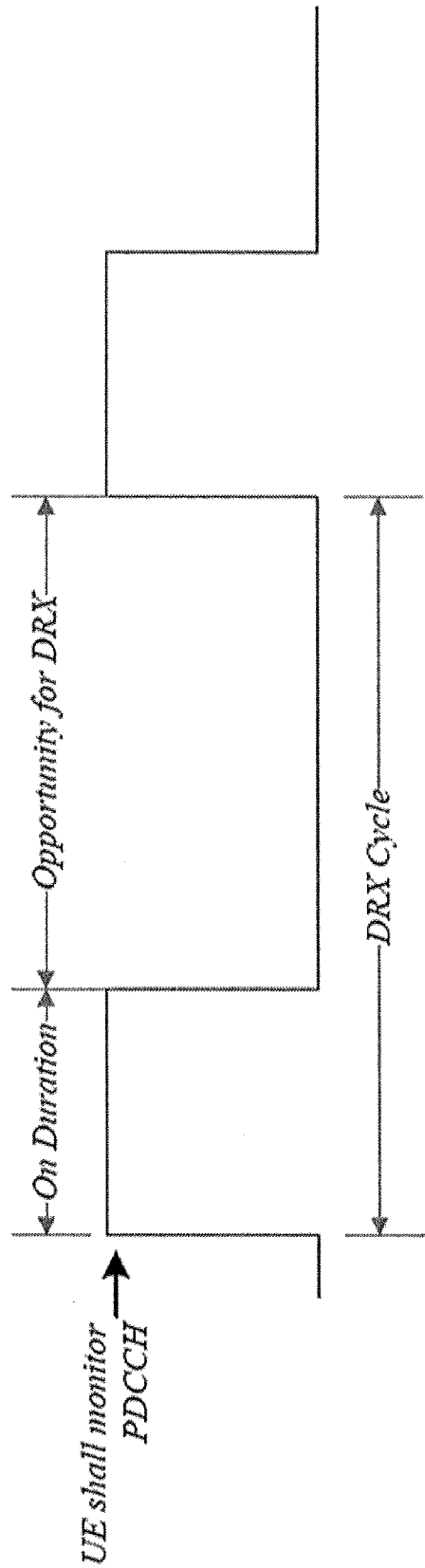


FIG. 2

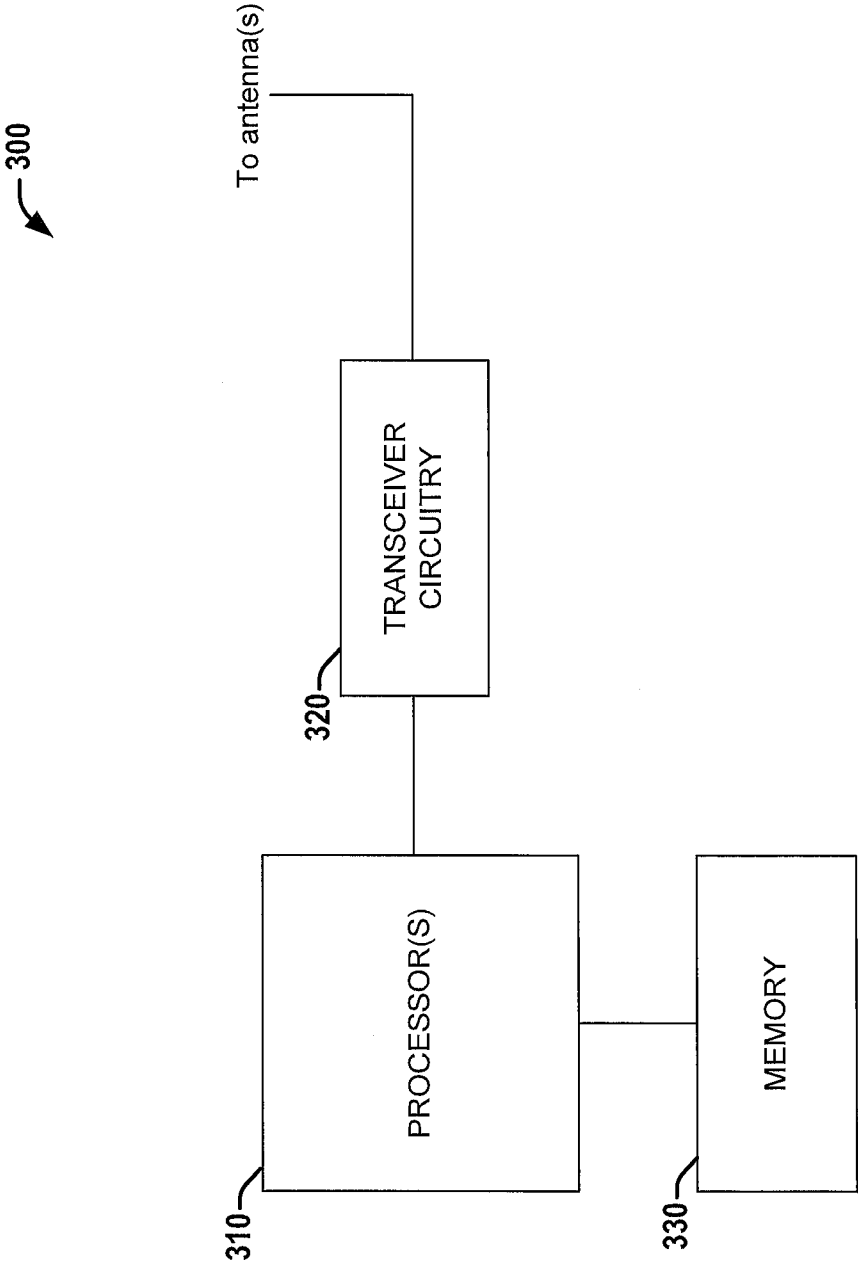


FIG. 3

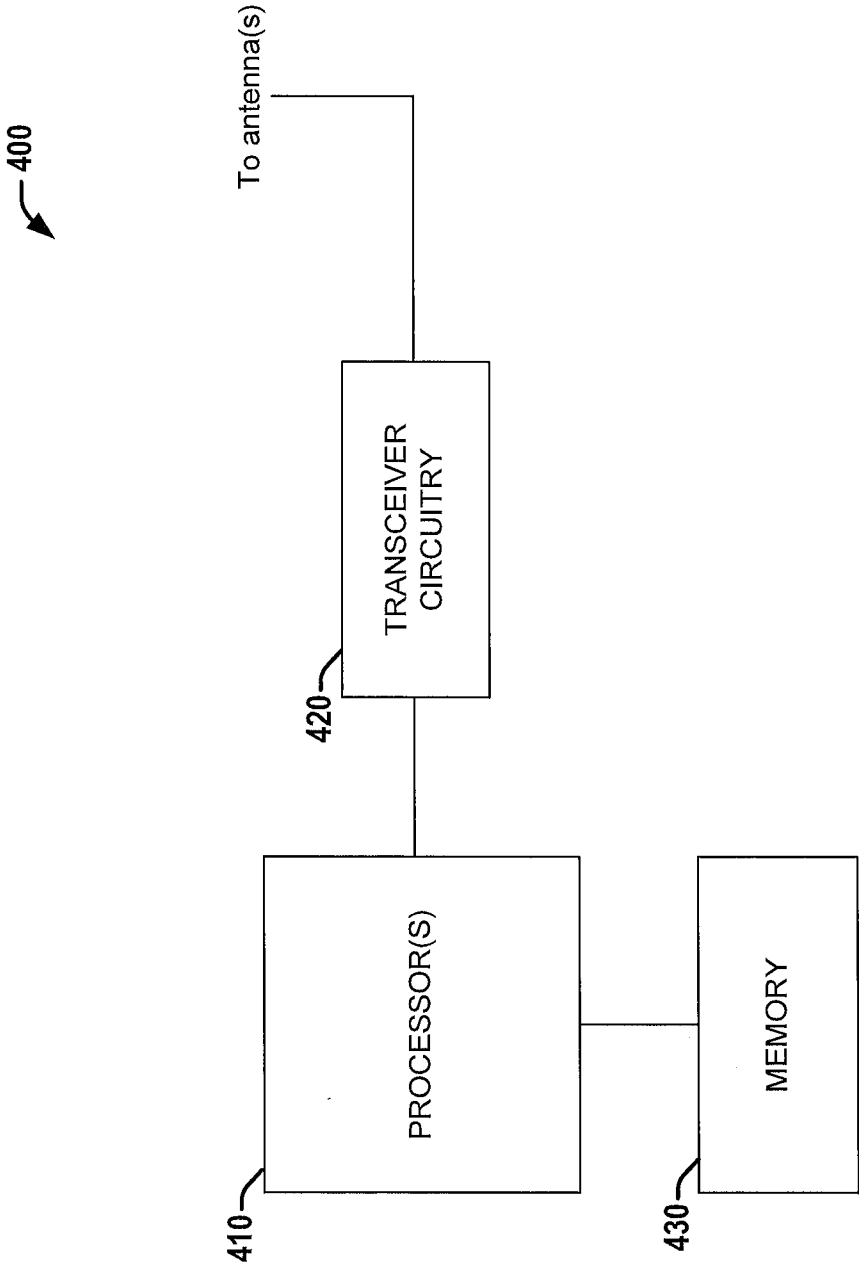
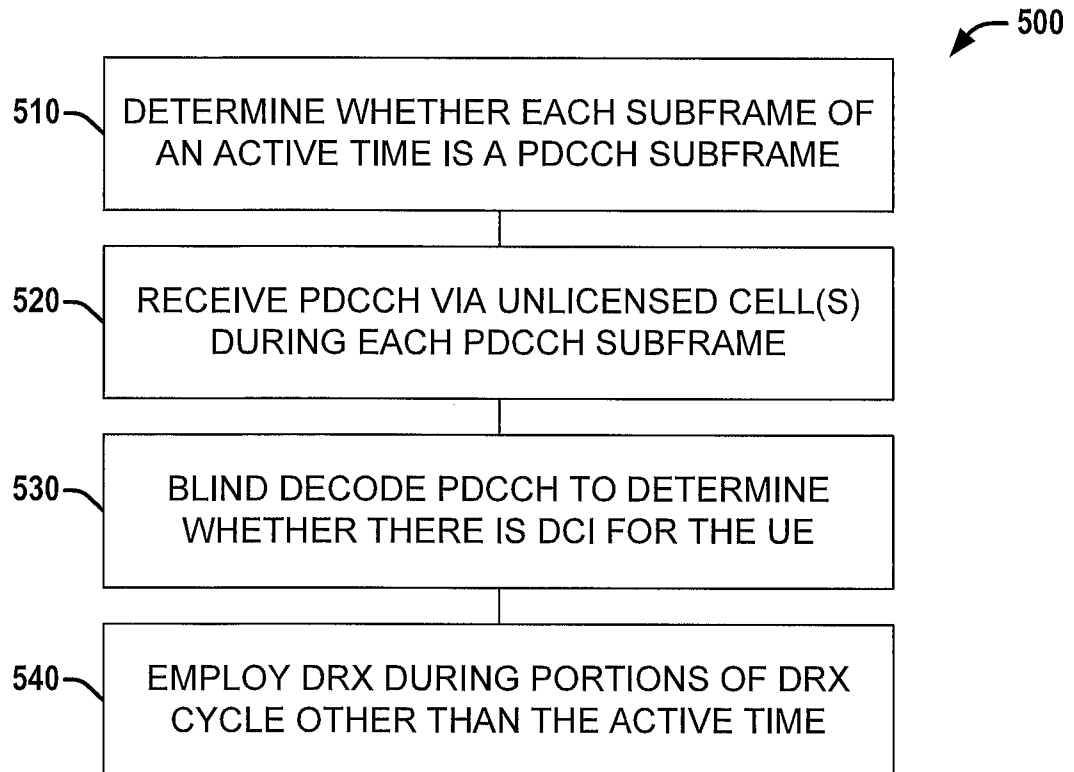
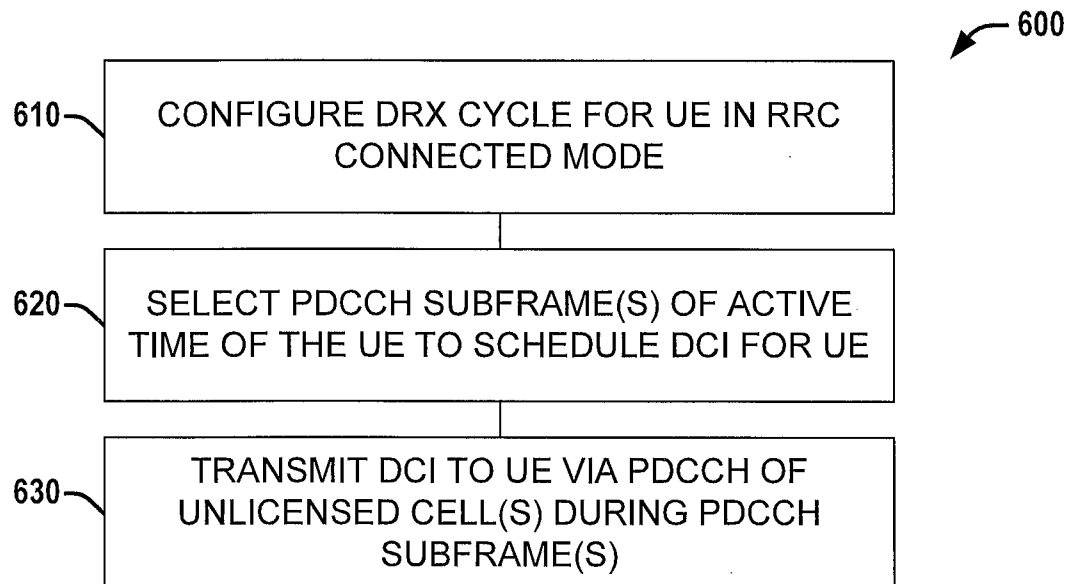


FIG. 4

**FIG. 5**

**FIG. 6**

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2016/053982

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W76/04 H04W52/02
 ADD. H04W16/14 H04W76/02

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2010/078365 A1 (INTERDIGITAL PATENT HOLDINGS [US]; TERRY STEPHEN E [US]; BALA ERDEM [U] 8 July 2010 (2010-07-08) paragraph [0033] - paragraph [0034] paragraph [0047] - paragraph [0048] paragraph [0058] - paragraph [0066] -----	1-28
X	US 2014/029459 A1 (KWON KI BUM [KR] ET AL) 30 January 2014 (2014-01-30) paragraph [0077] paragraph [0084] - paragraph [0090] paragraph [0109] - paragraph [0111] paragraph [0189] claim 1 ----- -/-	1-28



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

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Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
 NL - 2280 HV Rijswijk
 Tel. (+31-70) 340-2040,
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Information on patent family members

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