



(51) International Patent Classification:

H04L 1/00 (2006.01) **H04L 1/18** (2006.01)

(21) International Application Number:

PCT/US2016/068985

(22) International Filing Date:

28 December 2016 (28.12.2016)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

62/378,552 23 August 2016 (23.08.2016) US

(71) **Applicant:** INTEL IP CORPORATION [US/US]; 2200 Mission College Boulevard, Santa Clara, California 95054 (US).(72) **Inventors:** BHORKAR, Abhijeet; 3300 Darwin Drive, Fremont, California 94555 (US). NIU, Huaning; 1308 Knollview Drive, Milpitas, California 95035 (US). JEON, Jeongho; 310 Crescent Village Cir., Apt. 2304, San Jose, California 95134 (US). YE, Qiaoyang; 4536 Piper St, Fremont, California 94538 (US).(74) **Agent:** PERDOK, Monique M. et al.; Schwegman, Lundberg & Woessner, P.A., P.O. Box 2938, Minneapolis, Minnesota 55402 (US).(81) **Designated States** (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.(84) **Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).**Published:**

— with international search report (Art. 21(3))

(54) Title: TRANSMISSION OF CONTROL INFORMATION AFTER UPLINK GRANT

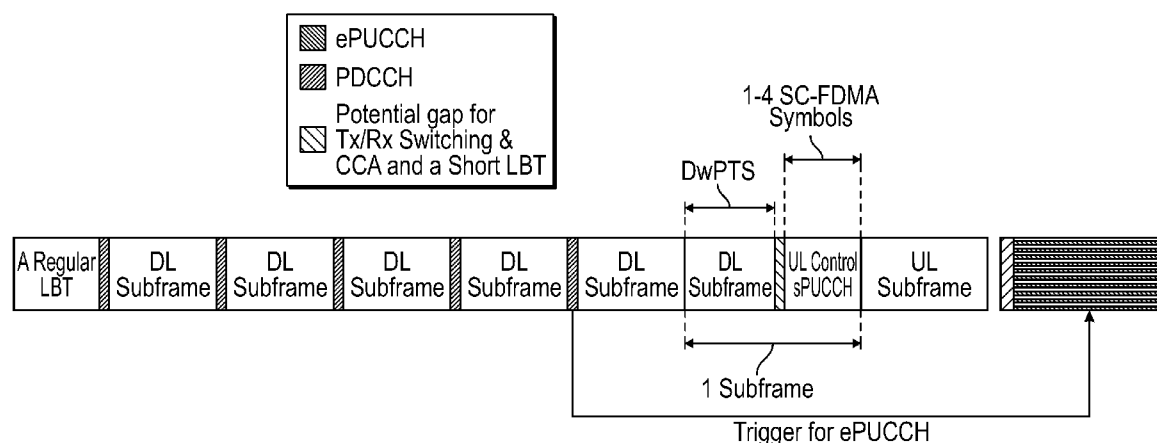


FIG. 2

(57) **Abstract:** Methods and apparatus are described by which an evolved Node B (eNB) triggers transmission of uplink control information from a user equipment (UE) over unlicensed carrier that are applicable to, for example, MulteFire and Licensed-Assisted Access (LAA) systems. Embodiments of downlink control information (DCI) formats are described that contain an indication as to whether UCI is requested and as to whether the UL grant is to trigger transmission of an extended physical uplink control channel (ePUCCH) or a physical uplink shared channel (PUSCH).

TRANSMISSION OF CONTROL INFORMATION AFTER UPLINK GRANT

5 **Priority Claim**

[0001] This application claims priority to United States Provisional Patent Application Serial No. 62/378,552 filed August 23, 2016, which is incorporated herein by reference in their entirety

10 **Technical Field**

[0002] Embodiments described herein relate generally to wireless networks and communications systems. Some embodiments relate to cellular communication networks including 3GPP (Third Generation Partnership Project) networks, 3GPP LTE (Long Term Evolution) networks, and 3GPP
15 LTE-A (LTE Advanced) networks, although the scope of the embodiments is not limited in this respect.

Background

20 [0003] The explosive growth in wireless traffic growth has led to an urgent need for rate improvement. With mature physical layer techniques, further improvement in spectral efficiency will be marginal. On the other hand, the scarcity of licensed spectrum in the low frequency band makes spectral expansion problematic. Thus, there are emerging interests in the operation of LTE systems
25 in unlicensed spectrum. One such technique is labeled Licensed-Assisted Access (LAA), which expands the system bandwidth by utilizing the flexible carrier aggregation (CA) framework introduced by the LTE-Advanced where a primary component carrier (termed the primary cell or PCell) is operated in licensed spectrum and one or secondary component carriers (termed secondary cells or
30 SCells) are operated in licensed spectrum. Another approach is a standalone LTE system in the unlicensed spectrum, where LTE-based technology solely operates

in unlicensed spectrum without requiring an “anchor” in licensed spectrum what is called MulteFire (MF).

[0004] In order to operate in unlicensed spectrum, MF and LAA systems require signal structures and signaling techniques different from those of legacy
5 LTE systems. For example, the non-exclusive nature of unlicensed spectrum requires a mechanism for LAA/MF systems to fairly share the wireless medium with other systems including those operating with other technologies such as Wi-Fi. LAA/MF incorporate a Listen-Before-Talk (LBT) procedure radio transmitters first sense the medium and transmit only if the medium is sensed to
10 be idle. The present disclosure relates to procedures for triggering and transmitting uplink control information (UCI) applicable to LAA/MF systems.

Brief Description of the Drawings

[0005] Fig. 1 illustrates an example UE and eNB according to some embodiments.

15 [0006] Fig. 2 shows an example of a MulteFire or LAA frame structure according to some embodiments.

[0007] Fig. 3 illustrates the ePUCCH being triggered by one of the reserved MCS index states according to some embodiments.

[0008] Fig. 4 illustrates a DCI where UCI is to be transmitted on the PUSCH
20 if the MCS index value is a non-reserved state according to some embodiments.

[0009] Fig. 5 illustrates a DCI where UCI is to be transmitted on the PUSCH if the MCS index value is a non-reserved state according to some embodiments.

[0010] Fig. 6 illustrates a consistent or inconsistent state of the RIV and NDI being utilized to indicate transmission of UCI using ePUCCH or PUSCH
25 according to some embodiments.

[0011] Fig. 7 illustrates an inconsistent state of the RV and the MCS index being utilized to indicate whether transmission of UCI is to be over the ePUCCH or PUSCH according to some embodiments.

[0012] Fig. 8 illustrates an inconsistent state of the RV and the MCS index being utilized to indicate whether transmission of UCI is to be over the ePUCCH or PUSCH according to some embodiments.

5 [0013] Fig. 9 illustrates an ePUCCH trigger bit is combined with one of the reserved MCS index states to indicate if UCI transmission is to be triggered according to some embodiments.

[0014] Fig. 10 illustrates an example of a user equipment device according to some embodiments.

10 [0015] Fig. 11 illustrates an example of a computing machine according to some embodiments.

Detailed Description

[0016] In Long Term Evolution (LTE) systems, a mobile terminal (referred to as a User Equipment or UE) connects to the cellular network via a base station (referred to as an evolved Node B or eNB). LTE systems usually utilize licensed spectrum for both uplink (UL) and downlink (DL) transmissions between a UE and an eNB. Fig. 1 illustrates an example of the components of a UE 400 and a base station or eNB 300. The eNB 300 includes processing circuitry 301
15 connected to a radio transceiver 302 for providing an air interface. The UE 400 includes processing circuitry 401 connected to a radio transceiver 402 for providing an air interface over the wireless medium. Each of the transceivers in the devices is connected to antennas 55.

[0017] Current LTE systems utilize orthogonal frequency division multiple access (OFDMA) based on orthogonal frequency division multiplexing (OFDM)
25 for the downlink (DL) and a related technique, single carrier frequency division multiple access (SC-FDMA) based on DFT-precoded OFDM, for the uplink (UL). LTE systems may operate in either time division duplex (TDD) mode, where UL and DL communications are time-multiplexed in separate time-slots
30 within the same frequency band, or frequency-division duplex (FDD) mode with uplink and downlink communication taking place in different frequency bands. Due to the lack of a pair of frequency bands in unlicensed spectrum to which the

LTE system has exclusive use, unlicensed carriers for both LAA and MF are typically operated in TDD mode.

[0018] In LTE, DL data flows to and from the medium access control (MAC) protocol layer via a transport channel referred to as the downlink shared channel (DL-SCH). UL data flows to and from the MAC layer via a transport channel referred to as the uplink shared channel (UL-SCH). The physical layer conveys UL data via the physical uplink shared channel (PUSCH) and DL data via the physical downlink shared channel (PDSCH). An eNB transmits downlink control information (DCI) to a UE via a physical downlink control channel (PDCCH). A UE transmits uplink control information (UCI) to an eNB via a physical uplink control channel (PUCCH) or via the PUSCH where the UCI is multiplexed with UL data.

[0019] The UCI transmitted by a UE may include one or more of the following. Hybrid automatic-request repeat acknowledgements (HARQ-ACKs) are transmitted in response to data packet reception over the DL where, depending on whether the data packet reception is correct or incorrect, the HARQ-ACK has an ACK or a NAK value, respectively. (A HARQ-ACK may also be referred to herein as an A/N.) The UE may also transmit a scheduling request (SR) signals to request UL resources for data transmission. The UE transmits channel state information (CSI) reports either periodically or aperiodically at the request of the eNB. A CSI report may include a channel quality indicator (CQI) signal to inform the eNB of the DL channel conditions it experiences and a precoder matrix indicator/rank indicator (PMI/RI) signal to inform the eNB how to combine the transmission of a signal to the UE from multiple eNB antennas in accordance with a Multiple-Input Multiple-Output (MIMO) principle.

[0020] LAA is based on the carrier aggregation framework of LTE. The primary component carrier (referred to as the primary cell or PCell) operates in licensed spectrum and acts as an anchor and is aggregated with one or more secondary component carriers (referred to as secondary cells or SCells) operating in unlicensed spectrum. An LAA system may also have one or more SCells operating in licensed spectrum as in conventional LTE carrier aggregation. In MF systems, the SCell and any PCells operate only

in unlicensed spectrum. In both LAA and MF systems, a listen-before-talk (LBT) mechanism is implemented that involves a transmitter ensuring that there are no ongoing transmissions on the carrier frequency prior to transmitting. LBT provides a fair coexistence between the LAA/MF system and other technologies such as Wi-Fi utilizing the same spectrum. A transmitter performs the LBT procedure by assessing whether the frequency channel is available (i.e., a clear channel assessment or CCA) and, if the channel sensed to be idle, transmitting a contiguous burst over the channel that spans one or more subframes depending on the reserved maximum channel occupancy time (MCOT).

[0021] Fig. 2 shows an example of a MulteFire or LAA frame structure for time division duplex (TDD) mode according to one embodiment. In this structure, a DL burst from the eNB is preceded by a regular LBT. The subsequent DL subframes contain a PDCCH that precedes the DL data. Among other things, the PDCCH may contain UL grants of PUSCH resources to the UE for transmission of UL data in UL subframes and/or may grant transmission of resources for a so-called long or extended physical uplink control channel (ePUCCH). The ePUCCH constitutes a full subframe (e.g., 14 OFDM symbols) and is triggered by the UL grant. UL control signals may also be transmitted via a so-called shortened PUCCH (sPUCCH) format that is in the UL portion of the special subframe where the transition between DL and UL subframes occurs. The waveform for transmission of the PUSCH and ePUCCH in MulteFire carriers and LAA unlicensed carriers is block-interleaved frequency division multiple access (B-IFDMA) which is a generalization of DFT-precoded OFDMA with interleaved subcarrier allocation. The B-IFDMA waveform is an interlaced structure where each interlace is made up of one or more RBs spaced apart in frequency. In one embodiment, each interlace comprises 10 RBs distributed (equally-spaced) over the entire bandwidth. Single or multiple interlaces can be assigned to each UE. In one embodiment, the PUSCH comprises one or more interlaces, and the ePUCCH comprises one interlace.

[0022] Similar to the legacy type PUCCH described above, the contents of the ePUCCH may include various types of UCI such as HARQ-ACK feedback for the PDSCH, scheduling requests (SR), and/or channel state information

(CSI) feedback in the form of CSI reports. Some of the embodiments described herein relate to the design of the UL grant via the PDCCH in LAA/MF systems to trigger UCI transmission by the UE on the PUSCH or the ePUCCH. Other embodiments relate a UL grant format designed to support multi-subframe UL scheduling.

5 **[0023]** The DCI contained in the PDCCH can be categorized into different types called formats that vary according to their functions. Legacy LTE design uses DCI format 0 and DCI format 4 for scheduling PUSCH transmissions, where format 4 is used in the case of UL spatial multiplexing. Among other things, both
10 DCI formats 0 and 4 contain: 1) a carrier indicator field to indicate the component carrier the DCI relates to when cross-carrier scheduling is enabled, 2) a resource indicator value (RIV) to indicates the resource blocks upon which the device should transmit the PUSCH, 3) a modulation and coding scheme (MCS) field used to provide the device with information about the modulation scheme, the code
15 rate, and the transport block (TB) size as indicated by an MCS index I_{MCS} , where reserved states of the MCS index are used to implicitly signal the redundancy version (RV) used in the LTE soft-combining with incremental redundancy forward error correction scheme, 4) a new data indicator (NDI), 5) MCS and NDI fields for a second transport block in the case of format 4, 6) cyclic shift of the
20 demodulation reference signal (DM-RS) to be applied to the DM-RS transmitted with the PUSCH along with an orthogonal cover code (OCC), and 7) a channel state information (CSI) request field to request a CSI report.

[0024] Described herein are embodiments of DCI formats that are particularly applicable to LAA and MF systems. These formats may correspond
25 to legacy formats 0 or 4 to include the legacy fields as described above and, in addition, an indication as to whether the UL grant is to trigger transmission of an ePUCCH or a PUSCH, a trigger for including UCI in a PUSCH, and triggers to include HARQ-ACK signals and/or CSI report requests in the UCI transmitted via the PUSCH or ePUCCH.

30 **[0025]** In some embodiments, the RV for UL subframe scheduling is indicated explicitly by a separate field of the DCI. Reserved states of the MCS index I_{MCS} (e.g., 29, 30, and 31 as in legacy LTE) may then be used for another purpose such as indication as to whether the UL grant is for a PUSCH or an

ePUCCH. In one embodiment, as illustrated by Fig. 3, an ePUCCH is triggered by one of the reserved states of 29, 30 or 31 of the MCS index being present in the UL grant. In one embodiment, if an ePUCCH is triggered, a PUSCH resource is not granted, and, if an MCS index from 0-28 is present (i.e., a non-
 5 reserved MCS index state that indicates a valid MCS), a PUSCH resource is granted. In some embodiments, ePUCCH resources are indicated via the UL grant via the DM-RS cyclic shift bits used for PUSCH transmission of the legacy UL grant. For example, the field can be reused to indicate up to 8 orthogonal code code (OCC) values for the ePUCCH. In some embodiments, the indication
 10 to trigger aperiodic CSI (aCSI) can reuse the legacy LTE design where 1-3 bits are used to indicate whether there is aCSI or not and 1 bit to indicate whether the UE is to feedback HARQ-ACK or not.

[0026] Fig. 4 illustrates an embodiment of a DCI format where aperiodic CSI reports and/or HARQ-ACKs are to be transmitted on the PUSCH if the
 15 MCS index value is 0-28. If the MCS index value is set to one of the reserved values 29-31, the aCSI (and HARQ-ACK if indicated) is to be transmitted on an ePUCCH if the number of bits transmitted is less than X bits and on a PUSCH otherwise. In one embodiment, X is 125 bits.

[0027] Fig. 5 illustrates another embodiment of a DCI where aperiodic CSI
 20 reports and/or HARQ-ACKs are to be transmitted on the PUSCH if the MCS index value is 0-28. In this embodiment, if the MCS index is set to a first reserved state (e.g., 31), CSI reports and/or HARQ-ACKs are to be transmitted on an ePUCCH and transmitted on a PUSCH with a default MCS if the MCS index is set to a second reserved state (e.g., 29).

[0028] In another embodiment as illustrated by Fig. 6, a consistent or
 25 inconsistent state of the RIV and NDI is utilized to indicate transmission of UCI using ePUCCH or PUSCH. If $RIV = 0$ and $NDI = 1$, for example, an inconsistent state exists since no resources are being allocated for a new data transmission. It is not expected that a first transmission of RIV uses a
 30 redundancy version different from 0. In this embodiment, CSI reports and/or HARQ-ACKs are to be transmitted on a PUSCH (and possibly multiplexed with U-SCH data) if the NDI and RIV values indicate a consistent state. If the NDI and RIV values indicate an inconsistent state where $RIV = 0$ and $NDI = 1$, CSI

reports and/or HARQ-ACKs are to be transmitted on an ePUCCH unless the number of bits transmitted is greater than X in which case the CSI reports (and possibly HARQ-ACKs) are to be transmitted on a PUSCH without being multiplexed with UL-SCH data. In one embodiment, X is 125 bits.

- 5 **[0029]** In another embodiment, an inconsistent state of the RV and the MCS index is utilized to indicate whether transmission of UCI is to use ePUCCH or PUSCH. An inconsistent state exists if the MCS index is set to a reserved state and the RV is non-zero. In one embodiment, a consistent state between the MCS index and the RV indicates that the UCI should be transmitted on the PUSCH,
 10 and an inconsistent state indicates that the UCI should be transmitted via the ePUCCH. In one example as shown in Fig. 7, if $RV = 0-3$ and $I_{MCS} = 0-28$, the UCI is transmitted on the PUSCH multiplexed with UL-SCH data. If $RV = 1$ and $I_{MCS} = 29$, then UCI is transmitted on the ePUCCH, and if $RV = 2$ and $I_{MCS} = 29$, then UCI is transmitted on the PUSCH with or without UL-SCH data. In
 15 another embodiment illustrated by Fig. 8, if $RV = 1$ and $I_{MCS} = 29$, then UCI is transmitted on the PUSCH without UL-SCH. If $RV = 2$ and $I_{MCS} = 29$, then UCI is transmitted on the ePUCCH. In one embodiment, for format 0B/4B DCIs that are capable of scheduling multiple UL subframes with a single UL grant, UCI may be transmitted on the PUSCH without UL-SCH data if only one subframe is
 20 scheduled by the UL grant.

- [0030]** In another embodiment, a new bit, which can be referred to as the ePUCCH trigger bit, is combined with one of the reserved MCS index states 29, 30, or 31 to indicate if UCI transmission is to be triggered and, if so, whether the UCI should be transmitted via ePUCCH or PDSCH. In the example illustrated
 25 by Fig. 9, when the ePUCCH trigger bit is set, UCI is transmitted via an ePUCCH using the ePUCCH format when the MCS index is set to a reserved state (e.g., 29, 30, or 31) and transmitted via the PUSCH using the indicated MCS when the MCS index is set to a valid MCS state (i.e., 0-28). If the ePUCCH trigger bit is not set, the UL grant is for PUSCH transmission using the
 30 indicated MCS without transmission of UCI. In another embodiment, two new bits are added to indicate to indicate if UCI transmission is to be triggered and, if

so, whether the UCI should be transmitted via ePUCCH or PDSCH. In this case, the reserved MCS states are not used.

[0031] A HARQ-ACK request can also be indicated in a UL grant scheduling multiple subframes via what are referred to as DCI formats 0B and 4B. In one embodiment, a HARQ-ACK request is indicated by one bit. Transmission of the HARQ-ACK on the PUSCH may then occur in a specific subframe scheduled by the UL grant. In one embodiment, when bit(s) requesting an aperiodic CSI report are toggled, predetermined timing for such aperiodic CSI reports is followed. In another embodiment, the last subframe scheduled by the UL grant is used for UCI transmission, including aperiodic CSI reports. In one embodiment, two new bits are added to DCI formats 0B/4B for multi-subframe UL grants to indicate UCI on ePUCCH and/or UCI on the PUSCH transmission.

Example UE Description

[0032] 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.

[0033] Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software. Fig. 10 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.

[0034] 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
5 may be configured to execute instructions stored in the memory/storage to enable various applications and/or operating systems to run on the system.

[0035] 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
10 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
15 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
20 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,
25 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)
30 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.

[0036] 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 be 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).

[0037] 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.

[0038] 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.

[0039] 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.

[0040] 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.

[0041] 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
5 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.

[0042] In some embodiments, the output baseband signals and the input baseband signals may be analog baseband signals, although the scope of the
10 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
15 to communicate with the RF circuitry 106.

[0043] 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.

[0044] In some embodiments, the synthesizer circuitry 106d may be a
20 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.

[0045] 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.

[0046] In some embodiments, frequency input may be provided by a voltage
30 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.

[0047] 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.

[0048] 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 (f_{LO}). In some embodiments, the RF circuitry 106 may include an IQ/polar converter.

[0049] 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.

[0050] 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).

[0051] 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.

Example Machine Description

[0052] Fig. 11 illustrates a block diagram of an example machine 500 upon which any one or more of the techniques (e.g., methodologies) discussed herein may perform. In alternative embodiments, the machine 500 may operate as a standalone device or may be connected (e.g., networked) to other machines. In a networked deployment, the machine 500 may operate in the capacity of a server machine, a client machine, or both in server-client network environments. In an example, the machine 500 may act as a peer machine in peer-to-peer (P2P) (or other distributed) network environment. The machine 500 may be a user equipment (UE), evolved Node B (eNB), Wi-Fi access point (AP), Wi-Fi station (STA), personal computer (PC), a tablet PC, a set-top box (STB), a personal digital assistant (PDA), a mobile telephone, a smart phone, a web appliance, a network router, switch or bridge, or any machine capable of executing instructions (sequential or otherwise) that specify actions to be taken by that machine. Further, while only a single machine is illustrated, the term “machine” shall also be taken to include any collection of machines that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein, such as cloud computing, software as a service (SaaS), other computer cluster configurations.

[0053] Examples, as described herein, may include, or may operate on, logic or a number of components, modules, or mechanisms. Modules are tangible entities (e.g., hardware) capable of performing specified operations and may be

configured or arranged in a certain manner. In an example, circuits may be arranged (e.g., internally or with respect to external entities such as other circuits) in a specified manner as a module. In an example, the whole or part of one or more computer systems (e.g., a standalone, client or server computer system) or one or more hardware processors may be configured by firmware or software (e.g., instructions, an application portion, or an application) as a module that operates to perform specified operations. In an example, the software may reside on a machine readable medium. In an example, the software, when executed by the underlying hardware of the module, causes the hardware to perform the specified operations.

[0054] Accordingly, the term “module” is understood to encompass a tangible entity, be that an entity that is physically constructed, specifically configured (e.g., hardwired), or temporarily (e.g., transitorily) configured (e.g., programmed) to operate in a specified manner or to perform part or all of any operation described herein. Considering examples in which modules are temporarily configured, each of the modules need not be instantiated at any one moment in time. For example, where the modules comprise a general-purpose hardware processor configured using software, the general-purpose hardware processor may be configured as respective different modules at different times. Software may accordingly configure a hardware processor, for example, to constitute a particular module at one instance of time and to constitute a different module at a different instance of time.

[0055] Machine (e.g., computer system) 500 may include a hardware processor 502 (e.g., a central processing unit (CPU), a graphics processing unit (GPU), a hardware processor core, or any combination thereof), a main memory 504 and a static memory 506, some or all of which may communicate with each other via an interlink (e.g., bus) 508. The machine 500 may further include a display unit 510, an alphanumeric input device 512 (e.g., a keyboard), and a user interface (UI) navigation device 514 (e.g., a mouse). In an example, the display unit 510, input device 512 and UI navigation device 514 may be a touch screen display. The machine 500 may additionally include a storage device (e.g., drive unit) 516, a signal generation device 518 (e.g., a speaker), a network interface device 520, and one or more sensors 521, such as a global positioning system

(GPS) sensor, compass, accelerometer, or other sensor. The machine 500 may include an output controller 528, such as a serial (e.g., universal serial bus (USB), parallel, or other wired or wireless (e.g., infrared (IR), near field communication (NFC), etc.) connection to communicate or control one or more peripheral devices (e.g., a printer, card reader, etc.).

[0056] The storage device 516 may include a machine readable medium 522 on which is stored one or more sets of data structures or instructions 524 (e.g., software) embodying or utilized by any one or more of the techniques or functions described herein. The instructions 524 may also reside, completely or at least partially, within the main memory 504, within static memory 506, or within the hardware processor 502 during execution thereof by the machine 500. In an example, one or any combination of the hardware processor 502, the main memory 504, the static memory 506, or the storage device 516 may constitute machine readable media.

[0057] While the machine readable medium 522 is illustrated as a single medium, the term "machine readable medium" may include a single medium or multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) configured to store the one or more instructions 524.

[0058] The term "machine readable medium" may include any medium that is capable of storing, encoding, or carrying instructions for execution by the machine 500 and that cause the machine 500 to perform any one or more of the techniques of the present disclosure, or that is capable of storing, encoding or carrying data structures used by or associated with such instructions. Non-limiting machine readable medium examples may include solid-state memories, and optical and magnetic media. Specific examples of machine readable media may include: non-volatile memory, such as semiconductor memory devices (e.g., Electrically Programmable Read-Only Memory (EPROM), Electrically Erasable Programmable Read-Only Memory (EEPROM)) and flash memory devices; magnetic disks, such as internal hard disks and removable disks; magneto-optical disks; Random Access Memory (RAM); and CD-ROM and DVD-ROM disks. In some examples, machine readable media may include non-transitory machine readable media. In some examples, machine readable media may include machine readable media that is not a transitory propagating signal.

[0059] The instructions 524 may further be transmitted or received over a communications network 526 using a transmission medium via the network interface device 520 utilizing any one of a number of transfer protocols (e.g., frame relay, internet protocol (IP), transmission control protocol (TCP), user datagram protocol (UDP), hypertext transfer protocol (HTTP), etc.). Example communication networks may include a local area network (LAN), a wide area network (WAN), a packet data network (e.g., the Internet), mobile telephone networks (e.g., cellular networks), Plain Old Telephone (POTS) networks, and wireless data networks (e.g., Institute of Electrical and Electronics Engineers (IEEE) 802.11 family of standards known as Wi-Fi®, IEEE 802.16 family of standards known as WiMax®, IEEE 802.15.4 family of standards, a Long Term Evolution (LTE) family of standards, a Universal Mobile Telecommunications System (UMTS) family of standards, peer-to-peer (P2P) networks, among others. In an example, the network interface device 520 may include one or more physical jacks (e.g., Ethernet, coaxial, or phone jacks) or one or more antennas to connect to the communications network 526. In an example, the network interface device 520 may include a plurality of antennas to wirelessly communicate using at least one of single-input multiple-output (SIMO), multiple-input multiple-output (MIMO), or multiple-input single-output (MISO) techniques. In some examples, the network interface device 520 may wirelessly communicate using Multiple User MIMO techniques. The term “transmission medium” shall be taken to include any intangible medium that is capable of storing, encoding or carrying instructions for execution by the machine 500, and includes digital or analog communications signals or other intangible medium to facilitate communication of such software.

Additional Notes and Examples

[0060] In Example 1, an apparatus for a user equipment (UE), comprises: memory and processing circuitry; wherein the processing circuitry is to: demodulate downlink control information (DCI) received from an evolved Node B (eNB) in a current subframe over a physical downlink control channel (PDCCH), wherein the DCI grants an uplink (UL) resource in a subsequent subframe; and, if the DCI contains a request for transmission of uplink control

information (UCI), encode the UCI for transmission in the granted UL resource, wherein the granted UL resource is either for transmission of an extended physical uplink control channel (ePUCCH) or a physical uplink shared channel (PUSCH) as indicated by the DCI.

- 5 **[0061]** In Example 1a, an apparatus for a user equipment (UE), comprises: memory and processing circuitry; wherein the processing circuitry is to: demodulate downlink control information (DCI) received from an evolved Node B (eNB) in a current subframe over a physical downlink control channel (PDCCH), wherein the DCI grants uplink (UL) resources for multiple
10 subsequent subframes; and, if the DCI contains a request for transmission of uplink control information (UCI), encode the UCI for transmission in specific subframe as indicated by the DCI of the granted UL resources, wherein the granted UL resource in the specific subframe is either for transmission of an extended physical uplink control channel (ePUCCH) or a physical uplink shared
15 channel (PUSCH) as indicated by the DCI.

[0062] In Example 1b, the subject matter of any of the examples herein may optionally include wherein the ePUCCH is made up of a block-interleaved frequency division multiple access (B-IFDMA) interlace.

- [0063]** In Example 1c, the subject matter of any of the examples herein may
20 optionally include wherein the memory is to store the DCI.

- [0064]** In Example 2, the subject matter of any of the examples herein may optionally include: wherein the processing circuitry is further to include a hybrid automatic request repeat acknowledgement (HARQ-ACK), a channel state information (CSI) report, or both in the UCI as indicated by specified bits in the
25 DCI.

- [0065]** In Example 3, the subject matter of any of the examples herein may optionally include: wherein the processing circuitry is further to: encode the UCI in the PUSCH if a modulation and coding scheme (MCS) for the PUSCH is indicated by a non-reserved MCS index (I_{MCS}) value in the DCI; and, encode the
30 UCI in the ePUCCH if the I_{MCS} value in the DCI is set to a reserved state.

[0066] In Example 3a, the subject matter of any of the examples herein may optionally include: wherein the processing circuitry is further to: encode the UCI in the PUSCH with uplink shared channel(UL-SCH) data if a modulation and

coding scheme (MCS) for the PUSCH is indicated by a non-reserved MCS index (I_{MCS}) value in the DCI; and, encode the UCI in the PUSCH without UL-SCH data if the I_{MCS} value in the DCI is set to a reserved state.

[0067] In Example 4, the subject matter of any of the examples herein may optionally include: wherein I_{MCS} values from 0-28 are non-reserved and indicate that the granted UL resource is the PUSCH and wherein I_{MCS} values from 29-31 are reserved states that indicate that the granted UL resource is the ePUCCH.

[0068] In Example 5, the subject matter of any of the examples herein may optionally include: wherein the processing circuitry is further to: encode the UCI in the PUSCH if a modulation and coding scheme (MCS) for the PUSCH is indicated by a non-reserved MCS index (I_{MCS}) value in the DCI; encode the UCI in the ePUCCH if the I_{MCS} value in the DCI is set to a reserved state and the number of bits in the UCI is less than or equal to a specified number X; and, encode the UCI in the PUSCH if the I_{MCS} value in the DCI is set to a reserved state and the number of bits in the UCI is greater than X.

[0069] In Example 6, the subject matter of any of the examples herein may optionally include: wherein the processing circuitry is further to: encode the UCI in the PUSCH with uplink scheduled channel (UL-SCH) data if a modulation and coding scheme (MCS) for the PUSCH is indicated by a non-reserved MCS index (I_{MCS}) value in the DCI; encode the UCI in the ePUCCH if the I_{MCS} value in the DCI is set to a first reserved state; and, encode the UCI in the PUSCH without UL-SCH data using a default MCS if the I_{MCS} value in the DCI is set to a second reserved state.

[0070] In Example 7, the subject matter of any of the examples herein may optionally include: wherein the default MCS is quadrature phase shift keying (QPSK).

[0071] In Example 8, the subject matter of any of the examples herein may optionally include: wherein the processing circuitry is further to: encode the UCI in the PUSCH if there is no inconsistency between a resource indication value (RIV) and a new data indicator (NDI) in the DCI; if the RIV equals 0 and the NDI equals 1 to indicate an inconsistency, and if the number of bits in the UCI is less than or equal to a specified number X, encode the UCI in the ePUCCH; and,

if the RIV equals 0 and the NDI equals 1 to indicate an inconsistency, and if the number of bits in the UCI is greater than X , encode the UCI in the PUSCH.

[0072] In Example 9, the subject matter of any of the examples herein may optionally include: wherein the processing circuitry is further to, if the RIV
5 equals 0 and the NDI equals 1 to indicate an inconsistency, and if the number of bits in the UCI is greater than X , encode the UCI in the PUSCH without multiplexing the UCI with UL data from an uplink shared channel (UL-SCH).

[0073] In Example 10, the subject matter of any of the examples herein may optionally include: wherein the processing circuitry is further to: encode the UCI
10 in the PUSCH with uplink scheduled channel (UL-SCH) data if a modulation and coding scheme (MCS) for the PUSCH is indicated by an MCS index (I_{MCS}) value in the DCI; encode the UCI in the ePUCCH if the I_{MCS} value in the DCI is set to a reserved state and a redundancy value (RV) in the DCI is set to a first specified value; and encode the UCI in the PUSCH without UL-SCH data using
15 a default MCS if the I_{MCS} value in the DCI is set to a reserved state and the RV in the DCI is set to a second specified value.

[0074] In Example 11, the subject matter of any of the examples herein may optionally include: wherein the processing circuitry is further to: if UCI is
20 requested by the DCI as indicated by an ePUCCH trigger bit in the DCI being set, and if a modulation and coding scheme (MCS) for the PUSCH is indicated by a non-reserved MCS index (I_{MCS}) value in the DCI, encode the UCI in the PUSCH using the indicated MCS; if no UCI is requested by the DCI as indicated by the ePUCCH trigger bit in the DCI not being set, and if an MCS is indicated for the PUSCH by a non-reserved I_{MCS} value in the DCI, encode UL data from
25 an UL shared channel (UL-SCH) in the PUSCH without UCI using the indicated MCS; if UCI is requested by the DCI as indicated by an ePUCCH trigger bit in the DCI being set, and if the I_{MCS} value in the DCI is set to a reserved state, encode the UCI in the ePUCCH.

[0075] In Example 12, the subject matter of any of the examples herein may
30 optionally include: wherein the processing circuitry is further to: if UCI is requested by the DCI as indicated by an ePUCCH trigger field in the DCI being set to a first state, encode the UCI in the ePUCCH; if UCI is requested by the DCI as indicated by the ePUCCH trigger field in the DCI being set to a second

state, and if a modulation and coding scheme (MCS) for the PUSCH is indicated by an MCS index (I_{MCS}) value in the DCI, encode the UCI in the PUSCH using the indicated MCS; if no UCI is requested by the DCI as indicated by the ePUCCH trigger field in the DCI being set to a third state, and if an MCS for the PUSCH is indicated by the I_{MCS} value in the DCI, encode UL data from an UL shared channel (UL-SCH) in the PUSCH without UCI using the indicated MCS.

5 [0076] In Example 13, an apparatus for an evolved Node B (eNB), comprises: memory and processing circuitry configured to: encode downlink control information (DCI) for transmission to a user equipment (UE) in a current subframe over a physical downlink control channel (PDCCH) that grants an uplink (UL) resource to the UE in a subsequent subframe; and, encode in the DCI an indication whether a request for transmission of uplink control information (UCI) from the UE in the granted UL resource is requested and whether the granted UL resource is for transmission of an extended physical uplink control channel (ePUCCH) or a physical uplink shared channel (PUSCH).

10 [0077] In Example 13a, the subject matter of any of the examples herein may optionally include: wherein the processing circuitry is further to: encode downlink control information (DCI) for transmission to a UE in a current subframe over a physical downlink control channel (PDCCH) that grants uplink (UL) resources for multiple subsequent subframes; and, encode in the DCI an indication whether a request for transmission of uplink control information (UCI) from the UE in the granted UL resource is requested and whether the granted UL resource is for transmission of an extended physical uplink control channel (ePUCCH) or a physical uplink shared channel (PUSCH) in a specified subframe of the granted UL resources.

15 [0078] In Example 14, the subject matter of any of the examples herein may optionally include: wherein the processing circuitry is further to include specified bits in the DCI that indicate whether a hybrid automatic request repeat acknowledgement (HARQ-ACK), a channel state information (CSI) report, or both should be included in the UCI.

[0079]

20 [0080] In Example 15, the subject matter of any of the examples herein may optionally include: wherein the processing circuitry is further to: indicate that

requested UCI should be encoded in the PUSCH by indicating a modulation and coding scheme (MCS) for the PUSCH with a non-reserved MCS index (I_{MCS}) value in the DCI; and, indicate that requested UCI should be encoded in the ePUCCH by setting the I_{MCS} value in the DCI to a reserved state.

5 **[0081]** In Example 16, the subject matter of any of the examples herein may optionally include: wherein I_{MCS} values from 0-28 indicate that the granted UL resource is the PUSCH and wherein I_{MCS} from 29-31 are reserved states that indicate that the granted UL resource is the ePUCCH.

10 **[0082]** In Example 17, the subject matter of any of the examples herein may optionally include: wherein the processing circuitry is further to: indicate that requested UCI should be encoded in the PUSCH by indicating a modulation and coding scheme (MCS) for the PUSCH with an MCS index (I_{MCS}) value in the DCI; indicate that requested UCI should be encoded in the ePUCCH if the number of bits in the UCI is less than or equal to a specified number X by
15 setting the I_{MCS} value in the DCI to a reserved state; and, indicate that requested UCI should be encoded in the PUSCH if the number of bits in the UCI is greater than X by setting the I_{MCS} value in the DCI to a reserved state.

20 **[0083]** In Example 18, the subject matter of any of the examples herein may optionally include: wherein the processing circuitry is further to: indicate that requested UCI should be encoded in the PUSCH with uplink shared channel (UL-SCH) data by indicating a modulation and coding scheme (MCS) for the PUSCH with a non-reserved MCS index (I_{MCS}) value in the DCI; indicate that requested UCI should be encoded in the ePUCCH by setting the I_{MCS} value in the DCI to a first reserved state; and, indicate that requested UCI should be
25 encoded in the PUSCH without UL-SCH data using a default MCS by setting the I_{MCS} value in the DCI to a second reserved state.

30 **[0084]** In Example 19, the subject matter of any of the examples herein may optionally include: wherein the processing circuitry is further to: indicate that requested UCI should be encoded in the PUSCH by maintaining consistency between a resource indication value (RIV) and a new data indicator (NDI) in the DCI; indicate that requested UCI should be encoded in ePUCCH if the number of bits in the UCI is less than or equal to a specified number X by setting the RIV to 0 and setting the NDI to 1 to indicate an inconsistency; and, indicate that

requested UCI should be encoded in PUSCH if the number of bits in the UCI is greater than X by setting the RIV to 0 and setting the NDI to 1 to indicate an inconsistency.

[0085] In Example 20, the subject matter of any of the examples herein may optionally include: wherein the processing circuitry is further to: indicate that requested UCI should be encoded the PUSCH with uplink shared channel (UL-SCH) data by indicating a modulation and coding scheme (MCS) for the PUSCH with an MCS index (I_{MCS}) value in the DCI; indicate that requested UCI should be encoded in the ePUCCH by setting the I_{MCS} value in the DCI to a reserved state and setting a redundancy value (RV) in the DCI to a first specified value; and indicate that requested UCI should be encoded in the PUSCH without UL-SCH data using a default MCS by setting the I_{MCS} value in the DCI to a reserved state and setting the RV in the DCI to a second specified value.

[0086] In Example 20a, the subject matter of any of the examples herein may optionally include: wherein the processing circuitry is further to: indicate that UCI is requested and that the requested UCI should be encoded in the PUSCH by setting an ePUCCH trigger bit in the DCI and indicate setting an MCS index (I_{MCS}) value in the DCI to a reserved state; indicate that no UCI is requested and that UL data from an UL shared channel (UL-SCH) should be transmitted in the PUSCH without UCI by not setting the ePUCCH trigger bit in the DCI and setting the MCS index to a non-reserved value in the DCI; indicate that UCI is requested and that the requested UCI should be encoded in the ePUCCH by setting an ePUCCH trigger bit in the DCI and setting an I_{MCS} value in the DCI is to a reserved state..

[0087] In Example 21, a computer-readable medium comprises instructions to cause a user equipment (UE), upon execution of the instructions by processing circuitry of the UE, to perform any of the functions of the memory and processing circuitry as recited in Examples 1 through 12.

[0088] In Example 22, a computer-readable medium comprises instructions to cause an eNB upon execution of the instructions by processing circuitry of the eNB, to perform any of the functions of the memory and processing circuitry as recited in Examples 13 through 20a.

[0089] In Example 23, a method for operating a UE comprises performing any of the functions of the memory and processing circuitry as recited in any of Examples 1 through 12.

5 [0090] In Example 24, a method for operating an eNB comprises performing any of the functions of the memory and processing circuitry and transceiver as recited in any of Examples 13 through 20a.

[0091] In Example 25, an apparatus for a UE comprises means for performing any of the functions of the memory and processing circuitry and transceiver as recited in any of Examples 1 through 12.

10 [0092] In Example 26, an apparatus for an eNB comprises means for performing any of the functions of the memory and processing circuitry and transceiver as recited in any of Examples 13 through 20a.

[0093] In Example 27, the subject matter of any of the Examples herein may further include a radio transceiver connected to the memory and
15 processing circuitry.

[0094] The above detailed description includes references to the accompanying drawings, which form a part of the detailed description. The drawings show, by way of illustration, specific embodiments that may be practiced. These embodiments are also referred to herein as “examples.” Such examples may include elements in addition to those shown or described. However, also contemplated are examples that include the elements shown or described. Moreover, also contemplate are examples using any combination or permutation of those elements shown or described (or one or more aspects thereof), either with respect to a particular example (or one or more aspects thereof), or with respect to other examples (or one or more aspects thereof) shown or described herein.

[0095] Publications, patents, and patent documents referred to in this document are incorporated by reference herein in their entirety, as though individually incorporated by reference. In the event of inconsistent usages between this document and those documents so incorporated by reference, the usage in the incorporated reference(s) are supplementary to that of this

document; for irreconcilable inconsistencies, the usage in this document controls.

[0096] In this document, the terms “a” or “an” are used, as is common in patent documents, to include one or more than one, independent of any other instances or usages of “at least one” or “one or more.” In this document, the term “or” is used to refer to a nonexclusive or, such that “A or B” includes “A but not B,” “B but not A,” and “A and B,” unless otherwise indicated. In the appended claims, the terms “including” and “in which” are used as the plain-English equivalents of the respective terms “comprising” and “wherein.” Also, in the following claims, the terms “including” and “comprising” are open-ended, that is, a system, device, article, or process that includes elements in addition to those listed after such a term in a claim are still deemed to fall within the scope of that claim. Moreover, in the following claims, the terms “first,” “second,” and “third,” etc. are used merely as labels, and are not intended to suggest a numerical order for their objects.

[0097] The embodiments as described above may be implemented in various hardware configurations that may include a processor for executing instructions that perform the techniques described. Such instructions may be contained in a machine-readable medium such as a suitable storage medium or a memory or
5 other processor-executable medium.

[0098] The embodiments as described herein may be implemented in a number of environments such as part of a wireless local area network (WLAN), 3rd Generation Partnership Project (3GPP) Universal Terrestrial Radio Access Network (UTRAN), or Long-Term-Evolution (LTE) or a Long-Term-Evolution
10 (LTE) communication system, although the scope of the invention is not limited in this respect. An example LTE system includes a number of mobile stations, defined by the LTE specification as User Equipment (UE), communicating with a base station, defined by the LTE specifications as an eNB.

[0099] Antennas referred to herein may comprise one or more directional or
15 omnidirectional antennas, including, for example, dipole antennas, monopole antennas, patch antennas, loop antennas, microstrip antennas or other types of antennas suitable for transmission of RF signals. In some embodiments, instead of two or more antennas, a single antenna with multiple apertures may be used.

In these embodiments, each aperture may be considered a separate antenna. In some multiple-input multiple-output (MIMO) embodiments, antennas may be effectively separated to take advantage of spatial diversity and the different channel characteristics that may result between each of antennas and the antennas of a transmitting station. In some MIMO embodiments, antennas may be separated by up to 1/10 of a wavelength or more.

[00100] In some embodiments, a receiver as described herein may be configured to receive signals in accordance with specific communication standards, such as the Institute of Electrical and Electronics Engineers (IEEE) standards including IEEE 802.11 standards and/or proposed specifications for WLANs, although the scope of the invention is not limited in this respect as they may also be suitable to transmit and/or receive communications in accordance with other techniques and standards. In some embodiments, the receiver may be configured to receive signals in accordance with the IEEE 802.16-2004, the IEEE 802.16(e) and/or IEEE 802.16(m) standards for wireless metropolitan area networks (WMANs) including variations and evolutions thereof, although the scope of the invention is not limited in this respect as they may also be suitable to transmit and/or receive communications in accordance with other techniques and standards. In some embodiments, the receiver may be configured to receive signals in accordance with the Universal Terrestrial Radio Access Network (UTRAN) LTE communication standards. For more information with respect to the IEEE 802.11 and IEEE 802.16 standards, please refer to “IEEE Standards for Information Technology -- Telecommunications and Information Exchange between Systems” - Local Area Networks - Specific Requirements – Part 11 “Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY), ISO/IEC 8802-11: 1999”, and Metropolitan Area Networks - Specific Requirements – Part 16: “Air Interface for Fixed Broadband Wireless Access Systems,” May 2005 and related amendments/versions. For more information with respect to UTRAN LTE standards, see the 3rd Generation Partnership Project (3GPP) standards for UTRAN-LTE, including variations and evolutions thereof.

[00101] The above description is intended to be illustrative, and not restrictive. For example, the above-described examples (or one or more aspects

thereof) may be used in combination with others. Other embodiments may be used, such as by one of ordinary skill in the art upon reviewing the above description. The Abstract is to allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. Also, in the above Detailed Description, various features may be grouped together to streamline the disclosure. However, the claims may not set forth every feature disclosed herein as embodiments may feature a subset of said features. Further, embodiments may include fewer features than those disclosed in a particular example. Thus, the following claims are hereby incorporated into the Detailed Description, with a claim standing on its own as a separate embodiment. The scope of the embodiments disclosed herein is to be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled.

CLAIMS

1. An apparatus for a user equipment (UE), comprising:

memory and processing circuitry;

wherein the processing circuitry is to demodulate downlink control
5 information (DCI) received from an evolved Node B (eNB) in a current
subframe over a physical downlink control channel (PDCCH), wherein the DCI
grants an uplink (UL) resource in a subsequent subframe;

wherein the memory is to store the DCI; and,

wherein the processing circuitry is to, if the DCI contains a request for
10 transmission of uplink control information (UCI), encode the UCI for
transmission in the granted UL resource, wherein the granted UL resource is
either for transmission of an extended physical uplink control channel
(ePUCCH) or a physical uplink shared channel (PUSCH) as indicated by the
DCI, wherein the ePUCCH is made up of a block-interleaved frequency division
15 multiple access (B-IFDMA) interlace.

2. The apparatus of claim 1 wherein the processing circuitry is further to
include a hybrid automatic request repeat acknowledgement (HARQ-ACK), a
channel state information (CSI) report, or both in the UCI as indicated by
20 specified bits in the DCI.

3. The apparatus of claim 1 wherein the processing circuitry is further to:

encode the UCI in the PUSCH if a modulation and coding scheme
(MCS) for the PUSCH is indicated by a non-reserved MCS index (I_{MCS}) value in
25 the DCI; and,

encode the UCI in the ePUCCH if the I_{MCS} value in the DCI is set to a
reserved state.

4. The apparatus of claim 3 wherein I_{MCS} values from 0-28 are non-reserved and indicate that the granted UL resource is the PUSCH and wherein I_{MCS} values from 29-31 are reserved states that indicate that the granted UL resource is the
5 ePUCCH.

5. The apparatus of claim 1 wherein the processing circuitry is further to:

encode the UCI in the PUSCH if a modulation and coding scheme (MCS) for the PUSCH is indicated by a non-reserved MCS index (I_{MCS}) value in
10 the DCI;

encode the UCI in the ePUCCH if the I_{MCS} value in the DCI is set to a reserved state and the number of bits in the UCI is less than or equal to a specified number X; and,

encode the UCI in the PUSCH if the I_{MCS} value in the DCI is set to a
15 reserved state and the number of bits in the UCI is greater than X.

6. The apparatus of claim 1 wherein the processing circuitry is further to:

encode the UCI in the PUSCH with uplink scheduled channel (UL-SCH) data if a modulation and coding scheme (MCS) for the PUSCH is indicated by a
20 non-reserved MCS index (I_{MCS}) value in the DCI;

encode the UCI in the ePUCCH if the I_{MCS} value in the DCI is set to a first reserved state; and,

encode the UCI in the PUSCH without UL-SCH data using a default MCS if the I_{MCS} value in the DCI is set to a second reserved state.

25

7 The apparatus of claim 6 wherein the default MCS is quadrature phase shift keying (QPSK).

8. The apparatus of claim 1 wherein the processing circuitry is further to:

5 encode the UCI in the PUSCH if there is no inconsistency between a resource indication value (RIV) and a new data indicator (NDI) in the DCI;

 if the RIV equals 0 and the NDI equals 1 to indicate an inconsistency, and if the number of bits in the UCI is less than or equal to a specified number X, encode the UCI in the ePUCCH; and,

10 if the RIV equals 0 and the NDI equals 1 to indicate an inconsistency, and if the number of bits in the UCI is greater than X, encode the UCI in the PUSCH.

9. The apparatus of claim 8 wherein the processing circuitry is further to, if
15 the RIV equals 0 and the NDI equals 1 to indicate an inconsistency, and if the number of bits in the UCI is greater than X, encode the UCI in the PUSCH without multiplexing the UCI with UL data from an uplink shared channel (UL-SCH).

20

10. The apparatus of claim 1 wherein the processing circuitry is further to:
- encode the UCI in the PUSCH with uplink scheduled channel (UL-SCH) data if a modulation and coding scheme (MCS) for the PUSCH is indicated by an MCS index (I_{MCS}) value in the DCI;
- 5 encode the UCI in the ePUCCH if the I_{MCS} value in the DCI is set to a reserved state and a redundancy value (RV) in the DCI is set to a first specified value; and
- encode the UCI in the PUSCH without UL-SCH data using a default MCS if the I_{MCS} value in the DCI is set to a reserved state and the RV in the DCI
- 10 is set to a second specified value.
11. The apparatus of claim 1 wherein the processing circuitry is further to:
- if UCI is requested by the DCI as indicated by an ePUCCH trigger bit in the DCI being set, and if a modulation and coding scheme (MCS) for the
- 15 PUSCH is indicated by a non-reserved MCS index (I_{MCS}) value in the DCI, encode the UCI in the PUSCH using the indicated MCS;
- if no UCI is requested by the DCI as indicated by the ePUCCH trigger bit in the DCI not being set, and if an MCS is indicated for the PUSCH by a non-reserved I_{MCS} value in the DCI, encode UL data from an UL shared channel
- 20 (UL-SCH) in the PUSCH without UCI using the indicated MCS;
- if UCI is requested by the DCI as indicated by an ePUCCH trigger bit in the DCI being set, and if the I_{MCS} value in the DCI is set to a reserved state, encode the UCI in the ePUCCH.

12. The apparatus of claim 1 wherein the processing circuitry is further to:

if UCI is requested by the DCI as indicated by an ePUCCH trigger field in the DCI being set to a first state, encode the UCI in the ePUCCH;

5 if UCI is requested by the DCI as indicated by the ePUCCH trigger field in the DCI being set to a second state, and if a modulation and coding scheme (MCS) for the PUSCH is indicated by an MCS index (I_{MCS}) value in the DCI, encode the UCI in the PUSCH using the indicated MCS;

10 if no UCI is requested by the DCI as indicated by the ePUCCH trigger field in the DCI being set to a third state, and if an MCS for the PUSCH is indicated by the I_{MCS} value in the DCI, encode UL data from an UL shared channel (UL-SCH) in the PUSCH without UCI using the indicated MCS.

13. An apparatus for an evolved Node B (eNB), comprising:

memory and processing circuitry configured to:

15 encode downlink control information (DCI) for transmission to a user equipment (UE) in a current subframe over a physical downlink control channel (PDCCH) that grants an uplink (UL) resource to the UE in a subsequent subframe; and,

20 encode in the DCI an indication whether a request for transmission of uplink control information (UCI) from the UE in the granted UL resource is requested and whether the granted UL resource is for transmission of an extended physical uplink control channel (ePUCCH) or a physical uplink shared channel (PUSCH), wherein the ePUCCH is made up of a block-interleaved frequency division multiple access (B-IFDMA) interlace.

25

14. The apparatus of claim 13 wherein the processing circuitry is further to include specified bits in the DCI that indicate whether a hybrid automatic request repeat acknowledgement (HARQ-ACK), a channel state information (CSI) report, or both should be included in the UCI.

5

15. The apparatus of claim 13 wherein the processing circuitry is further to:

indicate that requested UCI should be encoded in the PUSCH by indicating a modulation and coding scheme (MCS) for the PUSCH with a non-reserved MCS index (I_{MCS}) value in the DCI; and,

10 indicate that requested UCI should be encoded in the ePUCCH by setting the I_{MCS} value in the DCI to a reserved state.

16. The apparatus of claim 15 wherein I_{MCS} values from 0-28 indicate that the granted UL resource is the PUSCH and wherein I_{MCS} from 29-31 are reserved states that indicate that the granted UL resource is the ePUCCH.

15

17. The apparatus of claim 13 wherein the processing circuitry is further to:

indicate that requested UCI should be encoded in the PUSCH by indicating a modulation and coding scheme (MCS) for the PUSCH with an MCS index (I_{MCS}) value in the DCI;

20

indicate that requested UCI should be encoded in the ePUCCH if the number of bits in the UCI is less than or equal to a specified number X by setting the I_{MCS} value in the DCI to a reserved state; and,

indicate that requested UCI should be encoded in the PUSCH if the number of bits in the UCI is greater than X by setting the I_{MCS} value in the DCI to a reserved state.

25

18. The apparatus of claim 13 wherein the processing circuitry is further to:
- indicate that requested UCI should be encoded in the PUSCH with uplink shared channel (UL-SCH) data by indicating a modulation and coding scheme (MCS) for the PUSCH with a non-reserved MCS index (I_{MCS}) value in the DCI;
- 5 indicate that requested UCI should be encoded in the ePUCCH by setting the I_{MCS} value in the DCI to a first reserved state; and,
- indicate that requested UCI should be encoded in the PUSCH without UL-SCH data using a default MCS by setting the I_{MCS} value in the DCI to a second reserved state.
- 10
19. The apparatus of claim 13 wherein the processing circuitry is further to:
- indicate that requested UCI should be encoded in the PUSCH by maintaining consistency between a resource indication value (RIV) and a new data indicator (NDI) in the DCI;
- 15 indicate that requested UCI should be encoded in ePUCCH if the number of bits in the UCI is less than or equal to a specified number X by setting the RIV to 0 and setting the NDI to 1 to indicate an inconsistency; and,
- indicate that requested UCI should be encoded in PUSCH if the number of bits in the UCI is greater than X by setting the RIV to 0 and setting the NDI to
- 20 1 to indicate an inconsistency.
20. The apparatus of claim 13 wherein the processing circuitry is further to:
- indicate that requested UCI should be encoded the PUSCH with uplink shared channel (UL-SCH) data by indicating a modulation and coding scheme
- 25 (MCS) for the PUSCH with an MCS index (I_{MCS}) value in the DCI;

indicate that requested UCI should be encoded in the ePUCCH by setting the I_{MCS} value in the DCI to a reserved state and setting a redundancy value (RV) in the DCI to a first specified value; and

- 5 indicate that requested UCI should be encoded in the PUSCH without UL-SCH data using a default MCS by setting the I_{MCS} value in the DCI to a reserved state and setting the RV in the DCI to a second specified value..

21. A computer-readable medium comprising instructions to cause a user equipment (UE), upon execution of the instructions by processing circuitry of
10 the UE, to:

demodulate downlink control information (DCI) received from an evolved Node B (eNB) in a current subframe over a physical downlink control channel (PDCCH) that grants an uplink (UL) resource in a subsequent subframe; and,

- 15 if the DCI contains a request for transmission of uplink control information (UCI), encode the UCI for transmission in the granted UL resource, wherein the granted UL resource is either for transmission of an extended physical uplink control channel (ePUCCH) or a physical uplink shared channel (PUSCH) as indicated by the DCI, wherein the ePUCCH is made up of a block-
20 interleaved frequency division multiple access (B-IFDMA) interlace..

22. The medium of claim 21 further comprising instructions to:

encode the UCI in the PUSCH if a modulation and coding scheme (MCS) for the PUSCH is indicated by an MCS index (I_{MCS}) value in the DCI; and,

5 encode the UCI in the ePUCCH if the I_{MCS} value in the DCI is set to a reserved state.

23. The medium of claim 21 further comprising instructions to:

10 encode the UCI in the PUSCH if a modulation and coding scheme (MCS) for the PUSCH is indicated by an MCS index (I_{MCS}) value in the DCI;

encode the UCI in the ePUCCH if the I_{MCS} value in the DCI is set to a reserved state and the number of bits in the UCI is less than or equal to a specified number X; and,

15 encode the UCI in the PUSCH if the I_{MCS} value in the DCI is set to a reserved state and the number of bits in the UCI is greater than X.

24. The medium of claim 21 further comprising instructions to:

encode the UCI in the PUSCH if a modulation and coding scheme (MCS) for the PUSCH is indicated by an MCS index (I_{MCS}) value in the DCI;

20 encode the UCI in the ePUCCH if the I_{MCS} value in the DCI is set to a first reserved state; and,

encode the UCI in the PUSCH using a default MCS if the I_{MCS} value in the DCI is set to a second reserved state.

25. The medium of claim 21 further comprising instructions to:

encode the UCI in the PUSCH if there is no inconsistency between a resource indication value (RIV) and a new data indicator (NDI) in the DCI;

if the RIV equals 0 and the NDI equals 1 to indicate an inconsistency,
5 and if the number of bits in the UCI is less than or equal to a specified number X, encode the UCI in the ePUCCH; and,

if the RIV equals 0 and the NDI equals 1 to indicate an inconsistency,
and if the number of bits in the UCI is greater than X, encode the UCI in the PUSCH.

10

1/8

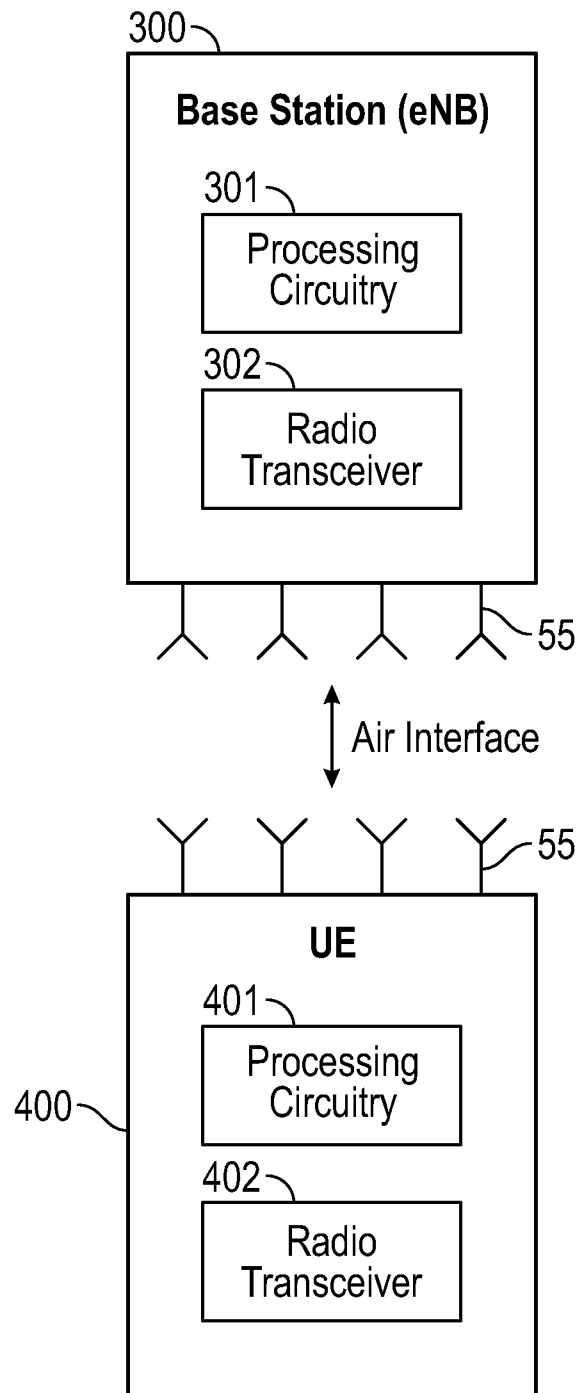


FIG. 1

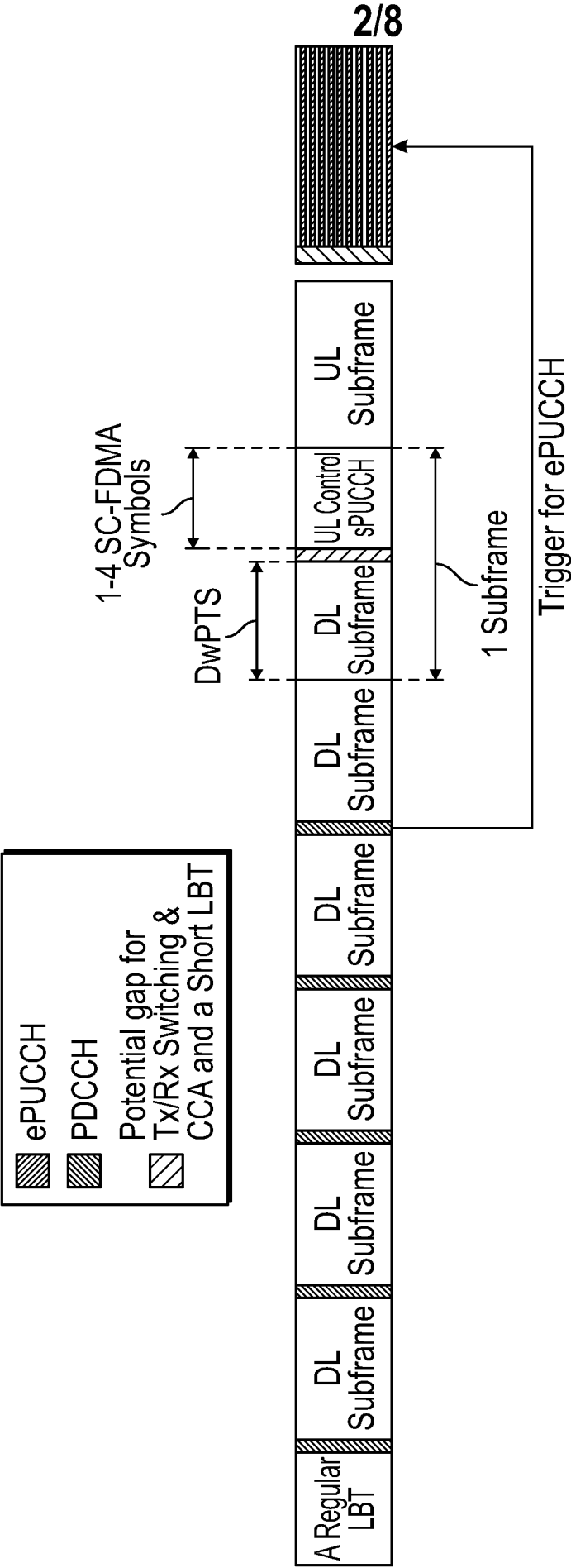


FIG. 2

3/8

Field	Bit Length (Format 0A)	Bit Length (Format 4A)
Carrier Indicator	3	3
RA	6 or 10	6 or 10
MCS/ePUCCH Indication	5	10
RV	2	4
NDI	1	2
TPC	2	2
Cyclic Shift (Also OCC for ePUCCH)	3	3
CQI Request	1-3	1-3
SRS Request	1	2
HARQ ID	4	4
LBT	1	1
Starting UL Position	1	1
Cross-Burst Type 2	1	1
Timing Relationship	4	4
HARQ ACK with PUCCH	1	1

FIG. 3

4/8

	MCS	CQI Request	A/N
CSI on PUSCH	0-28	1	0
A/N on PUSCH	0-28	0	1
aCSI and A/N on PUSCH	0-28	1	1
aCSI on ePUCCH If $aCSI \leq X$ Bits, Otherwise aCSI on PUSCH	31	1	0
A/N on ePUCCH	31	0	1
aCSI and A/N on ePUCCH If $\leq X$ Bits, Otherwise aCSI on PUSCH	31	1	1

FIG. 4

	MCS	aCSI	A/N
aCSI on PUSCH	0-28	1	0
A/N on PUSCH	0-28	0	1
aCSI and A/N on PUSCH	0-28	1	1
aCSI on ePUCCH	31	1	0
A/N on ePUCCH	31	0	1
aCSI and A/N on ePUCCH	31	1	1
aCSI on PUSCH	29	1	0
aCSI and A/N on PUSCH	29	1	1

FIG. 5

5/8

	RIV	NDI	CQI Request	A/N
CSI on PUSCH with UL-SCH	>0 if NDI = 1, $=0$ if NDI = 0	0 or 1	1	0
A/N on PUSCH with UL-SCH	>0 if NDI = 1, $=0$ if NDI = 0	0 or 1	0	1
aCSI and A/N on PUSCH with UL-SCH	>0 if NDI = 1, $=0$ if NDI = 0	0 or 1	1	1
aCSI on ePUCCH If $aCSI \leq X$ Bits, Otherwise aCSI on PUSCH without UL-SCH	$=0$	1	1	0
A/N on ePUCCH without UL-SCH	$=0$	1	0	1
aCSI and A/N on ePUCCH If $aCSI \leq X$ Bits, Otherwise aCSI on PUSCH without UL-SCH	$=0$	1	1	1

FIG. 6

	MCS	RV	CQI Request	A/N
UL-SCH + CSI on PUSCH	0-28	0-3	1	0
UL-SCH + A/N on PUSCH	0-28	0-3	0	1
UL-SCH + aCSI and A/N on PUSCH	0-28	0-3	1	1
aCSI on ePUCCH	29	1	1	0
A/N on ePUCCH	29	1	0	1
aCSI and A/N on ePUCCH	29	1	1	1
aCSI on PUSCH	29	2	1	0
aCSI and A/N on PUSCH	29	2	1	1

FIG. 7

6/8

	MCS	RV	CQI Request	A/N
UL-SCH + CSI on PUSCH	0-28	0-3	1	0
UL-SCH + A/N on PUSCH	0-28	0-3	0	1
UL-SCH + aCSI and A/N on PUSCH	0-28	0-3	1	1
aCSI on ePUCCH	29	2	1	0
A/N on ePUCCH	29	2	0	1
aCSI and A/N on ePUCCH	29	2	1	1
aCSI on PUSCH	29	1	1	0
aCSI and A/N on PUSCH	29	1	1	1

FIG. 8

ePUCCH Trigger Bit	One I_{MCS} State (29 or 30 or 31)	Transmission Indication
Trigger is Set	I_{MCS} is set to the Reserved	ePUCCH Transmission Using ePUCCH Format
Trigger is Set	I_{MCS} is set to 0-28	UCI on PUSCH, Where PUSCH Transmit Using the MCS Indicated in the Grant
Trigger is not Set	I_{MCS} is set to 0-28	PUCCH Transmission without UCI, Using the MCS Indicated in the Grant

FIG. 9

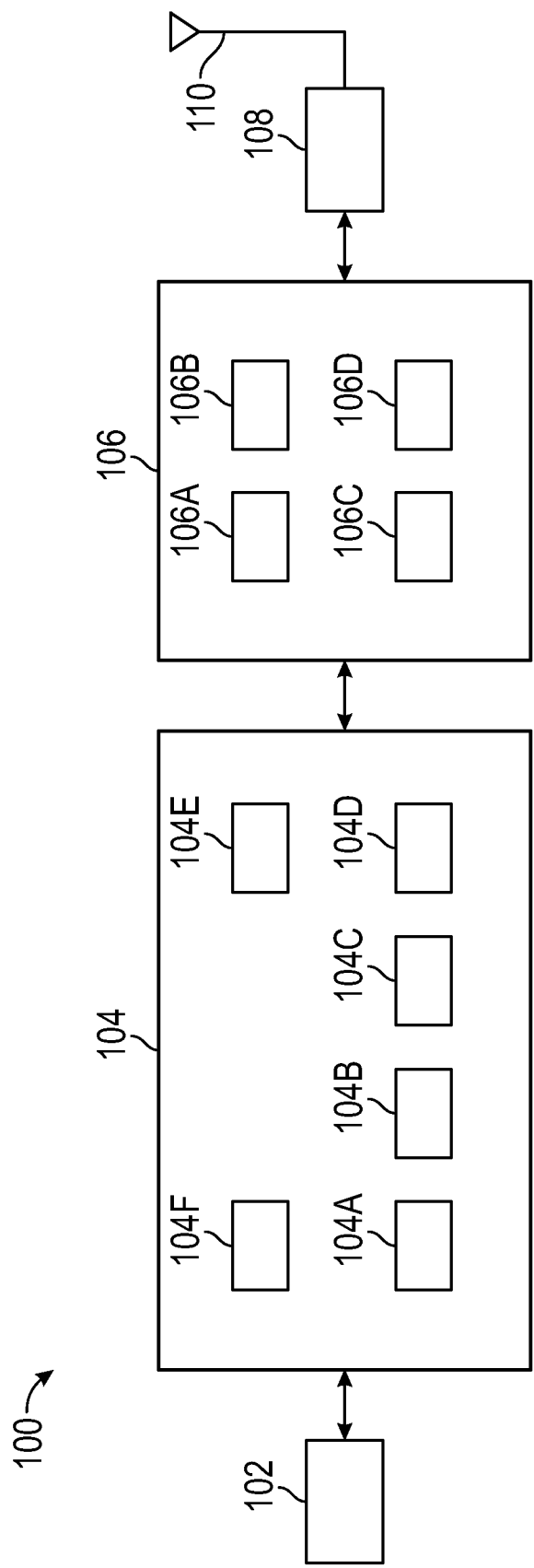


FIG. 10

8/8

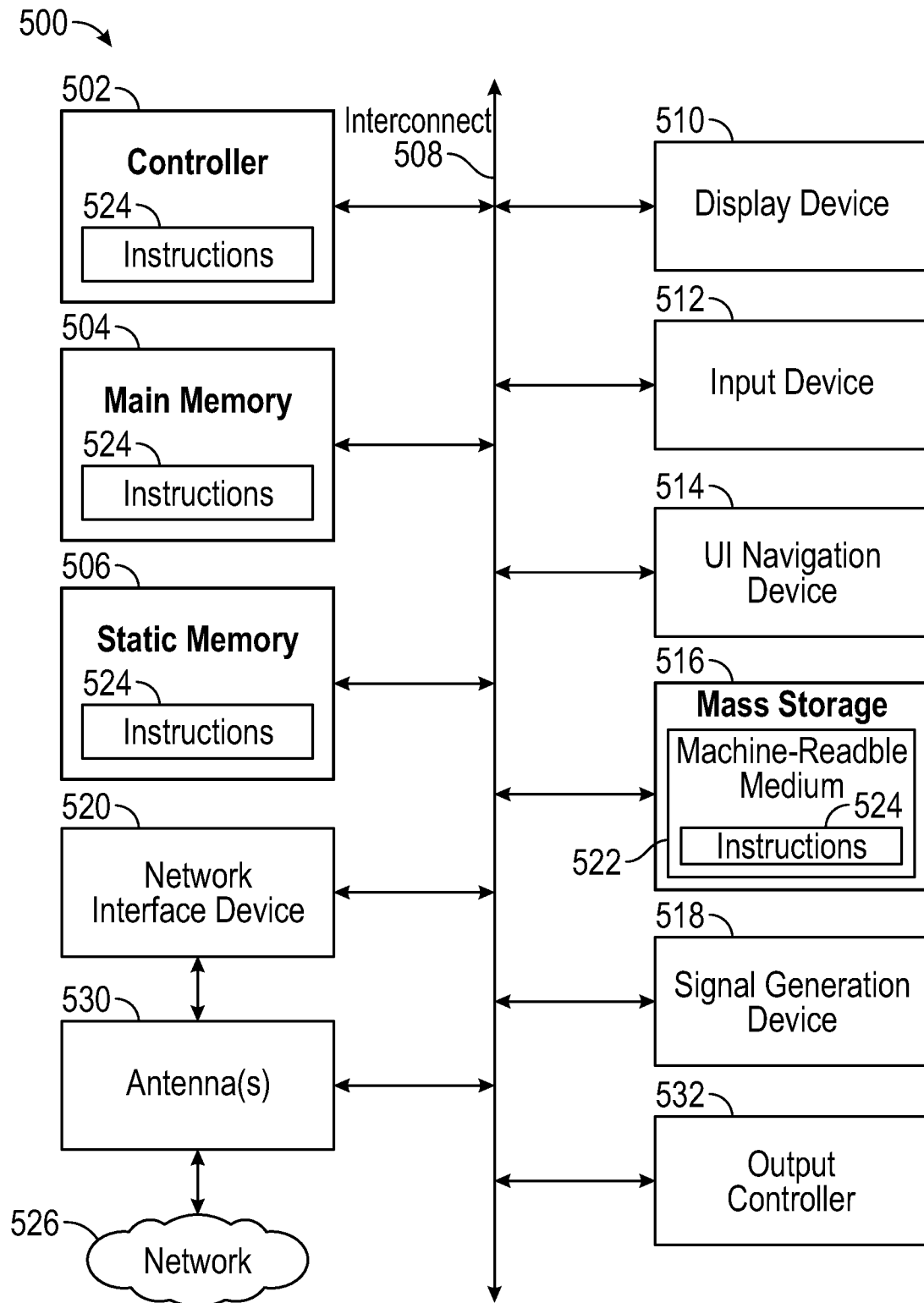


FIG. 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/068985**A. CLASSIFICATION OF SUBJECT MATTER****H04L 1/00(2006.01)i, H04L 1/18(2006.01)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)

H04L 1/00; H04L 5/00; H04W 24/10; H04W 72/04; H04W 72/08; H04L 1/18

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: extended PUCCH (ePUCCH), PUSCH, block-interleaved frequency division multiple access (B-IFDMA) interlace, DCI, UCI**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	INTEL CORPORATION, 'Transmission of Uplink Control Information on an LAA SCell', R1-162357, 3GPP TSG RAN WG1 Meeting #84bis, Busan, Korea, 02 April 2016 See sections 2-3.4.	1-25
Y	NOKIA NETWORKS et al., 'On the need for PUCCH in eLAA', R1-160777, 3GPP TSG RAN WG1 Meeting #84, St. Julian's, Malta, 05 February 2016 See section 4.	1-25
Y	US 2015-0049706 A1 (LG ELECTRONICS INC.) 19 February 2015 See paragraphs [0123]-[0126]; and figure 5.	3-7, 10-12, 15-18, 20, 22-24
Y	US 2015-0172028 A1 (SAMSUNG ELECTRONICS CO., LTD.) 18 June 2015 See paragraphs [0115], [0116], [0127]-[0129], [0136], [0139]; and figures 6, 7.	5-10, 17-20, 23-25
A	US 2016-0100406 A1 (QUALCOMM INCORPORATED) 07 April 2016 See paragraphs [0075]-[0079], [0113]-[0131]; and figures 6-10.	1-25

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

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

25 April 2017 (25.04.2017)

Date of mailing of the international search report

25 April 2017 (25.04.2017)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea



Facsimile No. +82-42-481-8578

Authorized officer

Lee, Eun Kyu

Telephone No. +82-42-481-3580



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2016/068985

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2015-0049706 A1	19/02/2015	US 9490947 B2	08/11/2016
US 2015-0172028 A1	18/06/2015	CN 102934381 A	13/02/2013
		CN 102934381 B	06/04/2016
		EP 2577897 A2	10/04/2013
		EP 2577897 A4	04/01/2017
		JP 2013-527729 A	27/06/2013
		JP 5781605 B2	24/09/2015
		KR 10-2013-0083391 A	22/07/2013
		US 2011-0299484 A1	08/12/2011
		US 8971261 B2	03/03/2015
		US 9270439 B2	23/02/2016
		WO 2011-152673 A2	08/12/2011
		WO 2011-152673 A3	26/04/2012
US 2016-0100406 A1	07/04/2016	WO 2016-057191 A1	14/04/2016