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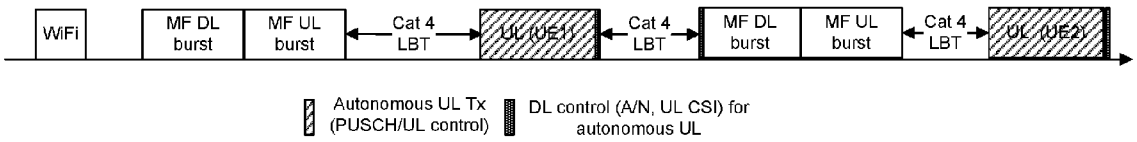


FIG. 1

(57) Abstract: Technology for an eNodeB operable to encode downlink control information for transmission to a user equipment (UE) is disclosed. The eNodeB can decode an autonomous physical uplink shared channel (PUSCH) transmission received from the UE when a channel between the eNodeB and the UE is sensed to be idle based on a listen before talk (LBT) procedure. The autonomous PUSCH transmission can be received from the UE without an explicit uplink grant from the eNodeB. The eNodeB can encode downlink control information for transmission from the eNodeB to the UE over a physical downlink control channel (PDCCH) in response to the autonomous PUSCH transmission that is received from the UE. The downlink control information can include an acknowledgement (ACK) feedback or a negative acknowledgement (NACK) feedback.

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IMPROVED DOWNLINK CONTROL TRANSMISSION FOR AUTONOMOUS UPLINK TRANSMISSION

BACKGROUND

[0001] Wireless systems typically include multiple User Equipment (UE) devices communicatively coupled to one or more Base Stations (BS). The one or more BSs may be Long Term Evolved (LTE) evolved NodeBs (eNB) or New Radio (NR) next generation NodeBs (gNB) that can be communicatively coupled to one or more UEs by a Third-Generation Partnership Project (3GPP) network.

[0002] Next generation wireless communication systems are expected to be a unified network/system that is targeted to meet vastly different and sometimes conflicting performance dimensions and services. New Radio Access Technology (RAT) is expected to support a broad range of use cases including Enhanced Mobile Broadband (eMBB), Massive Machine Type Communication (mMTC), Mission Critical Machine Type Communication (uMTC), and similar service types operating in frequency ranges up to 100 GHz.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] Features and advantages of the disclosure will be apparent from the detailed description which follows, taken in conjunction with the accompanying drawings, which together illustrate, by way of example, features of the disclosure; and, wherein:

[0004] FIG. 1 illustrates an autonomous uplink transmission in accordance with an example;

[0005] FIG. 2 illustrates a physical downlink control channel (PDCCH) transmission from an eNodeB on a blanked physical uplink shared channel (PUSCH) transmission in accordance with an example;

[0006] FIG. 3 illustrates a physical downlink control channel (PDCCH) transmission from an eNodeB within a maximum channel occupancy time (MCOT) obtained from a user equipment (UE) in accordance with an example;

[0007] FIG. 4 depicts functionality of an eNodeB operable to encode downlink control

information for transmission to a user equipment (UE) in accordance with an example;

[0008] FIG. 5 depicts functionality of a user equipment (UE) operable to perform autonomous uplink transmissions with an eNodeB in accordance with an example;

[0009] FIG. 6 depicts a flowchart of a machine readable storage medium having instructions embodied thereon for encoding downlink control information for transmission from an eNodeB to a user equipment (UE) in accordance with an example;

[0010] FIG. 7 illustrates an architecture of a wireless network in accordance with an example;

[0011] FIG. 8 illustrates a diagram of a wireless device (e.g., UE) in accordance with an example;

[0012] FIG. 9 illustrates interfaces of baseband circuitry in accordance with an example; and

[0013] FIG. 10 illustrates a diagram of a wireless device (e.g., UE) in accordance with an example.

[0014] Reference will now be made to the exemplary embodiments illustrated, and specific language will be used herein to describe the same. It will nevertheless be understood that no limitation of the scope of the technology is thereby intended.

DETAILED DESCRIPTION

[0015] Before the present technology is disclosed and described, it is to be understood that this technology is not limited to the particular structures, process actions, or materials disclosed herein, but is extended to equivalents thereof as would be recognized by those ordinarily skilled in the relevant arts. It should also be understood that terminology employed herein is used for the purpose of describing particular examples only and is not intended to be limiting. The same reference numerals in different drawings represent the same element. Numbers provided in flow charts and processes are provided for clarity in illustrating actions and operations and do not necessarily indicate a particular order or sequence.

DEFINITIONS

[0016] As used herein, the term "User Equipment (UE)" refers to a computing device capable of wireless digital communication such as a smart phone, a tablet computing device, a laptop computer, a multimedia device such as an iPod Touch®, or other type computing device that provides text or voice communication. The term "User Equipment (UE)" may also be referred to as a "mobile device," "wireless device," of "wireless mobile device."

[0017] As used herein, the term "Base Station (BS)" includes "Base Transceiver Stations (BTS)," "NodeBs," "evolved NodeBs (eNodeB or eNB)," and/or "next generation NodeBs (gNodeB or gNB)," and refers to a device or configured node of a mobile phone network that communicates wirelessly with UEs.

[0018] As used herein, the term "cellular telephone network," "4G cellular," "Long Term Evolved (LTE)," "5G cellular" and/or "New Radio (NR)" refers to wireless broadband technology developed by the Third Generation Partnership Project (3GPP).

EXAMPLE EMBODIMENTS

[0019] An initial overview of technology embodiments is provided below and then specific technology embodiments are described in further detail later. This initial summary is intended to aid readers in understanding the technology more quickly but is not intended to identify key features or essential features of the technology nor is it intended to limit the scope of the claimed subject matter.

[0020] The explosive growth in wireless traffic has led to a demand for rate improvement. However, with mature physical layer techniques, further improvement in spectral efficiency has been marginal. In addition, the scarcity of licensed spectrum in the low frequency band results in a deficit in the data rate boost. There are emerging interests in the operation of LTE systems in unlicensed spectrum. In 3GPP LTE Release 13, one enhancement has been to enable operation in the unlicensed spectrum via licensed-assisted access (LAA). LAA can expand the system bandwidth by utilizing a flexible carrier aggregation (CA) framework, as introduced in the LTE-Advanced system (3GPP LTE Release 10 system). Release 13 LAA focuses on the downlink (DL) design, while

3GPP Release14 enhanced LAA (or eLAA) focuses on the uplink (UL) design. Enhanced operation of LTE systems in the unlicensed spectrum is expected in Fifth Generation (5G) wireless communication systems. In one example, LTE operation in the unlicensed spectrum can be achieved using dual connectivity (DC) based LAA. In DC based LAA, an anchor deployed in the licensed spectrum can be utilized.

[0021] In another example, 3GPP Release 14 describes that LTE operation in the unlicensed system can be achieved using a MuLTEfire system, which does not utilize an anchor in the licensed spectrum. The MuLTEfire system is a standalone LTE system that operates in the unlicensed spectrum, and does not necessitate assistance from the licensed spectrum and combines the performance benefits of LTE technology with the simplicity of WiFi-like deployments. Therefore, Release 14 eLAA and MuLTEfire systems can potentially be significant evolutions in future wireless networks to handle ever-increasing wireless traffic.

[0022] In one example, the unlicensed frequency band of current interest for 3GPP systems is the 5 gigahertz (GHz) band, which has wide spectrum with global common availability. The 5 GHz band in the United States is governed using Unlicensed National Information Infrastructure (U-NII) rules by the Federal Communications Commission (FCC). The main incumbent system in the 5 GHz band is the wireless local area networks (WLAN), specifically those based on the IEEE 802.11 a/n/ac technologies. WLAN systems are widely deployed both by individuals and operators for carrier-grade access service and data offloading. Therefore, listen-before-talk (LBT) in the unlicensed spectrum is a mandatory feature in the 3GPP Release 13 LAA system, which can enable fair coexistence with the incumbent system. LBT is a procedure in which radio transmitters first sense the medium, and transmit only if the medium is sensed to be idle.

[0023] For MuLTEfire and LAA Release 13/14 systems, a scheduled based UL LAA design can be utilized, in which an UL physical uplink shared channel (PUSCH) transmission can be determined based on an explicit UL grant transmission via a physical downlink control channel (PDCCH). The UL grant transmission can be performed after completing an LBT procedure at an eNodeB on a component carrier over which the PUSCH transmission is expected. After receiving the UL grant, the scheduled UE can perform a short LBT or a Category 4 (Cat 4) LBT during an allocated time interval. If the

LBT is successful at the scheduled UE, then the UE can transmit the PUSCH on resources indicated by the UL grant.

[0024] For Release 13/14 LAA, an UL performance in the unlicensed spectrum can be significantly degraded. The main cause of this UL starvation can be due to the double LBT constraints at both the eNodeB when sending the UL grant and at the scheduled UEs before transmission. This is a generic problem when a scheduled system, i.e., LTE, coexists with a non-scheduled autonomous system, i.e., Wi-Fi. On the other hand, one particular limitation imposed on the LTE system is the 4-subframe processing delay. This limitation restricts that the initial 4 subframes in a transmission burst cannot be configured to UL as the UL grants are unavailable for those subframes within the same transmission burst.

[0025] In order to resolve the issues of the scheduled system, an autonomous UL design with a grant-less UL transmission can be utilized, in which the eNodeB does not transmit the UL grant for the PUSCH transmission. In an autonomous technique for UL PUSCH transmission, LBT is performed only at the UE and an additional LBT procedure is not performed at the eNodeB. In this non-scheduled technique for UL PUSCH transmissions, the UE does not wait for the UL grant, which reduces the additional 4 subframe delay for accessing a channel for the UL transmission.

[0026] FIG. 1 illustrates an example of an autonomous uplink transmission. A first UE (UE1) can perform a Category 4 LBT procedure prior to performing an autonomous UL transmission (Tx) with an eNodeB. The autonomous UL transmission can be a PUSCH transmission or an UL control information transmission. The UE can perform the autonomous UL transmission without an explicit UL grant transmission from the eNodeB via a PDCCH. The autonomous UL transmission can be followed by DL control information. For example, the DL control information can include an acknowledgement (A) or a negative acknowledgement (N) for the autonomous UL transmission. In addition, the DL control information can include UL channel state information (CSI) for the autonomous UL transmission. Similarly, a second UE (UE2) can perform a Category 4 LBT procedure prior to performing an autonomous UL transmission with the eNodeB, and the autonomous UL transmission can be followed by DL control information.

[0027] As shown in FIG. 1, an autonomous (or grant-less) UE can transmit the PUSCH

and perform channel contention without an explicit indication from the eNodeB. The autonomous UE can perform Category 4 LBT before the UL transmission. The UE can indicate UL burst control information to enable the eNodeB to decode the PUSCH, which can include a UE identifier (ID), a modulation and coding scheme (MCS), a redundancy version (RV) and a new data indicator (NDI). The eNodeB can perform a PUSCH presence detection based on a demodulation reference signal (DMRS) sequence, and the eNodeB can feedback to the UE the A/N and the UL CSI corresponding to the received PUSCH. After PUSCH reception at the eNodeB, the eNodeB can perform decoding of one or more PUSCH transmissions before sending the ACK feedback to the UE.

[0028] In one example, the mechanism in which the eNodeB sends the DL control information (e.g., ACK/NACK, UL CSI) to the UE is a key design component to enable autonomous (grantless) transmissions from the UE. As described in further detail below, various techniques can be employed to improve the transmission of DL control information from the eNodeB to the UE with respect to autonomous UL transmissions from the UE to the eNodeB.

[0029] In one configuration, various techniques can be employed to improve a transmission probability of ACK transmissions from the eNodeB. The eNodeB can transmit an ACK as a PDCCH transmission, and various techniques can be employed to improve the PDCCH transmission.

[0030] For example, with respect to downlink control information (DCI) formats/contents for ACK/NACK feedback, there can be a DCI format 0/4/0A/4A carrying an UL grant for retransmission and a new DCI format carrying only ACK/NACK feedback.

[0031] In another example, with respect to transmission techniques for the PDCCH carrying ACK/NACK feedback, the eNodeB can configure each UE with periodic opportunities, and the eNB can transmit a PDCCH (for pending ACK feedback of PUSCH transmissions to one or several UEs). Each opportunity can include one or more OFDM symbols. A PUSCH transmission that coincides with a periodic opportunity can be blanked for a configured interval of the periodic opportunity. Before the PUSCH transmission, the UE can perform Category 4 LBT with a specific priority. The LBT allowed UE and the eNodeB can share the medium for a maximum channel occupancy duration corresponding to a priority used by the UE by regulations. Specifically, if there is

a gap of more than 16 micro seconds (us) between an ending of the PUSCH transmission and the PDCCH transmission, the eNodeB can transmit the PDCCH with a single interval LBT (e.g., performing LBT for 25us).

[0032] In yet another example, with respect to an LBT technique for the PDCCH transmission, the eNodeB can perform single-interval LBT or no LBT when within a transmission opportunity (TxOP), or the eNodeB can perform Category 4 LBT when outside the TxOP.

[0033] In a further example, a technique for determining a maximum channel occupancy time (MCOT) at the eNodeB can be based on the following: The UE can indicate remaining subframes in an UL burst in a shortened or enhanced (s/e) PUCCH in a first subframe of the UL burst of every subframe of the UL burst. The UE can indicate a LBT priority in the (s/e)PUCCH, and based on the priority, the eNodeB can determine the MCOT. In addition, the UE can indicate a remaining MCOT in the (s/e)PUCCH in a first subframe of the UL burst or every subframe of the UL burst.

[0034] In one configuration, it is important to control the delay between transmission of the autonomous PUSCH transmission and reception of the ACK feedback of the PUSCH transmission at the UE. Without careful consideration, the UE can retransmit the PUSCH if the delay between the PUSCH transmission and the eNodeB ACK/NACK feedback is too long. Therefore, as described below, various DL control transmission techniques can be employed to shorten the ACK/NACK feedback delay and improve the network performance.

[0035] In one configuration, with respect to DCI formats/content, the DL control information can be carried in the PDCCH for ACK/NACK feedback. In a first option, DCI format 0/4/0A/4A can be used to carry the UL grant for retransmission. In the first option, after decoding the UE autonomous PUSCH transmission, the eNodeB can send a re-transmission grant for a hybrid automatic repeat request (HARQ) process received in error, where the transmission of the UL grant can be subject to LBT depending on if the PDCCH transmission is within a TxOP. With the first option, the following behavior regarding reception of the UL grant can be considered: If the UL grant for retransmission is received, this implies the NACK feedback for the corresponding PUSCH transmission. On the other hand, for HARQ processes which do not receive the retransmission grant,

the HARQ process can be treated as successful when no re-transmission grant is received within a higher layer specified timer. Alternatively, HARQ processes transmitted earlier than the requested HARQ process can be considered as successful.

[0036] In a second option, a new DCI format can be defined to only send ACK/NACK feedback. In the second option, the new DCI format can be defined, and transmitted in a UE specific search space. In the new DCI format, a bit mapped ACK/NACK can be transmitted. With the second option, the following behavior regarding reception of the UL grant can be considered: When the PDCCH carrying the ACK/NACK feedback is received, the UE behavior can follow the feedback. Specifically, when ACK is indicated, then the transmission of the HARQ process is successful. When NACK or discontinuous transmission (DTX) is indicated, the UE can restart an autonomous transmission for the retransmission of the HARQ process. Alternatively, the UE can wait for the UL grant from the eNodeB to schedule the retransmission of the HARQ process. On the other hand, when the ACK/NACK feedback is not received within a higher layer specified timer, the HARQ process can be treated as a failure. The UE can restart another autonomous UL transmission for this HARQ process. Alternatively, the UE can wait for the UL grant from the eNodeB to schedule the retransmission of the HARQ process.

[0037] In a third option, the ACK/NACK feedback can be added in an UL grant or a DL grant. When a bit map of the ACK/NACK is transmitted within a retransmission UL grant, the UE can utilize configured parameters to retransmit the HARQ processes corresponding to the NACK. When the bit map of the ACK/NACK is transmitted within the DL grant, the UE can wait for a next opportunity for another autonomous transmission. When the PDCCH carrying the ACK/NACK feedback is received, the UE behavior can follow the feedback. Specifically, when ACK is indicated, then the transmission of the HARQ process is successful. When NACK/DTX is indicated, and the HARQ-ACK feedback is not carried in a retransmission UL grant, the UE can restart an autonomous transmission for the retransmission of the HARQ process. Alternatively, the UE can wait for the UL grant from the eNodeB to schedule the retransmission of the HARQ process. On the other hand, when the ACK/NACK feedback is not received within a higher layer specified timer, the HARQ process can be treated as failure. The UE can restart another autonomous UL transmission for this HARQ process. Alternatively, the

UE can wait for the UL grant from the eNodeB to schedule the retransmission of the HARQ process.

[0038] In one configuration, several techniques can be employed for improving a transmission probability of the PDCCH carrying the ACK/NACK feedback. A first technique can involve periodic transmission opportunities for ACK/NACK feedback. The eNodeB can configure each UE with periodic opportunities, and the eNodeB can transmit DCI carrying ACK/NACK feedback for an autonomous PUSCH transmission. Each opportunity can include one or more OFDM symbols that can be predefined or semi-statically configured. The PUSCH transmission that coincides with the periodic opportunity can be blanked for a predefined/configured interval of the periodic opportunity.

[0039] FIG. 2 illustrates an example of a physical downlink control channel (PDCCH) transmission from an eNodeB on a blanked physical uplink shared channel (PUSCH) transmission. A user equipment (UE) can perform an autonomous UL transmission. The autonomous UL transmission can be a PUSCH transmission or an UL control information transmission. The UE can perform the autonomous UL transmission without an explicit UL grant transmission from the eNodeB via a PDCCH. In addition, a blanked PUSCH can occur in accordance with a PUSCH blanking periodicity (e.g., every N symbols, wherein N is an integer). The PUSCH blanking can occur for one or more OFDM symbols, so that the eNodeB can transmit DL control information during the blanked PUSCH (which is not utilized by the UE). In other words, the eNodeB can perform a PDCCH transmission on a blanked PUSCH transmission, and there can be periodic resources for the PDCCH transmission during which the PUSCH transmission is blanked. The DL control information can include an acknowledgement (A) or a negative acknowledgement (N) for the autonomous UL transmission. In addition, the DL control information can include UL channel state information (CSI) for the autonomous UL transmission.

[0040] Returning back to the first technique, the UE can be configured with a periodic configuration via higher layer signaling. Radio resource control (RRC) signaling can be used to provide the periodic configuration, or alternatively, a system information block (SIB) transmission can configure each UE with the periodic configuration. The periodic

configuration can include a PUSCH blanking periodicity, in terms of a number of subframes. In addition, the periodic configuration can include a PUSCH blanking interval consisting of one or more subframes or one or more symbols (e.g., the interval can be set to 1 symbol). After the UE receives the periodic configuration, the UE can blank the PUSCH when the subframe overlaps with the periodic configuration interval. In one example, only UEs that are allowed to perform autonomous UL transmission are configured with a periodic opportunity. In the first technique, autonomous UL transmissions from UEs associated with the eNodeB may not block the PDCCH transmission of the eNodeB, which can improve a transmission probability of the PDCCH. Moreover, when the PDCCH transmission is within a TxOP, no Category 4 LBT is utilized, which can further increase the transmission probability.

[0041] In a second technique for improving the transmission probability of the PDCCH carrying the ACK/NACK feedback, the UE can perform category 4 LBT and reserve the channel for a maximum channel occupancy time (MCOT), which can be shared with the eNodeB for the PDCCH transmission. Before the PUSCH transmission, the UE can perform Category 4 LBT with a specific priority. The LBT can allow the UE and the eNodeB to share the channel or medium for the MCOT corresponding to the priority used by the UE by regulations. The eNodeB can transmit ACK/NACK in the PDCCH following the PUSCH transmission, within the MCOT reserved by UE.

[0042] FIG. 3 illustrates an example of a physical downlink control channel (PDCCH) transmission from an eNodeB within a maximum channel occupancy time (MCOT) obtained from a user equipment (UE). The UE can perform an autonomous UL transmission. The autonomous UL transmission can be a PUSCH transmission or an UL control information transmission. The UE can perform the autonomous UL transmission without an explicit UL grant transmission from the eNodeB via a PDCCH. The UE can perform the autonomous UL transmission during the MCOT reserved by the UE. Within the MCOT reserved by the UE, the eNodeB can transmit DL control information. The DL control information can include an acknowledgement (A) or a negative acknowledgement (N) for the autonomous UL transmission. In addition, the DL control information can include UL channel state information (CSI) for the autonomous UL transmission. Therefore, the eNodeB can send the DL control information for the autonomous UL

transmission, in which the UE can reserve the channel or medium in accordance with the MCOT, and the eNodeB can transmit the DL control information in the PDCCH with a single shot within the MCOT.

[0043] In one example, the PDCCH can be sent immediately following the PUSCH transmission burst. In another example, a last N symbol of an end subframe of the UL burst can be left blank for the PDCCH transmission. Alternatively, the PDCCH can be sent in a next subframe following the end of the UL burst. In yet another example, the PDCCH can be transmitted with a fixed timing relationship between the PUSCH transmission and the PDCCH transmission. Depending on a capability of the eNodeB to decode the autonomous UL transmission and prepare the ACK/NACK feedback transmission, the PDCCH can carry the ACK/NACK feedback for all previous PUSCH transmissions with outstanding ACK/NACK feedback. Alternatively, the PDCCH can carry the ACK/NACK feedback for all PUSCH transmitted N subframes before, e.g.. N=4.

[0044] With respect to the second technique, when there is a gap of more than 16us between an ending of the PUSCH transmission and the PDCCH transmission, the eNodeB can transmit the PDCCH with a single interval LBT (e.g., performing LBT for 25us). When there is a gap of no more than 16us between the ending of the PUSCH transmission and the PDCCH transmission, the eNodeB can transmit the PDCCH without LBT. Thus, the eNodeB can send the ACK/NACK feedback without going through the Category 4 LBT process, which can improve the transmission probability of the ACK/NACK feedback. In addition, when the MCOT reserved by the UE has expired, the eNodeB can perform a Category 4 LBT (e.g., with priority 1) for the PDCCH following the PUSCH.

[0045] In one configuration, LBT techniques can be defined for the PDCCH carrying the ACK/NACK feedback. The LBT techniques can be classified into two cases: within a TxOP and outside a TxOP. When the PDCCH transmission is within a TxOP, either reserved by the eNodeB or by the associated UEs, no LBT or single-interval LBT can be performed. When a gap between the end of a previous transmission within the TxOP and a start of the PDCCH is more than 16us, the eNodeB can transmit the PDCCH subject to a single-interval LBT (e.g., performing LBT for 25us). When the gap between the end of

previous transmission within the TxOP and the start of the PDCCH is no more than 16us, the eNodeB can transmit the PDCCH without LBT (e.g., performing LBT for 25us).

[0046] In one example, when the PDCCH transmission is outside a TxOP, the eNodeB can perform Category 4 LBT for the PDCCH transmission. For example, the eNodeB can perform priority 1 Category 4 LBT, and then send a PDCCH only transmission following eLAA specification. In this case, when the first option of DCI design is adopted as described earlier (i.e. an UL grant for retransmission is carried in the DCI), the UE can retransmit the PUSCH with a corresponding HARQ process, following a cross-TxOP scheduling procedure. In another example, the eNodeB can perform priority 2 or 3 Category 4 LBT, and reserve a longer TxOP. The UE retransmission of the PUSCH can be within a TxOP following a single-interval LBT or no LBT.

[0047] In one example, when the TxOP is reserved by associated UEs and shared with the eNodeB for the PDCCH transmission, a length of (remaining) MCOT can be determined at the eNodeB. Several techniques can be utilized to determine the MCOT at the eNodeB. In a first technique, the UE can indicate MCOT information in uplink control information (UCI) in a first subframe of an UL burst, or every subframe of the UL burst, or a subset of the subframes (e.g., the last two subframes). The MCOT information can include a total length of the MCOT, in terms of number of subframes, and/or number of slots, and/or number of symbols. In addition, the MCOT information can include a remaining length of the MCOT, in terms of number of subframes, and/or number of slots, and/or number of symbols. In a second technique, the UE can indicate an LBT priority used for a channel reservation in the UCI, and based on the LBT priority, the eNodeB can determine the MCOT.

[0048] In one configuration, a UE can operate on an unlicensed spectrum capable of LBT. The UE can communicate with an eNodeB using a licensed medium and/or an unlicensed medium. The UE can sense the unlicensed medium before a physical uplink shared channel (PUSCH) transmission. For example, when the unlicensed medium is determined to be idle, the UE can transmit the PUSCH, and when the unlicensed medium is determined to be busy, the UE can prevent the PUSCH transmission. The UE can receive the PUSCH transmission from the UE.

[0049] In one example, the UE can transmit the PUSCH autonomously without an

explicit indication to transmit on the UL from the eNodeB. For example, the UE can perform the PUSCH transmission without an explicit indication of an UL grant from the eNodeB. In another example, a mode of operation, e.g., a non-scheduled (autonomous) or scheduled mode of operation, can be dynamically indicated by layer 1 (L1) or layer 2 (L2) signaling.

[0050] In one example, the eNodeB can send a re-transmission grant to the UE to schedule a retransmission of an UE autonomous initial transmission. In another example, a HARQ process can be successful when no UL grant for re-transmission is received at the UE, within a higher layer specified timer. In yet another example, HARQ processes transmitted earlier than a requested HARQ process can be successful.

[0051] In one example, a new DCI format can be defined to carry only ACK/NACK feedback. In another example, a bit mapped ACK/NACK can be transmitted in the DCI. In yet another example, when an ACK is received in the DCI, a transmission of the HARQ process can be successful and there can be no retransmission for that HARQ process. In a further example, when a NACK/DTX is received in the DCI, the UE can restart an autonomous transmission for a retransmission of the HARQ process, or the UE can wait for an UL grant to schedule the retransmission of the HARQ process. In yet a further example, when ACK/NACK feedback is not received within a higher layer specified timer, the HARQ process can be considered a failure, and the UE can re-start another autonomous UL transmission for the HARQ process, or the UE can wait for an UL grant from the eNodeB to schedule the retransmission of the HARQ process.

[0052] In one example, ACK/NACK feedback can be added to an UL grant or a DL grant. In another example, a bit map of the ACK/NACK can be transmitted within a re-transmission UL grant, and the UE can utilize configured parameters to retransmit HARQ processes corresponding to the NACK. In yet another example, a bit map of the ACK/NACK can be transmitted within a DL grant, and the UE can wait for a next opportunity for autonomous transmission with the NACK feedback. In a further example, when ACK/NACK feedback is not received within a higher layer specified timer, the HARQ process can be considered a failure, and the UE can restart another autonomous UL transmission for the HARQ process, or the UE can wait for an UL grant from the eNodeB to schedule the retransmission of the HARQ process.

[0053] In one example, the eNodeB can configure each UE with periodic opportunities, and the eNodeB can transmit a PDCCH for pending ACK feedback of PUSCH transmissions from one or several UEs. In another example, each opportunity can include one or more OFDM symbols that can be predefined or semi-statically configured, and the PUSCH transmission that coincides with the periodic opportunity can be blanked for the predefined/configured number of symbols. In yet another example, the periodic opportunity can be configured via higher layer signaling, via RRC signaling, or via a SIB transmission. In a further example, configuration information can include a periodicity of the opportunities, e.g., in terms of number of subframes, and a PUSCH blanking interval within each periodic opportunity, e.g., in terms of number of subframes or symbols. In yet a further example, after the UE receives the periodic configuration, the UE can blank the PUSCH on certain symbols or a whole subframe if the subframe overlaps with a periodic configuration interval. In addition, UEs may only be permitted to perform autonomous UL transmissions when configured with the periodic opportunity.

[0054] In one example, the UE can perform Category 4 LBT and reserve a channel for a MCOT, which can be shared with the eNodeB for a PDCCH transmission. In another example, the eNodeB can transmit an ACK/NACK in the PDCCH immediately following a PUSCH transmission, within the MCOT reserved by the UE. In yet another example, a last N symbol of an end subframe of an UL burst can be left blank for the PDCCH transmission. In a further example, the PDCCH for ACK/NACK feedback can be sent in a next subframe following the end of the UL burst. In yet a further example, the PDCCH can be transmitted with a fixed timing relationship between the PUSCH transmission and the PDCCH transmission.

[0055] In one example, depending on a capability of the eNodeB to decode an autonomous UL transmission and a preparation of the ACK/NACK feedback transmission, the PDCCH can carry the ACK/NACK feedback for all previous PUSCH transmissions with outstanding ACK/NACK feedback, or alternatively, the PDCCH can carry the ACK/NACK feedback for all PUSCH transmissions transmitted N subframes before, e.g. N=4. In another example, the UE can indicate MCOT information in UCI in a subframe of an UL burst, or every subframe of the UL burst, or a subset of the subframes (e.g., the last two subframes). In yet another example, the MCOT information can include

a total length of MCOT, in terms of number of subframes, and/or number of slots, and/or number of symbols. The MCOT can include a remaining length of MCOT, in terms of number of subframes, and/or number of slots, and/or number of symbols. In addition, the UE can indicate a LBT priority used for a channel reservation in the UCI, based on which, the eNodeB can determine the MCOT.

[0056] In one example, the PDCCH transmission can be within a TxOP, either reserved by the eNodeB or by the associated UEs, and no LBT or single-interval LBT can be performed. In another example, when a gap between an end of a previous transmission within the TxOP and a start of the PDCCH is more than 16us, the eNodeB can transmit the PDCCH subject to a single-interval LBT (e.g., performing LBT for 25us). In yet another example, when the gap between the end of the previous transmission within the TxOP and the start of the PDCCH is no more than 16us, the eNodeB can transmit the PDCCH without LBT (e.g., performing LBT for 25us).

[0057] In one example, when the PDCCH transmission is outside a TxOP, the eNodeB can perform Category 4 LBT for the PDCCH transmission. In another example, the eNodeB can perform priority 1 Category 4 LBT, and send a PDCCH only transmission following an eLAA specification. In this case, when a first option of DCI design is adopted (i.e., an UL grant for retransmission is carried in the DCI), the UE can retransmit the PUSCH with a corresponding HARQ process, following a cross-TxOP scheduling procedure. In yet another example, the eNodeB can perform priority 2 or 3 Category 4 LBT and reserve a longer TxOP, and a UE re-transmission of the PUSCH can be within a TxOP following a single-interval LBT or no LBT.

[0058] Another example provides functionality 400 of an eNodeB operable to encode downlink control information for transmission to a user equipment (UE), as shown in FIG. 4. The eNodeB can comprise one or more processors configured to decode, at the eNodeB, an autonomous physical uplink shared channel (PUSCH) transmission received from the UE when a channel between the eNodeB and the UE is sensed to be idle based on a listen before talk (LBT) procedure, wherein the autonomous PUSCH transmission is received from the UE without an explicit uplink grant from the eNodeB, as in block 410. The eNodeB can comprise one or more processors configured to encode, at the eNodeB, downlink control information for transmission from the eNodeB to the UE over a

physical downlink control channel (PDCCH) in response to the autonomous PUSCH transmission that is received from the UE, wherein the downlink control information includes an acknowledgement (ACK) feedback or a negative acknowledgement (NACK) feedback, as in block 420. In addition, the eNodeB can comprise a memory interface configured to send to a memory the downlink control information.

[0059] Another example provides functionality 500 of a user equipment (UE) operable to perform autonomous uplink transmissions with an eNodeB, as shown in FIG. 5. The UE can comprise one or more processors configured to perform, at the UE, a listen before talk (LBT) procedure to sense a channel between the UE and the eNodeB, as in block 510. The UE can comprise one or more processors configured to encode, at the UE, an autonomous physical uplink shared channel (PUSCH) transmission for delivery to the eNodeB when the channel between the UE and the eNodeB is sensed to be idle based on the LBT procedure, wherein the autonomous PUSCH transmission is sent from the UE without an explicit uplink grant from the eNodeB, as in block 520. The UE can comprise one or more processors configured to decode, at the UE, downlink control information received from the eNodeB over a physical downlink control channel (PDCCH) in response to the autonomous PUSCH transmission that is sent from the UE to the eNodeB, wherein the downlink control information includes an acknowledgement (ACK) feedback or a negative acknowledgement (NACK) feedback, as in block 530. In addition, the UE can comprise a memory interface configured to retrieve from a memory the autonomous PUSCH transmission.

[0060] Another example provides at least one machine readable storage medium having instructions 600 embodied thereon for encoding downlink control information for transmission from an eNodeB to a user equipment (UE), as shown in FIG. 6. The instructions can be executed on a machine, where the instructions are included on at least one computer readable medium or one non-transitory machine readable storage medium. The instructions when executed by one or more processors of the eNodeB perform: decoding, at the eNodeB, an autonomous physical uplink shared channel (PUSCH) transmission received from the UE when a channel between the eNodeB and the UE is sensed to be idle based on a listen before talk (LBT) procedure, wherein the autonomous PUSCH transmission is received from the UE without an explicit uplink grant from the

eNodeB, as in block 610. The instructions when executed by one or more processors of the eNodeB perform: encoding, at the eNodeB, downlink control information for transmission from the eNodeB to the UE over a physical downlink control channel (PDCCH) in response to the autonomous PUSCH transmission that is received from the UE, wherein the downlink control information includes an acknowledgement (ACK) feedback or a negative acknowledgement (NACK) feedback, as in block 620.

[0061] FIG. 7 illustrates an architecture of a system 700 of a network in accordance with some embodiments. The system 700 is shown to include a user equipment (UE) 701 and a UE 702. The UEs 701 and 702 are illustrated as smartphones (e.g., handheld touchscreen mobile computing devices connectable to one or more cellular networks), but may also comprise any mobile or non-mobile computing device, such as Personal Data Assistants (PDAs), pagers, laptop computers, desktop computers, wireless handsets, or any computing device including a wireless communications interface.

[0062] In some embodiments, any of the UEs 701 and 702 can comprise an Internet of Things (IoT) UE, which can comprise a network access layer designed for low-power IoT applications utilizing short-lived UE connections. An IoT UE can utilize technologies such as machine-to-machine (M2M) or machine-type communications (MTC) for exchanging data with an MTC server or device via a public land mobile network (PLMN), Proximity-Based Service (ProSe) or device-to-device (D2D) communication, sensor networks, or IoT networks. The M2M or MTC exchange of data may be a machine-initiated exchange of data. An IoT network describes interconnecting IoT UEs, which may include uniquely identifiable embedded computing devices (within the Internet infrastructure), with short-lived connections. The IoT UEs may execute background applications (e.g., keep-alive messages, status updates, etc.) to facilitate the connections of the IoT network.

[0063] The UEs 701 and 702 may be configured to connect, e.g., communicatively couple, with a radio access network (RAN) 710 — the RAN 710 may be, for example, an Evolved Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (E-UTRAN), a NextGen RAN (NG RAN), or some other type of RAN. The UEs 701 and 702 utilize connections 703 and 704, respectively, each of which comprises a physical communications interface or layer (discussed in further detail below); in this

example, the connections 703 and 704 are illustrated as an air interface to enable communicative coupling, and can be consistent with cellular communications protocols, such as a Global System for Mobile Communications (GSM) protocol, a code-division multiple access (CDMA) network protocol, a Push-to-Talk (PTT) protocol, a PTT over Cellular (POC) protocol, a Universal Mobile Telecommunications System (UMTS) protocol, a 3GPP Long Term Evolution (LTE) protocol, a fifth generation (5G) protocol, a New Radio (NR) protocol, and the like.

[0064] In this embodiment, the UEs 701 and 702 may further directly exchange communication data via a ProSe interface 705. The ProSe interface 705 may alternatively be referred to as a sidelink interface comprising one or more logical channels, including but not limited to a Physical Sidelink Control Channel (PSCCH), a Physical Sidelink Shared Channel (PSSCH), a Physical Sidelink Discovery Channel (PSDCH), and a Physical Sidelink Broadcast Channel (PSBCH).

[0065] The UE 702 is shown to be configured to access an access point (AP) 706 via connection 707. The connection 707 can comprise a local wireless connection, such as a connection consistent with any IEEE 802.15 protocol, wherein the AP 706 would comprise a wireless fidelity (WiFi®) router. In this example, the AP 706 is shown to be connected to the Internet without connecting to the core network of the wireless system (described in further detail below).

[0066] The RAN 710 can include one or more access nodes that enable the connections 703 and 704. These access nodes (ANs) can be referred to as base stations (BSs), NodeBs, evolved NodeBs (eNBs), next Generation NodeBs (gNB), RAN nodes, and so forth, and can comprise ground stations (e.g., terrestrial access points) or satellite stations providing coverage within a geographic area (e.g., a cell). The RAN 710 may include one or more RAN nodes for providing macrocells, e.g., macro RAN node 711, and one or more RAN nodes for providing femtocells or picocells (e.g., cells having smaller coverage areas, smaller user capacity, or higher bandwidth compared to macrocells), e.g., low power (LP) RAN node 712.

[0067] Any of the RAN nodes 711 and 712 can terminate the air interface protocol and can be the first point of contact for the UEs 701 and 702. In some embodiments, any of the RAN nodes 711 and 712 can fulfill various logical functions for the RAN 710

including, but not limited to, radio network controller (RNC) functions such as radio bearer management, uplink and downlink dynamic radio resource management and data packet scheduling, and mobility management.

[0068] In accordance with some embodiments, the UEs 701 and 702 can be configured to communicate using Orthogonal Frequency-Division Multiplexing (OFDM) communication signals with each other or with any of the RAN nodes 711 and 712 over a multicarrier communication channel in accordance various communication techniques, such as, but not limited to, an Orthogonal Frequency-Division Multiple Access (OFDMA) communication technique (e.g., for downlink communications) or a Single Carrier Frequency Division Multiple Access (SC-FDMA) communication technique (e.g., for uplink and ProSe or sidelink communications), although the scope of the embodiments is not limited in this respect. The OFDM signals can comprise a plurality of orthogonal subcarriers.

[0069] In some embodiments, a downlink resource grid can be used for downlink transmissions from any of the RAN nodes 711 and 712 to the UEs 701 and 702, while uplink transmissions can utilize similar techniques. The grid can be a time-frequency grid, called a resource grid or time-frequency resource grid, which is the physical resource in the downlink in each slot. Such a time-frequency plane representation is a common practice for OFDM systems, which makes it intuitive for radio resource allocation. Each column and each row of the resource grid corresponds to one OFDM symbol and one OFDM subcarrier, respectively. The duration of the resource grid in the time domain corresponds to one slot in a radio frame. The smallest time-frequency unit in a resource grid is denoted as a resource element. Each resource grid comprises a number of resource blocks, which describe the mapping of certain physical channels to resource elements. Each resource block comprises a collection of resource elements; in the frequency domain, this may represent the smallest quantity of resources that currently can be allocated. There are several different physical downlink channels that are conveyed using such resource blocks.

[0070] The physical downlink shared channel (PDSCH) may carry user data and higher-layer signaling to the UEs 701 and 702. The physical downlink control channel (PDCCH) may carry information about the transport format and resource allocations

related to the PDSCH channel, among other things. It may also inform the UEs 701 and 702 about the transport format, resource allocation, and H-ARQ (Hybrid Automatic Repeat Request) information related to the uplink shared channel. Typically, downlink scheduling (assigning control and shared channel resource blocks to the UE 702 within a cell) may be performed at any of the RAN nodes 711 and 712 based on channel quality information fed back from any of the UEs 701 and 702. The downlink resource assignment information may be sent on the PDCCH used for (e.g., assigned to) each of the UEs 701 and 702.

[0071] The PDCCH may use control channel elements (CCEs) to convey the control information. Before being mapped to resource elements, the PDCCH complex-valued symbols may first be organized into quadruplets, which may then be permuted using a sub-block interleaver for rate matching. Each PDCCH may be transmitted using one or more of these CCEs, where each CCE may correspond to nine sets of four physical resource elements known as resource element groups (REGs). Four Quadrature Phase Shift Keying (QPSK) symbols may be mapped to each REG. The PDCCH can be transmitted using one or more CCEs, depending on the size of the downlink control information (DCI) and the channel condition. There can be four or more different PDCCH formats defined in LTE with different numbers of CCEs (e.g., aggregation level, L=1, 2, 4, or 8).

[0072] Some embodiments may use concepts for resource allocation for control channel information that are an extension of the above-described concepts. For example, some embodiments may utilize an enhanced physical downlink control channel (EPDCCH) that uses PDSCH resources for control information transmission. The EPDCCH may be transmitted using one or more enhanced the control channel elements (ECCEs). Similar to above, each ECCE may correspond to nine sets of four physical resource elements known as an enhanced resource element groups (EREGs). An ECCE may have other numbers of EREGs in some situations.

[0073] The RAN 710 is shown to be communicatively coupled to a core network (CN) 720 —via an S1 interface 713. In embodiments, the CN 720 may be an evolved packet core (EPC) network, a NextGen Packet Core (NPC) network, or some other type of CN. In this embodiment the S1 interface 713 is split into two parts: the S1-U interface 714,

which carries traffic data between the RAN nodes 711 and 712 and the serving gateway (S-GW) 722, and the S1-mobility management entity (MME) interface 715, which is a signaling interface between the RAN nodes 711 and 712 and MMEs 721.

[0074] In this embodiment, the CN 720 comprises the MMEs 721, the S-GW 722, the Packet Data Network (PDN) Gateway (P-GW) 723, and a home subscriber server (HSS) 724. The MMEs 721 may be similar in function to the control plane of legacy Serving General Packet Radio Service (GPRS) Support Nodes (SGSN). The MMEs 721 may manage mobility aspects in access such as gateway selection and tracking area list management. The HSS 724 may comprise a database for network users, including subscription-related information to support the network entities' handling of communication sessions. The CN 720 may comprise one or several HSSs 724, depending on the number of mobile subscribers, on the capacity of the equipment, on the organization of the network, etc. For example, the HSS 724 can provide support for routing/roaming, authentication, authorization, naming/addressing resolution, location dependencies, etc.

[0075] The S-GW 722 may terminate the S1 interface 713 towards the RAN 710, and routes data packets between the RAN 710 and the CN 720. In addition, the S-GW 722 may be a local mobility anchor point for inter-RAN node handovers and also may provide an anchor for inter-3GPP mobility. Other responsibilities may include lawful intercept, charging, and some policy enforcement.

[0076] The P-GW 723 may terminate an SGi interface toward a PDN. The P-GW 723 may route data packets between the EPC network 723 and external networks such as a network including the application server 730 (alternatively referred to as application function (AF)) via an Internet Protocol (IP) interface 725. Generally, the application server 730 may be an element offering applications that use IP bearer resources with the core network (e.g., UMTS Packet Services (PS) domain, LTE PS data services, etc.). In this embodiment, the P-GW 723 is shown to be communicatively coupled to an application server 730 via an IP communications interface 725. The application server 730 can also be configured to support one or more communication services (e.g., Voice-over-Internet Protocol (VoIP) sessions, PTT sessions, group communication sessions, social networking services, etc.) for the UEs 701 and 702 via the CN 720.

[0077] The P-GW 723 may further be a node for policy enforcement and charging data collection. Policy and Charging Enforcement Function (PCRF) 726 is the policy and charging control element of the CN 720. In a non-roaming scenario, there may be a single PCRF in the Home Public Land Mobile Network (HPLMN) associated with a UE's Internet Protocol Connectivity Access Network (IP-CAN) session. In a roaming scenario with local breakout of traffic, there may be two PCRFs associated with a UE's IP-CAN session: a Home PCRF (H-PCRF) within a HPLMN and a Visited PCRF (V-PCRF) within a Visited Public Land Mobile Network (VPLMN). The PCRF 726 may be communicatively coupled to the application server 730 via the P-GW 723. The application server 730 may signal the PCRF 726 to indicate a new service flow and select the appropriate Quality of Service (QoS) and charging parameters. The PCRF 726 may provision this rule into a Policy and Charging Enforcement Function (PCEF) (not shown) with the appropriate traffic flow template (TFT) and QoS class of identifier (QCI), which commences the QoS and charging as specified by the application server 730.

[0078] FIG. 8 illustrates example components of a device 800 in accordance with some embodiments. In some embodiments, the device 800 may include application circuitry 802, baseband circuitry 804, Radio Frequency (RF) circuitry 806, front-end module (FEM) circuitry 808, one or more antennas 810, and power management circuitry (PMC) 812 coupled together at least as shown. The components of the illustrated device 800 may be included in a UE or a RAN node. In some embodiments, the device 800 may include less elements (e.g., a RAN node may not utilize application circuitry 802, and instead include a processor/controller to process IP data received from an EPC). In some embodiments, the device 800 may include additional elements such as, for example, memory/storage, display, camera, sensor, or input/output (I/O) interface. In other embodiments, the components described below may be included in more than one device (e.g., said circuitries may be separately included in more than one device for Cloud-RAN (C-RAN) implementations).

[0079] The application circuitry 802 may include one or more application processors. For example, the application circuitry 802 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 or may include memory/storage and may be configured to execute instructions stored in the memory/storage to enable various applications or operating systems to run on the device 800. In some embodiments, processors of application circuitry 802 may process IP data packets received from an EPC.

[0080] The baseband circuitry 804 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 804 may include one or more baseband processors or control logic to process baseband signals received from a receive signal path of the RF circuitry 806 and to generate baseband signals for a transmit signal path of the RF circuitry 806. Baseband processing circuity 804 may interface with the application circuitry 802 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 806. For example, in some embodiments, the baseband circuitry 804 may include a third generation (3G) baseband processor 804a, a fourth generation (4G) baseband processor 804b, a fifth generation (5G) baseband processor 804c, or other baseband processor(s) 804d for other existing generations, generations in development or to be developed in the future (e.g., second generation (2G), sixth generation (6G), etc.). The baseband circuitry 804 (e.g., one or more of baseband processors 804a-d) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 806. In other embodiments, some or all of the functionality of baseband processors 804a-d may be included in modules stored in the memory 804g and executed via a Central Processing Unit (CPU) 804e. 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 804 may include Fast-Fourier Transform (FFT), precoding, or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 804 may include convolution, tail-biting convolution, turbo, Viterbi, 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.

[0081] In some embodiments, the baseband circuitry 804 may include one or more audio

digital signal processor(s) (DSP) 804f. The audio DSP(s) 804f 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 804 and the application circuitry 802 may be implemented together such as, for example, on a system on a chip (SOC).

[0082] In some embodiments, the baseband circuitry 804 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 804 may support communication with an evolved universal terrestrial radio access network (EUTRAN) 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 804 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

[0083] RF circuitry 806 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 806 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 806 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 808 and provide baseband signals to the baseband circuitry 804. RF circuitry 806 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 804 and provide RF output signals to the FEM circuitry 808 for transmission.

[0084] In some embodiments, the receive signal path of the RF circuitry 806 may include mixer circuitry 806a, amplifier circuitry 806b and filter circuitry 806c. In some embodiments, the transmit signal path of the RF circuitry 806 may include filter circuitry 806c and mixer circuitry 806a. RF circuitry 806 may also include synthesizer circuitry 806d for synthesizing a frequency for use by the mixer circuitry 806a of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 806a of the receive signal path may be configured to down-convert RF signals received from the

FEM circuitry 808 based on the synthesized frequency provided by synthesizer circuitry 806d. The amplifier circuitry 806b may be configured to amplify the down-converted signals and the filter circuitry 806c 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 804 for further processing. In some embodiments, the output baseband signals may be zero-frequency baseband signals, although this is not a necessity. In some embodiments, mixer circuitry 806a of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[0085] In some embodiments, the mixer circuitry 806a of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 806d to generate RF output signals for the FEM circuitry 808. The baseband signals may be provided by the baseband circuitry 804 and may be filtered by filter circuitry 806c.

[0086] In some embodiments, the mixer circuitry 806a of the receive signal path and the mixer circuitry 806a of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and upconversion, respectively. In some embodiments, the mixer circuitry 806a of the receive signal path and the mixer circuitry 806a 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 806a of the receive signal path and the mixer circuitry 806a may be arranged for direct downconversion and direct upconversion, respectively. In some embodiments, the mixer circuitry 806a of the receive signal path and the mixer circuitry 806a of the transmit signal path may be configured for super-heterodyne operation.

[0087] 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 806 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 804 may include a digital baseband interface to communicate with the RF circuitry 806.

[0088] 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.

[0089] In some embodiments, the synthesizer circuitry 806d 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 806d may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[0090] The synthesizer circuitry 806d may be configured to synthesize an output frequency for use by the mixer circuitry 806a of the RF circuitry 806 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 806d may be a fractional N/N+1 synthesizer.

[0091] In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although that is not a necessity. Divider control input may be provided by either the baseband circuitry 804 or the applications processor 802 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 802.

[0092] Synthesizer circuitry 806d of the RF circuitry 806 may include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider may be a dual modulus divider (DMD) and the phase accumulator may be a digital phase accumulator (DPA). In some embodiments, the DMD may be configured to divide the input signal by either N or N+1 (e.g., based on a carry out) to provide a fractional division ratio. In some example embodiments, the DLL may include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-flop. In these embodiments, the delay elements may be configured to break a VCO period up into Nd equal packets of phase, where Nd is the number of delay elements in the delay line. In this way, the DLL provides negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

[0093] In some embodiments, synthesizer circuitry 806d 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 806 may include an IQ/polar converter.

[0094] FEM circuitry 808 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 810, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 806 for further processing. FEM circuitry 808 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 806 for transmission by one or more of the one or more antennas 810. In various embodiments, the amplification through the transmit or receive signal paths may be done solely in the RF circuitry 806, solely in the FEM 808, or in both the RF circuitry 806 and the FEM 808.

[0095] In some embodiments, the FEM circuitry 808 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 an LNA to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 806). The transmit signal path of the FEM circuitry 808 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 806), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 810).

[0096] In some embodiments, the PMC 812 may manage power provided to the baseband circuitry 804. In particular, the PMC 812 may control power-source selection, voltage scaling, battery charging, or DC-to-DC conversion. The PMC 812 may often be included when the device 800 is capable of being powered by a battery, for example, when the device is included in a UE. The PMC 812 may increase the power conversion efficiency while providing desirable implementation size and heat dissipation characteristics.

[0097] While FIG. 8 shows the PMC 812 coupled only with the baseband circuitry 804. However, in other embodiments, the PMC 8 12 may be additionally or alternatively coupled with, and perform similar power management operations for, other components such as, but not limited to, application circuitry 802, RF circuitry 806, or FEM 808.

[0098] In some embodiments, the PMC 812 may control, or otherwise be part of, various power saving mechanisms of the device 800. For example, if the device 800 is in an RRC_Connected state, where it is still connected to the RAN node as it expects to receive traffic shortly, then it may enter a state known as Discontinuous Reception Mode (DRX) after a period of inactivity. During this state, the device 800 may power down for brief intervals of time and thus save power.

[0099] If there is no data traffic activity for an extended period of time, then the device 800 may transition off to an RRC_Idle state, where it disconnects from the network and does not perform operations such as channel quality feedback, handover, etc. The device 800 goes into a very low power state and it performs paging where again it periodically wakes up to listen to the network and then powers down again. The device 800 may not receive data in this state, in order to receive data, it can transition back to RRC_Connected state.

[00100] An additional power saving mode may allow a device to be unavailable to the network for periods longer than a paging interval (ranging from seconds to a few hours). During this time, the device is totally unreachable to the network and may power down completely. Any data sent during this time incurs a large delay and it is assumed the delay is acceptable.

[00101] Processors of the application circuitry 802 and processors of the baseband circuitry 804 may be used to execute elements of one or more instances of a protocol stack. For example, processors of the baseband circuitry 804, alone or in combination, may be used execute Layer 3, Layer 2, or Layer 1 functionality, while processors of the application circuitry 804 may utilize data (e.g., packet data) received from these layers and further execute Layer 4 functionality (e.g., transmission communication protocol (TCP) and user datagram protocol (UDP) layers). As referred to herein, Layer 3 may comprise a radio resource control (RRC) layer, described in further detail below. As referred to herein, Layer 2 may comprise a medium access control (MAC) layer, a radio

link control (RLC) layer, and a packet data convergence protocol (PDCP) layer, described in further detail below. As referred to herein, Layer 1 may comprise a physical (PHY) layer of a UE/RAN node, described in further detail below.

[00102] FIG. 9 illustrates example interfaces of baseband circuitry in accordance with some embodiments. As discussed above, the baseband circuitry 804 of FIG. 8 may comprise processors 804a-804e and a memory 804g utilized by said processors. Each of the processors 804a-804e may include a memory interface, 904a-904e, respectively, to send/receive data to/from the memory 804g.

[00103] The baseband circuitry 804 may further include one or more interfaces to communicatively couple to other circuitries/devices, such as a memory interface 912 (e.g., an interface to send/receive data to/from memory external to the baseband circuitry 804), an application circuitry interface 914 (e.g., an interface to send/receive data to/from the application circuitry 802 of FIG. 8), an RF circuitry interface 916 (e.g., an interface to send/receive data to/from RF circuitry 806 of FIG. 8), a wireless hardware connectivity interface 918 (e.g., an interface to send/receive data to/from Near Field Communication (NFC) components, Bluetooth® components (e.g., Bluetooth® Low Energy), Wi-Fi® components, and other communication components), and a power management interface 920 (e.g., an interface to send/receive power or control signals to/from the PMC 812.

[00104] FIG. 10 provides an example illustration of the wireless device, such as a user equipment (UE), a mobile station (MS), a mobile wireless device, a mobile communication device, a tablet, a handset, or other type of wireless device. The wireless device can include one or more antennas configured to communicate with a node, macro node, low power node (LPN), or, transmission station, such as a base station (BS), an evolved Node B (eNB), a baseband processing unit (BBU), a remote radio head (RRH), a remote radio equipment (RRE), a relay station (RS), a radio equipment (RE), or other type of wireless wide area network (WWAN) access point. The wireless device can be configured to communicate using at least one wireless communication standard such as, but not limited to, 3GPP LTE, WiMAX, High Speed Packet Access (HSPA), Bluetooth, and WiFi. The wireless device can communicate using separate antennas for each wireless communication standard or shared antennas for multiple wireless communication standards. The wireless device can communicate in a wireless local area network

(WLAN), a wireless personal area network (WPAN), and/or a WWAN. The wireless device can also comprise a wireless modem. The wireless modem can comprise, for example, a wireless radio transceiver and baseband circuitry (e.g., a baseband processor). The wireless modem can, in one example, modulate signals that the wireless device transmits via the one or more antennas and demodulate signals that the wireless device receives via the one or more antennas.

[00105] FIG. 10 also provides an illustration of a microphone and one or more speakers that can be used for audio input and output from the wireless device. The display screen can be a liquid crystal display (LCD) screen, or other type of display screen such as an organic light emitting diode (OLED) display. The display screen can be configured as a touch screen. The touch screen can use capacitive, resistive, or another type of touch screen technology. An application processor and a graphics processor can be coupled to internal memory to provide processing and display capabilities. A non-volatile memory port can also be used to provide data input/output options to a user. The non-volatile memory port can also be used to expand the memory capabilities of the wireless device. A keyboard can be integrated with the wireless device or wirelessly connected to the wireless device to provide additional user input. A virtual keyboard can also be provided using the touch screen.

Examples

[00106] The following examples pertain to specific technology embodiments and point out specific features, elements, or actions that can be used or otherwise combined in achieving such embodiments.

[00107] Example 1 includes an apparatus of an eNodeB operable to encode downlink control information for transmission to a user equipment (UE), the apparatus comprising: one or more processors configured to: decode, at the eNodeB, an autonomous physical uplink shared channel (PUSCH) transmission received from the UE when a channel between the eNodeB and the UE is sensed to be idle based on a listen before talk (LBT) procedure, wherein the autonomous PUSCH transmission is received from the UE without an explicit uplink grant from the eNodeB; and encode, at the eNodeB, downlink control information for transmission from the eNodeB to the UE over a physical downlink control channel (PDCCH) in response to the autonomous PUSCH transmission

that is received from the UE, wherein the downlink control information includes an acknowledgement (ACK) feedback or a negative acknowledgement (NACK) feedback; and a memory interface configured to retrieve from a memory the downlink control information.

[00108] Example 2 includes the apparatus of Example 1, further comprising a transceiver configured to: receive the autonomous PUSCH transmission from the UE; and transmit the downlink control information to the UE.

[00109] Example 3 includes the apparatus of any of Examples 1 to 2, wherein the one or more processors are further configured to encode an uplink retransmission grant for transmission to the UE using downlink control information (DCI) format 0/4/0A/4A when the eNodeB is unable to successfully decode the autonomous PUSCH transmission received from the UE, wherein the uplink retransmission grant is sent to the UE when the downlink control information transmitted to the UE includes the NACK feedback for the autonomous PUSCH transmission.

[00110] Example 4 includes the apparatus of any of Examples 1 to 3, wherein the one or more processors are further configured to encode the downlink control information that includes the ACK/NACK feedback for transmission to the UE in a UE specific search space using a new downlink control information (DCI) format.

[00111] Example 5 includes the apparatus of any of Examples 1 to 4, wherein the one or more processors are further configured to encode the ACK/NACK feedback for transmission to the UE in an uplink grant or a downlink grant of the downlink control information, wherein: the uplink grant includes a grant to schedule an autonomous PUSCH retransmission from the UE when the downlink control information includes the NACK feedback; or the downlink grant enables the UE to perform the autonomous PUSCH retransmission from the UE at a next opportunity when the downlink control information includes the NACK feedback.

[00112] Example 6 includes the apparatus of any of Examples 1 to 5, wherein the one or more processors are further configured to: encode a periodic configuration for transmission to the UE that includes periodic opportunities for the eNodeB to send the downlink control information to the UE over the PDCCH, wherein the periodic

configuration instructs the UE to blank a PUSCH transmission for a predefined interval that coincides with one of the periodic opportunities indicated in the periodic configuration; and encode the downlink control information for transmission to the UE over the PDCCH on the blanked PUSCH transmission, wherein the periodic configuration is transmitted to the UE via radio resource control (RRC) signaling or via a system information block (SIB) transmission, wherein the periodic configuration includes: a PUSCH blanking periodicity in terms of a number of subframes, and a PUSCH blanking interval of one or more subframes or one or more symbols.

[00113] Example 7 includes the apparatus of any of Examples 1 to 6, wherein the one or more processors are configured to encode the downlink control information for transmission to the UE over the PDCCH within a maximum channel occupancy time (MCOT) reserved by the UE, wherein the downlink control information is transmitted over the PDCCH without an LBT procedure being performed at the eNodeB when a gap between an ending of the autonomous PUSCH transmission and a transmission of the downlink control information over the PDCCH is within a defined time duration within the MCOT.

[00114] Example 8 includes the apparatus of any of Examples 1 to 7, wherein the one or more processors are configured to: decode maximum channel occupancy time (MCOT) information received from the UE in an uplink burst from the UE, wherein the MCOT information includes a total length of a MCOT and a remaining length of the MCOT; or decode a LBT priority received from the UE in uplink control information (UCI), wherein the LBT priority is used for a channel reservation at the UE; and determine the MCOT reserved by the UE based on the MCOT information or the LBT priority.

[00115] Example 9 includes the apparatus of any of Examples 1 to 8, wherein the one or more processors are configured to: encode the downlink control information for transmission to the UE over the PDCCH after performing no LBT or a single-interval LBT procedure when the downlink control information is transmitted over the PDCCH within a transmission opportunity (TXoP) reserved by the eNodeB or the UE; or encode the downlink control information for transmission to the UE over the PDCCH after performing a Category 4 LBT procedure when the downlink control information is transmitted over the PDCCH outside a TXoP reserved by the eNodeB or the UE.

[00116] Example 10 includes an apparatus of a user equipment (UE) operable to perform autonomous uplink transmissions with an eNodeB, the apparatus comprising: one or more processors configured to: perform, at the UE, a listen before talk (LBT) procedure to sense a channel between the UE and the eNodeB; encode, at the UE, an autonomous physical uplink shared channel (PUSCH) transmission for delivery to the eNodeB when the channel between the UE and the eNodeB is sensed to be idle based on the LBT procedure, wherein the autonomous PUSCH transmission is sent from the UE without an explicit uplink grant from the eNodeB; and decode, at the UE, downlink control information received from the eNodeB over a physical downlink control channel (PDCCH) in response to the autonomous PUSCH transmission that is sent from the UE to the eNodeB, wherein the downlink control information includes an acknowledgement (ACK) feedback or a negative acknowledgement (NACK) feedback; and a memory interface configured to retrieve from a memory the autonomous PUSCH transmission.

[00117] Example 11 includes the apparatus of Example 10, wherein the one or more processors are further configured to decode an uplink retransmission grant received from the eNodeB using downlink control information (DCI) format 0/4/0A/4A, wherein the uplink retransmission grant is received at the UE when the autonomous PUSCH transmission is unable to be decoded at the eNodeB, wherein the uplink retransmission grant is received at the UE when the downlink control information includes the NACK feedback for the autonomous PUSCH transmission.

[00118] Example 12 includes the apparatus of any of Examples 10 to 11, wherein the one or more processors are further configured to decode the downlink control information that includes the ACK/NACK feedback received from the eNodeB in a UE specific search space using a new downlink control information (DCI) format.

[00119] Example 13 includes the apparatus of any of Examples 10 to 12, wherein the one or more processors are further configured to: decode an uplink grant received from the eNodeB to schedule an autonomous PUSCH retransmission when the downlink control information includes the NACK feedback; and encode the autonomous PUSCH retransmission for delivery to the eNodeB after receiving the uplink grant from the eNodeB.

[00120] Example 14 includes the apparatus of any of Examples 10 to 13, wherein the

one or more processors are further configured to encode an autonomous PUSCH retransmission for delivery to the eNodeB when the downlink control information includes the NACK feedback.

[00121] Example 15 includes the apparatus of any of Examples 10 to 14, wherein the one or more processors are further configured to decode the ACK/NACK feedback received from the eNodeB in an uplink grant or a downlink grant of the downlink control information, wherein: the uplink grant includes a grant to schedule an autonomous PUSCH retransmission from the UE when the downlink control information includes the NACK feedback; or the downlink grant enables the UE to perform the autonomous PUSCH retransmission from the UE at a next opportunity when the downlink control information includes the NACK feedback

[00122] Example 16 includes the apparatus of any of Examples 10 to 15, wherein the one or more processors are further configured to: decode a periodic configuration received from the eNodeB that includes periodic opportunities for the eNodeB to send the downlink control information to the UE over the PDCCH; blank a PUSCH transmissions for a predefined interval that coincides with one of the periodic opportunities indicated in the periodic configuration; and decode the downlink control information received from the eNodeB over the PDCCH on the blanked PUSCH transmission, wherein the periodic configuration is received at the UE via radio resource control (RRC) signaling or a system information block (SIB) transmission, wherein the periodic configuration includes: a PUSCH blanking periodicity in terms of a number of subframes, and a PUSCH blanking interval of one or more subframes or one or more symbols.

[00123] Example 17 includes the apparatus of any of Examples 10 to 16, wherein the one or more processors are further configured to: perform a second LBT procedure at the UE and reserve a channel for a maximum channel occupancy time (MCOT); and decode the downlink control information received from the eNodeB over the PDCCH within the MCOT reserved by the UE, wherein the downlink control information is received at the UE over the PDCCH without an LBT procedure being performed at the eNodeB when a gap between an ending of the autonomous PUSCH transmission and a transmission of the downlink control information over the PDCCH is within a defined time duration within the MCOT.

[00124] Example 18 includes the apparatus of any of Examples 10 to 17, wherein the one or more processors are configured to: encode maximum channel occupancy time (MCOT) information for transmission to the eNodeB in an uplink burst from the UE, wherein the MCOT information includes a total length of a MCOT and a remaining length of the MCOT; and encode a LBT priority for transmission to the eNodeB in uplink control information (UCI), wherein the LBT priority is used for a channel reservation at the UE, wherein the MCOT information or the LBT priority enables the eNodeB to determine the MCOT reserved by the UE.

[00125] Example 19 includes at least one machine readable storage medium having instructions embodied thereon for encoding downlink control information for transmission from an eNodeB to a user equipment (UE), the instructions when executed by one or more processors of the eNodeB perform the following: decoding, at the eNodeB, an autonomous physical uplink shared channel (PUSCH) transmission received from the UE when a channel between the eNodeB and the UE is sensed to be idle based on a listen before talk (LBT) procedure, wherein the autonomous PUSCH transmission is received from the UE without an explicit uplink grant from the eNodeB; and encoding, at the eNodeB, downlink control information for transmission from the eNodeB to the UE over a physical downlink control channel (PDCCH) in response to the autonomous PUSCH transmission that is received from the UE, wherein the downlink control information includes an acknowledgement (ACK) feedback or a negative acknowledgement (NACK) feedback.

[00126] Example 20 includes the at least one machine readable storage medium of Example 19, further comprising instructions when executed perform the following: encoding an uplink retransmission grant for transmission to the UE using downlink control information (DCI) format 0/4/0A/4A when the eNodeB is unable to successfully decode the autonomous PUSCH transmission received from the UE, wherein the uplink retransmission grant is sent to the UE when the downlink control information transmitted to the UE includes the NACK feedback for the autonomous PUSCH transmission; and decoding an autonomous PUSCH retransmission received from the UE after the uplink retransmission grant is transmitted from the eNodeB to the UE.

[00127] Example 21 includes the at least one machine readable storage medium of any

of Examples 19 to 20, further comprising instructions when executed perform the following: encoding the downlink control information that includes the ACK/NACK feedback for transmission to the UE in a UE specific search space using a new downlink control information (DCI) format.

[00128] Example 22 includes the at least one machine readable storage medium of any of Examples 19 to 21, further comprising instructions when executed perform the following: encoding the ACK/NACK feedback for transmission to the UE in an uplink grant or a downlink grant of the downlink control information, wherein: the uplink grant includes a grant to schedule an autonomous PUSCH retransmission from the UE when the downlink control information includes the NACK feedback; or the downlink grant enables the UE to perform the autonomous PUSCH retransmission from the UE at a next opportunity when the downlink control information includes the NACK feedback.

[00129] Example 23 includes the at least one machine readable storage medium of any of Examples 19 to 22, further comprising instructions when executed perform the following: encoding a periodic configuration for transmission to the UE that includes periodic opportunities for the eNodeB to send the downlink control information to the UE over the PDCCH, wherein the periodic configuration instructs the UE to blank a PUSCH transmission for a predefined interval that coincides with one of the periodic opportunities indicated in the periodic configuration; and encoding the downlink control information for transmission to the UE over the PDCCH on the blanked PUSCH transmission, wherein the periodic configuration is transmitted to the UE via radio resource control (RRC) signaling or via a system information block (SIB) transmission, wherein the periodic configuration includes: a PUSCH blanking periodicity in terms of a number of subframes, and a PUSCH blanking interval of one or more subframes or one or more symbols.

[00130] Example 24 includes the at least one machine readable storage medium of any of Examples 19 to 23, further comprising instructions when executed perform the following: decoding maximum channel occupancy time (MCOT) information received from the UE in an uplink burst from the UE, wherein the MCOT information includes a total length of a MCOT and a remaining length of the MCOT; decoding a LBT priority received from the UE in uplink control information (UCI), wherein the LBT priority is

used for a channel reservation at the UE; determining the MCOT reserved by the UE based on the MCOT information or the LBT priority; and encoding the downlink control information for transmission to the UE over the PDCCH within the MCOT reserved by the UE, wherein the downlink control information is transmitted over the PDCCH without an LBT procedure being performed at the eNodeB when a gap between an ending of the autonomous PUSCH transmission and a transmission of the downlink control information over the PDCCH is within a defined time duration within the MCOT.

[00131] Example 25 includes the at least one machine readable storage medium of any of Examples 19 to 24, further comprising instructions when executed perform the following: encoding the downlink control information for transmission to the UE over the PDCCH after performing no LBT or a single-interval LBT procedure when the downlink control information is transmitted over the PDCCH within a transmission opportunity (TXoP) reserved by the eNodeB or the UE; or encoding the downlink control information for transmission to the UE over the PDCCH after performing a Category 4 LBT procedure when the downlink control information is transmitted over the PDCCH outside a TXoP reserved by the eNodeB or the UE.

[00132] Example 26 includes an eNodeB operable to encode downlink control information for transmission to a user equipment (UE), the eNodeB comprising: means for decoding, at the eNodeB, an autonomous physical uplink shared channel (PUSCH) transmission received from the UE when a channel between the eNodeB and the UE is sensed to be idle based on a listen before talk (LBT) procedure, wherein the autonomous PUSCH transmission is received from the UE without an explicit uplink grant from the eNodeB; and means for encoding, at the eNodeB, downlink control information for transmission from the eNodeB to the UE over a physical downlink control channel (PDCCH) in response to the autonomous PUSCH transmission that is received from the UE, wherein the downlink control information includes an acknowledgement (ACK) feedback or a negative acknowledgement (NACK) feedback.

[00133] Example 27 includes the eNodeB of Example 26, further comprising: means for encoding an uplink retransmission grant for transmission to the UE using downlink control information (DCI) format 0/4/0A/4A when the eNodeB is unable to successfully decode the autonomous PUSCH transmission received from the UE, wherein the uplink

retransmission grant is sent to the UE when the downlink control information transmitted to the UE includes the NACK feedback for the autonomous PUSCH transmission; and means for decoding an autonomous PUSCH retransmission received from the UE after the uplink retransmission grant is transmitted from the eNodeB to the UE.

[00134] Example 28 includes the eNodeB of any of Examples 26 to 27, further comprising: means for encoding the downlink control information that includes the ACK/NACK feedback for transmission to the UE in a UE specific search space using a new downlink control information (DCI) format.

[00135] Example 29 includes the eNodeB of any of Examples 26 to 28, further comprising: means for encoding the ACK/NACK feedback for transmission to the UE in an uplink grant or a downlink grant of the downlink control information, wherein: the uplink grant includes a grant to schedule an autonomous PUSCH retransmission from the UE when the downlink control information includes the NACK feedback; or the downlink grant enables the UE to perform the autonomous PUSCH retransmission from the UE at a next opportunity when the downlink control information includes the NACK feedback.

[00136] Example 30 includes the eNodeB of any of Examples 26 to 29, further comprising: means for encoding a periodic configuration for transmission to the UE that includes periodic opportunities for the eNodeB to send the downlink control information to the UE over the PDCCH, wherein the periodic configuration instructs the UE to blank a PUSCH transmission for a predefined interval that coincides with one of the periodic opportunities indicated in the periodic configuration; and means for encoding the downlink control information for transmission to the UE over the PDCCH on the blanked PUSCH transmission, wherein the periodic configuration is transmitted to the UE via radio resource control (RRC) signaling or via a system information block (SIB) transmission, wherein the periodic configuration includes: a PUSCH blanking periodicity in terms of a number of subframes, and a PUSCH blanking interval of one or more subframes or one or more symbols.

[00137] Example 31 includes the eNodeB of any of Examples 26 to 30, further comprising: means for decoding maximum channel occupancy time (MCOT) information received from the UE in an uplink burst from the UE, wherein the MCOT information

includes a total length of a MCOT and a remaining length of the MCOT; means for decoding a LBT priority received from the UE in uplink control information (UCI), wherein the LBT priority is used for a channel reservation at the UE; means for determining the MCOT reserved by the UE based on the MCOT information or the LBT priority; and means for encoding the downlink control information for transmission to the UE over the PDCCH within the MCOT reserved by the UE, wherein the downlink control information is transmitted over the PDCCH without an LBT procedure being performed at the eNodeB when a gap between an ending of the autonomous PUSCH transmission and a transmission of the downlink control information over the PDCCH is within a defined time duration within the MCOT.

[00138] Example 32 includes the eNodeB of any of Examples 26 to 31, further comprising: means for encoding the downlink control information for transmission to the UE over the PDCCH after performing no LBT or a single-interval LBT procedure when the downlink control information is transmitted over the PDCCH within a transmission opportunity (TXoP) reserved by the eNodeB or the UE; or means for encoding the downlink control information for transmission to the UE over the PDCCH after performing a Category 4 LBT procedure when the downlink control information is transmitted over the PDCCH outside a TXoP reserved by the eNodeB or the UE.

[00139] Various techniques, or certain aspects or portions thereof, may take the form of program code (i.e., instructions) embodied in tangible media, such as floppy diskettes, compact disc-read-only memory (CD-ROMs), hard drives, non-transitory computer readable storage medium, or any other machine-readable storage medium wherein, when the program code is loaded into and executed by a machine, such as a computer, the machine becomes an apparatus for practicing the various techniques. In the case of program code execution on programmable computers, the computing device may include a processor, a storage medium readable by the processor (including volatile and non-volatile memory and/or storage elements), at least one input device, and at least one output device. The volatile and non-volatile memory and/or storage elements may be a random-access memory (RAM), erasable programmable read only memory (EPROM), flash drive, optical drive, magnetic hard drive, solid state drive, or other medium for storing electronic data. The node and wireless device may also include a transceiver

module (i.e., transceiver), a counter module (i.e., counter), a processing module (i.e., processor), and/or a clock module (i.e., clock) or timer module (i.e., timer). In one example, selected components of the transceiver module can be located in a cloud radio access network (C-RAN). One or more programs that may implement or utilize the various techniques described herein may use an application programming interface (API), reusable controls, and the like. Such programs may be implemented in a high level procedural or object oriented programming language to communicate with a computer system. However, the program(s) may be implemented in assembly or machine language, if desired. In any case, the language may be a compiled or interpreted language, and combined with hardware implementations.

[00140] 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.

[00141] It should be understood that many of the functional units described in this specification have been labeled as modules, in order to more particularly emphasize their implementation independence. For example, a module may be implemented as a hardware circuit comprising custom very-large-scale integration (VLSI) circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. A module may also be implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices or the like.

[00142] Modules may also be implemented in software for execution by various types of processors. An identified module of executable code may, for instance, comprise one or more physical or logical blocks of computer instructions, which may, for instance, be organized as an object, procedure, or function. Nevertheless, the executables of an identified module may not be physically located together, but may comprise disparate

instructions stored in different locations which, when joined logically together, comprise the module and achieve the stated purpose for the module.

[00143] Indeed, a module of executable code may be a single instruction, or many instructions, and may even be distributed over several different code segments, among different programs, and across several memory devices. Similarly, operational data may be identified and illustrated herein within modules, and may be embodied in any suitable form and organized within any suitable type of data structure. The operational data may be collected as a single data set, or may be distributed over different locations including over different storage devices, and may exist, at least partially, merely as electronic signals on a system or network. The modules may be passive or active, including agents operable to perform desired functions.

[00144] Reference throughout this specification to "an example" or "exemplary" means that a particular feature, structure, or characteristic described in connection with the example is included in at least one embodiment of the present technology. Thus, appearances of the phrases "in an example" or the word "exemplary" in various places throughout this specification are not necessarily all referring to the same embodiment.

[00145] As used herein, a plurality of items, structural elements, compositional elements, and/or materials may be presented in a common list for convenience. However, these lists should be construed as though each member of the list is individually identified as a separate and unique member. Thus, no individual member of such list should be construed as a de facto equivalent of any other member of the same list solely based on their presentation in a common group without indications to the contrary. In addition, various embodiments and example of the present technology may be referred to herein along with alternatives for the various components thereof. It is understood that such embodiments, examples, and alternatives are not to be construed as defacto equivalents of one another, but are to be considered as separate and autonomous representations of the present technology.

[00146] Furthermore, the described features, structures, or characteristics may be combined in any suitable manner in one or more embodiments. In the following description, numerous specific details are provided, such as examples of layouts, distances, network examples, etc., to provide a thorough understanding of embodiments

of the technology. One skilled in the relevant art will recognize, however, that the technology can be practiced without one or more of the specific details, or with other methods, components, layouts, etc. In other instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of the technology.

[00147] While the forgoing examples are illustrative of the principles of the present technology in one or more particular applications, it will be apparent to those of ordinary skill in the art that numerous modifications in form, usage and details of implementation can be made without the exercise of inventive faculty, and without departing from the principles and concepts of the technology.

CLAIMS

What is claimed is:

1. An apparatus of an eNodeB operable to encode downlink control information for transmission to a user equipment (UE), the apparatus comprising:

one or more processors configured to:

decode, at the eNodeB, an autonomous physical uplink shared channel (PUSCH) transmission received from the UE when a channel between the eNodeB and the UE is sensed to be idle based on a listen before talk (LBT) procedure, wherein the autonomous PUSCH transmission is received from the UE without an explicit uplink grant from the eNodeB; and

encode, at the eNodeB, downlink control information for transmission from the eNodeB to the UE over a physical downlink control channel (PDCCH) in response to the autonomous PUSCH transmission that is received from the UE, wherein the downlink control information includes an acknowledgement (ACK) feedback or a negative acknowledgement (NACK) feedback; and

a memory interface configured to retrieve from a memory the downlink control information.

2. The apparatus of claim 1, further comprising a transceiver configured to:

receive the autonomous PUSCH transmission from the UE; and

transmit the downlink control information to the UE.

3. The apparatus of claim 1, wherein the one or more processors are further configured to encode an uplink retransmission grant for transmission to the UE using downlink control information (DCI) format 0/4/0A/4A when the eNodeB is unable to successfully decode the autonomous PUSCH transmission received from the UE, wherein the uplink retransmission grant is sent to the UE when the downlink control information transmitted to the UE includes the NACK feedback for the autonomous PUSCH transmission.

4. The apparatus of any of claims 1 to 3, wherein the one or more processors are further configured to encode the downlink control information that includes the ACK/NACK feedback for transmission to the UE in a UE specific search space using a new downlink control information (DCI) format.

5. The apparatus of any of claims 1 to 3, wherein the one or more processors are further configured to encode the ACK/NACK feedback for transmission to the UE in an uplink grant or a downlink grant of the downlink control information, wherein:

the uplink grant includes a grant to schedule an autonomous PUSCH retransmission from the UE when the downlink control information includes the NACK feedback; or

the downlink grant enables the UE to perform the autonomous PUSCH retransmission from the UE at a next opportunity when the downlink control information includes the NACK feedback.

6. The apparatus of claim 1, wherein the one or more processors are further configured to:

encode a periodic configuration for transmission to the UE that includes periodic opportunities for the eNodeB to send the downlink control information to the UE over the PDCCH, wherein the periodic configuration instructs the UE to blank a PUSCH transmission for a predefined interval that coincides with one of the periodic opportunities indicated in the periodic configuration; and

encode the downlink control information for transmission to the UE over the PDCCH on the blanked PUSCH transmission,

wherein the periodic configuration is transmitted to the UE via radio resource control (RRC) signaling or via a system information block (SIB) transmission,

wherein the periodic configuration includes: a PUSCH blanking periodicity in terms of a number of subframes, and a PUSCH blanking interval of one or more subframes or one or more symbols.

7. The apparatus of claim 1, wherein the one or more processors are configured to encode the downlink control information for transmission to the UE over the PDCCH within a maximum channel occupancy time (MCOT) reserved by the UE, wherein the downlink control information is transmitted over the PDCCH without an LBT procedure being performed at the eNodeB when a gap between an ending of the autonomous PUSCH transmission and a transmission of the downlink control information over the PDCCH is within a defined time duration within the MCOT.

8. The apparatus of claim 1, wherein the one or more processors are configured to:

decode maximum channel occupancy time (MCOT) information received from the UE in an uplink burst from the UE, wherein the MCOT information includes a total length of a MCOT and a remaining length of the MCOT; or

decode a LBT priority received from the UE in uplink control information (UCI), wherein the LBT priority is used for a channel reservation at the UE; and

determine the MCOT reserved by the UE based on the MCOT information or the LBT priority.

9. The apparatus of claim 1, wherein the one or more processors are configured to:

encode the downlink control information for transmission to the UE over the PDCCH after performing no LBT or a single-interval LBT procedure when the downlink control information is transmitted over the PDCCH within a transmission opportunity (TXoP) reserved by the eNodeB or the UE; or

encode the downlink control information for transmission to the UE over the PDCCH after performing a Category 4 LBT procedure when the downlink control information is transmitted over the PDCCH outside a TXoP reserved by the eNodeB or the UE.

10. An apparatus of a user equipment (UE) operable to perform autonomous uplink transmissions with an eNodeB, the apparatus comprising:

one or more processors configured to:

perform, at the UE, a listen before talk (LBT) procedure to sense a channel between the UE and the eNodeB;

encode, at the UE, an autonomous physical uplink shared channel (PUSCH) transmission for delivery to the eNodeB when the channel between the UE and the eNodeB is sensed to be idle based on the LBT procedure, wherein the autonomous PUSCH transmission is sent from the UE without an explicit uplink grant from the eNodeB; and

decode, at the UE, downlink control information received from the eNodeB over a physical downlink control channel (PDCCH) in response to the autonomous PUSCH transmission that is sent from the UE to the eNodeB, wherein the downlink control information includes an acknowledgement (ACK) feedback or a negative acknowledgement (NACK) feedback; and

a memory interface configured to retrieve from a memory the autonomous PUSCH transmission.

11. The apparatus of claim 10, wherein the one or more processors are further configured to decode an uplink retransmission grant received from the eNodeB using downlink control information (DCI) format 0/4/0A/4A, wherein the uplink retransmission grant is received at the UE when the autonomous PUSCH transmission is unable to be decoded at the eNodeB, wherein the uplink retransmission grant is received at the UE when the downlink control information includes the NACK feedback for the autonomous PUSCH transmission.

12. The apparatus of claim 10, wherein the one or more processors are further configured to decode the downlink control information that includes the ACK/NACK feedback received from the eNodeB in a UE specific search space using a new downlink control information (DCI) format.

13. The apparatus of any of claims 10 to 12, wherein the one or more processors are further configured to:

decode an uplink grant received from the eNodeB to schedule an autonomous PUSCH retransmission when the downlink control information includes the NACK feedback; and

encode the autonomous PUSCH retransmission for delivery to the eNodeB after receiving the uplink grant from the eNodeB.

14. The apparatus of any of claims 10 to 12, wherein the one or more processors are further configured to encode an autonomous PUSCH retransmission for delivery to the eNodeB when the downlink control information includes the NACK feedback.

15. The apparatus of claim 10, wherein the one or more processors are further configured to decode the ACK/NACK feedback received from the eNodeB in an uplink grant or a downlink grant of the downlink control information, wherein:

the uplink grant includes a grant to schedule an autonomous PUSCH retransmission from the UE when the downlink control information includes the NACK feedback; or

the downlink grant enables the UE to perform the autonomous PUSCH retransmission from the UE at a next opportunity when the downlink control information includes the NACK feedback

16. The apparatus of claim 10, wherein the one or more processors are further configured to:

decode a periodic configuration received from the eNodeB that includes periodic opportunities for the eNodeB to send the downlink control information to the UE over the PDCCH;

blank a PUSCH transmissions for a predefined interval that coincides with one of the periodic opportunities indicated in the periodic configuration; and

decode the downlink control information received from the eNodeB over the PDCCH on the blanked PUSCH transmission,

wherein the periodic configuration is received at the UE via radio resource control (RRC) signaling or a system information block (SIB) transmission,

wherein the periodic configuration includes: a PUSCH blanking periodicity in terms of a number of subframes, and a PUSCH blanking interval of one or more subframes or one or more symbols.

17. The apparatus of claim 10, wherein the one or more processors are further configured to:

perform a second LBT procedure at the UE and reserve a channel for a maximum channel occupancy time (MCOT); and

decode the downlink control information received from the eNodeB over the PDCCH within the MCOT reserved by the UE, wherein the downlink control information is received at the UE over the PDCCH without an LBT procedure being performed at the eNodeB when a gap between an ending of the autonomous PUSCH transmission and a transmission of the downlink control information over the PDCCH is within a defined time duration within the MCOT.

18. The apparatus of claim 10, wherein the one or more processors are configured to:

encode maximum channel occupancy time (MCOT) information for transmission to the eNodeB in an uplink burst from the UE, wherein the MCOT information includes a total length of a MCOT and a remaining length of the MCOT; and

encode a LBT priority for transmission to the eNodeB in uplink control information (UCI), wherein the LBT priority is used for a channel reservation at the UE,

wherein the MCOT information or the LBT priority enables the eNodeB to determine the MCOT reserved by the UE.

19. At least one machine readable storage medium having instructions embodied thereon for encoding downlink control information for transmission from an eNodeB to a user equipment (UE), the instructions when executed by one or more processors of the eNodeB perform the following:

decoding, at the eNodeB, an autonomous physical uplink shared channel (PUSCH) transmission received from the UE when a channel between the eNodeB and the UE is sensed to be idle based on a listen before talk (LBT) procedure, wherein the autonomous PUSCH transmission is received from the UE without an explicit uplink grant from the eNodeB; and

encoding, at the eNodeB, downlink control information for transmission from the eNodeB to the UE over a physical downlink control channel (PDCCH) in response to the autonomous PUSCH transmission that is received from the UE, wherein the downlink control information includes an acknowledgement (ACK) feedback or a negative acknowledgement (NACK) feedback.

20. The at least one machine readable storage medium of claim 19, further comprising instructions when executed perform the following:

encoding an uplink retransmission grant for transmission to the UE using downlink control information (DCI) format 0/4/0A/4A when the eNodeB is unable to successfully decode the autonomous PUSCH transmission received from the UE, wherein the uplink retransmission grant is sent to the UE when the downlink control information transmitted to the UE includes the NACK feedback for the autonomous PUSCH transmission; and

decoding an autonomous PUSCH retransmission received from the UE after the uplink retransmission grant is transmitted from the eNodeB to the UE.

21. The at least one machine readable storage medium of claim 19, further comprising instructions when executed perform the following: encoding the downlink control information that includes the ACK/NACK feedback for

transmission to the UE in a UE specific search space using a new downlink control information (DCI) format.

22. The at least one machine readable storage medium of claim 19, further comprising instructions when executed perform the following: encoding the ACK/NACK feedback for transmission to the UE in an uplink grant or a downlink grant of the downlink control information, wherein:

the uplink grant includes a grant to schedule an autonomous PUSCH retransmission from the UE when the downlink control information includes the NACK feedback; or

the downlink grant enables the UE to perform the autonomous PUSCH retransmission from the UE at a next opportunity when the downlink control information includes the NACK feedback.

23. The at least one machine readable storage medium of claim 19, further comprising instructions when executed perform the following:

encoding a periodic configuration for transmission to the UE that includes periodic opportunities for the eNodeB to send the downlink control information to the UE over the PDCCH, wherein the periodic configuration instructs the UE to blank a PUSCH transmission for a predefined interval that coincides with one of the periodic opportunities indicated in the periodic configuration; and

encoding the downlink control information for transmission to the UE over the PDCCH on the blanked PUSCH transmission,

wherein the periodic configuration is transmitted to the UE via radio resource control (RRC) signaling or via a system information block (SIB) transmission,

wherein the periodic configuration includes: a PUSCH blanking periodicity in terms of a number of subframes, and a PUSCH blanking interval of one or more subframes or one or more symbols.

24. The at least one machine readable storage medium of any of claims 19 to 23, further comprising instructions when executed perform the following:

decoding maximum channel occupancy time (MCOT) information received from the UE in an uplink burst from the UE, wherein the MCOT information includes a total length of a MCOT and a remaining length of the MCOT;

decoding a LBT priority received from the UE in uplink control information (UCI), wherein the LBT priority is used for a channel reservation at the UE;

determining the MCOT reserved by the UE based on the MCOT information or the LBT priority; and

encoding the downlink control information for transmission to the UE over the PDCCH within the MCOT reserved by the UE, wherein the downlink control information is transmitted over the PDCCH without an LBT procedure being performed at the eNodeB when a gap between an ending of the autonomous PUSCH transmission and a transmission of the downlink control information over the PDCCH is within a defined time duration within the MCOT.

25. The at least one machine readable storage medium of any of claims 19 to 23, further comprising instructions when executed perform the following:

encoding the downlink control information for transmission to the UE over the PDCCH after performing no LBT or a single-interval LBT procedure when the downlink control information is transmitted over the PDCCH within a transmission opportunity (TXoP) reserved by the eNodeB or the UE; or

encoding the downlink control information for transmission to the UE over the PDCCH after performing a Category 4 LBT procedure when the downlink control information is transmitted over the PDCCH outside a TXoP reserved by the eNodeB or the UE.

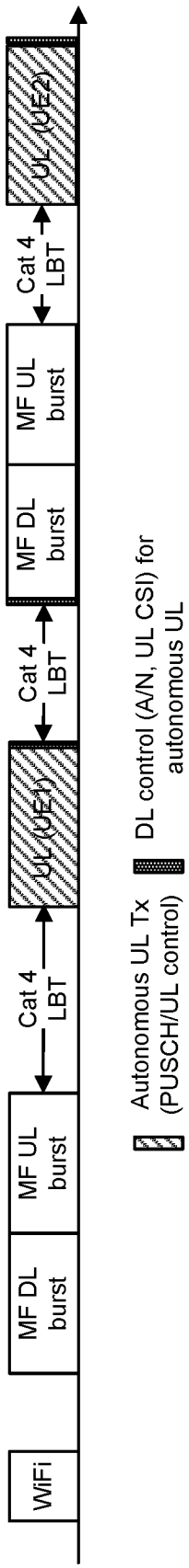

WiFi
MF DL burst
MF UL burst
Cat 4 LBT
UL (UE1)
Cat 4 LBT
MF DL burst
MF UL burst
Cat 4 LBT
UL (UE2)
Autonomous UL Tx (PUSCH/UL control)
DL control (A/N, UL CSI) for autonomous UL

FIG. 1

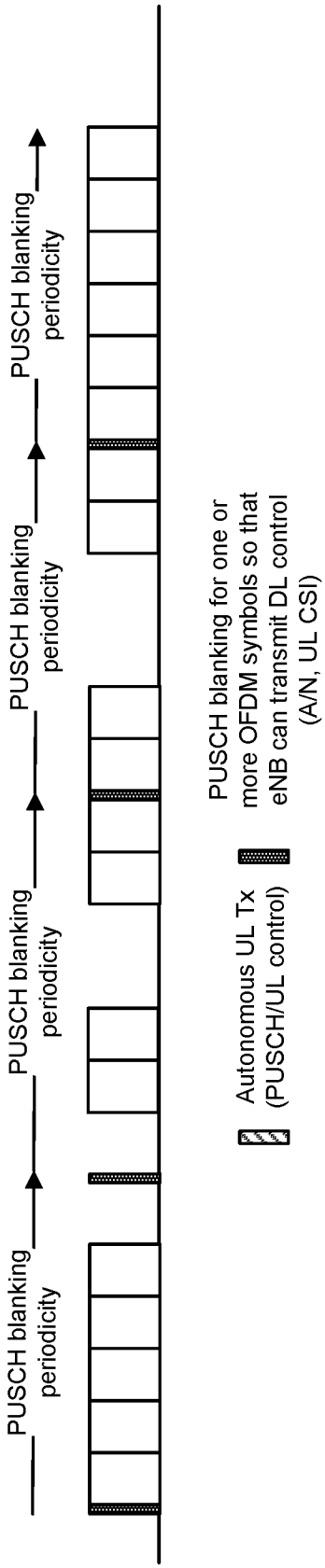

PUSCH blanking periodicity
PUSCH blanking periodicity
PUSCH blanking periodicity
PUSCH blanking periodicity
Autonomous UL Tx (PUSCH/UL control)
PUSCH blanking for one or more OFDM symbols so that eNB can transmit DL control (A/N, UL CSI)

FIG. 2

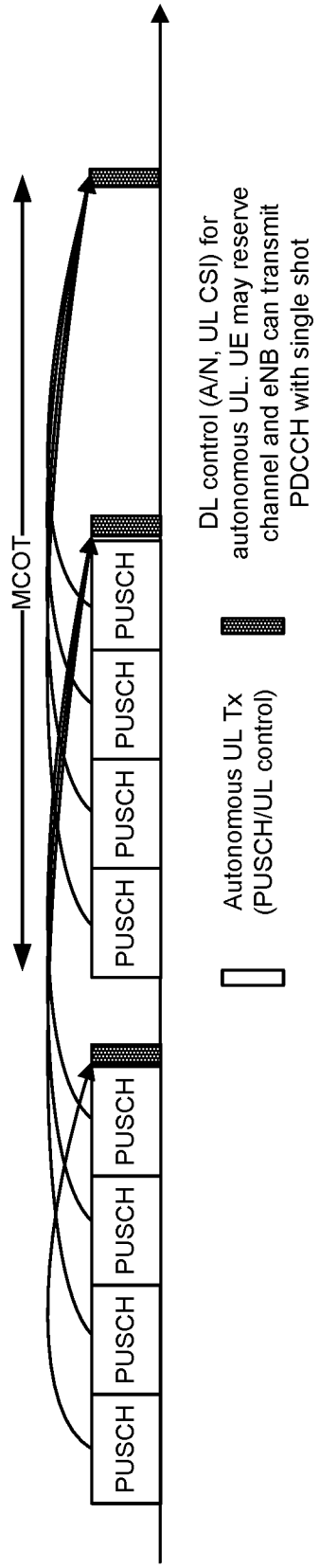

MCOT
PUSCH
PUSCH
PUSCH
PUSCH
PUSCH
PUSCH
PUSCH
PUSCH
Autonomous UL Tx (PUSCH/UL control)
DL control (A/N, UL CSI) for autonomous UL. UE may reserve channel and eNB can transmit PDCCH with single shot

FIG. 3

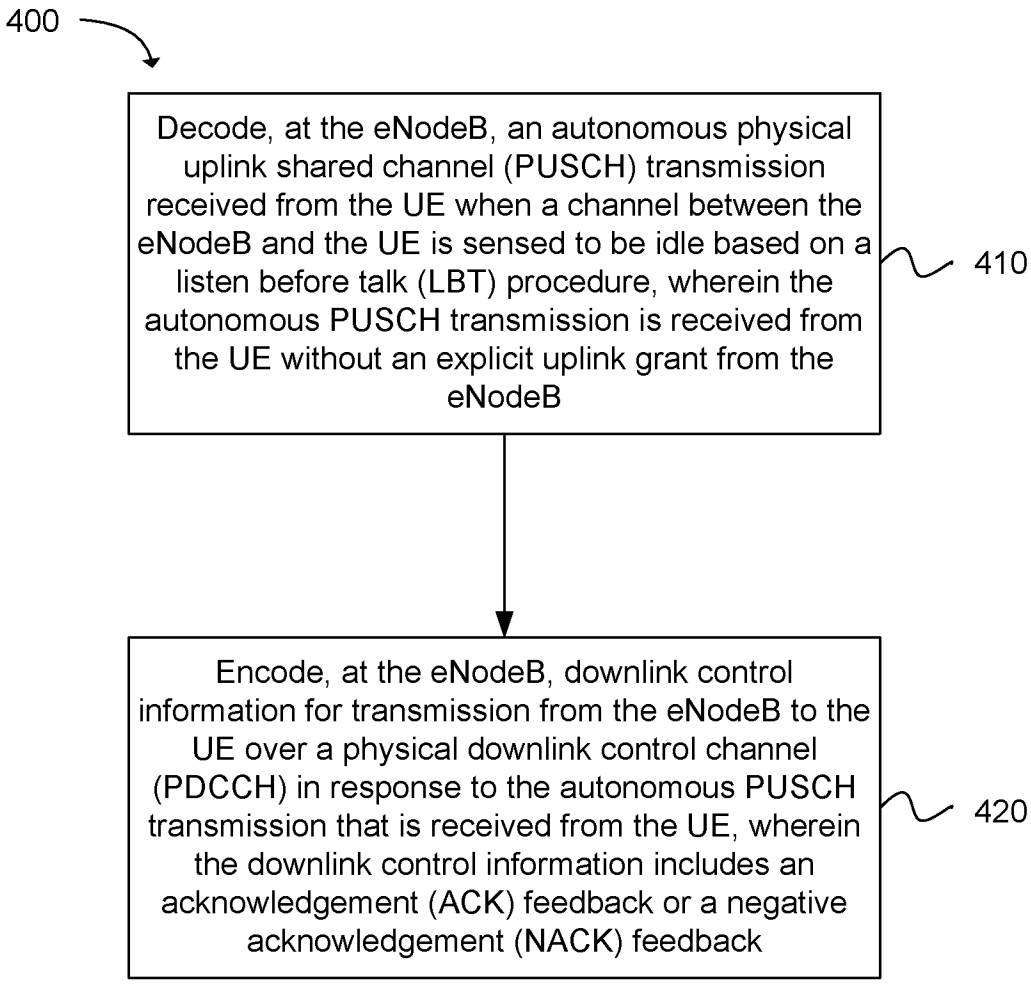

400
Decode, at the eNodeB, an autonomous physical uplink shared channel (PUSCH) transmission received from the UE when a channel between the eNodeB and the UE is sensed to be idle based on a listen before talk (LBT) procedure, wherein the autonomous PUSCH transmission is received from the UE without an explicit uplink grant from the eNodeB
410
Encode, at the eNodeB, downlink control information for transmission from the eNodeB to the UE over a physical downlink control channel (PDCCH) in response to the autonomous PUSCH transmission that is received from the UE, wherein the downlink control information includes an acknowledgement (ACK) feedback or a negative acknowledgement (NACK) feedback
420

FIG. 4

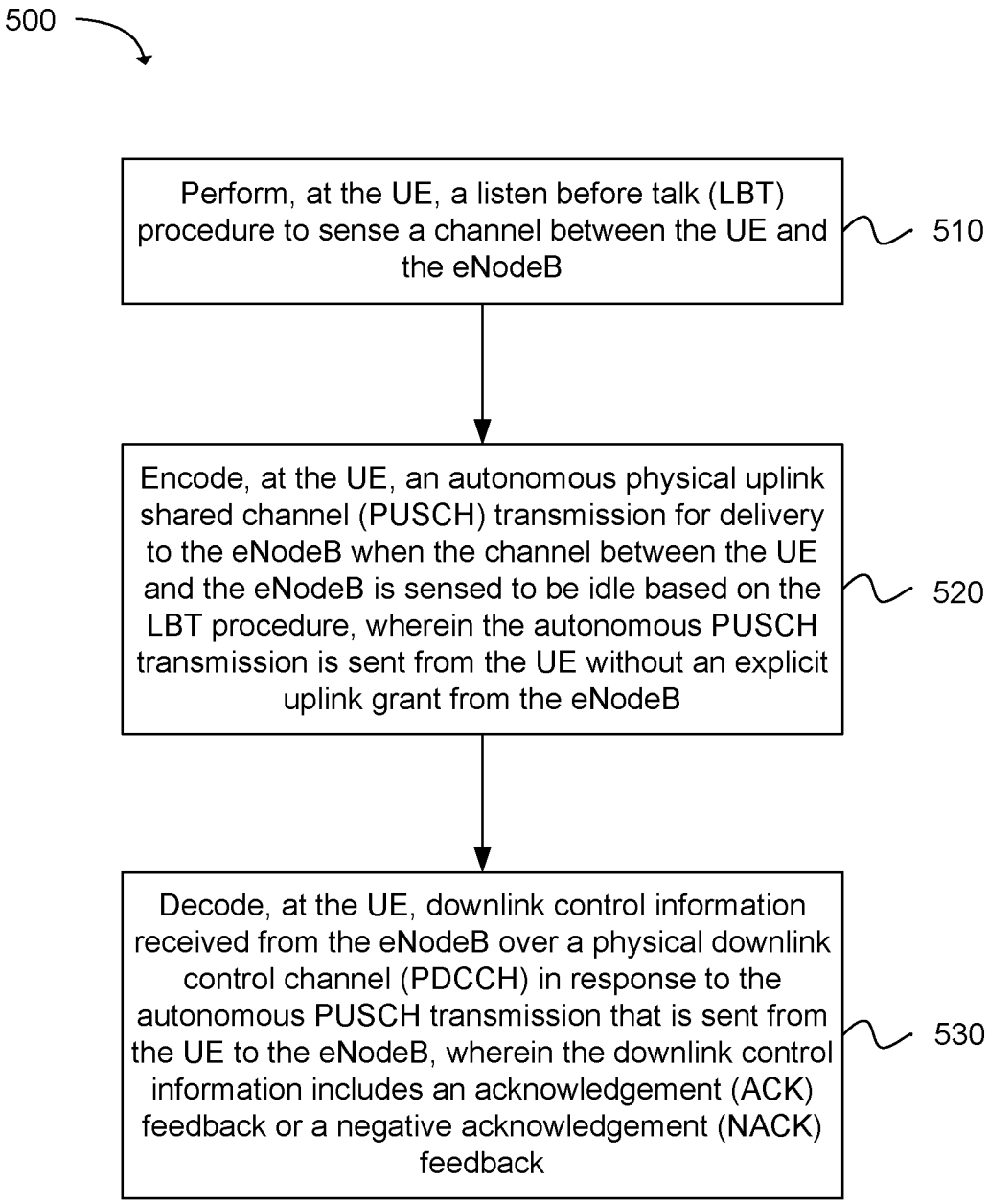

500
Perform, at the UE, a listen before talk (LBT) procedure to sense a channel between the UE and the eNodeB
510
Encode, at the UE, an autonomous physical uplink shared channel (PUSCH) transmission for delivery to the eNodeB when the channel between the UE and the eNodeB is sensed to be idle based on the LBT procedure, wherein the autonomous PUSCH transmission is sent from the UE without an explicit uplink grant from the eNodeB
520
Decode, at the UE, downlink control information received from the eNodeB over a physical downlink control channel (PDCCH) in response to the autonomous PUSCH transmission that is sent from the UE to the eNodeB, wherein the downlink control information includes an acknowledgement (ACK) feedback or a negative acknowledgement (NACK) feedback
530

FIG. 5

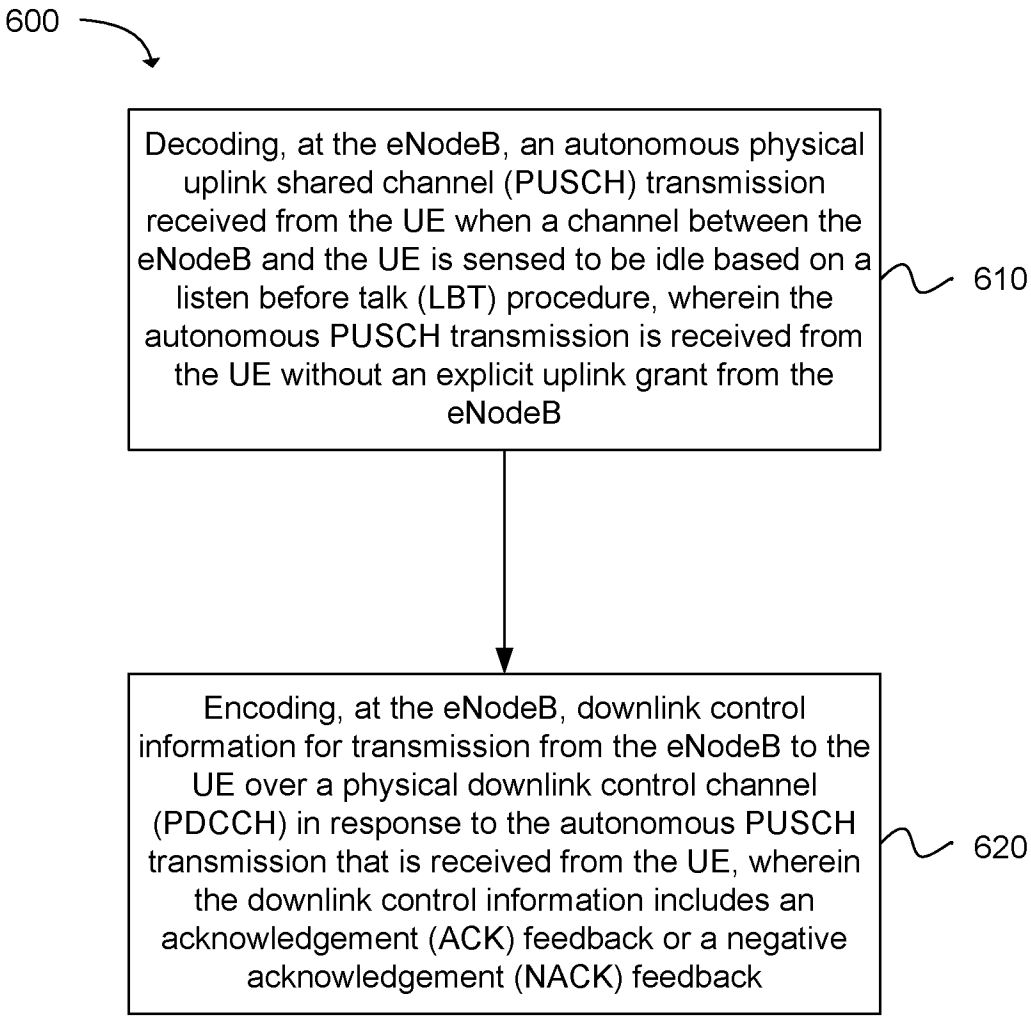

600
Decoding, at the eNodeB, an autonomous physical uplink shared channel (PUSCH) transmission received from the UE when a channel between the eNodeB and the UE is sensed to be idle based on a listen before talk (LBT) procedure, wherein the autonomous PUSCH transmission is received from the UE without an explicit uplink grant from the eNodeB
610
Encoding, at the eNodeB, downlink control information for transmission from the eNodeB to the UE over a physical downlink control channel (PDCCH) in response to the autonomous PUSCH transmission that is received from the UE, wherein the downlink control information includes an acknowledgement (ACK) feedback or a negative acknowledgement (NACK) feedback
620

FIG. 6

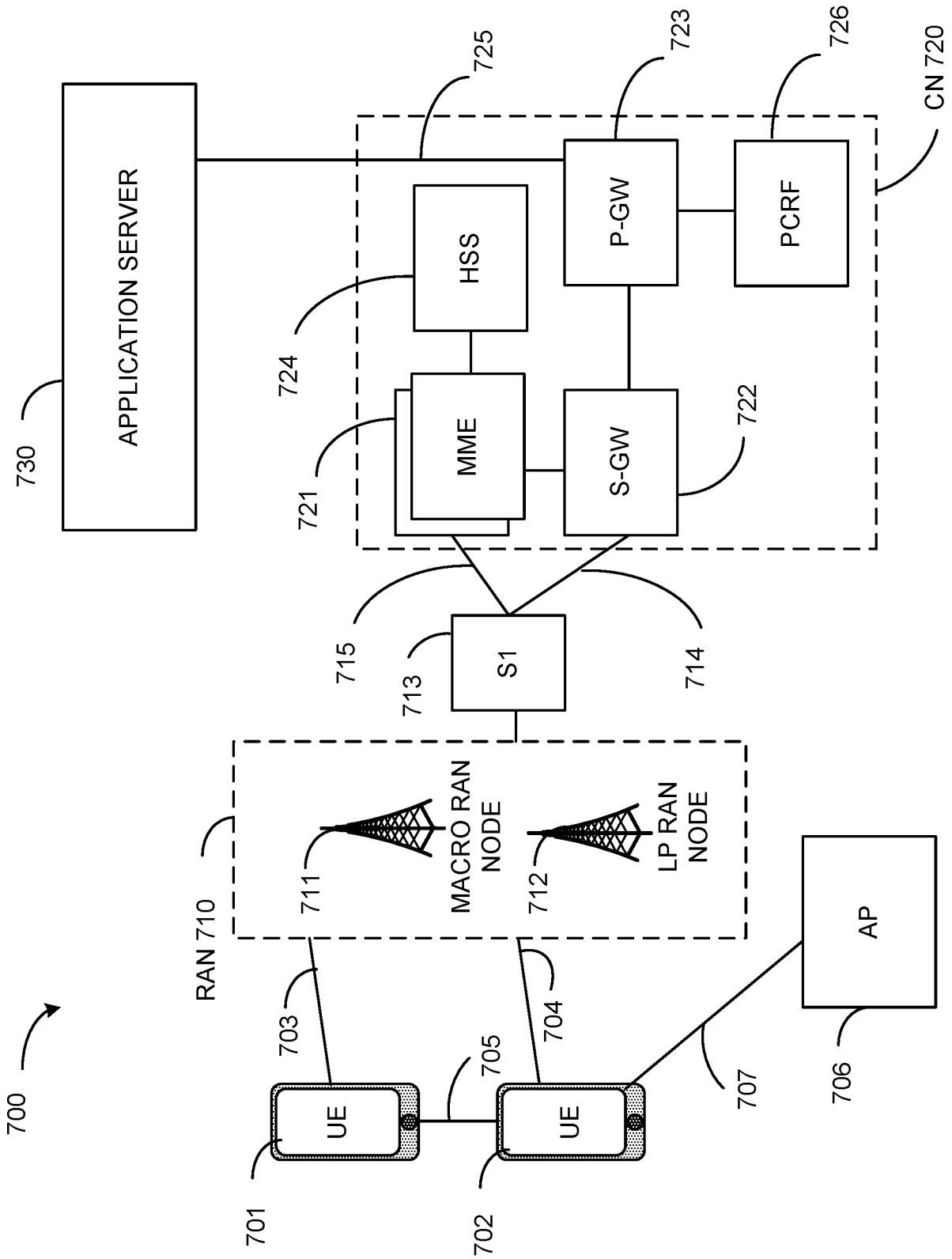

700
APPLICATION SERVER
730
725
723
726
CN 720
HSS
P-GW
PCRF
724
MME
S-GW
721
722
715
713
S1
714
RAN 710
711
MACRO RAN NODE
712
LP RAN NODE
AP
703
704
705
707
706
UE
UE
701
702

FIG. 7

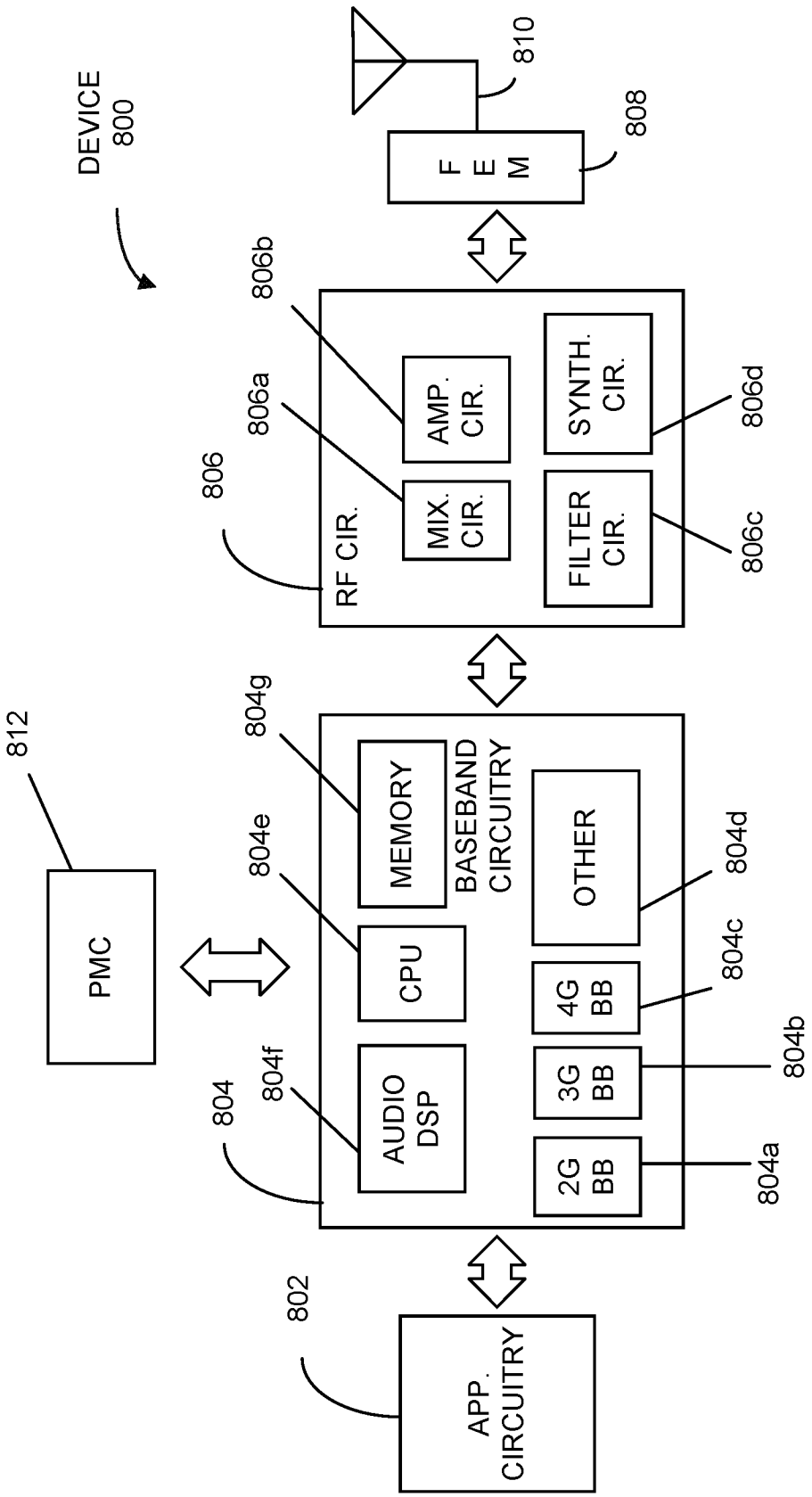

DEVICE
800
810
808
F E M
806b
806a
806
AMP. CIR.
MIX. CIR.
RF CIR.
SYNTH. CIR.
FILTER CIR.
806d
806c
812
804g
804e
804f
804
PMC
MEMORY
CPU
AUDIO DSP
BASEBAND CIRCUITRY
OTHER
4G BB
3G BB
2G BB
804d
804c
804b
804a
802
APP. CIRCUITRY

FIG. 8

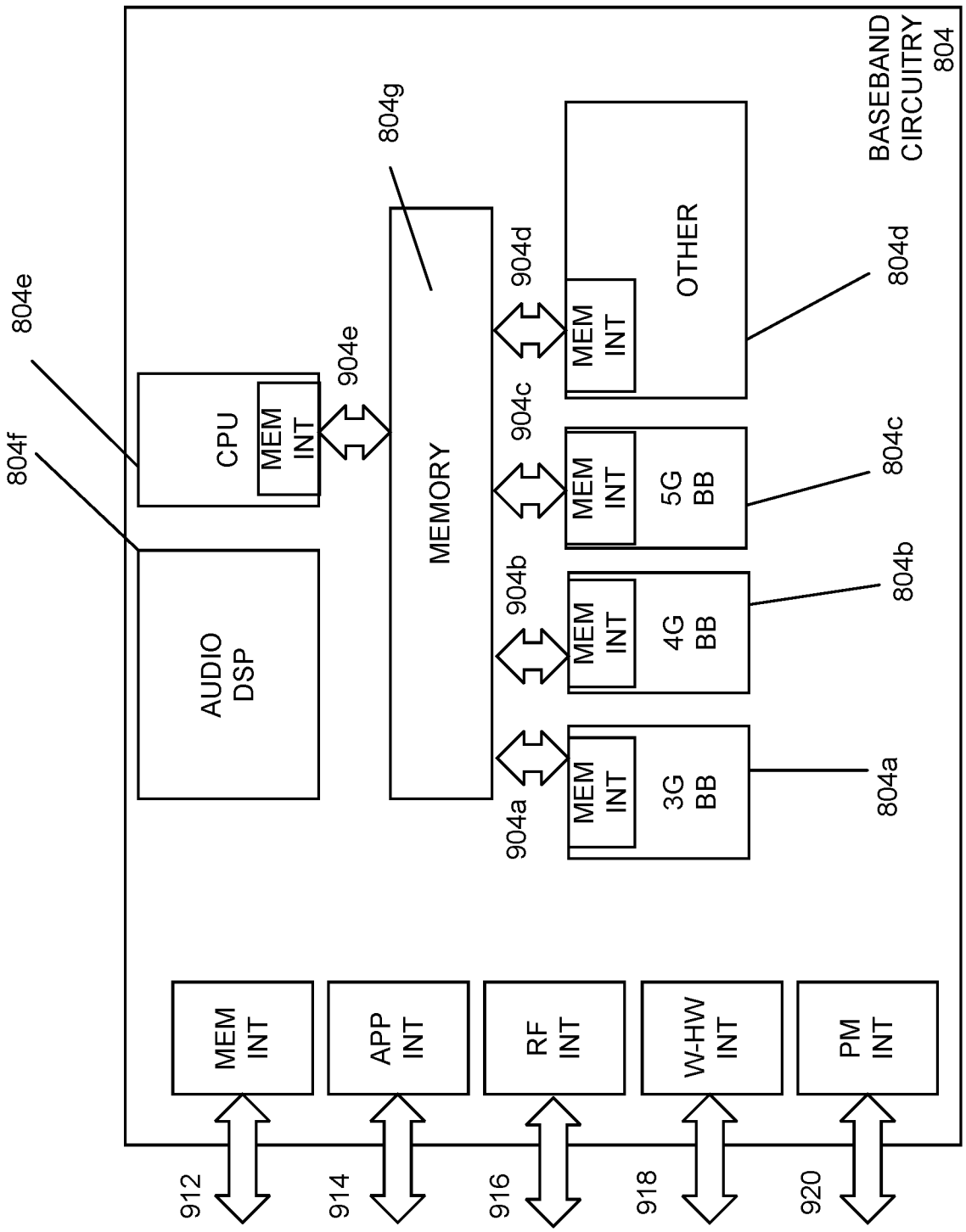

BASEBAND CIRCUITRY
804
804g
804e
804f
CPU
MEM INT
AUDIO DSP
MEMORY
904e
904d
904c
904b
904a
MEM INT
OTHER
5G BB
4G BB
3G BB
804d
804c
804b
804a
MEM INT
APP INT
RF INT
W-HW INT
PM INT
912
914
916
918
920

FIG. 9

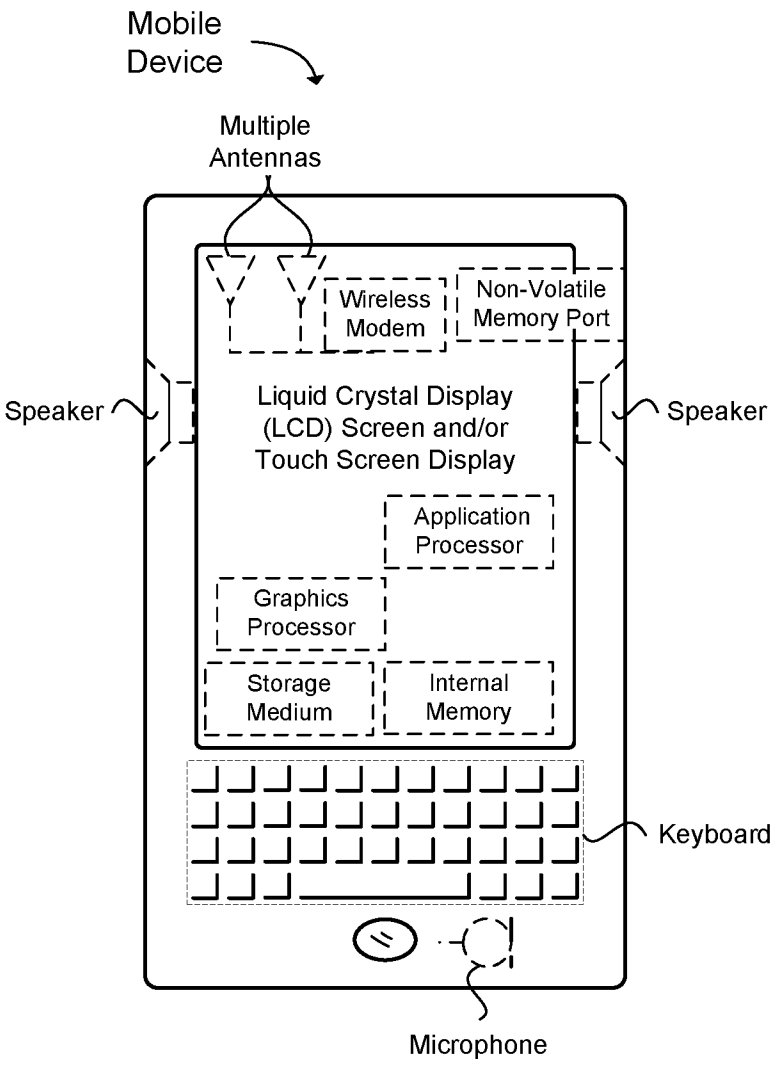

Mobile Device
Multiple Antennas
Wireless Modem
Non-Volatile Memory Port
Speaker
Liquid Crystal Display (LCD) Screen and/or Touch Screen Display
Speaker
Application Processor
Graphics Processor
Storage Medium
Internal Memory
Keyboard
Microphone

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/056642

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L1/18
ADD.

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

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	NOKIA ET AL: "Channel Access for LAA UL", 3GPP DRAFT; R1-162920 CHANNEL ACCESS FOR LAA UL - FINAL, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Busan, South Korea; 20160411 - 20160415 2 April 2016 (2016-04-02), XP051080412, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_84b/Docs/ [retrieved on 2016-04-02] paragraph [0001] - paragraph [0004] ----- -/--	1-5, 7-15, 17-22, 24,25

[X] Further documents are listed in the continuation of Box C.

[ ] See patent family annex.

* Special categories of cited documents :

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 January 2018	18/01/2018

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Papantoniou, Antonis

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/056642

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	ZTE: "UL framework for LAA", 3GPP DRAFT; R1-156994 UL FRAMEWORK FOR LAA, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Anaheim, USA; 20151115 - 20151122 15 November 2015 (2015-11-15), XP051003305, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN1/Docs/ [retrieved on 2015-11-15] paragraph [0001] - paragraph [0003] paragraph [04.8]; figure 1 -----	1,2,10, 19

1