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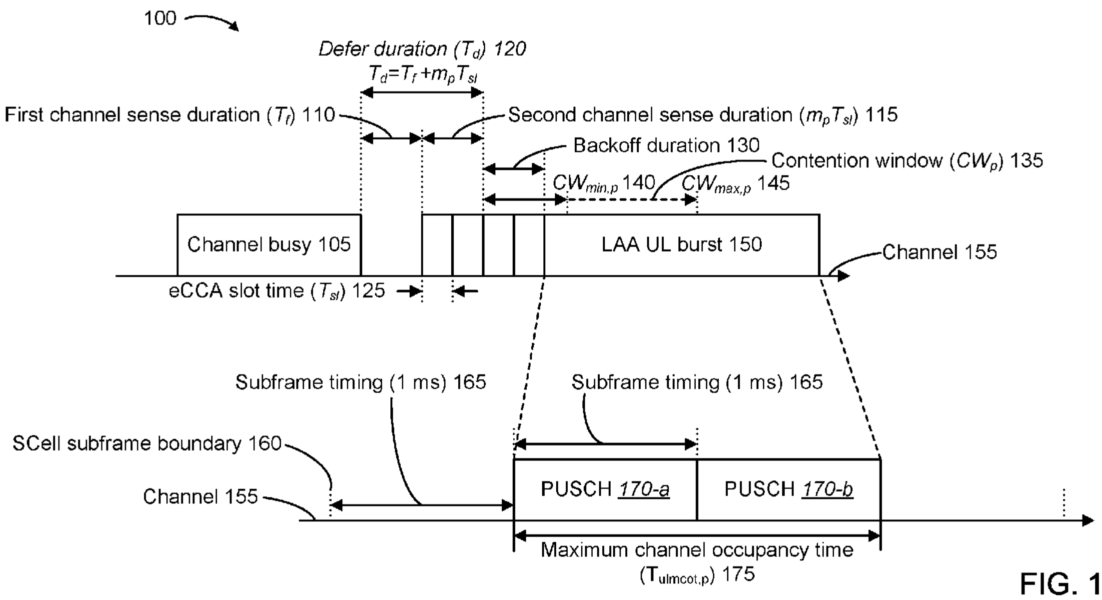

FIG. 1

(57) **Abstract:** Systems, methods, and devices for accessing an unlicensed channel of a license-assisted access (LAA) secondary cell (SCell) are described. A channel access priority class (p) of an uplink communication is identified. A number of slots (m_p) that have a slot duration (T_{sl}) to use as a second channel sensing duration ($m_p T_{sl}$) is determined. The number of slots (m_p) is at least two and is based on the identified channel access priority class. The channel is sensed for a defer duration (T_d) that includes a first channel sensing duration (T_f) and the second channel sensing duration ($m_p T_{sl}$). Access to the channel for the uplink communication is allowed when the channel is sensed to be idle for the defer duration (T_d) and any backoff duration.

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DEFER DURATION FOR UPLINK LISTEN BEFORE TALK

Related Applications

[0001] This application claims priority to U.S. Provisional Patent Application No. 62/336,397, filed May 13, 2016, which is hereby incorporated by reference herein in its entirety.

Technical Field

[0002] The present disclosure generally relates to the use of unlicensed spectrum. Since unlicensed spectrum can be used by various users without any centralized scheduling, access procedures are used for accessing the unlicensed spectrum in a fair manner.

Background

[0003] Wireless mobile communication technology enables communication of mobile user equipment devices, such as smartphones, tablet computing devices, laptop computers, and the like. Mobile communication technology may enable connectivity of various types of devices.

[0004] Wireless mobile communication technology uses radio spectrum for communication. Spectrum can either be licensed spectrum or unlicensed spectrum. Access to licensed spectrum is limited to the licensee (and those that they allow to use the licensed spectrum, for example). Access to unlicensed spectrum on the other hand is generally available to any user subject to certain contention access procedures.

[0005] Wireless mobile communication technology uses various standards and protocols to transmit data between a base station and a wireless communication device. Wireless wide area network (WWAN) communication system standards and protocols can include, for example, the 3rd Generation Partnership Project (3GPP) long term evolution (LTE), and the IEEE 802.16 standard, which is commonly known to industry groups as worldwide interoperability for microwave access (WiMAX). Wireless local area network (WLAN) can include, for example, the IEEE 802.11 standard, which is commonly known to industry groups as Wi-Fi. Other WWAN and WLAN standards and protocols are also known. WWAN communication systems generally operate using licensed spectrum while WLAN communication systems generally operate using unlicensed spectrum. Since licensed spectrum is limited, there is considerable interest in utilizing both licensed spectrum and unlicensed spectrum for wireless communications.

Brief Description of the Drawings

[0006] FIG. 1 is a block diagram illustrating an example of an uplink (UL) burst transmission that implements the present systems and methods.

[0007] FIG. 2 is a flow diagram of a method for a category 4 LBT (e.g., Cat. 4 LBT) device to access a channel.

[0008] FIG. 3 is a flow diagram of a method for accessing a channel.

[0009] FIG. 4 is a flow diagram of a method for accessing a channel.

[0010] FIG. 5 is a flow diagram of a method for accessing a channel.

[0011] FIG. 6 is a block diagram illustrating electronic device circuitry that may be evolved Node B (eNB) circuitry, user equipment (UE) circuitry, network node circuitry, or some other type of circuitry in accordance with various embodiments.

[0012] FIG. 7 is a block diagram illustrating, for one embodiment, example components of a UE, mobile station (MS) device, or eNB.

Detailed Description

[0013] The following detailed description refers to the accompanying drawings. The same reference numbers may be used in different drawings to identify the same or similar elements. In the following description, for purposes of explanation and not limitation, specific details are set forth such as particular structures, architectures, interfaces, techniques, etc., in order to provide a thorough understanding of the various aspects of the disclosed embodiments. However, it will be apparent to those skilled in the art having the benefit of the present disclosure that the various aspects of the embodiments may be practiced in other examples that depart from these specific details. In certain instances, descriptions of well-known devices, circuits, and methods are omitted so as not to obscure the description of the embodiments with unnecessary detail.

[0014] In 3GPP LTE radio access networks (RANs), an Evolved Universal Terrestrial Radio Access Network (E-UTRAN) may include one or more base stations, which are called E-UTRAN Node Bs (also commonly denoted as evolved Node Bs, enhanced Node Bs, eNodeBs, or eNBs) and/or Radio Network Controllers (RNCs). In LTE networks, one or more eNBs may communicate with one or more wireless communication devices, known as user equipments (UEs). An evolved packet core (EPC) may communicatively couple the E-UTRAN to an external network, such as the internet. LTE networks include radio access technologies (RATs) and core radio network architecture that can provide high data rate, low latency, packet optimization, and improved system capacity and coverage.

[0015] There is an increasing demand for high data rates over wireless communication systems. For example, there is an increasing demand for high data rates over LTE. In general, LTE uses licensed spectrum. One of the challenges associated with licensed spectrum is that the usable licensed spectrum is often limited (bandwidth limited, for example). These limitations have led to the exploration of using both licensed spectrum and unlicensed spectrum for wireless communication. The use of both licensed and unlicensed spectrum is enabled at least in part because of the rise in homogeneous networks.

[0016] In homogeneous networks, a node, also called a macro node or macro cell, may provide basic wireless coverage to wireless devices in a cell. The cell may be the area in which the wireless devices can communicate with the macro node. Heterogeneous networks (HetNets) may be used to handle the increased traffic loads on the macro nodes due to increased usage and functionality of wireless devices. HetNets may include a layer of planned high power macro nodes (macro-eNBs or macro cells) overlaid with layers of lower power nodes (small cells, small-eNBs, micro-eNBs, pico-eNBs, femto-eNBs, or home eNBs (HeNBs)) that may be deployed in a less well-planned or even entirely uncoordinated manner within the coverage area (cell) of a macro node. The lower power nodes may generally be referred to as “small cells,” small nodes, or low power nodes. HetNets may also include various types of nodes utilizing varying types of RATs, such as LTE eNBs, 3G NodeBs, Wi-Fi APs, and WiMAX base stations. In some cases, one or more high power macro nodes may utilize licensed spectrum (e.g., LTE over licensed spectrum) while one or more lower power nodes may utilize unlicensed spectrum (e.g., LTE over unlicensed spectrum).

[0017] As used herein, the terms “node” and “cell” are both intended to be synonymous and refer to a wireless transmission point operable to communicate with multiple wireless mobile devices, such as a UE, or another base station. Furthermore, cells or nodes may also be Wi-Fi access points (APs), or multi-radio cells with Wi-Fi/cellular or additional RATs. For example, nodes or cells may include various technologies such that cells operating on different RATs are integrated in one unified HetNet.

[0018] The ever-increasing demand for high data rates over wireless systems combined with the bandwidth constraints of the usable licensed spectrum has led to the operation of LTE system in the unlicensed spectrum. The operation of LTE in the unlicensed spectrum is called License-Assisted Access (LAA).

[0019] The unlicensed frequency band of initial interest in 3GPP is the 5 GHz band, which has a relatively wide spectrum with global common availability. The 5 GHz band is governed by Federal Communications Commission (FCC) in the United States (US) and the European Telecommunications Standards Institute (ETSI) in Europe (EP). The main incumbent system in the 5 GHz band is WLAN, specifically those based on the Institute of Electrical and Electronics Engineers (IEEE) 802.11 a/n/ac standards/technologies. Since WLAN systems are widely deployed both by individuals and operators for carrier-grade access service and data offloading, sufficient care should be taken before the deployment of LAA. This is why a Listen-Before-Talk (LBT) mechanism was considered as a mandatory feature of 3GPP Release 13 LAA systems for fair coexistence with incumbent systems. LBT is a procedure whereby radio transmitters first sense the medium and transmit only if the medium is sensed to be idle.

[0020] 3GPP Release 13 LAA mainly focused on enabling downlink (DL) access using both licensed spectrum and unlicensed spectrum via carrier aggregation. In 3GPP Release 13 LAA, UL access was limited to the use of licensed spectrum.

[0021] The main design goal of 3GPP Release 14 enhanced LAA (eLAA) is to specify UL support for LAA Secondary Cell (SCell) operation in unlicensed spectrum. The specification of UL support for LAA SCell shall encompass the design of the Sounding Reference Signal (SRS), the Physical Uplink Shared Channel (PUSCH), and possibly the Physical Uplink Control Channel (PUCCH) and the Physical Random Access Channel (PRACH), if supported.

[0022] The present systems and methods are directed to specifying the parameters for UL support for eLAA operation in unlicensed spectrum. In particular, the present systems and methods are directed to specifying a defer period for UL LBT. It is to be appreciated that the defer period for UL LBT is different than the defer period for DL LBT.

[0023] During 3GPP Release 13, the channel access mechanism for DL LBT was specified including a defer duration (T_d) (based on the value of m_p, for example) for each channel access priority class (*p*). The defer duration (T_d) for DL LBT consists of duration $T_f = 16\mu s$ (microseconds (μs)) immediately followed by m_p consecutive slot durations where each slot duration is $T_{sl} = 9\mu s$, and T_f includes an idle slot duration T_{sl} at the start of the T_f. So the DL defer duration T_d is based on the value of m_p and the value of m_p is dependent upon the channel access priority class (*p*). The m_p consecutive slot durations for DL LBT depends on the channel access priority class (*p*) as illustrated in Table 1, which is a reproduction of Table 15.1.1-1 in 3GPP Technical Specification (TS) 36.213 V13.0.1.

Channel Access Priority Class (p)	m_p	$CW_{\min,p}$	$CW_{\max,p}$	$T_{m\cot,p}$	**allowed CW_p sizes**
1	1	3	7	2 ms	{3,7}
2	1	7	15	3 ms	{7,15}
3	3	15	63	8 or 10 ms	{15,31,63}
4	7	15	1023	8 or 10 ms	{15,31,63,127,255,511,1023}

Table 1

[0024] In addition, to specifying the m_p consecutive slot durations to be used with each channel access priority class (*p*) for DL LBT, Table 1 specifies the minimum contention window size ($CW_{\min,p}$), the maximum contention window size ($CW_{\max,p}$), the maximum channel occupancy time ($T_{m\cot,p}$), and the allowed contention window sizes (CW_p) to be used with each channel access priority class (*p*) for DL LBT.

[0025] As noted above, the present systems and methods are directed to specifying the parameters for UL support for eLAA operation in unlicensed spectrum. In particular, the present systems and methods are directed to specifying a defer period for UL LBT.

[0026] As described herein, the defer duration (T_d) for UL LBT consists of duration $T_f = 16\mu s$ (microseconds (μs)) immediately followed by m_p consecutive slot durations where each slot duration is $T_{sl} = 9\mu s$, and T_f includes an idle slot duration T_{sl} at the start of the T_f. So, like the DL defer duration T_d, the UL defer duration T_d is based on the value of m_p and the value of m_p is dependent upon the channel access priority class (*p*). The m_p consecutive slot durations for UL LBT depends on the channel access priority class (*p*) as illustrated in Table 2.

Channel Access Priority Class (p)	m_p	$CW_{\min,p}$	$CW_{\max,p}$	$T_{ulm\cot,p}$	allowed CW_p sizes
1	2	3	7	2 ms	{3,7}
2	2	7	15	3 ms	{7,15}
3	3	15	1023	6 or 10 ms	{15,31,63,127,255,511,1023}
4	7	15	1023	6 or 10 ms	{15,31,63,127,255,511,1023}

Table 2

[0027] As set forth in Table 2, the specified m_p consecutive slot durations for UL LBT is 2 when the channel access priority class (*p*) is 1 or 2. This is different than the m_p consecutive slot durations for DL LBT.

[0028] In addition, to specifying the m_p consecutive slot durations to be used with each channel access priority class (*p*) for UL LBT, Table 2 specifies the minimum contention window size ($CW_{\min,p}$), the maximum contention window size ($CW_{\max,p}$), the maximum UL channel occupancy time ($T_{ulm\mathrm{cot},p}$), and the allowed contention window sizes (CW_p) to be used with each channel access priority class (*p*) for UL LBT.

[0029] It is appreciated that the analog of the LTE defer duration T_d in WLAN is the Arbitration Inter-Frame Spacing (AIFS) duration for a particular Access Category (AC) (AIFS[AC]) and the analog of the LTE m_p in WLAN is the AIFS-number (AIFSN[AC]). The duration AIFS[AC] is a duration derived from the value of the AIFSN[AC] by the relation AIFS[AC] = AIFSN[AC] x aSlotTime + aSIFSTime, where aSlotTime is the slot time (ST) and where aSIFSTime is the Short Interframe Space (SIFS).

[0030] According to the IEEE Std. 802.11eTM-2005 Amendment 8, the value of AIFSN[AC] shall be greater than or equal to 2 for non-AP Quality of Service (QoS) Stations (QSTAs) and the value of AIFSN[AC] shall be greater than or equal to 1 for QoS APs (QAPs). In addition the IEEE Std. 802.11eTM-2005 Amendment 8 provides that the default configuration for STAs is AIFSN={2, 2, 3, 7} for access priority classes 1 to 4 respectively. So the 3GPP Release 13 LAA design of the DL defer duration T_d is in accordance with the default configuration for QAPs and the proposed 3GPP Release 14 eLAA design of the UL defer duration T_d is in accordance with the default configuration for QSTAs. Therefore the DL defer duration T_d and the proposed UL defer duration T_d honor the incumbent WLAN systems so as to enable fair competition in channel access.

[0031] In view of the above, the described systems and methods relate to specifying that the number of consecutive time slots (e.g., m_p) is 2 when the channel access priority class (*p*) is 1 or 2. In some embodiments, the number of consecutive time slots (e.g., m_p) is greater than or equal to 2 when the channel access priority class (*p*) is 1 or 2.

[0032] Referring now to the figures, FIG. 1 is a block diagram illustrating an example of an UL burst transmission 100 that implements the present systems and methods. A device (not shown), such as a UE, for example, may have an LAA UL burst 150 to transmit. The device may monitor a channel 155 and may wait until the channel 155 is clear before transmitting the LAA UL burst 150. As illustrated in FIG. 1, the channel 155 may be busy 105 for a period of time. The device may sense the channel 155 to determine when the channel 155 becomes idle (e.g., not busy 105).

[0033] When the channel 155 becomes idle, the device may wait for a defer duration (T_d) 120, which consists of a first channel sense duration (T_f) 110 and a second channel sense duration (m_pT_{sl}) 125, before initiating a contention procedure (e.g., backoff duration 130). If the channel 155 is idle for both the defer duration (T_d) 120 and the backoff duration 130 (subject to contention access procedures, for example) then the device may transmit the LAA UL burst 150 on the channel 155.

[0034] The first channel sense duration (T_f) 110 may have a fixed duration of 16 μs. The second channel sense duration ($m_p T_{sl}$) 115 may have a variable duration that is dependent on m_p and T_{sl} where T_{sl} is an enhanced clear channel access (eCCA) slot time (T_{sl}) 125, which has a fixed duration 9 μs, and where m_p is an integer that specifies the number of consecutive eCCA slot times (T_{sl}) 125 that the second channel sense duration 115 should be. As noted above, m_p is dependent on the channel access priority class (*p*) as set forth in Table 2.

[0035] FIG. 1 illustrates an example where the channel access priority class (*p*) is channel access priority class 1. Therefore, as per Table 2, m_p=2, the minimum contention window size ($CW_{\min,p}$) is 3, the maximum contention window size ($CW_{\max,p}$) is 7, and the maximum UL channel occupancy time ($T_{ulm\cot,p}$) is 2 milliseconds (ms) (i.e., 2 subframes). As illustrated, the defer duration (T_d) 120 is 34 μs (i.e., $T_f = 16\,\mu s$ and $m_p T_{sl} = 2 \cdot 9\,\mu s = 18\,\mu s$).

[0036] If the channel 155 is idle for the defer duration (T_d) 120, then immediately following (e.g., consecutive to) the defer duration (T_d) 120, a contention access procedure is initiated. The contention access procedure is known to those in the art and is only described briefly herein. The contention access procedure provides fair access to the channel 155 and helps mitigate and address collisions during contention access. In the contention access procedure, the device selects a random number N (e.g., uniformly random N) from the range of 0 to contention window (CW_p) 135 where CW_p 135 is the size of the contention window in terms of the eCCA slot time (T_{sl}) 125, which in this case (e.g., channel access priority class 1) can either be 3 eCCA slot times (T_{sl}) 125 (e.g., $CW_{\min,p}$ 140) or 7 eCCA slot times (T_{sl}) 125 (e.g., $CW_{\max,p}$ 145) as set forth in Table 2. Contention access procedures define an algorithm for decrementing N. In the simplest case (where there is no other device with a lower N so the channel remains idle, for example), N is decremented for each eCCA slot time (T_{sl}) 125 following the defer duration (T_d) 120. As illustrated, N=2 so the backoff duration 130 is 2 eCCA slot times (T_{sl}) 125 (this assumes no interference from other devices, for example).

[0037] Immediately following the defer duration (T_d) 120 and any backoff duration 130, the device transmits the LAA UL burst 150. As set forth in Table 2, different channel access priority classes (*p*) have a plurality of different maximum channel occupancy times ($T_{ulm\text{cot},p}$) 175. In the case of channel access priority class 1, the maximum channel occupancy time ($T_{ulm\text{cot},p}$) 175 is 2 ms. This corresponds to 2 LTE subframes, which have a subframe timing 165 of 1 ms per subframe. In some embodiments, the LAA UL burst 150 may include one or more Physical Uplink Shared Channel (PUSCH) subframes 170. As illustrated, the LAA UL burst 150 includes a first PUSCH subframe 170-a and a second PUSCH subframe 170-b. In some embodiments, the subframe timing 165 associated with the first and second PUSCH subframes 170 may be in sequence with one or more SCell subframe boundaries 160 associated with the channel 155.

[0038] As can be appreciated from the foregoing description, the duration of the second channel sense duration 115 is variable based on the value of m_p, and the value of m_p is dependent upon the access channel priority class (*p*) as set forth in Table 2.

[0039] FIG. 2 is a flow diagram of a method 200 for a category 4 LBT (e.g., Cat. 4 LBT) device to access a channel. As used herein, a Cat. 4 LBT device may be a UE that is capable of supporting both UL and DL LAA burst transmissions.

[0040] At 205, the method begins and the channel is sensed. At 210, a determination is made if the channel is idle for the defer duration (T_d). If the channel is idle for the defer duration (T_d) (e.g., yes) then the method continues to 215. Otherwise (e.g., no), the method stays at 210 and the channel continues to be sensed.

[0041] At 215, an integer value for N is randomly selected from a range of 0 to CW_p where each integer in the range of 0 to CW_p has a uniform probability of being selected. At 220, a determination is made as to whether N equals 0. If N equals 0 (e.g., yes), then the method ends 225 (and the channel can be accessed, for example). Otherwise (e.g., no), a determination is made as to whether the channel is idle for a slot time (T_{sl}) 230. If the channel is idle for the slot time (T_{sl}) (e.g., yes), then N is decremented 235 (e.g., N=N-1) and the method returns to 220 where a determination is made as to whether N equals 0. Otherwise (e.g., no) (another device is accessing the channel, for example), the channel is sensed at 240. At 245, a determination is made as to whether (C1) the channel is sensed busy for a slot time (T_{sl}) or (C2) the channel is idle for a defer duration (T_d). If C1, then the channel continues to be sensed at 240. If C2, then the method returns to 220 where a determination is made as to whether N equals 0.

[0042] It is appreciated that the method 200 may be modified or adjusted without impacting the scope of the described systems and methods. Additionally it is noted, that the method 200 requires that the channel be idle for at least the defer duration (T_d) before any backoff duration (e.g., N, decision 220 as to whether N equals 0) is considered.

[0043] FIG. 3 is a flow diagram of a method 300 for accessing a channel. The method 300 is performed by a device, such as a UE or the like. In particular, the method 300 may be performed by a processor (e.g., a baseband processor) within the device. Although the operations of the method 300 are illustrated as being performed in a particular order, it is understood that the operations of the method 300 may be reordered without departing from the scope of the method.

[0044] At 305, a channel access priority class (p) of an uplink communication is identified. At 310, a number (m_p) of slot durations (T_{sl}) to use as a second channel sense duration ($m_p T_{sl}$) is determined, where the number (m_p) is based on the identified channel access priority class. The number (m_p) is at least 2. At 315, the channel is sensed for a defer duration (T_d) that includes a first channel sensing duration (T_f) and the second channel sensing duration ($m_p T_{sl}$). At 320, access to the channel for uplink communication is allowed when the channel is sensed to be idle for the defer duration (T_d) and any backoff duration.

[0045] The operations of the method 300 may be performed by an application specific processor, programmable application specific integrated circuit (ASIC), field programmable gate array (FPGA), or the like.

[0046] FIG. 4 is a flow diagram of a method 400 for accessing a channel. The method 400 is performed by a device, such as a UE, or the like. In particular, the method 400 may be performed by a processor (e.g., a baseband processor) within the device. Although the operations of the method 400 are illustrated as being performed in a particular order, it is understood that the operations of the method 400 may be reordered without departing from the scope of the method.

[0047] At 405, an uplink message to be sent on a channel is identified. The channel access priority class (*p*) of the uplink message is channel access priority class 1. At 410, the channel is sensed for a defer duration (T_d) that consists of a channel sensing duration (T_f) and a number of consecutive slots (m_p) that have a slot duration (T_{sl}). The number of consecutive slots (m_p) is at least two for channel access priority class 1 uplink messages. At 415, the channel is determined to be idle for the defer duration (T_d) before contending for access to the channel.

[0048] The operations of the method 400 may be performed by an application specific processor, programmable ASIC, FPGA, or the like.

[0049] FIG. 5 is a flow diagram of a method 500 for accessing a channel. The method 500 is performed by a device, such as a UE, or the like. In particular, the method 500 may be performed by a processor (e.g., a baseband processor) within the device. Although the operations of the method 500 are illustrated as being performed in a particular order, it is understood that the operations of the method 500 may be reordered without departing from the scope of the method.

[0050] At 505, an uplink message to be sent on a channel is identified. The channel access priority class (*p*) of the uplink message is channel access priority class 2. At 510, the channel is sensed for a defer duration (T_d) that consists of a channel sensing duration (T_f) and a number of consecutive slots (m_p) that have a slot duration (T_{sl}). The number of consecutive slots (m_p) is at least two for channel access priority class 2 uplink messages. At 515, the channel is determined to be idle for the defer duration (T_d) before contending for access to the channel.

[0051] The operations of the method 500 may be performed by an application specific processor, programmable ASIC, FPGA, or the like.

[0052] FIG. 6 is a block diagram illustrating an electronic device circuitry 600 that may be eNB circuitry, UE circuitry, network node circuitry, or some other type of circuitry in accordance with various embodiments. In embodiments, the electronic device circuitry 600 may be, or may be incorporated into or otherwise a part of, an eNB, a UE, an MS, a base transceiver station (BTS), a network node, or some other type of electronic device. In embodiments, the electronic device circuitry 600 may include a radio transmit circuitry 605 and a receive circuitry 610 coupled to a control circuitry 615. In some embodiments, the transmit circuitry 605 and/or the receive circuitry 610 may be elements or modules of transceiver circuitry, as shown. The electronic device circuitry 600 may be coupled with one or more antenna elements 620 of one or more antennas. The electronic device circuitry 600 and/or the components of the electronic device circuitry 600 may be configured to perform operations similar to those described elsewhere in this disclosure.

[0053] In embodiments where the electronic device circuitry 600 is or is incorporated into or otherwise part of a UE, the transmit circuitry 605 can transmit an SCell UL LAA message, as shown in FIG. 1. The receive circuitry 610 can receive an SCell DL LAA message.

[0054] In embodiments where the electronic device circuitry 600 is an eNB, UE, BTS, and/or a network node, or is incorporated into or is otherwise part of an eNB, UE, BTS, and/or a network node, the transmit circuitry 605 can transmit an SCell DL LAA message. The receive circuitry 610 can receive an SCell UL LAA message as shown in FIG. 1.

[0055] In certain embodiments, the electronic device circuitry 600 shown in FIG. 6 is operable to perform one or more methods, such as the methods shown in FIGS. 3-5.

[0056] As used herein, the term “circuitry” may refer to, be part of, or include an 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.

[0057] Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software. FIG. 7 is a block diagram illustrating, for one embodiment, example components of a UE, an MS device, or an evolved Node B (eNB) 700. In some embodiments, the UE device 700 may include application circuitry 705, baseband circuitry 710, radio frequency (RF) circuitry 715, front-end module (FEM) circuitry 720, and one or more antennas 725, coupled together at least as shown in FIG. 7.

[0058] The application circuitry 705 may include one or more application processors. By way of non-limiting example, the application circuitry 705 may include 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 processor(s) may be operably coupled and/or include memory/storage, and may be configured to execute instructions stored in the memory/storage to enable various applications and/or operating systems to run on the system.

[0059] By way of non-limiting example, the baseband circuitry 710 may include one or more single-core or multi-core processors. The baseband circuitry 710 may include one or more baseband processors and/or control logic. The baseband circuitry 710 may be configured to process baseband signals received from a receive signal path of the RF circuitry 715. The baseband circuitry 710 may also be configured to generate baseband signals for a transmit signal path of the RF circuitry 715. The baseband circuitry 710 may interface with the application circuitry 705 for generation and processing of the baseband signals, and for controlling operations of the RF circuitry 715.

[0060] By way of non-limiting example, the baseband circuitry 710 may include at least one of a second generation (2G) baseband processor 710A, a third generation (3G) baseband processor 710B, a fourth generation (4G) baseband processor 710C, one or more other baseband processor(s) 710D for other existing generations, and generations in development or to be developed in the future (e.g., fifth generation (5G), sixth generation (6G), etc.). The baseband circuitry 710 (e.g., at least one of the baseband processors 710A-710D) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 715. By way of non-limiting example, the radio control functions may include signal modulation/demodulation, encoding/decoding, radio frequency shifting, other functions, and combinations thereof. In some embodiments, modulation/demodulation circuitry of the baseband circuitry 710 may be programmed to perform Fast-Fourier Transform (FFT), precoding, constellation mapping/demapping functions, other functions, and combinations thereof. In some embodiments, encoding/decoding circuitry of the baseband circuitry 710 may be programmed to perform convolutions, tail-biting convolutions, turbo, Viterbi, Low Density Parity Check (LDPC) encoder/decoder functions, other functions, and combinations thereof. Embodiments of modulation/demodulation and encoder/decoder functions are not limited to these examples, and may include other suitable functions.

[0061] In some embodiments, the baseband circuitry 710 may include elements of a protocol stack. By way of non-limiting example, elements of an evolved universal terrestrial radio access network (E-UTRAN) protocol including, for example, physical (PHY), media access control (MAC), radio link control (RLC), packet data convergence protocol (PDCP), and/or radio resource control (RRC) elements. A central processing unit (CPU) 710E of the baseband circuitry 710 may be programmed to run elements of the protocol stack for signaling of the PHY, MAC, RLC, PDCP and/or RRC layers. In some embodiments, the baseband circuitry 710 may include one or more audio digital signal processor(s) (DSP) 710F. The audio DSP(s) 710F may include elements for compression/decompression and echo cancellation. The audio DSP(s) 710F may also include other suitable processing elements.

[0062] The baseband circuitry 710 may further include a memory/storage 710G. The memory/storage 710G may include data and/or instructions for operations performed by the processors of the baseband circuitry 710 stored thereon. In some embodiments, the memory/storage 710G may include any combination of suitable volatile memory and/or non-volatile memory. The memory/storage 710G may also include any combination of various levels of memory/storage including, but not limited to, read-only memory (ROM) having embedded software instructions (e.g., firmware), random access memory (e.g., dynamic random access memory (DRAM)), cache, buffers, etc. In some embodiments, the memory/storage 710G may be shared among the various processors or dedicated to particular processors.

[0063] The baseband circuitry 710 may additionally include a Wi-Fi processor 710H for handling WLAN communication, including LTE communication over unlicensed spectrum that is traditionally occupied by Wi-Fi. The Wi-Fi processor 710H may be coupled to a Wi-Fi RF circuitry 730, a Wi-Fi FEM circuitry 735, and a Wi-Fi antenna 740. These components may be colocated with the respective RF circuitry 715, FEM circuitry 720, and/or the antennas 725 or may be separately located (as shown). Although separate, the Wi-Fi specific hardware (e.g., 730-740) may serve comparable functions as the cellular circuitry (e.g., 715-725).

[0064] Components of the baseband circuitry 710 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 710 and the application circuitry 705 may be implemented together, such as, for example, on a system on a chip (SOC).

[0065] In some embodiments, the baseband circuitry 710 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 710 may support communication with an evolved universal terrestrial radio access network (E-UTRAN) and/or other wireless metropolitan area networks (WMAN), a WLAN, or a wireless personal area network (WPAN). Embodiments in which the baseband circuitry 710 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

[0066] The RF circuitry 715 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 715 may include switches, filters, amplifiers, etc., to facilitate the communication with the wireless network. The RF circuitry 715 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 720, and provide baseband signals to the baseband circuitry 710. The RF circuitry 715 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 710, and provide RF output signals to the FEM circuitry 720 for transmission.

[0067] In some embodiments, the RF circuitry 715 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 715 may include a mixer circuitry 715A, an amplifier circuitry 715B, and a filter circuitry 715C. The transmit signal path of the RF circuitry 715 may include the filter circuitry 715C and the mixer circuitry 715A. The RF circuitry 715 may further include a synthesizer circuitry 715D configured to synthesize a frequency for use by the mixer circuitry 715A of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 715A of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 720 based on the synthesized frequency provided by the synthesizer circuitry 715D. The amplifier circuitry 715B may be configured to amplify the down-converted signals.

[0068] The filter circuitry 715C may include 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 710 for further processing. In some embodiments, the output baseband signals may include zero-frequency baseband signals, although this is not a requirement. In some embodiments, the mixer circuitry 715A of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[0069] In some embodiments, the mixer circuitry 715A of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 715D to generate RF output signals for the FEM circuitry 720. The baseband signals may be provided by the baseband circuitry 710 and may be filtered by the filter circuitry 715C. The filter circuitry 715C may include a low-pass filter (LPF), although the scope of the embodiments is not limited in this respect. In some embodiments, the mixer circuitry 715A of the receive signal path and the mixer circuitry 715A of the transmit signal path may include two or more mixers, and may be arranged for quadrature downconversion and/or upconversion, respectively. In some embodiments, the mixer circuitry 715A of the receive signal path and the mixer circuitry 715A 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 715A of the receive signal path and the mixer circuitry 715A of the transmit signal path may be arranged for direct downconversion and/or direct upconversion, respectively. In some embodiments, the mixer circuitry 715A of the receive signal path and the mixer circuitry 715A of the transmit signal path may be configured for super-heterodyne operation.

[0070] 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 such embodiments, the RF circuitry 715 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry, and the baseband circuitry 710 may include a digital baseband interface to communicate with the RF circuitry 715.

[0071] In some dual-mode embodiments, separate radio integrated circuit (IC) circuitry may be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect.

[0072] In some embodiments, the synthesizer circuitry 715D may include one or more of a fractional-N synthesizer and 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, the synthesizer circuitry 715D may include a delta-sigma synthesizer, a frequency multiplier, a synthesizer comprising a phase-locked loop with a frequency divider, other synthesizers, and combinations thereof.

[0073] The synthesizer circuitry 715D may be configured to synthesize an output frequency for use by the mixer circuitry 715A of the RF circuitry 715 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 715D may be a fractional N/N+1 synthesizer.

[0074] In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although that is not a requirement. Divider control input may be provided by either the baseband circuitry 710 or the application circuitry 705 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 application circuitry 705.

[0075] The synthesizer circuitry 715D of the RF circuitry 715 may include a divider, a delay-locked loop (DLL), a multiplexer, and a phase accumulator. In some embodiments, the divider may include a dual modulus divider (DMD), and the phase accumulator may include 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 such embodiments, the delay elements may be configured to break a VCO period into N_d equal packets of phase, where N_d is the number of delay elements in the delay line. In this way, the DLL may provide negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

[0076] In some embodiments, the synthesizer circuitry 715D may be configured to generate a carrier frequency as the output frequency. In some embodiments, the output frequency may be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency, etc.) and used in conjunction with a 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 local oscillator (LO) frequency (fLO). In some embodiments, the RF circuitry 715 may include an IQ/polar converter.

[0077] The FEM circuitry 720 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 725, amplify the received signals, and provide the amplified versions of the received signals to the RF circuitry 715 for further processing. The FEM circuitry 720 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 715 for transmission by at least one of the antennas 725.

[0078] In some embodiments, the FEM circuitry 720 may include a TX/RX switch configured to switch between a transmit mode and a receive mode operation. The FEM circuitry 720 may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry 720 may include a low-noise amplifier (LNA) to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 715). The transmit signal path of the FEM circuitry 720 may include a power amplifier (PA) configured to amplify input RF signals (e.g., provided by the RF circuitry 715), and one or more filters configured to generate RF signals for subsequent transmission (e.g., by one or more of the antennas 725).

[0079] In some embodiments, the MS device 700 may include additional elements such as, for example, memory/storage, a display, a camera, one or more sensors, an input/output (I/O) interface, other elements, and combinations thereof.

[0080] In some embodiments, the MS device 700 may be configured to perform one or more processes, techniques, and/or methods as described herein, or portions thereof.

[0081] <u>Examples</u>

[0082] The following examples pertain to further embodiments.

[0083] Example 1 is an apparatus for a user equipment. The apparatus includes circuitry to detect energy on a channel of a license-assisted access (LAA) secondary cell (SCell). The apparatus also includes one or more baseband processing units to identify a channel access priority class (p) of an uplink communication. The apparatus also includes one or more baseband processing units to determine a number of slots (m_p) that have a slot duration (T_{sl}) to use as a second channel sensing duration (m_pT_{sl}), where the number of slots (m_p) is based on the identified channel access priority class, and where the number of slots (m_p) is at least two. The one or more baseband processing units are further to sense the channel for a defer duration (T_d) that includes a first channel sensing duration (T_f) and the second channel sensing duration (m_pT_{sl}), and allow access to the channel for the uplink communication when the channel is sensed to be idle for the defer duration (T_d) and any backoff duration.

[0084] Example 2 is the apparatus of Example 1 and/or any of the other examples described herein, where the identified channel access priority class (p) of the uplink communication is one (1), and where the number of slots (m_1) for channel access priority class 1 is two (2).

[0085] Example 3 is the apparatus of Example 1 and/or any of the other examples described herein, where the identified channel access priority class (p) of the uplink communication is one (1), and where the number of slots (m_2) for channel access priority class 2 is two (2).

[0086] Example 4 is the apparatus of any of Examples 1-3 and/or any of the other examples described herein, where the number of slots (m_p) are consecutive.

[0087] Example 5 is the apparatus of Example 4 and/or any of the other examples described herein, where the slot duration (T_{sl}) is nine (9) microseconds (μs).

[0088] Example 6 is the apparatus of Example 5 and/or any of the other examples described herein, where the first channel sensing duration (T_f) is 16 μs.

[0089] Example 7 is the apparatus of any of Examples 1-3 and/or any of the other examples described herein, where the second channel sensing duration (m_pT_{sl}) is consecutive to the first channel sensing duration (T_f).

[0090] Example 8 is the apparatus of any of Examples 1-3 and/or any of the other examples described herein, where the backoff duration is consecutive to the defer duration (T_d).

[0091] Example 9 is the apparatus of any of Examples 1-3 and/or any of the other examples described herein, where the uplink communication comprises a physical uplink shared channel (PUSCH) communication.

[0092] Example 10 is the apparatus of any of Examples 1-3 and/or any of the other examples described herein, where any backup duration is based on a random backoff counter (N).

[0093] Example 11 is an apparatus for a user equipment. The apparatus includes memory to store a channel sensing duration (T_f) and a slot duration (T_{sl}), and logic to detect energy on a channel of a license-assisted access (LAA) secondary cell (SCell). The apparatus also includes one or more processing units to: identify an uplink message to be sent on a channel of a license-assisted access (LAA) secondary cell (SCell), where a channel access priority class (p) of the uplink message is channel access priority class 1, sense the channel for a defer duration (T_d), where the defer duration (T_d) consists of the channel sensing duration (T_f) and a number of consecutive slots (m_p) that have the slot duration (T_{sl}), where the number of consecutive slots (m_p) is at least two (2) for channel access priority class 1 uplink messages, and determine that the channel is idle for the defer duration (T_d) before contending for access to the channel.

[0094] Example 12 is the apparatus of Example 11 and/or any of the other examples described herein, where the number of consecutive slots (m_p) is two (2) for channel access priority class 1.

[0095] Example 13 is the apparatus of Example 11 and/or any of the other examples described herein, where the one or more processing units are further to determine that the channel is available for the uplink message when the channel is idle and a random backoff counter (N) equals zero (0).

[0096] Example 14 is the apparatus of any of Examples 11-13 and/or any of the other examples described herein, where the slot duration (T_{sl}) is nine (9) microseconds (μs).

[0097] Example 15 is the apparatus of any of Examples 11-13 and/or any of the other examples described herein, where the channel sensing duration (T_f) is 16 μs.

[0098] Example 16 is a computer-readable medium. The computer-readable medium having instructions stored thereon, the instructions, when executed by a computing device, cause the computing device to identify an uplink message to be sent on a channel of a license-assisted access (LAA) secondary cell (SCell), where a channel access priority class (p) of the uplink message is channel access priority class 2. The computer-readable medium having instructions stored thereon, the instructions, when executed by a computing device, cause the computing device to sense the channel for a defer duration (T_d), where the defer duration (T_d) consists of a channel sensing duration (T_f) and a number of consecutive slots (m_p) that have a slot duration (T_{sl}), where the number of consecutive slots (m_p) is at least two (2) for channel access priority class 2 uplink messages, and determine that the channel is idle for the defer duration (T_d) before contending for access to the channel.

[0099] Example 17 is the computer-readable medium of Example 16 and/or any of the other examples described herein, where the number of consecutive slots (m_p) is two (2) for channel access priority class 2.

[0100] Example 18 is the computer-readable medium of Example 16 and/or any of the other examples described herein, where the one or more processing units are further to determine that the channel is available for the uplink message when the channel is idle and a random backoff counter (N) equals zero (0).

[0101] Example 19 is the computer-readable medium of any of Examples 16-18 and/or any of the other examples described herein, where the slot duration (T_{sl}) is nine (9) microseconds (μs).

[0102] Example 20 is the computer-readable medium of any of Examples 16-18 and/or any of the other examples described herein, where the channel sensing duration (T_f) is 16 μs.

[0103] Example 21 is a method for wireless communication. The method includes identifying an uplink message to be sent on a channel of a license-assisted access (LAA) secondary cell (SCell), where a channel access priority class (p) of the uplink message is channel access priority class 2, sensing the channel for a defer duration (T_d), where the defer duration (T_d) consists of a channel sensing duration (T_f) and a number of consecutive slots (m_p) that have a slot duration (T_{sl}), where the number of consecutive slots (m_p) is at least two for at least one of channel access priority class 1 uplink messages and channel access priority class 2 uplink messages, and determining that the channel is idle for the defer duration (T_d) before contending for access to the channel.

[0104] Example 22 is the method of Example 16 and/or any of the other examples described herein, where the number of consecutive slots (m_p) is two for channel access priority class 1.

[0105] Example 23 is the method of Example 16 and/or any of the other examples described herein, where the number of consecutive slots (m_p) is two for channel access priority class 2.

[0106] Example 24 is the method of Example 16 and/or any of the other examples described herein, where the method further includes determining that the channel is available for the uplink message when the channel is idle and a random backoff counter (N) equals zero.

[0107] Example 25 is the method of any of Examples 16-19 and/or any of the other examples described herein, where the slot duration (T_{sl}) is 9 microseconds (μs).

[0108] Example 26 is the method of any of Examples 16-19 and/or any of the other examples described herein, where the channel sensing duration (T_f) is 16 μs.

[0109] Example 27 is an apparatus including means to perform any of the methods described herein.

[0110] Example 28 is a machine-readable storage including machine-readable instructions that when executed by a processor cause the processor to implement any method or realize any apparatus described herein.

[0111] Example 29 is a machine-readable medium including code, that when executed, causes a machine to perform any of the methods described herein.

[0112] It will be obvious to those having skill in the art that many changes may be made to the details of the above-described embodiments without departing from the underlying principles of the invention. The scope of the present invention should, therefore, be determined only by the following claims.

Claims

1. An apparatus for a user equipment, the apparatus comprising:

circuitry to detect energy on a channel of a license-assisted access (LAA) secondary cell (SCell); and

one or more baseband processing units to:

identify a channel access priority class (p) of an uplink communication;

determine a number of slots (m_p) that have a slot duration (T_{sl}) to use as a second channel sensing duration (m_pT_{sl}), wherein the number of slots (m_p) is based on the identified channel access priority class, and wherein the number of slots (m_p) is at least two;

sense the channel for a defer duration (T_d) that includes a first channel sensing duration (T_f) and the second channel sensing duration (m_pT_{sl}); and

allow access to the channel for the uplink communication when the channel is sensed to be idle for the defer duration (T_d) and any backoff duration.

2. The apparatus of claim 1, wherein the identified channel access priority class (p) of the uplink communication is 1, and wherein the number of slots (m_1) for channel access priority class 1 is two.

3. The apparatus of claim 1, wherein the identified channel access priority class (p) of the uplink communication is 1, and wherein the number of slots (m_2) for channel access priority class 2 is two.

4. The apparatus of any of claims 1-3, wherein the number of slots (m_p) are consecutive.

5. The apparatus of claim 4, wherein the slot duration (T_{sl}) is 9 microseconds (μs).

6. The apparatus of claim 5, wherein the first channel sensing duration (T_f) is 16 μs.

7. The apparatus of any of claims 1-3, wherein the second channel sensing duration (m_pT_{sl}) is consecutive to the first channel sensing duration (T_f).

8. The apparatus of any of claims 1-3, wherein the backoff duration is consecutive to the defer duration (T_d).

9. The apparatus of any of claims 1-3, wherein the uplink communication comprises a physical uplink shared channel (PUSCH) communication.

10. The apparatus of any of claims 1-3, wherein any backup duration is based on a random backoff counter (N).

11. An apparatus for a user equipment, the apparatus comprising:

memory to store a channel sensing duration (T_f) and a slot duration (T_{sl})

logic to detect energy on a channel of a license-assisted access (LAA) secondary cell (SCell); and

one or more processing units to:

identify an uplink message to be sent on a channel of a license-assisted access (LAA) secondary cell (SCell), wherein a channel access priority class (p) of the uplink message is channel access priority class 1;

sense the channel for a defer duration (T_d), wherein the defer duration (T_d) consists of the channel sensing duration (T_f) and a number of consecutive slots (m_p) that have the slot duration (T_{sl}), wherein the number of consecutive slots (m_p) is at least two for channel access priority class 1 uplink messages; and

determine that the channel is idle for the defer duration (T_d) before contending for access to the channel.

12. The apparatus of claim 11, wherein the number of consecutive slots (m_p) is two for channel access priority class 1.

13. The apparatus of claim 11, wherein the one or more processing units are further to:

determine that the channel is available for the uplink message when the channel is idle and a random backoff counter (N) equals zero.

14. The apparatus of any of claims 11-13, wherein the slot duration (T_{sl}) is 9 microseconds (μs).

15. The apparatus of any of claims 11-13, wherein the channel sensing duration (T_f) is 16 μs.

16. A method for wireless communication, comprising:

identifying an uplink message to be sent on a channel of a license-assisted access (LAA) secondary cell (SCell), wherein a channel access priority class (p) of the uplink message is channel access priority class 2;

sensing the channel for a defer duration (T_d), wherein the defer duration (T_d) consists of a channel sensing duration (T_f) and a number of consecutive slots (m_p) that have a slot duration (T_{sl}), wherein the number of consecutive slots (m_p) is at least two for at least one of channel access priority class 1 uplink messages and channel access priority class 2 uplink messages; and

determining that the channel is idle for the defer duration (T_d) before contending for access to the channel.

17. The method of claim 16, wherein the number of consecutive slots (m_p) is two for channel access priority class 1.

18. The method of claim 16, wherein the number of consecutive slots (m_p) is two for channel access priority class 2.

19. The method of claim 16, further comprising:

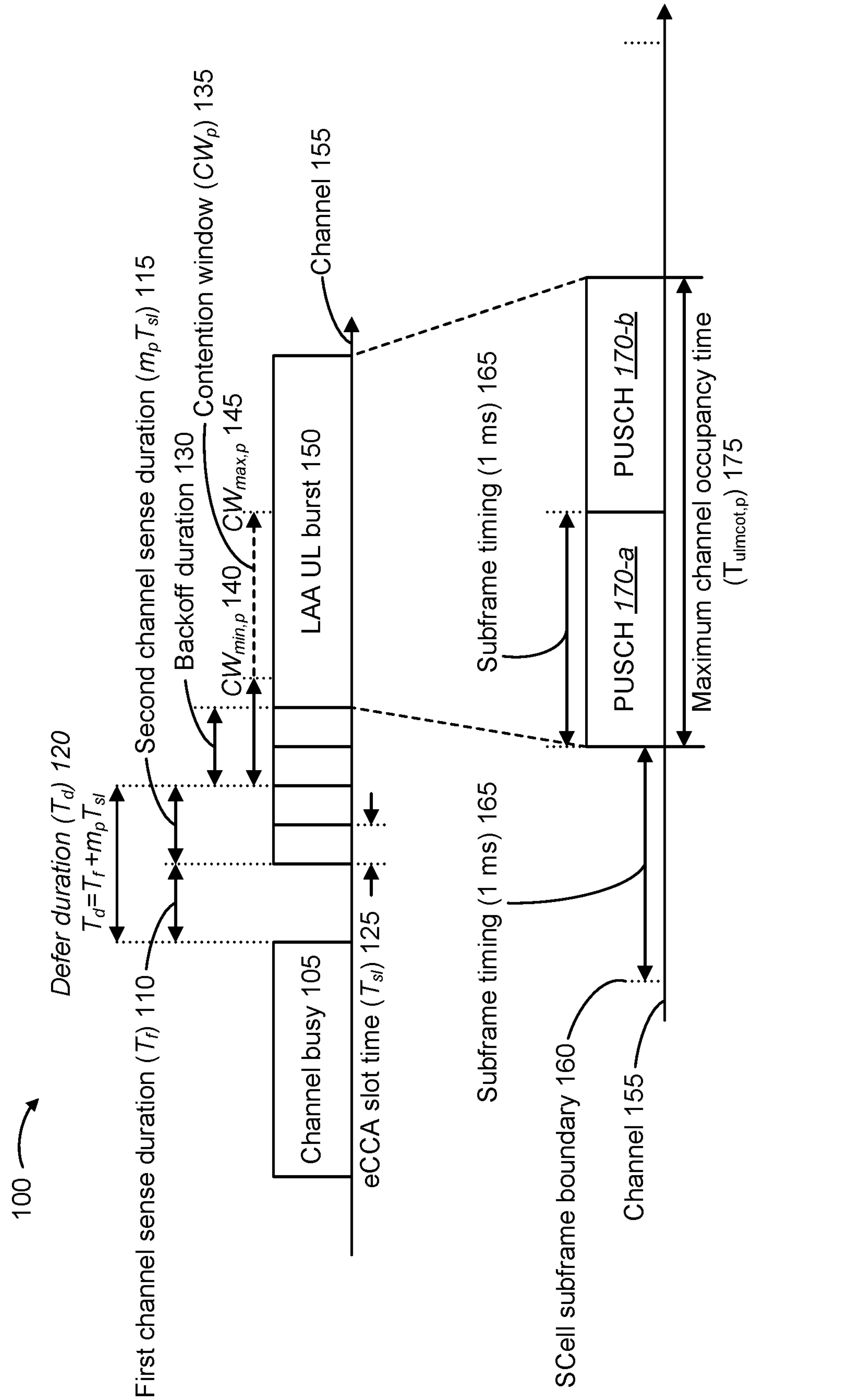
determining that the channel is available for the uplink message when the channel is idle and a random backoff counter (N) equals zero.

20. The method of any of claims 16-19, wherein the slot duration (T_{sl}) is 9 microseconds (μs).

21. The method of any of claims 16-19, wherein the channel sensing duration (T_f) is 16 μs.

22. An apparatus comprising means to perform a method as claimed in any preceding claim.

23. Machine-readable storage including machine-readable instructions that when executed implement a method or realize an apparatus as claimed in any preceding claim.



100
Defer duration (T_d) 120
$T_d = T_f + m_p T_{sl}$
First channel sense duration (T_f) 110
Second channel sense duration ($m_p T_{sl}$) 115
Backoff duration 130
Contention window (CW_p) 135
$CW_{min,p}$ 140
$CW_{max,p}$ 145
Channel busy 105
LAA UL burst 150
eCCA slot time (T_{sl}) 125
Channel 155
Subframe timing (1 ms) 165
Subframe timing (1 ms) 165
PUSCH 170-a
PUSCH 170-b
Maximum channel occupancy time ($T_{ulmcot,p}$) 175
SCell subframe boundary 160
Channel 155

FIG. 1

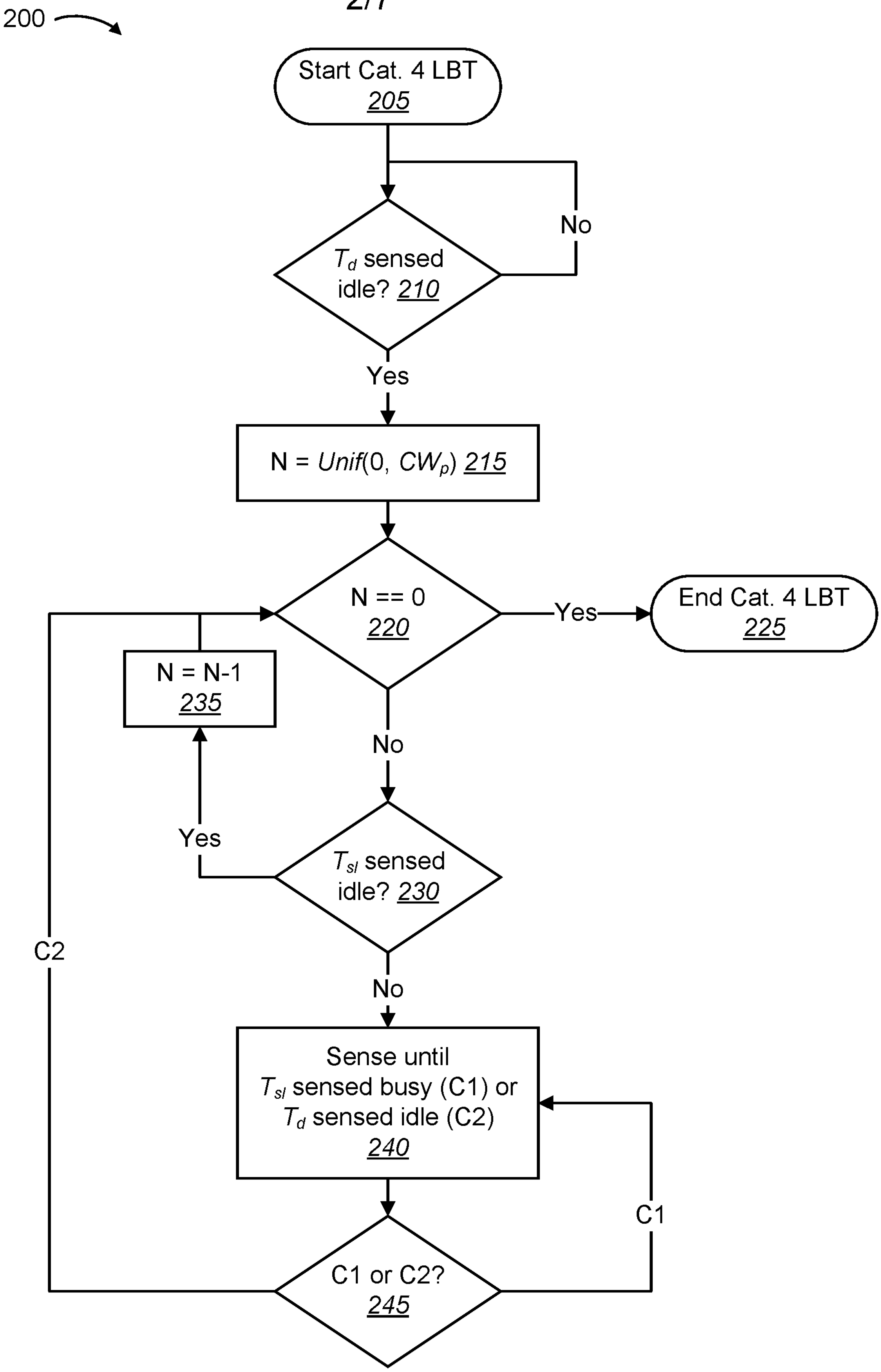

200
Start Cat. 4 LBT 205
T_d sensed idle? 210
No
Yes
N = $Unif(0, CW_p)$ 215
N == 0 220
Yes
End Cat. 4 LBT 225
N = N-1 235
No
Yes
T_{sl} sensed idle? 230
C2
No
Sense until T_{sl} sensed busy (C1) or T_d sensed idle (C2) 240
C1
C1 or C2? 245

FIG. 2

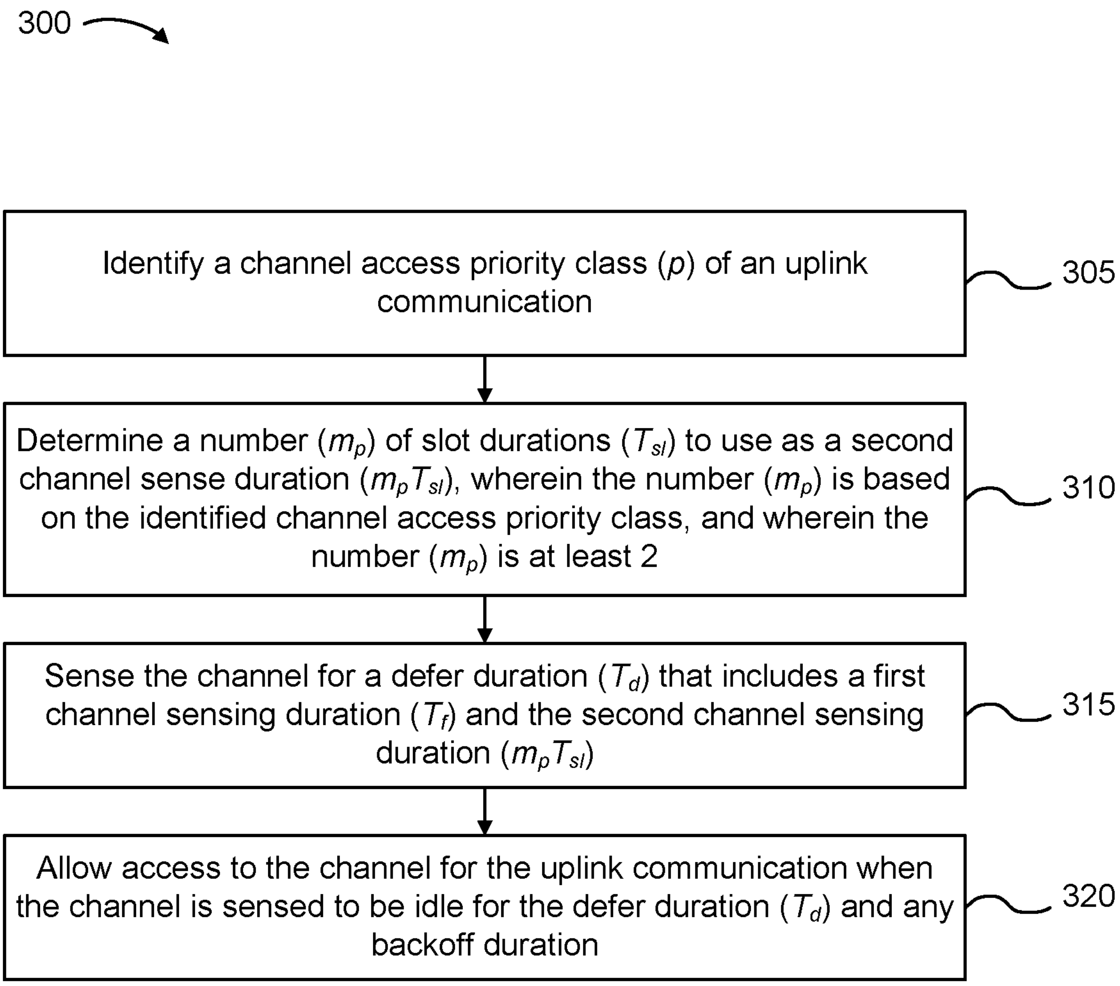

300
Identify a channel access priority class (p) of an uplink communication
305
Determine a number (m_p) of slot durations (T_{sl}) to use as a second channel sense duration (m_pT_{sl}), wherein the number (m_p) is based on the identified channel access priority class, and wherein the number (m_p) is at least 2
310
Sense the channel for a defer duration (T_d) that includes a first channel sensing duration (T_f) and the second channel sensing duration (m_pT_{sl})
315
Allow access to the channel for the uplink communication when the channel is sensed to be idle for the defer duration (T_d) and any backoff duration
320

FIG. 3

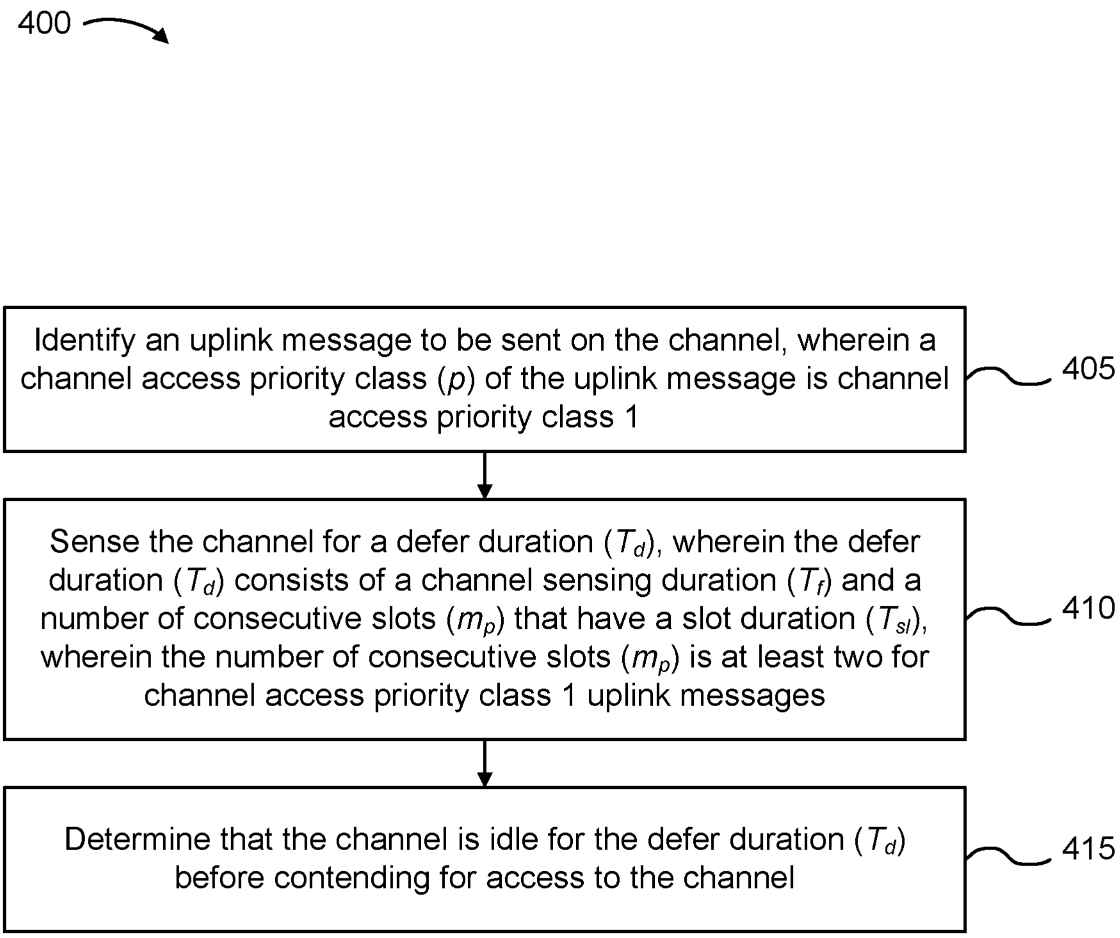

400
Identify an uplink message to be sent on the channel, wherein a channel access priority class (p) of the uplink message is channel access priority class 1
405
Sense the channel for a defer duration (T_d), wherein the defer duration (T_d) consists of a channel sensing duration (T_f) and a number of consecutive slots (m_p) that have a slot duration (T_{sl}), wherein the number of consecutive slots (m_p) is at least two for channel access priority class 1 uplink messages
410
Determine that the channel is idle for the defer duration (T_d) before contending for access to the channel
415

FIG. 4

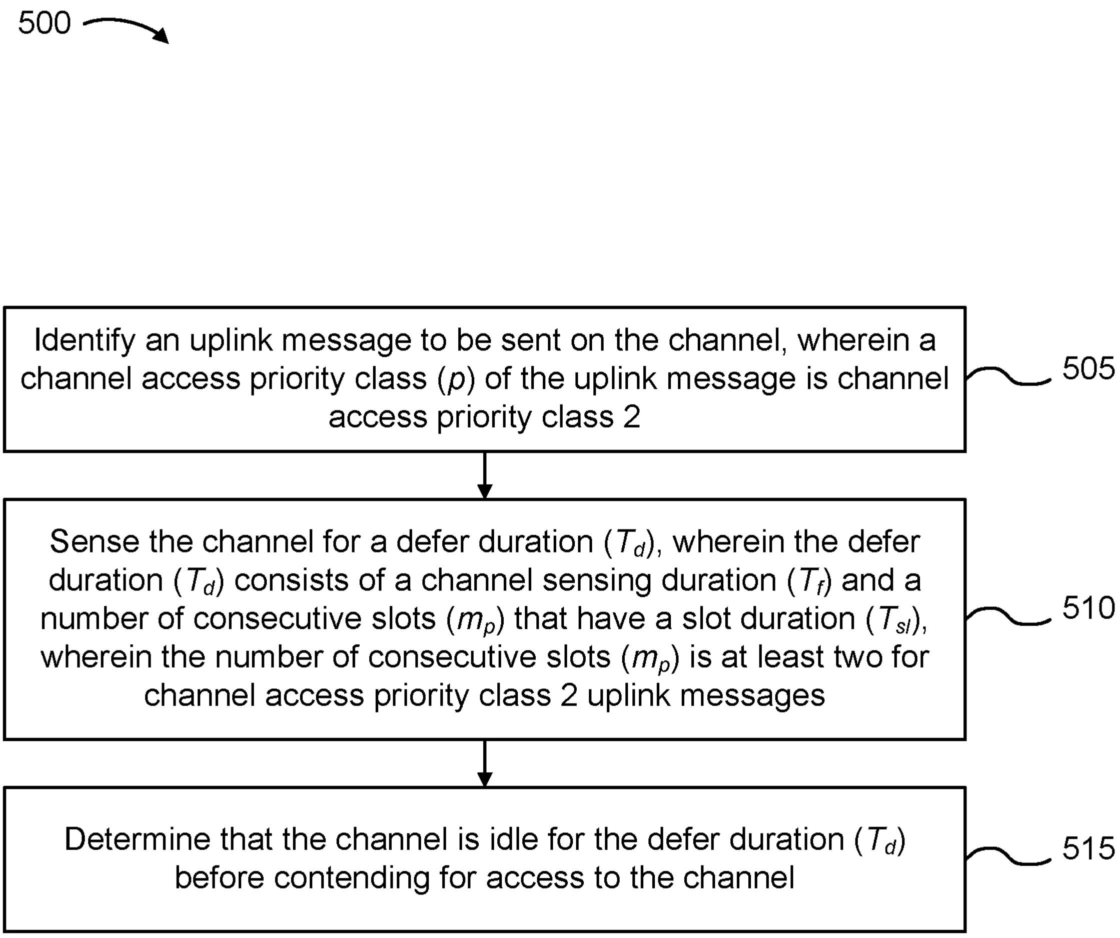

500
Identify an uplink message to be sent on the channel, wherein a channel access priority class (p) of the uplink message is channel access priority class 2
505
Sense the channel for a defer duration (T_d), wherein the defer duration (T_d) consists of a channel sensing duration (T_f) and a number of consecutive slots (m_p) that have a slot duration (T_{sl}), wherein the number of consecutive slots (m_p) is at least two for channel access priority class 2 uplink messages
510
Determine that the channel is idle for the defer duration (T_d) before contending for access to the channel
515

FIG. 5

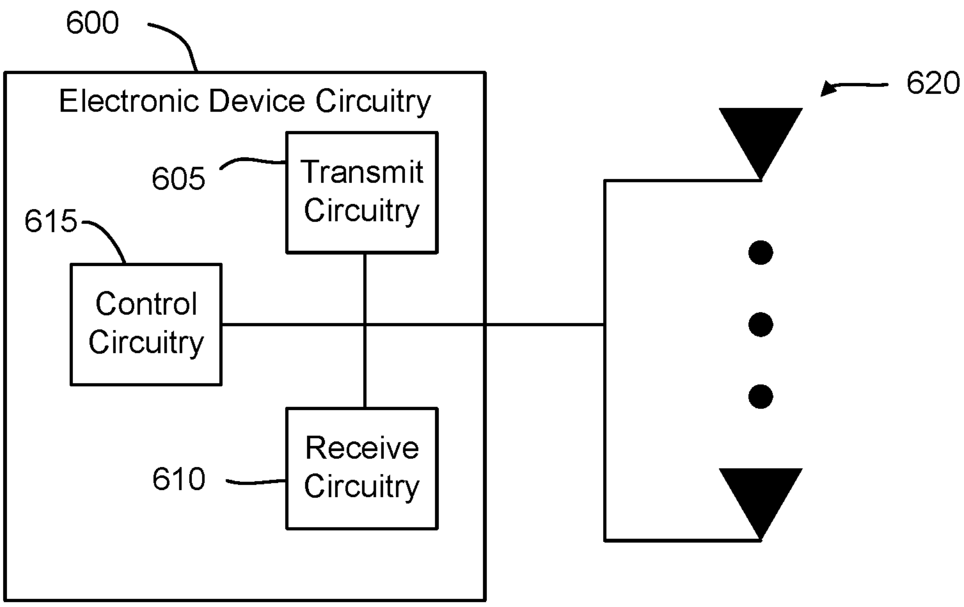
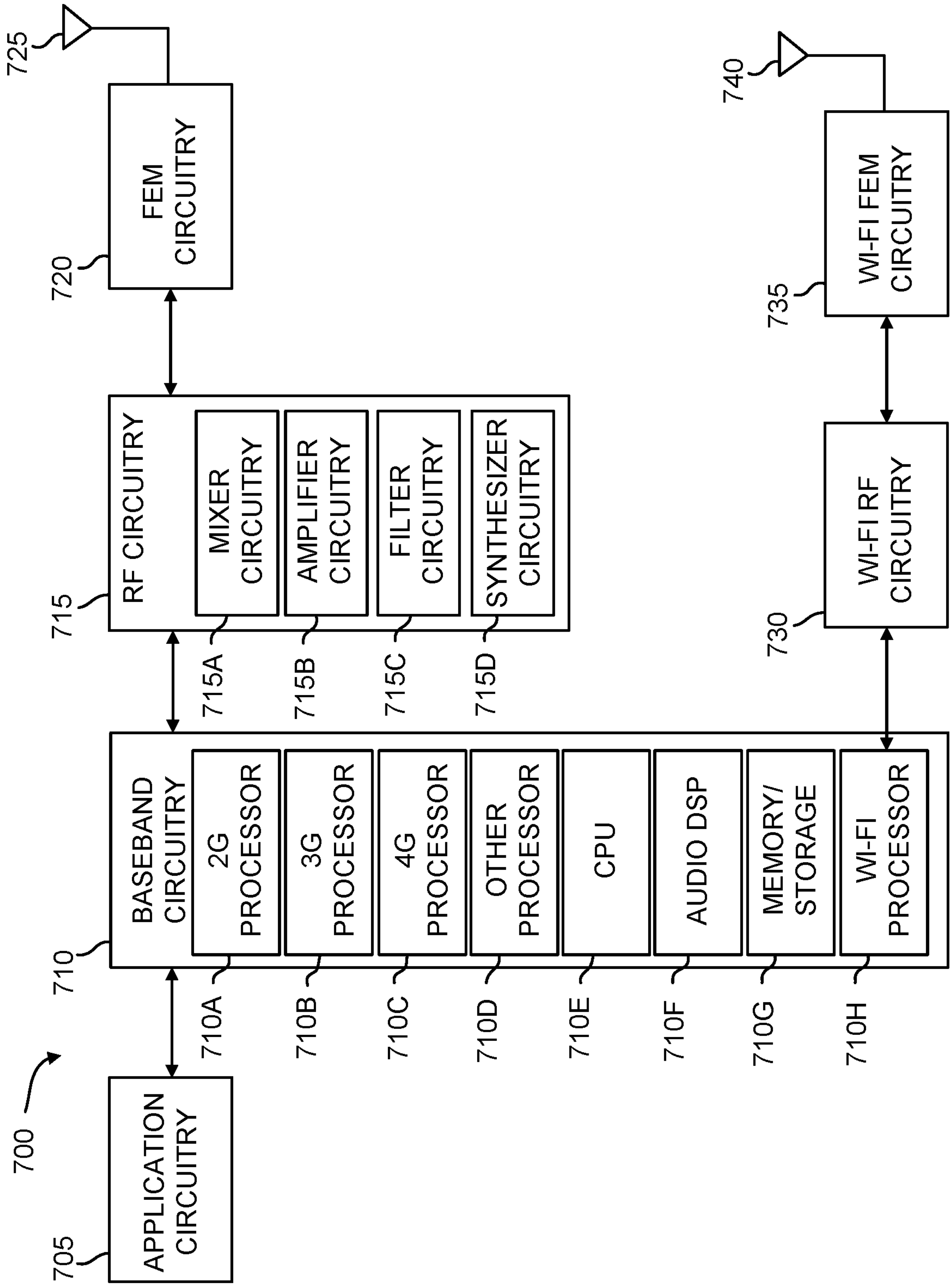

600
Electronic Device Circuitry
605
Transmit Circuitry
615
Control Circuitry
610
Receive Circuitry
620

FIG. 6



700
705
APPLICATION CIRCUITRY
710
BASEBAND CIRCUITRY
2G PROCESSOR
3G PROCESSOR
4G PROCESSOR
OTHER PROCESSOR
CPU
AUDIO DSP
MEMORY/ STORAGE
WI-FI PROCESSOR
710A
710B
710C
710D
710E
710F
710G
710H
715
RF CIRCUITRY
MIXER CIRCUITRY
AMPLIFIER CIRCUITRY
FILTER CIRCUITRY
SYNTHESIZER CIRCUITRY
715A
715B
715C
715D
720
FEM CIRCUITRY
725
730
WI-FI RF CIRCUITRY
735
WI-FI FEM CIRCUITRY
740

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/016989

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W74/08
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)
H04W

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	LENOVO: "LBT mechanism for LAA uplink", 3GPP DRAFT; R1-161013, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. St Julian's, Malta; 20160215 - 20160219 6 February 2016 (2016-02-06), XP051064493, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_84/Docs/ [retrieved on 2016-02-06] the whole document -----	1-23

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[X] Further documents are listed in the continuation of Box C. [X] 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
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"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
25 April 2017	09/05/2017

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	Schut, Gerhard

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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/016989

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	MEDIATEK INC: "Uplink channel access in LAA", 3GPP DRAFT; R1-160976, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. St Julian's, Malta; 20160215 - 20160219 24 February 2016 (2016-02-24), XP051079075, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_84/Docs/ [retrieved on 2016-02-24] paragraph [0002] -----	1-23
A	US 2007/165665 A1 (GAUR SUDHANSHU [US] ET AL) 19 July 2007 (2007-07-19) paragraphs [0018] - [0030]; figure 1 -----	1-23

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2017/016989

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2007165665 A1	19-07-2007	JP 2007189690 A	26-07-2007
		US 2007165665 A1	19-07-2007