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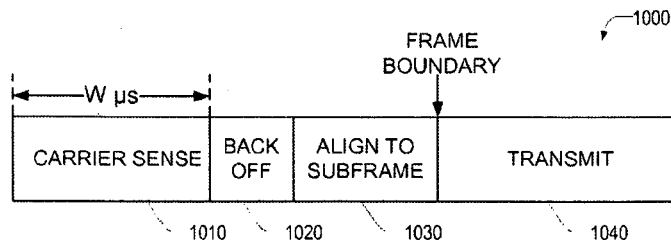


FIG. 1

(57) Abstract: Disclosed in some examples are systems, machine-readable media, methods, and cellular wireless devices which implement a Listen-Before-Talk (LBT) access scheme for a device operating according to a cellular wireless protocol in an unlicensed channel. A cellular wireless device may utilize the cellular wireless protocol in the unlicensed channel after the LBT access scheme has determined that a channel (a defined range of frequencies) in the unlicensed channel is idle for a particular period of time.

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SUBFRAME ALIGNED LISTEN-BEFORE-TALK FOR CELLULAR IN UNLICENSED BAND

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PRIORITY CLAIM

[0001] This patent application claims the benefit of priority to United States Application Serial Number 14/711,278, filed May 13, 2015, which claims the benefit of priority to United States Provisional Patent Application Serial Number 10 62/076,083, filed on November 6, 2014, all of which are hereby incorporated by reference herein in their entirety.

TECHNICAL FIELD

[0002] Embodiments pertain to cellular wireless technologies. Some 15 embodiments relate to cellular wireless technologies operating in unlicensed communication bands.

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BACKGROUND

[0004] Cellular wireless technologies typically operate in a licensed 30 frequency spectrum. A licensed frequency spectrum is a range of frequencies that are assigned to a particular entity (e.g., a particular wireless carrier) for use. As the available licensed frequency spectrums are limited and as demand rises for cellular wireless services, the amount of free spectrum available for use is limited.

[0005] In contrast to licensed frequency spectrums, there are various unlicensed frequency spectrums which allow for use of certain frequencies without an entity obtaining legal approval. These frequencies are shared amongst devices which wish to use them, and devices that use these spectrums have protocols to allow them to share the spectrum with other devices. Often these unlicensed spectrums are not licensed primarily for cellular wireless uses and often these spectrums are subject to contention or utilization by other devices.

10 BRIEF DESCRIPTION OF THE DRAWINGS

[0006] In the drawings, which are not necessarily drawn to scale, like numerals may describe similar components in different views. Like numerals having different letter suffixes may represent different instances of similar components. The drawings illustrate generally, by way of example, but not by way of limitation, various embodiments discussed in the present document.

15 [0007] FIG. 1 is a timeline of a synchronous Listen-Before-Talk (LBT) method according to some examples of the present disclosure.

[0008] FIG. 2A shows a slit diagram of symbol aligned slits according to some examples of the present disclosure.

20 [0009] FIG. 2B shows a slit diagram of evenly divided slits according to some examples of the present disclosure.

[0010] FIG. 3 shows a flowchart of a method of a first option for LBT sensing and backoff according to some examples of the present disclosure.

25 [0011] FIG. 4 shows a flowchart of a method of a second option for LBT sensing and backoff according to some examples of the present disclosure.

[0012] FIG. 5 shows a flowchart of a method of a third option for LBT sensing and backoff according to some examples of the present disclosure.

[0013] FIG. 6 shows a diagram of anticipatory scheduling of the SDL according to some examples of the present disclosure.

30 [0014] FIG. 7 shows a flowchart of a method of anticipatory scheduling of the SDL according to some examples of the present disclosure.

[0015] FIG. 8 shows a diagram of puncturing symbols of a subframe according to some examples of the present disclosure.

[0016] FIG. 9 shows a flowchart of a method of a cellular wireless device puncturing symbols according to some examples of the present disclosure.

[0017] FIG. 10 shows a schematic of a cellular wireless device according to some examples of the present disclosure.

5 [0018] FIG. 11 shows a schematic of a wireless environment according to some examples of the present disclosure.

[0019] FIG. 12 shows a block diagram of an example machine upon which any one or more of the techniques (e.g., methodologies) discussed herein may be performed according to some examples of the present disclosure.

10 DETAILED DESCRIPTION

[0020] As demand for licensed spectrum for cellular wireless protocols such as Long Term Evolution (LTE) increases, designers of LTE systems have begun to explore the use of these licensed protocols in unlicensed frequencies. Usage of cellular and other licensed protocols in unlicensed frequencies presents certain
15 challenges. Unlicensed frequencies may include the industrial, scientific, and medical (ISM) band, for example, 2.4 GHz, 5 GHz, and the like. The unlicensed frequencies may be determined by one or more governmental entities, such as the U.S. Federal Communications Commission (FCC).

[0021] For example, cellular wireless devices (e.g., a base station or a mobile
20 device such as a smart phone) utilize licensed channels which ensure that these devices have exclusive use of the particular wireless channel. A “channel” is a band of (usually but not always contiguous) frequencies used for wireless communications. As a result, a design assumption of these cellular protocols is that they have exclusive access to the frequencies on which they operate. They
25 are generally concerned with coordinating amongst other devices participating in the same network. For example, in LTE systems, a base station (an eNodeB) typically coordinates transmission and reception from one or more User Equipments (UEs) that are associated with the eNodeB. The eNodeB generally does not consider other users in other networks when planning transmission and
30 reception of data. If a cellular wireless network began transmitting in the unlicensed channel without modification, the cellular wireless devices would transmit and receive continuously. This would prevent other devices from utilizing the channel.

[0022] In contrast, devices operating in unlicensed channels consider not only devices operating in a single network (e.g., controlled by a single operator), but devices operating in many different networks and devices operating using other protocols. For example, devices operating according to wireless protocols such as an 802.11 standard defined by the Institute for Electrical and Electronics Engineers (IEEE) (Wi-Fi) consider not only devices in their own network (i.e., a Basic Service Set – BSS), but devices in other BSSs and indeed devices running other protocols before determining whether they can use the wireless medium.

[0023] What are therefore needed are methods for adapting a cellular wireless protocol to operate in an unlicensed channel in an efficient manner. Disclosed in some examples are systems, machine-readable media, methods, and cellular wireless devices which implement modifications for operating according to a cellular wireless protocol in an unlicensed band. Such modifications include implementing a Listen-Before-Talk (LBT) access scheme that the cellular wireless device employs in the unlicensed channels, optimizing scheduling, and optimizing channel sensing.

[0024] A “cellular wireless device,” as used herein, is any device that is operating according to a cellular wireless protocol. A “cellular wireless protocol” is a wireless protocol defining a cellular wireless network which is distributed over land areas called cells, with each cell served by at least one fixed-location transceiver, known as a cell site or base station. These cell sites are interconnected to provide wireless services over a wide geographic area. Example cellular wireless protocols that may be adapted for transmission in the unlicensed channels include cellular wireless protocols according to one of an LTE family of standards promulgated by the Third Generation Partnership Project (3GPP) (including an LTE Advanced (LTE-A) Family of Standards), a Universal Mobile Telecommunications System (UMTS) family of standards promulgated by 3GPP, a Global System for Mobile Communications (GSM) family of standards, and the like. A cellular wireless device may be a base station such as a NodeB or an eNodeB, or may be a mobile device such as a UE.

[0025] In some examples, a cellular wireless device may use the licensed band for controlling the transmissions on the unlicensed band (for example,

obtaining Channel State Information (CSI) feedback, scheduling on a Physical Downlink Control Channel (PDCCH) and the like).

[0026] Example transmissions of the cellular wireless devices in the unlicensed channel include transmissions to support one or more of Layer 1, Layer 2, Layer 3, and other layers of these cellular protocols (for example, the Physical (PHY) layer, the Media Access Control (MAC) layer, the Radio Link Control (RLC) layer, the Packet Data Convergence Protocol (PDCP), and the Radio Resource Control (RRC) layers). Channels transmitted in the unlicensed frequency may include any uplink data channels, uplink control channels, downlink data channels, and downlink control channels. Examples include one or more of a Physical Downlink Shared Channel (PDSCH), a Physical Uplink Shared Channel (PUSCH), a PDCCH, and a Physical Uplink Control Channel (PUCCH).

[0027] In some examples, a cellular wireless device such as a cellular base station (e.g., eNodeB) may provide a cell with uplink and downlink capabilities in the licensed spectrum and also provide a supplemental downlink (SDL) channel in an unlicensed spectrum. The SDL channel may carry one or more LTE channels, such as a PDSCH. The LBT techniques may be applied to the SDL channel to ensure that the unlicensed channels are idle and free of interference. In other examples, for uplink channels on the unlicensed spectrum, the UE may be the cellular wireless device which implements the LBT mechanisms. In some examples, the SDL may be scheduled on a PDCCH on the primary (licensed) frequencies. For example, the UE may be scheduled on the PDCCH of a licensed frequency for receiving data on the SDL PDSCH on the unlicensed frequency (i.e., using cross carrier scheduling).

[0028] Aspects of the cellular wireless protocols may be modified in one or more ways such as disclosed herein in order to operate within the unlicensed frequency spectrum. For example, an LBT access scheme may be implemented in the cellular wireless protocol by the cellular wireless device.

30 **LBT, Channel Sensing, and Backoff Designs**

[0029] In some examples, the cellular wireless device implementing an LBT access mode for the unlicensed band may listen to the channel for a channel listen time (a predetermined period of time). If the channel is idle for the

channel listen time, the cellular wireless device may deem that the channel is available for transmission.

[0030] FIG. 1 shows a timeline 1000 of a cellular wireless device operating synchronously in an unlicensed channel using an LBT mechanism. At stage 5 1010, a transceiver of the cellular wireless device conducts carrier sensing (CS) for a channel in the unlicensed band for a period of $W \mu s$ and determines the average power received. If the received power is less than a threshold $T \text{ dBm}$, the channel is considered idle. Otherwise, if the received power is greater than the threshold, the channel is considered busy. At stage 1020, if the channel is 10 determined to be idle, the transceiver enters a backoff phase. In the backoff phase, the transceiver chooses a backoff time period. The time period may be chosen randomly from a selection of legal values. In some examples this time period may be a multiple of LTE symbols. During this backoff period, the transceiver senses the channel. If the channel is busy during this period, the 15 transceiver goes back to the carrier sense phase at stage 1010. If the channel is idle, the transceiver enters stage 1030. The backoff period of stage 1020 may be considered a random duration extension of the fixed duration carrier sense phase of stage 1010. The backoff period prevents numerous wireless devices with the same value for W all trying to access the medium at the same time.

20 [0031] During stage 1030, the transceiver may send a reservation message or signal to reserve the channel until the next subframe boundary of the cellular network or until the next subframe boundary plus the amount of time needed to transmit the next subframe in order to align to the subframe. Example reservation signals may be a Wi-Fi Request to Send (RTS) or Clear to Send 25 (CTS). Once the subframe boundary has passed, the transceiver may transmit at stage 1040.

[0032] For downlink operation on the unlicensed channel, for an LTE network, the eNodeB may implement the LBT decision making, while on the uplink, the eNodeB may implement the LBT mechanism, but convey 30 information to the UE to enable the UE to transmit during the stage 1040.

[0033] Within the context of a cellular wireless network such as LTE, what is needed is to define how often to sample the channel when carrier sensing or backoff sensing. Sampling the channel too often leads to increased costs of

manufacturing and increased workloads on the transceiver. Sampling the channel too infrequently can lead to erroneously reporting the channel as idle and causing collisions.

[0034] Within an LTE subframe there are fourteen symbols. In some

5 examples, the channel may be sampled once per symbol. However, this level of sampling granularity may be too infrequent as each frame is 1 millisecond, and $1/14^{\text{th}}$ of 1 millisecond is approximately 70 microseconds.

[0035] In some examples, a smaller granularity for a sample may be utilized.

For example, each symbol may be subdivided into two or more "slits." A slit, as
10 used herein, may be defined as the basic unit of granularity for sensing a channel and may be defined with reference to timing information of the cellular wireless protocol. For example, each symbol may be divided into four slits. In these examples, the slits do not cross a symbol boundary. This presents a dilemma because in an LTE subframe the first and eighth symbols are slightly larger,
15 having 2208 samples compared to 2192 samples as in the other symbols. In these examples, the slits of the first and eighth symbols may be 552 samples and the remaining slits may be 548 samples. In other examples, for the first and eighth symbols, the extra samples (16) may be divided up in other ways. For example, three of the slits of these symbols may be 548 samples, and the
20 remaining slit may be 564 samples. FIG. 2A shows one example slit diagram 2000 of symbol aligned slits. Slit 2010, as shown, is slightly larger than slits 2020-2040 of symbol one and the rest of the slits of symbols 2-14, with the exception of one or more slits in symbol eight (as symbol 8 also contains 2208 samples).

25 **[0036]** In other examples, rather than divide the symbols to create the slits, the subframe itself may be sub-divided into equal, fixed-size slits. In this example, a slit may include portions of two consecutive symbols. That is, the slit may cross a symbol boundary. FIG. 2B shows one example slit diagram 2100 of evenly divided slits. In some examples, the first slit 2110 starts on the
30 beginning of the subframe and the last slit 2120 ends on the subframe ending boundary. As can be appreciated from the figure, slits may cross symbol boundaries, such as slit 2130, which cross symbols 1 and 2. In some examples, if N is the number of samples in one slit, because it may be desirable that the slit

boundary coincides with a subframe boundary (which has 30720 samples), N may be chosen such that N is a factor of 30720. Thus, the number of slits may be described by $30720/N$. As each subframe is 1 millisecond (ms) in duration ($10^3 \mu\text{s}$), and because there are 30720 samples in a subframe, there are 30.72 samples in 1 microsecond. As the LTE specification defines the minimum sensing period for the unlicensed channel as 20 microseconds (μs), multiplying by 20, we get 614.4 samples in 20 microseconds as the minimum number of samples to sense.

[0037] Because the sample is the smallest granularity in LTE, having 0.4 samples may be rounded up (as 614 would produce a sensing time of less than 2 microseconds) to at least 615. However, it may be desirable that N be a factor of 30720 so that all the slits fit into the same subframe. One option may be 48 slits in a subframe, which works out to be 640 samples for each slit. Having 640 samples/slit means each slit is approximately 20.83 microseconds long which is slightly above the minimum of 20 microseconds. In other examples, more slits per subframe may be utilized; however, the cellular wireless device may need to sense for more than a single slit in order to meet the minimum specified in the LTE specification.

[0038] To implement the sensing and backoff, disclosed herein are three example designs. These options are all suitable for co-existence between a cellular wireless protocol such as LTE and a wireless protocol that operates on the unlicensed channel such as Wi-Fi.

[0039] FIG. 3 shows a flowchart of a method 3000 of a first option for LBT sensing and backoff according to some examples of the present disclosure. In the first option, a Contention Window (CW) is employed to determine when the channel is clear. The transceiver of the cellular wireless device may select a random number between 1 and q at operation 3010. In some examples, q is defined as a predetermined value between 4 and 32 that, in some cases, may be determined by the manufacturer of the cellular wireless device. In other examples, q may be dynamically changed. At operation 3020, the transceiver of the cellular wireless device may sense the channel for a period of time that is (or is approximately) the CW multiplied by the Clear Channel Assessment (CCA) Duration (CD) (CD is in microseconds). CD may be defined as one or more

whole slits. To determine if the channel is idle, in some examples, the received power of the channel during a particular CD may be compared to a predetermined threshold (e.g., a threshold of -62 dBm). If the power is less than the threshold, then the channel may be deemed idle during that slit. If the power is above the threshold, then the channel may be deemed busy during that slit. In some examples, if a single slit is deemed busy, then the whole period may be deemed busy. In other examples, if more than a predetermined amount of slits are deemed busy, then the whole CW*CD period may be deemed busy. In still other examples, the received power may be sampled at each slit and then averaged over the entire CW*CD period and the average power over that period may be compared with a threshold. If the average power is above the threshold, the channel may be deemed busy. If the average power is below the threshold, the channel may be deemed idle.

[0040] If the channel is deemed idle, the cellular wireless device may proceed with transmitting the SDL at operation 3030. If the channel is deemed busy, the cellular wireless device may return to operation 3010 and start over.

[0041] In some examples, this method of detecting that the medium is idle differs from that of Wi-Fi carrier sensing. In Wi-Fi carrier sensing, a Wi-Fi device uses both an energy detection mechanism and a signal detection mechanism. If the Wi-Fi device detects a Wi-Fi signal using the signal detection mechanism, the Wi-Fi device assumes that the channel is occupied. In some examples, the LBT method disclosed herein uses only the energy detection mechanism and not the Wi-Fi signal detection mechanisms. Note that in FIG. 3, CD is the duration in μ s of the clear channel assessment (CCA) which may be the slit duration or a multiple thereof.

[0042] FIG. 4 shows a flowchart of a method 4000 of a second option for sensing and backoff LBT implementation. At operation 4010, the transceiver senses the channel for W μ s. W may be a time period that is equal to one or more slits. At operation 4020, a comparison is made and if the received power is above a threshold T for W time period, then the transceiver returns to operation 4010. If the received power is below the threshold T for W time period, then the transceiver goes to operation 4030. If W encompasses more than a single slit, the power comparison may be an average power across all slits, or the

comparison at operation 4020 may be *per slit*. In the per slit case, if more than a predetermined number (e.g., one or more) of slits fail the comparison (e.g., the power level is greater than the threshold) then the comparison at operation 4020 fails and flow proceeds back to operation 4010.

5 [0043] At operation 4030 the transceiver may generate a random number CW between 1 and q, where q (as previously noted) is a number between 4 and 32. At operation 4040 CW may be decremented (e.g., $CW = CW - 1$). At operation 4050 a comparison is made to determine if CW is less than or equal to zero. If CW is less than or equal to zero, then the channel is clear and the
10 transceiver may transmit at operation 4060. If $CW > 0$, then at operation 4070, the transceiver may sense the channel for a slit period. At operation 4080 a comparison is made and if the observed power level is less than a threshold, it is determined that the channel is idle for that slit and operations proceed to 4040 where the CW is decremented again. If the channel is not idle, operation reverts
15 to 4010. Note that in FIG. 4, CD is the duration in μs of the clear channel assessment (CCA) which may be the slit duration or a multiple thereof.

[0044] FIG. 5 shows a flowchart of a method of a third option for LBT sensing and backoff according to some examples of the present disclosure. At operation 5010, the transceiver senses the channel for W μs . W may be a time
20 period that is equal to one or more slits. At operation 5020, a comparison is made and if the received power is above a threshold T for W time period, then the transceiver returns to operation 5010. If the received power is below the threshold T for W time period, then the transceiver goes to operation 5030. If W encompasses more than a single slit, the power comparison may be an average
25 power across all slits, or the comparison at operation 5020 may be *per slit*. In the per slit case, if more than a predetermined number (e.g., one or more) of slits fail the comparison (e.g., the power level is greater than the threshold), then the comparison at operation 5020 fails and flow proceeds back to operation 5010.

[0045] At operation 5030 the transceiver may determine if the channel is
30 congested. For example, if the transceiver had to sense the channel for W μs at operation 5010 more than a predetermined number of times the transceiver may determine that the channel is congested. In other examples, the transceiver may determine that the channel is congested based upon errors in previous

transmissions – for example, utilizing a transport block error (TBE) level. If the TBE is above a predetermined threshold, then channel may be determined to be congested.

- [0046] At operation 5050, if the channel is congested, a parameter, CWT, may be set to the maximum of: double the last CWT and the maximum contention window (CWMAX). CWT, CWMIN, and CWMAX may be predefined; for example, CWT may be initially 1, CWMIN may be 1, and CWMAX may be 1024. At operation 5040, if the channel is not congested, CWT may be set to 1.
- 10 [0047] At operation 5070 the transceiver may generate a random number CW by adding a value D to a random number chosen between CMIN and CWT. D may be equal to the time in number of slits it takes to transmit one or more LTE symbols. At operation 5080, CW may be decremented by D (e.g., $CW = CW - D$). At operation 5090 a comparison is made to determine if CW is
- 15 less than or equal to zero. If CW is less than or equal to zero, then the channel is clear and the transceiver may transmit at operation 5100. If $CW > 0$, then at operation 5110, the transceiver may sense the channel for D time period (which may be one or more slits). If at operation 5120 it is determined that the channel is idle, operations proceeds to operation 5080 where the CW is decremented
- 20 again. If the channel is not idle, operation reverts to operation 5010. The channel may be determined idle as described in options 1 and 2 (i.e. the observed power in each slit may be below a threshold, an average power observed in each slit may be below a threshold, or a predetermined number of slits in the CD period may be below a threshold).

25 Scheduling Optimizations

- [0048] In some examples, the SDL may be implemented using a control channel on the licensed channel (i.e., the primary channel). For example, in LTE, the SDL may be implemented utilizing the PDCCH on the licensed channel. The PDCCH is typically carried on the first three symbols of the
- 30 current subframe and schedules the current subframe. If the backoff period completes before the start of the next subframe the eNodeB may reserve the channel by sending a channel reservation message on the unlicensed channel (e.g., a Request-to-Send – RTS, or Clear-to-Send – CTS message) and schedule

the SDL using the PDCCH of the next subframe. If the backoff period ends during the PDCCH transmission of the next subframe, it may be possible to schedule the SDL depending on the other scheduling and on the bandwidth of the PDCCH. If the backoff period ends before the SDL can be scheduled on the PDCCH of the licensed channel, the SDL transmission opportunity may be wasted.

[0049] In some examples, the eNodeB may schedule the SDL even if the backoff period will not end until after the start of the subframe. For example, the eNodeB may predict that the backoff period may complete successfully (the channel remains idle the entire period) and may schedule the SDL for the remaining part of the subframe after the backoff procedure is scheduled for completion. For example, if the backoff procedure is to be completed half-way through the subframe, the eNodeB may schedule half of the subframe in anticipation that the backoff process may complete successfully.

[0050] In some examples, predicting the backoff period may complete successfully may include assuming that the backoff period completes successfully. In some examples, past history of the channel may be used to predict the backoff period is to complete successfully. In these examples, if the eNodeB successfully completed the backoff process above a threshold percentage of time in the past on this channel, the eNodeB may predict that the backoff process this time may be successful. Other algorithms may include factoring in one or more of: time of the access, history of the channel, past error rates, and the like. Example algorithms may utilize if-then statements that compare these factors to predetermined thresholds.

[0051] In some examples, the backoff overlap may be limited to the first three symbols of the current subframe (where the PDCCH is normally transmitted). Thus if the backoff will complete in the first three symbols of the current subframe, the eNodeB may schedule the SDL PDSCH. Otherwise, if the backoff is not scheduled to be complete within the first three symbols of the current subframe, the eNodeB will not schedule the SDL PDSCH in the current subframe.

[0052] In cases in which the eNodeB anticipatorily schedules the SDL PDSCH, the UE receives the data on the SDL if the backoff period successfully

completes and the eNodeB is able to transmit the SDL. If the channel becomes busy before the backoff period ends and the eNodeB does not get access to the unlicensed channel, the UE may not know this and will receive data that is not valid (e.g., noise). The UE would not be able to successfully decode the PDSCH on the SDL. In an idealized situation, the UE would simply discard the PDSCH on the SDL for this subframe. The UE, thinking it missed data that was transmitted to it, will utilize Hybrid Automatic Repeat Request (HARQ) functionality to request re-transmission of the missed data. In this case, the eNodeB may ignore any HARQ requests for this data and may indicate to the UE to remove this data from its HARQ buffers. For example, a new Downlink Control Information (DCI) format may be defined to carry an indication that the SDL was not actually sent over the unlicensed channel. Alternatively, in some examples, a new physical signal or channel can be defined to carry the new indication message.

[0053] Turning now to FIG. 6, a diagram 6000 of anticipatory scheduling of the SDL is shown. LBT and backoff starts at symbol 6010 of subframe 6020. If the backoff is predicted to be complete by symbol 6030 (the third symbol of subframe 2 6040), then the eNodeB may schedule the SDL on subframe 2 6040. For example, the eNodeB may schedule a UE to receive data on symbol 6050.

[0054] Turning now to FIG. 7 a flowchart of a method 7000 of anticipatory scheduling of the SDL is shown. At operation 7010 the cellular wireless device (e.g., the eNodeB) may engage in the LBT and Backoff processes (e.g., FIGs. 3-5). At operation 7020 the cellular wireless device predicts if the LBT and backoff process will complete in time. In some examples, this is simply assuming that the backoff process will not return a busy channel and determining if there is enough time to schedule any part of the SDL. For example, if the backoff process were to complete within the first three symbols of a particular subframe, that subframe may be scheduled. In other examples, other criteria, such as past channel usage history or past LBT and backoff success rates, may be used.

[0055] If at operation 7030 the backoff is not predicted to be completed on time, then flow proceeds to operation 7040. At operation 7040, the channel may be reserved once the backoff process is completed until a subframe can be

scheduled and transmitted on the SDL. If the backoff process is scheduled to be completed on time, at operation 7050, the subframe may be scheduled on the PDCCH of the licensed channel when appropriate. At operation 7070, the cellular wireless device may determine if the LBT and backoff completed on time. If it did, at operation 7080, the cellular wireless device may transmit the SDL on the unlicensed channel as normal. If it did not, at operation 7090, the cellular wireless device may ignore any HARQ retransmission requests from any UEs scheduled on the SDL for the unsent SDL subframe. At operation 7100, the cellular wireless device may send a message to the UEs that were scheduled on the SDL to clear their HARQ buffers and terminate retransmission tries for this data.

Channel Sense Optimizations

[0056] In some examples, in order to send multiple subframes, the cellular wireless device may utilize one or more symbols in the current subframe in which data is not transmitted to perform sensing and backoff in order to meet the requirements to transmit another subframe. The symbols of the current subframe used to perform the sensing and backoff operations are “punctured.” In some examples, the last K symbols of the current frame are punctured. In some examples $K = 2$. In some examples, every subframe may be punctured by K symbols. In yet other examples, every L subframes may be punctured (e.g., every other subframe, or every 3 subframes, and the like). K may be static (that is, every L th subframe, K symbols may be punctured), but in some examples K may change so that K in one subframe is different from K in another subframe.

[0057] The UEs associated with the eNodeB may be notified of the symbol puncturing in order to discard any received data during these symbols. Notifications to the UE may include exact locations of the punctured symbols. Example notifications may include a new DCI. The DCI may include a bit-map of B (up to 14) bits, indicating the positions of the punctured symbols in the subframe. In other examples, the DCI may be avoided if the transceiver on the cellular wireless device uses significantly higher redundancy MCS (with lower code rate) transmissions to counteract the puncturing.

[0058] Turning now to FIG. 8, a diagram 8000 of puncturing the last two symbols 8020 and 8030 of a subframe is shown. Three symbols 8040 of

subframe 1 are taken up by Wi-Fi traffic or are idle. Three symbols 8050 are sensing and backoff, and eight symbols 8060 are reserved by the cellular wireless device prior to the start of subframe 2. Once subframe 2 is started, the cellular wireless device may transmit the SDL PDSCH 8070. Symbols 8030 and 8020 are punctured to start the sensing and backoff for the next subframe (not shown).

[0059] In some examples, the backoff implemented may be any one of the previously described methods. In some examples, the channel sense optimizations may be combined with the scheduling optimizations. In any case, all the various options for channel sense and backoff are compatible and may be used with either or both of the channel sense optimizations and scheduling optimizations.

[0060] Turning now to FIG. 9, a method 9000 of a cellular wireless device puncturing K symbols is shown according to some examples. At operation 9010, the cellular wireless device may determine that another subframe is desired for SDL transmission. For example, the eNodeB may have additional data for one or more UEs. At operation 9020, the eNodeB may determine K . K may be predetermined, or may be variable. At operation 9030, the puncturing parameters may be communicated to one or more UEs that are scheduled on the current subframe. Puncturing parameters may include the symbols that are to be punctured or one or more pieces of information that allows the UE to deduce the symbols that are to be punctured (e.g., K). At operation 9040, the cellular wireless device may perform LBT and Backoff in the punctured symbols of the current subframe.

[0061] Turning now to FIG. 10, a schematic of a cellular wireless device 10000 is shown, according to some examples. The cellular wireless device 10000 may be any device that is capable of communicating using a licensed cellular protocol. The cellular wireless device 10000 may be a nodeB, an eNodeB, a UE, a Base Transceiver Station (BTS), a Wi-Fi access point, a cell phone, a smart phone, a desktop computer, a laptop computer, a medical device (e.g., a heart rate monitor, a blood pressure monitor, or the like), a wearable device (e.g., computing glasses, a smart watch), or the like.

[0062] The cellular wireless device 10000 may contain a first wireless transceiver 10030, a second wireless transceiver 10040, and control circuitry 10020 for controlling the first and second wireless transceivers. The first wireless transceiver 10030 may operate on an unlicensed channel, and in some examples, implement a wireless protocol that is not a cellular wireless protocol. In some examples, the first wireless transceiver 10030 may implement a wireless protocol that operates in the unlicensed channels, such as an IEEE 802.11 wireless protocol, a Bluetooth wireless protocol, a Bluetooth Low Energy (BLE) wireless protocol, a Zigbee wireless protocol, or the like. In some examples, the first wireless transceiver 10030 may determine whether the unlicensed channel is occupied with other traffic. In some examples, the first transceiver 10030 may detect the power level on the unlicensed channel and if the average power level is below a particular threshold for a predetermined period of time, then the control circuitry 10020 may determine that the channel is unoccupied using one or more of the methods of FIGs. 3-5.

[0063] Control circuitry 10020 may control the backoff process once the channel is deemed unoccupied. The control circuitry 10020 may, in cooperation with the first transceiver 10030, cause the operations of FIGs. 3-5 to be implemented, such as selecting a random contention window, decrementing the contention window, using the first transceiver 10030 to sense the channel for $W \mu s$, determining if the backoff period is over, or, if activity is detected on the channel during the backoff period, signaling the first transceiver 10030 to once again determine if the medium is free by detecting the power level on the unlicensed channel for a channel listen period of time. Once the control circuitry 10020 and first transceiver 10030 have determined that the channel is once again free, the control circuitry 10020 will start over and once again implement the backoff procedure.

[0064] Control circuitry 10020 may also implement the Scheduling and Channel Sense optimizations. For example, control circuitry 10020 may predict if the LBT and Backoff will be completed in time to schedule a subframe. If the LBT/backoff is not predicted to be completed in time, the control circuitry 10020 may instruct the first or second transceivers 10030, 10040 to transmit reservation messages once the LBT and backoff are completed for the next available

subframe. If the LBT/back off is predicted to be complete in time to transmit the SDL PDSCH in the current subframe, then the control circuitry will schedule one or more UEs on the SDL PDSCH via the PDCCH transmitted by the second transceiver 10040. If the UEs were scheduled but the LBT/backoff procedure failed to successfully complete, the control circuitry may ignore any HARQ transmissions related to the subframe. The control circuitry may also instruct any receivers (e.g., UEs) via the second transceiver 10040 or first transceiver 10030 (e.g., over the licensed or unlicensed channels) to remove these items from their HARQ queues so they will no longer request retransmission.

5 [0065] Control circuitry 10020 may also implement one or more channel sense optimizations. Control circuitry 10020 may determine K and L , and communicate with any receivers (e.g., UEs) via the second transceiver 10040 or the first transceiver 10030 (e.g., over the licensed or unlicensed channels) about the puncturing parameters. Additionally the control circuitry 10020 may

10 implement this puncturing via the first transceiver.

[0066] The second wireless transceiver 10040 may implement a cellular wireless protocol and may generally transmit over a licensed frequency. Example cellular wireless protocols may include a Long Term Evolution (LTE family of standards promulgated by the Third Generation Partnership Project

20 (3GPP), Universal Mobile Telecommunications (UMTS) promulgated by 3GPP, an Institute for Electrical and Electronics Engineers (IEEE) 802.16 standard known as Worldwide Interoperability for Microwave Access (WiMAX), and the like. The second transceiver 10040 may provide for one or more protocol layers of the cellular wireless protocol to enable communications. For example, if the

25 cellular wireless device 10000 is an eNodeB, the second transceiver 10040 provides the functionality to implement the eNodeB. If the cellular wireless device 10000 is a UE, the second transceiver 10040 provides the functionality to connect to the cellular network and transfer data across that network. The second transceiver 10040 may utilize the licensed bandwidth, but may also have

30 circuitry to send and receive data across the unlicensed bandwidth.

[0067] Control circuitry 10020 may control the first transceiver 10030, as well as second transceiver 10040. When the control circuitry 10020 determines that the unlicensed channels are to be used for the cellular wireless protocol, the

control circuitry 10020 may determine when the channel is free using first transceiver 10030, and in some examples, reserve the channel using a channel reservation message via first transceiver 10030. Once the channel is free, the control circuitry 10020 may instruct either the first or second transceivers 10030 and 10040 to transmit on the unlicensed band using the cellular wireless protocol.

[0068] In some examples, the cellular wireless device 10000 may send a reservation message on the unlicensed channels. In some examples, the reservation message has a duration field which may be set to the duration of cellular data transfer (e.g., a subframe). In some examples, the cellular wireless device 10000 may not begin transmitting until a subframe boundary. In these examples, if a reservation message is sent, the reservation message may have a duration equal to the duration of cellular data transfer plus the amount of time until the next subframe boundary.

[0069] FIG. 11 shows a schematic of an example wireless environment 11000 according to some examples of the present disclosure. Cellular wireless device in the form of an eNodeB 11010 provides cellular wireless communications for one or more cellular wireless devices in the form of UEs 11030. In some examples, the UEs 11030 may utilize the cellular network provided by the eNodeB 11010 to access a network, such as the internet 11060. The cellular wireless communications may be according to one or more wireless standards such as LTE. Cellular wireless devices 11010 and 11030 may include the components of FIGs. 10 and FIGs. 12, as well as implementing any one or more of the methods or timelines shown in FIGs. 1-9. The cellular wireless devices 11010 and 11030 may communicate on the licensed or unlicensed frequencies. Wireless device 11050 (e.g., a laptop computer) may access one or more local area networks provided by a wireless device 11040 (e.g., an access point) which may operate in the unlicensed frequencies. Wireless device 11050 may access the network, such as the internet 11060 through the wireless connection with wireless device 11040.

[0070] FIG. 12 illustrates a block diagram of an example machine 12000 upon which any one or more of the techniques (e.g., methodologies) discussed herein may be performed. In alternative embodiments, the machine 12000 may

operate as a standalone device or may be connected (e.g., networked) to other machines. In a networked deployment, the machine 12000 may operate in the capacity of a server machine, a client machine, or both in server-client network environments. In an example, the machine 12000 may act as a peer machine in
5 peer-to-peer (P2P) (or other distributed) network environment. The machine 12000 may be a cellular wireless device, a wireless device, or the like. Example cellular wireless devices include an eNodeB, a UE, a personal computer (PC), a tablet PC, a set-top box (STB), a personal digital assistant (PDA), a mobile telephone, a web appliance, a network router, switch, or bridge, or any machine
10 capable of executing instructions (sequential or otherwise) that specify actions to be taken by that machine. Further, while only a single machine is illustrated, the term "machine" shall also be taken to include any collection of machines that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein, such as cloud
15 computing, software as a service (SaaS), or other computer cluster configurations.

[0071] Examples, as described herein, may include, or may operate on, logic or a number of components, modules, circuitry, or mechanisms. Modules and circuitry are tangible entities (e.g., hardware) capable of performing specified
20 operations and may be configured or arranged in a certain manner. In an example, circuits may be arranged (e.g., internally or with respect to external entities such as other circuits) in a specified manner as circuitry. In an example, the whole or part of one or more computer systems (e.g., a standalone, client, or server computer system) or one or more hardware processors may be configured
25 by firmware or software (e.g., instructions, an application portion, or an application) as circuitry that operates to perform specified operations.

[0072] Accordingly, the term "circuitry" is understood to encompass a tangible entity, be that an entity that is physically constructed, specifically configured (e.g., hardwired), or temporarily (e.g., transitorily) configured (e.g.,
30 programmed) to operate in a specified manner or to perform part or all of any operation described herein. Considering examples in which circuitry is temporarily configured, each of the circuits need not be instantiated at any one moment in time. For example, where the circuits comprise a general-purpose

hardware processor configured using software, the general-purpose hardware processor may be configured as respective different circuitry at different times. Software may accordingly configure a hardware processor, for example, to constitute a particular circuit at one instance of time and to constitute a different circuit at a different instance of time.

5 [0073] The machine (e.g., computer system) 12000 may include a hardware processor 12002 (e.g., a central processing unit (CPU), a graphics processing unit (GPU), a hardware processor core, or any combination thereof), a main memory 12001, and a static memory 12006, some or all of which may
10 communicate with each other via an interlink (e.g., bus) 12008. The machine 12000 may further include a display unit 12010, an alphanumeric input device 12012 (e.g., a keyboard), and a user interface (UI) navigation device 12014 (e.g., a mouse). In an example, the display unit 12010, alphanumeric input device 12012, and UI navigation device 12014 may be a touch screen display. The
15 machine 12000 may additionally include a storage device (e.g., drive unit) 12016, a signal generation device 12018 (e.g., a speaker), a network interface device 12020, and one or more sensors 12021, such as a global positioning system (GPS) sensor, compass, accelerometer, or other sensor. The machine 12000 may include an output controller 12028, such as a serial (e.g., universal
20 serial bus (USB)), parallel, or other wired or wireless (e.g., infrared (IR), near field communication (NFC), etc.) connection to communicate with or control one or more peripheral devices (e.g., a printer, card reader, etc.).

[0074] The storage device 12016 may include a machine readable medium 12022 on which is stored one or more sets of data structures or instructions
25 12024 (e.g., software) embodying or utilized by any one or more of the techniques or functions described herein. The instructions 12024 may also reside, completely or at least partially, within the main memory 12001, within the static memory 12006, or within the hardware processor 12002 during execution thereof by the machine 12000. In an example, one or any combination
30 of the hardware processor 12002, the main memory 12001, the static memory 12006, or the storage device 12016 may constitute machine readable media.

[0075] While the machine readable medium 12022 is illustrated as a single medium, the term "machine readable medium" may include a single medium or

multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) configured to store the one or more instructions 12024.

- [0076] The term “machine readable medium” may include any medium that is capable of storing, encoding, or carrying instructions for execution by the machine 12000 and that cause the machine 12000 to perform any one or more of the techniques of the present disclosure, or that is capable of storing, encoding, or carrying data structures used by or associated with such instructions. A machine readable medium may include a non-transitory machine readable medium. A machine-readable medium is not a transitory propagating signal.
- 10 Non-limiting machine readable medium examples may include solid-state memories, and optical and magnetic media. Specific examples of machine readable media may include non-volatile memory, such as semiconductor memory devices (e.g., Electrically Programmable Read-Only Memory (EPROM), Electrically Erasable Programmable Read-Only Memory (EEPROM)) and flash memory devices; magnetic disks, such as internal hard disks and removable disks; magneto-optical disks; Random Access Memory (RAM); and CD-ROM and DVD-ROM disks. The instructions 12024 may further be transmitted or received over a communications network 12026 using a transmission medium via the network interface device 12020 utilizing any one of
- 20 a number of transfer protocols (e.g., frame relay, internet protocol (IP), transmission control protocol (TCP), user datagram protocol (UDP), hypertext transfer protocol (HTTP), and the like). Example communication networks may include a local area network (LAN), a wide area network (WAN), a packet data network (e.g., the Internet), mobile telephone networks (e.g., cellular networks),
- 25 Plain Old Telephone (POTS) networks, and wireless data networks (e.g., IEEE 802.11 family of standards known as Wi-Fi®, IEEE 802.16 family of standards known as WiMax®, IEEE 802.15.4 family of standards, and peer-to-peer (P2P) networks, among others. In an example, the network interface device 12020 may include one or more physical jacks (e.g., Ethernet, coaxial, or phone jacks)
- 30 or one or more antennas to connect to the communications network 12026.

[0077] In an example, the network interface device 12020 may include a plurality of antennas to wirelessly communicate using at least one of single-input multiple-output (SIMO), multiple-input multiple-output (MIMO), or multiple-

input single-output (MISO) techniques. The term “transmission medium” shall be taken to include any intangible medium that is capable of storing, encoding, or carrying instructions for execution by the machine 12000, and includes digital or analog communications signals or other intangible media to facilitate communication of such software.

[0078] Other Notes and Examples

[0079] Example 1 includes subject matter (such as a device, apparatus, or machine) comprising: a first transceiver to transmit and receive in an unlicensed channel; a second transceiver to transmit and receive in a licensed channel and in the unlicensed channel according to a cellular wireless protocol; and a controller to: sense, via the first transceiver, an energy of the unlicensed channel over a predetermined number of one or more slits to determine that the unlicensed channel is unoccupied, the slits defined with reference to timing information of the cellular wireless protocol, and in response to determining that the channel is unoccupied: schedule, via a control channel transmitted on the licensed channel, at least one User Equipment (UE) serviced by the eNodeB to receive data in the unlicensed channel; and transmit the data over the unlicensed channel starting at a cellular subframe boundary via the second transceiver.

[0080] In Example 2, the subject matter of Example 1 may include, wherein the first transceiver is configured to transmit and receive according to a non-cellular wireless protocol, and wherein the data transmitted over the unlicensed channel is a Supplemental Downlink (SDL) Physical Downlink Shared Channel (PDSCH), and wherein the controller is further configured to send a wireless reservation message on the unlicensed channel via the first transceiver to reserve the unlicensed channel for the data transmitted over the unlicensed channel.

[0081] In Example 3, the subject matter of any one of Examples 1 to 2 may include, wherein the one or more slits are configured to subdivide a plurality of samples in a current cellular subframe such that the one or more slits do not cross a symbol boundary in the current cellular subframe.

[0082] In Example 4, the subject matter of any one of Examples 1 to 3 may include, wherein at least one of the one or more slits is configured to cross a symbol boundary of a current cellular subframe.

[0083] In Example 5, the subject matter of any one of Examples 1 to 4 may include, wherein the one or more slits are punctured from a current cellular subframe.

5 [0084] In Example 6, the subject matter of any one of Examples 1 to 5 may include, wherein the cellular wireless protocol is a Long Term Evolution (LTE) or Long Term Evolution-Advanced (LTE-A) family of Standards defined by the Third Generation Partnership (3GPP).

[0085] In Example 7, the subject matter of any one of Examples 1 to 6 may include, wherein the first transceiver is configured to transmit and receive
10 according to an Institute for Electrical and Electronics Engineers (IEEE) 802.11 protocol.

[0086] In Example 8, the subject matter of any one of Examples 1 to 7 may include, wherein the controller is to implement a backoff process, and is to refrain from transmitting the data on the unlicensed channel until the backoff
15 process is successful.

[0087] In Example 9, the subject matter of any one of Examples 1 to 8 may include, wherein control channel is a Physical Downlink Control Channel (PDCCH) and wherein the controller is to: predict that a backoff process will complete before an end of a transmission of the PDCCH, and in response,
20 schedule the at least one User Equipment (UE) serviced by the eNodeB to receive data on unlicensed channel via the PDCCH on the licensed channel transmitted by the second transceiver prior to completion of the backoff process.

[0088] In Example 10, the subject matter of any one of Examples 1 to 9 may include, wherein the controller is to: determine that the backoff process did not
25 complete before the end of the transmission of the PDCCH, and in response: ignore a Hybrid Automatic Repeat Requests (HARQ) for data scheduled on the unlicensed channel; and notify the UE to clear a HARQ buffer for data scheduled on the unlicensed channel.

[0089] In Example 11, the subject matter of any one of Examples 1 to 10
30 may include, wherein the second transceiver is configured to provide a PDSCH in a licensed channel.

[0090] Example 12 includes subject matter (such as a device, apparatus, or machine) comprising: sense a secondary channel that is not exclusively licensed

for cellular wireless communications over one or more slits; determine that a received power of the secondary channel indicates that the secondary channel is idle during the one or more slits; and in response: send a reservation message on the secondary channel; schedule at least one User Equipment (UE) to receive
5 data on a Physical Downlink Shared Channel (PDSCH) transmitted on the secondary channel; communicate the schedule to the UE via a control channel on a primary channel that is licensed for cellular wireless communications; and transmit the PDSCH over the secondary channel beginning at a subframe boundary.

10 [0091] In Example 13, the subject matter of Example 12 may include, wherein the one or more slits are defined with reference to timing information of a cellular wireless protocol.

[0092] In Example 14, the subject matter of any one of Examples 12 to 13 may include, wherein the instructions configure the eNodeB to: determine that a
15 backoff process will complete after a current subframe and during a next subframe, the next subframe beginning at the subframe boundary; and responsive to determining that the backoff process will complete after the current subframe and during the next subframe, schedule the at least one UE prior to the completion of the backoff process on a Physical Downlink Control Channel
20 (PDCCH) transmitted on the primary channel.

[0093] In Example 15, the subject matter of any one of Examples 12 to 14 may include, wherein the instructions further configure the eNodeB to successfully complete a backoff procedure prior to transmitting the PDSCH over the primary channel.

25 [0094] In Example 16, the subject matter of any one of Examples 12 to 15 may include, wherein the instructions for the backoff procedure comprise instructions to: generate a random contention window; channel sense for a second predetermined period of time equal to a slit for each contention window; and determine that the backoff procedure was successful by determining that for
30 each particular contention window, a received power during that particular contention window was below a predetermined threshold.

[0095] In Example 17, the subject matter of any one of Examples 12 to 16 may include, wherein the instructions for the backoff procedure comprise

instructions to: determine that the secondary channel is congested, and in response, doubling the contention window.

5 **[0096]** Example 18 includes subject matter (such as a device, apparatus, or machine) comprising: one or more processors to: determine that a power level of a first channel over one or more slits is below a first predetermined threshold, the first channel being a wireless channel that is not exclusively licensed for cellular wireless, and in response: select a random backoff window; determine that the power level of the first channel for the backoff window is below a second predetermined threshold; schedule a User Equipment (UE) to receive data on a Supplemental Downlink (SDL) Physical Downlink Shared Channel (PDSCH) on 10 the first channel using a control channel on a second, licensed channel; and transmit the SDL PDSCH over the first channel at a cellular subframe boundary responsive to the power level of the first channel for the random backoff window is below the second threshold.

15 **[0097]** In Example 19, the subject matter of Example 18 may include wherein the one or more processors are configured to provide a PDSCH on the second channel.

20 **[0098]** In Example 20, the subject matter of any one of Examples 18 to 19 may include, wherein the one or more slits are aligned with respect to a Long Term Evolution (LTE) or Long Term Evolution-Advanced (LTE-A) symbol.

25 **[0099]** In Example 21, the subject matter of any one of Examples 18 to 20 may include, wherein a duration in symbols of one or more slits are a consistent number of samples and are a factor of the number of samples in an Long Term Evolution (LTE) or Long Term Evolution-Advanced (LTE-A) subframe.

30 **[00100]** In Example 22, the subject matter of any one of Examples 18 to 21 may include, wherein the one or more processors are configured to send a wireless reservation message in response to the determination that the power level of the first channel for the backoff window is below the second threshold.

35 **[00101]** In Example 23, the subject matter of any one of Examples 18 to 22 may include, wherein the wireless reservation message is a Clear To Send (CTS) message and wherein the CTS message has a duration field that is set to a value that is at least a time until the cellular subframe boundary plus a time to transmit a PDSCH subframe.

[00102] In Example 24, the subject matter of any one of Examples 18 to 23 may include, wherein the one or more processors are configured to determine that the power level of the first channel for the random backoff window is below the second threshold by at least being configured to determine that for each
5 decrement of the random backoff window that a received power is below the second threshold.

[00103] In Example 25, the subject matter of any one of Examples 18 to 24 may include, an antenna.

[00104] Example 26 includes subject matter (such as a method, means for
10 performing acts, machine readable medium including instructions that when performed by a machine cause the machine to performs acts, or an apparatus to perform) comprising: using one or more processors to: determine that a power level of a first channel over one or more slits is below a first predetermined threshold, the first channel being a wireless channel that is not exclusively
15 licensed for cellular wireless, and in response: select a random backoff window; determine that the power level of the first channel for the backoff window is below a second predetermined threshold; schedule a User Equipment (UE) to receive data on a Supplemental Downlink (SDL) Physical Downlink Shared Channel (PDSCH) on the first channel using a control channel on a second,
20 licensed channel; and transmit the SDL PDSCH over the first channel at a cellular subframe boundary responsive to the power level of the first channel for the random backoff window is below the second threshold.

[00105] In Example 27, the subject matter of Example 26 may include, wherein the one or more processors are configured to provide a PDSCH on the
25 second channel.

[00106] In Example 28, the subject matter of any one of Examples 26 to 27 may include, wherein the one or more slits are aligned with respect to a Long Term Evolution (LTE) or Long Term Evolution-Advanced (LTE-A) symbol.

[00107] In Example 29, the subject matter of any one of Examples 26 to 28
30 may include, wherein a duration in symbols of one or more slits are a consistent number of samples and are a factor of the number of samples in an Long Term Evolution (LTE) or Long Term Evolution-Advanced (LTE-A) subframe.

- [00108] In Example 30, the subject matter of any one of Examples 26 to 29 may include, wherein the one or more processors are configured to send a wireless reservation message in response to the determination that the power level of the first channel for the backoff window is below the second threshold.
- 5 [00109] In Example 31, the subject matter of any one of Examples 26 to 30 may include, wherein the wireless reservation message is a Clear To Send (CTS) message and wherein the CTS message has a duration field that is set to a value that is at least a time until the cellular subframe boundary plus a time to transmit a PDSCH subframe.
- 10 [00110] In Example 32, the subject matter of any one of Examples 26 to 31 may include, wherein the one or more processors are configured to determine that the power level of the first channel for the random backoff window is below the second threshold by at least being configured to determine that for each decrement of the random backoff window that a received power is below the
- 15 second threshold.
- [00111] Example 33 includes subject matter (such as a device, apparatus, or machine) comprising: means for determining that a power level of a first channel over one or more slits is below a first predetermined threshold, the first channel being a wireless channel that is not exclusively licensed for cellular wireless, and
- 20 in response: select a random backoff window; means for determining that the power level of the first channel for the backoff window is below a second predetermined threshold; means for scheduling a User Equipment (UE) to receive data on a Supplemental Downlink (SDL) Physical Downlink Shared Channel (PDSCH) on the first channel using a control channel on a second,
- 25 licensed channel; and means for transmitting the SDL PDSCH over the first channel at a cellular subframe boundary responsive to the power level of the first channel for the random backoff window is below the second threshold.
- [00112] In Example 34, the subject matter of Example 33 may include, means for providing a PDSCH on the second channel.
- 30 [00113] In Example 35, the subject matter of any one of Examples 33 to 34 may include, wherein the one or more slits are aligned with respect to a Long Term Evolution (LTE) or Long Term Evolution-Advanced (LTE-A) symbol.

[00114] In Example 36, the subject matter of any one of Examples 33 to 35 may include, wherein a duration in symbols of one or more slots are a consistent number of samples and are a factor of the number of samples in an Long Term Evolution (LTE) or Long Term Evolution-Advanced (LTE-A) subframe.

- 5 [00115] In Example 37, the subject matter of any one of Examples 33 to 36 may include, means for sending a wireless reservation message in response to the determination that the power level of the first channel for the backoff window is below the second threshold.

- 10 [00116] In Example 38, the subject matter of any one of Examples 33 to 37 may include, wherein the wireless reservation message is a Clear To Send (CTS) message and wherein the CTS message has a duration field that is set to a value that is at least a time until the cellular subframe boundary plus a time to transmit a PDSCH subframe.

- 15 [00117] In Example 39, the subject matter of any one of Examples 33 to 38 may include, wherein the means for determining that the power level of the first channel for the random backoff window is below the second threshold comprises means for determining that for each decrement of the random backoff window that a received power is below the second threshold.

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WHAT IS CLAIMED IS

1. An eNodeB comprising:
a first transceiver to transmit and receive in an unlicensed channel;
5 a second transceiver to transmit and receive in a licensed channel and in the unlicensed channel according to a cellular wireless protocol; and
a controller to:
sense, via the first transceiver, an energy of the unlicensed channel over a
predetermined number of one or more slits to determine that the unlicensed
10 channel is unoccupied, the slits defined with reference to timing information of the cellular wireless protocol, and in response to determining that the channel is unoccupied:
schedule, via a control channel transmitted on the licensed channel, at least one
User Equipment (UE) serviced by the eNodeB to receive data in the unlicensed
15 channel; and
transmit the data over the unlicensed channel starting at a cellular subframe
boundary via the second transceiver.
2. The eNodeB of claim 1, wherein the first transceiver is configured to
20 transmit and receive according to a non-cellular wireless protocol, and wherein the data transmitted over the unlicensed channel is a Supplemental Downlink (SDL) Physical Downlink Shared Channel (PDSCH), and wherein the controller is further configured to send a wireless reservation message on the unlicensed
channel via the first transceiver to reserve the unlicensed channel for the data
25 transmitted over the unlicensed channel.
3. The eNodeB of claim 1, wherein the one or more slits are configured to
subdivide a plurality of samples in a current cellular subframe such that the one
or more slits do not cross a symbol boundary in the current cellular subframe.
30
4. The eNodeB of claim 1, wherein at least one of the one or more slits is
configured to cross a symbol boundary of a current cellular subframe.

5. The eNodeB of claim 1, wherein the one or more slits are punctured from a current cellular subframe.
6. The eNodeB of claim 1, wherein the cellular wireless protocol is a Long
5 Term Evolution (LTE) or Long Term Evolution-Advanced (LTE-A) family of Standards defined by the Third Generation Partnership (3GPP).
7. The eNodeB of claim 1, wherein the first transceiver is configured to transmit and receive according to an Institute for Electrical and Electronics
10 Engineers (IEEE) 802.11 protocol.
8. The eNodeB of claim 1, wherein the controller is to implement a backoff process, and is to refrain from transmitting the data on the unlicensed channel until the backoff process is successful.
- 15
9. The eNodeB of claim 8, wherein control channel is a Physical Downlink Control Channel (PDCCH) and wherein the controller is to:
predict that a backoff process will complete before an end of a transmission of the PDCCH, and in response, schedule the at least one User Equipment (UE)
20 serviced by the eNodeB to receive data on unlicensed channel via the PDCCH on the licensed channel transmitted by the second transceiver prior to completion of the backoff process.
10. The eNodeB of claim 9, wherein the controller is to:
25 determine that the backoff process did not complete before the end of the transmission of the PDCCH, and in response:
ignore a Hybrid Automatic Repeat Requests (HARQ) for data scheduled on the unlicensed channel; and
notify the UE to clear a HARQ buffer for data scheduled on the
30 unlicensed channel.
11. The eNodeB of claim 1, wherein the second transceiver is configured to provide a PDSCH in a licensed channel.

12. An eNodeB configured for communication in both a licensed and unlicensed spectrum, the eNodeB comprising:
- one or more processors to:
- 5 determine that a power level of a first channel over one or more slits is below a first predetermined threshold, the first channel being a wireless channel that is not exclusively licensed for cellular wireless, and in response:
- select a random backoff window;
- determine that the power level of the first channel for the backoff window is
- 10 below a second predetermined threshold;
- schedule a User Equipment (UE) to receive data on a Supplemental Downlink (SDL) Physical Downlink Shared Channel (PDSCH) on the first channel using a control channel on a second, licensed channel; and
- transmit the SDL PDSCH over the first channel at a cellular subframe boundary
- 15 responsive to the power level of the first channel for the random backoff window is below the second threshold.
13. The eNodeB of claim 12 wherein the one or more processors are configured to provide a PDSCH on the second channel.
- 20 14. The eNodeB of claim 12, wherein the one or more slits are aligned with respect to a Long Term Evolution (LTE) or Long Term Evolution-Advanced (LTE-A) symbol.
- 25 15. The eNodeB of claim 12, wherein a duration in symbols of one or more slits are a consistent number of samples and are a factor of the number of samples in an Long Term Evolution (LTE) or Long Term Evolution-Advanced (LTE-A) subframe.
- 30 16. The eNodeB of claim 12, wherein the one or more processors are configured to send a wireless reservation message in response to the determination that the power level of the first channel for the backoff window is below the second threshold.

17. The eNodeB of claim 16, wherein the wireless reservation message is a Clear To Send (CTS) message and wherein the CTS message has a duration field that is set to a value that is at least a time until the cellular subframe boundary plus a time to transmit a PDSCH subframe.

18. A method comprising:
 using one or more processors to:
 determine that a power level of a first channel over one or more slits is below a first predetermined threshold, the first channel being a wireless channel that is not exclusively licensed for cellular wireless, and in response:
 select a random backoff window;
 determine that the power level of the first channel for the backoff window is below a second predetermined threshold;
15 schedule a User Equipment (UE) to receive data on a Supplemental Downlink (SDL) Physical Downlink Shared Channel (PDSCH) on the first channel using a control channel on a second, licensed channel; and
 transmit the SDL PDSCH over the first channel at a cellular subframe boundary responsive to the power level of the first channel for the random backoff window
20 is below the second threshold.

19. The method of claim 18, wherein the one or more processors are configured to provide a PDSCH on the second channel.

20. The method of claim 18, wherein the one or more slits are aligned with respect to a Long Term Evolution (LTE) or Long Term Evolution-Advanced (LTE-A) symbol.

21. The method of claim 18, wherein a duration in symbols of one or more slits are a consistent number of samples and are a factor of the number of samples in an Long Term Evolution (LTE) or Long Term Evolution-Advanced (LTE-A) subframe.

22. The method of claim 18, wherein the one or more processors are configured to send a wireless reservation message in response to the determination that the power level of the first channel for the backoff window is below the second threshold.
- 5 23. The method of claim 22, wherein the wireless reservation message is a Clear To Send (CTS) message and wherein the CTS message has a duration field that is set to a value that is at least a time until the cellular subframe boundary plus a time to transmit a PDSCH subframe.
- 10 24. A machine-readable medium including code, which when executed, cause a machine to perform the method of any one of claims 18-23.
- 15 25. An eNodeB comprising:
means for determining that a power level of a first channel over one or more slits is below a first predetermined threshold, the first channel being a wireless channel that is not exclusively licensed for cellular wireless, and in response:
20 select a random backoff window;
means for determining that the power level of the first channel for the backoff window is below a second predetermined threshold;
means for scheduling a User Equipment (UE) to receive data on a Supplemental Downlink (SDL) Physical Downlink Shared Channel (PDSCH) on
25 the first channel using a control channel on a second, licensed channel; and
means for transmitting the SDL PDSCH over the first channel at a cellular subframe boundary responsive to the power level of the first channel for the random backoff window is below the second threshold.

30

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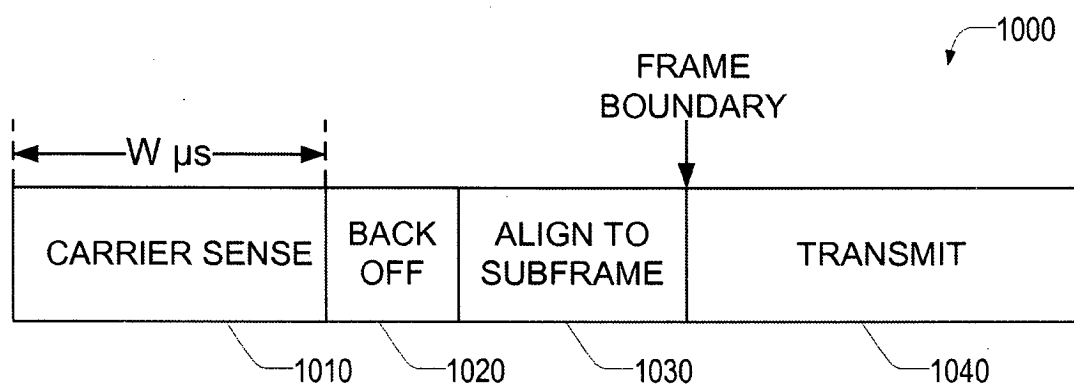


FIG. 1

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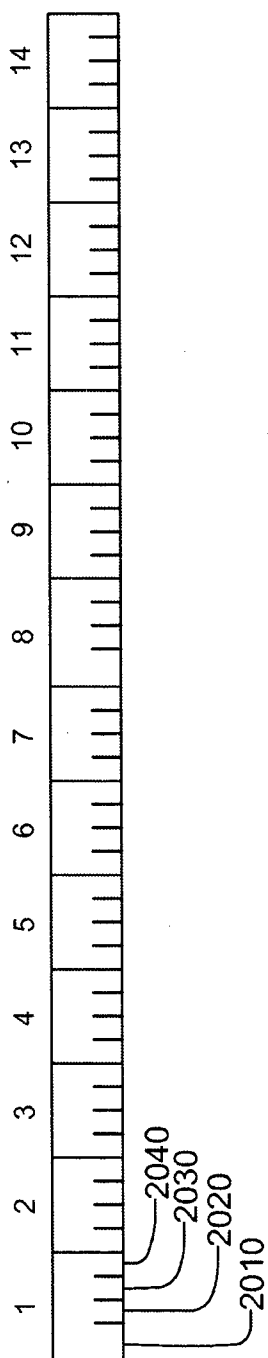


FIG. 2A

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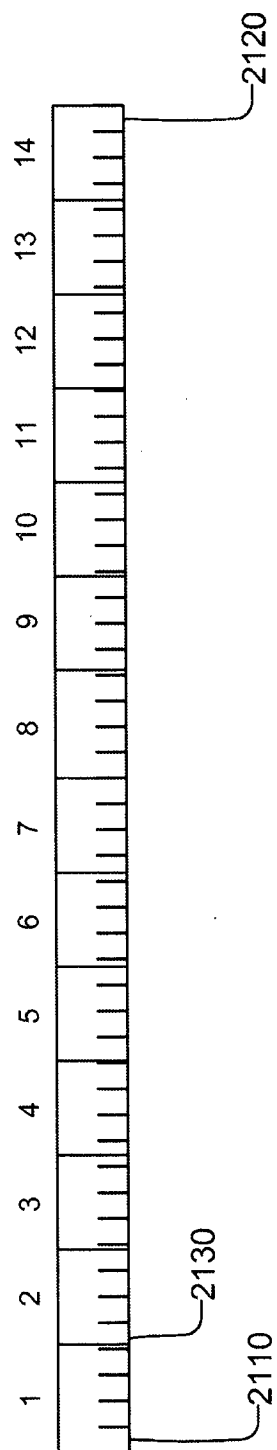


FIG. 2B

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3000

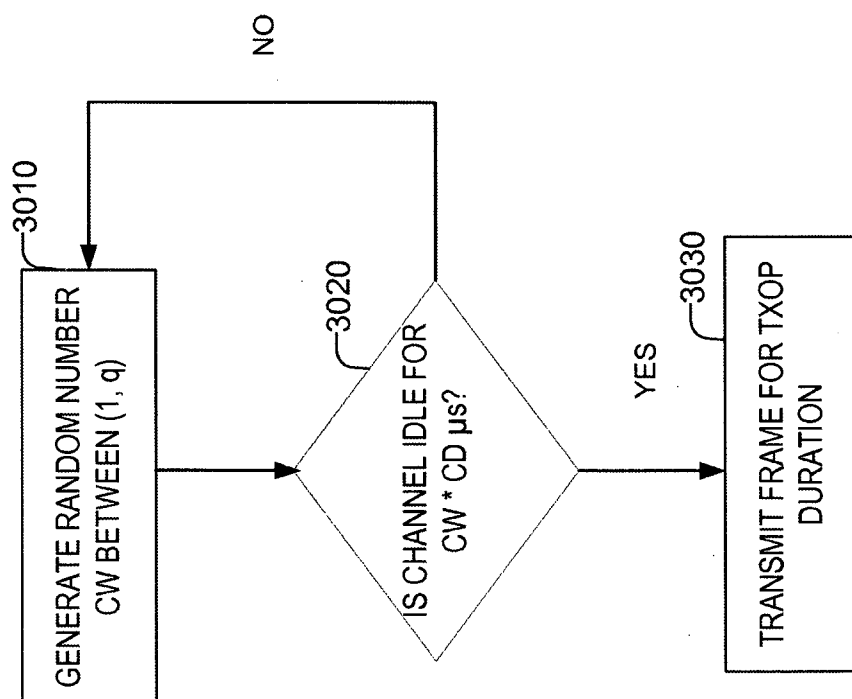


FIG. 3

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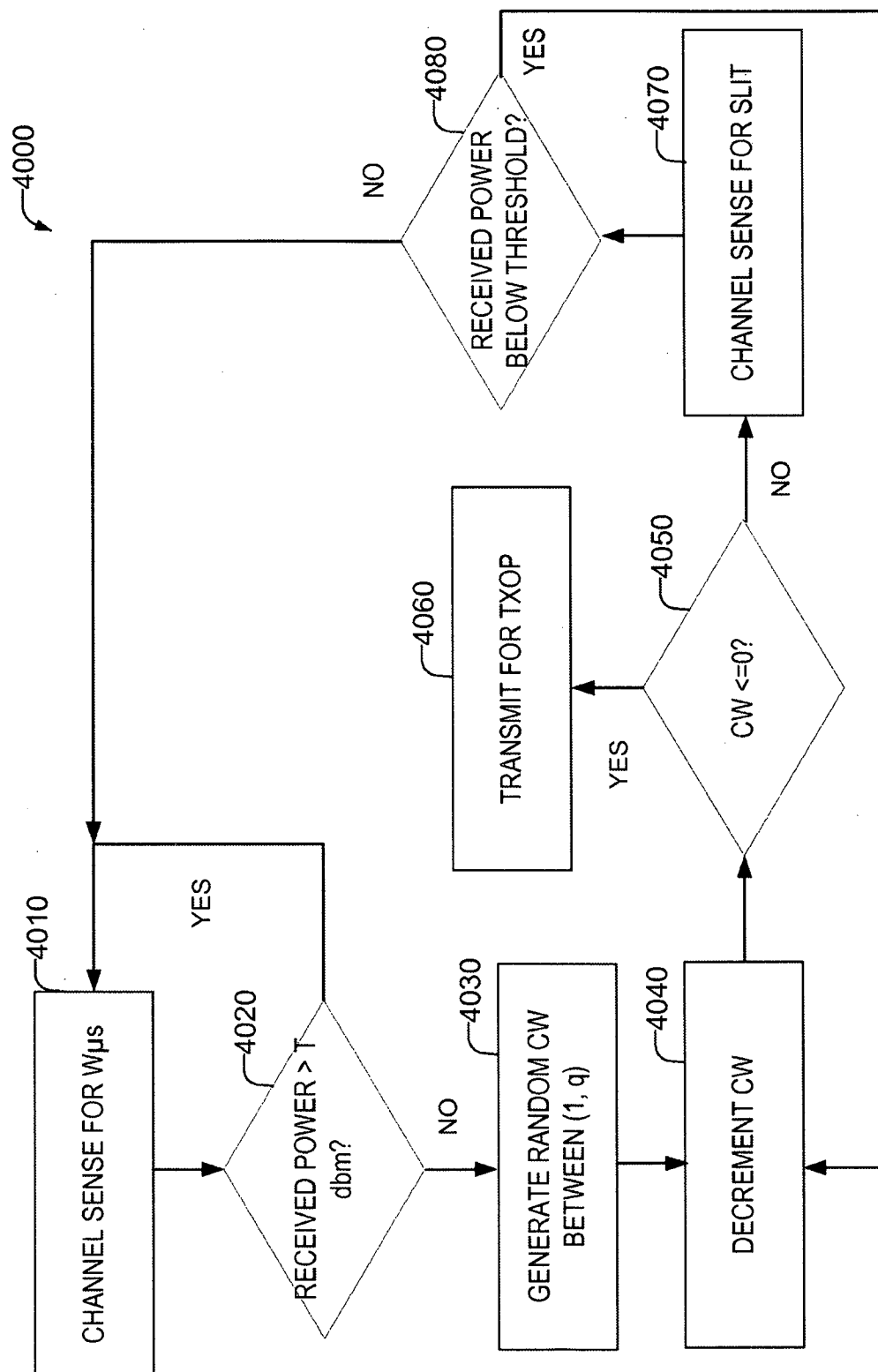


FIG. 4

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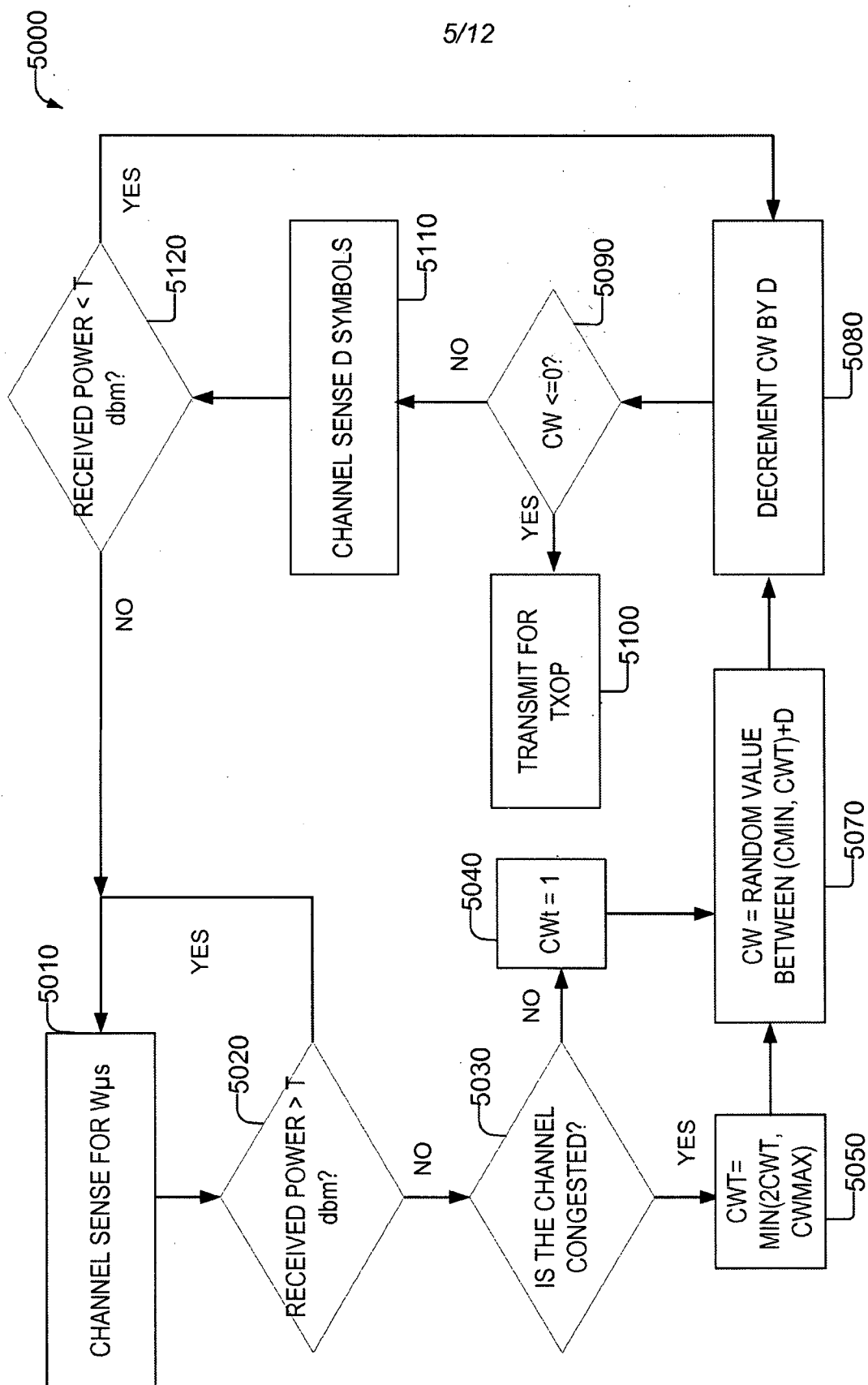


FIG. 5

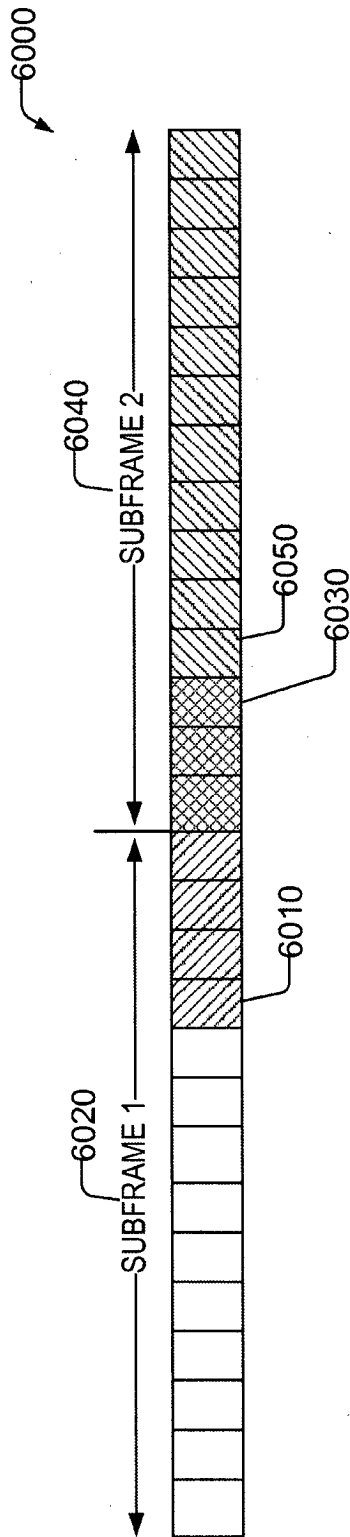


FIG. 6

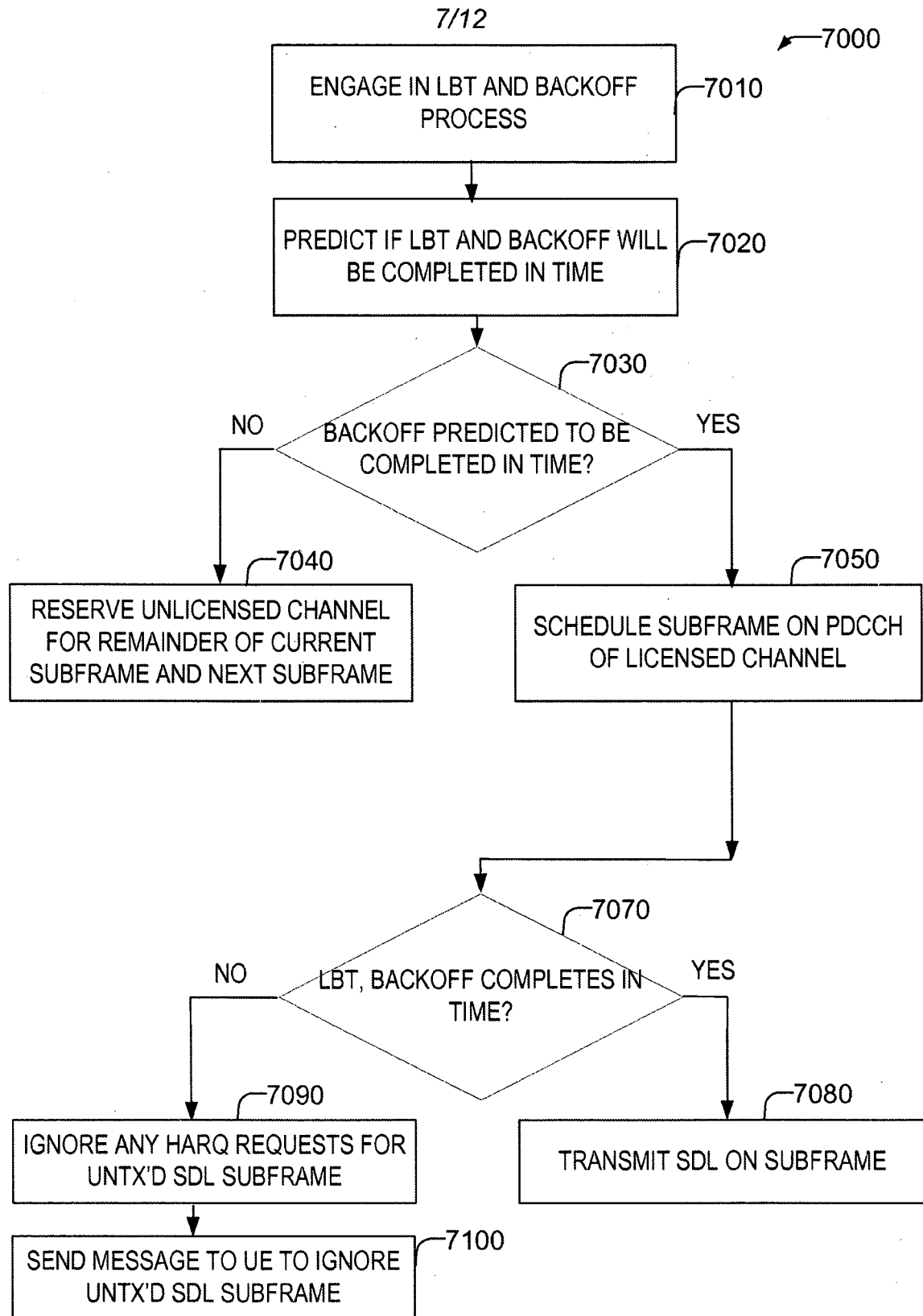


FIG. 7

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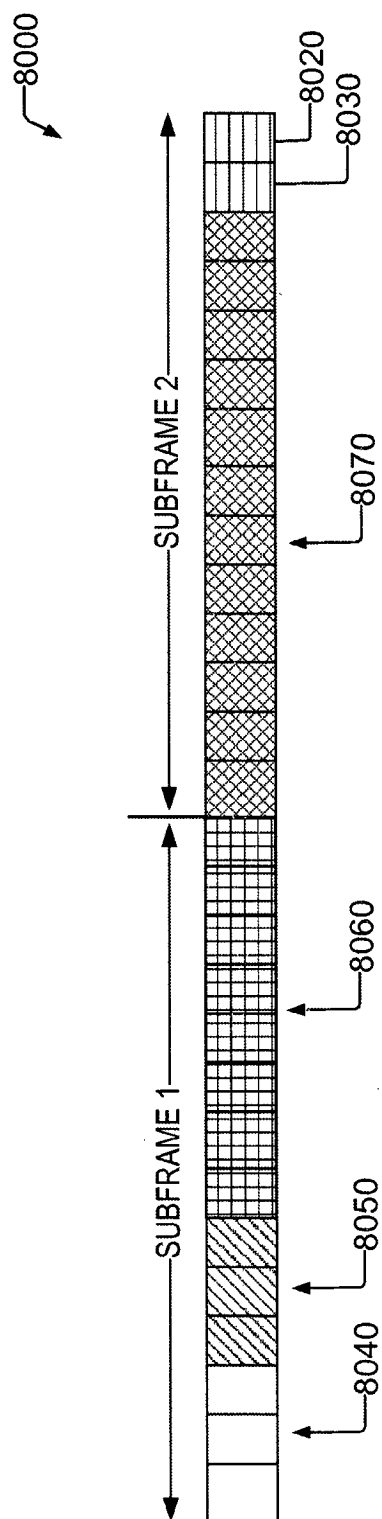


FIG. 8

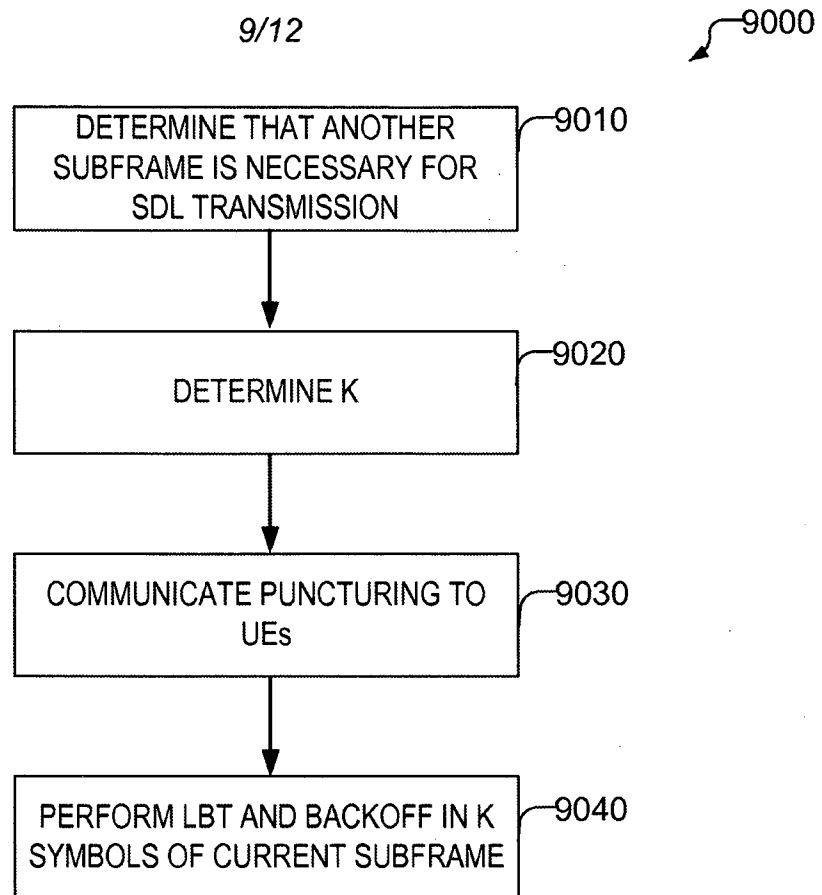


FIG. 9

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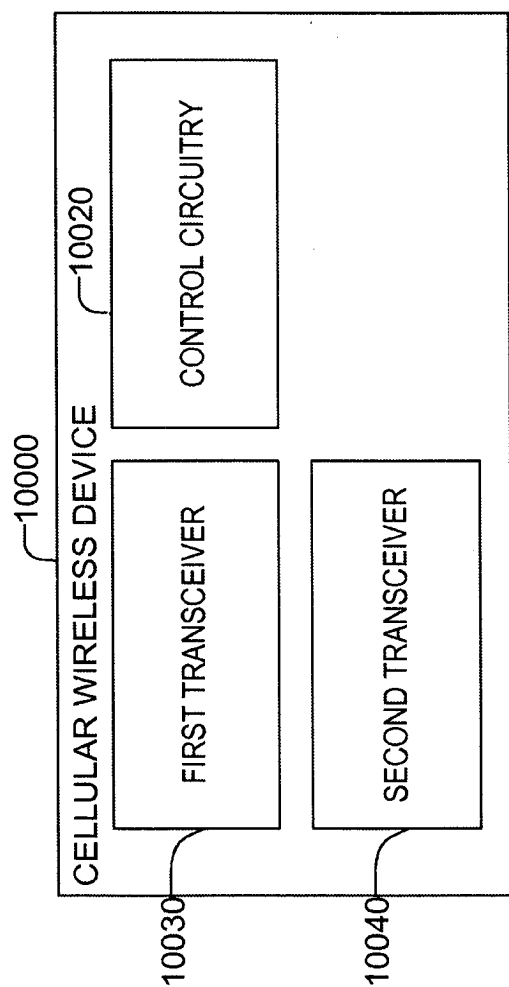


FIG. 10

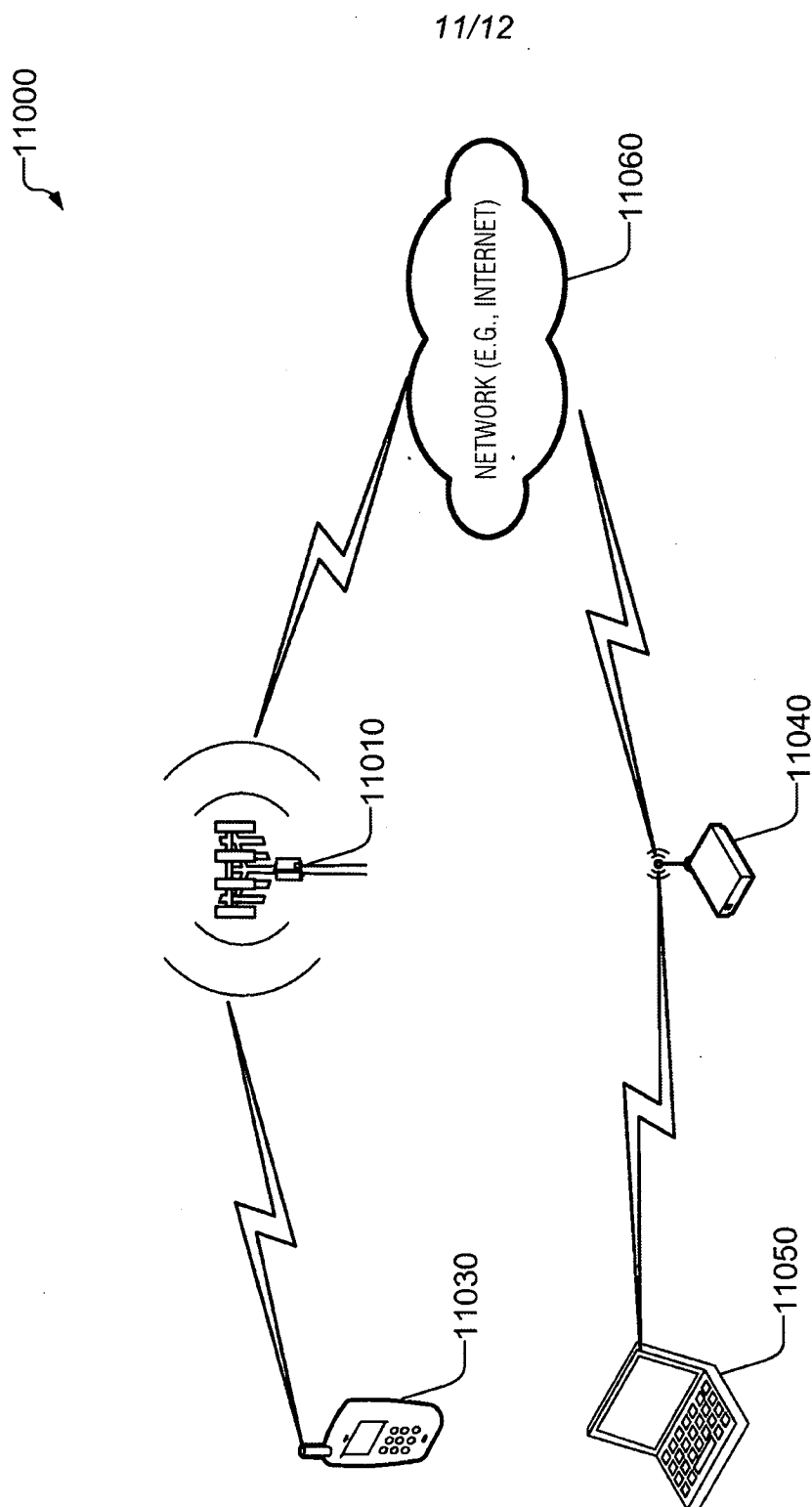


FIG. 11

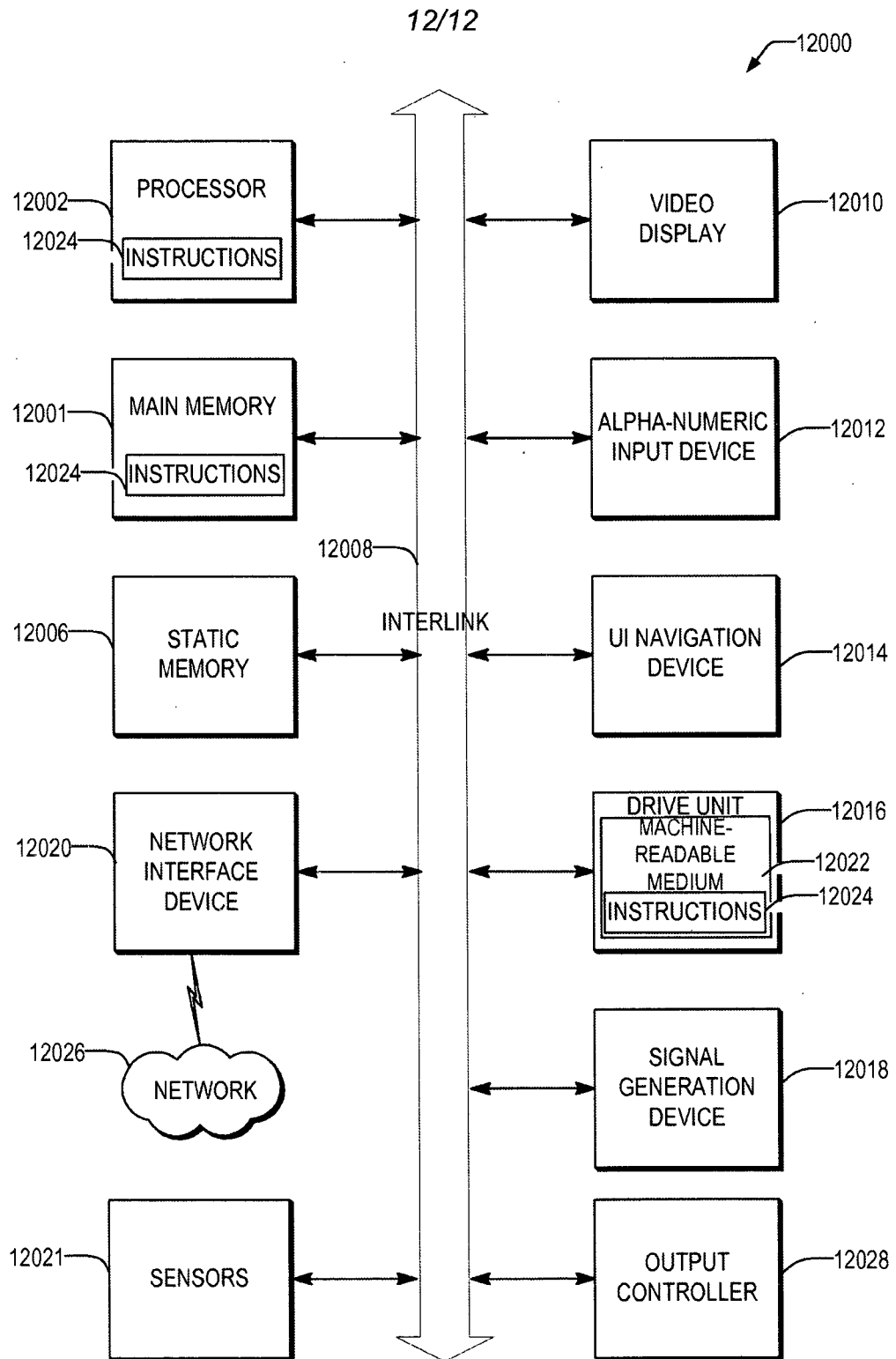


FIG. 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/059051**A. CLASSIFICATION OF SUBJECT MATTER****H04W 74/08(2009.01)i, H04W 72/12(2009.01)i, H04W 88/08(2009.01)i**

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W 74/08; H04L 5/00; H04Q 7/20; H04W 72/10; H04W 72/04; H04M 3/00; H04B 1/00; H04W 72/12; H04W 88/08

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & keywords: licensed, unlicensed, channel, backoff, energy, threshold

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2013-0337821 A1 (MICHAEL CLEGG) 19 December 2013 See paragraphs [0033], [0057]-[0068]; and figures 5, 6.	1-25
A	WO 2012-078565 A1 (INTER-DIGITAL PATENT HOLDINGS, INC.) 14 June 2012 See claim 1.	1-25
A	US 2006-0223448 A1 (JOHANNES PETRUS KRUYSS) 05 October 2006 See paragraphs [0018]-[0026]; and figures 2, 3.	1-25
A	US 2014-0036818 A1 (RENESAS MOBILE CORPORATION) 06 February 2014 See paragraphs [0063]-[0083]; and figures 2, 3.	1-25
A	US 2007-0026868 A1 (GARY D. SCHULZ et al.) 01 February 2007 See paragraphs [0021], [0022]; and figure 3.	1-25



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

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Date of mailing of the international search report

15 February 2016 (15.02.2016)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

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

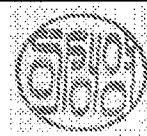


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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/059051

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代理人 龙淳 岳磊

(51)Int.Cl.

H04W 16/14(2009.01)

H04W 74/08(2009.01)

H04W 72/12(2009.01)

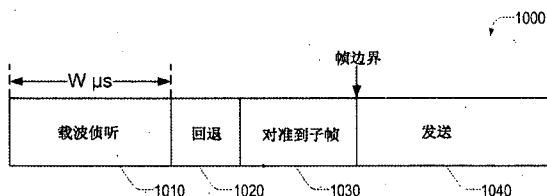
权利要求书3页 说明书14页 附图12页

(54)发明名称

免授权频段中用于蜂窝的子帧对准的先听后说

(57)摘要

在一些示例中公开了在免授权信道中为根据蜂窝无线协议操作的设备实现先听后说(LBT)接入方案的系统、机器可读介质、方法和蜂窝无线设备。在LBT接入方案已经确定免授权信道中的信道(定义的频率范围)对于特定时间段是空闲的之后,蜂窝无线设备可以在免授权信道中利用蜂窝无线协议。



1. 一种eNodeB,包括:

第一收发机,用于:在免授权信道中进行发送和接收;

第二收发机,用于:根据蜂窝无线协议,在授权信道和免授权信道中进行发送和接收;
和

控制器,用于:

经由所述第一收发机,在预定数量的一个或多个缝隙上侦听免授权信道的能量,以确定免授权信道是未被占用的,所述缝隙是参考蜂窝无线协议的定时信息来定义的,并且响应于确定信道是未被占用的:

经由在授权信道上传输的控制信道,调度由所述eNodeB服务的至少一个用户设备 (UE) 在免授权信道中接收数据;以及

经由所述第二收发机,在蜂窝子帧边界处开始,在免授权信道上发送数据。

2. 根据权利要求1所述的eNodeB,其中,所述第一收发机被配置为:根据非蜂窝无线协议进行发送和接收;并且其中,在免授权信道上发送的数据是补充下行链路 (SDL) 物理下行链路共享信道 (PDSCH),并且其中,所述控制器还被配置为:经由所述第一收发机在免授权信道上发送无线预留消息,以便为在免授权信道上发送的数据预留免授权信道。

3. 根据权利要求1所述的eNodeB,其中,所述一个或多个缝隙被配置为:细分当前蜂窝子帧中的多个样本,使得所述一个或多个缝隙不跨越当前蜂窝子帧中的符号边界。

4. 根据权利要求1所述的eNodeB,其中,所述一个或多个缝隙中的至少一个缝隙被配置为:跨越当前蜂窝子帧的符号边界。

5. 根据权利要求1所述的eNodeB,其中,所述一个或多个缝隙从当前蜂窝子帧被打孔。

6. 根据权利要求1所述的eNodeB,其中,所述蜂窝无线协议是由第三代合作伙伴项目 (3GPP) 定义的长期演进 (LTE) 或长期演进高级 (LTE-A) 标准族。

7. 根据权利要求1所述的eNodeB,其中,所述第一收发机被配置为:根据电气和电子工程师协会 (IEEE) 802.11协议进行发送和接收。

8. 根据权利要求1所述的eNodeB,其中,所述控制器用于:实现回退过程,并且在回退过程成功之前禁止在免授权信道上发送数据。

9. 根据权利要求8所述的eNodeB,其中,控制信道是物理下行链路控制信道 (PDCCH),并且其中,所述控制器用于:

预测回退过程将在PDCCH的传输结束之前完成,并且作为响应,在回退过程完成之前,经由所述第二收发机在授权信道上发送的PDCCH来调度由所述eNodeB服务的所述至少一个用户设备 (UE) 在免授权信道上接收数据。

10. 根据权利要求9所述的eNodeB,其中,所述控制器用于:

确定回退过程在PDCCH的传输结束之前未完成,并且作为响应:

忽略在免授权信上调度的对数据的混合自动重传请求 (HARQ);以及

通知UE针对在免授权信上调度的数据清除HARQ缓冲区。

11. 根据权利要求1所述的eNodeB,其中,所述第二收发机被配置为:在授权信道中提供PDSCH。

12. 一种被配置用于在授权频谱和免授权频谱中进行通信的eNodeB,所述eNodeB包括:
一个或多个处理器,用于:

确定第一信道在一个或多个缝隙上的功率水平低于第一预定阈值,所述第一信道是并非专门授权于蜂窝无线的无线信道,并且作为响应:

选择随机回退窗口;

确定所述第一信道在所述回退窗口内的功率水平低于第二预定阈值;

使用授权的第二信道上的控制信道,调度用户设备(UE)在所述第一信道上接收补充下行链路(SDL)物理下行链路共享信道(PDSCH)上的数据;以及

响应于所述第一信道在所述随机回退窗口内的功率水平低于所述第二阈值,于蜂窝子帧边界处,在所述第一信道上发送SDL PDSCH。

13. 根据权利要求12所述的eNodeB,其中,所述一个或多个处理器被配置为:在所述第二信道上提供PDSCH。

14. 根据权利要求12所述的eNodeB,其中,所述一个或多个缝隙相对于长期演进(LTE)或长期演进高级(LTE-A)符号是对准的。

15. 根据权利要求12所述的eNodeB,其中,一个或多个缝隙的符号持续时间是数量一致的样本,并且是长期演进(LTE)或长期演进高级(LTE-A)子帧中的样本数量的因子。

16. 根据权利要求12所述的eNodeB,其中,所述一个或多个处理器被配置为:响应于确定所述第一信道在所述回退窗口内的功率水平低于所述第二阈值,发送无线预留消息。

17. 根据权利要求16所述的eNodeB,其中,所述无线预留消息是清除-发送(CTS)消息,并且其中,所述CTS消息具有持续时间字段,所述持续时间字段的值被设定为至少直到蜂窝子帧边界的时间加上发送PDSCH子帧的时间。

18. 一种方法,包括:

使用一个或多个处理器进行:

确定第一信道在一个或多个缝隙上的功率水平低于第一预定阈值,所述第一信道是并非专门授权于蜂窝无线的无线信道,并且作为响应:

选择随机回退窗口;

确定所述第一信道在所述回退窗口内的功率水平低于第二预定阈值;

使用授权的第二信道上的控制信道,调度用户设备(UE)在所述第一信道上接收补充下行链路(SDL)物理下行链路共享信道(PDSCH)上的数据;以及

响应于所述第一信道在所述随机回退窗口内的功率水平低于所述第二阈值,于蜂窝子帧边界处,在所述第一信道上发送SDL PDSCH。

19. 根据权利要求18所述的方法,其中,所述一个或多个处理器被配置为:在所述第二信道上提供PDSCH。

20. 根据权利要求18所述的方法,其中,所述一个或多个缝隙相对于长期演进(LTE)或长期演进高级(LTE-A)符号是对准的。

21. 根据权利要求18所述的方法,其中,一个或多个缝隙的符号持续时间是数量一致的样本,并且是长期演进(LTE)或长期演进高级(LTE-A)子帧中的样本数量的因子。

22. 根据权利要求18所述的方法,其中,所述一个或多个处理器被配置为:响应于确定所述第一信道在所述回退窗口内的功率水平低于所述第二阈值,发送无线预留消息。

23. 根据权利要求22所述的方法,其中,所述无线预留消息是清除-发送(CTS)消息,并且其中,所述CTS消息具有持续时间字段,所述持续时间字段的值被设定为至少直到蜂窝子

帧边界的时间加上发送PDSCH子帧的时间。

24. 一种包含代码的机器可读介质, 所述代码在被执行时使机器执行根据权利要求18-23中任一项所述的方法。

25. 一种eNodeB, 包括:

用于确定第一信道在一个或多个缝隙上的功率水平低于第一预定阈值的单元, 所述第一信道是并非专门授权于蜂窝无线的无线信道, 并且作为响应:

选择随机回退窗口;

用于确定所述第一信道在所述回退窗口内的功率水平低于第二预定阈值的单元;

用于使用授权的第二信道上的控制信道, 调度用户设备 (UE) 在所述第一信道上接收补充下行链路 (SDL) 物理下行链路共享信道 (PDSCH) 上的数据的单元; 和

用于响应于所述第一信道在所述随机回退窗口内的功率水平低于所述第二阈值, 于蜂窝子帧边界处, 在所述第一信道上发送SDL PDSCH的单元。

免授权频段中用于蜂窝的子帧对准的先听后说

[0001] 优先权要求

[0002] 本专利申请要求于2015年5月13日提交的美国申请序列号14/711,278的优先权权益,后者要求于2014年11月6日提交的美国临时专利申请序列号62/076,083的优先权权益,这两个申请均通过引用整体并入本文。

技术领域

[0003] 实施例属于蜂窝无线技术。一些实施例涉及在免授权通信频段中操作的蜂窝无线技术。

[0004] 版权声明

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背景技术

[0006] 蜂窝无线技术通常在授权频谱中操作。授权频谱是分配给特定实体(例如,特定无线载波)进行使用的频率范围。由于可用的授权频谱是有限的,并且随着对蜂窝无线服务的需求上升,可供使用的自由频谱的量受到限制。

[0007] 与授权频谱相反,存在允许在实体没有获得合法批准的情况下使用某些频率的各种免授权频谱。这些频率在希望使用它们的设备之间共享,并且使用这些频谱的设备具有允许它们与其它设备共享频谱的协议。通常,这些免授权频谱不是主要针对蜂窝无线用途进行授权的,并且通常,这些频谱面临其它设备的竞争或利用。

附图说明

[0008] 在不一定按比例绘制的附图中,类似数字可以在不同的视图中描述类似组件。具有不同字母后缀的类似数字可以表示类似组件的不同实例。附图通过示例而不是限制的方式总体示出了本文件中讨论的各种实施例。

[0009] 图1是根据本公开的一些示例的同步先听后说(LBT)方法的时间线。

[0010] 图2A示出了根据本公开的一些示例的符号对准的缝隙的缝隙图。

[0011] 图2B示出了根据本公开的一些示例的均匀划分的缝隙的缝隙图。

[0012] 图3示出了根据本公开的一些示例的用于LBT侦听和回退的第一选项的方法的流程图。

[0013] 图4示出了根据本公开的一些示例的用于LBT侦听和回退的第二选项的方法的流程图。

[0014] 图5示出了根据本公开的一些示例的用于LBT侦听和回退的第三选项的方法的流程图。

- [0015] 图6示出了根据本公开的一些示例的SDL的预期调度的图示。
- [0016] 图7示出了根据本公开的一些示例的SDL的预期调度的方法的流程图。
- [0017] 图8示出了根据本公开的一些示例的对子帧的符号进行打孔(puncture)的图示。
- [0018] 图9示出了根据本公开的一些示例的蜂窝无线设备对符号进行打孔的方法的流程图。
- [0019] 图10示出了根据本公开的一些示例的蜂窝无线设备的示意图。
- [0020] 图11示出了根据本公开的一些示例的无线环境的示意图。
- [0021] 图12示出了根据本公开的一些示例可以在其上执行本文讨论的任何一种或多种技术(例如,方法)的示例机器的框图。

具体实施方式

[0022] 随着对蜂窝无线协议(例如,长期演进(LTE))的授权频谱的需求增加,LTE系统的设计者们已经开始探索在免授权频率中使用这些授权协议。在免授权频率中使用蜂窝协议和其它授权协议提出了一些挑战。免授权频率可以包括工业、科学和医疗(ISM)频段,例如2.4GHz、5GHz等。免授权频率可以由一个或多个政府实体(例如,美国联邦通信委员会(FCC))来确定。

[0023] 例如,蜂窝无线设备(例如,基站或诸如智能电话的移动设备)利用授权信道,这确保这些设备具有对特定无线信道的独占使用。“信道”是用于无线通信的(通常是但并非总是连续的)一段频率。因此,这些蜂窝协议的设计假设在于,它们对其操作的频率具有独占接入。它们通常关心在参与同一网络的其它设备当中进行协调。例如,在LTE系统中,基站(eNodeB)典型地协调来自与该eNodeB关联的一个或多个用户设备(UE)的发送和接收。当规划数据的发送和接收时,eNodeB通常不会考虑其它网络中的其它用户。如果蜂窝无线网络开始在免授权信道中发送而不进行修改,则蜂窝无线设备将连续地进行发送和接收。这将阻止其它设备利用该信道。

[0024] 相比之下,在免授权信道中操作的设备不仅考虑在(例如,由单个运营商控制的)单个网络中操作的设备,而且还考虑在许多不同网络中操作的设备以及使用其它协议操作的设备。例如,根据诸如电气和电子工程师协会(IEEE)定义的802.11标准(Wi-Fi)的无线协议操作的设备在确定它们是否能够使用无线介质之前,不仅考虑它们自己网络中的设备(即,基本服务集-BSS),而且还考虑其它BSS中的设备,甚至运行其它协议的设备。

[0025] 因此,需要的是使蜂窝无线协议适于以高效的方式在免授权信道中操作的方法。在一些示例中公开了针对在免授权频段中根据蜂窝无线协议进行操作实现修改的系统、机器可读介质、方法和蜂窝无线设备。这些修改包括实现蜂窝无线设备在免授权信道中使用的先听后说(LBT)接入方案,优化调度,和优化信道侦听。

[0026] 如本文所使用的,“蜂窝无线设备”是根据蜂窝无线协议操作的任何设备。“蜂窝无线协议”是定义蜂窝无线网络的无线协议,蜂窝无线网络分布在称为小区的陆地区域上,每个小区由称为小区站点或基站的至少一个位置固定的收发机来服务。这些小区站点是互连的,以在广泛的地理区域提供无线服务。可以适于在免授权信道中进行传输的示例蜂窝无线协议包括根据以下标准之一的蜂窝无线协议:由第三代合作伙伴项目(3GPP)颁布的LTE标准族(包括LTE高级(LTE-A)标准族)、由3GPP颁布的通用移动通信系统(UMTS)标准族、全

球移动通信系统 (GSM) 标准族等。蜂窝无线设备可以是基站 (例如, NodeB 或 eNodeB), 或者是移动设备 (例如, UE)。

[0027] 在一些示例中, 蜂窝无线设备可以使用授权频段来控制免授权频段上的传输 (例如, 获得信道状态信息 (CSI) 反馈, 在物理下行链路控制信道 (PDCCH) 上进行调度等)。

[0028] 蜂窝无线设备在免授权信道中的示例传输包括支持这些蜂窝协议的层1、层2、层3 以及其它层 (例如物理 (PHY) 层、媒体访问控制 (MAC) 层、无线链路控制 (RLC) 层、分组数据汇聚协议 (PDCP) 层、和无线资源控制 (RRC) 层) 中的一个或多个的传输。在免授权频率中进行传输的信道可以包括任何上行链路数据信道、上行链路控制信道、下行链路数据信道和下行链路控制信道。示例包括物理下行链路共享信道 (PDSCH)、物理上行链路共享信道 (PUSCH)、PDCCH 和物理上行链路控制信道 (PUCCH) 中的一个或多个。

[0029] 在一些示例中, 诸如蜂窝基站 (例如, eNodeB) 的蜂窝无线设备可以在授权频谱中向小区提供上行链路和下行链路能力, 并且还在免授权频谱中提供补充下行链路 (SDL) 信道。SDL 信道可以携带一个或多个 LTE 信道, 例如 PDSCH。LBT 技术可以应用于 SDL 信道, 以确保免授权信道是空闲的且没有干扰。在其它示例中, 对于免授权频谱上的上行链路信道, UE 可以是实现 LBT 机制的蜂窝无线设备。在一些示例中, 可以在主 (授权) 频率上的 PDCCH 上调度 SDL。例如, 可以在授权频率的 PDCCH 上调度 UE, 以便在免授权频率上的 SDL PDSCH 上接收数据 (即, 使用交叉载波调度)。

[0030] 可以以一种或多种方式, 例如本文所公开的方式, 来修改蜂窝无线协议的各方面, 以便在免授权频谱内进行操作。例如, 可以通过蜂窝无线设备在蜂窝无线协议中实现 LBT 接入方案。

[0031] LBT、信道侦听和回退设计

[0032] 在一些示例中, 实现用于免授权频段的 LBT 接入模式的蜂窝无线设备可以监听信道持续信道监听时间 (预定时间段)。如果信道对于信道监听时间是空闲的, 则蜂窝无线设备可以认为信道可供用于传输。

[0033] 图1示出了使用 LBT 机制在免授权信道中同步操作的蜂窝无线设备的时间线 1000。在步骤 1010, 蜂窝无线设备的收发机对免授权频段中的信道进行载波侦听 (CS), 持续 $W_{\mu s}$ 的时段, 并确定接收到的平均功率。如果接收功率小于阈值 T_{dBm} , 则该信道被认为是空闲的。否则, 如果接收功率大于阈值, 则信道被认为是忙的。在步骤 1020, 如果信道被确定为空闲的, 则收发机进入回退阶段。在回退阶段, 收发机选择回退时间段。该时间段可以从一组合法值中随机地选取。在一些示例中, 该时间段可以是 LTE 符号的倍数。在这个回退期间, 收发机侦听信道。如果信道在此时段期间忙, 则收发机返回到步骤 1010 处的载波侦听阶段。如果信道空闲, 则收发机进入步骤 1030。步骤 1020 的回退期可以被认为是步骤 1010 的固定持续时间载波侦听阶段的随机持续时间扩展。回退期防止对于 W 具有相同值的大量无线设备均同时尝试接入介质。

[0034] 在步骤 1030 期间, 收发机可以发送预留消息或信号, 以预留信道, 直到蜂窝网络的下一个子帧边界, 或者直到下一个子帧边界加上发送下一个子帧所需的时间量, 以便对准到该子帧。示例预留信号可以是 Wi-Fi 请求-发送 (RTS) 或清除-发送 (CTS)。一旦经过了子帧边界, 收发机就可以在步骤 1040 进行发送。

[0035] 对于免授权信道上的下行链路操作, 对于 LTE 网络而言, eNodeB 可以实现 LBT 决策,

而在上行链路上,eNodeB可以实现LBT机制,但是向UE传送使UE能够在步骤1040期间进行发送的信息。

[0036] 在诸如LTE的蜂窝无线网络的背景下,所需要的是定义当载波侦听或回退侦听时对信道进行采样的频度。对信道的采样频度太高会导致制造成本增加和收发机上的工作负载增加。对信道的采样频度太低会导致将信道错误地报告为空闲并导致冲突。

[0037] 在LTE子帧内有十四个符号。在一些示例中,可以每符号对信道采样一次。然而,这个水平的采样粒度可能是太不频繁的,因为每个帧是1毫秒,而1毫秒的1/14是大约70微秒。

[0038] 在一些示例中,可以利用较小的样本粒度。例如,每个符号可以被细分成两个或更多个“缝隙(slot)”。如本文所使用,缝隙可以被定义为侦听信道的基本粒度单位,并且可以参考蜂窝无线协议的定时信息来定义。例如,每个符号可以分成四个缝隙。在这些示例中,缝隙不跨过符号边界。这呈现出两难的局面,因为在LTE子帧中,第一符号和第八符号略大,与其它符号中的2192个样本相比,具有2208个样本。在这些示例中,第一符号和第八符号的缝隙可以是552个样本,其余的缝隙可以是548个样本。在其它示例中,对于第一符号和第八符号,额外的符号(16)可以以其它方式进行分割。例如,这些符号的其中三个缝隙可以是548个样本,其余的缝隙可以是564个样本。图2A示出了符号对准的缝隙的一个示例缝隙图2000。如图所示,符号1的缝隙2010比符号1的缝隙2020-2040和其余符号2-14的缝隙略大,除了符号8中的一个或多个缝隙(符号8也包含2208个样本)之外。

[0039] 在其它示例中,不是划分符号以生成缝隙,而是可以将子帧本身细分成相等的大小固定的缝隙。在该示例中,缝隙可能包括两个相继符号的部分。也就是说,缝隙可能跨过符号边界。图2B示出了均匀划分的缝隙的一个示例缝隙图2100。在一些示例中,第一个缝隙2110起始于子帧的开始,并且最后一个缝隙2120结束于子帧结束边界。如从图中可以看出的,缝隙可能跨过符号边界,例如跨过符号1和2的缝隙2130。在一些示例中,如果N是一个缝隙中的样本数,因为可能期望的是缝隙边界与子帧边界(其具有30720个样本)相一致,所以N可以被选取为使得N是30720的因子。因此,缝隙的数量可以由 $30720/N$ 来描述。由于每个子帧的持续时间为1毫秒(ms) ($10^3\mu s$),并且因为子帧中有30720个样本,所以在1微秒内有30.72个样本。由于LTE规范将用于免授权信道的最小侦听周期定义为20微秒(μs),因此乘以20,得到在20微秒内有614.4个样本,作为要侦听的最小样本数。

[0040] 因为样本是LTE中最小的粒度,所以具有0.4个样本可以向上取整(因为614将产生小于2微秒的侦听时间)为至少615。然而,可能期望的是N为30720的因子,使得所有的缝隙纳入同一子帧。一个选项可以是子帧中有48个缝隙,算出对于每个缝隙是640个样本。具有640个样本/缝隙意味着每个缝隙大约20.83微秒长,这略高于20微秒的最小值。在其它示例中,可以利用每子帧更多的缝隙;然而,蜂窝无线设备可能需要侦听多于一个缝隙,以便满足LTE规范中规定的最小值。

[0041] 为了实现侦听和回退,本文公开了三个示例设计。这些选项都适用于蜂窝无线协议(例如,LTE)与在免授权信道上操作的无线协议(例如,Wi-Fi)之间的共存。

[0042] 图3示出了根据本公开的一些示例的用于LBT侦听和回退的第一选项的方法3000的流程图。在第一选项中,采用竞争窗口(CW)来确定信道何时是干净的。在操作3010,蜂窝无线设备的收发机可以选择1与q之间的随机数。在一些示例中,q被定义为在4与32之间的预定值,在一些情况下,预定值可以由蜂窝无线设备的制造商来确定。在其它示例中,q可以

动态地改变。在操作3020,蜂窝无线设备的收发机可以侦听信道持续一段时间,这段时间为(或大约为)CW乘以干净信道评估(CCA)持续时间(CD)(CD处于微秒量级)。CD可以被定义为一个或多个完整缝隙。为了确定信道是否空闲,在一些示例中,可以将特定CD期间信道的接收功率与预定阈值(例如,-62dBm的阈值)进行比较。如果该功率小于阈值,则在该缝隙期间,信道可以被认为是空闲的。如果该功率高于阈值,则在该缝隙期间,信道可以被认为是忙的。在一些示例中,如果单个缝隙被认为是忙的,则整个周期可以被认为是忙的。在其它示例中,如果多于预定量的缝隙被认为是忙的,则整个CW*CD周期可以被认为是忙的。在另外的示例中,可以在每个缝隙处对接收功率进行采样,然后在整个CW*CD周期上进行平均,并且将该周期上的平均功率与阈值进行比较。如果平均功率高于阈值,则信道可以被认为是忙的。如果平均功率低于阈值,则信道可以被认为是空闲的。

[0043] 如果信道被认为是空闲的,则蜂窝无线设备可以继续于:在操作3030,发送SDL。如果信道被认为是忙的,则蜂窝无线设备可以返回到操作3010并重新开始。

[0044] 在一些示例中,这种检测介质空闲的方法与Wi-Fi载波侦听的方法不同。在Wi-Fi载波侦听中,Wi-Fi设备使用能量检测机制和信号检测机制两者。如果Wi-Fi设备使用信号检测机制检测到Wi-Fi信号,则Wi-Fi设备假定该信道被占用。在一些示例中,在此公开的LBT方法仅使用能量检测机制,而不使用Wi-Fi信号检测机制。注意到,在图3中,CD是干净信道评估(CCA)的持续时间(以 μs 计),其可以是缝隙持续时间或其倍数。

[0045] 图4示出了用于侦听和回退LBT实现的第二选项的方法4000的流程图。在操作4010,收发机侦听信道持续 $W\mu s$ 。W可以是等于一个或多个缝隙的时间段。在操作4020,进行比较,并且如果接收功率高于阈值T持续W时间段,则收发机返回到操作4010。如果接收功率低于阈值T持续W时间段,则收发机进入操作4030。如果W包含多于单个缝隙,则功率比较可以是所有缝隙上的平均功率,或者在操作4020处的比较可以是每缝隙的。在每缝隙情况下,如果多于预定数量(例如,一个或多个)缝隙在比较中失败(例如,功率水平大于阈值),则操作4020处的比较失败并且流程回到操作4010。

[0046] 在操作4030,收发机可以生成1与q之间的随机数CW,其中q(如前所述)是4与32之间的数字。在操作4040,CW可以递减(例如, $CW=CW-1$)。在操作4050,进行比较以确定CW是否小于或等于零。如果CW小于或等于零,则信道是干净的,并且收发机可以在操作4060进行发送。如果 $CW>0$,则在操作4070,收发机可以侦听信道持续缝隙时段。在操作4080,进行比较,并且如果观察到的功率水平小于阈值,则确定信道对于该缝隙是空闲的,并且操作进行到4040,其中CW再次递减。如果信道不是空闲的,则操作回到4010。注意到,在图4中,CD是干净信道评估(CCA)的持续时间(以 μs 计),其可以是缝隙持续时间或其倍数。

[0047] 图5示出了根据本公开的一些示例的用于LBT侦听和回退的第三选项的方法的流程图。在操作5010,收发机侦听信道持续 $W\mu s$ 。W可以是等于一个或多个缝隙的时间段。在操作5020,进行比较,并且如果接收功率高于阈值T持续W时间段,则收发机返回到操作5010。如果接收功率低于阈值T持续W时间段,则收发机进入操作5030。如果W包含多于单个缝隙,则功率比较可以是所有缝隙上的平均功率,或者在操作5020处的比较可以是每缝隙的。在每缝隙情况下,如果多于预定数量(例如,一个或多个)缝隙在比较中失败(例如,功率水平大于阈值),则操作5020处的比较失败并且流程回到操作5010。

[0048] 在操作5030,收发机可以确定信道是否拥塞。例如,如果收发机不得不在操作5010

处侦听信道持续 W_{us} 超过预定次数,则收发机可以确定信道是拥塞的。在其它示例中,收发机可以基于先前传输中的错误(例如,利用传输块错误(TBE)水平)来确定信道拥塞。如果TBE高于预定阈值,则可以确定信道是拥塞的。

[0049] 在操作5050,如果信道是拥塞的,则可以将参数CWT设定为以下中的最大值:最后CWT的两倍和最大竞争窗口(CWMAX)。CWT、CWMIN和CWMAX可以是预先定义的;例如,CWT可以最初为1,CWMIN可以是1,CWMAX可以是1024。在操作5040,如果信道不是拥塞的,则CWT可以被设定为1。

[0050] 在操作5070,收发机可以通过将值D与在CMIN和CWT之间选取的随机数相加,来生成随机数CW。D可以等于发送一个或多个LTE符号所需的缝隙数量的时间。在操作5080,CW可以递减D(例如, $CW = CW - D$)。在操作5090,进行比较以确定CW是否小于或等于零。如果CW小于或等于零,则信道是干净的,并且收发机可以在操作5100进行发送。如果 $CW > 0$,则在操作5110,收发机可以侦听信道持续D时间段(其可以是一个或多个缝隙)。如果在操作5120确定信道是空闲的,则操作进行到操作5080,在这里,CW再次递减。如果信道不是空闲的,则操作回到操作5010。可以如选项1和2中所描述的那样确定信道是空闲的(即,每个缝隙中观察到的功率可以低于阈值,每个缝隙中观察到的平均功率可以低于阈值,或者CD周期中的预定数量的缝隙可以低于阈值)。

[0051] 调度优化

[0052] 在一些示例中,可以使用授权信道(即,主信道)上的控制信道来实现SDL。例如,在LTE中,可以利用授权信道上的PDCCH来实现SDL。PDCCH典型地被携带在当前子帧的前三个符号上,并调度当前子帧。如果回退期在下一个子帧的开始之前完成,则eNodeB可以通过在免授权信道上发送信道预留消息(例如,请求-发送-RTS消息,或者清除-发送-CTS消息)来预留信道,并使用下一个子帧的PDCCH来调度SDL。如果回退期在下一子帧的PDCCH传输期间结束,则可以根据其它调度和PDCCH的带宽来调度SDL。如果回退期在能够在授权信道的PDCCH上调度SDL之前结束,则SDL传输机会可能被浪费。

[0053] 在一些示例中,即使回退期将在子帧开始之后才会结束,eNodeB也可以调度SDL。例如,eNodeB可以预测到回退期可以成功完成(信道在整个周期内保持空闲),并且可以在调度完成回退过程之后调度SDL持续子帧的剩余部分。例如,如果回退过程将要在子帧的中途完成,则eNodeB可以在预期到回退过程可以成功完成的情况下调度一半子帧。

[0054] 在一些示例中,预测回退期可以成功完成可以包括:假定回退期成功完成。在一些示例中,可以使用信道的过去历史来预测回退期将要成功完成。在这些示例中,如果eNodeB在该信道上过去成功完成回退过程高于阈值时间百分比,则eNodeB可以预测这次的回退过程可能是成功的。其它算法可以包括考虑以下因素中的一个或多个:接入时间、信道历史、过去错误率等。示例算法可以利用将这些因素与预定阈值进行比较的if-then语句。

[0055] 在一些示例中,回退重叠可以限于当前子帧的前三个符号(在这里通常发送PDCCH)。因此,如果回退将在当前子帧的前三个符号中完成,则eNodeB可以调度SDL PDSCH。否则,如果在当前子帧的前三个符号内没有调度完成回退,则eNodeB将不在当前子帧中调度SDL PDSCH。

[0056] 在eNodeB预期调度SDL PDSCH的情况下,如果回退期成功完成并且eNodeB能够发送SDL,则UE在SDL上接收数据。如果信道在回退期结束之前变为忙,并且eNodeB没有获得对

免授权信道的接入,则UE可能不知道该情况并且将接收到无效的数据(例如,噪声)。UE将无法成功解码SDL上的PDSCH。在理想情况下,UE将简单地针对该子帧丢弃SDL上的PDSCH。UE认为它丢失了发送给它的数据,因此将利用混合自动重传请求(HARQ)功能来请求重新传输丢失的数据。在这种情况下,eNodeB可以忽略对该数据的任何HARQ请求,并且可以向UE指示从其HARQ缓冲区中移除该数据。例如,可以定义新的下行链路控制信息(DCI)格式,以携带实际上在免授权信道上没有发送SDL的指示。替换地,在一些示例中,可以定义新的物理信号或信道,以携带新的指示消息。

[0057] 现在转到图6,示出了SDL的预期调度的图示6000。LBT和回退开始于子帧6020的符号6010。如果回退被预测在符号6030(子帧26040的第三个符号)之前完成,则eNodeB可以在子帧26040上调度SDL。例如,eNodeB可以调度UE接收符号6050上的数据。

[0058] 现在转到图7,示出了SDL的预期调度的方法7000的流程图。在操作7010,蜂窝无线设备(例如,eNodeB)可以参与LBT和回退过程(例如,图3-5)。在操作7020,蜂窝无线设备预测LBT和回退过程是否将及时完成。在一些示例中,这是简单地假定回退过程不返回忙信道,并确定是否有足够的时间调度SDL的任何部分。例如,如果回退过程将要在特定子帧的前三个符号内完成,则可以调度该子帧。在其它示例中,可以使用其它标准,例如过去的信道使用历史或过去的LBT和回退成功率。

[0059] 如果在操作7030,回退没有被预测为按时完成,则流程进行到操作7040。在操作7040,一旦回退过程完成,就可以预留信道,直到能够在SDL上调度和发送子帧。如果回退过程被调度为按时完成,则在操作7050,可以在适当时在授权信道的PDCCH上调度子帧。在操作7070,蜂窝无线设备可以确定LBT和回退是否按时完成。如果是,则在操作7080,蜂窝无线设备可以正常地在免授权信道上发送SDL。如果没有,则在操作7090,蜂窝无线设备可以忽略来自在SDL上调度的任何UE的、针对未发送的SDL子帧的任何HARQ重传请求。在操作7100,蜂窝无线设备可以向在SDL上调度的UE发送消息,以清除其HARQ缓冲区并终止对该数据的重传尝试。

[0060] 信道侦听优化

[0061] 在一些示例中,为了发送多个子帧,蜂窝无线设备可以利用当前子帧中的、没有发送数据的一个或多个符号来执行侦听和回退,以便满足发送另一子帧的要求。用于执行侦听和回退操作的当前子帧的符号被“打孔”。在一些示例中,当前帧的最后K个符号被打孔。在一些示例中, $K=2$ 。在一些示例中,每个子帧可以被打孔K个符号。在其它示例中,可以对每L个子帧进行打孔(例如,每两个子帧,或者每三个子帧等)。K可以是静态的(即,每第L子帧,可以打孔K个符号),但是在一些示例中,K可以改变,使得一个子帧中的K与另一个子帧中的K不同。

[0062] 与eNodeB关联的UE可以被通知符号打孔,以便在这些符号期间丢弃任何接收到的数据。对UE的通知可以包括打孔符号的精确位置。示例通知可以包括新的DCI。DCI可以包括B个(多至14个)比特的位图,指示打孔符号在子帧中的位置。在其它示例中,如果蜂窝无线设备上的收发机使用显著更高的冗余MCS(具有较低的编码率)传输来抵消打孔,则可以避免了DCI。

[0063] 现在转到图8,示出了对子帧的最后两个符号8020和8030进行打孔的图示8000。子帧1的三个符号8040被Wi-Fi业务占用,或者是空闲的。三个符号8050是侦听和回退,并且在

子帧2开始之前由蜂窝无线设备预留八个符号8060。一旦子帧2开始,蜂窝无线设备就可以发送SDL PDSCH 8070。符号8030和8020被打孔,以便为下一个子帧(未示出)开始侦听和回退。

[0064] 在一些示例中,实现的回退可以是前述方法中的任一个。在一些示例中,信道侦听优化可以与调度优化相结合。在任何情况下,用于信道侦听和回退的所有各种选项是兼容的,并且可以与信道侦听优化和调度优化中的任一个或两者一起使用。

[0065] 现在转到图9,根据一些示例示出了蜂窝无线设备打孔K个符号的方法9000。在操作9010,蜂窝无线设备可以确定期望另一子帧用于SDL传输。例如,eNodeB可以具有用于一个或多个UE的附加数据。在操作9020,eNodeB可以确定K。K可以是预定的,或者可以是可变的。在操作9030,可以将打孔参数传送到在当前子帧上调度的一个或多个UE。打孔参数可以包括将要被打孔的符号,或者允许UE推断将要被打孔的符号的一条或多条信息(例如,K)。在操作9040,蜂窝无线设备可以在当前子帧的被打孔符号中执行LBT和回退。

[0066] 现在转到图10,根据一些示例示出了蜂窝无线设备10000的示意图。蜂窝无线设备10000可以是能够使用授权蜂窝协议进行通信的任何设备。蜂窝无线设备10000可以是nodeB、eNodeB、UE、基站收发台(BTS)、Wi-Fi接入点、蜂窝电话、智能电话、台式计算机、膝上型计算机、医疗设备(例如,心率监测器、血压监测器等)、可穿戴设备(例如,计算眼镜、智能手表)等。

[0067] 蜂窝无线设备10000可以包含第一无线收发机10030、第二无线收发机10040和用于控制第一无线收发机和第二无线收发机的控制电路10020。第一无线收发机10030可以在免授权信道上操作,并且在一些示例中,实现不是蜂窝无线协议的无线协议。在一些示例中,第一无线收发机10030可以实现在免授权信道中操作的无线协议,例如IEEE802.11无线协议、蓝牙无线协议、低功耗蓝牙(BLE)无线协议、Zigbee无线协议等。在一些示例中,第一无线收发机10030可以确定免授权信道是否被其它业务占用。在一些示例中,第一收发机10030可以检测免授权信道上的功率水平,并且如果平均功率水平低于特定阈值持续预定时间段,则控制电路10020可以使用图3-5的方法中的一种或多种方法来确定信道没有被占用。

[0068] 一旦信道被认为没有被占用,控制电路10020就可以控制回退过程。控制电路10020可以与第一收发机10030协作地实现图3-5的操作,例如选择随机竞争窗口,递减竞争窗口,使用第一收发机10030检测信道持续 $W_{\mu s}$,确定回退期是否结束,或者如果在回退期间在信道上检测到活动,则以信号告知第一收发机10030,以再一次通过检测免授权信道上的功率水平持续信道监听时间段来确定介质是否是空闲的。一旦控制电路10020和第一收发机10030已经确定信道再次是空闲的,则控制电路10020将重新启动并再次实现回退过程。

[0069] 控制电路10020还可以实现调度优化和信道侦听优化。例如,控制电路10020可以预测LBT和回退是否将及时完成以调度子帧。如果LBT/回退没有被预测为及时完成,则控制电路10020可以吩咐第一收发机10030或第二收发机10040:对于下一个可用子帧,一旦LBT和回退完成,就发送预留消息。如果LBT/回退被预测为及时完成以在当前子帧中发送SDL PDSCH,则控制电路将经由第二收发机10040发送的PDCCH在SDL PDSCH上调度一个或多个UE。如果UE被调度,但是LBT/回退程序没有成功完成,则控制电路可以忽略与该子帧相关的

任何HARQ传输。控制电路还可以经由第二收发机10040或第一收发机10030(例如,通过授权信道或免授权信道)吩咐任何接收机(例如,UE)从它们的HARQ队列中移除这些项目,所以它们将不再请求重传。

[0070] 控制电路10020还可以实现一种或多种信道侦听优化。控制电路10020可以确定K和L,并且经由第二收发机10040或第一收发机10030(例如,通过授权信道或免授权信道)与任何接收器(例如,UE)关于打孔参数进行通信。此外,控制电路10020可以经由第一收发机来实现该打孔。

[0071] 第二无线收发机10040可以实现蜂窝无线协议,并且通常可以通过授权频率进行传输。示例蜂窝无线协议可以包括由第三代合作伙伴项目(3GPP)颁布的长期演进(LTE)标准族、由3GPP颁布的通用移动通信(UMTS)、被称为全球微波接入互操作性(WiMAX)的电气和电子工程师协会(IEEE) 802.16标准等。第二收发机10040可以提供蜂窝无线协议的一个或多个协议层以实现通信。例如,如果蜂窝无线设备10000是eNodeB,则第二收发机10040提供实现eNodeB的功能。如果蜂窝无线设备10000是UE,则第二收发机10040提供连接到蜂窝网络并且在该网络上传送数据的功能。第二收发机10040可以利用授权带宽,但是也可以具有在免授权带宽上发送和接收数据的电路。

[0072] 控制电路10020可以控制第一收发机10030以及第二收发机10040。当控制电路10020确定免授权信道将要用于蜂窝无线协议时,控制电路10020可以使用第一收发机10030确定信道何时是空闲的,并且在一些示例中,经由第一收发机10030使用信道预留消息来预留信道。一旦信道是空闲的,控制电路10020就可以吩咐第一收发机10030或第二收发机10040使用蜂窝无线协议在免授权频段上进行传输。

[0073] 在一些示例中,蜂窝无线设备10000可以在免授权信道上发送预留消息。在一些示例中,预留消息具有可以被设定为蜂窝数据传送的持续时间(例如,子帧)的持续时间字段。在一些示例中,蜂窝无线设备10000可以直到子帧边界才开始进行传输。在这些示例中,如果发送了预留消息,则预留消息的持续时间可以等于蜂窝数据传送的持续时间加上直到下一个子帧边界的时间量。

[0074] 图11示出了根据本公开的一些示例的示例无线环境11000的示意图。eNodeB 11010形式的蜂窝无线设备为UE 11030形式的一个或多个蜂窝无线设备提供蜂窝无线通信。在一些示例中,UE 11030可以利用由eNodeB 11010提供的蜂窝网络来接入网络,例如互联网11060。蜂窝无线通信可以根据一种或多种无线标准,例如LTE。蜂窝无线设备11010和11030可以包括图10和图12的组件,以及实现图1-9所示的方法或时间线中的任何一个或多个。蜂窝无线设备11010和11030可以在授权频率或免授权频率上进行通信。无线设备11050(例如,膝上型计算机)可以访问由可以在免授权频率中操作的无线设备11040(例如,接入点)提供的一个或多个局域网。无线设备11050可以通过与无线设备11040的无线连接来访问诸如互联网11060的网络。

[0075] 图12示出了可以在其上执行本文讨论的任何一种或多种技术(例如,方法)的示例机器12000的框图。在替换实施例中,机器12000可以作为独立设备操作,或者可以连接(例如,联网)到其它机器。在联网部署中,机器12000可以以服务器机器、客户端机器或两者的角色在服务器-客户端网络环境中操作。在一个示例中,机器12000可以用作对等(P2P)(或其它分布式)网络环境中的对等机器。机器12000可以是蜂窝无线设备、无线设备等。示例蜂

寓无线设备包括eNodeB、UE、个人计算机(PC)、平板PC、机顶盒(STB)、个人数字助理(PDA)、移动电话、网络设备、网络路由器、交换机或网桥,或者能够(顺序地或以其它方式)执行指定机器要采取的操作的指令的任何机器。此外,虽然仅示出了单个机器,但是术语“机器”还应当被视为包括单独或共同执行一组(或多组)指令以执行本文所讨论的任何一种或多种方法的机器的任何集合,例如云计算配置、软件即服务(SaaS)配置或其它计算机集群配置。

[0076] 如本文所述的,示例可以包括逻辑或多个组件、模块、电路或机构,或者可以在其上操作。模块和电路是能够执行指定操作的有形实体(例如,硬件),并且可以以某种方式进行配置或布置。在一个示例中,电路可以以指定方式被布置(例如,在内部或相对于外部实体(例如,其它电路))作为电路系统。在一个示例中,一个或多个计算机系统(例如,单机计算机系统、客户端计算机系统或服务器计算机系统)或者一个或多个硬件处理器的全部或部分可以由固件或软件(例如,指令、应用部分或应用)配置为操作以执行指定操作的电路系统。

[0077] 因此,术语“电路系统”被理解为包括有形实体,无论是物理地构造成、具体配置(例如,硬连线)成、或暂时(例如,瞬时性)配置(例如,经编程)成以指定方式操作或执行本文所述的任何操作的部分或全部的实体。考虑临时配置电路系统的示例,每个电路不需要在任何时刻被实例化。例如,在电路包括使用软件配置的通用硬件处理器的情况下,通用硬件处理器可以在不同时间被配置为相应的不同电路系统。因此,软件可以将硬件处理器配置为例如在一个时间实例构成特定电路,并在不同的时间实例构成不同的电路。

[0078] 机器(例如,计算机系统)12000可以包括硬件处理器12002(例如,中央处理单元(CPU)、图形处理单元(GPU)、硬件处理器核心或其任何组合)、主机存储器12001和静态存储器12006,其中一些或全部可以经由互连(例如,总线)12008彼此通信。机器12000还可以包括显示单元12010、字母数字输入设备12012(例如,键盘)和用户界面(UI)导航设备12014(例如,鼠标)。在一个示例中,显示单元12010、字母数字输入设备12012和UI导航设备12014可以是触摸屏显示器。机器12000可以附加地包括存储设备(例如,驱动单元)12016、信号生成设备12018(例如,扬声器)、网络接口设备12020以及一个或多个传感器12021例如,全球定位系统(GPS)传感器、罗盘、加速度计或其它传感器)。机器12000可以包括输出控制器12028,例如串行连接(例如,通用串行总线(USB))、并行连接、或者其它有线或无线连接(例如,红外(IR)、近场通信(NFC)等),以与一个或多个外围设备(例如,打印机、读卡器等)进行通信或对其进行控制。

[0079] 存储设备12016可以包括机器可读介质12022,在其上存储有一组或多组数据结构或指令12024(例如,软件),这些数据结构或指令12024体现本文所描述的任何一个或多个技术或功能,或者由它们来利用。指令12024在由机器12000执行它们期间还可以完全地或至少部分地驻留在主存储器12001内,在静态存储器12006内,或者在硬件处理器12002内。在示例中,硬件处理器12002、主存储器12001、静态存储器12006或存储设备12016之一或任何组合可以构成机器可读介质。

[0080] 虽然机器可读介质12022被示为单个介质,但是术语“机器可读介质”可以包括单个介质或多个介质(例如,集中式或分布式数据库和/或相关联的高速缓存和服务器等),其被配置为存储一个或多个指令12024。

[0081] 术语“机器可读介质”可以包括能够存储、编码或携带由机器12000执行的指令并

使机器12000执行本公开的任何一种或多种技术的任何介质,或者能够存储、编码或携带由这些指令使用的或与之关联的数据结构的任何介质。机器可读介质可以包括非瞬时性机器可读介质。机器可读介质不是瞬时性传播信号。非限制性机器可读介质示例可以包括固态存储器以及光学介质和磁性介质。机器可读介质的具体示例可以包括非易失性存储器,例如半导体存储器件(例如,电可编程只读存储器(EPROM)、电可擦除可编程只读存储器(EEPROM)和闪存器件;磁盘,例如内部硬盘和可移除磁盘;磁光盘;随机存取存储器(RAM);和CD-ROM和DVD-ROM磁盘。指令12024还可以通过使用传输介质的通信网络12026,经由网络接口设备12020利用多种传输协议(例如,帧中继、因特网协议(IP)、传输控制协议(TCP)、用户数据报协议(UDP)、超文本传输协议(HTTP)等)中的任何一种协议进行发送或接收。示例通信网络可以包括局域网(LAN)、广域网(WAN)、分组数据网络(例如,因特网)、移动电话网络(例如,蜂窝网络)、普通老式电话(POTS)网络、和无线数据网络(例如,称为Wi-Fi®的IEEE 802.11标准族,称为WiMax®的IEEE 802.16标准族,IEEE 802.15.4标准族和对等(P2P)网络等。在一个示例中,网络接口设备12020可以包括一个或多个物理插孔(例如,以太网、同轴电缆或电话插孔)或一个或多个天线,以连接到通信网络12026。

[0082] 在一个示例中,网络接口设备12020可以包括多个天线,以使用单输入多输出(SIMO)、多输入多输出(MIMO)或多输入单输出(MISO)技术中的至少一种进行无线通信。术语“传输介质”应当被视为包括能够存储、编码或携带由机器12000执行的指令的任何无形介质,并且包括有助于这种软件的传递的数字或模拟通信信号或其它无形介质。

[0083] 其它注释和示例

[0084] 示例1包括主题(例如,设备、装置或机器),包括:第一收发机,用于:在免授权信道中进行发送和接收;第二收发机,用于:根据蜂窝无线协议,在授权信道和免授权信道中进行发送和接收;和控制器,用于:经由所述第一收发机,在预定数量的一个或多个缝隙上侦听免授权信道的能量,以确定免授权信道是未被占用的,所述缝隙是参考蜂窝无线协议的定时信息来定义的,并且响应于确定信道是未被占用的:经由在授权信道上传输的控制信道,调度由所述eNodeB服务的至少一个用户设备(UE)在免授权信道中接收数据;以及经由所述第二收发机,在蜂窝子帧边界处开始,在免授权信道上发送数据。

[0085] 在示例2中,示例1的主题可以包括,其中,所述第一收发机被配置为:根据非蜂窝无线协议进行发送和接收,并且其中,在免授权信道上发送的数据是补充下行链路(SDL)物理下行链路共享信道(PDSCH),并且其中,所述控制器还被配置为:经由所述第一收发机在免授权信道上发送无线预留消息,以便为在免授权信道上发送的数据预留免授权信道。

[0086] 在示例3中,示例1至2中任一项的主题可以包括,其中,所述一个或多个缝隙被配置为:细分当前蜂窝子帧中的多个样本,使得所述一个或多个缝隙不跨越当前蜂窝子帧中的符号边界。

[0087] 在示例4中,示例1至3中任一项的主题可以包括,其中,所述一个或多个缝隙中的至少一个缝隙被配置为:跨越当前蜂窝子帧的符号边界。

[0088] 在示例5中,示例1至4中任一项的主题可以包括,其中,所述一个或多个缝隙从前蜂窝子帧被打孔。

[0089] 在示例6中,示例1至5中任一项的主题可以包括,其中,所述蜂窝无线协议是由第三代合作伙伴项目(3GPP)定义的长期演进(LTE)或长期演进高级(LTE-A)标准族。

[0090] 在示例7中,示例1至6中任一项的主题可以包括,其中,所述第一收发机被配置为:根据电气和电子工程师协会(IEEE) 802.11协议进行发送和接收。

[0091] 在示例8中,示例1至7中任一项的主题可以包括,其中,所述控制器用于:实现回退过程,并且在回退过程成功之前禁止在免授权信道上发送数据。

[0092] 在示例9中,示例1至8中任一项的主题可以包括,其中,控制信道是物理下行链路控制信道(PDCCH),并且其中,所述控制器用于:预测回退过程将在PDCCH的传输结束之前完成,并且作为响应,在回退过程完成之前,经由所述第二收发机在授权信道上发送的PDCCH,调度由所述eNodeB服务的所述至少一个用户设备(UE)在免授权信道上接收数据。

[0093] 在示例10中,示例1至9中任一项的主题可以包括,其中,所述控制器用于:确定回退过程在PDCCH的传输结束之前未完成,并且作为响应:忽略针对在免授权信道上调度的数据的混合自动重传请求(HARQ);以及通知UE针对在免授权信道上调度的数据清除HARQ缓冲区。

[0094] 在示例11中,示例1至10中任一项的主题可以包括,其中,所述第二收发机被配置为:在授权信道中提供PDSCH。

[0095] 示例12包括主题(例如,设备、装置或机器),包括:在一个或多个缝隙上侦听并非专门授权于蜂窝无线通信的辅信道;确定辅信道的接收功率指示辅信道在所述一个或多个缝隙期间是空闲的;以及作为响应:在辅信道上发送预留消息;调度至少一个用户设备(UE)接收在辅信道上传输的物理下行链路共享信道(PDSCH)上的数据;经由被授权于蜂窝无线通信的主信道上的控制信道,向UE传递该调度;以及在子帧边界处开始,在辅信道上发送PDSCH。

[0096] 在示例13中,示例12的主题可以包括,其中,所述一个或多个缝隙是参考蜂窝无线协议的定时信息来定义的。

[0097] 在示例14中,示例12至13中任一项的主题可以包括,其中,所述指令将所述eNodeB配置为:确定回退过程将在当前子帧之后且在下一个子帧期间完成,所述下一个子帧开始于所述子帧边界;并且响应于确定回退过程将在当前子帧之后且在下一个子帧期间完成,在回退过程完成之前,在主信道上传输的物理下行链路控制信道(PDCCH)上调度所述至少一个UE。

[0098] 在示例15中,示例12至14中任一项的主题可以包括,其中,所述指令将所述eNodeB进一步配置为:在主信道上发送PDSCH之前,成功完成回退过程。

[0099] 在示例16中,示例12至15中任一项的主题可以包括,其中,用于回退过程的指令包括如下指令:生成随机竞争窗口;对于每个竞争窗口,进行信道侦听持续等于缝隙的第二预定时间段;以及通过确定对于每个特定竞争窗口,在该特定竞争窗口期间的接收功率低于预定阈值,来确定回退过程是成功的。

[0100] 在示例17中,示例12至16中任一项的主题可以包括,其中,用于回退过程的指令包括如下指令:确定辅信道是拥塞的,并且作为响应,使竞争窗口加倍。

[0101] 示例18包括主题(例如,设备、装置或机器),包括:一个或多个处理器,用于:确定第一信道在一个或多个缝隙上的功率水平低于第一预定阈值,所述第一信道是并非专门授权于蜂窝无线的无线信道,并且作为响应:选择随机回退窗口;确定所述第一信道在所述回退窗口内的功率水平低于第二预定阈值;使用授权的第二信道上的控制信道,调度用户设

备 (UE) 在所述第一信道上接收补充下行链路 (SDL) 物理下行链路共享信道 (PDSCH) 上的数据; 以及响应于所述第一信道在所述随机回退窗口内的功率水平低于所述第二阈值, 于蜂窝子帧边界处, 在第一信道上发送 SDL PDSCH。

[0102] 在示例19中, 示例18的主题可以包括, 其中, 所述一个或多个处理器被配置为: 在所述第二信道上提供PDSCH。

[0103] 在示例20中, 示例18至19中任一项的主题可以包括, 其中, 所述一个或多个缝隙相对于长期演进 (LTE) 或长期演进高级 (LTE-A) 符号是对准的。

[0104] 在示例21中, 示例18至20中任一项的主题可以包括, 其中, 一个或多个缝隙的符号持续时间是数量一致 (consistent number) 的样本, 并且是长期演进 (LTE) 或长期演进高级 (LTE-A) 子帧中的样本数量的因子。

[0105] 在示例22中, 示例18至21中任一项的主题可以包括, 其中, 所述一个或多个处理器被配置为: 响应于确定所述第一信道在所述回退窗口内的功率水平低于所述第二阈值, 发送无线预留消息。

[0106] 在示例23中, 示例18至22中任一项的主题可以包括, 其中, 所述无线预留消息是清除-发送 (CTS) 消息, 并且其中, 所述CTS消息具有持续时间字段, 所述持续时间字段的值被设定为至少直到蜂窝子帧边界的时间加上发送PDSCH子帧的时间。

[0107] 在示例24中, 示例18至23中任一项的主题可以包括, 其中, 所述一个或多个处理器被配置为: 通过至少被配置为确定对于随机回退窗口的每次递减, 接收功率低于所述第二阈值, 来确定所述第一信道在所述随机回退窗口内的功率水平低于所述第二阈值。

[0108] 在示例25中, 示例18至24中任一项的主题可以包括天线。

[0109] 示例26包括主题 (例如, 方法、用于执行动作的单元、包含指令的机器可读介质, 所述指令当由机器执行时使机器执行动作, 或者使装置执行), 包括: 使用一个或多个处理器进行: 确定第一信道在一个或多个缝隙上的功率水平低于第一预定阈值, 所述第一信道是并非专门授权于蜂窝无线的无线信道, 并且作为响应: 选择随机回退窗口; 确定所述第一信道在所述回退窗口内的功率水平低于第二预定阈值; 使用授权的第二信道上的控制信道, 调度用户设备 (UE) 在所述第一信道上接收补充下行链路 (SDL) 物理下行链路共享信道 (PDSCH) 上的数据; 以及响应于所述第一信道在所述随机回退窗口内的功率水平低于所述第二阈值, 于蜂窝子帧边界处, 在第一信道上发送 SDL PDSCH。

[0110] 在示例27中, 示例26的主题可以包括, 其中, 所述一个或多个处理器被配置为: 在第二信道上提供PDSCH。

[0111] 在示例28中, 示例26至27中任一项的主题可以包括, 其中, 所述一个或多个缝隙相对于长期演进 (LTE) 或长期演进高级 (LTE-A) 符号是对准的。

[0112] 在示例29中, 示例26至28中任一项的主题可以包括, 其中, 一个或多个缝隙的符号持续时间是数量一致的样本, 并且是长期演进 (LTE) 或长期演进高级 (LTE-A) 子帧中的样本数量的因子。

[0113] 在示例30中, 示例26至29中任一项的主题可以包括, 其中, 所述一个或多个处理器被配置为: 响应于确定所述第一信道在所述回退窗口内的功率水平低于所述第二阈值, 发送无线预留消息。

[0114] 在示例31中, 示例26至30中任一项的主题可以包括, 其中, 所述无线预留消息是清

除-发送 (CTS) 消息, 并且其中, 所述CTS消息具有持续时间字段, 所述持续时间字段的值被设定为至少直到蜂窝子帧边界的时间加上发送PDSCH子帧的时间。

[0115] 在示例32中, 示例26至31中任一项的主题可以包括, 其中, 所述一个或多个处理器被配置为: 通过至少被配置为确定对于随机回退窗口的每次递减, 接收功率低于所述第二阈值, 来确定所述第一信道在所述随机回退窗口内的功率水平低于所述第二阈值。

[0116] 示例33包括主题 (例如, 设备、装置或机器), 包括: 用于确定第一信道在一个或多个缝隙上的功率水平低于第一预定阈值的单元, 所述第一信道是并非专门授权于蜂窝无线的无线信道, 并且作为响应: 选择随机回退窗口; 用于确定所述第一信道在所述回退窗口内的功率水平低于第二预定阈值的单元; 用于使用授权的第二信道上的控制信道, 调度用户设备 (UE) 在所述第一信道上接收补充下行链路 (SDL) 物理下行链路共享信道 (PDSCH) 上的数据的单元; 和用于响应于所述第一信道在所述随机回退窗口内的功率水平低于所述第二阈值, 于蜂窝子帧边界处, 在所述第一信道上发送SDL PDSCH的单元。

[0117] 在示例34中, 示例33的主题可以包括, 用于在第二信道上提供PDSCH的单元。

[0118] 在示例35中, 示例33至34中任一项的主题可以包括, 其中, 所述一个或多个缝隙相对于长期演进 (LTE) 或长期演进高级 (LTE-A) 符号是对准的。

[0119] 在示例36中, 示例33至35中任一项的主题可以包括, 其中, 一个或多个缝隙的符号持续时间是数量一致的样本, 并且是长期演进 (LTE) 或长期演进高级 (LTE-A) 子帧中的样本数量的因子。

[0120] 在示例37中, 示例33至36中任一项的主题可以包括: 用于响应于确定所述第一信道在所述回退窗口内的功率水平低于所述第二阈值, 发送无线预留消息的单元。

[0121] 在示例38中, 示例33至37中任一项的主题可以包括, 其中, 所述无线预留消息是清除-发送 (CTS) 消息, 并且其中, 所述CTS消息具有持续时间字段, 所述持续时间字段的值被设定为至少直到蜂窝子帧边界的时间加上发送PDSCH子帧的时间。

[0122] 在示例39中, 示例33至38中任一项的主题可以包括, 其中, 用于确定所述第一信道在所述随机回退窗口内的功率水平低于所述第二阈值的单元包括用于确定对于随机回退窗口的每次递减, 接收功率低于所述第二阈值的单元。

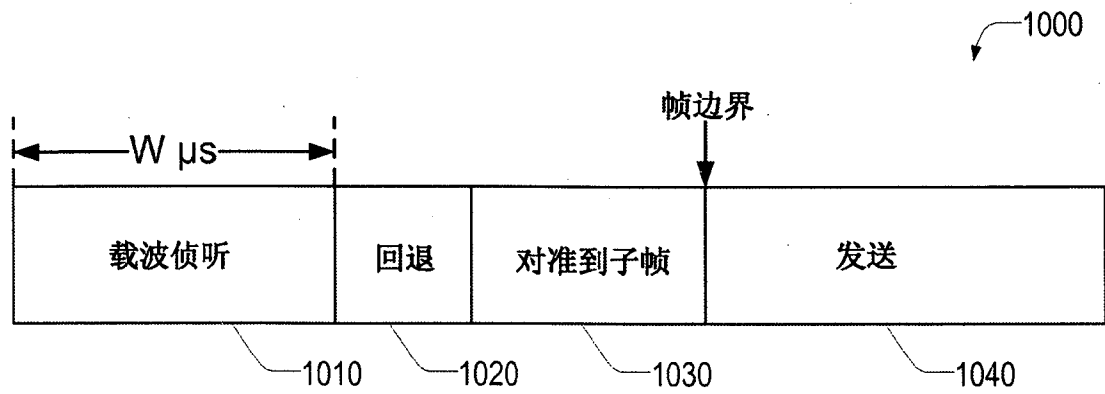


图1

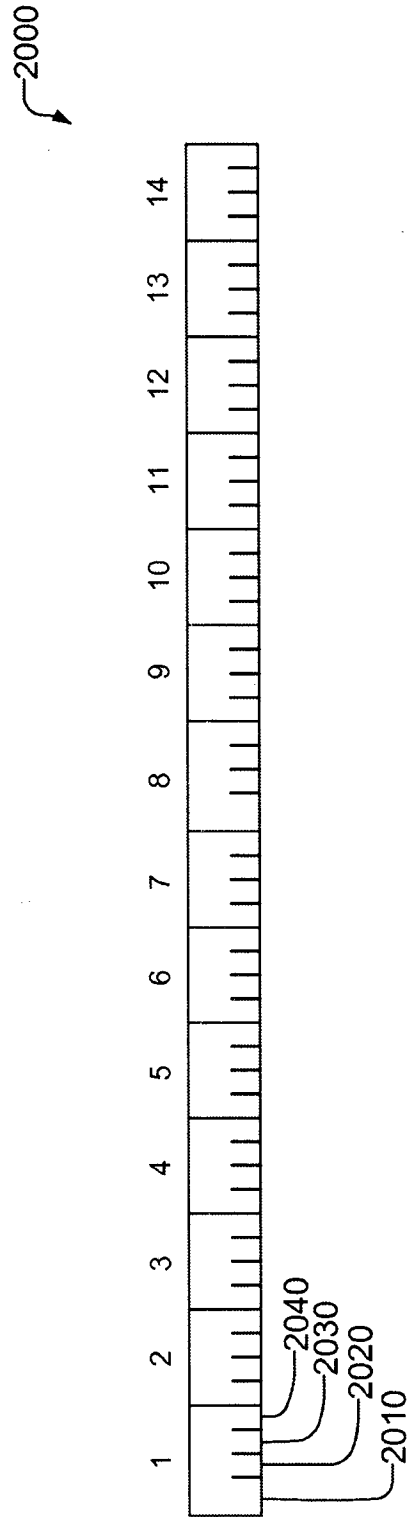


图2A

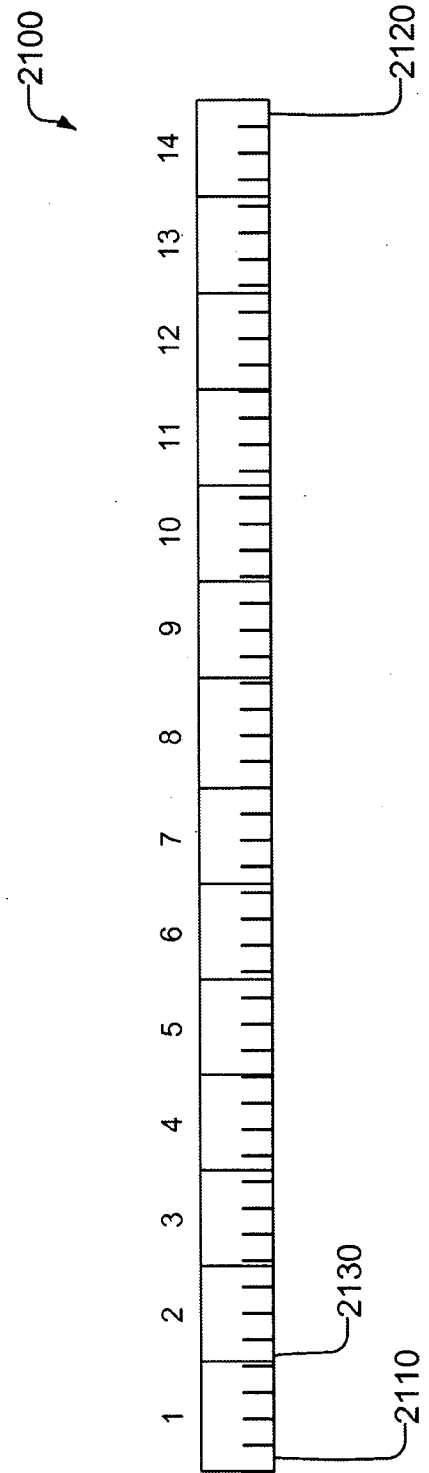


图2B

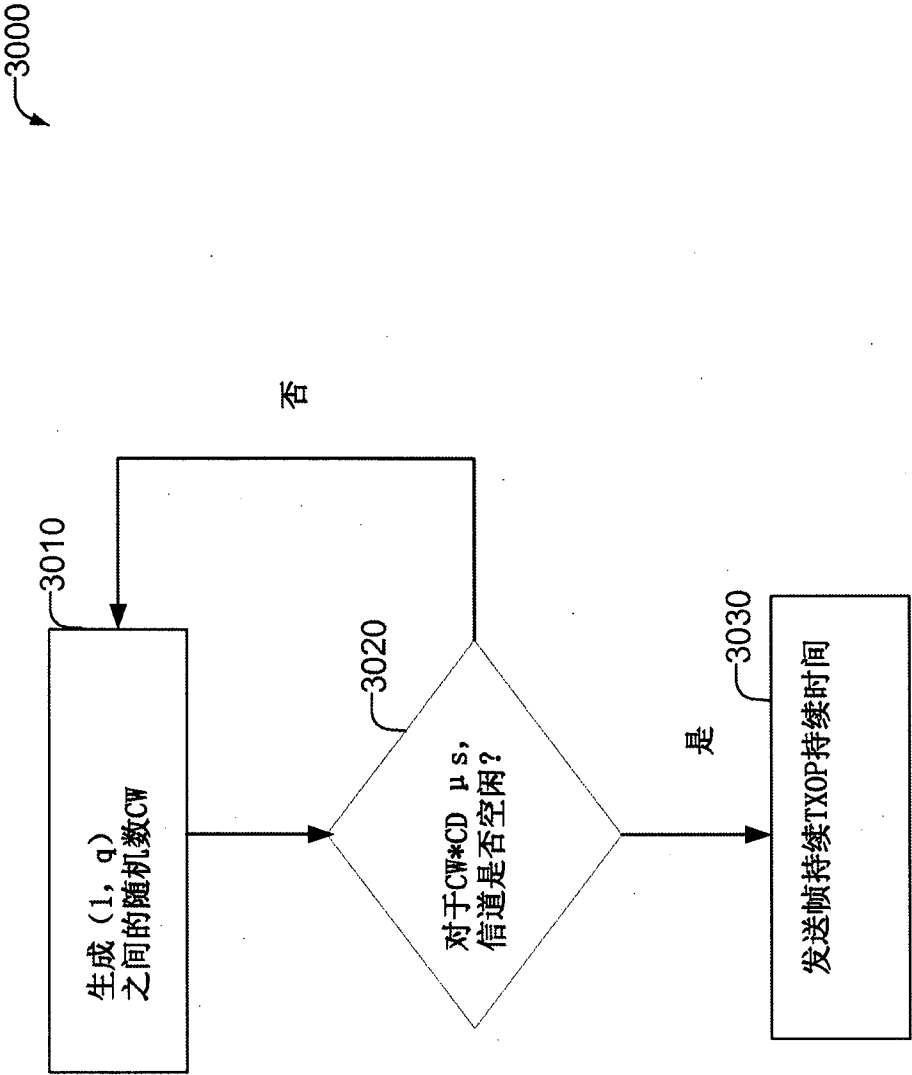


图3

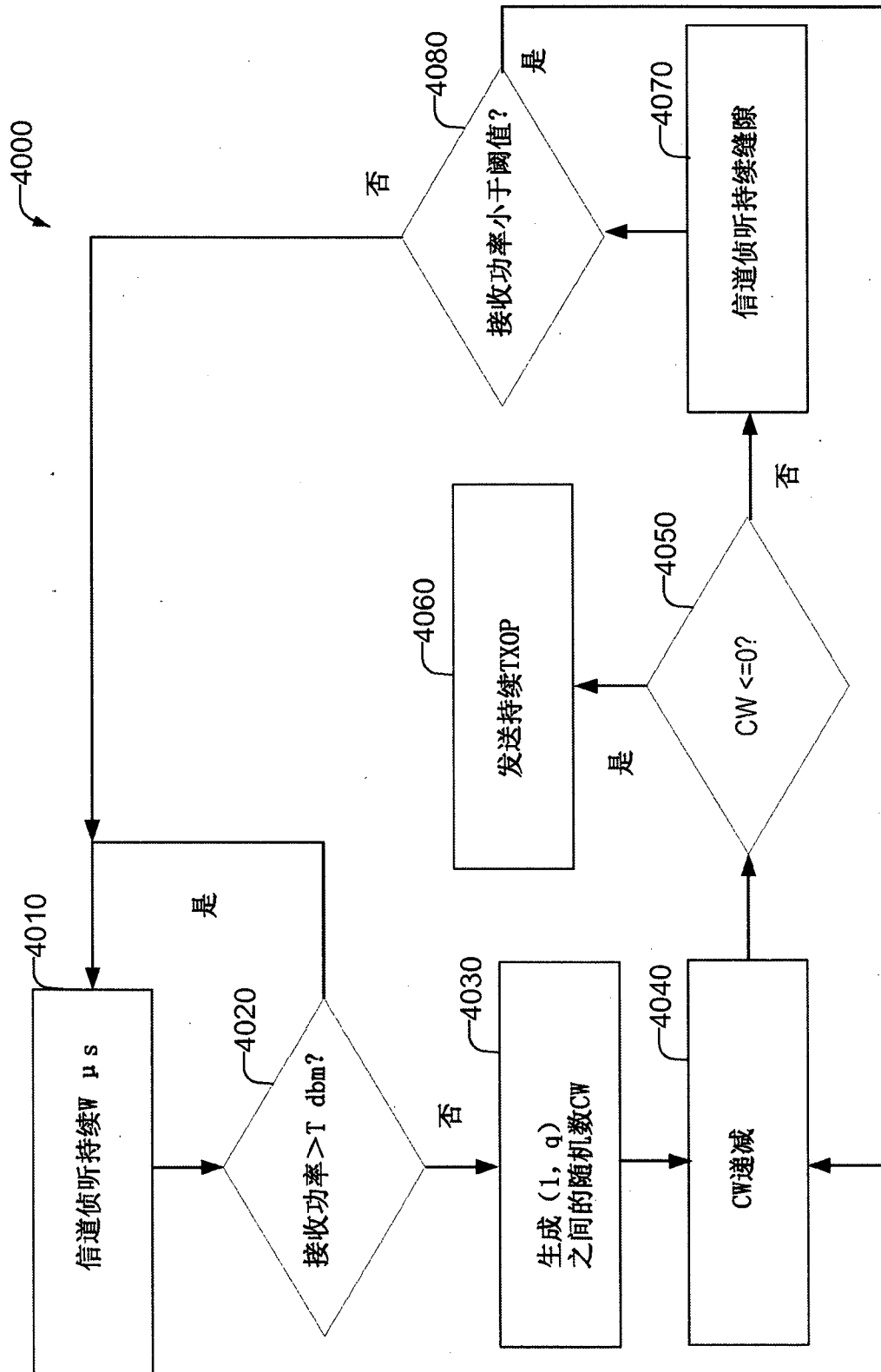


图4

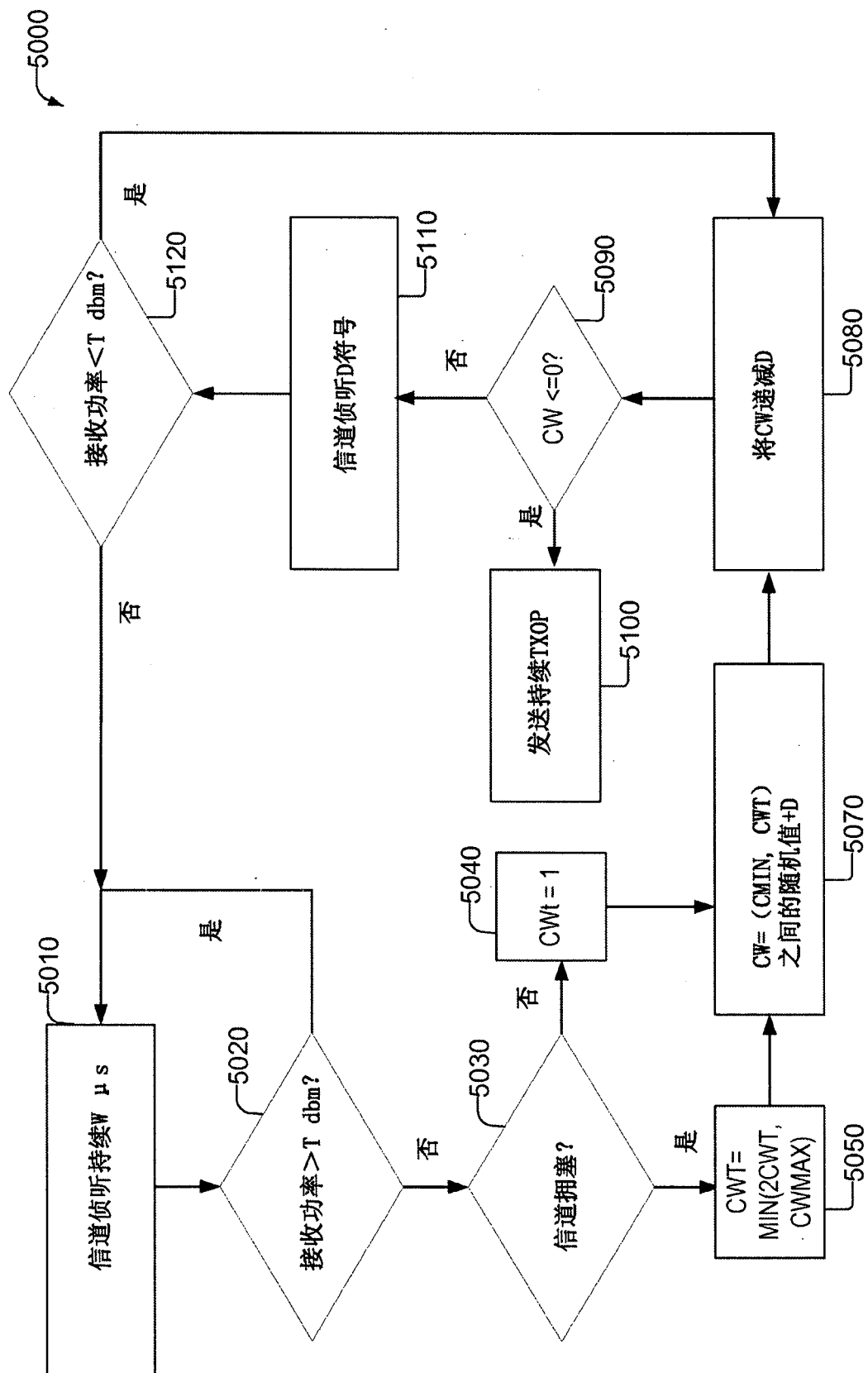


图5

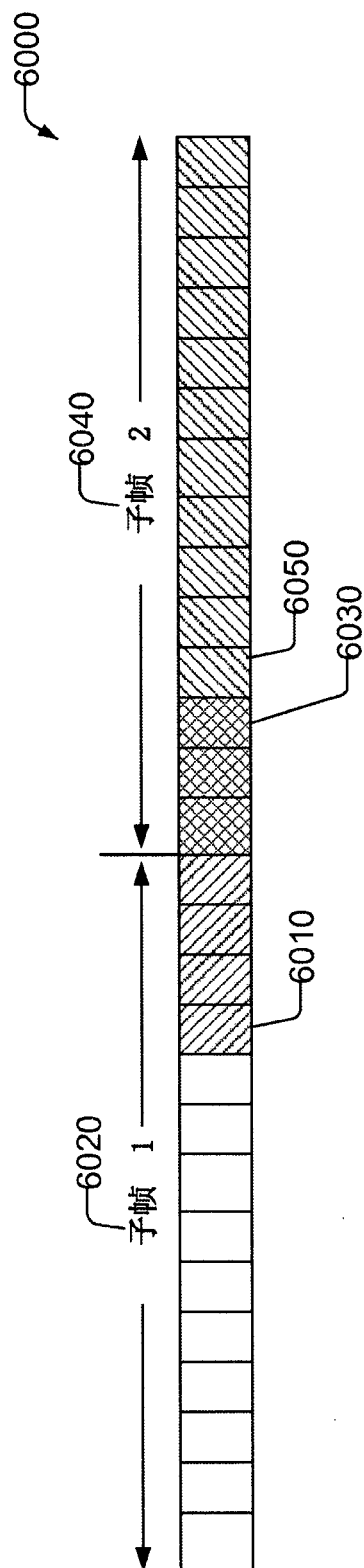


图6

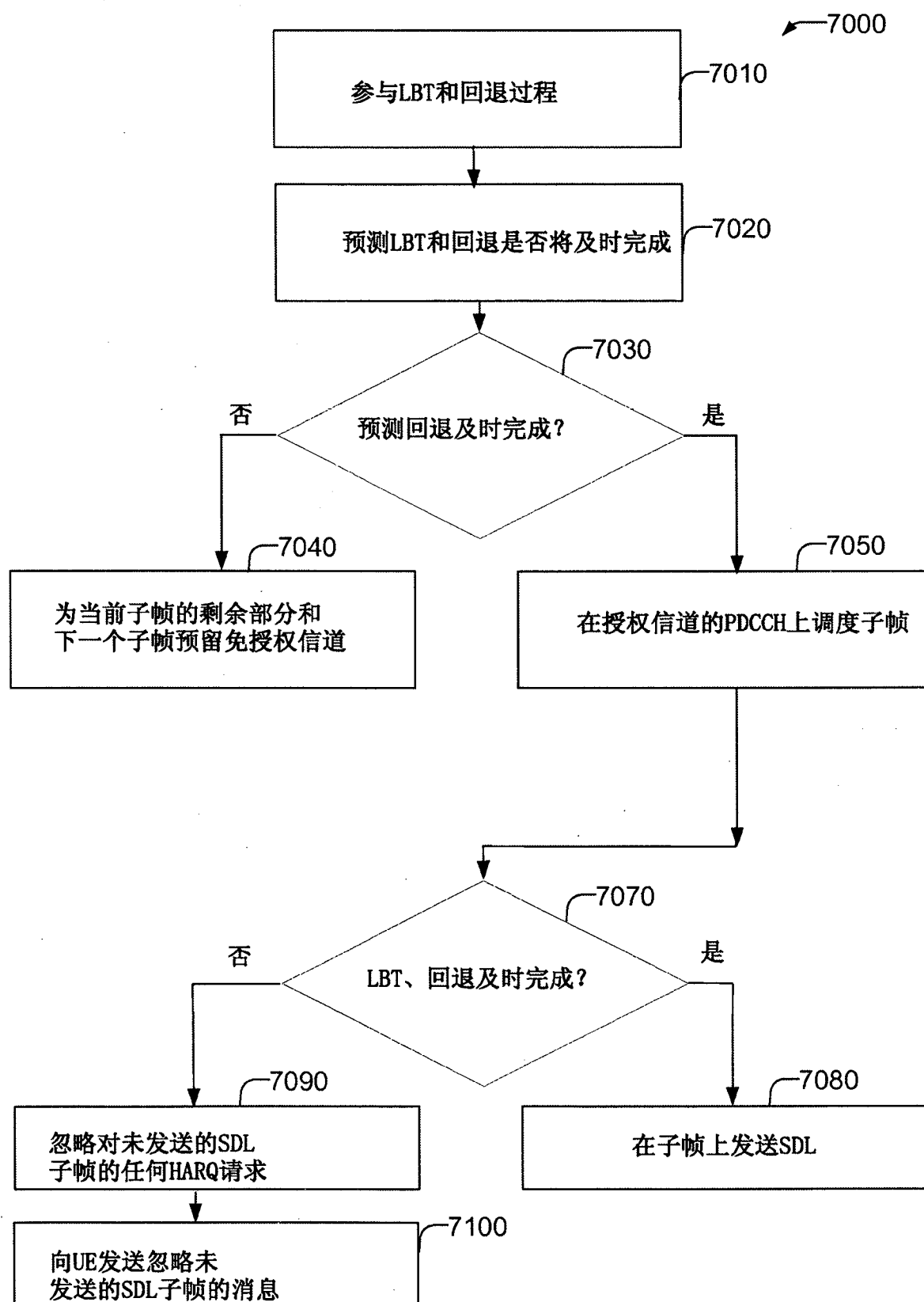


图7

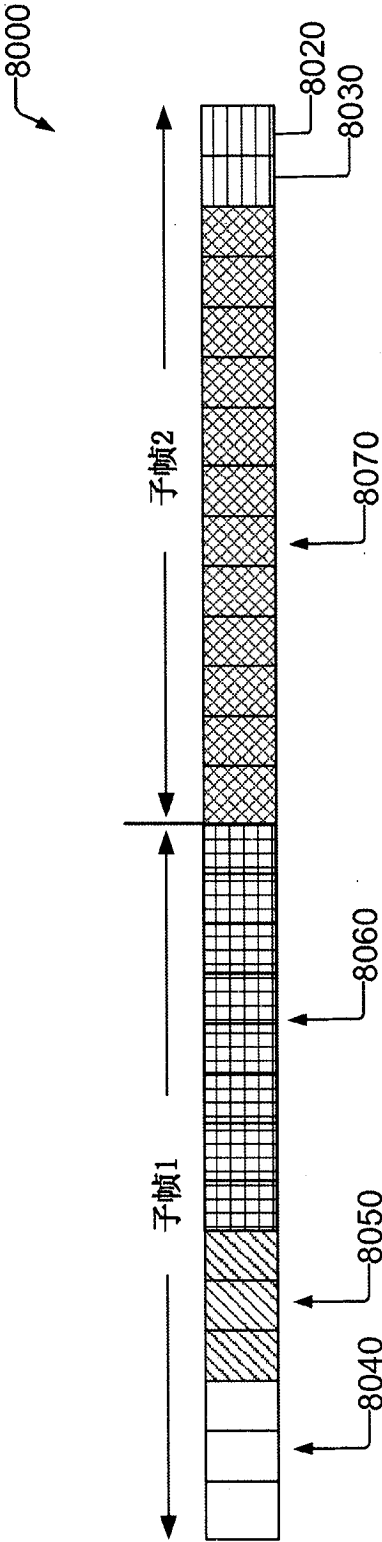


图8

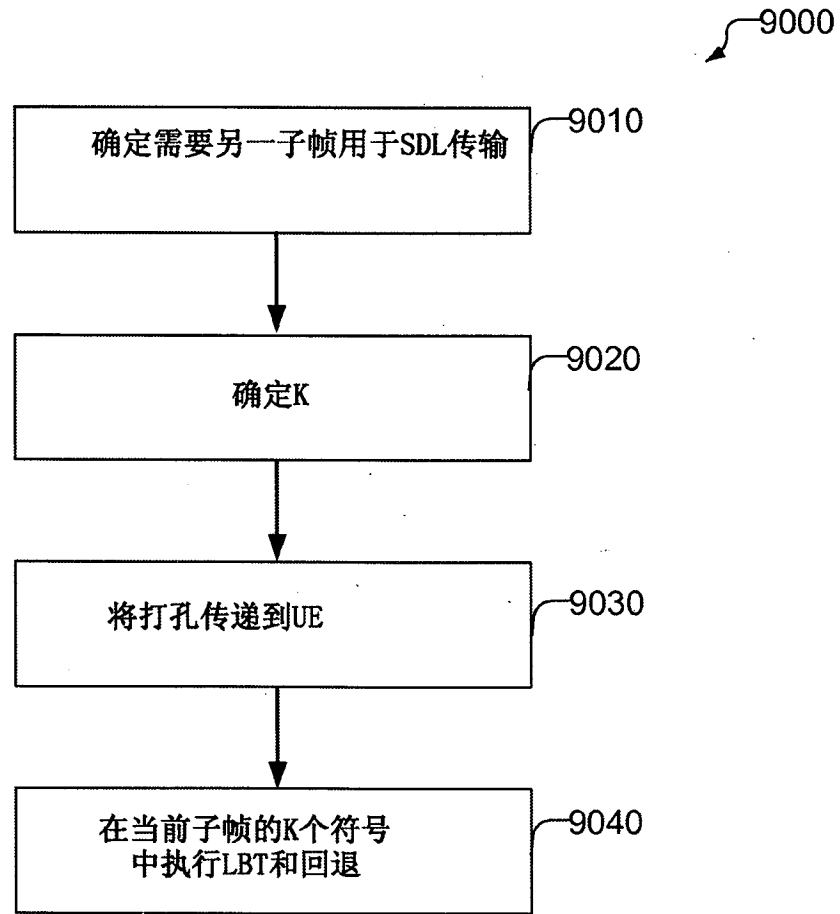


图9

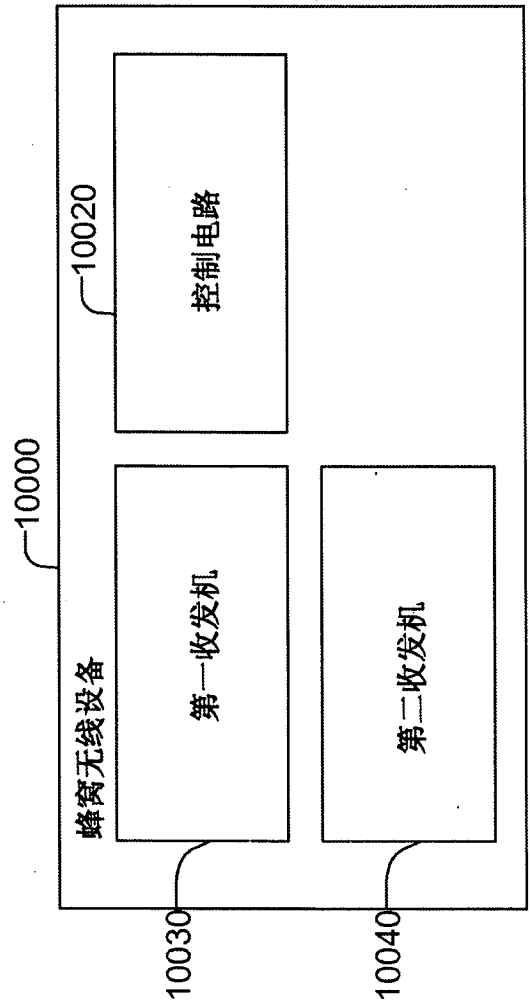


图10

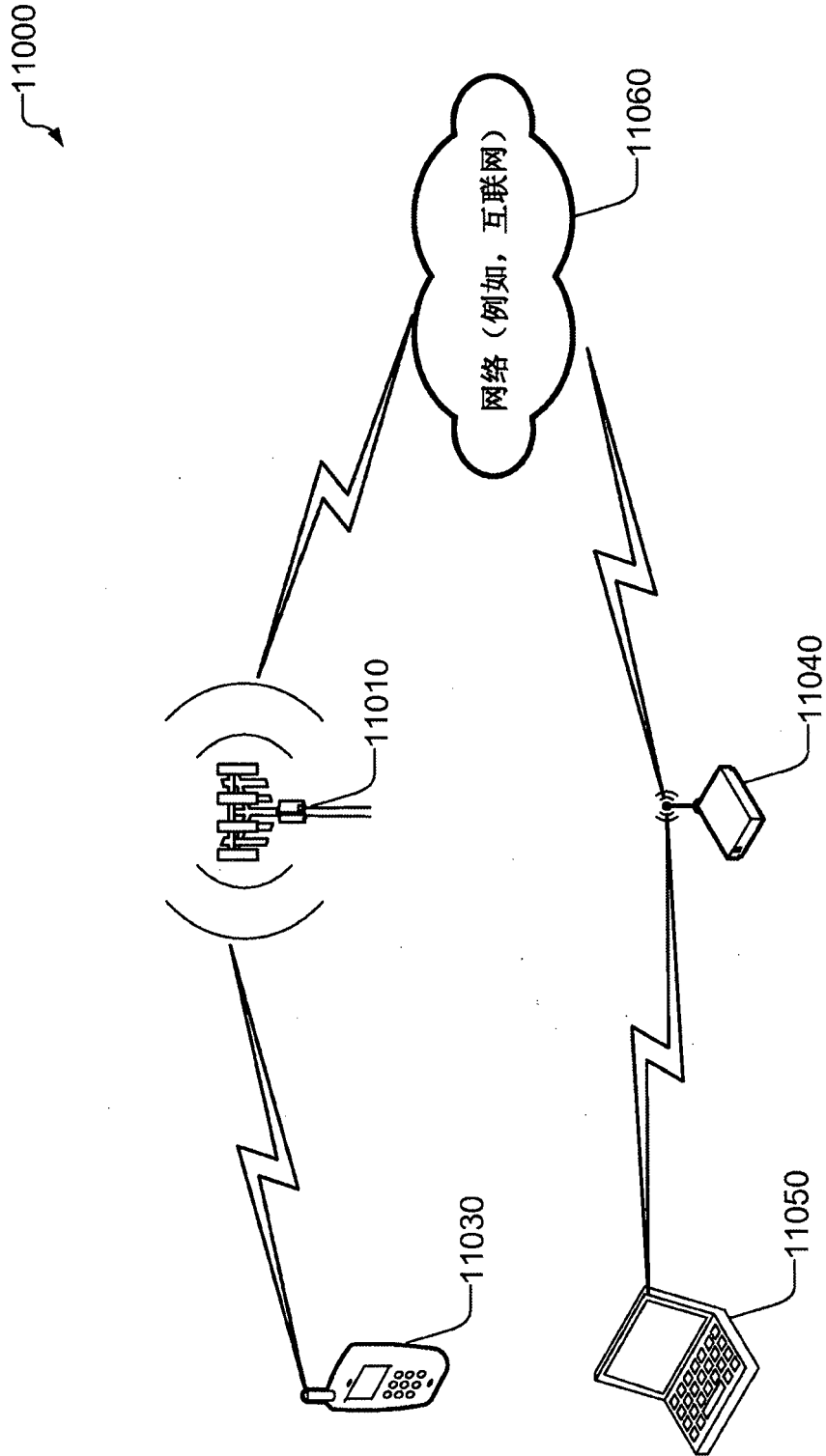


图11

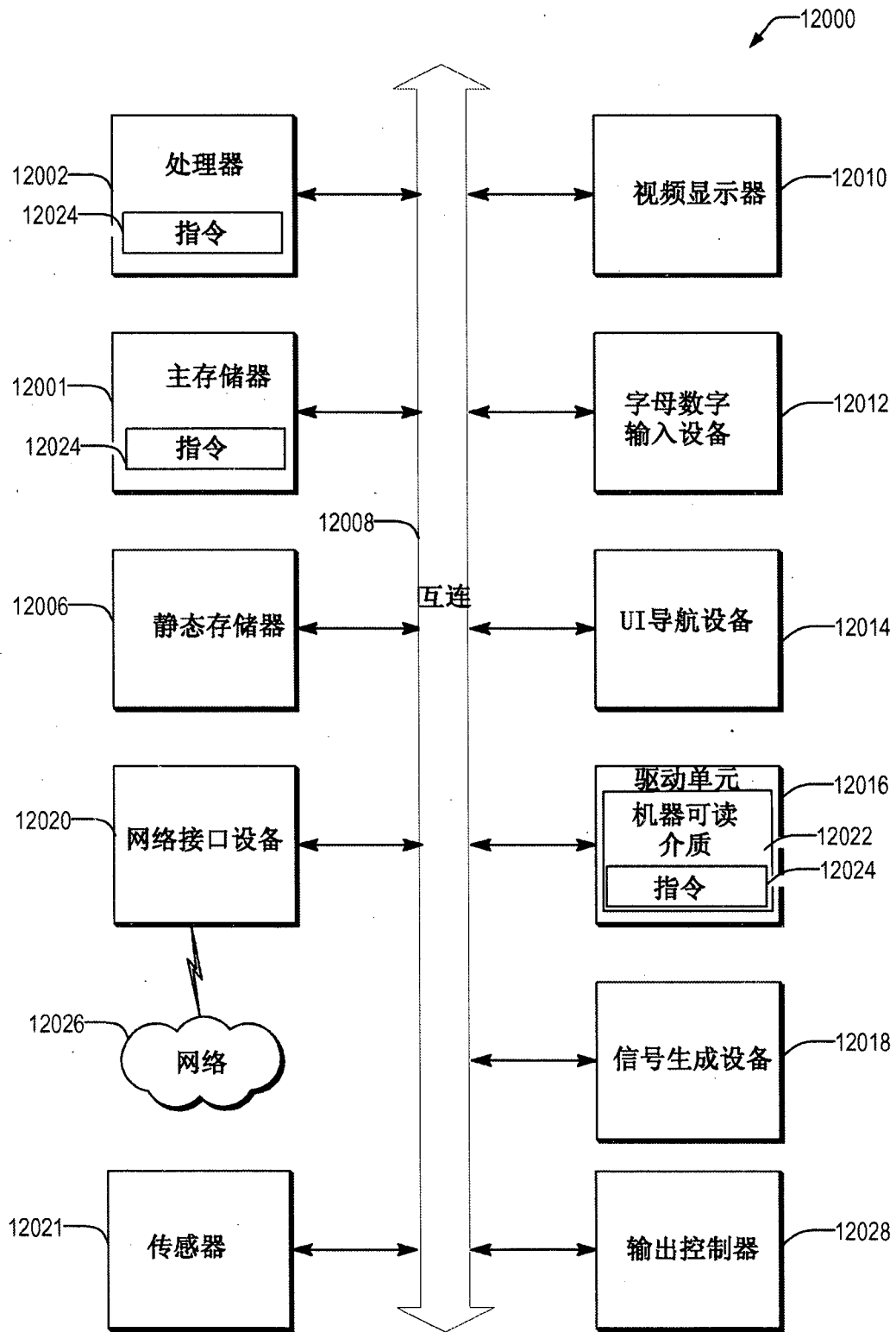


图12

Subframe Aligned Listen-Before-Talk for Cellular in Unlicensed Band

ABSTRACT

Disclosed in some examples are systems, machine-readable media, methods, and cellular wireless devices which implement a Listen-Before-Talk (LBT) access scheme for a device operating according to a cellular wireless protocol in an unlicensed channel. A cellular wireless device may utilize the cellular wireless protocol in the unlicensed channel after the LBT access scheme has determined that a channel (a defined range of frequencies) in the unlicensed channel is idle for a particular period of time.

免授权频段中用于蜂窝的子帧对准的先听后说

摘 要

在一些示例中公开了在免授权信道中为根据蜂窝无线协议操作的设备实现先听后说(LBT)接入方案的系统、机器可读介质、方法和蜂窝无线设备。在 LBT 接入方案已经确定免授权信道中的信道(定义的频率范围)对于特定时间段是空闲的之后,蜂窝无线设备可以在免授权信道中利用蜂窝无线协议。