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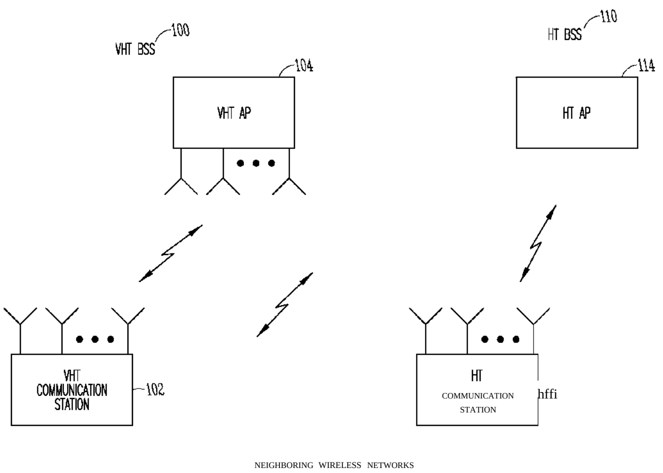
(54) Title: MULTI-CHANNEL COMMUNICATION STATION FOR COMMUNICATING A MULTI-CHANNEL PPDU AND METHODS OF REDUCING COLLISIONS ON SECONDARY CHANNELS IN MULTI-CHANNEL WIRELESS NETWORKS

(57) Abstract: Embodiments of a very-high throughput communication station and method for communicating on a primary channel and up to three or more secondary channels are generally described herein. Short-preamble detection may be performed during a contention window to detect packet transmissions on any one of the secondary channels starting within the contention window. Guard-interval detection is also performed during the contention window to detect a guard interval of a packet transmission on any one of the secondary channels. The short-preamble detection and the guard-interval detection may be performed concurrently during the contention window to determine if any of the secondary channels are busy.



NEIGHBORING WIRELESS NETWORKS

FIG. 1

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MULTI-CHANNEL COMMUNICATION STATION FOR COMMUNICATING A MULTI-CHANNEL PPDU AND METHODS OF REDUCING COLLISIONS ON SECONDARY CHANNELS IN MULTI-CHANNEL WIRELESS NETWORKS

TECHNICAL FIELD

Embodiments pertain to wireless communications. Some embodiments relate to multi-channel wireless networks that communicate packets, such as Physical Layer Convergence Protocol (PLCP) protocol data units (PPDUs), over multiple channels. Some embodiments relate to wireless networks and devices that operate in accordance with one of the IEEE 802. 11 standards, including the IEEE 802. 1In and IEEE 802. 1lac standards.

BACKGROUND

One issue with communicating over wireless networks is collisions between transmissions of stations of neighboring basic service sets (BSSs). Conventionally, a collision-avoidance protocol, such as a carrier-sense multiple-access with collision-avoidance (CSMA/CA) protocol, is employed to help reduce these collisions. As wireless networks use additional channels employing wider bandwidths for communicating, the potential for collisions increases. These additional channels may include a primary channel and one or more secondary channels. Collisions are particularly a concern between the transmissions of stations of different networks that do not use the same channel as a primary channel.

Thus, what are needed are multichannel communication stations and methods that may help reduce the probability of collisions. What are needed are multichannel communication stations and methods that can detect transmissions of other wireless networks on secondary channels to help reduce the probability of collisions.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates neighboring wireless communication networks in accordance with some embodiments;

FIG. 2 illustrates a channel and congestion aware (CCA) technique in accordance with some embodiments;

FIG. 3 illustrates a functional block diagram of a very-high throughput (VHT) communication station in accordance with some embodiments;

FIGs. 4A and 4B illustrate collision and collision avoidance in accordance with some embodiments; and

FIG. 5 is a procedure for communicating a multi-channel PPDU on a primary channel and up to three or more secondary channels in accordance with some embodiments.

DETAILED DESCRIPTION

The following description and the drawings sufficiently illustrate specific embodiments to enable those skilled in the art to practice them. Other embodiments may incorporate structural, logical, electrical, process, and other changes. Portions and features of some embodiments may be included in, or substituted for, those of other embodiments. Embodiments set forth in the claims encompass all available equivalents of those claims.

FIG. 1 illustrates neighboring wireless communication networks in accordance with some embodiments. The neighboring wireless communication networks may include two or more basic service sets (BSS), such as very-high throughput (VHT) BSS 100 and high-throughput (HT) BSS 110. VHT BSS 100 may include VHT access point (AP) 104 and one or more VHT communication stations (STA) 102, and HT BSS 110 may include neighboring HT AP 114 and one or more HT communication stations (STA) 112. VHT BSS 100 may be configured to operate in accordance with IEEE 802. 1lac. HT BSS 110 may be configured to operate in accordance with IEEE 802. 1In.

VHT BSS 100 may utilize a primary channel and up to three or more secondary channels. HT BSS 110, on the other hand, may be limited to using a primary channel and a single secondary channel. VHT communication station 102 and HT communication station 112 may utilize a contention-based collision-avoidance protocol such as the CSMA/CA protocol to contend for access.

When the primary channel utilized by VHT BSS 100 is not the same primary channel utilized by HT BSS 110, one or more of the secondary channels of VHT BSS 100 may reside on the primary channel of HT BSS 110. This may result in a potential increase in collisions.

In accordance with some embodiments, VHT communication station 102 may be configured to communicate a data unit, such as a PPDU, on a primary channel and up to three or more secondary channels, and HT communication station 112 may be configured to communicate a PPDU on a primary channel and up to one secondary channel. VHT communication station 102 may be configured to reduce collisions that may occur with HT communication station 112 by detecting packets on the secondary channels of VHT BSS 100. In these embodiments, VHT communication station 102 may perform short preamble detection and guard-interval detection during a contention window to detect a packet transmission on any one of the secondary channels. These embodiments are described in more detail below.

FIG. 2 illustrates a CCA technique in accordance with some embodiments. Primary channel 208 and up to three or more secondary channels 210 may be used by a VHT communication station, such as VHT communication station 102 (FIG. 1). In accordance with embodiments, VHT communication station 102 may perform short-preamble detection (PD) 202 during a contention window (CW) 216 to detect packet transmissions on any one of the secondary channels 210 from a station such as HT communication station 112 (FIG. 1) of the HT BSS 110 (FIG. 1) starting within the contention window 216. VHT communication station 102 may also perform guard-interval detection (GD) 204 during the contention window 216 to detect a guard-interval of a packet transmission on any one of the secondary channels 210. The short-preamble detection 202 and the guard-interval detection 204 may be performed concurrently during the contention window 216. The guard-interval detection 204 and the short-preamble detection 202 are performed after a distributed coordination function (DCF) interframe space (DIFS) 214 which is provided, for example, after an acknowledge (ACK) packet 212. The ACK packet 212 may have been transmitted by AP 104 of a VHT BSS 100 (FIG. 1) or by AP 114 of a HT BSS 110 acknowledging a prior receipt of a data packet from a communication station. The ACK packet 212 may also have been transmitted by one of the communication stations.

The additional capability to perform short-preamble detection 202 on the secondary channels 210 to detect signals starting in the contention window 216 allows the VHT communication station 102 to detect packet transmissions on channels of a neighboring BSS, such as HT BSS 110. Unlike energy detection, which is conventionally performed to detect signals as part of a CSMA/CA protocol, the short-preamble detection 202 and the guard-interval detection 204 may detect packets that would not be able to be detected with energy detection techniques. For example, the short-preamble detection 202 and the guard-interval detection 204 may detect packets well below (e.g., up to 20 dB below) the energy detection threshold of energy detection techniques, which is conventionally about -62 dBm for secondary channels.

The packet transmissions detected on one of the secondary channels 210 by either the short-preamble detection 202 or the guard-interval detection 204 may be signal transmissions of HT communication station 112 of the neighboring HT BSS 110. The neighboring HT BSS 110 may have its primary channel co-located on one of the secondary channels 210 of the VHT BSS 100.

The VHT communication station 102 may utilize the primary channel 208 and up to three or more secondary channels 210 to provide transfer speeds of up to one giga-bit-per second (Gbps) and greater. The transfer speed may depend on the number of antennas used as well as the usage bandwidth. Accordingly, the transfer speed may be significantly greater than the transfer rate of HT communication stations, such as HT communication station 112. The primary channel 208 may have a bandwidth of 20 MHZ, and each secondary channel 210 may have a bandwidth of 20 MHZ to provide a usage bandwidth of up to 80 MHz when three secondary channels 210 are used, and a usage bandwidth of up to 160 MHz when up to four additional secondary channels (not illustrated) are used. HT communication station 112, on the other hand, may be limited to using a single primary channel and a single secondary channel.

The short-preamble detection 202 may include detection of a predetermined sequence comprising a short preamble indicating a beginning of a packet. The guard-interval detection 204 may include a correlation (e.g., an autocorrelation) to detect a repeating pattern corresponding to a cyclic prefix of an OFDM symbol within one or more frames of a packet. The detection of a cyclic prefix by the guard-interval detection 204 may indicate a valid frame within the packet.

The short-preamble detection 202 may be performed to detect packet preambles on any one of the secondary channels 210 starting in time slots of the contention window 216. The short-preamble detection 202 is configured to be completed within a time slot of the contention window 216. In these embodiments, contention window 216 may comprise a plurality of time slots. The short-preamble detection 202 may be performed within any one or more of these time slots and may be completed during the time slot in which it was started. The short-preamble detection 202 may be configured to continuously search for a short packet preamble during the contention window 216.

The guard-interval detection 204 may be performed during an interval of a point-coordination function (PCF) interframe spacing (PIFS) 206 immediately preceding an expiration of a backoff counter of a contention-based collision-avoidance protocol such as the CSMA/CA protocol. When either the guard-interval detection 204 or the short-preamble detection 202 detects a packet transmission on one of the secondary channels 210, the secondary channel 210 is designated as a busy secondary channel. When both the guard-interval detection 204 and the short-preamble detection 202 fail to detect a packet transmission on one of the secondary channels 210, the secondary channel 210 is designated as an idle secondary channel.

The VHT communication station 102 may also be configured to refrain from transmitting on any one of the secondary channels 210 designated as a busy secondary channel. When the primary channel 208 is idle, the VHT communication station 102 may also be configured to transmit a PPDU on the primary channel 208 and any one or more of the secondary channels 210 designated as an idle secondary channel. A PPDU that is transmitted on the primary channel 208 and at least one of the secondary channels 210 may be referred to as a multichannel PPDU.

VHT communication station 102 may communicate on one primary channel 208 and three secondary channels 210. In some other embodiments, VHT communication station 102 may communicate on one primary channel 208 and seven secondary channels 210.

To determine if the primary channel 208 is idle or busy, the VHT communication station 102 is configured to perform an energy detection, short-preamble detection 202, and guard-interval detection 204 on the primary channel 208. The energy detection may be performed by measuring signal levels in the primary channel 208 during the contention window 216. The short-preamble detection 202 may be performed during the contention window 216 to detect packet transmissions on the primary channel 208. The guard-interval detection 204 may be performed during the contention window 216 to detect a guard-interval of a packet transmission on the primary channel 208. In this way, the VHT communication station 102 may determine whether the primary channel 208 is idle or busy. In these embodiments, the energy detection, the short-preamble detection 202 and the guard-interval detection 204 that are performed on the primary channel 208 may be performed concurrently during the contention window 216 along with the guard-interval detection 204 and the short-preamble detection 202 that is performed on the secondary channels 210. When the primary channel 208 is determined to be idle for a time period that includes the DIFS 214 plus the contention window 216, the VHT communication station 102 may transmit a packet on the primary channel 208 and any of the secondary channels 210 that are designated as idle secondary channels.

The VHT communication station 102 may also be configured to perform a CSMA/CA protocol using a DCF on the primary channel 208 for access to the primary channel 208 and refrain from performing a collision-avoidance protocol such as the CSMA/CA protocol on the secondary channels 210. In these embodiments, the collision-avoidance protocol is performed on the primary channel 208 and is not performed on the secondary channels 210.

The VHT communication station 102 is configured to communicate with an access point 104 over a 20 MHz primary channel 208 and up to three or more 20 MHz secondary channels 210 in accordance with IEEE 802. 1lac. In these embodiments, the primary channel 208 may be used for performing the CSMA/CA protocol as well as for communicating data packets, such as PPDUs, with the access point 104. One or more of the secondary channels 210 along with the primary channel 208 may be used for communicating multi-channel data packets, such as multi-channel PPDUs. For example, when the channels are 20 MHz channels, a 20 MHz PPDU may be communicated when the VHT communication station 102 uses only the primary channel 208. A 40 MHz multi-channel PPDU may be communicated when the VHT communication station 102 uses the primary channel 208 and one of the secondary channels 210. A 60 MHz multi-channel PPDU may be communicated when the VHT communication station 102 uses the primary channel 208 and two of the secondary channels 210. An 80 MHz multi-channel PPDU may be communicated when the VHT communication station 102 uses the primary channel 208 and three of the secondary channels 210. Up to a 160 MHz multi-channel PPDU may be communicated when the VHT communication station 102 uses the primary channel 208 and up to four additional secondary channels (not illustrated). For a multi-channel PPDU, different information may be transmitted on each 20 MHz channel utilized by the multi-channel PPDU.

In some of these embodiments, the HT BSS 110 is configured to communicate in accordance with an IEEE 801. 1In, which uses one primary channel and one secondary channel for communicating. The packets detected on a secondary channel 210 by either the short-preamble detection 202 or the guard-interval detection 204 may be transmissions on a primary or secondary channel of the HT BSS 110 (FIG. 1). Accordingly, collisions with a neighboring BSS may be reduced and possibly eliminated. It should be noted that collisions between stations of the same BSS are generally not an issue because each BSS may use the same primary channel for both 802. 1lac stations and 802. 1In stations, and stations can easily detect packet transmissions on the primary channel of their own BSS. In the same BSS, 1In and 1lac stations use the same primary channel, so they can detect each other's transmission without a collision problem due to undetected transmissions in a secondary channel.

FIG. 3 illustrates a functional block diagram of a VHT communication station in accordance with some embodiments. VHT communication station 300 may include, among other things, front-end circuitry 310 to receive signals through spatially-diverse antennas 311, a short-preamble detection module 302, a guard-interval detection module 304, logical OR' circuitry 306, and medium-access control (MAC) layer circuitry 308. VHT communication station 300 may be suitable for use as VHT communication station 102 (FIG. 1), although other configurations may also be suitable.

The short-preamble detection module 302 may be configured to perform short-preamble detection 202 (FIG. 2) on received data samples 301. The guard-interval detection module 304 may be configured to perform guard-interval detection 204 (FIG. 2) on received data samples 301. The logical OR' circuitry 306 may be configured to provide either a channel busy or channel idle indication 307 to the MAC layer circuitry 308 to designate the primary channel 208 (FIG. 2) and each of the secondary channels 210 (FIG. 2) as either busy or idle. In these embodiments, the logical OR' circuitry 306 may be configured to receive a detection output from the short-preamble detection 202 and the guard-interval detection 204 and for the primary channel 208 and each secondary channel 210 and to provide either a channel busy or channel idle indication 307 to MAC layer circuitry 308. The output of the logical OR' circuitry 306 may allow the MAC layer circuitry 308 to designate the primary channel 208 and each secondary channel 210 as either idle or busy.

VHT communication station 300 may implement a MIMO communication technique using the plurality of spatially-diverse antennas 311 to communicate multiple data streams concurrently over the primary channel 208 and the up to three or more secondary channels 210. In these embodiments, the VHT communication station 300 may be configured to perform the guard-interval detection 204 and the short-preamble detection 202 on the secondary channels 210 using a single one of the antennas 311, although this is not a requirement as VHT communication station 300 may utilize up to four or more of antennas 311 to perform the guard-interval detection 204 and the short-preamble detection 202 on the secondary channels 210.

Although VHT communication station 300 is illustrated as having several separate functional elements, one or more of the functional elements may be combined and may be implemented by combinations of software-configured elements, such as processing elements including digital signal processors (DSPs), and/or other hardware elements. For example, some elements may comprise one or more microprocessors, DSPs, application-specific integrated circuits (ASICs), radio-frequency integrated circuits (RFICs) and combinations of various hardware and logic circuitry for performing at least the functions described herein. The functional elements of VHT communication station 300 may refer to one or more processes operating on one or more processing elements.

VHT communication station 300 may be a portable wireless communication device, such as a personal digital assistant (PDA), a laptop or portable computer with wireless communication capability, a smart phone, a web tablet, a wireless telephone, a wireless headset, a pager, an instant messaging device, a digital camera, an access point, a television, a medical device (e.g., a heart rate monitor, a blood pressure monitor, etc.), or other device that may receive and/or transmit information wirelessly.

VHT communication station 300 operating within VHT BSS 100 may be configured to communicate orthogonal frequency division multiplexed (OFDM) communication signals over each of its channels including primary channel 208 and secondary channels 210. HT BSS 110 (FIG. 1) may also be configured to communicate OFDM communication signals over each of its channels. The OFDM signals may comprise symbols modulated on a plurality of orthogonal subcarriers. Each channel may comprise a predetermined number of these orthogonal subcarriers. In some example embodiments, each channel may comprise fifty-two subcarriers although this is not a requirement.

Antennas 311 may comprise one or more directional or omnidirectional antennas, including, for example, dipole antennas, monopole antennas, patch antennas, loop antennas, microstrip antennas or other types of antennas suitable for transmission of RF signals. Instead of two or more antennas, a single antenna with multiple apertures may be used. In these embodiments, each aperture may be considered a separate antenna. In some multiple-input, multiple-output (MIMO) embodiments, antennas 311 may be effectively separated to take advantage of spatial diversity and the different channel characteristics that may result between each of antennas 311 and VHT access point 104 (FIG. 1). Antennas 311 may be separated by up to 1/10 of a wavelength or more.

FIGs. 4A and 4B illustrate collision and collision-avoidance in accordance with some embodiments. As illustrated in FIGs. 4A and 4B, VHT communication station 102 of VHT BSS 100 (FIG. 1) may communicate on primary channel 208 and up to three secondary channels 210 illustrated as secondary channel 210A, secondary channel 210B and secondary channel 210C. HT communication station 112 of HT BSS 110 (FIG. 1) may communicate on a primary channel 408 and secondary channel 410. In this example, the primary channel 408 used by that HT communication station 112 coincides with secondary channel 210B used by VHT communication station 102. The secondary channel 410 used by HT communication station 112 coincides with secondary channel 210C used by VHT communication station 102.

As illustrated in FIG. 4A, the VHT communication station 102 may have just completed an 80 MHz multichannel PPDU transmission over the primary channel 208 and all three secondary channels 210A, 210B and 210C, which is acknowledged on each channel acknowledge packets 412. If the VHT communication station 102 has additional data to transmit, the VHT communication station 102 may start by deferring and sensing the primary channel 208 for the time period of DIFS 214 plus the contention window 216 to determine if the primary channel 208 is idle or busy.

As discussed above, the VHT communication station 102 may also sense the three secondary channels 210A, 210B and 210C. Because HT communication station 112 of neighboring HT BSS 110 knows the end of the prior transmission of the VHT communication station 102, the HT communication station 112 may also try to access the medium by deferring for the time period of DIFS 214 plus the contention window 416. In this example, the contention window 416 of the HT communication station 112 is one time-slot less than the contention window 216 of the VHT communication station 102 (e.g., due to random backoff).

If the HT communication station 112 determines that at least some channels are idle, it may transmit a multi-channel PPDU 414 on primary channel 408 and secondary channel 410, which correspond to the secondary channels 210B and 210C utilized by VHT communication station 102. If the VHT communication station 102 does not perform short-preamble detection 202 in the secondary channels 210 and because it may require between 10-14 micro-seconds to complete a CCA for packet transmission, the VHT communication station 102 would have to start guard-interval detection 204 at least one slot-time before the last slot-time 2 18 of its contention window 216. However, in this example, the multi-channel PPDU 414 transmitted by HT communication station 112 starts from the last slot-time 218 of the contention window 216 of VHT communication station 102 and thus it does not fully overlap with the GD CCA sensing time for reliable signal detection. Thus, the VHT communication station 102 fails to detect the multi-channel PPDU 414 transmitted by HT communication station 112 starting from the last slot-time 218 of the contention window 216. As a result, the VHT communication station 102 believes the secondary channels 210A, 210B and 21C are idle and may transmit a multi-channel PPDU 418 over all four channels (208, 210A, 210B, 210C), which collides with the transmission of PPDU 414 of HT communication station 112. In this example, it is assumed that the signal level in either secondary channel 2 10B or 2 IOC is below an energy detection threshold level but above the short-preamble or the guard-interval detection levels.

As illustrated in FIG. 4B, if the VHT communication station 102 performs short-preamble detection 202 (FIG. 2) and guard-interval detection 204 (FIG. 2) during the contention window 216, the PPDU 414 of HT communication station 112 may be detected, causing VHT communication station 102 to designate secondary channels 210B and 2 IOC as busy. As a result, VHT communication station 102 may transmit a multi-channel PPDU 419 on primary channel 208 and secondary channel 2 1OA, avoiding a collision with PPDU 414. In this example, since short-preamble detection 202 may take only about four microseconds to detect a signal in one of the second channels 210A, 210B or 2 IOC, the short-preamble detection 202 may be completed in the last time slot of the contention window 216 of VHT communication station 102.

Performing short-preamble detection 202 may be used to achieve a rapid timing sync with a transmitted frame, which may be used to help identify positions of the guard-intervals of OFDM symbols transmitted on the secondary channels 210. Knowledge of the guard- intervals decreases the probability of a false detection. As a result, an increase in detection sensitivity may be achieved when guard-interval detection follows preamble detection than can be achieved using guard-interval detection alone. In these embodiments, the predetermined structure of a PPDU may include a short-training field (STF) followed by a long-training field (LTF) followed by OFDM symbols. Each OFDM symbol may have a guard-interval. In these embodiments, when the short-preamble detection module 302 identifies the start of the PPDU (e.g., by identifying the short-training field), the guard interval detection module 304 may be configured to identify where the guard intervals of the PPDU are likely to occur, thereby improving sensitivity for detecting the guard intervals that follow the long-training field. The short-preamble detection module 302 may provide an indication to the guard-interval detection module 304 that it has detected a short preamble, such as the short-training field.

HT communication stations 112 of HT BSS 110 generally only perform energy detection in their secondary channel 410 to detect signal transmissions because it is a less complex technique. As a result, HT communication stations 112 may fail to detect some transmissions on their secondary channel 410 from stations of a neighboring BSS, such as VHT BSS 100, resulting in an increase in collisions on secondary channel 410. Since HT BSS 110 utilizes only a single secondary channel 410, the performance degradation may be more tolerable than for VHT BSS 100, which uses from between three and seven secondary channels 210. Failure of the VHT communication station 102 of VHT BSS 100 to detect transmissions on its secondary channels 210, however, may degrade network performance significantly. Therefore, the improved transmission detection technique disclosed herein may be more important for VHT communication station 102, particularly for VHT communication stations configured to operate in accordance with IEEE 802.1 lac.

FIG. 5 is a procedure for communicating a multi-channel PPDU on a primary channel and up to three or more secondary channels in accordance with some embodiments. Procedure 500 may be performed by a VHT communication station, such as VHT communication station 102 (FIG. 1).

Operation 502 comprises performing short-preamble detection during a contention window to detect packet transmissions on any one of the secondary channels starting within the contention window.

Operation 504 comprises performing guard-interval detection during the contention window to detect a guard interval of a packet transmission on any one of the secondary channels. The short-preamble detection and the guard-interval detection may be performed concurrently during the contention window.

Operation 506 comprises designating a secondary channel as busy when either the guard-interval detection or the short-preamble detection detects a packet transmission on the secondary channel.

Operation 508 comprises designating a secondary channel as idle when both the guard-interval detection and the short-preamble detection fail to detect a packet transmission on a secondary channel. In operation 510, the VHT communication station may be free to transmit a multichannel PPDU on a primary channel and any one or more of the secondary channels that are idle.

The Abstract is provided to comply with 37 C.F.R. Section 1.72(b) requiring an abstract that will allow the reader to ascertain the nature and gist of the technical disclosure. It is submitted with the understanding that it will not be used to limit or interpret the scope or meaning of the claims. The following claims are hereby incorporated into the detailed description, with each claim standing on its own as a separate embodiment.

CLAIMS

What is claimed is:

1. A communication station configured to communicate on a primary channel and up to three or more secondary channels, the communication station configured to:

perform short-preamble detection during a contention window to detect a packet transmission on any one of the secondary channels starting within the contention window; and

perform guard-interval detection during the contention window to detect a guard interval of a packet transmission on any one of the secondary channels,

wherein the short-preamble detection and the guard-interval detection are performed concurrently during the contention window.

2. The communication station of claim 1 wherein the packet transmission to be detected on one of the secondary channels by either the short-preamble detection or the guard-interval detection comprises packet transmissions of a communication station of a neighboring basic service set having its primary channel co-located on one of the secondary channels.

3. The method of claim 2 wherein the packet transmissions to be detected comprise a protocol data unit having a predetermined structure including a short-training field followed by a long training field followed by OFDM symbols, each OFDM symbol having a guard interval,

wherein the short-preamble detection is to:

identify the short-training field; and

identify likely locations of guard-intervals of the protocol data unit based on the identification of the short-training field and the predetermined structure of the protocol data unit, and

wherein the guard-interval detection comprises performing guard-interval detection at the likely locations of the guard-intervals of the protocol data unit identified by the short-preamble detection.

4. The communication station of claim 1 wherein the guard-interval detection and the short-preamble detection are performed after a distributed coordination function

interframe space, and

wherein the distributed coordination function interframe space is provided after an acknowledge packet.

5. The communication station of claim 4 wherein the short-preamble detection comprises detection of a predetermined sequence comprising a short preamble indicating a beginning of a packet transmission, and

wherein the guard-interval detection comprises a correlation to detect a repeating pattern corresponding to a cyclic prefix of an orthogonal frequency division multiplexed (OFDM) symbol within one or more frames of a packet, wherein the detection of a cyclic prefix indicates a valid frame within the packet.

6. The communication station of claim 5 wherein the short-preamble detection is performed to detect packet preambles on any one of the secondary channels starting in time slots of the contention window.

7. The communication station of claim 6 wherein the short-preamble detection is configured to be completed within a time slot of the contention window, and

wherein the guard-interval detection is performed during an interval of a point-coordination function interframe spacing immediately preceding an expiration of a backoff counter.

8. The communication station of claim 1 wherein when either the guard-interval detection or the short-preamble detection detects a packet transmission on one of the secondary channels, the secondary channel is designated as a busy secondary channel, and

wherein when both the guard-interval detection and the short-preamble detection fail to detect a packet transmission on one of the secondary channels, the secondary channel is designated as an idle secondary channel.

9. The communication station of claim 8 wherein the communication station is configured to:

refrain from transmitting on any one of the secondary channels designated as a busy secondary channel; and

when the primary channel is idle, transmit a data unit on the primary channel and any one or more of the secondary channels designated as an idle secondary channel.

10. The communication station of claim 9 wherein to determine if the primary channel is idle or busy, the communication station is further configured to:

perform energy detection in the primary channel during the contention window to determine whether the primary channel is idle or busy;

perform short-preamble detection during the contention window to detect packet transmissions on the primary channel; and

perform guard-interval detection during the contention window to detect a guard interval of a packet transmission on the primary channel.

11. The communication station of claim 9 wherein when the primary channel is determined to be idle for a time that includes a distributed coordination function interframe space plus the contention window, the communication station is configured to transmit a packet on the primary channel and any of the secondary channels that are designated as idle secondary channels.

12. The communication station of claim 11 wherein the communication station is further configured to:

perform a carrier-sense multiple-access with collision-avoidance (CSMA/CA) protocol using a distributed coordination function on the primary channel for access to the primary channel; and

refrain from performing the CSMA/CA protocol on the secondary channels.

13. The communication station of claim 1, wherein the communication station is a very-high throughput (VHT) communication station configured to communicate with an access point over a twenty megahertz primary channel and up to three or more twenty megahertz secondary channels,

wherein the VHT communication station is part of a VHT basic service set (BSS) configured to communicate in accordance with 802. 1lac,

wherein the packet transmissions detected on one of the secondary channels by either the short-preamble detection or the guard-interval detection comprise signal transmissions of a communication station of a neighboring BSS, and

wherein the neighboring BSS has its primary channel co-located on one of the secondary channel of the VHT BSS.

14. The communication station of claim 1 further comprising:

a short-preamble detection module to perform the short-preamble detection;

a guard-interval detection module to perform the guard-interval detection;

medium-access control (MAC) layer circuitry; and

logical OR' circuitry,

wherein the logical OR' circuitry is to provide either a channel busy or channel idle indication to the MAC layer circuitry to designate each of the secondary channels as either busy or idle.

15. A method of communicating a multi-channel data unit on a primary channel and up to three or more secondary channels, the method comprising:

performing short-preamble detection during a contention window to detect a packet transmission on any one of the secondary channels starting within the contention window; and

performing guard-interval detection during the contention window to detect a guard interval of a packet transmission on any one of the secondary channels,

wherein the short-preamble detection and the guard-interval detection are performed concurrently during the contention window.

16. The method of claim 15 wherein the packet transmission to be detected on one of the secondary channels by either performing the short-preamble detection or performing the guard-interval detection comprises packet transmissions of a communication station of a neighboring basic service set having its primary channel co-located on one of the secondary channels.

17. The method of claim 15 wherein the guard-interval detection and the short-preamble detection are performed after a distributed coordination function interframe space, and

wherein the distributed coordination function interframe space is provided after an acknowledge packet.

18. The method of claim 15 wherein when performing either the guard-interval detection or the short-preamble detection detects a packet transmission on one of the secondary channels, the method includes designating the secondary channel as a busy secondary channel, and

wherein when performing both the guard-interval detection and the short-preamble detection fail to detect a packet transmission on one of the secondary channels, the method includes designating the secondary channel as an idle secondary channel.

19. The method of claim 18 further comprising:
refraining from transmitting on any one of the secondary channels designated as a busy secondary channel; and

when the primary channel is idle, transmitting a data unit on the primary channel and any one or more of the secondary channels designated as an idle secondary channel.

20. The method of claim 19 wherein to determine if the primary channel is idle or busy, the method further comprises:

performing energy detection in the primary channel during the contention window to determine whether the primary channel is idle or busy;

performing short-preamble detection during the contention window to detect packet transmissions on the primary channel; and

performing guard-interval detection during the contention window to detect a guard interval of a packet transmission on the primary channel,

wherein when the primary channel is determined to be idle for a time that includes a distributed coordination function interframe space plus the contention window, the method comprises transmitting a packet on the primary channel and any of the secondary channels that are designated as idle secondary channels.

21. A method of transmitting a multi-channel data unit in accordance with IEEE 802. 1lac, the method comprising:

performing short-preamble detection during a contention window to detect packet transmissions on any one of a plurality of secondary channels starting within the contention window;

performing guard-interval detection during the contention window to detect a guard interval of a packet transmission on any one of the secondary channels;

designating, based on the short-preamble detection and the guard-interval detection, any of the secondary channels as busy when a packet transmission is detected; and

transmitting a multi-channel data unit on a primary channel and any of the secondary channels that are not designated as busy.

22. The method of claim 2 1 further comprising:

performing a carrier-sense multiple-access with collision-avoidance (CSMA/CA) protocol using a distributed coordination function (DCF) on the primary channel for access to the primary channel; and

refraining from performing the CSMA/CA protocol on the secondary channels.

23. The method of claim 22 wherein as part of the CSMA/CA protocol, the method further comprises:

performing energy detection in the primary channel during the contention window to determine whether the primary channel is idle or busy;

performing short-preamble detection during the contention window to detect packet transmissions on the primary channel; and

performing guard-interval detection during the contention window to detect a guard interval of a packet transmission on the primary channel.

24. The method of claim 23 wherein the packet transmission to be detected on one of the secondary channels by performing either the short-preamble detection or the guard-interval detection comprises packet transmissions of a communication station of a neighboring basic service set having its primary channel co-located on one of the secondary channels.

25. The method of claim 24 wherein the method is performed by a very-high throughput (VHT) communication station configured to communicate with an access point over a twenty megahertz primary channel and up to three or more twenty megahertz secondary channels,

wherein the VHT communication station is part of a VHT basic service set (BSS) configured to communicate in accordance with 802. 1lac,

wherein the packet transmissions to be detected on one of the secondary channels by either the short-preamble detection or the guard-interval detection comprise signal transmissions of a communication station of a neighboring BSS, and

wherein the neighboring BSS has its primary channel co-located on one of the secondary channels of the VHT BSS.

26. A method performed by a station of a basic service set (BSS) configured to operate in accordance with IEEE 802.1 lac for transmitting a multi-channel data unit over

a primary channel and up to three or more secondary channels of the BSS, the method comprising detecting transmissions of a station of a neighboring BSS configured to operate in accordance with IEEE 802. 1In, wherein a primary channel of the neighboring BSS coincides with one of the secondary channels of the BSS configured in accordance with IEEE 802.1 lac,

wherein detecting transmissions of the station of the neighboring BSS comprises performing short-preamble detection during a contention window to detect a packet transmission on the up to three or more secondary channels starting within the contention window.

27. The method of claim 26 further comprising:

performing guard-interval detection during the contention window to detect a guard interval of a packet transmission on any one of the secondary channels; and

designating, based on the short-preamble detection and the guard-interval detection, any of the secondary channels as busy when a packet transmission is detected.

28. The method of claim 27 wherein the packet transmissions to be detected comprise a protocol data unit having a predetermined structure including a short-training field followed by a long training field followed by OFDM symbols, each OFDM symbol having a guard interval,

wherein the short-preamble detection is to:

identify the short-training field; and

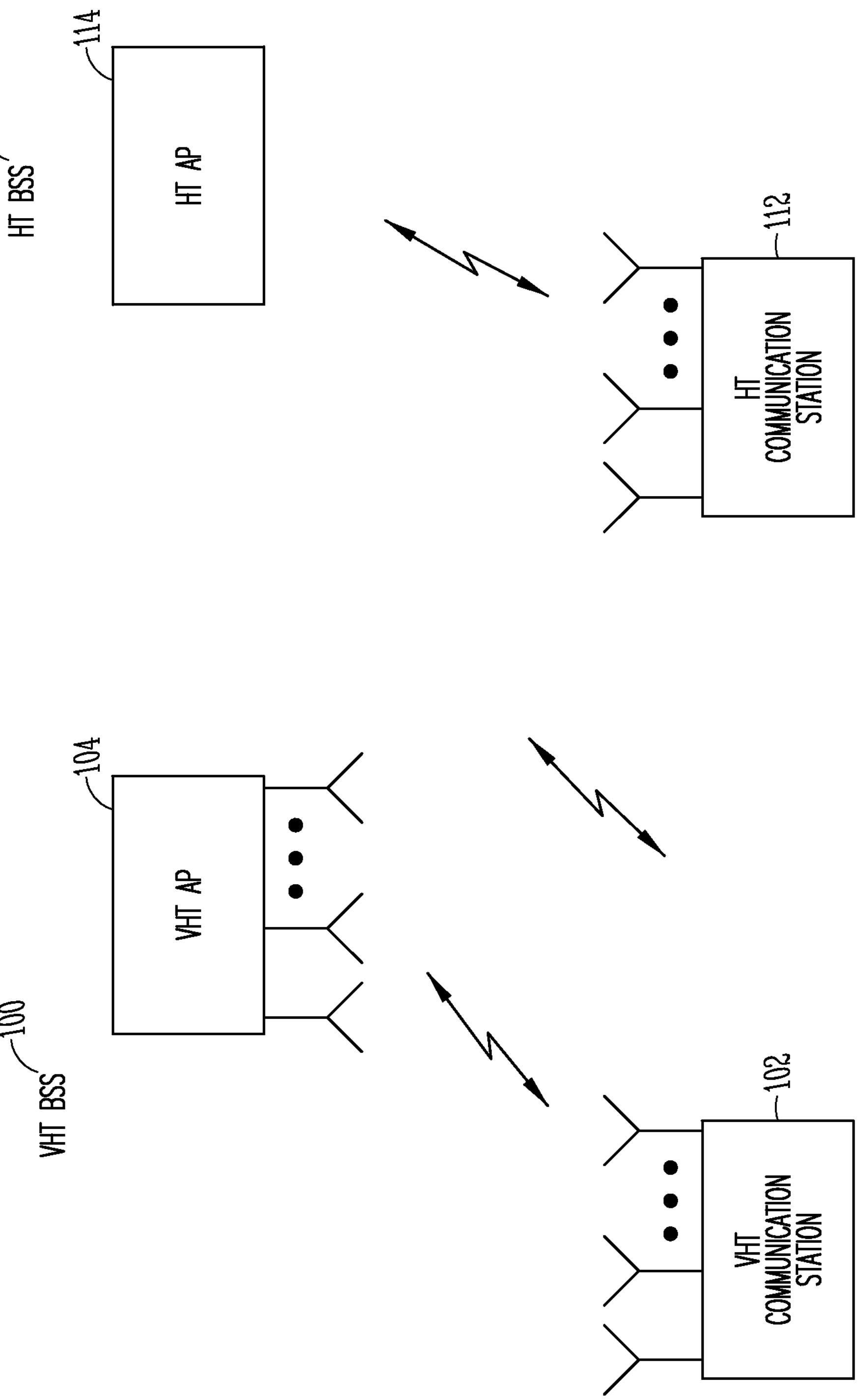
identify likely locations of guard-intervals of the protocol data unit based on the identification of the short-training field and the predetermined structure of the protocol data unit, and

wherein the guard-interval detection comprises performing guard-interval detection at the likely locations of the guard-intervals of the protocol data unit identified by the short-preamble detection.

29. The method of claim 27 further comprising:

transmitting a multi-channel data unit on the primary channel of the BSS configured to operate in accordance with IEEE 802.1 lac and any of the secondary channels that are not designated as busy; and

refraining from transmitting the multi-channel data unit on any of the secondary channels that are not designated as busy.



NEIGHBORING WIRELESS NETWORKS

FIG. 1

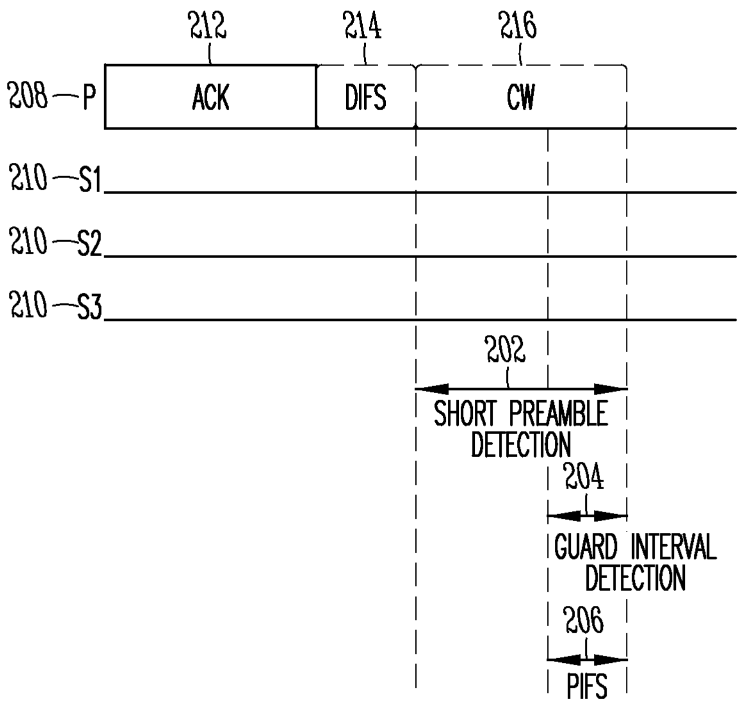
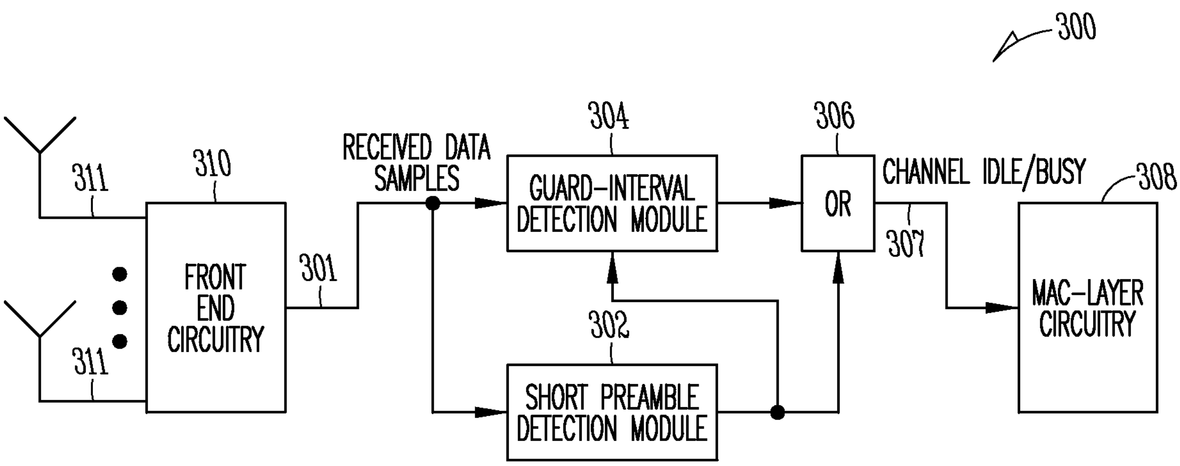


FIG. 2



VHT COMMUNICATION STATION

FIG. 3

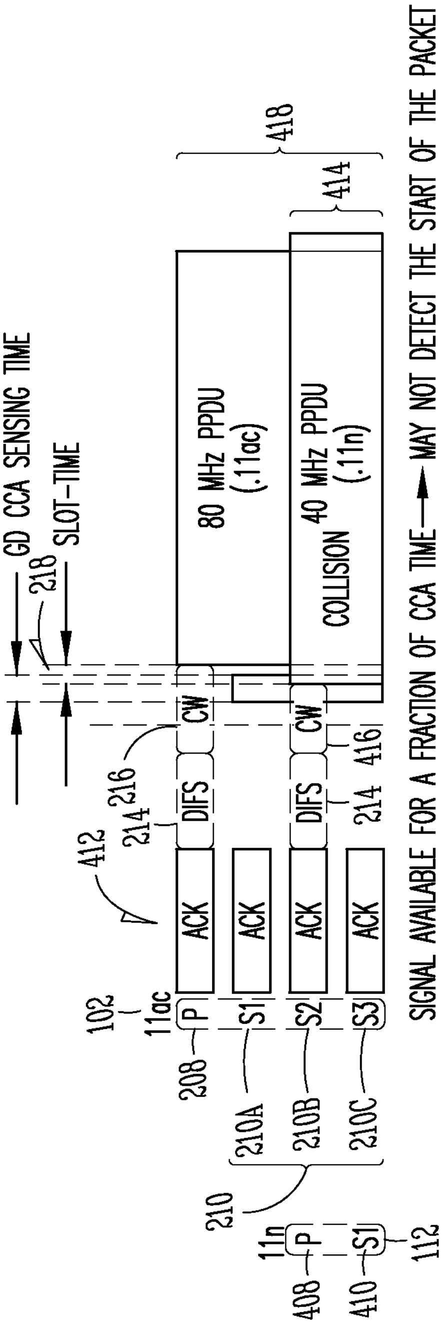

GD CCA SENSING TIME
SLOT–TIME
218
412
102
11ac
214
216
P
S1
S2
S3
ACK
DIFS
CW
80 MHz PPDU (.11ac)
40 MHz PPDU (.11n)
COLLISION
418
414
416
208
210A
210B
210C
210
11n
408
410
112
SIGNAL AVAILABLE FOR A FRACTION OF CCA TIME → MAY NOT DETECT THE START OF THE PACKET

FIG. 4A

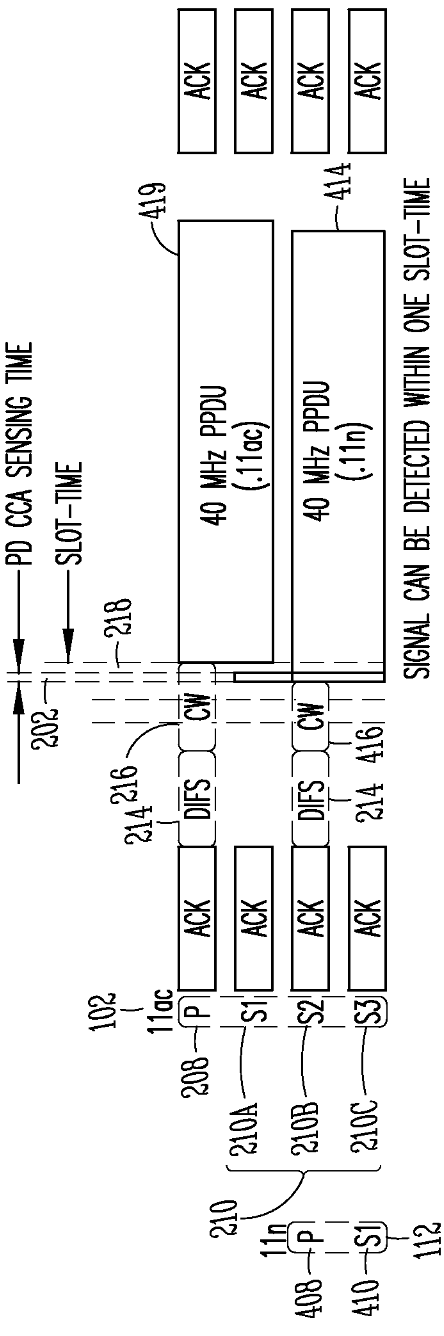

PD CCA SENSING TIME
SLOT–TIME
202
218
102
11ac
214
216
P
S1
S2
S3
ACK
DIFS
CW
40 MHz PPDU (.11ac)
40 MHz PPDU (.11n)
419
414
416
208
210A
210B
210C
210
11n
408
410
112
SIGNAL CAN BE DETECTED WITHIN ONE SLOT–TIME

FIG. 4B

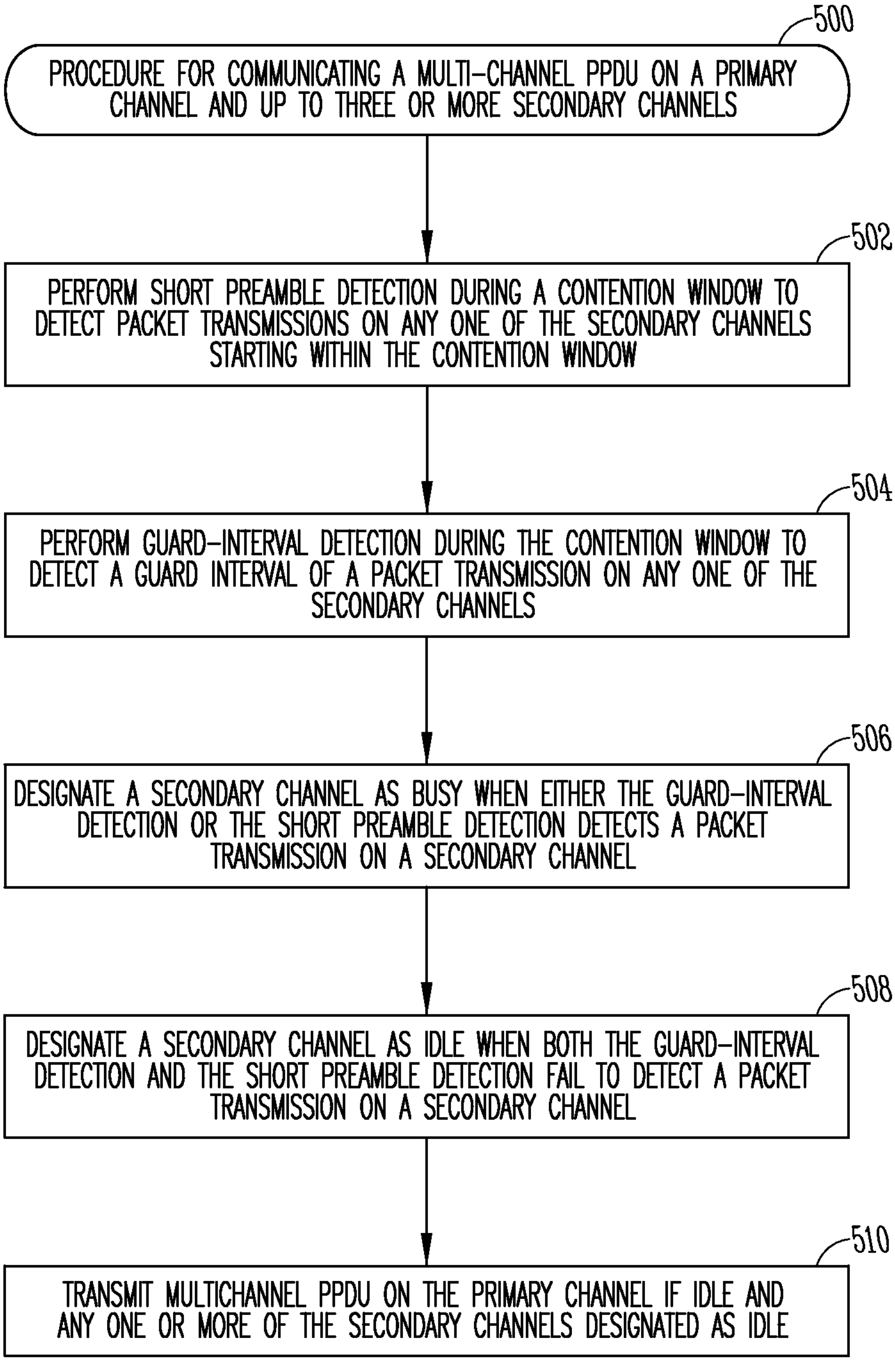

500
PROCEDURE FOR COMMUNICATING A MULTI-CHANNEL PPDU ON A PRIMARY CHANNEL AND UP TO THREE OR MORE SECONDARY CHANNELS
502
PERFORM SHORT PREAMBLE DETECTION DURING A CONTENTION WINDOW TO DETECT PACKET TRANSMISSIONS ON ANY ONE OF THE SECONDARY CHANNELS STARTING WITHIN THE CONTENTION WINDOW
504
PERFORM GUARD-INTERVAL DETECTION DURING THE CONTENTION WINDOW TO DETECT A GUARD INTERVAL OF A PACKET TRANSMISSION ON ANY ONE OF THE SECONDARY CHANNELS
506
DESIGNATE A SECONDARY CHANNEL AS BUSY WHEN EITHER THE GUARD-INTERVAL DETECTION OR THE SHORT PREAMBLE DETECTION DETECTS A PACKET TRANSMISSION ON A SECONDARY CHANNEL
508
DESIGNATE A SECONDARY CHANNEL AS IDLE WHEN BOTH THE GUARD-INTERVAL DETECTION AND THE SHORT PREAMBLE DETECTION FAIL TO DETECT A PACKET TRANSMISSION ON A SECONDARY CHANNEL
510
TRANSMIT MULTICHANNEL PPDU ON THE PRIMARY CHANNEL IF IDLE AND ANY ONE OR MORE OF THE SECONDARY CHANNELS DESIGNATED AS IDLE

FIG. 5