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62/007,287 3 June 2014 (03.06.2014) US(71) Applicant: **INTERDIGITAL PATENT HOLDINGS, INC.** [US/US]; 200 Bellevue Parkway, Suite 300, Wilmington, DE 19809 (US).(72) Inventors: **OTERI, Oghenekome**; 8488 Lower Scarborough Lane, San Diego, CA 92127 (US). **WANG, Xiaofei**; 30 Chestnut Court, Cedar Grove, NJ 07009 (US). **ZHANG, Guodong**; 14 Walnut Drive, Syosset, NY 11791 (US). **XIA, Pengfei**; 4180 Misty Ridge, San Diego, CA 92130 (US). **LOU, Hanqing**; 47 Southwood Circle, Syosset, NY 11791 (US). **LA SITA, Frank**; 91 Bennetts Road, Setauket, NY 11733 (US). **GHOSH, Monisha**; 569 Millwood Road, Chappaqua, NY 10514 (US). **SHAH, Nirav, B.**; 14670 Via Fiesta #2, San Diego, CA 92127 (US).**OLESEN, Robert, L.**; 3 Country Club Drive, Huntington, NY 11743 (US).(74) Agents: **ROCCIA, Vincent, J.** et al.; Condo Roccia Kop-tiw Llp, 1800 Jfk Blvd., Suite 1700, Philadelphia, PA 19103 (US).

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(54) Title: SYSTEMS AND METHODS FOR RECEPTION FAILURE IDENTIFICATION AND REMEDIATION COLLISION AWARE TRANSMISSION (REFIRE CAT) FOR WIFI

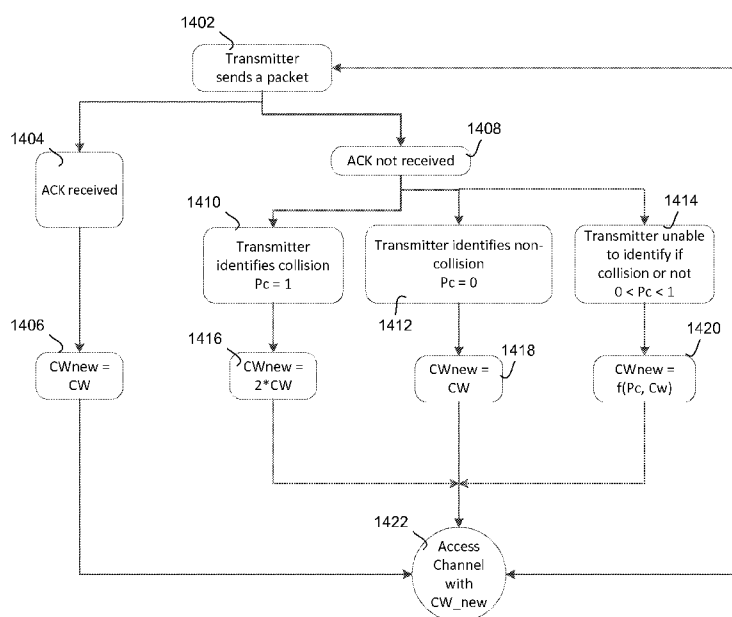


FIG. 14

(57) Abstract: Systems, methods and instrumentalities are disclosed to enable reception failure identification and remediation for collision aware transmission for WiFi. A station (STA) for channel coordination may include a transceiver and a controller configured to adjust a clear channel assessment threshold based on collision statistics within a network. Channel coordination for reception failure identification and remediation may be conducted. An access point (AP) may receive feedback from one or more stations, where feedback comprises collision statistics. The AP may estimate a collision statistic for each of the stations. The AP may adjust a clear channel assessment threshold based on collision statistics within a network. The AP may send collision statistics to the stations.



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SYSTEMS AND METHODS FOR RECEPTION FAILURE IDENTIFICATION AND REMEDIATION COLLISION AWARE TRANSMISSION (REFIRE CAT) FOR WIFI

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of the United States Provisional Application No. 62/007,287, filed June 3, 2014, which is hereby incorporated by reference herein.

BACKGROUND

[0002] Access points may use information, such as reception failure, to provide management for better work performance. Efficient and effective inter-BSS information collection, coordination, and performance management (*e.g.*, based on statistics of different types of reception failures) may better utilize reception failure information to improve network performance.

SUMMARY

[0003] Systems, methods and instrumentalities are disclosed to enable reception failure identification and remediation for collision aware transmission for WiFi. A station (STA) for channel coordination may include a transceiver and a controller configured to adjust a clear channel assessment threshold based on collision statistics within a network. Channel coordination for reception failure identification and remediation may be conducted. An access point (AP) may receive feedback from one or more stations, where feedback comprises collision statistics. The AP may estimate a collision statistic for each of the stations. The AP may adjust a clear channel assessment threshold based on collision statistics within a network. The AP may send collision statistics to the stations.

[0004] An access point (AP) may comprise memory and processor. The AP may measure at least one of a collision probability or a change in collision probability. The AP may compare the measured at least one of the collision probability or the change in collision probability to a threshold. The AP may determine that the measured at least one of the collision probability or the change in collision probability higher than the threshold. The AP may select a collision mitigation transmission mode, wherein the collision mitigation mode comprises a contention window adaptation or a clear channel assessment adaptation.

[0005] The AP may send a packet to a receiver. The AP may determine that an acknowledgement of the packet is not received due to a collision. The AP may change a length of a contention window by multiplying the length of the contention window by two.

[0006] The AP may send a packet to a receiver. The AP may determine that an acknowledgement of the packet is not received. The cause of the acknowledgement not being received may be unknown. The AP may change a length of a contention window based on the collision probability. The length of the contention window may be based on the collision window size.

[0007] The AP may estimate the collision probability of data transmitted by a station. The AP may determine that the estimated collision probability is higher than a second threshold. The AP may reduce, based on the estimated collision probability, a clear channel assessment threshold value for downlink transmission.

[0008] The AP may estimate the collision probability of data transmitted by a station. The AP may determine that the estimated collision probability is lower than a second threshold. The AP may increase, based on the estimated collision probability, a clear channel assessment threshold value for downlink transmission.

[0009] The AP may estimate the collision probability of data received by a station. The AP may determine that the estimated collision probability is higher than a second threshold. The AP may reduce, based on the estimated collision probability, a clear channel assessment threshold value for uplink transmission.

[0010] The AP may estimate the collision probability of data received by a station. The AP may determine that the estimated collision probability is lower than a second threshold. The AP may increase, based on the estimated collision probability, a clear channel assessment threshold value for uplink transmission.

[0011] The AP may measure at least one of a collision probability or a change in collision probability. The AP may compare the measured at least one of the collision probability or the change in collision probability to a threshold. The AP may determine that the measured at

least one of the collision probability or the change in collision probability lower than the threshold. The AP may select a weak channel mitigation transmission mode, wherein the weak channel mitigation transmission mode is collision aware HARQ combining or collision aware MCS adaptation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] A more detailed understanding may be had from the following description, given by way of example in conjunction with the accompanying drawings.

[0013] FIG. 1 illustrates an example of Wireless Local Area Network (WLAN) devices.

[0014] FIG. 2 is an example of enhanced distributed channel access (EDCA) operation.

[0015] FIG. 3 is an example of collision aware transmission taxonomy.

[0016] FIG. 4 is an example of WLAN tools to detect that a packet is correctly received.

[0017] FIG. 5 is an example design of the coordination response information element (IE).

[0018] FIG. 6 is an example design of the coordination request information element (IE).

[0019] FIG. 7 is an example design of the Coordination Request IE.

[0020] FIG. 8 is an example design of a Coordination Response IE.

[0021] FIG. 9 is an example of collision aware transmission technologies and management modes.

[0022] FIG. 10A is an example of staggered collision (SC1) from asynchronous interference.

[0023] FIG. 10B is an example of staggered collision (SC2) from asynchronous interference.

[0024] FIG. 11 is an example of a CCA adaptation with individual STA adaption.

[0025] FIG. 12 is an example of a CCA adaptation with individual STA adaption

[0026] FIG. 13 is an example of a contention window adaptation.

[0027] FIG. 14 is an example contention window adaptation.

[0028] FIG. 15A is a system diagram of an example communications system in which one or more disclosed embodiments may be implemented.

[0029] FIG. 15B is a system diagram of an example wireless transmit/receive unit (WTRU) that may be used within the communications system illustrated in FIG. 15A.

DETAILED DESCRIPTION

[0030] A detailed description of illustrative embodiments will now be described with reference to the various figures. Although this description provides a detailed example of possible implementations, it should be noted that the details are intended to be exemplary and in no way limit the scope of the application.

[0031] FIG. 1 illustrates exemplary wireless local area network (WLAN) devices. The WLAN may include, but is not limited to, access point (AP) 102, station (STA) 110, and STA 112. STA 110 and 112 may be associated with AP 102. The WLAN may be configured to implement one or more protocols of the IEEE 802.11 communication standard, which may include a channel access scheme, such as DSSS, OFDM, OFDMA, etc. A WLAN may operate in a mode, e.g., an infrastructure mode, an ad-hoc mode, etc.

[0032] A WLAN operating in an infrastructure mode may comprise one or more APs communicating with one or more associated STAs. An AP and STA(s) associated with the AP may comprise a basic service set (BSS). For example, AP 102, STA 110, and STA 112 may comprise BSS 122. An extended service set (ESS) may comprise one or more APs (with one or more BSSs) and STA(s) associated with the APs. An AP may have access to, and/or interface to, distribution system (DS) 116, which may be wired and/or wireless and may carry traffic to and/or from the AP. Traffic to a STA in the WLAN originating from outside the WLAN may be received at an AP in the WLAN, which may send the traffic to the STA in the WLAN. Traffic originating from a STA in the WLAN to a destination outside the WLAN, e.g., to server 118, may be sent to an AP in the WLAN, which may send the traffic to the destination, e.g., via DS 116 to network 114 to be sent to server 118. Traffic between STAs within the WLAN may be sent through one or more APs. For example, a source STA (e.g., STA 110) may have traffic intended for a destination STA (e.g., STA 112). STA 110 may send the traffic to AP 102, and, AP 102 may send the traffic to STA 112.

[0033] A WLAN may operate in an ad-hoc mode. The ad-hoc mode WLAN may be referred to as independent basic service set (IBBS). In an ad-hoc mode WLAN, the STAs may communicate directly with each other (e.g., STA 110 may communicate with STA 112 without such communication being routed through an AP).

[0034] IEEE 802.11 devices (e.g., IEEE 802.11 APs in a BSS) may use beacon frames to announce the existence of a WLAN network. An AP, such as AP 102, may transmit a beacon on a channel, e.g., a fixed channel, such as a primary channel. A STA may use a channel, such as the primary channel, to establish a connection with an AP.

[0035] STA(s) and/or AP(s) may use a Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) channel access mechanism. In CSMA/CA a STA and/or an AP may

sense the primary channel. For example, if a STA has data to send, the STA may sense the primary channel. If the primary channel is detected to be busy, the STA may back off. For example, a WLAN or portion thereof may be configured so that one STA may transmit at a given time, e.g., in a given BSS. Channel access may include RTS and/or CTS signaling. For example, an exchange of a request to send (RTS) frame may be transmitted by a sending device and a clear to send (CTS) frame that may be sent by a receiving device. For example, if an AP has data to send to a STA, the AP may send an RTS frame to the STA. If the STA is ready to receive data, the STA may respond with a CTS frame. The CTS frame may include a time value that may alert other STAs to hold off from accessing the medium while the AP initiating the RTS may transmit its data. On receiving the CTS frame from the STA, the AP may send the data to the STA.

[0036] A device may reserve spectrum via a network allocation vector (NAV) field. For example, in an IEEE 802.11 frame, the NAV field may be used to reserve a channel for a time period. A STA that wants to transmit data may set the NAV to the time for which it may expect to use the channel. When a STA sets the NAV, the NAV may be set for an associated WLAN or subset thereof (e.g., a BSS). Other STAs may count down the NAV to zero. When the counter reaches a value of zero, the NAV functionality may indicate to the other STA that the channel is now available.

[0037] The devices in a WLAN, such as an AP or STA, may include one or more of the following: a processor, a memory, a radio receiver and/or transmitter (e.g., which may be combined in a transceiver), one or more antennas (e.g., antennas 106 in FIG. 1), etc. A processor function may comprise one or more processors. For example, the processor may comprise one or more of: a general purpose processor, a special purpose processor (e.g., a baseband processor, a MAC processor, etc.), a digital signal processor (DSP), Application Specific Integrated Circuits (ASICs), Field Programmable Gate Array (FPGAs) circuits, any other type of integrated circuit (IC), a state machine, and the like. The one or more processors may be integrated or not integrated with each other. The processor (e.g., the one or more processors or a subset thereof) may be integrated with one or more other functions (e.g., other functions such as memory). The processor may perform signal coding, data processing, power control, input/output processing, modulation, demodulation, and/or any other functionality that may enable the device to operate in a wireless environment, such as the WLAN of FIG. 1. The processor may be configured to execute processor executable code (e.g., instructions) including, for example, software and/or firmware instructions. For example, the processor may be configured to execute computer readable instructions included on one or more of the processor (e.g., a chipset that includes

memory and a processor) or memory. Execution of the instructions may cause the device to perform one or more of the functions described herein.

[0038] A device may include one or more antennas. The device may employ multiple input multiple output (MIMO) techniques. The one or more antennas may receive a radio signal. The processor may receive the radio signal, e.g., via the one or more antennas. The one or more antennas may transmit a radio signal (e.g., based on a signal sent from the processor).

[0039] The device may have a memory that may include one or more devices for storing programming and/or data, such as processor executable code or instructions (e.g., software, firmware, etc.), electronic data, databases, or other digital information. The memory may include one or more memory units. One or more memory units may be integrated with one or more other functions (e.g., other functions included in the device, such as the processor). The memory may include a read-only memory (ROM) (e.g., erasable programmable read only memory (EPROM), electrically erasable programmable read only memory (EEPROM), etc.), random access memory (RAM), magnetic disk storage media, optical storage media, flash memory devices, and/or other non-transitory computer-readable media for storing information. The memory may be coupled to the processor. The processor may communicate with one or more entities of memory, e.g., via a system bus, directly, etc.

[0040] In IEEE 802.11n, High Throughput (HT) STAs may use a 40 MHz wide channel for communication. This may be achieved, for example, by combining the primary 20 MHz channel, with an adjacent 20 MHz channel to form a 40 MHz wide contiguous channel.

[0041] In IEEE 802.11ac, very high throughput (VHT) STAs may support 20 MHz, 40 MHz, 80 MHz, and/or 160 MHz wide channels. The 40 MHz, and 80 MHz, channels may be formed, e.g., by combining contiguous 20 MHz channels. A 160 MHz channel may be formed, for example, by combining eight contiguous 20 MHz channels, or by combining two non-contiguous 80 MHz channels (e.g., referred to as an 80+80 configuration). For the 80+80 configuration, the data, after channel encoding, may be passed through a segment parser that may divide it into two streams. Inverse fast Fourier transform (IFFT), and time domain, processing may be done on each stream separately. The streams may be mapped on to the two channels, and the data may be transmitted. At the receiver, this mechanism may be reversed, and the combined data may be sent to the MAC.

[0042] IEEE 802.11af and IEEE 802.11ah may support sub 1 GHz modes of operation. For these specifications the channel operating bandwidths may be reduced relative to those used in IEEE 802.11n, and IEEE 802.11ac. IEEE 802.11af may support 5 MHz, 10 MHz and/or 20 MHz bandwidths in the TV White Space (TVWS) spectrum, and IEEE 802.11ah may support 1

MHz, 2 MHz, 4 MHz, 8 MHz, and/or 16 MHz bandwidths, e.g., using non-TVWS spectrum. IEEE 802.11ah may support Meter Type Control (MTC) devices in a macro coverage area. MTC devices may have capabilities including, for example, support for limited bandwidths, and a requirement for a very long battery life.

[0043] In WLAN systems that may support multiple channels, and channel widths, e.g., IEEE 802.11n, IEEE 802.11ac, IEEE 802.11af, and/or IEEE 802.11ah, may include a channel, which may be designated as the primary channel. The primary channel may have a bandwidth that may be equal to the largest common operating bandwidth supported by the STAs in the BSS. The bandwidth of the primary channel may be limited by a STA operating in a BSS that may support the smallest bandwidth operating mode. For example, in IEEE 802.11ah, the primary channel may be 1 MHz wide, if there may be STAs (e.g., MTC type devices) that may support a 1 MHz mode even if the AP, and other STAs in the BSS, may support a 2 MHz, 4 MHz, 8 MHz, 16 MHz, or other channel bandwidth operating modes. The carrier sensing, and NAV settings, may depend on the status of the primary channel. If the primary channel is busy, for example, due to a STA supporting a 1 MHz operating mode transmitting to the AP, the available frequency bands may be considered busy even though majority of the bands may stay idle and available.

[0044] In the United States, for example, the available frequency bands that may be used by IEEE 802.11ah may be from 902 MHz to 928 MHz. In Korea, for example, it may be from 917.5 MHz to 923.5 MHz. In Japan, for example, it may be from 916.5 MHz to 927.5 MHz. The total bandwidth available for IEEE 802.11ah may be 6 MHz to 26 MHz may depend on the country code.

[0045] A Wireless Local Access Network (WLAN) in infrastructure basic service set (BSS) mode may have an Access Point (AP) for the BSS and may have one or more station(s) (STA) associated with the AP. The AP may have access to and/or interface with a distribution system (DS) and/or another type of network (e.g., wired or wireless) that may carry traffic in and/or out of the BSS. Traffic to STAs that may originate from outside the BSS may arrive through the AP and be delivered to the STAs. Traffic originating from STAs to destinations that may be outside the BSS may be sent to the AP to be delivered to destinations. Traffic between STAs within the BSS may be sent through the AP. The source STA may send traffic to the AP and the AP may deliver the traffic to the destination STA. Traffic between STAs within a BSS may be peer-to-peer traffic. Peer-to-peer traffic may be sent directly between the source and destination STAs (e.g., with direct link setup (DLS) or tunneled DLS). A WLAN in Independent BSS mode may not have an AP and STAs may communicate directly with each other.

[0046] WiFi systems and associated access points may require support for a larger number of devices than those currently in operation, for example, as a result of the proliferation of personal mobile devices and applications. The number of stations that may need to be supported may grow.

[0047] Channels allocated in spectrum sub 1GHz (*e.g.*, 802.11ah) may be limited in size and bandwidth. The spectrum may also be fragmented, for example, available channels may not be adjacent and/or it may not be possible to combine channels to support larger than normal transmission bandwidths.

[0048] Enhanced distributed channel access (EDCA) may be an extension of distributed coordinated function (DCF) (*e.g.*, as introduced in 802.11) to support prioritized Quality of Service (QoS). FIG. 2 depicts an example of EDCA.

[0049] A point coordination function (PCF) may use contention-free channel access. PCF may support time-bounded services and polling by an AP. As illustrated in FIG. 2, an AP may send a polling message after waiting for PIFS. If a client has nothing to transmit, the client may return a null data frame. Because PIFS is smaller than DIFS, it may lock out all the asynchronous traffic. PCF may be deterministic and fair, and may be efficient for both low duty-cycle and heavy or bursty traffic. HCCA may be an enhancement of PCF. HCCA may support, for example, AP polling an STA (*e.g.*, during a contention period (CP) and/or contention-free period (CFP)). HCCA may transmit multiple frames under one poll.

[0050] Hybrid coordination function controlled channel access (HCCA) may be an enhancement of PCF. In HCCA, an AP may poll a station during both contention periods (CPs) and contention-free periods (CFPs). Multiple frames may be transmitted under one poll.

[0051] FIG. 3 depicts an example of collision aware transmission taxonomy. Collision Aware Transmission (CAT) may adapt the parameters and/or techniques used in a transmission while accounting for the effects due to packet collisions separate from the effects due to channel errors. Collision events may be identified, the effects of collision may be remediated and/or the location of remediation may be identified, for example, to implement CAT.

[0052] Collision event identification may be one or more of collision event identification (*e.g.*, actual and/or immediate) and/or collision probability estimation (*e.g.*, statistical and/or long-term). Collision event identification (*e.g.*, actual and/or immediate) may identify collisions based on channel reservation and/or specific frame interactions, etc. Collision event identification may have some ambiguous events. Collision probability estimation (*e.g.*, statistical and/or long term) may estimate the probability that a collision will occur.

[0053] CAT remediation may be immediate remediation, long term and/or statistical remediation, and/or hybrid remediation. Immediate remediation may use immediate collision estimate to modify the transmission. For example, the doubling of the contention window (CW) length in the event of a transmission failure in WiFi may be immediate remediation. The non-reception of an ACK after transmission that may be used to identify the collision in legacy WiFi may not be strictly accurate. Long term and/or statistical remediation may use long term behavior and/or statistics to modify transmission. For example, a collision probability estimate may be used to assist in rate adaptation. Hybrid remediation may use long term and immediate information to modify transmission.

[0054] The remediation operation may be centralized and/or distributed. Centralized remediation operation may be where the AP and/or a centralized entity receives collision information from STAs in the BSS and/or modifies parameters based on the information received. Distributed remediation operation may be where STA(s) modifies parameters based on local collision estimates.

[0055] Transmitting and/or receiving STAs may not differentiate between types of reception failures, for example, in WLAN specifications. A transmitting STA may assume that a collision occurred, such as when the transmitting STA transmits a packet for which no ACK has been received. The transmitting STA may conduct exponential backoff. A receiving STA may wait an extended interframe space (EIFS) before attempting to conduct medium access, for example, if the STA cannot receive a packet correctly.

[0056] FIG. 4 depicts an example of WLAN tools that may be used to detect that a packet is correctly received. These are tools the receiving STA may use to detect whether a packet has been correctly received 400. The tools may include one or more of Short Training Fields (STFs) 402, Long Training Fields (LTFs) 404, Remaining PLCP header 406, PLCP Header CRC 408, Frame Check Sequence (FCS), Frame body 410, or Framebody CRC 412. STFs 402 and LTFs 404 may be part of the WLAN PLCP header. The receiving STAs may use STFs 402 and LTFs 404 to detect the presence of WLAN packets or to determine whether CCA is busy 420. PLCP Header CRC 408 may be part of the WLAN PLCP header. The receiving STA may use the PLCP Header CRC 408 field to verify whether a valid PLCP header has been received 422. The FCS may be part of the MAC frame body 410. The receiving STA MAC layer may use the FCS field to determine whether a WLAN packet has been correctly received 424.

[0057] Reception failure may be assumed to result from collisions by transmissions from other nodes (*e.g.*, non-hidden nodes in the same BSS, hidden nodes in the same BSS, nodes in overlapping BSSs, *etc.*), for example, in WiFi systems.

[0058] The cause of the reception failure may be identified (*e.g.*, whether it is as a result of transmission failures due to weak signal reception, additive noise, collisions between nodes transmitting at the same time, *etc.*). Identifying the failure cause may be used to remediate and/or reverse the effects of the reception failure. For example, a node may transmit with a Modulation and Coding Scheme (MCS) that is not supportable by the channel between the transmitter and receiver. Adjusting the contention window (*e.g.*, to reduce the number of collisions) may result in an inefficient use of resources. Identifying this failure may allow for a different remediation to be used.

[0059] Reception failure identification and remediation may be provided. For example, one or more reference signals in LTS may be inserted in the frame body of the WLAN packets. Overlapping and/or partially overlapping packet collision may be detected, such as when one or more reference signals may not be correctly recovered. For example, a receiving STA may send received versions of the packet to the transmitting STA, such as when detecting that a packet may not have been correctly received. The transmitting STA may compare the transmitted version and the received version of the packet to identify the cause of the reception failure. For example, the packet collision probability may be estimated (*e.g.*, based on the medium reservation status, such as successful RTS/CTS exchanges, *etc.*).

[0060] Inter-AP coordination may be provided. Examples of inter-AP coordination, for example, to conduct coordination for parameters and/or settings of OBSS include, but are not limited to, QoS load and settings, primary and coordination channels, TXOP, and/or UL Access and TIM indications, *etc.*

[0061] Inter-AP coordination may be used to coordinate a variety of parameters and settings for OBSS, including, for example, QoS load and settings, primary and coordination channels, TXOP, and/or UL access and TIM indications. FIG. 5 illustrates an example Coordination Response information element (IE) 500. Coordination Response IE 500 may comprise an Element ID field 502, a Length field 504, Options field 506, Results 508, Fields (*e.g.*, Field 1 field 510 to Field n field 512). Each of the Field fields may comprise a Type subfield 514 and/or a Contents subfield 516). FIG. 6 illustrates an example Coordination Request information element (IE) 600. Coordination Request IE 600 may comprise an Element ID field 602, a Length field 604, an Options field 606, and one or more Fields (*e.g.*, Field 1 field 608 to Field n field 610). Each of the Field fields may comprise a Type subfield 612 and/or a

Contents subfield 614). Interference and neighboring BSS reporting may be used as part of inter-BSS coordination.

[0062] Inter-BSS management based on reception failure statistics may be provided. For example, such inter-BSS management may be based on reception failure statistics and/or inter-BSS communication.

[0063] An STA may set a parameter (e.g., dot11ReceptionFailureDetection) to true, for example, to indicate that it has implemented reception failure detection. An STA may set the parameter (e.g., dot11ReceptionFailureDetection) to true, for example, if an STA is capable of detecting the nature of a reception failure. An STA capable of detecting the nature of reception failure may be able to differentiate the types of reception failure, including, but not limited to one or more of the following described herein. Reception failure may be caused by too high MCS and/or when the MCS that may be used for the Physical Layer Service Data Unit (PSDU) is too high for the channel conditions. Reception failure may be from overlap, partial overlap, and/or when the reception of a first packet may be disrupted by the transmission of a second packet that starts at a point of time, such as later than that of the first packet. Reception failure may be from noise and/or interference and/or or when the power of the received packet may be insufficient to decode the PLCP header. Reception failure may be from collision and/or when the transmission of one or more packets may start at the same time and may cause reception failures, such as at the receiving STAs, etc.

[0064] An STA may be capable of detecting reception failure. The STA may collect statistics on when a reception failure occurs, including but not limited to statistics regarding reception failures described herein. Statistics may be collected on reception failures from too high MCS and/or when the MCS that may be used for when the Physical Layer Service Data Unit (PSDU) is too high for the channel conditions. Statistics may be collected on reception failures from overlap, partial overlap, and/or when the reception of a first packet may be disrupted by the transmission of a second packet that starts at a point of time, such as later than that of the first packet. Statistics may be collected on reception failures from noise and/or interference and/or or when the power of the received packet may be insufficient to decode the PLCP header. Statistics may be collected on reception failures from collision and/or when the transmission of one or more packets may start at the same time and may cause reception failures, such as at the receiving STAs. Statistics may be collected on the total number of reception failures. Statistics may be collected on the probability of collision if there is a packet loss, where P_{stat} is the probability of collision if there is a packet loss. Statistics may be collected, for example, where a subfield content may include the value of P_{stat} . The parameter $P_{threshold}$, where

$P_{\text{threshold}}$ is a threshold defined for P_{stat} and, for example, where the subfield content may include the value of $P_{\text{threshold}}$. Statistics may be presented in different forms, such as percentages (*e.g.*, percentages of the total number of reception failures).

[0065] An AP may collect the reception failure statistics from STA(s) in its BSS. An AP may conduct coordination with an OBSS for increased network performance. An AP may use a Coordination Request IE to request coordination with the OBSS. FIG. 7 depicts an example design of the Coordination Request IE. FIG. 7 illustrates an example Coordination Request information element (IE) 700. Coordination Response IE 700 may comprise an Element ID field 702, a Length field 704, an Options field 706, and one or more Fields (*e.g.*, Field 1 field 708 to Field n field 710). Each of the Field fields may comprise a Type subfield 712 and/or a Contents subfield 714). Type subfield 712 may provide Inter-BSS Reception Failure Identification and Remediation (ReFire) Statistics and/or Inter-BSS ReFire Coordination. Content subfield 714 may provide a format for Inter-BSS ReFire Statistics report and/or Inter-BSS ReFire Coordination parameters. Content in one or more of fields Field 1 to Field N (*e.g.*, type and/or contents subfields) in coordination request IE may represent Inter-BSS ReFire statistics exchange and/or Inter-BSS ReFire Coordination parameters on performance adjustment.

[0066] Inter-BSS ReFire statistics exchange may include reception failures. An inter-BSS ReFire statistics exchange may be an exchange between BSS entities reporting observed ReFire events and/or statistics relating to such observations. An inter-BSS ReFire statistics exchange may include data associated with reception failures (*e.g.*, reception failures observed by a BSS entity and sent to another BSS entity. Inter-BSS ReFire statistics may exchange the number of too high MCS and/or when the MCS that may be used for the Physical Layer Service Data Unit (PSDU) is too high for the channel conditions causing reception failure. Inter-BSS ReFire statistics may exchange the number of overlap, partial overlap, and/or when the reception of a first packet may be disrupted by the transmission of a second packet that starts at a point of time, such as later than that of the first packet, causing reception failure. Inter-BSS ReFire statistics may exchange the number of noise and/or interference and/or when the power of the received packet may be insufficient to decode the PLCP header causing reception failure. Inter-BSS ReFire statistics may exchange the number of collisions and/or when the transmission of one or more packets may start at the same time and may cause reception failures, such as at the receiving STAs, causing reception failure. Inter-BSS ReFire statistics may exchange the total number of reception failures. Inter-BSS ReFire statistics may exchange the number of measurement intervals. Measurement interval may be omitted if measurement is conducted for a predetermined time and/or a fixed amount of TU. Reception failure statistics that may be based

on too high MCS and/or when the MCS that may be used for the Physical Layer Service Data Unit (PSDU) is too high for the channel conditions may have contents that may be implemented as integers and/or percentages of the total number of reception failures and/or percentages of the total number of receptions. Reception failure statistics that may be based on overlap, partial overlap, and/or when the reception of a first packet may be disrupted by the transmission of a second packet that starts at a point of time, such as later than that of the first packet, may have contents that may be implemented as integers and/or percentages of the total number of reception failures and/or percentages of the total number of receptions. Reception failure statistics that may be based on noise and/or interference and/or or when the power of the received packet may be insufficient to decode the PLCP header may have contents that may be implemented as integers and/or percentages of the total number of reception failures and/or percentages of the total number of receptions. Reception failure statistics that may be based on collision and/or when the transmission of one or more packets may start at the same time and may cause reception failures, such as at the receiving STAs, may have contents that may be implemented as integers and/or percentages of the total number of reception failures and/or percentages of the total number of receptions. The total number of reception failures statistics may have contents that may be implemented as integers and/or percentages of the total number of reception failures and/or percentages of the total number of receptions. Measurement interval statistics may have contents that include the interval during which the measurement is done.

[0067] Inter-BSS ReFire coordination parameters on performance adjustment may include targeted entities, MCS setting aggressiveness, and/or CCA level adjustment. Targeted entities may be the entities that are targeted and/or identified, for example, by the coordination request. Targeted entity type may include BSS, group of STAs, STA, non-AP STA, Personal Basic Service Set (PBSS), etc. The targeted entity may be the transmitting AP, BSS, STA, *etc.*, such as when that transmitting AP, BSS, STA, *etc.*, may attempt to adjust its own parameters. The targeted entity contents may be implemented as IDs of the targeted entity. For example, a BSS may be identified by its BSSID. An STA may be identified by its AID, MAC address, *etc.*, and/or in combination of the BSSID of the BSS to which the interfering STA may belong. A group of STAs may be identified by the group address. MCS setting aggressiveness may include contents that may be implemented as integers to represent the SINR adjustment (*e.g.*, unit in dBs) relative to normal MCS to SINR mapping and/or setting. CCA level adjustment type may be CCA level used in the BSS. CCA level adjustment contents may be implemented as integers to represent the SINR adjustment (*e.g.*, unit in dBs) relative to normal MCS to SINR mapping and/or setting.

[0068] FIG. 8 depicts an example design of a Coordination Response IE. In FIG. 8, the coordination Response IE 800 may comprise an Element ID field 802, a Length field 804, Options field 806, Results 808, Fields (e.g., Field 1 field 810 to Field n field 812). Each of the Field fields may comprise a Type subfield 814 and/or a Contents subfield 816. Type subfields 814 may provide for Inter-BSS ReFire Statistics and Inter-BSS ReFire Coordination. Content subfields 816 may provide for format for Inter-BSS ReFire Statistics report and Inter-BSS ReFire Coordination parameters. An AP, STA and/or some coordination entity may reply with a frame including the Coordination Response IE. The AP, STA and/or some coordination entity may receive a frame including the Coordination Request IE, if it is capable of coordination. The design of the Coordination Response IE may follow the design of the Coordination Request IE. The design of the Coordination Response IE may not follow the design of the Coordination Request IE with respect to some features (e.g., the results fields may indicate the status of the Coordination Request and/or may have potential values for success, reject, and/or alternative values).

[0069] The Coordination Request IEs and/or Coordination Response IEs may be used as a part of exchanges between an STA and an AP for intra-BSS coordination purposes. The Coordination Request and/or Coordination Response are used as examples, and may be implemented using one or more of management, control, or other types of frames, or as a part these frames, including, e.g., MAC/PLCP headers, fields or subfields, *etc.*

[0070] Inter-BSS coordination based on reception failure statistics may be disclosed. An AP may coordinate with other APs on reception failure related parameters and/or settings (e.g., in a distributed and/or centralized manner).

[0071] An entity may exist that conducts coordination among one or more APs in an area (e.g., in an OBSS), such as in centralized coordination. The entity may be an AP, which may be referred to as a Coordination AP (CAP). Centralized coordination may be described herein, which may include one or more of the following. An AP may determine that another AP, STA, group of STAs, BSS, *etc.* is causing reception failures, for example, due to aggressive settings such as MCS selections, contention window parameters, QoS parameters, *etc.* An AP (e.g., a requesting AP) may send a Coordination Request to the CAP requesting different parameter settings. The transmitting AP may request (e.g., in the Coordination Request) that a targeted BSS, STA, AP, *etc.* change aggressiveness in MCS selections, contention window parameters and/or QoS parameters settings, *etc.*, such as by including (e.g., identifying) the targeted BSS, STA, AP, *etc.* ID and/or parameters. The transmitting AP may request (e.g., in the Coordination Request) that it and/or its BSS modify settings (e.g., for MCS selection, contention window

parameters and/or QoS parameter, *etc.*) by including the ID of the transmitting AP or its BSSID in the targeted entity field and/or parameters. The CAP may evaluate the requested changes, such as after receiving the Coordination Request. The CAP may query a third AP, BSS, STA, *etc.* for possibilities to alter its settings. The CAP may query a third AP, BSS, STA, *etc.* if a third AP, BSS, STA, *etc.* is involved. The CAP may query a third AP, BSS, STA, *etc.* if the third AP, BSS, STA, *etc.* settings need to be altered as requested by the requesting AP, BSS, STA, *etc.* The CAP may use the response from the third AP, BSS, STA, *etc.* to decide the appropriate response to the requesting STA. The CAP may respond (*e.g.*, with a Coordination Response) accepting and/or rejecting the changes requested by the requesting AP and/or provide alternative values. The requesting AP may accept the alternative values and/or restart the coordination process, such as until an acceptable set of parameter settings may be received from the CAP and/or until the CAP accepts the requested parameters. The CAP may distribute the parameter settings and/or changes to all and/or some AP, BSS, STA, *etc.* The APs, STAs, and/or the like may distribute the changes to each of the STAs, such as one or more STAs in its own BSS.

[0072] One or more AP, BSS, and/or the like may maintain a list of Coordinating Neighbors (CNs), such as in distributed coordination. The Coordinating Neighbors may be the APs of some or all neighboring BSSs, for example, in the OBSS. For example, the APs of some or all neighboring BSSs may be set as the CN. Distributed Coordination may be disclosed herein, which may include one or more of the following. An AP may determine that another AP, STA, group of STAs, BSS, *etc.* may be causing reception failures due to aggressive settings, such as MCS selections, contention window parameters and/or QoS parameters, *etc.* An AP may send a Coordination Request to the CN requesting parameter settings, such as if an AP (*e.g.*, the requesting AP) requests one or more of its CNs to change parameters and/or settings. An AP may send a Coordination Request to some and/or all CNs, for example, if an AP requests to change parameters. The transmitting AP may request (*e.g.*, in the Coordination Request) that a targeted BSS, STA, AP, *etc.* change aggressiveness in MCS selections, contention window parameters and/or QoS parameters settings, *etc.*, such as by including the targeted BSS, STA, AP, *etc.* ID and/or parameters. The transmitting AP may request (*e.g.*, in the Coordination Request) that it and/or its BSS needs modifications in settings for MCS selection, contention window parameters and/or QoS parameter settings, *etc.* by including the ID or BSSID in the targeted entity field and/or parameters. A CN may evaluate the requested changes, such as after receiving the Coordination Request. The CN may respond (*e.g.*, with a Coordination Response) accepting and/or rejecting the changes requested by the requesting AP and/or provide alternative values. The alternative values may be the setting and/or parameters for the requesting AP, BSS,

STA, etc. and/or setting and/or parameters for the responding AP, BSS, STA, *etc.*, such as identified in the targeted entity field. The requesting AP may accept the alternative values and/or restart the coordination process, for example, until an acceptable set of parameter settings may be received from the CN and/or until the CN accepts the requested parameters. The requesting AP may start to use the settings and/or parameters, such as if it has received a Coordination Response from some or all CNs accepting the requested change and/or a pre-defined number of beacon periods have passed since the Coordination Requests have been sent to some or all CNs. The requesting and/or responding AP may distribute the new parameter and/or settings to some or all AP, BSS, STAs, *etc.* involved, such as the STAs in its BSS.

[0073] Reception failure remediation based on reception failure information may be disclosed herein. CAT techniques may be used to reduce the occurrence of problems, such as channel errors and/or collision errors.

[0074] CAT technologies (*e.g.*, channel impairment and/or weak signal management technologies and/or collision management technology) may improve transmission. FIG. 9 depicts collision aware transmission technologies and management modes.

[0075] An access point (AP) may comprise a memory and processor. The AP may measure at least one of a collision probability or a change in collision probability. The AP may compare the measured at least one of the collision probability or the change in collision probability to a threshold. The AP may determine that the measured at least one of the collision probability or the change in collision probability higher than the threshold. The AP may select a collision mitigation transmission mode, wherein the collision mitigation mode comprises a contention window adaptation or a clear channel assessment adaptation.

[0076] The AP may measure at least one of a collision probability or a change in collision probability. The AP may compare the measured at least one of the collision probability or the change in collision probability to a threshold. The AP may determine that the measured at least one of the collision probability or the change in collision probability lower than the threshold. The AP may select a weak channel mitigation transmission mode, wherein the weak channel mitigation transmission mode is collision aware HARQ combining or collision aware MCS adaptation.

[0077] As shown in FIG. 9, weak signal management technologies may use collision identification information to improve transmission due to channel impairments (*e.g.*, pure channel impairments, such as noise and/or interference). Weak signal management technologies include management modes, such as collision aware rate adaption, collision aware HARQ, and collision aware LLR estimation. Collision aware rate adaptation may enable selection of MCS

based on channel errors and/or the combined effect of channel errors and collision errors. Collision aware HARQ may enable combining of retransmissions while minimizing the effect of collisions. Collision aware LLR estimation may estimate LLR using collision information.

[0078] As shown in FIG. 9, collision management technologies may use collision identification information to reduce the occurrence of collisions in a network. Collision management technologies include management modes, such as collision aware clear channel assessment threshold adaption, collision aware contention window length and/or packet length adaption, collision aware channel reservation adaption. Collision aware clear channel assessment threshold adaptation may enable modification of the CCA threshold based, for example, on the effect and/or type of collisions experienced by the node. CCA adaptation may be performed by CCA threshold adaptation. Collision aware contention window length and/or packet length adaptation may adapt contention window length and/or packet length based, for example, on effect and/or type of collisions. Collision aware channel reservation adaptation may adapt the use of mechanisms, such as the RTS-CTS packet exchange, the CTS-to-self packet exchange and/or TxOP duration, based, for example, on the effect and/or type of collisions

[0079] Multi-mode collision aware transmission technologies may be used that switch (e.g., between and/or within) collision management (e.g., CCA adaption, CW length, packet length) and/or weak signal management (e.g., Rate Adaptation, HARQ) based, for example, on the relationship between collision statistics, packet loss, and/or the like.

[0080] The AP may send a packet to a receiver. The AP may determine that an acknowledgement of the packet is not received due to a collision. The AP may change a length of a contention window by multiplying the length of the contention window by two.

[0081] The AP may send a packet to a receiver. The AP may determine that an acknowledgement of the packet is not received. The cause of the acknowledgement not being received may be unknown. The AP may change a length of a contention window based on the collision probability. The length of the contention window may be based on the collision window size.

[0082] The AP may estimate the collision probability of data transmitted by a station. The AP may determine that the estimated collision probability is higher than a second threshold. The AP may reduce, based on the estimated collision probability, a clear channel assessment threshold value for downlink transmission.

[0083] The AP may estimate the collision probability of data transmitted by a station. The AP may determine that the estimated collision probability is lower than a second threshold.

The AP may increase, based on the estimated collision probability, a clear channel assessment threshold value for downlink transmission.

[0084] The AP may estimate the collision probability of data received by a station. The AP may determine that the estimated collision probability is higher than a second threshold. The AP may reduce, based on the estimated collision probability, a clear channel assessment threshold value for uplink transmission.

[0085] The AP may estimate the collision probability of data received by a station. The AP may determine that the estimated collision probability is lower than a second threshold. The AP may increase, based on the estimated collision probability, a clear channel assessment threshold value for uplink transmission.

[0086] CAT collision management technologies that may address system level adaptations to improve system performance may be disclosed herein.

[0087] Collision identification and/or parameter estimation may be disclosed herein. The presence and/or type of collisions may be identified to enable collision aware transmission schemes. Collision parameters may be estimated to enable collision aware transmission schemes. Frame losses (*e.g.*, in IEEE 802.11) may result from channel impairment errors. Channel impairment errors may result from channel fading, Additive White Gaussian Noise (AWGN), and/or frame collision errors that occur when frames from multiple transmitters are present in the medium at the same time. Frame collision errors may result from collisions including, but not limited to, direct collisions (DC), staggered collision (SC1) from asynchronous interference, and/or staggered collision (SC2) from asynchronous interference. Direct collisions may occur when more than one node within the range of a receiver start transmitting concurrently and/or at similar times.

[0088] FIG. 10A depicts an example of staggered collision (SC1) from asynchronous interference. In FIG. 10A, packet 1002 may receive interference from packet 1004 and may experience a staggered collision. Packet 1002 may arrive before packet 1004. As shown in FIG. 10A, the preamble 1010 of packet 1002 may be available. The preamble 1010 may perform channel/noise estimation. An STA may identify packets 1002 and 1004. Packet 1002 may be the packet desired for receipt by the STA. Pilots may be known signals that may enable the receiver to estimate and track the channel accurately when receiving packets. The pilots in data portion 1012 may be corrupted due to interference. A receiving STA may be unable to conduct pilot tracking if the pilots are corrupt. A receiving STA may be able to estimate interference power using the corrupted pilots. Staggered collision (SC1) from asynchronous interference may occur

due to interference from hidden nodes, for example, where the node transmits first and is interrupted.

[0089] FIG. 10B depicts an example of staggered collision (SC2) from asynchronous interference. In FIG. 10B, packet 1052 may receive interference from packet 1050. The STA may desire to receive packet 1052, but packet 1052 receives interference from packet 1050. Packet 1050 arrives before packet 1052. Unlike in FIG. 10A, packet 1052 is unable to use the preamble or the pilots and all of packet 1052 is lost. Staggered collision (SC2) from asynchronous interference may occur due to interference from hidden nodes, for example, where the node interrupts another node already in transmission.

[0090] The type and/or parameters of the collision-prone environment may be identified. For example, the AP may send a Busy-Idle signal to indicate its channel occupancy. STA(s) (*e.g.*, each STA) may use this signal to estimate its collision probability. A collision probability estimation period may be set with the rate reduced to a minimum and/or the contention window set to a maximum. An error estimate may be attributed to collisions. Collisions may be estimated at the receiver and/or sent to the transmitter. Start-of-packet detection correlation, frame interactions and/or radio frequency power monitoring techniques to identify the collision types may be used. A frame (*e.g.*, 802.11 frame) may include a short training field (STF), long training field (LTF), and/or a signal (SIG) field. The STF may be used for start-of-packet detection, automatic gain control (AGC), and/or coarse frequency and/or timing correction. The LTF may be used for fine frequency and/or timing correction and/or channel estimation. The SIG field may include physical layer information, such as MCS, packet length and bandwidth, for decoding and/or other functions.

[0091] Table 1 illustrates examples of different types of collisions. As illustrated in Table 1, different collision types may be distinguished by monitoring the start-of-packet detection correlations on STF/LTF and/or signal field (SIG) detection. The desired packet and/or interference packet collide from the beginning of the packet, and the difference between the packet arrival times may be within a cyclic prefix, for example, in DC. The STF and LTF, which may be common for some or all packets, may be detected by auto-correlation and/or cross-correlation algorithms. SIG fields may not be detected successfully, for example, since they may be different for each packet. The STF, LTF and/or SIG field of the desired packet may be detected, for example, if the collision happens after the completion of the preamble, such as in SC1. The STF, LTF and/or SIG fields may not be detected, for example, if the desired packet arrives after the interfering packet transmission is underway, such as in SC2. Some or all of the packets may have the same preamble format (*e.g.*, the mixed format defined in 802.11n).

Table 1

Signal Field/Type	DC	SC1	SC2
STF and LTF	YES	YES	No
SIG	No	YES	No

[0092] CCA adaptation may be collision aware CCA adaptation, *e.g.*, that may address system level adaptations to improve system performance, may be disclosed herein. CCA may be performed by CCA adaption.

[0093] An STA(s) and/or an AP may adjust CCA adaption(s). A CCA adaptation may be adjusted based on collision statistics, *e.g.*, collision statistics within the network. The adjustment may be controlled in a centralized manner in which the AP directs some and/or all the STAs to adjust CCA adaptations. The adjustment may be in a distributed manner, such as each STA adjusts its CCA threshold independently.

[0094] The AP may estimate the collision probability of data transmitted by a station. The AP may determine that the estimated collision probability is lower than a second threshold. The AP may increase, based on the estimated collision probability, a clear channel assessment threshold value for downlink transmission.

[0095] The AP may estimate the collision probability of data received by a station. The AP may determine that the estimated collision probability is higher than a second threshold. The AP may reduce, based on the estimated collision probability, a clear channel assessment threshold value for uplink transmission.

[0096] The AP may estimate the collision probability of data received by a station. The AP may determine that the estimated collision probability is lower than a second threshold. The AP may increase, based on the estimated collision probability, a clear channel assessment threshold value for uplink transmission.

[0097] Receiver collision statistics estimation and feedback may be described. A receiver may estimate the collision statistics of data transmitted for the receiver. The receiver may track the collision statistics of one or more (*e.g.*, each) transmitter separately, for example, when a node may include multiple transmitters, such as an AP in infrastructure mode. The statistic may be long term, such as the probability of collision (P_c) and/or the conditional probability of collision, such as if there has been a packet loss ($P_c|PI$). The statistic may be short term, such as the occurrence of a collision event. The receiver may keep track of interferers (*e.g.*, worst case interferers and/or the BSS ID and STA ID of the STAs that interfere with it the most, and/or the like). The receiver may send (*e.g.*, periodically send) collision statistic(s) to the

transmitter, such as to enable it use the statistic to modify its clear channel assessment threshold (e.g., via a control/management frame). The transmitter may request information (e.g., feedback) using a ReFire statistics request/response frame exchange. The receiver may send a ReFire statistics response frame (e.g., unsolicited) to the transmitter. The feedback may use frames, such as those described herein. The feedback request may include a request for information (e.g., of the BSSID and/or STA ID and/or of the worst-case interferers in neighboring BSSs) to populate the fields in the Inter-BSS ReFire Coordination Parameters frame and/or to enable inter-BSS setting of the CCA threshold values.

[0098] Transmitter collision statistics estimation and feedback may be described. A transmitter may estimate the collision statistics of data it transmits. The transmitter may track the collision statistics of one or more (e.g., each) transmitter separately, for example, for a node with multiple receivers (e.g., an AP in infrastructure node). The statistic may be long term, such as the probability of collision (P_c) and/or the conditional probability of collision, for example, if there has been a packet loss ($P_c|P_l$). The transmitter may periodically send the collision statistic to the receiver (e.g., in centralized CCA adaption), such as via a control/management frame, to enable the receiver to use the statistic to estimate a clear channel assessment threshold. The receiver may request information (e.g., feedback) using a ReFire statistics request/response frame exchange. The transmitter may send a ReFire statistics response frame (e.g., unsolicited) to the receiver. The transmitter may be an STA. The receiver may be an AP or centralized controller. The feedback may use frames described herein.

[0099] FIG. 11 depicts an example of a CCA adaptation that is centralized with individual STA adaption. CCA adaptation may be performed by centralized CCA adaptation. Centralized CCA adaptation adjustment may be described. In FIG. 11, at 1110, the STA1 1104 may estimate collision statistics. The STA2 1106 may estimate collision statistics at 1115. Feedback may be from STA1 1104 and/or STA2 1106 to the AP 1102. For example, at 1120, STA1 1104 may feedback to the AP 1102 and, at 1125, STA2 1106 may feedback to the AP 1102. At 1130, the AP 1102 may estimate the collision probability for one or more (e.g., each) STA 1104/1106. The AP 1102 may set the CCA adaptation for itself and/or some or all STAs 1104/1106. The AP 1102 may have access to the collision statistics for its transmission to one or more (e.g., each) of the STAs 1104/1106 in its BSS. This information may be used to set the CCA adaptation value of the AP 1102 during downlink transmission. The AP 1102 may have access to the collision statistics for its reception, such as from one or more (e.g., each) of the STAs 1104/1106 in its BSS. This information may be used to set the CCA adaptation value of one or more (e.g., each) STA during uplink transmission. Downlink transmission and setting the

CCA adaptation for the AP may be described. The AP 1102 may identify the STA(s) with certain statistic(s) (*e.g.*, the worst statistic(s), the STA with the maximum P_c , and/or the mean of the largest n P_c s where n is a parameter, *etc.*).

[0100] At 1135 and 1140, the AP 1102 may adjust its CCA adaptation up or down based on a value identified. The CCA adaptation may be reduced, such as to reduce the aggressiveness of the AP's channel access and/or reduce the collision probability, for example, if the value identified is greater than a threshold. The CCA adaptation may be increased to increase the aggressiveness of the AP's channel access and/or increase the collision probability, for example, if the value is less than a threshold. The thresholds may not be the same, such as to introduce some hysteresis into the CCA adaptation change. The AP 1102 may send a request to the neighboring (*e.g.*, worst-case) BSS and/or STA 1104/1106 to adjust their CCA using the Inter-BSS ReFire Coordination frame. The request may be sent through a centralized coordinator, for example, to the neighboring BSS. The AP 1102 may use STAs 1104/1106 to relay the information to the neighboring BSS. A packet may be sent to the STA 1104/1106 in its own BSS, for example, with instructions to re-broadcast and/or relay the packet to the neighboring BSS/STA. STAs in the neighboring BSS may relay this information to the AP 1102 of the neighboring BSS for action. The target may take action independently, for example, based on the relayed packet. The AP 1102 may set STA 1104/1106 CCA adaptation levels, for example, based on the collision probability of the receiving STA 1104/1106. The CCA adaptation level of the AP 1102 may be set, for example, based on the STA 1104/1106 to which it may transmit. The CCA adaptation level may be adjusted, for example, based on the statistic associated with the AP's 1102 transmission to the STA 1104/1106. Uplink Transmission and setting the CCA threshold for one or more (*e.g.*, each) STA 1104/1106 may be described. The AP 1102 may compare the collision statistic for reception from one or more (*e.g.*, each) STA 1104/1106 to an internal threshold. The AP 1102 may send STAs 1104/1106 CCA threshold adjustment commands, for example, based information and/or comparisons described herein. The CCA threshold may be reduced to reduce the aggressiveness of the AP's channel access and/or reduce the collision probability, such as if the value is greater than a threshold. The CCA threshold may be increased to increase the aggressiveness of the APs channel access and/or increase the collision probability, such as if the value is less than a threshold. The thresholds may not be the same, such as to introduce some hysteresis into the CCA adaptation change.

[0101] FIG. 12 depicts an example of a CCA adaptation that is distributed with individual STA adaption. CCA adaptation may be performed using distributed CCA adaptation. Distributed CCA Adaptation Adjustment may be described. Feedback may be from the STAs

1204/1206 to the AP 1202 and/or *vice versa*. An STA 1204/1206 may estimate collision statistics at 1210 and 1215. An STA 1204/1206 may independently set its CCA adaptation. At 1220, the STA1 1204 may send the estimated collision statistics to the AP 1202. At 1225, the STA2 1206 may send the estimated collision statistics to the AP 1202. The AP 1202 may have the collision statistics for its transmission to one or more (e.g., each) of the STAs 1204/1206 in its BSS, such as at the AP 1202. The AP 1202 may estimate the collision probability for one or more (e.g., each) STA 1204/1206. This information may be used to set the CCA adaptation value of the AP during downlink transmission. An STA 1204/1206 may have collision statistics for transmission to the AP 1202 and/or collision statistics for reception from the AP 1202, such as at the STA 1204/1206. This information may be used to set the CCA adaptation value of the STAs 1204/1206 during uplink transmission. Downlink Transmission and/or setting the CCA threshold for the AP 1202 may be described. The AP 1202 may identify the STA(s) with certain statistic(s) (e.g., the worst statistic(s), the STA with the maximum P_c , the mean of the largest n P_c s where n is a parameter, *etc.*).

[0102] The AP may adjust its CCA threshold up or down based on a value identified. The CCA threshold may be reduced to reduce the aggressiveness of the AP's channel access and/or reduce the collision probability, such as if the value identified is greater than a threshold. The CCA threshold may be increased to increase the aggressiveness of the AP's channel access and/or increase the collision probability, such as if the value is less than a threshold. The thresholds may not be the same, such as so as to introduce some hysteresis into the CCA threshold change. Uplink Transmission and/or setting the CCA threshold for one or more (e.g., each) STA may be described. At 1235, the threshold may be broadcast. The AP 1202 may set a collision probability threshold for the network. This may be done *via* a control and/or management frame, and/or *via* a beacon frame. The AP 1202 at 1240 may feedback the collision probability to the STA 1204. The STA 1204 may increase or decrease the CCA threshold at 1245. The STA 1204 may reduce CCA level to be less aggressive in transmitting, for example, if the collision probability for the STA is higher than a threshold. The STA 1204 may independently adjust its CCA threshold up or down commands, for example, based on the information and/or comparisons described herein. The AP 1202 at 1250 may feedback the collision probability to the STA 1206. The STA 1206 may increase or decrease the CCA threshold at 1255. The STA 1206 may reduce CCA level to be less aggressive in transmitting, for example, if the collision probability for the STA is higher than a threshold. The STA 1206 may independently adjust its CCA threshold up or down commands, for example, based on the information and/or comparisons described herein.

[0103] The system may increase and/or decrease CCA in a fixed increment, for example, in increasing and/or decreasing CCA threshold. The STA 1204/1206 may choose one CCA value from a set of quantized CCA threshold values, for example, in increasing and/or decreasing CCA threshold. The CCA threshold may be BSS wide and/or individual to one or more (e.g., each) STA

[0104] Collision aware contention window length adaption, *e.g.*, that may address system level adaptations to improve system performance, may be disclosed herein. The contention window may be doubled, for example, when a packet loss is experienced, such as in 802.11. Window length may be doubled irrespective of whether packet loss was caused by a collision or not. The contention window may be changed if packet loss occurs.

[0105] The AP may send a packet to a receiver. The AP may determine that an acknowledgement of the packet is not received due to a collision. The AP may change a length of a contention window by multiplying the length of the contention window by two.

[0106] The AP may send a packet to a receiver. The AP may determine that an acknowledgement of the packet is not received. The cause of the acknowledgement not being received may be unknown. The AP may change a length of a contention window based on the collision probability. The length of the contention window may be based on the collision window size.

[0107] The AP may estimate the collision probability of data transmitted by a station. The AP may determine that the estimated collision probability is higher than a second threshold. The AP may reduce, based on the estimated collision probability, a clear channel assessment threshold value for downlink transmission.

[0108] FIG. 13 depicts an example of a contention window adaptation. Performance improvements may be obtained, for example, if the contention window is changed when a collision occurs. The contention window may be kept constant, for example, when a packet loss is not due to a collision (e.g., packet failure due to AWGN noise). Collision detection may be difficult. The collision probability may be known. The contention window may be changed as a function of the collision probability (P_c). P_c may equal one and/or the CW may be changed, for example, where the transmission is a collision. P_c may equal 0 and/or the CW may be kept constant, for example, where the transmission is successful. The node may use a function of its long term collision probability to decide whether to increase the contention window, for example, where the node cannot identify if a collision event occurred.

[0109] For example, as illustrated in FIG. 13, at 1302, the transmitter may send a packet. If the transmitter does not receive an acknowledgement, at 1304, the transmitter may double the

contention window at 1306. At 1312, the transmitter may utilize an access channel with the doubled contention window, for example, when the acknowledgement is not received. If the transmitter receives an acknowledgement at 1308, the transmitter may keep the contention window the same at 1310. At 1312, the transmitter may utilize an access channel with the same contention window, for example, when the acknowledgement is received.

[0110] FIG. 14 depicts an example contention window adaptation. Contention window adaptation may be collision aware contention window adaptation. At 1402, the transmitter may send a packet to a receiver. The transmitter may identify the status of its receiver. For example, at 1404 the transmitter may receive an acknowledgement. At 1406, the transmitter may not make a change to its contention window (*e.g.*, $CW_{new} = CW$), such as if an ACK is received. At 1422, the transmitter may utilize an access channel with the same contention window, for example, when the acknowledgement is received.

[0111] At 1408, the transmitter may determine that an acknowledgement was not received. For example, at 1410, the transmitter may determine that the packet was not received due to a collision. At 1416, the transmitter may double the contention window (*e.g.*, up to a limit CW_{Max}), such as if an ACK is not received and/or the transmitter identifies that it is due to a collision:

$$CW_{new} = 2 * CW, \text{ if } CW < CW_{Max}$$

$$CW_{new} = CW, \text{ if } CW = CW_{Max}$$

[0112] At 1422, the transmitter may utilize an access channel with the doubled contention window.

[0113] At 1414, the transmitter may be unable to determine whether the packet was not received due to a collision. At 1420, the transmitter may modify the contention window, for example, based on the collision probability of the transmitter, such as if an ACK is not received and/or the transmitter cannot identify that this is due to a collision:

$$CW_{state} = \text{function}(CW_{state}, P_{col})$$

For example,

$$CW_{state} = CW_{state} + P_{col},$$

such as if

$$CW_{state} > CW_{change_threshold}, CW_{new} = 2 * CW, CW_{state} = 0$$

[0114] At 1422, the transmitter may utilize an access channel with the new contention window on the collision probability of the transmitter.

[0115] The variable $CW_{change_threshold}$ may be set to one. If $CW_{change_threshold}$ is greater than or equal to zero, then the scheme may fall back to the legacy scheme. The

transmitter may use the new contention window value to access the channel. At 1422, the transmitter may utilize an access channel with the same contention window.

[0116] At 1412, the transmitter may identify that the packet was not received due to a non-collision. At 1418, the transmitter may keep the contention window the same.

[0117] Channel access priority may be based on P_c . Channel access priority in Enhanced Distributed Channel Access (EDCA) may be a function of the CW size (CW_{max}), AIFS, the Backoff duration, or the TXOP limit, *etc.*. In channel access priority based on P_c , an 802.11e compliant station may have one or more of Arbitration InterFrame Spacing Access Categories (AIFS[AC]), Backoff Duration Access Categories (Backoff [AC] Duration), Transmit Opportunity (TXOP) limit, or minimum and maximum contention window (CW_{max}/CW_{min}), *etc.* AIFS[AC] may be the Arbitration InterFrame Spacing that changes for different Access Categories (AC), such as background traffic, best effort traffic, video traffic, or voice traffic, *etc.* Backoff[AC] duration may be the back-off duration for access categories. TXOP limit may be the maximum allowable transmit opportunity that may define the time duration during which a station may transfer data of a particular class. CW_{max}/CW_{min} may be the maximum and minimum contention window sizes. Parameters may be adapted based on the access category. Parameters may be adapted based on the collision probabilities estimated. The AIFS, backoff duration, or contention window, *etc.* limits may be increased with increasing collision probability. The TXOP limit may be reduced with increasing TXOP limits. AIFS[AC, P_c] may be the Arbitration InterFrame Spacing that changes for different Access Categories (AC) be it background traffic, best effort traffic, video traffic or voice traffic. Backoff[AC, P_c] duration may be the back-off duration for access categories. TXOP limit[AC, P_c] may be the maximum allowable transmit opportunity that may define the time duration during which a station may transfer data of a particular class. CW_{max} [AC, P_c], CW_{min} [AC, P_c] may be the maximum and minimum contention window sizes allowed.

[0118] Multi-mode collision aware transmission that may address system level adaptations to improve system performance may be disclosed herein. Switching between remediation methods for weak signal management (*e.g.*, rate adaptation and/or HARQ) and collision management (*e.g.*, CCA threshold and/or contention) and provide solutions regarding certain criteria may be disclosed herein. The relationship between collision statistics and/or packet loss may be used. P_c may be collision probability. P_l may be packet loss probability. P_{stat} may equal Prob(collision|packet loss). Bayes rule shows:

$$P_{stat} = Prob(col|loss) = \frac{Prob(loss|col) \cdot P_c}{P_l}$$

where P_e and P_l may be estimated empirically and $Prob(loss|col)$ may be estimated analytically. The changes in CW_{min} may have a minor effect on staggered collisions (*e.g.*, SC1 and/or SC2). The changes in CW_{min} may affect the direct collision probability. The changes in the CCA threshold may have an effect on the staggered collisions from hidden nodes.

[0119] The number of collisions in an environment may be reduced (*e.g.*, by CW length adaptation and/or CCA adaptation based on the collision probability, *etc.*), such as when the collision probability is high. The CW length adaptation may be used, for example, until the change in collision probability is minimal. This may indicate that the collision probability due to DC is minimized. CCA adaptation may be used to reduce the collision probability due to SC1 and/or SC2 type collisions. Link performance between the nodes (*e.g.*, rate adaptation and collision aware HARQ), such as where the collision probability is low.

[0120] Multi-mode collision aware transmission and/or parameter adaptation may be described. A central entity (*e.g.*, an AP) may indicate that the collision probability may be estimated and/or fed back. A central entity (*e.g.*, an AP) may send a multi-mode threshold to some and/or each of the nodes in the network. Transmitter estimated collision probability estimation may occur. A central entity (*e.g.*, an AP) may send a start-of-measurement packet to indicate to STAs that a collision probability measurement period may begin. Nodes may send out information at a minimum rate (*e.g.*, indicated by a central entity and/or AP) to lessen the effect of errors, for example, due to weak signal and/or or poor channels, such as during a measurement period. The minimum rate may be network wide and/or node specific. A central entity (*e.g.*, an AP) may indicate desire to measure staggered collision probability in start-of-measurement frame. Nodes may use CW_{max} to minimize errors due to direct collisions, for example, with this flag set, such as during measurement period. A central entity (*e.g.*, an AP) may send an end-of-measurement packet to indicate to STAs that the measurement period is at and/or near an end. The central entity (*e.g.*, an AP) may send Busy-Idle packet indicating time slots that the central entity was busy and/or idle, for example, to enable STAs to estimate P_c locally. Nodes may estimate the metric (*e.g.*, P , P_c , P_l and/or P_{stat} , W). The STAs may feed back the metric (*e.g.*, P , P_c , P_l and/or P_{stat} , W) to the central entity (*e.g.*, AP). The central entity (*e.g.*, AP) may estimate a multi-mode threshold for the network. The threshold may be estimated by a central controller for multiple APs, for example, based on their interaction with each other. The threshold may be implicitly set by a specification. A receiver estimated collision probability estimation may occur. The receiver may estimate the collision probability based on one or more packets transmitted to the receiver. Receivers (*e.g.*, STAs) may feed back a metric (*e.g.*, P , P_c , P_l and/or P_{stat} , W) to the central entity (*e.g.*, AP) and the central entity estimates a multi-mode

threshold for the network. The threshold may be estimated by a central controller for multiple APs, for example, based on their interaction with each other. The threshold may be implicitly set by a specification.

[0121] Collision management may be utilized, for example, if the metric (P) is greater than the multi-mode threshold. STA(S) may store a variable (*e.g.*, ΔP) that may indicate the change in the collision metric (*e.g.*, P) based on a previous adaptation. The value of this variable may determine, for example, if the contention window and/or the CCA threshold may be adapted. Larger than normal changes in the variable may indicate the presence of direct collisions (*e.g.*, implying the need for a change in the CW size). Small changes in the variable that may be coupled with a large value of P_{stat} or P_{col} may indicate the presence of staggered collisions and/or hidden nodes (*e.g.*, implying the need for a change in the CCA threshold). Direct collisions may be present and/or contention window adaptation may be performed, for example, when (ΔP) is greater than $\Delta P_{threshold}$ and/or (P) is greater than $P_{multimode_threshold}$. The collision window may be adapted by collision window modification (*e.g.*, $CW_{new} = CW \times 2$, if no ACK received and/or collision aware collision window adaptation described herein). Collisions may be due to staggered collisions (*e.g.*, hidden nodes) and/or CCA threshold adaptation may be performed, for example, if (ΔP) is less than $\Delta P_{threshold}$ and/or (P) is greater than $P_{multimode_threshold}$. The transmitter may adapt $CCA_{threshold}$. The CCA threshold may be adapted as described herein.

[0122] Weak signal management may be utilized, for example, if (P) is less than the multi-mode threshold. The transmitter may use the value of (P) to assist in selecting the MCS to be used, such as in collision aware rate adaptation. The receiver may use the value of (P) to assist in the HARQ combination of the retransmitted signals. This may be by collision aware log likelihood estimation and HARQ combining, immediate collision aware HARQ combining, statistical collision aware HARQ combining, hybrid collision aware HARQ combining, exhaustive collision aware HARQ combining, *etc.* In collision aware log likelihood estimation and HARQ combining, the collision probability may be used to estimate the log-likelihood of the received bits for use in the channel-code decoder. In immediate collision aware HARQ combining, the received signal may be decoded multiple times with or without HARQ combining to estimate, for example, if HARQ combining is needed. The received signal may be decoded without HARQ combining, and if it fails, it may be decoded with HARQ combining. The known properties of the past collision event(s) may be used to determine whether past information is combined in the HARQ buffer or not (*e.g.*, if the x -th received signal was received with a collision event, and the energy in the data portion of the received signal is much higher

than that of the preamble, the x -th received signal may not be added to the HARQ buffer). In statistical collision aware HARQ combining, the received signal may be decoded multiple times with or without HARQ combining, for example, to estimate if HARQ combining may be needed. The received signal may be decoded without HARQ combining, and if it fails, it may be decoded with HARQ combining. In the HARQ combining, the past information may be weighted and/or added to the HARQ buffer based on the collision statistics (P). In hybrid collision aware HARQ combining, the received signal may be decoded one or more times with or without HARQ combining to estimate, for example, if HARQ combining is needed. The HARQ combining may use both immediate and/or statistical weighting of the past information based on the collision event(s) associated with them. In exhaustive collision aware HARQ combining, an exhaustive combination of all retransmissions may be performed based on immediate and/or statistical information. The received signal may be HARQ-combined with previous transmissions. The transmitter and/or receiver based techniques may be combined by the use of incremental redundancy HARQ combining to enable combining. The redundancy version of the code and/or the MCS used may be signaled by the transmitter to enable the receiver to combine the multiple retransmitted signals. The transmitter and/or receiver techniques may be implemented in a disjoint manner. The transmitter may adapt MCS and Nss. The HARQ may be implemented, for example, on failure of the rate adaptation. The transmitter may adapt MCS and Nss after some and/or all retries have failed. Collision aware rate adaptation may be interleaved with collision aware HARQ combining.

[0123] The transmitter may adapt the contention window size first, then CCA level, for example, with collision management. The transmitter may adapt the CCA level first, then contention window size. This may be implementation dependent. The transmitter may adapt according to the hardware sensitivity and/or BSS capability.

[0124] The multi-mode threshold may be a fixed value. The multi-mode threshold may be adjust, for example, based on the current mode that the system is in (*e.g.*, collision management mode, weak signal management mode, *etc.*). The adjustable threshold may be needed to introduce hysteresis and/or prevent rapid toggling between both modes. $\text{multimode_threshold}_{\text{collision_management}}$ may be less than $\text{multimode_threshold}_{\text{weak_signal_management}}$.

[0125] The transmitter may adapt MCS. The transmitter may adapt Nss. The transmitter may adapt HARQ retransmissions. For example, the transmitter may adapt MCS and Nss first, and then HARQ retransmission, and/or adapt MCS, Nss and HARQ jointly, for example, in weak signal management. The transmitter may prepare HARQ retransmission first and then adapt MSC and Nss. Transmitter adaptation may be implementation dependent and/or depend on

different optimization criteria. The transmitter may choose HARQ, such as if the transmitter intends to maximize the MAC throughput. The transmitter may choose to lower MCS and Nss, such as if the transmitter intends to provide more reliable transmission.

[0126] FIG. 15A is a diagram of an example communications system 1500 in which one or more disclosed embodiments may be implemented. The communications system 1500 may be a multiple access system that provides content, such as voice, data, video, messaging, broadcast, *etc.*, to multiple wireless users. The communications system 1500 may enable multiple wireless users to access such content through the sharing of system resources, including wireless bandwidth. For example, the communications systems 1500 may employ one or more channel access methods, such as code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal FDMA (OFDMA), single-carrier FDMA (SC-FDMA), and the like.

[0127] As shown in FIG. 15A, the communications system 1500 may include at least one wireless transmit/receive unit (WTRU), such as a plurality of WTRUs, for instance WTRUs 1502a, 1502b, 1502c, and 1502d, a radio access network (RAN) 1504, a core network 1506, a public switched telephone network (PSTN) 1508, the Internet 1510, and other networks 1512, though it should be appreciated that the disclosed embodiments contemplate any number of WTRUs, base stations, networks, and/or network elements. One or more (e.g., each) of the WTRUs 1502a, 1502b, 1502c, 1502d may be any type of device configured to operate and/or communicate in a wireless environment. By way of example, the WTRUs 1502a, 1502b, 1502c, 1502d may be configured to transmit and/or receive wireless signals and may include user equipment (UE), a mobile station, a fixed or mobile subscriber unit, a pager, a cellular telephone, a personal digital assistant (PDA), a smartphone, a laptop, a netbook, a personal computer, a wireless sensor, consumer electronics, and the like.

[0128] The communications systems 1500 may also include a base station 1514a and a base station 1514b. Each of the base stations 1514a, 1514b may be any type of device configured to wirelessly interface with at least one of the WTRUs 1502a, 1502b, 1502c, 1502d to facilitate access to one or more communication networks, such as the core network 1506, the Internet 1510, and/or the networks 1512. By way of example, the base stations 1514a, 1514b may be a base transceiver station (BTS), a Node-B, an eNode B, a Home Node B, a Home eNode B, a site controller, an access point (AP), a wireless router, and the like. While the base stations 1514a, 1514b are each depicted as a single element, it should be appreciated that the base stations 1514a, 1514b may include any number of interconnected base stations and/or network elements.

[0129] The base station 1514a may be part of the RAN 1504, which may also include other base stations and/or network elements (not shown), such as a base station controller (BSC), a radio network controller (RNC), relay nodes, *etc.* The base station 1514a and/or the base station 1514b may be configured to transmit and/or receive wireless signals within a particular geographic region, which may be referred to as a cell (not shown). The cell may further be divided into cell sectors. For example, the cell associated with the base station 1514a may be divided into three sectors. Thus, in one embodiment, the base station 1514a may include three transceivers, *e.g.*, one for each sector of the cell. In another embodiment, the base station 1514a may employ multiple-input multiple output (MIMO) technology and, therefore, may utilize multiple transceivers for each sector of the cell.

[0130] The base stations 1514a, 1514b may communicate with one or more of the WTRUs 1502a, 1502b, 1502c, 1502d over an air interface 1516, which may be any suitable wireless communication link (*e.g.*, radio frequency (RF), microwave, infrared (IR), ultraviolet (UV), visible light, *etc.*). The air interface 1516 may be established using any suitable radio access technology (RAT).

[0131] More specifically, as noted above, the communications system 1500 may be a multiple access system and may employ one or more channel access schemes, such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA, and the like. For example, the base station 1514a in the RAN 1504 and the WTRUs 1502a, 1502b, 1502c may implement a radio technology such as Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (UTRA), which may establish the air interface 1516 using wideband CDMA (WCDMA). WCDMA may include communication protocols such as High-Speed Packet Access (HSPA) and/or Evolved HSPA (HSPA+). HSPA may include High-Speed Downlink Packet Access (HSDPA) and/or High-Speed Uplink Packet Access (HSUPA).

[0132] In another embodiment, the base station 1514a and the WTRUs 1502a, 1502b, 1502c may implement a radio technology such as Evolved UMTS Terrestrial Radio Access (E-UTRA), which may establish the air interface 1516 using Long Term Evolution (LTE) and/or LTE-Advanced (LTE-A).

[0133] In other embodiments, the base station 1514a and the WTRUs 1502a, 1502b, 1502c may implement radio technologies such as IEEE 802.16 (*e.g.*, Worldwide Interoperability for Microwave Access (WiMAX)), CDMA2000, CDMA2000 1X, CDMA2000 EV-DO, Interim Standard 2000 (IS-2000), Interim Standard 95 (IS-95), Interim Standard 856 (IS-856), Global System for Mobile communications (GSM), Enhanced Data rates for GSM Evolution (EDGE), GSM EDGE (GERAN), and the like.

[0134] The base station 1514b in FIG. 15A may comprise a wireless router, Home Node B, Home eNode B, or access point, for example, and may utilize any suitable RAT for facilitating wireless connectivity in a localized area, such as a place of business, a home, a vehicle, a campus, and the like. In one embodiment, the base station 1514b and the WTRUs 1502c, 1502d may implement a radio technology such as IEEE 802.11 to establish a wireless local area network (WLAN). In another embodiment, the base station 1514b and the WTRUs 1502c, 1502d may implement a radio technology such as IEEE 802.15 to establish a wireless personal area network (WPAN). In yet another embodiment, the base station 1514b and the WTRUs 1502c, 1502d may utilize a cellular-based RAT (*e.g.*, WCDMA, CDMA2000, GSM, LTE, LTE-A, *etc.*) to establish a picocell or femtocell. As shown in FIG. 15A, the base station 1514b may have a direct connection to the Internet 1510. Thus, the base station 1514b may not be required to access the Internet 1510 via the core network 1506.

[0135] The RAN 1504 may be in communication with the core network 1506, which may be any type of network configured to provide voice, data, applications, and/or voice over internet protocol (VoIP) services to one or more of the WTRUs 1502a, 1502b, 1502c, 1502d. For example, the core network 1506 may provide call control, billing services, mobile location-based services, pre-paid calling, Internet connectivity, video distribution, *etc.*, and/or perform high-level security functions, such as user authentication. Although not shown in FIG. 15A, it should be appreciated that the RAN 1504 and/or the core network 1506 may be in direct or indirect communication with other RANs that employ the same RAT as the RAN 1504 or a different RAT. For example, in addition to being connected to the RAN 1504, which may be utilizing an E-UTRA radio technology, the core network 1506 may also be in communication with another RAN (not shown) employing a GSM radio technology.

[0136] The core network 1506 may also serve as a gateway for the WTRUs 1502a, 1502b, 1502c, 1502d to access the PSTN 1508, the Internet 1510, and/or other networks 1512. The PSTN 1508 may include circuit-switched telephone networks that provide plain old telephone service (POTS). The Internet 1510 may include a global system of interconnected computer networks and devices that use common communication protocols, such as the transmission control protocol (TCP), user datagram protocol (UDP) and the internet protocol (IP) in the TCP/IP internet protocol suite. The networks 1512 may include wired or wireless communications networks owned and/or operated by other service providers. For example, the networks 1512 may include another core network connected to one or more RANs, which may employ the same RAT as the RAN 1504 or a different RAT.

[0137] Some or all of the WTRUs 1502a, 1502b, 1502c, 1502d in the communications system 1500 may include multi-mode capabilities, e.g., the WTRUs 1502a, 1502b, 1502c, 1502d may include multiple transceivers for communicating with different wireless networks over different wireless links. For example, the WTRU 1502c shown in FIG. 15A may be configured to communicate with the base station 1514a, which may employ a cellular-based radio technology, and with the base station 1514b, which may employ an IEEE 802 radio technology.

[0138] FIG. 15B is a system diagram of an example WTRU 1502. As shown in FIG. 15B, the WTRU 1502 may include a processor 1518, a transceiver 1520, a transmit/receive element 1522, a speaker/microphone 1524, a keypad 1526, a display/touchpad 1528, non-removable memory 1530, removable memory 1532, a power source 1534, a global positioning system (GPS) chipset 1536, and other peripherals 1538. It should be appreciated that the WTRU 1502 may include any sub-combination of the foregoing elements while remaining consistent with an embodiment.

[0139] The processor 1518 may comprise a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a microcontroller, Application Specific Integrated Circuits (ASICs), Field Programmable Gate Array (FPGAs) circuits, any other type of integrated circuit (IC), a state machine, and the like. The processor 1518 may perform signal coding, data processing, power control, input/output processing, and/or any other functionality that enables the WTRU 1502 to operate in a wireless environment. The processor 1518 may be coupled to the transceiver 1520, which may be coupled to the transmit/receive element 1522. While FIG. 15B depicts the processor 1518 and the transceiver 1520 as separate components, it should be appreciated that the processor 1518 and the transceiver 1520 may be integrated together in an electronic package or chip.

[0140] The transmit/receive element 1522 may be configured to transmit signals to, or receive signals from, a base station (e.g., the base station 1514a) over the air interface 1516. For example, in one embodiment, the transmit/receive element 1522 may be an antenna configured to transmit and/or receive RF signals. In another embodiment, the transmit/receive element 1522 may be an emitter/detector configured to transmit and/or receive IR, UV, or visible light signals, for example. In yet another embodiment, the transmit/receive element 1522 may be configured to transmit and receive both RF and light signals. It should be appreciated that the transmit/receive element 1522 may be configured to transmit and/or receive any combination of wireless signals.

[0141] In addition, although the transmit/receive element 1522 is depicted in FIG. 15B as a single element, the WTRU 1502 may include any number of transmit/receive elements 1522.

More specifically, the WTRU 1502 may employ MIMO technology. Thus, in one embodiment, the WTRU 1502 may include two or more transmit/receive elements 1522 (*e.g.*, multiple antennas) for transmitting and receiving wireless signals over the air interface 1516.

[0142] The transceiver 1520 may be configured to modulate the signals that are to be transmitted by the transmit/receive element 1522 and to demodulate the signals that are received by the transmit/receive element 1522. As noted above, the WTRU 1502 may have multi-mode capabilities. Thus, the transceiver 1520 may include multiple transceivers for enabling the WTRU 1502 to communicate via multiple RATs, such as UTRA and IEEE 802.11, for example.

[0143] The processor 1518 of the WTRU 1502 may be coupled to, and may receive user input data from, the speaker/microphone 1524, the keypad 1526, and/or the display/touchpad 1528 (*e.g.*, a liquid crystal display (LCD) display unit or organic light-emitting diode (OLED) display unit). The processor 1518 may also output user data to the speaker/microphone 1524, the keypad 1526, and/or the display/touchpad 1528. In addition, the processor 1518 may access information from, and store data in, any type of suitable memory, such as the non-removable memory 1530 and/or the removable memory 1532. The non-removable memory 1530 may include random-access memory (RAM), read-only memory (ROM), a hard disk, or any other type of memory storage device. The removable memory 1532 may include a subscriber identity module (SIM) card, a memory stick, a secure digital (SD) memory card, and the like. In other embodiments, the processor 1518 may access information from, and store data in, memory that is not physically located on the WTRU 1502, such as on a server or a home computer (not shown).

[0144] The processor 1518 may receive power from the power source 1534, and may be configured to distribute and/or control the power to the other components in the WTRU 1502. The power source 1534 may be any suitable device for powering the WTRU 1502. For example, the power source 1534 may include one or more dry cell batteries (*e.g.*, nickel-cadmium (NiCd), nickel-zinc (NiZn), nickel metal hydride (NiMH), lithium-ion (Li-ion), *etc.*), solar cells, fuel cells, and the like.

[0145] The processor 1518 may also be coupled to the GPS chipset 1536, which may be configured to provide location information (*e.g.*, longitude and latitude) regarding the current location of the WTRU 1502. In addition to, or in lieu of, the information from the GPS chipset 1536, the WTRU 1502 may receive location information over the air interface 1516 from a base station (*e.g.*, base stations 1514a, 1514b) and/or determine its location based on the timing of the signals being received from two or more nearby base stations. It should be appreciated that the WTRU 1502 may acquire location information by way of any suitable location-determination method while remaining consistent with an embodiment.

[0146] The processor 1518 may further be coupled to other peripherals 1538, which may include one or more software and/or hardware modules that provide additional features, functionality and/or wired or wireless connectivity. For example, the peripherals 1538 may include an accelerometer, an e-compass, a satellite transceiver, a digital camera (for photographs or video), a universal serial bus (USB) port, a vibration device, a television transceiver, a hands free headset, a Bluetooth® module, a frequency modulated (FM) radio unit, a digital music player, a media player, a video game player module, an Internet browser, and the like.

[0147] Although features and elements are described above in particular combinations, one of ordinary skill in the art will appreciate that each feature or element may be used alone or in any combination with the other features and elements. Other than the 802.11 protocols described herein, the features and elements described herein may be applicable to other wireless systems. Although the features and elements described herein may have been described for uplink operation, the methods and procedures may be applied to downlink operation. Although SIFS may have been used herein to indicate various inter frame spacing, other inter frame spacing, e.g., RIFS or other agreed time interval may be applied. In addition, the methods described herein may be implemented in a computer program, software, or firmware incorporated in a computer-readable medium for execution by a computer or processor. Examples of computer-readable media include electronic signals (transmitted over wired or wireless connections) and computer-readable storage media. Examples of computer-readable storage media include, but are not limited to, a read only memory (ROM), a random access memory (RAM), a register, cache memory, semiconductor memory devices, magnetic media such as internal hard disks and removable disks, magneto-optical media, optical media such as CD-ROM disks, and digital versatile disks (DVDs). A processor in association with software may be used to implement a radio frequency transceiver for use in a WTRU, WTRU, terminal, base station, RNC, or any host computer.

What is Claimed:

1. An access point (AP), comprising:
a memory; and
a processor configured to:
 measure a collision probability or a change in collision probability;
 compare the measured collision probability or change in collision probability to a threshold;
 determine that the measured collision probability or change in collision probability is higher than the threshold; and
 select a collision mitigation transmission mode, wherein the collision mitigation mode comprises a contention window adaptation or a clear channel assessment adaptation.
2. The AP of claim 1, wherein the contention window adaptation comprises the processor being further configured to:
 send a packet to a receiver;
 determine that an acknowledgement of the packet is not received due to a collision; and
 change a length of a contention window by multiplying the length of the contention window by two.
3. The AP of claim 1, wherein the contention window adaptation comprises the processor being further configured to:
 send a packet to a receiver;
 determine that an acknowledgement of the packet is not received, wherein the cause of the acknowledgement not being received is unknown; and
 change a length of a contention window based on the collision probability.
4. The AP of claim 3, wherein the length of the contention window is based on the collision window size.

5. The AP of claim 1, wherein the clear channel assessment adaptation comprises the processor being further configured to:
 - estimate the collision probability of data transmitted by a station;
 - determine that the estimated collision probability is higher than a second threshold;
 - reduce, based on the estimated collision probability, a clear channel assessment threshold value for downlink transmission.
6. The AP of claim 1, wherein the clear channel assessment adaptation comprises the processor being further configured to:
 - estimate the collision probability of data transmitted by a station;
 - determine that the estimated collision probability is lower than a second threshold;
 - increase, based on the estimated collision probability, a clear channel assessment threshold value for downlink transmission.
7. The AP of claim 1, wherein the clear channel assessment adaptation comprises the processor being further configured to:
 - estimate the collision probability of data received by a station;
 - determine that the estimated collision probability is higher than a second threshold;
 - reduce, based on the estimated collision probability, a clear channel assessment threshold value for uplink transmission.
8. The AP of claim 1, wherein the clear channel assessment adaptation comprises the processor being further configured to:
 - estimate the collision probability of data received by a station;
 - determine that the estimated collision probability is lower than a second threshold;
 - increase, based on the estimated collision probability, a clear channel assessment threshold value for uplink transmission.
9. An access point (AP), comprising:
 - a memory; and

a processor configured to:

- measure at least one of a collision probability or a change in collision probability;
- compare the measured at least one of the collision probability or the change in collision probability to a threshold;
- determine that the measured at least one of the collision probability or the change in collision probability lower than the threshold; and
- select a weak channel mitigation transmission mode, wherein the weak channel mitigation transmission mode is collision aware HARQ combining or collision aware MCS adaptation.

10. A method, comprising:

- measuring at least one of a collision probability or a change in collision probability;
- comparing the measured at least one of the collision probability or the change in collision probability to a threshold;
- determining that the measured at least one of the collision probability or the change in collision probability higher than the threshold; and
- selecting a collision mitigation transmission mode, wherein the collision mitigation mode comprises a contention window adaptation or a clear channel assessment adaptation.

11. The method claim 10, wherein the contention window adaptation comprises the method further comprising:

- sending a packet to a receiver;
- determining that an acknowledgement of the packet is not received due to a collision; and
- changing a length of a contention window by multiplying the length of the contention window by two.

12. The method claim 10, wherein the contention window adaptation comprises the method further comprising:

- sending a packet to a receiver;
- determining that an acknowledgement of the packet is not received, wherein the cause of the acknowledgement not being received is unknown; and

changing a length of a contention window based on the collision probability.

13. The method of claim 12, wherein the length of the contention window is based on the collision window size.
14. The method claim 10, wherein the clear channel assessment adaptation comprises the method further comprising:
 - estimating the collision probability of data transmitted by a station;
 - determining that the estimated collision probability is higher than a second threshold;
 - reducing, based on the estimated collision probability, a clear channel assessment threshold value for downlink transmission.
15. The method claim 10, wherein the clear channel assessment adaptation comprises the method further comprising:
 - estimating the collision probability of data transmitted by a station;
 - determining that the estimated collision probability is lower than a second threshold;
 - increasing, based on the estimated collision probability, a clear channel assessment threshold value for downlink transmission.
16. The method claim 10, wherein the clear channel assessment adaptation comprises the method further comprising:
 - estimating the collision probability of data received by a station;
 - determining that the estimated collision probability is higher than a second threshold;
 - reducing, based on the estimated collision probability, a clear channel assessment threshold value for uplink transmission.
17. The method claim 10, wherein the clear channel assessment adaptation comprises the method further comprising:
 - estimating the collision probability of data received by a station;
 - determining that the estimated collision probability is lower than a second threshold;

increasing, based on the estimated collision probability, a clear channel assessment threshold value for uplink transmission.

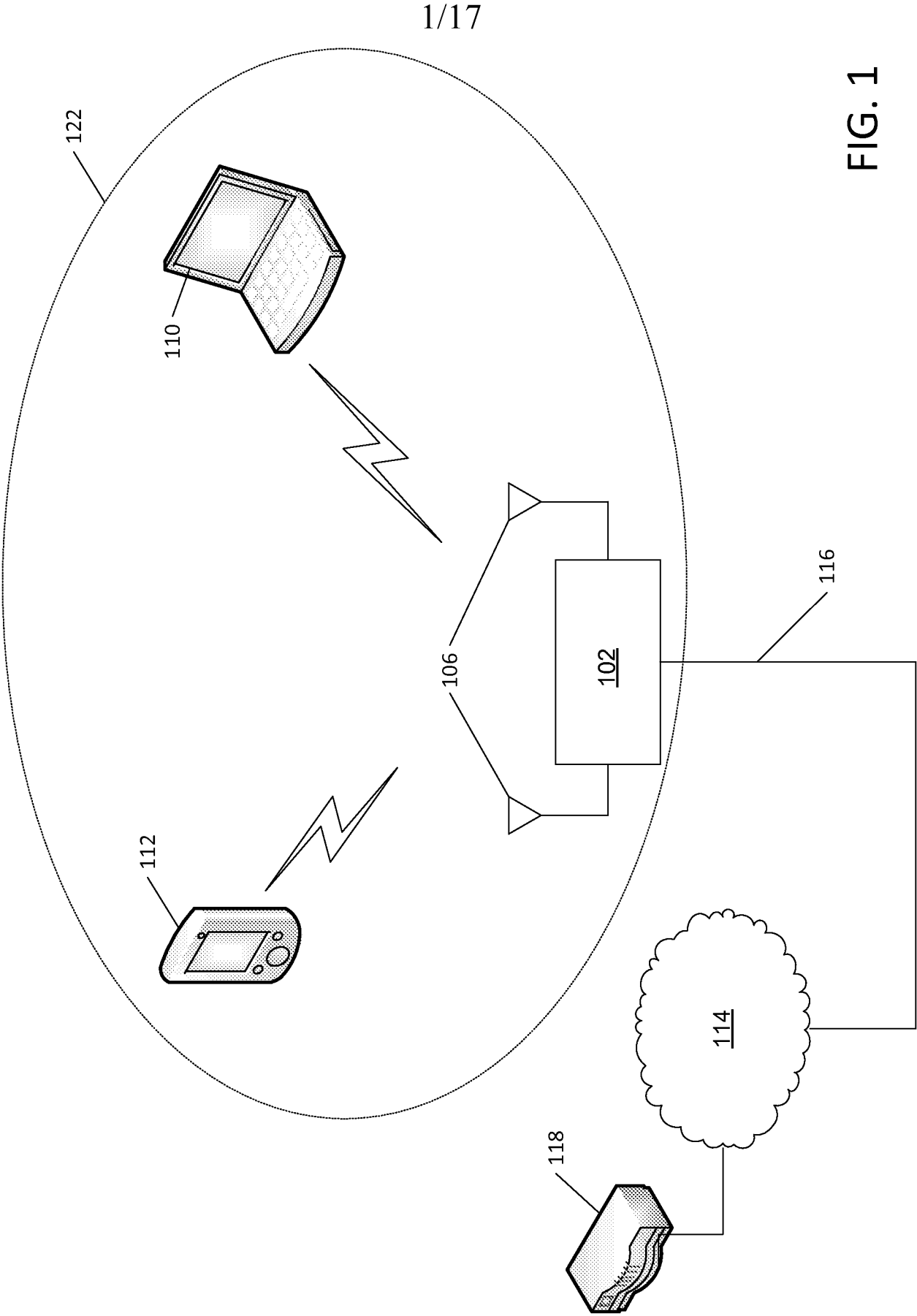


FIG. 1

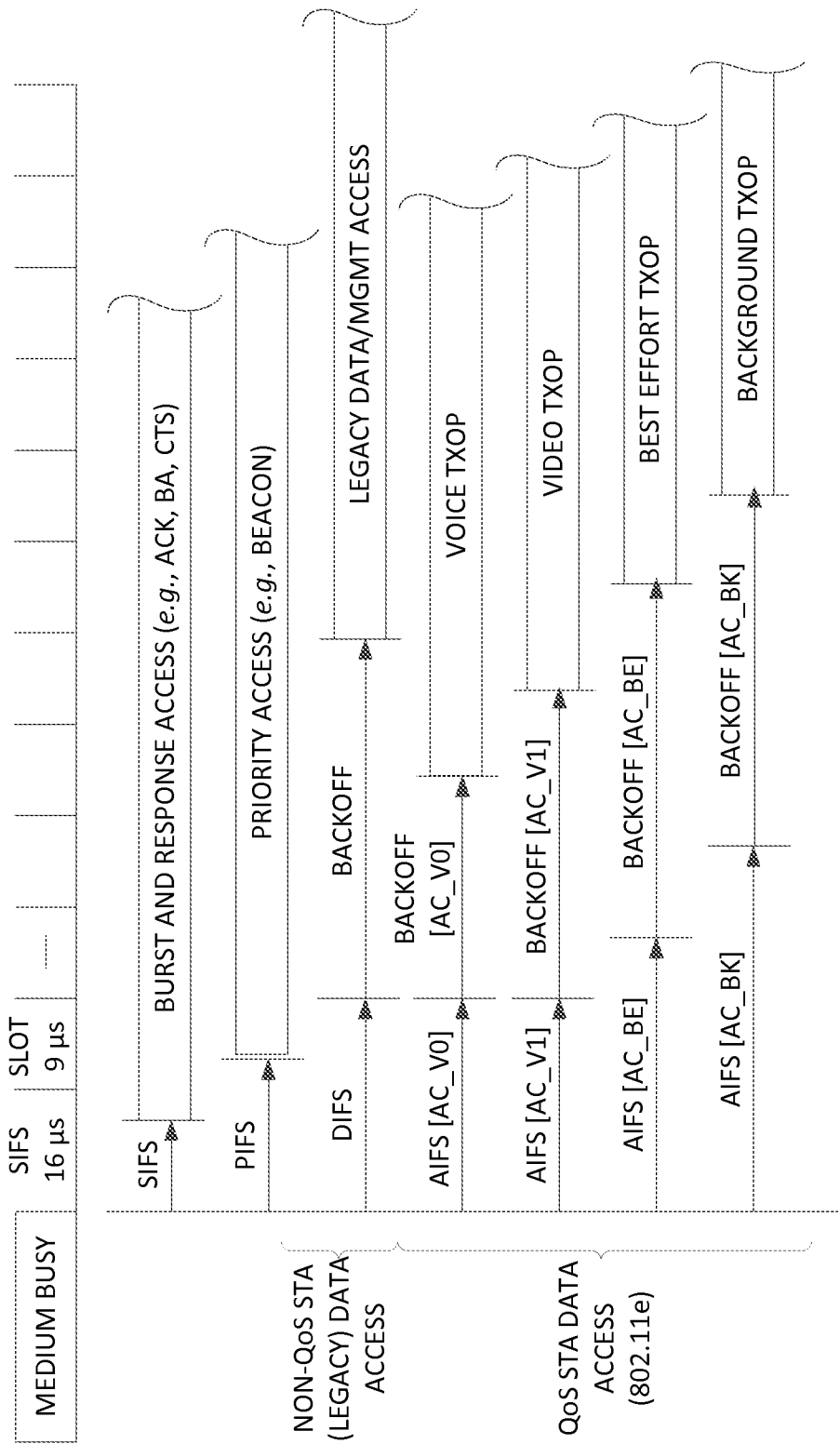


FIG. 2

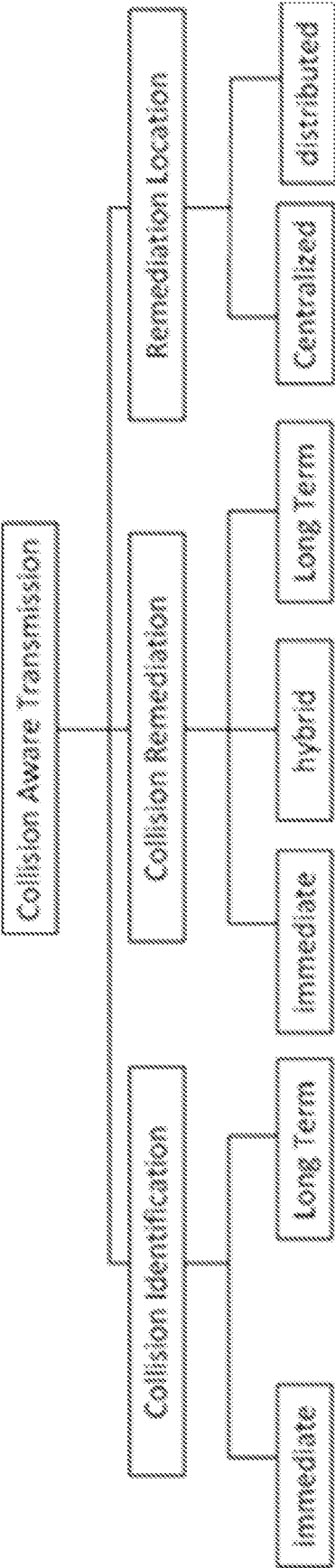


FIG. 3

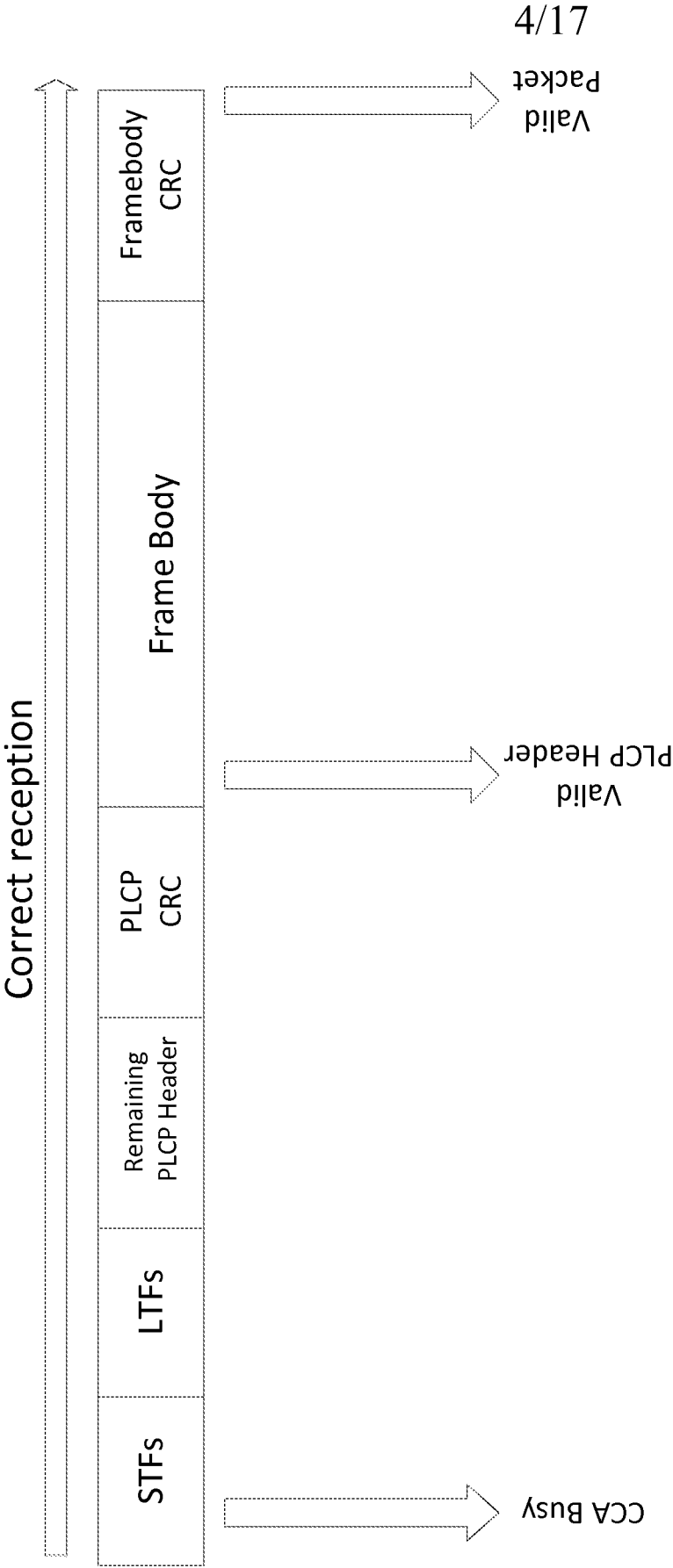


FIG. 4

500

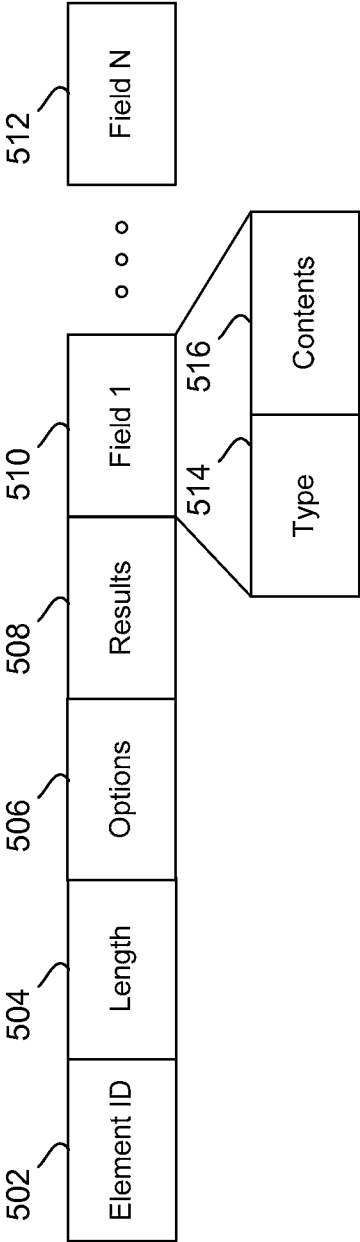


FIG. 5

600

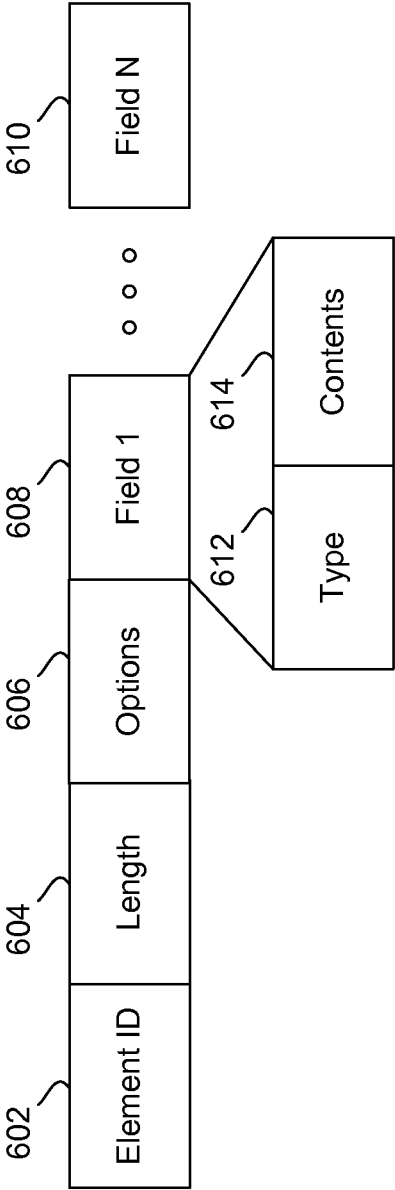


FIG. 6

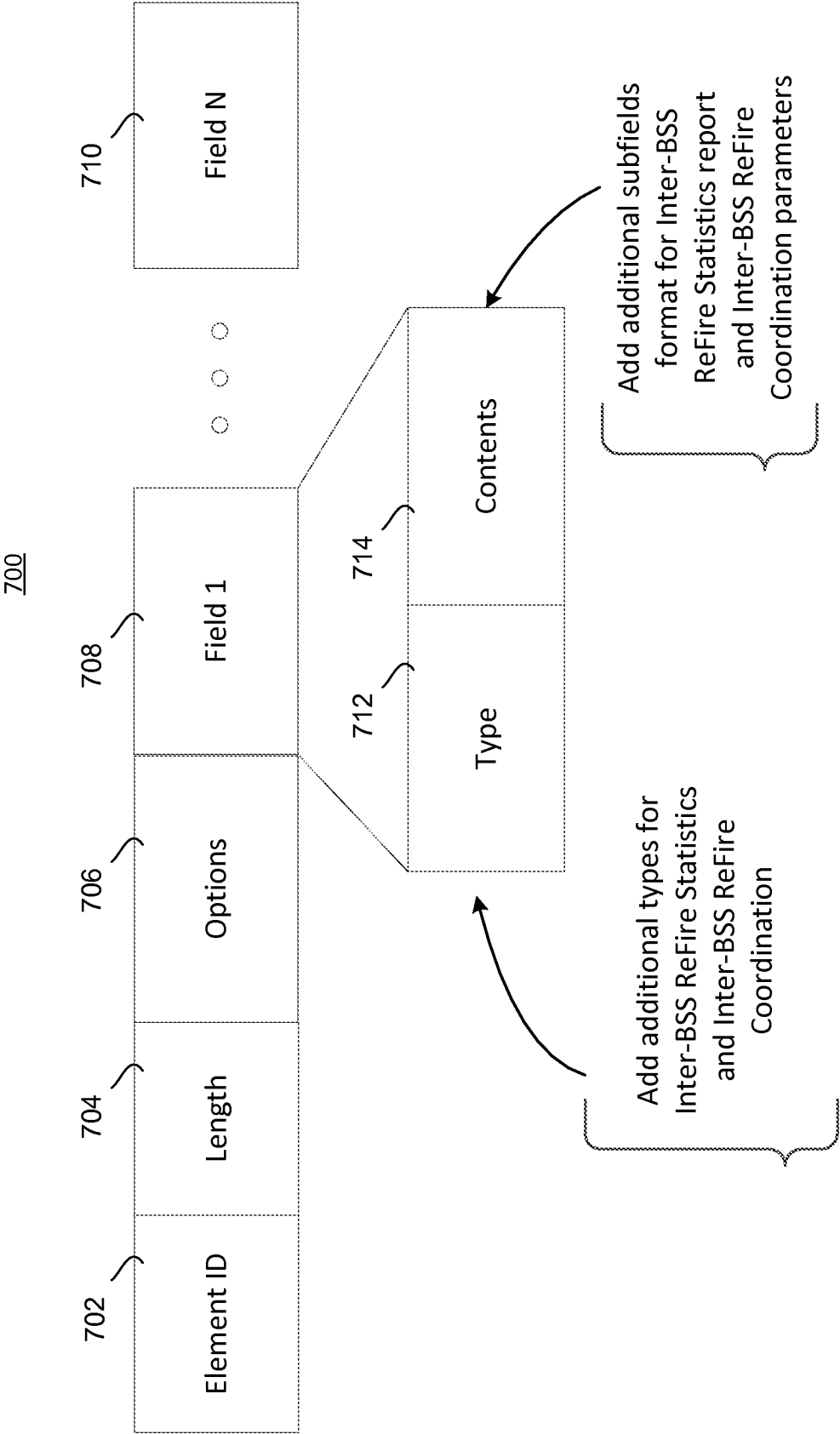


FIG. 7

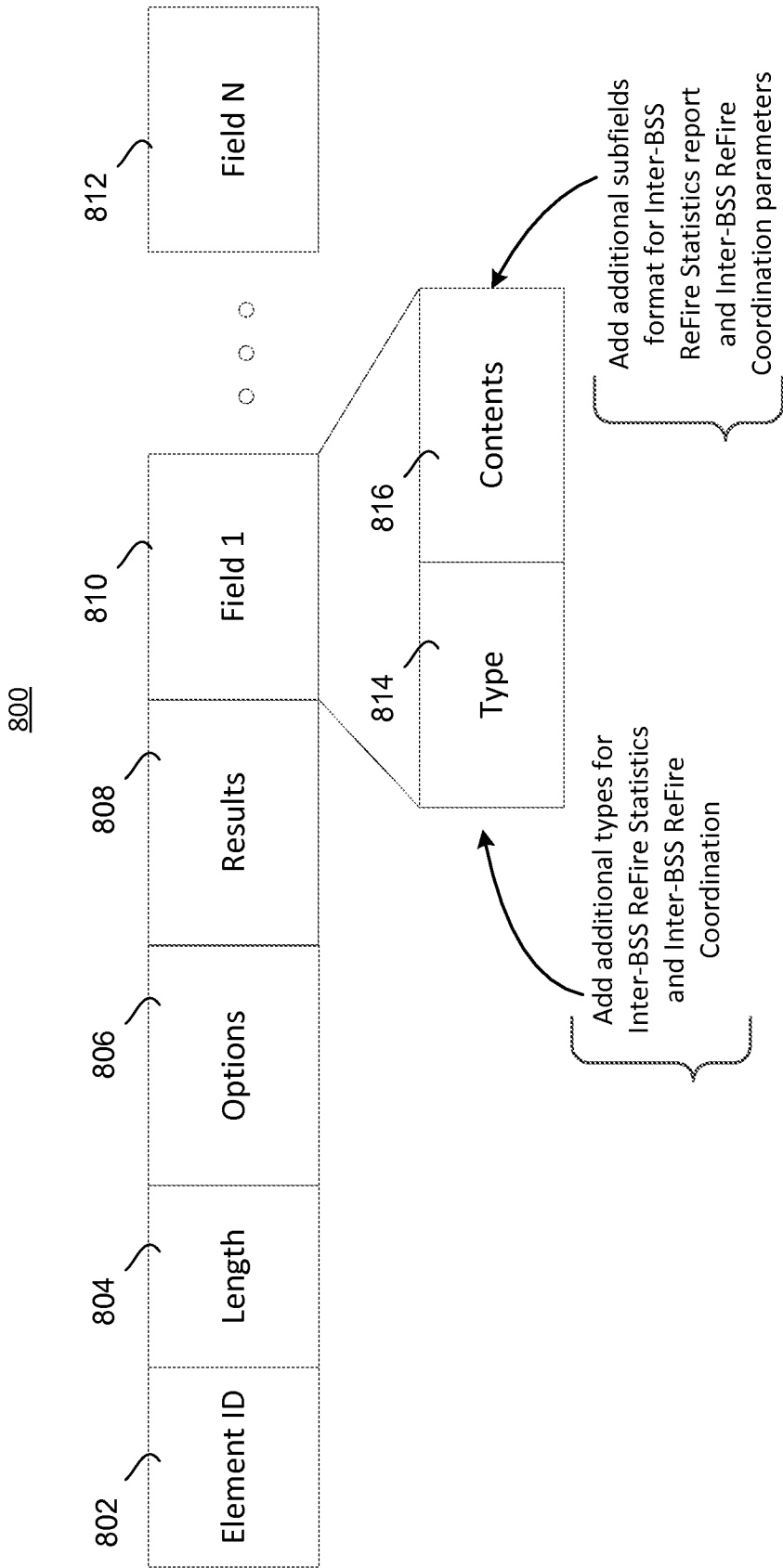


FIG. 8

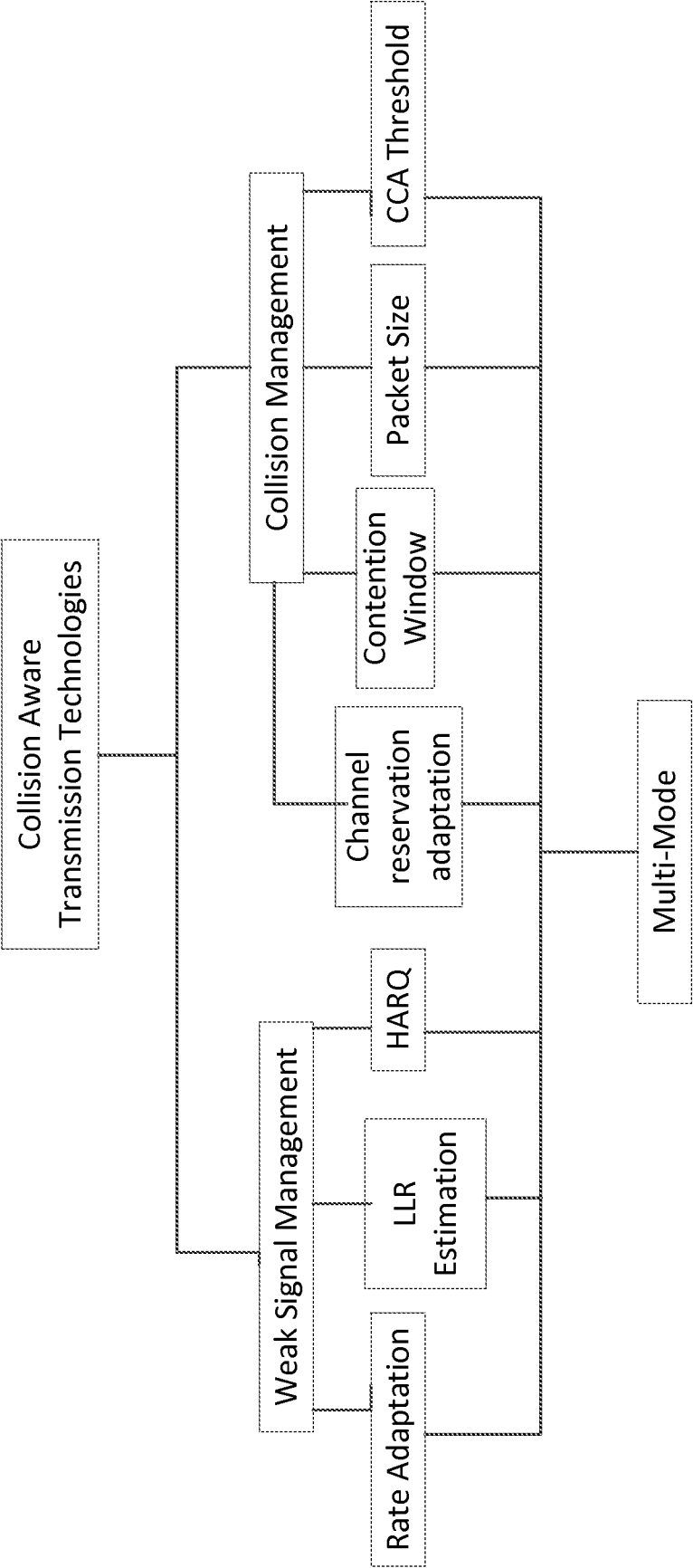


FIG. 9

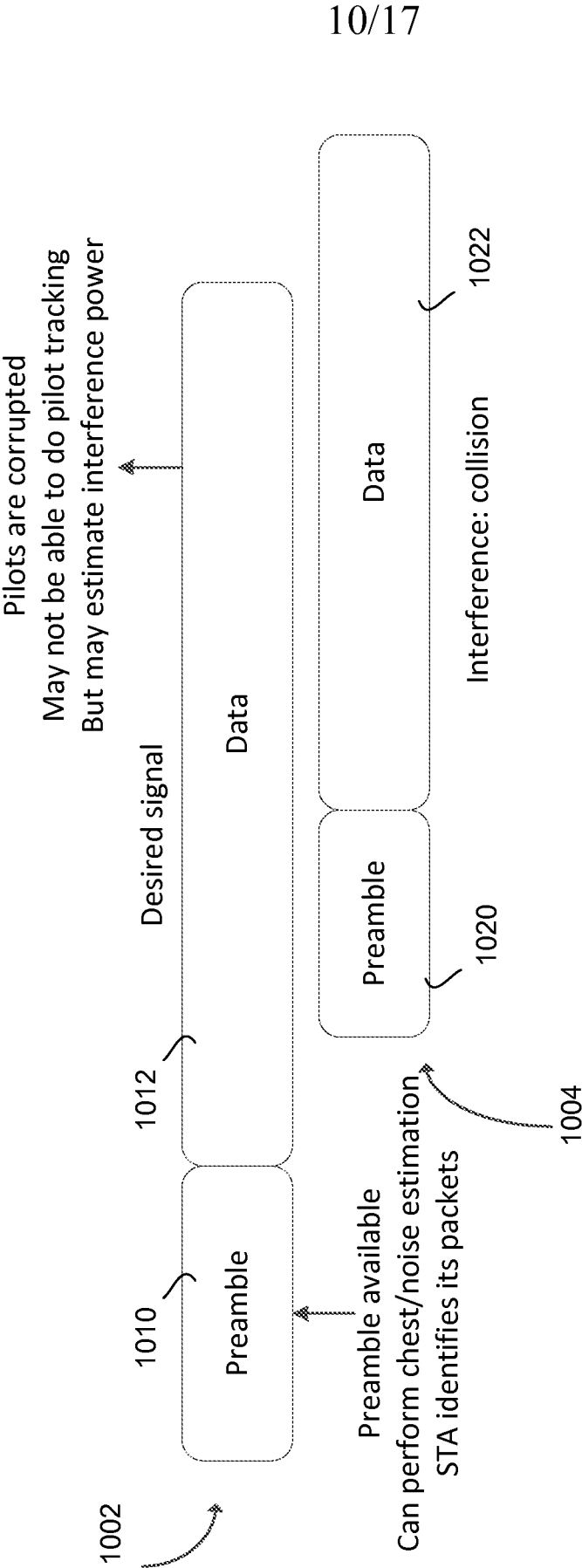


FIG. 10A

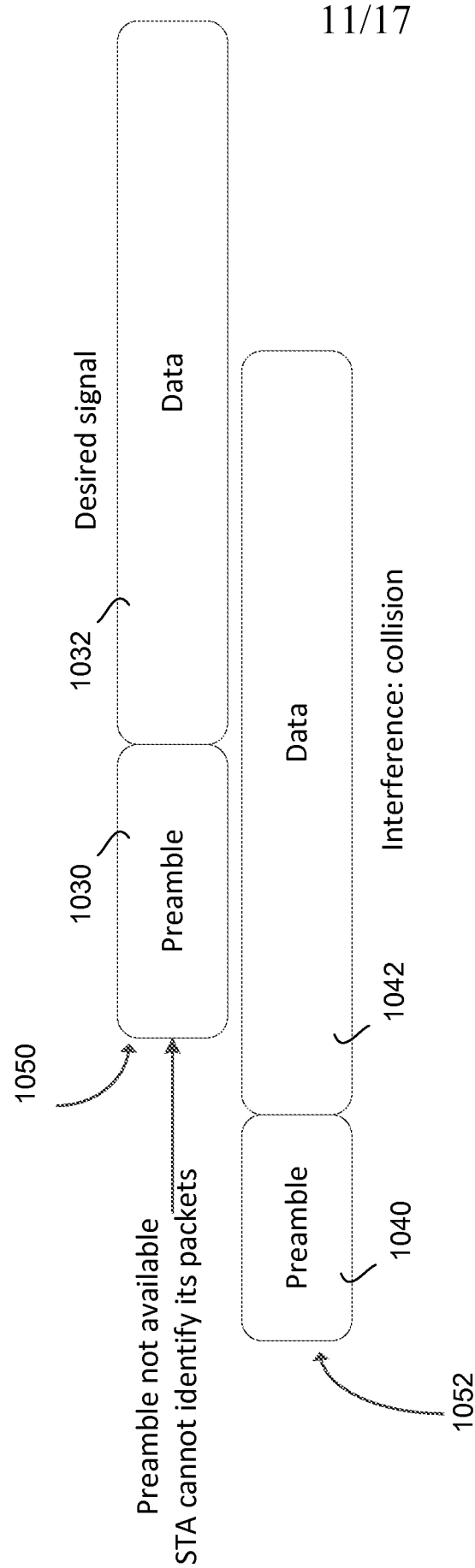


FIG. 10B

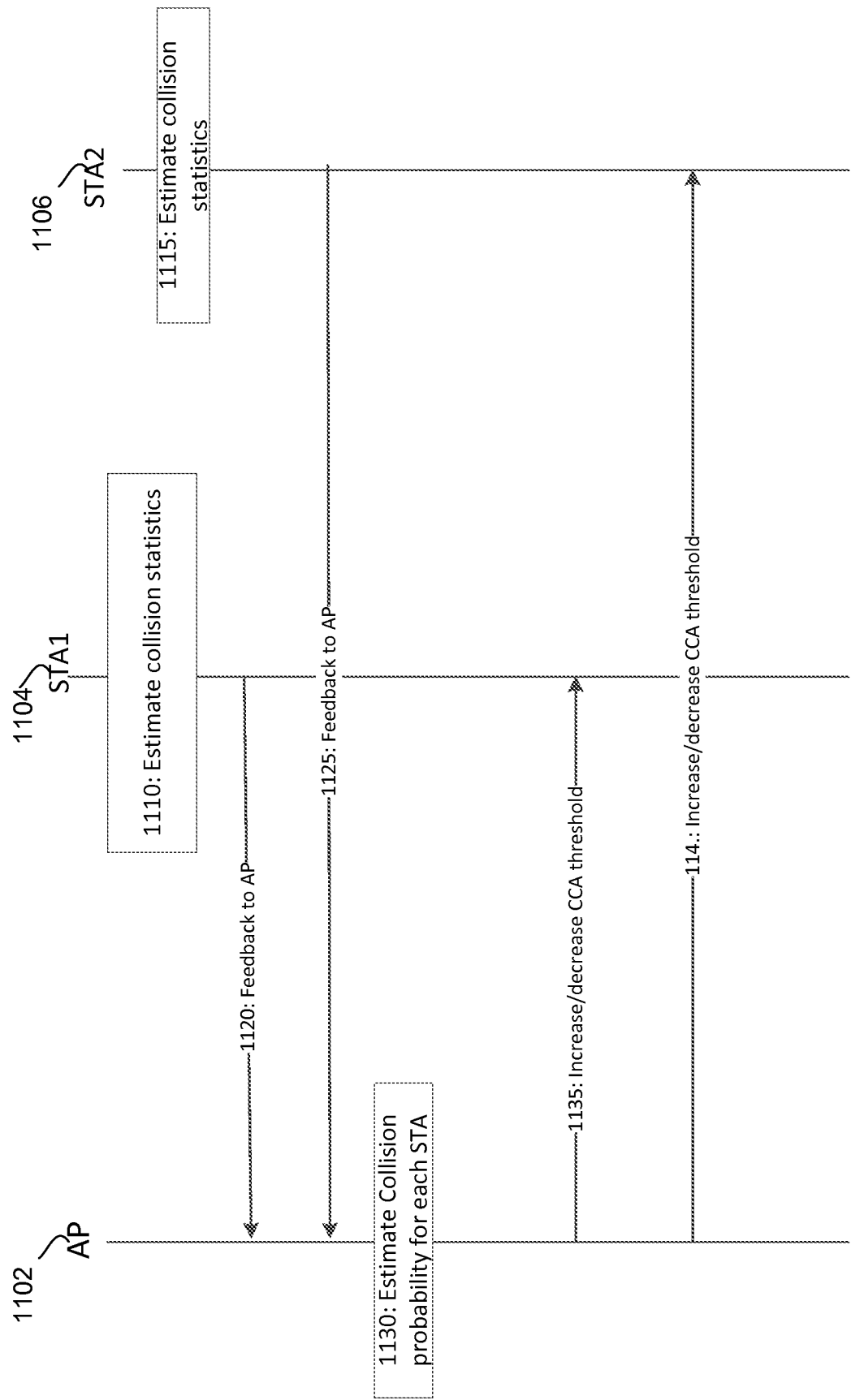


FIG. 11

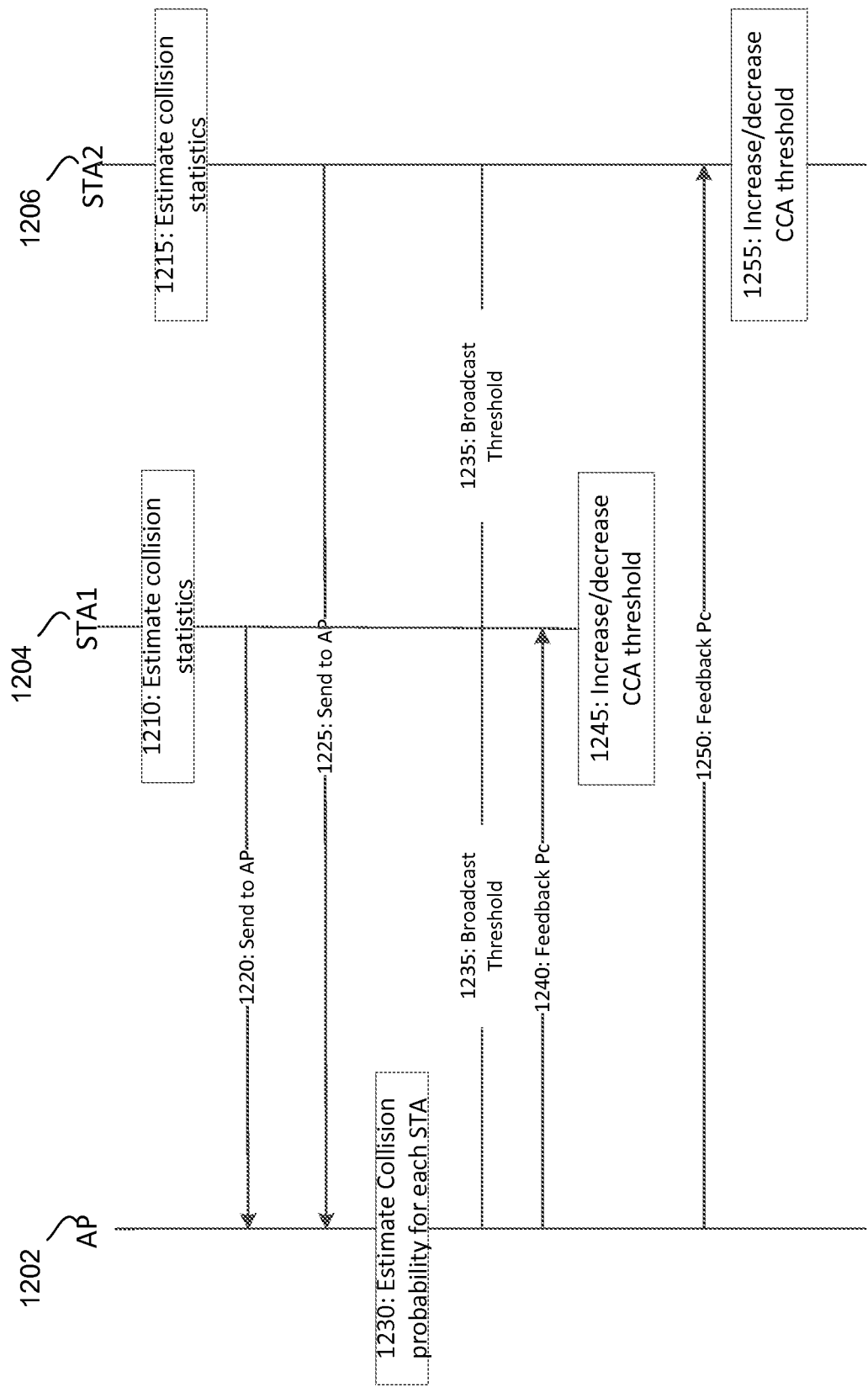


FIG. 12

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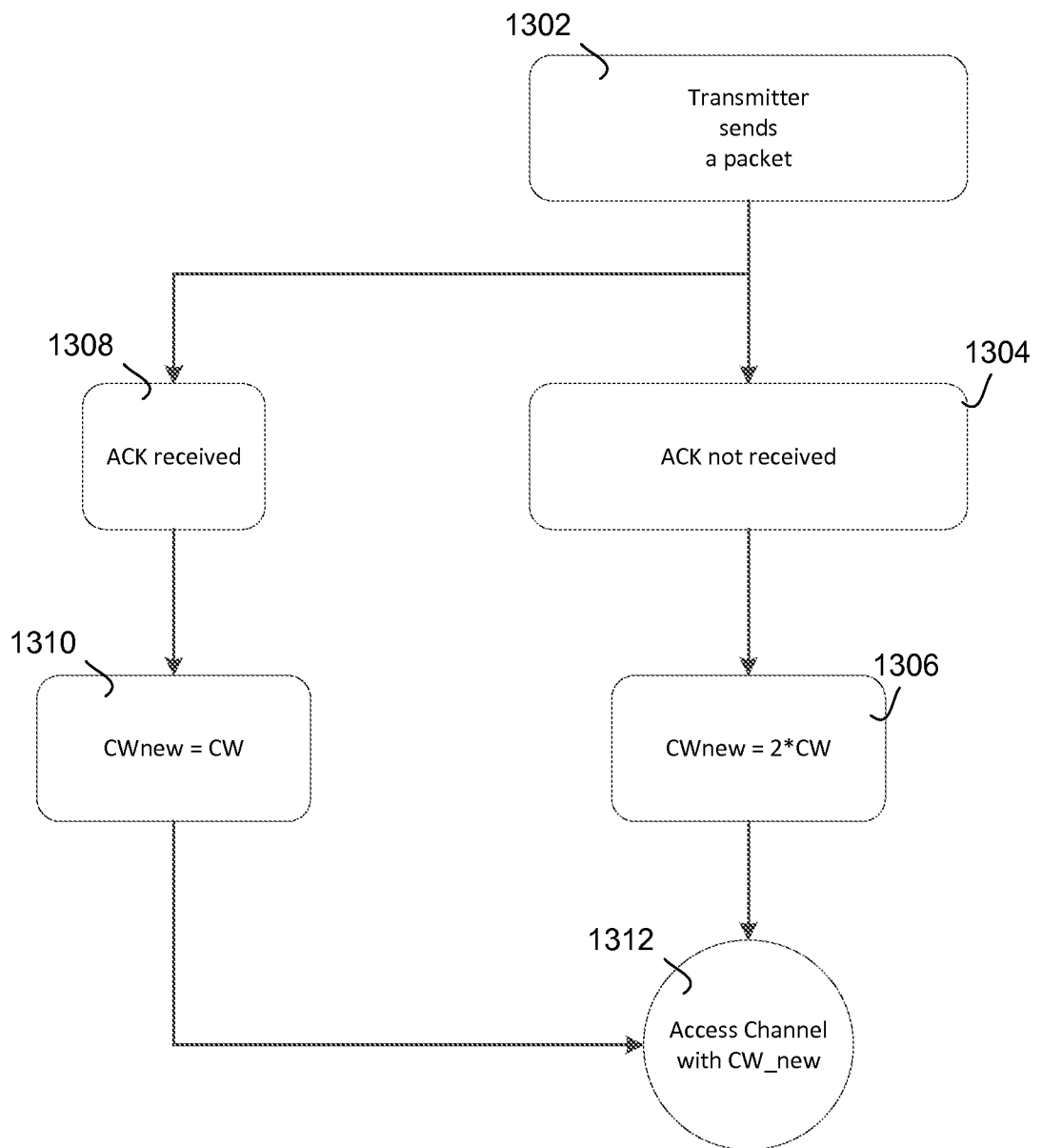


FIG. 13

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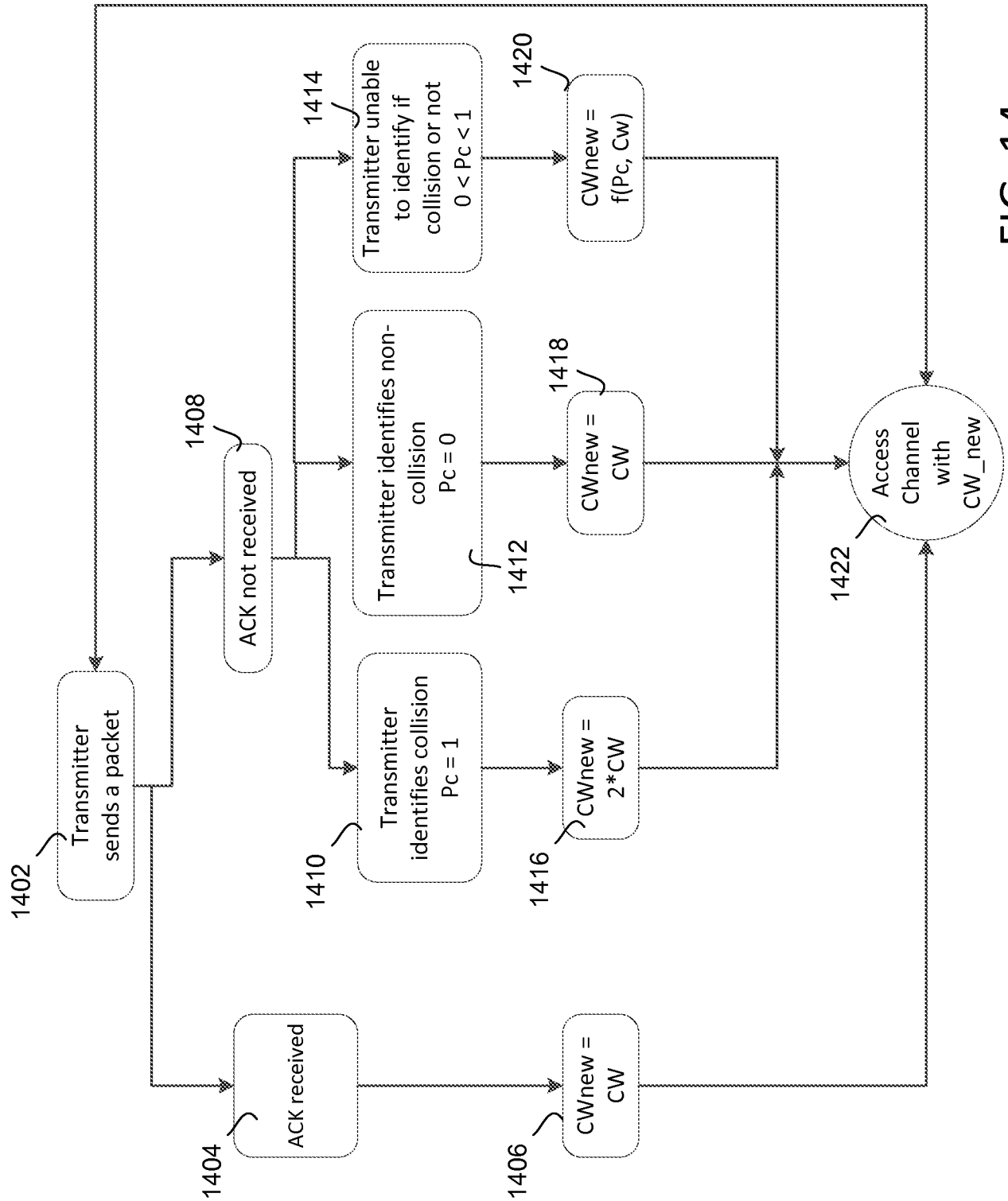


FIG. 14

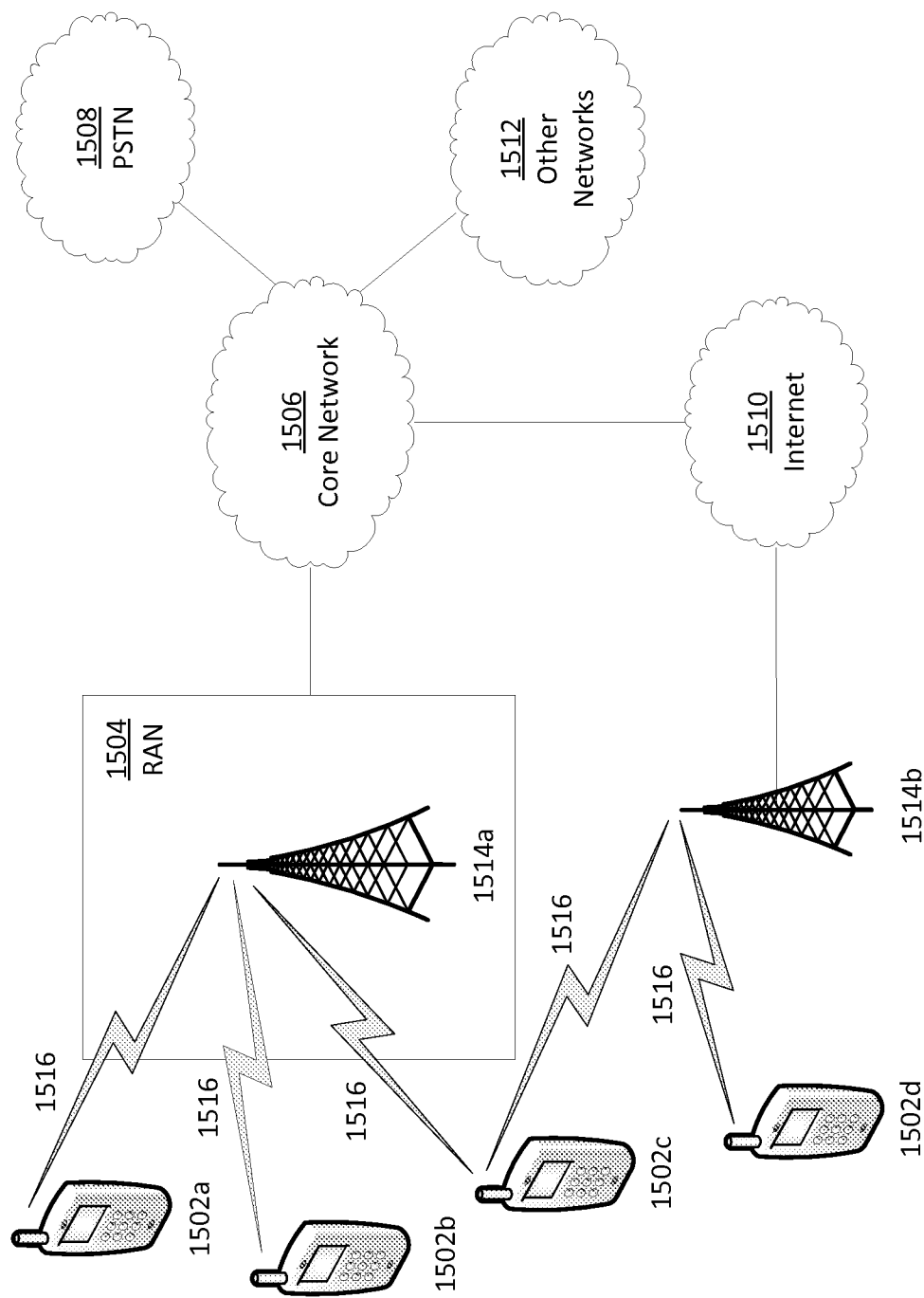


FIG. 15A

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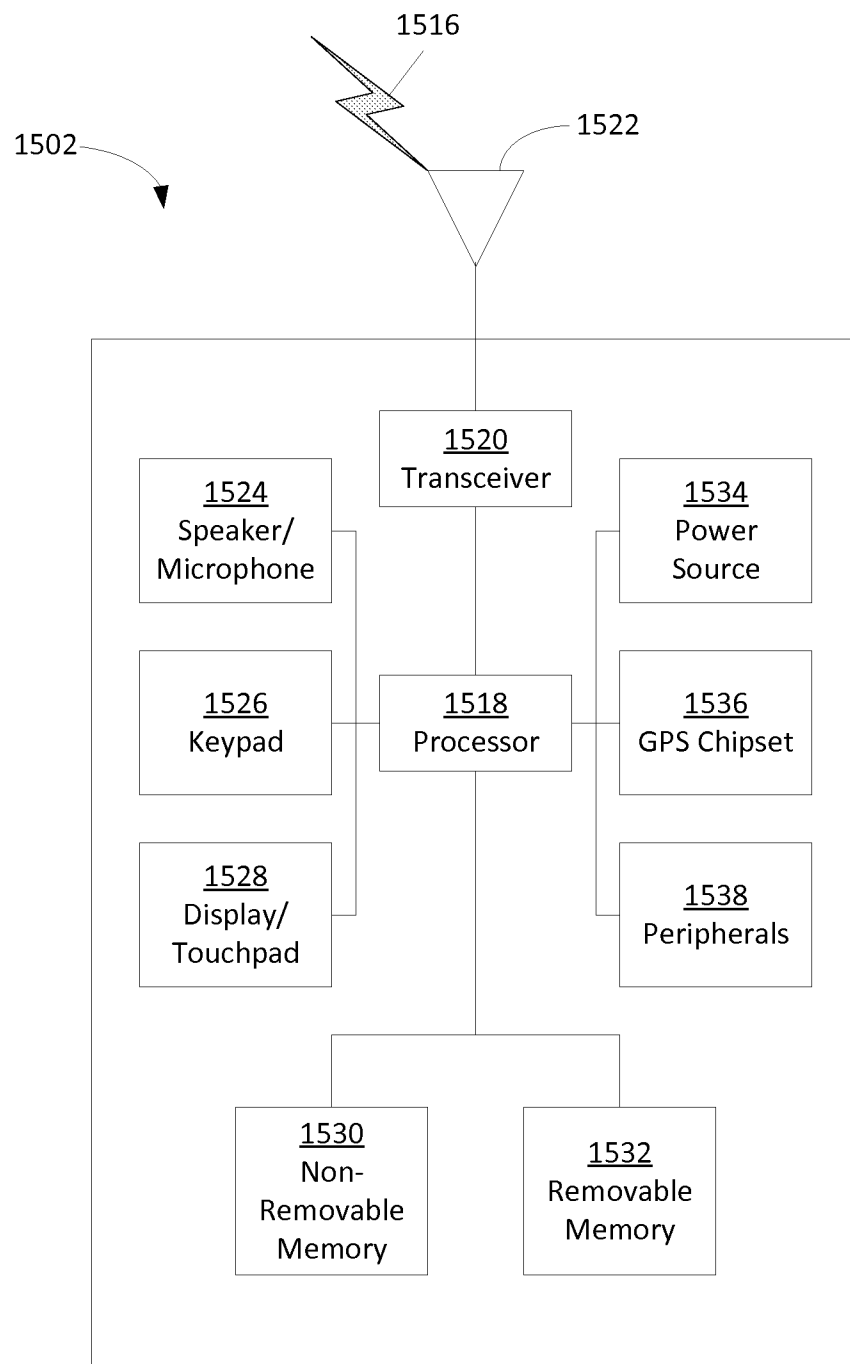


FIG. 15B

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/034035

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W74/08
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04W

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

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

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2013/132135 A1 (NOKIA CORP [FI]; KASSLIN MIKA [FI]; KNECKT JARKKO [FI]; ONG ENG HWEE []) 12 September 2013 (2013-09-12)	1,3-8, 10,12-17
Y	page 5 lines 5-8, 21-23, 34-36 page 6 lines 1-5, 26-27, 29-36 page 11 lines 2-17 page 13 lines 1-22 page 14 lines 9-26, 31-33 -----	2,9,11
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Further documents are listed in the continuation of Box C.



See patent family annex.

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"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

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"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

6 August 2015

Date of mailing of the international search report

13/08/2015

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Authorized officer

Saffell, Christine

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/034035

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Information on patent family members

International application No

PCT/US2015/034035

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