(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
5 March 2015 (05.03.2015)

WIPO | PCT

(10) International Publication Number
WO 2015/031487 A1

(51) International Patent Classification: *H04W 56/00* (2009.01)

(21) International Application Number: PCT/US2014/052923

(22) International Filing Date: 27 August 2014 (27.08.2014)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/870,711 27 August 2013 (27.08.2013) US
14/469,331 26 August 2014 (26.08.2014) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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(54) Title: HIGH EFFICIENCY WIRELESS (HEW) ACCESS POINT (AP) COORDINATION PROTOCOL

(57) Abstract: Systems, methods, and devices for high efficiency wireless (HEW) access point (AP) coordination protocol are described herein. According to certain aspects, a method for coordinating access to a shared medium by an access point (AP) is provided. The method generally synchronizing with one or more peer apparatuses based on synchronization messages detected during a listening time, outputting, for transmission, scheduling information to the one or more peer apparatuses, the scheduling information indicating one or more time periods during which coordinated access to the shared medium is desired, and outputting, for transmission, at least some of the scheduling information to devices served by the apparatus.

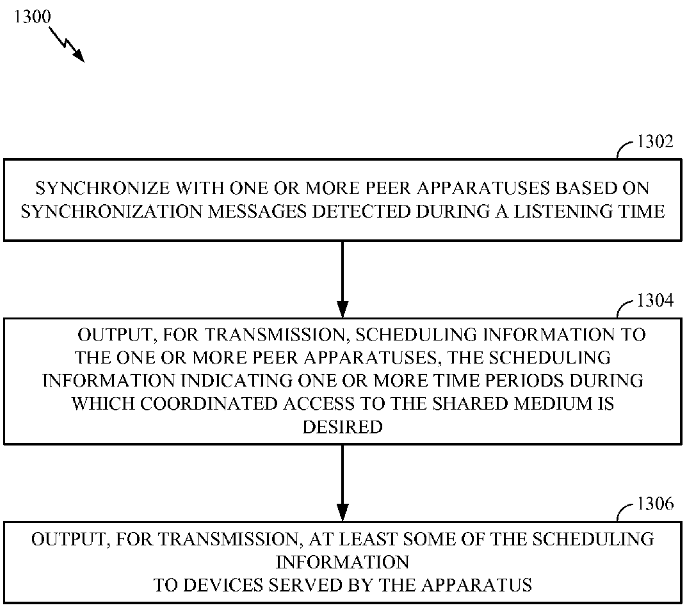

FIG. 13

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(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

HIGH EFFICIENCY WIRELESS (HEW) ACCESS POINT (AP) COORDINATION PROTOCOL

Cross-Reference to Related Application(s)

[0001] This application claims benefit of U.S. Provisional Patent Application Serial No. 61/870,711, filed August 27, 2013, and U.S. Patent Application Serial No. 14/469,331, filed August 26, 2014, both of which are herein incorporated by reference in their entirety.

BACKGROUND

I. Field of the Invention

[0002] The present application relates generally to wireless communications and, more specifically, to systems, methods, and devices for high efficiency wireless (HEW) access point (AP) coordination protocol.

II. Description of Related Art

[0003] In many telecommunication systems, communications networks are used to exchange messages among several interacting spatially-separated devices. Networks may be classified according to geographic scope, which could be, for example, a metropolitan area, a local area, or a personal area. Such networks would be designated respectively as a wide area network (WAN), metropolitan area network (MAN), local area network (LAN), wireless local area network (WLAN), or personal area network (PAN). Networks also differ according to the switching/routing technique used to interconnect the various network nodes and devices (e.g., circuit switching vs. packet switching), the type of physical media employed for transmission (e.g., wired vs. wireless), and the set of communication protocols used (e.g., Internet protocol suite, SONET (Synchronous Optical Networking), Ethernet, etc.).

[0004] Wireless networks are often preferred when the network elements are mobile and thus have dynamic connectivity needs, or if the network architecture is formed in an ad hoc, rather than fixed, topology. Wireless networks employ intangible physical media in an unguided propagation mode using electromagnetic waves in the radio, microwave, infra-red, optical, etc. frequency bands. Wireless networks advantageously facilitate user mobility and rapid field deployment when compared to fixed wired networks.

[0005] However, multiple wireless networks may exist in the same building, in nearby buildings, and/or in the same outdoor area. The prevalence of multiple wireless networks may cause interference, reduced throughput (e.g., because each wireless network is operating in the same area and/or spectrum), and/or prevent certain devices from communicating. Thus, improved systems, methods, and devices for communicating when wireless networks are densely populated are desired.

SUMMARY

[0006] The systems, methods, and devices of the disclosure each have several aspects, no single one of which is solely responsible for its desirable attributes. Without limiting the scope of this disclosure as expressed by the claims which follow, some features will now be discussed briefly. After considering this discussion, and particularly after reading the section entitled "Detailed Description" one will understand how the features of this disclosure provide advantages that include improved communications between access points and stations in a wireless network.

[0007] Techniques and apparatus are provided herein for high efficiency wireless (HEW) access point (AP) coordination protocol.

[0008] One aspect of this disclosure provides a method for coordinating access to a shared medium by an apparatus. The method generally includes synchronizing with one or more peer apparatuses based on synchronization messages detected during a listening time, outputting, for transmission, scheduling information to the one or more peer apparatuses, the scheduling information indicating one or more time periods during which coordinated access to the shared medium is desired, and outputting, for transmission, at least some of the scheduling information to devices served by the apparatus.

[0009] One aspect of this disclosure provides a method for coordinating access to a shared medium by an access point (AP). The method generally includes receiving, from another AP, a message to reserve a listening time for the other AP to listen to one or more synchronization messages, taking action to ensure stations served by the AP do not interfere with synchronization messages during the listening time, receiving, from the other AP, scheduling information indicating one or more reservation periods during which coordinated access to the shared medium is desired, and taking action to provide coordinated access during the one or more reservation periods.

[0010] One aspect of this disclosure provides an apparatus for wireless communications. The apparatus typically includes means for synchronizing with one or more peer apparatuses based on synchronization messages detected during a listening time, means for outputting, for transmission, scheduling information to the one or more peer apparatuses, the scheduling information indicating one or more time periods during which coordinated access to the shared medium is desired, and means for outputting, for transmission, at least some of the scheduling information to devices served by the apparatus.

[0011] One aspect of this disclosure provides an apparatus for wireless communications. The apparatus typically includes a processing system configured to synchronize with one or more peer apparatuses based on synchronization messages detected during a listening time and a transmitter configured to transmit scheduling information to the one or more peer apparatuses, the scheduling information indicating one or more time periods during which coordinated access to the shared medium is desired, and transmit at least some of the scheduling information to devices served by the apparatus.

[0012] One aspect of the present disclosure provides a computer program product for wireless communications. The computer program product generally includes a computer readable medium having instructions stored thereon for synchronizing with one or more peer apparatuses based on synchronization messages detected during a listening time, outputting, for transmission, scheduling information to the one or more peer apparatuses, the scheduling information indicating one or more time periods during which coordinated access to the shared medium is desired, and outputting, for transmission, at least some of the scheduling information to devices served by the apparatus.

[0013] One aspect of the present disclosure provides an access point (AP). The AP typically includes at least one antenna, a processing system configured to synchronize with one or more peer apparatuses based on synchronization messages detected during a listening time, and a transmitter configured to transmit, via the at least one antenna, scheduling information to the one or more peer apparatuses, the scheduling information indicating one or more time periods during which coordinated access to the shared medium is desired, and transmit, via the at least one antenna, at least some of the scheduling information to devices served by the apparatus.

[0014] Numerous other aspects are provided including methods, apparatus, systems, computer program products, and processing systems.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] So that the manner in which the above-recited features of the present disclosure can be understood in detail, a more particular description, briefly summarized above, may be had by reference to aspects, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only certain typical aspects of this disclosure and are therefore not to be considered limiting of its scope, for the description may admit to other equally effective aspects.

[0016] FIG. 1 shows an example wireless communication system in which aspects of the present disclosure may be employed.

[0017] FIG. 2A shows an example wireless communication system in which multiple wireless communication networks are present.

[0018] FIG. 2B shows another example wireless communication system in which multiple wireless communication networks are present.

[0019] FIG. 3 shows exemplary frequency multiplexing techniques that may be employed within the wireless communication systems of FIGS. 1 and 2B.

[0020] FIG. 4 shows an example functional block diagram of an exemplary wireless device that may be employed within the wireless communication systems of FIGS. 1, 2B, and 3.

[0021] FIG. 5 shows an example wireless communication system in which aspects of the present disclosure may be employed.

[0022] FIG. 5A is a representation of an example management frame that may be employed within the wireless communication systems disclosed herein.

[0023] FIG. 5B is a representation of an example action frame that may be employed within the wireless communication systems disclosed herein.

[0024] FIG. 5C is a representation of an example generic advertisement service (GAS) frame that may be employed within the wireless communication systems disclosed herein.

[0025] FIG. 5D is a representation of an example HTC control field that includes a reserve bit that may be employed within the wireless communication systems disclosed herein.

[0026] FIG. 6 is a representation of an example modified restricted access window (RAW) parameter set (RPS) information element defined by 802.11ah that may be employed within the wireless communication systems disclosed herein.

[0027] FIG. 7 is a representation of an example modified advertisement frame action field and of a transmission opportunity (TXOP) reservation field format defined by 802.11aa that may be employed within the wireless communication systems disclosed herein.

[0028] FIG. 8 is an exemplary wireless communication system employing time coordination that may be employed within the wireless communication systems disclosed herein.

[0029] FIG. 9 is an exemplary wireless communication system employing frequency coordination that may be employed within the wireless communication systems disclosed herein.

[0030] FIG. 10 illustrates cumulative distribution functions (CDFs) for downlink throughput in a regularly spaced network that may be employed within the wireless communication systems disclosed herein.

[0031] FIG. 11 illustrates an example frame field format for RAW that may be employed within the wireless communication systems disclosed herein.

[0032] FIG. 12 illustrates UL and DL schedule at the start of the power save multi-poll (PSMP) phase that may be employed within the wireless communication systems disclosed herein.

[0033] Fig. 13 illustrates example operations for coordinating access to a shared medium by an access point (AP) that may be performed within the wireless communication systems disclosed herein.

[0034] FIG. 13A illustrates example means capable of performing the operations shown in FIG. 13, in accordance with certain aspects of the present disclosure.

[0035] Fig. 14 illustrates example operations for coordinating access to a shared medium by an AP that may be performed within the wireless communication systems disclosed herein.

[0036] FIG. 14A illustrates example means capable of performing the operations shown in FIG. 14, in accordance with certain aspects of the present disclosure.

DETAILED DESCRIPTION

[0037] Various aspects of the novel systems, apparatuses, and methods are described more fully hereinafter with reference to the accompanying drawings. This disclosure may, however, be embodied in many different forms and should not be construed as limited to any specific structure or function presented throughout this disclosure. Rather, these aspects are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the disclosure to those skilled in the art. Based on the teachings herein one skilled in the art should appreciate that the scope of the disclosure is intended to cover any aspect of the novel systems, apparatuses, and methods disclosed herein, whether implemented independently of, or combined with, any other aspect of the disclosure. For example, an apparatus may be implemented or a method may be practiced using any number of the aspects set forth herein. In addition, the scope of the disclosure is intended to cover such an apparatus or method which is practiced using other structure, functionality, or structure and functionality in addition to or other than the various aspects of the invention set forth herein. It should be understood that any aspect disclosed herein may be embodied by one or more elements of a claim.

[0038] Although particular aspects are described herein, many variations and permutations of these aspects fall within the scope of the disclosure. Although some benefits and advantages of the preferred aspects are mentioned, the scope of the disclosure is not intended to be limited to particular benefits, uses, or objectives. Rather, aspects of the disclosure are intended to be broadly applicable to different wireless technologies, system configurations, networks, and transmission protocols, some of which are illustrated by way of example in the figures and in the following description of the preferred aspects. The detailed description and drawings are merely illustrative of the disclosure rather than limiting, the scope of the disclosure being defined by the appended claims and equivalents thereof.

[0039] Popular wireless network technologies may include various types of wireless local area networks (WLANs). A WLAN may be used to interconnect nearby devices together, employing widely used networking protocols. The various aspects described herein may apply to any communication standard, such as a wireless protocol.

[0040] In some aspects, wireless signals may be transmitted according to a high-efficiency 802.11 protocol using orthogonal frequency-division multiplexing (OFDM), direct–sequence spread spectrum (DSSS) communications, a combination of OFDM and DSSS communications, or other schemes. Implementations of the high-efficiency 802.11 protocol may be used for Internet access, sensors, metering, smart grid networks, or other wireless applications. Advantageously, aspects of certain devices implementing the high-efficiency 802.11 protocol using the techniques disclosed herein may include allowing for increased peer-to-peer services (e.g., Miracast, WiFi Direct Services, Social WiFi, etc.) in the same area, supporting increased per-user minimum throughput requirements, supporting more users, providing improved outdoor coverage and robustness, and/or consuming less power than devices implementing other wireless protocols.

[0041] In some implementations, a WLAN includes various devices which are the components that access the wireless network. For example, there may be two types of devices: access points ("APs") and clients (also referred to as stations, or "STAs"). In general, an AP may serve as a hub or base station for the WLAN and an STA serves as a user of the WLAN. For example, an STA may be a laptop computer, a personal digital assistant (PDA), a mobile phone, etc. In an example, an STA connects to an AP via a WiFi (e.g., IEEE 802.11 protocol) compliant wireless link to obtain general connectivity to the Internet or to other wide area networks. In some implementations an STA may also be used as an AP.

[0042] An access point ("AP") may also comprise, be implemented as, or known as a NodeB, Radio Network Controller ("RNC"), eNodeB, Base Station Controller ("BSC"), Base Transceiver Station ("BTS"), Base Station ("BS"), Transceiver Function ("TF"), Radio Router, Radio Transceiver, or some other terminology.

[0043] A station "STA" may also comprise, be implemented as, or known as an access terminal ("AT"), a subscriber station, a subscriber unit, a mobile station, a remote station, a remote terminal, a user terminal, a user agent, a user device, user equipment, or some other terminology. In some implementations an access terminal may comprise a cellular telephone, a cordless telephone, a Session Initiation Protocol ("SIP") phone, a wireless local loop ("WLL") station, a personal digital assistant ("PDA"), a handheld device having wireless connection capability, or some other suitable processing device connected to a wireless modem. Accordingly, one or more aspects taught herein may be incorporated into a phone (e.g., a cellular phone or smartphone), a computer (e.g., a laptop), a portable communication device, a headset, a portable computing device (e.g., a personal data assistant), an entertainment device (e.g., a music or video device, or a satellite radio), a gaming device or system, a global positioning system device, or any other suitable device that is configured to communicate via a wireless medium.

[0044] As discussed above, certain of the devices described herein may implement a high-efficiency 802.11 standard, for example. Such devices, whether used as an STA or AP or other device, may be used for smart metering or in a smart grid network. Such devices may provide sensor applications or be used in home automation. The devices may instead or in addition be used in a healthcare context, for example for personal healthcare. They may also be used for surveillance, to enable extended-range Internet connectivity (e.g. for use with hotspots), or to implement machine-to-machine communications.

Example Wireless Communications System

[0045] FIG. 1 shows an exemplary wireless communication system 100 in which aspects of the present disclosure may be employed. The wireless communication system 100 may operate pursuant to a wireless standard, for example a high-efficiency

802.11 standard. The wireless communication system 100 may include an access point (AP) 104, which communicates with stations (STAs) 106.

[0046] A variety of processes and methods may be used for transmissions in the wireless communication system 100 between the AP 104 and the STAs 106. For example, signals may be sent and received between the AP 104 and the STAs 106 in accordance with orthogonal frequency division multiplexing (OFDM)/OFDM access (OFDMA) techniques. If this is the case, the wireless communication system 100 may be referred to as an OFDM/OFDMA system. Alternatively, signals may be sent and received between the AP 104 and the STAs 106 in accordance with code division multiple access (CDMA) techniques. If this is the case, the wireless communication system 100 may be referred to as a CDMA system.

[0047] A communication link that facilitates transmission from the AP 104 to one or more of the STAs 106 may be referred to as a downlink (DL) 108, and a communication link that facilitates transmission from one or more of the STAs 106 to the AP 104 may be referred to as an uplink (UL) 110. Alternatively, a downlink 108 may be referred to as a forward link or a forward channel, and an uplink 110 may be referred to as a reverse link or a reverse channel.

[0048] The AP 104 may act as a base station and provide wireless communication coverage in a basic service area (BSA) 102. The AP 104 along with the STAs 106 associated with the AP 104 and that use the AP 104 for communication may be referred to as a basic service set (BSS). It should be noted that the wireless communication system 100 may not have a central AP 104, but rather may function as a peer-to-peer network between the STAs 106. Accordingly, the functions of the AP 104 described herein may alternatively be performed by one or more of the STAs 106.

[0049] In some aspects, a STA 106 may be required to associate with the AP 104 in order to send communications to and/or receive communications from the AP 104. In one aspect, information for associating is included in a broadcast by the AP 104. To receive such a broadcast, the STA 106 may, for example, perform a broad coverage search over a coverage region. A search may also be performed by the STA 106 by sweeping a coverage region in a lighthouse fashion, for example. After receiving the information for associating, the STA 106 may transmit a reference signal, such as an association probe or request, to the AP 104. In some aspects, the AP 104 may use backhaul services, for example, to communicate with a larger network, such as the Internet or a public switched telephone network (PSTN).

[0050] In an embodiment, the AP 104 includes an AP high-efficiency wireless component (HEWC) 154. The AP HEWC 154 may perform some or all of the operations described herein to enable communications between the AP 104 and the STAs 106 using the high-efficiency 802.11 protocol. The functionality of the AP HEWC 154 is described in greater detail below with respect to FIGS. 2B, 3, 4, and 5.

[0051] Alternatively or in addition, the STAs 106 may include a STA HEWC 156. The STA HEWC 156 may perform some or all of the operations described herein to enable communications between the STAs 106 and the AP 104 using the high-frequency 802.11 protocol. The functionality of the STA HEWC 156 is described in greater detail below with respect to FIGS. 2B, 3, 4, and 5.

[0052] In some circumstances, a BSA may be located near other BSAs. For example, FIG. 2A shows a wireless communication system 200 in which multiple wireless communication networks are present. As illustrated in FIG. 2A, BSAs 202A, 202B, and 202C may be physically located near each other. Despite the close proximity of the BSAs 202A-C, the APs 204A-C and/or STAs 206A-H may each communicate using the same spectrum. Thus, if a device in the BSA 202C (e.g., the AP 204C) is transmitting data, devices outside the BSA 202C (e.g., APs 204A-B or STAs 206A-F) may sense the communication on the medium.

[0053] Generally, wireless networks that use a regular 802.11 protocol (e.g., 802.11a, 802.11b, 802.11g, 802.11n, etc.) operate under a carrier sense multiple access (CSMA) mechanism for medium access. According to CSMA, devices sense the medium and only transmit when the medium is sensed to be idle. Thus, if the APs 204A-C and/or STAs 206A-H are operating according to the CSMA mechanism and a device in the BSA 202C (e.g., the AP 204C) is transmitting data, then the APs 204A-B and/or STAs 206A-F outside of the BSA 202C may not transmit over the medium even though they are part of a different BSA.

[0054] FIG. 2A illustrates such a situation. As illustrated in FIG. 2A, AP 204C is transmitting over the medium. The transmission is sensed by STA 206G, which is in the same BSA 202C as the AP 204C, and by STA 206A, which is in a different BSA than the AP 204C. While the transmission may be addressed to the STA 206G and/or only STAs in the BSA 202C, STA 206A nonetheless may not be able to transmit or receive communications (e.g., to or from the AP 204A) until the AP 204C (and any other device) is no longer transmitting on the medium. Although not shown, the same may apply to STAs 206D-F in the BSA 202B and/or STAs 206B-C in the BSA 202A as well (e.g., if the transmission by the AP 204C is stronger such that the other STAs can sense the transmission on the medium).

[0055] The use of the CSMA mechanism then creates inefficiencies because some APs or STAs outside of a BSA may be able to transmit data without interfering with a transmission made by an AP or STA in the BSA. As the number of active wireless devices continues to grow, the inefficiencies may begin to significantly affect network latency and throughput. For example, significant network latency issues may appear in apartment buildings, in which each apartment unit may include an access point and associated stations. In fact, each apartment unit may include multiple access points, as a resident may own a wireless router, a video game console with wireless media center capabilities, a television with wireless media center capabilities, a cell phone that can act like a personal hot-spot, and/or the like. Correcting the inefficiencies of the CSMA mechanism may then be vital to avoid latency and throughput issues and overall user dissatisfaction.

[0056] Such latency and throughput issues may not even be confined to residential areas. For example, multiple access points may be located in airports, subway stations, and/or other densely-populated public spaces. Currently, WiFi access may be offered in these public spaces, but for a fee. If the inefficiencies created by the CSMA mechanism are not corrected, then operators of the wireless networks may lose customers as the fees and lower quality of service begin to outweigh any benefits.

[0057] Accordingly, the high-efficiency 802.11 protocol described herein may allow for devices to operate under a modified mechanism that minimizes these inefficiencies and increases network throughput. Such a mechanism is described below with respect to FIGS. 2B, 3, and 4. Additional aspects of the high-efficiency 802.11 protocol are described below with respect to FIGS. 5-9.

[0058] FIG. 2B shows a wireless communication system 250 in which multiple wireless communication networks are present. Unlike the wireless communication system 200 of FIG. 2A, the wireless communication system 250 may operate pursuant to the high-efficiency 802.11 standard discussed herein. The wireless communication system 250 may include an AP 254A, an AP 254B, and an AP 254C. The AP 254A may communicate with STAs 256A-C, the AP 254B may communicate with STAs 256D-F, and the AP 254C may communicate with STAs 256G-H.

[0059] A variety of processes and methods may be used for transmissions in the wireless communication system 250 between the APs 254A-C and the STAs 256A-H. For example, signals may be sent and received between the APs 254A-C and the STAs 256A-H in accordance with OFDM/OFDMA techniques or CDMA techniques.

[0060] The AP 254A may act as a base station and provide wireless communication coverage in a BSA 252A. The AP 254B may act as a base station and provide wireless communication coverage in a BSA 252B. The AP 254C may act as a base station and provide wireless communication coverage in a BSA 252C. It should be noted that each BSA 252A, 252B, and/or 252C may not have a central AP 254A, 254B, or 254C, but rather may allow for peer-to-peer communications between one or more of the STAs 256A-H. Accordingly, the functions of the AP 254A-C described herein may alternatively be performed by one or more of the STAs 256A-H.

[0061] In an embodiment, the APs 254A-C and/or STAs 256A-H include a high-efficiency wireless component. As described herein, the high-efficiency wireless component may enable communications between the APs and STAs using the high-efficiency 802.11 protocol. In particular, the high-efficiency wireless component may enable the APs 254A-C and/or STAs 256A-H to use a modified mechanism that minimizes the inefficiencies of the CSMA mechanism (e.g., enables concurrent communications over the medium in situations in which interference would not occur). The high-efficiency wireless component is described in greater detail below with respect to FIG. 4.

[0062] As illustrated in FIG. 2B, the BSAs 252A-C are physically located near each other. When, for example, AP 254A and STA 256B are communicating with each other, the communication may be sensed by other devices in BSAs 252B-C. However, the communication may only interfere with certain devices, such as STA 256F and/or STA 256G. Under CSMA, AP 254B would not be allowed to communicate with STA 256E even though such communication would not interfere with the communication between AP 254A and STA 256B. Thus, the high-efficiency 802.11 protocol operates under a modified mechanism that differentiates between devices that can communicate concurrently and devices that cannot communicate concurrently. Such classification of devices may be performed by the high-efficiency wireless component in the APs 254A-C and/or the STAs 256A-H.

[0063] In an embodiment, the determination of whether a device can communicate concurrently with other devices is based on a location of the device. For example, a STA that is located near an edge of the BSA may be in a state or condition such that the STA cannot communicate concurrently with other devices. As illustrated in FIG. 2B, STAs 206A, 206F, and 206G may be devices that are in a state or condition in which they cannot communicate concurrently with other devices. Likewise, a STA that is located near the center of the BSA may be in a station or condition such that the STA can communicate concurrently with other devices. As illustrated in FIG. 2, STAs 206B, 206C, 206D, 206E, and 206H may be devices that are in a state or condition in which they can communicate concurrently with other devices. Note that the classification of devices is not permanent. Devices may transition between being in a state or condition such that they can communicate concurrently and being in a state or condition such that they cannot communicate concurrently (e.g., devices may change states or conditions when in motion, when associating with a new AP, when disassociating, etc.).

[0064] Furthermore, devices may be configured to behave differently based on whether they are ones that are or are not in a state or condition to communicate concurrently with other devices. For example, devices that are in a state or condition such that they can communicate concurrently may communicate within the same spectrum. However, devices that are in a state or condition such that they cannot communicate concurrently may employ certain techniques, such as spatial multiplexing or frequency domain multiplexing, in order to communicate over the medium. The controlling of the behavior of the devices may be performed by the high-efficiency wireless component in the APs 254A-C and/or the STAs 256A-H.

[0065] In an embodiment, devices that are in a state or condition such that they cannot communicate concurrently use spatial multiplexing techniques to communicate over the medium. For example, power and/or other information may be embedded within the preamble of a packet transmitted by another device. A device in a state or condition such that the device cannot communicate concurrently may analyze the preamble when the packet is sensed on the medium and decide whether or not to transmit based on a set of rules.

[0066] In another embodiment, devices that are in a state or condition such that they cannot communicate concurrently use frequency domain multiplexing techniques to communicate over the medium. FIG. 3 shows frequency multiplexing techniques that may be employed within the wireless communication systems 100 of FIG. 1 and 250 of FIG. 2B. As illustrated in FIG. 3, an AP 304A, 304B, 304C, and 304D may be present within a wireless communication system 300. Each of the APs 304A, 304B, 304C, and 304D may be associated with a different BSA and include the high-efficiency wireless component described herein.

[0067] As an example, the bandwidth of the communication medium may be 80MHz. Under the regular 802.11 protocol, each of the APs 304A, 304B, 304C, and 304D and the STAs associated with each respective AP attempt to communicate using the entire bandwidth, which can reduce throughput. However, under the high-efficiency 802.11 protocol using frequency domain multiplexing, the bandwidth may be divided into four 20MHz segments 308, 310, 312, and 314 (e.g., channels), as illustrated in FIG. 3. The AP 304A may be associated with segment 308, the AP 304B may be associated with segment 310, the AP 304C may be associated with segment 312, and the AP 304D may be associated with segment 314.

[0068] In an embodiment, when the APs 304A-D and the STAs that are in a state or condition such that the STAs can communicate concurrently with other devices (e.g., STAs near the center of the BSA) are communicating with each other, then each AP 304A-D and each of these STAs may communicate using a portion of or the entire 80MHz medium. However, when the APs 304A-D and the STAs that are in a state or condition such that the STAs cannot communicate concurrently with other devices (e.g., STAs near the edge of the BSA) are communicating with each other, then AP 304A and its STAs communicate using 20MHz segment 308, AP 304B and its STAs communicate using 20MHz segment 310, AP 304C and its STAs communicate using 20MHz segment

312, and AP 304D and its STAs communicate using 20MHz segment 314. Because the segments 308, 310, 312, and 314 are different portions of the communication medium, a first transmission using a first segment would not interference with a second transmission using a second segment.

[0069] Thus, APs and/or STAs, even those that are in a state or condition such that they cannot communicate concurrently with other devices when following 11ac or older protocols, if they include the high-efficiency wireless component, they can communicate concurrently with other APs and STAs without interference. Accordingly, the throughput of the wireless communication system 300 may be increased. In the case of apartment buildings or densely-populated public spaces, APs and/or STAs that use the high-efficiency wireless component may experience reduced latency and increased network throughput even as the number of active wireless devices increases, thereby improving user experience.

[0070] FIG. 4 shows an exemplary functional block diagram of a wireless device 402 that may be employed within the wireless communication systems 100, 250, and/or 300 of FIGS. 1, 2B, and 3. The wireless device 402 is an example of a device that may be configured to implement the various methods described herein. For example, the wireless device 402 may comprise the AP 104, one of the STAs 106, one of the APs 254, one of the STAs 256, and/or one of the APs 304.

[0071] The wireless device 402 may include a processor 404 which controls operation of the wireless device 402. The processor 404 may also be referred to as a central processing unit (CPU). Memory 406, which may include both read-only memory (ROM) and random access memory (RAM), may provide instructions and data to the processor 404. A portion of the memory 406 may also include non-volatile random access memory (NVRAM). The processor 404 typically performs logical and arithmetic operations based on program instructions stored within the memory 406. The instructions in the memory 406 may be executable to implement the methods described herein.

[0072] The processor 404 may comprise or be a component of a processing system implemented with one or more processors. The one or more processors may be implemented with any combination of general-purpose microprocessors, microcontrollers, digital signal processors (DSPs), field programmable gate array (FPGAs), programmable logic devices (PLDs), controllers, state machines, gated logic, discrete hardware components, dedicated hardware finite state machines, or any other suitable entities that can perform calculations or other manipulations of information.

[0073] The processing system may also include machine-readable media for storing software. Software shall be construed broadly to mean any type of instructions, whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise. Instructions may include code (e.g., in source code format, binary code format, executable code format, or any other suitable format of code). The instructions, when executed by the one or more processors, cause the processing system to perform the various functions described herein.

[0074] The wireless device 402 may also include a housing 408 that may include a transmitter 410 and/or a receiver 412 to allow transmission and reception of data between the wireless device 402 and a remote location. The transmitter 410 and receiver 412 may be combined into a transceiver 414. An antenna 416 may be attached to the housing 408 and electrically coupled to the transceiver 414. The wireless device 402 may also include (not shown) multiple transmitters, multiple receivers, multiple transceivers, and/or multiple antennas.

[0075] The wireless device 402 may also include a signal detector 418 that may be used in an effort to detect and quantify the level of signals received by the transceiver 414. The signal detector 418 may detect such signals as total energy, energy per subcarrier per symbol, power spectral density and other signals. The wireless device 402 may also include a digital signal processor (DSP) 420 for use in processing signals. The DSP 420 may be configured to generate a packet for transmission. In some aspects, the packet may comprise a physical layer data unit (PPDU).

[0076] The wireless device 402 may further comprise a user interface 422 in some aspects. The user interface 422 may comprise a keypad, a microphone, a speaker, and/or a display. The user interface 422 may include any element or component that conveys information to a user of the wireless device 402 and/or receives input from the user.

[0077] The wireless devices 402 may further comprise a high-efficiency wireless component 424 in some aspects. The high-efficiency wireless component 424 may include a classifier unit 428 and a transmit control unit 430. As described herein, the high-efficiency wireless component 424 may enable APs and/or STAs to use a modified mechanism that minimizes the inefficiencies of the CSMA mechanism (e.g., enables concurrent communications over the medium in situations in which interference would not occur).

[0078] The modified mechanism may be implemented by the classifier unit 428 and the transmit control unit 430. In an embodiment, the classifier unit 428 determines which devices are in a state or condition such that they can communicate concurrently with other devices and which devices are in a state or condition such that they cannot communicate concurrently with other devices without additional orthogonalization in time, frequency, or space. . In an embodiment, the transmit control unit 430 controls the behavior of devices. For example, the transmit control unit 430 may allow certain devices to transmit concurrently on the same medium and allow other devices to transmit using a spatial multiplexing or frequency domain multiplexing technique. The transmit control unit 430 may control the behavior of devices based on the determinations made by the classifier unit 428.

[0079] The various components of the wireless device 402 may be coupled together by a bus system 426. The bus system 426 may include a data bus, for example, as well as a power bus, a control signal bus, and a status signal bus in addition to the data bus. Those of skill in the art will appreciate the components of the wireless device 402 may be coupled together or accept or provide inputs to each other using some other mechanism.

[0080] Although a number of separate components are illustrated in FIG. 4, those of skill in the art will recognize that one or more of the components may be combined or commonly implemented. For example, the processor 404 may be used to implement not only the functionality described above with respect to the processor 404, but also to implement the functionality described above with respect to the signal detector 418 and/or the DSP 420. Further, each of the components illustrated in FIG. 4 may be implemented using a plurality of separate elements.

[0081] In some implementations, resources and operational modes of APs/STAs in networks with dense deployments of multiple BSSs are coordinated to reduce interference. In some aspects, one or more dimensions including time, frequency, space, and power are coordinated between APs/STAs. In some aspects, coordination messages are sent between APs/STAs. In some aspects, specific enhancements to 802.11ah scheduling and 802.11aa coordination protocol are employed.

[0082] Coordination can be achieved as explicit communication across APs/STAs of different BSSs. For example, via messages exchanged over the air or messages exchanged over a separate communication mean (e.g., cable backhaul connection). Messages can be exchanged directly between APs, between APs via STAs, directly between STAs, or between STAs via AP.

[0083] Coordination can be achieved as implicit communications/measurements based on observation of the traffic on the medium. For example, packets may be enhanced to carry partial information that can help the coordination

[0084] Coordination final decisions can be made by a central informed controller, at each AP, with a distributed heuristic, or at each STA, based on exchanged info.

[0085] FIG. 5 shows examples of coordinated transmissions that may be employed within the wireless communication systems 100 of FIG. 1 and 250 of FIG. 2B. FIG. 5 illustrates three access points 504A-C. Each access point 504A-C manages a corresponding BSS 502A-C. Each access point 504A-C is in communication with a plurality of stations 506. For example, access point 504A is in communication with stations 506A-C, while access point 504C is in communication with stations 506G-H.

[0086] In some aspects, the physical location of a station relative to other stations, its associated access point, and/or other access points may make the station more or less subject to interference. For example, because stations 506D-E are positioned relatively close to their access point 504B and relatively far from other BSS's 502A and 502C, and access points and stations communicating within those BSS's, stations 506D-E may be less susceptible to interference when either of those BSS's communicate. Similarly, STA 506H may be less susceptible to interference from transmissions generated by either BSS 502A or 502B. Because these devices may not be susceptible to interference, some of the devices may communicate concurrently with other devices, even if a traditional carrier sense media access mechanism would prevent such concurrent transmission. For example, STA 506H may communicate with access point 504C concurrently with access point 504B communicating with stations 506D or 506E.

[0087] Other stations may be more susceptible to interference, for example, stations positioned relatively further from their access points and/or relatively closer to wireless devices of other BSSs may be more susceptible to interference.

[0088] The wireless device 402 may comprise an AP 104, a STA 106, an AP 254, a STA 256, and/or an AP 304, and may be used to transmit and/or receive communications. That is, either AP 104, STA 106, AP 254, STA 256, or AP 304 may serve as transmitter or receiver devices. Certain aspects contemplate signal detector 418 being used by software running on memory 406 and processor 404 to detect the presence of a transmitter or receiver.

[0089] In a dense BSS scenario as illustrated in Figure 5, significant throughput gains can be achieved if BSSs coordinate their access to the airwaves or medium in one or more of time, frequency, space, and power. In some implementations, APs 504A, 504B, and 504C coordinate the use of resources and operational modes of the shared medium to reduce the likelihood that wireless devices 402 are subject to interference. A wireless device 402 can be subject to interference by either causing interference with another wireless device 402 or experiencing interference caused by another wireless device 402.

[0090] In other implementations, one of the APs 504A, 504B, and 504C receives instructions from another one of the APs 504A, 504B, and 504C to modify its use or one of the wireless devices 402 associated with the receiving AP use of the airwaves or medium to reduce the likelihood that a wireless device 402 is subject to interference. In certain embodiments, the APs 504A, 504B, and 504C exchange information to coordinate their use of the shared medium. In other embodiments the AP 504A, 504B, and 504C receives an instruction from another AP 504A, 504B, and 504C on how it should use the shared medium.

[0091] For example, the APs 504A, 504B, and 504C can coordinate access to the shared medium even when the APs are associated with different BSS 502A, 502B, and 502C. The APs 504A, 504B, and 504C can determine whether one or more wireless devices 402 is subject to interference with another wireless device in the wireless network. The APs 504A, 504B, and 504C identify the one or more wireless devices 402 that are subject to interference via identifying information such as a MAC address. The APs 504A, 504B, and 504C then receive information from each other on the nature of the interference and/or the shared medium. The APs 504A, 504B, and 504C then modify the use of the shared medium by one or more of the wireless devices 402 to reduce the likelihood that the wireless device is subject to interference. In some implementations, this modification includes transmission of one or more messages 508A, 508B, and 508C between APs as illustrated in Figure 5.

[0092] In other embodiments, the AP 504A, 504B, and 504C receives an instruction from another AP 504A, 504B, and 504C on how it should use the shared medium. For example, the AP 504A, 504B, and 504C can receive information associated with the first or second BSSs. The information can include an identification of one or more wireless devices that are subject to interference. The receiving AP 504A, 504B, and 504C then modifies, based on the received information, the use of the shared medium to reduce the likelihood that the one or more wireless devices are subject to interference. The modification can be to resources including, but not limited to, time, frequency, and space. The modification can be to operation modes including, but not limited to, transmission parameters and access modes.

Time

[0093] In some implementations where the modification or coordination relates to time, orthogonal activity periods are scheduled across APs 504A, 504B, and 504C. In some implementations, scheduling of orthogonal activity periods across APs 504A, 504B, and 504C is only for transmission to a certain subset of wireless devices 402 or users. Other users can be served at any time. An exemplary subset is "edge users" or wireless devices 402 that may suffer interference from neighboring APs 504A, 504B, and 504C. In some implementations, DL/UL transmissions are aligned across APs 504A, 504B, and 504C. Additional implementations are described below.

Frequency

[0094] In some implementations where the modification or coordination relates to frequency, orthogonal channels are scheduled for transmission use across BSS 502A, 502B, and 502C. For example, a primary channel location is scheduled across APs 504A, 504B, and 504C. In some implementations, orthogonal channels are scheduled across APs 504A, 504B, and 504C for only a subset of wireless devices 402 or STAs. Other wireless devices 402 or STAs can be served on any channel. In some implementations, channels used for DL/UL transmissions are aligned across APs 504A, 504B, and 504C. Additional implementations are described below.

Space

[0095] In some implementations where the modification or coordination relates to spatial domains, orthogonal "beams" are scheduled across BSS 502A, 502B, and 502C. In some implementations, beams are aligned across APs 504A, 504B, and 504C. Additional implementations are described below.

Power

[0096] In some implementations where the modification or coordination relates to power, coordination is achieved by selecting transmission power for DL and UL transmissions across APs 504A, 504B, and 504C. Additional implementations are described below.

Coordination of Resources

[0097] Coordination across APs 504A, 504B, and 504C can be achieved as explicit communications across APs 504A, 504B, and 504C/STAs 506A-H of different BSS 502A, 502B, and 502C and/or implicit communications/measurements based on observation of the traffic on the medium. For example, explicit messages (e.g., messages 508A-C) can be sent over the air or over a separate communication means such as a cable backhaul. In some implementations, messages are exchanged directly between APs 504A, 504B, and 504C, between APs 504A, 504B, and 504C via STAs 506A-H, directly between STAs 506A-H, and/or between STAs 506A-H via APs 504A, 504B, and 504C. In some implementations which use implicit communications, packets are enhanced to carry partial information that can help the coordination. In some implementations, coordination of final decisions are made by a central informed controller, with a distributed heuristic at each AP, and/or based on exchanged information at each STA.

[0098] In some implementations of the coordination protocol, APs 504A, 504B, and

504C/STAs 506A-H exchange information on resources including time/frequency/space/power. In some implementations, APs 504A, 504B, and 504C/STAs 506A-H exchange information on operation modes including transmission parameters and access modes. The exchanged information can include positive or negative requests. For example, a positive request can be for the sender AP 504A, 504B, and 504C to use a requested resources/operation modes. A negative request can be for the receiving AP 504A, 504B, and 504C to not use the indicated resources/operation modes.

Time

[0099] In some implementations where time is coordinated across APs 504A, 504B, and 504C, messages exchanged across APs 504A, 504B, and 504C/STAs 506A-H include positive/negative requests for one or more of start time, duration, periodicity of access time to which the positive/negative request is referred to, and/or types of allowed access. For example, types of access can include enhanced distributed channel access (EDCA) /backoff/schedule parameters such as an arbitration inter frame spacing (AIFS), contention window min or max (CWmin, CWmax), TXOP limit, and CCA thresholds. In some implementations, the type of access is traffic QoS such as admission control (AC), max amount of transmission time and/or bytes allowed.

[0100] In some implementations, the coordination protocol includes a mechanism that allows APs 504A, 504B, and 504C/STAs 506A-H to reach an agreement on time usage so that transmissions of neighboring APs 504A, 504B, and 504C/STAs 506A-H are disjoint in time and/or transmissions to/from a certain set of STAs 506A-H. For example, STAs 506 that are indicated as interfering in the messaging are allocated non overlapping RAWs/TWTs across neighboring APs 504A, 504B, and 504C. In certain implementations, the interfering wireless device may be an APs 504A, 504B, and 504C. For example, STAs 506A-H that are 'likely to be interfered' or have a weak link or have limitations on the BW such as edge STA 506A, 506F, 506G are allocated disjoint time resources. In some implementations UL transmissions (from STAs only) are allowed or DL transmission (from AP) are allowed, or both in an overlapping restricted access window (RAW) timing and/or target wakeup time (TWT) timing. In some implementations, it is preferred that transmissions to/from STAs with same or similar access modes (QoS/EDCA parameters) happen at the same time while transmissions to/from STAs with different access modes (QoS/EDCA parameters) happen at different times.

STAs/APs Coordination

[0101] In some implementations, APs 504A, 504B, and 504C/STAs 506A-H exchange requests/responses for use of resources and operation modes by specific STAs 506A-H/APs 504A, 504B, and 504C. Messages exchanged across APs 504A, 504B, and 504C/STAs 506A-H can include positive/negative requests for one or more specific STAs 506A-H/APs 504A, 504B, and 504C. For example, the specific STAs 506A-H/APs 504A, 504B, and 504C can be a number/group of STAs that belong to the AP sending the message. The sending AP would like to be active in terms of address, location, and/or a transmission characteristic such as power, rate, and interference condition.

[0102] In some implementations, the specific STAs 506A-H/APs 504A, 504B, and 504C is a group of STAs that include STAs belonging to the neighboring AP that will receive the message. The specific STAs 506 may be identified in terms of address, location, and/or transmission characteristic such as power, rate, and interference condition. In some implementations, the information identifies STAs 506 that interfere with the sending AP operation, or with operation of STAs associated with the sending AP.

[0103] In some implementations, the specific STAs 506A-H/APs 504A, 504B, and 504C is a group of STAs that indicate operation capability of STAs such as type of protocols supported (802.11a/n/ac/b), TX/RX parameters supported, and/or type of operation/traffic supported.

[0104] In some implementations, the coordination protocol includes a mechanism that allows APs 504A, 504B, and 504C/STAs 506A-H to reach an agreement on which STAs are allowed access to prevent interfering STAs from using the same resource and/or to schedule the same resources for STAs that have similar transmission characteristics. For example, in some implementations, edge STAs 506A, 506F, and 506G are scheduled at the same time while center STAs 506 B-E, H are scheduled at the same time. In some implementations, only STAs with compatible operation modes are sharing resources.

Frequency

[0105] In some implementations, APs 504A, 504B, and 504C/STAs 506A-H exchange requests/responses for use of resources and operation modes in certain frequency bands/channels. Messages exchanged across APs 504A, 504B, and 504C/STAs 506A-H can include positive/negative requests for one or more of a primary channel, channel(s) used for transmission, allowed transmission BW, allowed mode of transmission such as direction UL/DL and PHY mode, allowed STAs 506A-H/APs 504A, 504B, and 504C for transmission in each channel such as inner/outer STAs and interfering STAs that are allowed/not allowed to transmit.

[0106] In certain implementations, the coordination protocol includes a mechanism that allows APs 504A, 504B, and 504C/STAs 506A-H to reach an agreement on which STAs are allowed to access such that disjoint primary channels are allocated to interfering APs 504A, 504B, and 504C/STAs 506A-H. Allowed transmission BW can be optimized for reuse by, for example, limiting transmission BW such that independent resources are available for APs 504A, 504B, and 504C. In some implementations, different channels/BW are used for STAs in different locations/transmit conditions. For example, center STAs 506 B-E, H can be allowed to use all the BW while edge STAs 506A, 506F, and 506G use a channel that is different from the channel used by edge STAs 506A, 506F, and 506G in neighboring APs 504A, 504B, and 504C.

Spatial Coordination

[0107] In some implementations, APs 504A, 504B, and 504C/STAs may exchange requests/responses for use of resources and operation modes in certain spatial domains. Messages exchanged across APs 504A, 504B, and 504C/STAs 506A-H can include positive/negative requests for one or more of a location of the STA/APs 504A, 504B, and 504C that can use the shared medium including direction UL/DL. In some implementations, the requests relate to identification of the spatial domain such as absolute/relative geographical description/positioning or interfering relations between STAs/APs 504A, 504B, and 504C. In other implementations, the requests include an indication of whether beam forming is allowed or which spatial sectors or spatial beams are to be used. In some implementations, interfering relations between STAs/APs 504A, 504B, and 504C can be based on strength of interference and/or exact channel representation.

[0108] In some implementations, the communication protocol includes a mechanism that allows APs 504A, 504B, and 504C/STAs to reach an agreement such that non interfering spatial domains are used across BSS 502A, 502B, and 502C by, for example, employing orthogonal sectors, beams, and STAs locations. In some implementations, simultaneous transmissions are TX/RX filtered based on channel state information received by all involved STAs so that cross interference is minimized.

<u>Transmission of Coordination Messages</u>

[0109] In some implementations, coordination messages are sent by APs 504A, 504B, and 504C/STAs 506A-H on a common control channel. The common control channel can be a commonly identified frequency channel that is common among the operating BWs of the neighboring APs 504A, 504B, and 504C/STAs 506A-H. For example, the channel may be one of the 20Mhz channels out of the 80/160/320 data operation band or in a band that is disjoint from the data operation band such as when data is exchanged in 2.4GHz and control is exchanged in 900MHz. An advantage of using 900MHz is the transmission has a greater range than 2.4GHz to reach distant APs 504A, 504B, and 504C. In some implementations, the common control channel is statically identified by the standard specifications. For example, a default 20MHz channel for each allowed operating 20/40/80/160 BSS 502A, 502B, AND 502C operating channel is used in some implementations. In some implementations, channels are agreed across neighboring APs 504A, 504B, and 504C via a distributed election protocol. In some implementations, the coordination messages are sent at a common time agreed across neighboring APs 504A, 504B, and 504C/STAs 506A-H.

[0110] In some implementations, coordination messages are sent by APs 504A, 504B, and 504C and relayed by STAs 506A-H to reach neighboring APs 504A, 504B, and 504C. For example, the coordination messages can be carried by STA-STA or STA-AP communications across STAs 506A-H/APs 504A, 504B, and 504C that are not associated with each other. In some implementations, Generic Advertisement Service (GAS) frames or other frames are exchanged without an association in place to send coordination messages. In other implementations, coordination messages are carried by STA-STA or STA-AP communications across STAs/APs 504A, 504B, and 504C associated with each other using, for example, a new form of STA-STA or STA-AP association across BSS 502A, 502B, and 502C.

[0111] In some implementations, the coordination messages used to exchange information are sent in new frames defined by the IEEE standard such as management frames 520 (see Figure 5A), action frames 524 (see Figure 5B), and/or GAS frames 526 (see Figure 5C). The new frames can include HEW parameters 522 that can be exchanged across APs 504A, 504B, and 504C. In some implementations, only certain of the existing indications of the new frames are employed. In some implementations additional indications, such as the HEW parameters 522, are added to the existing indications already defined by the new frames.

[0112] In some implementations, the coordination messages are embedded in existing frames by using reserved bits. For example, reserved bits 528 can be used to override the HTC control field 530 in HT or VHT format as is illustrated in Figure 5D. In some implementations, parameters related to usage of resources are implicitly derived by measuring activity on the resource of interest.

Time Coordination

[0113] In some implementations where time is coordinated between APs 504A, 504B, and 504C, existing communication protocols are used. For example, 802.11ah defines protocols (alternative to hybrid coordination function (HCF) Controlled Channel Access (HCCA)) for time schedule within BSS 502A, 502B, and 502C with no coordination using restricted access window (RAW) and target wake time (TWT). RAW is an interval of time advertised by the AP in a beacon which is reserved for access to only a certain group of STAs. In a modification, the group is empty which prevents all STAs from transmitting at a certain time. TWT is an agreement between AP and an STA for a time when the STA is to be awake and engage in communication with the AP. In a modification, the STAs cannot transmit outside the agreed time.

[0114] In certain embodiments, the coordination protocol allows the exchange of RAW and TWT parameters across APs 504A, 504B, and 504C so that RAW / TWT parameter settings can be coordinated across APs 504A, 504B, and 504C. For example, the set of parameters that define a RAW are listed in the RPS Information element defined by 802.11ah.

[0115] FIG. 6 is a representation of a modified restricted access window (RAW) parameter set (RPS) information element defined by 802.11ah that includes HEW parameters 602 than can be exchanged across APs 504A, 504B, and 504C. In some implementations, only certain of the existing indications defined by 802.11ah are employed. In some implementations additional indications, such as HEW parameters 602, are added to the existing indications already defined by 802.11ah. Within the coordination protocol, APs 504A, 504B, and 504C can exchange one or more of the above indications including the HEW parameters 602 per each potential RAW or TWT or equivalent reservation protocol. The provided parameters may refer to a (positive) request for the sender AP 504A, 504B, and 504C to use the requested resources/operation modes or a (negative) request for the receiving AP 504A, 504B, and 504C not to use the indicated time/operation.

[0116] In some implementations, one or more of the above indications is included in the same or similar message as the Transmit Opportunity (TXOP) Advertisement frame used in 802.11aa. 802.11aa defines a protocol for AP 504A, 504B, and 504C to AP 504A, 504B, and 504C coordination where APs 504A, 504B, and 504C can decode each other's beacons. Protocol messaging is included in the beacon or exchanged though action frames. Messaging can be encrypted with a key known by APs 504A, 504B, and 504C. In some implementations, the messages include time synchronization (TSF) and/or requests for the use of an interval of time for medium access (TXOP) that is always available to the AP. The coordination protocol allows agreement on the TXOP allocation across APs 504A, 504B, and 504C. Under 802.11aa, APs 504A, 504B, and 504C exchange information to manage their STAs medium access by using a medium access procedure such as HCF Controlled Channel Access (HCCA). Under HCCA STAs are not allowed to access the medium unless they are polled by the AP 504A, 504B, and 504C. In this way the AP 504A, 504B, and 504C is in full control of medium usage. However, 802.11aa is limited in that it only uses AP-AP direct communications, only allows for time allocation of TXOP, and only refers to the use of HCCA as medium access techniques.

[0117] In some implementations, APs 504A, 504B, and 504C use action frames defined by 802.11aa to share request/responses about TXOP allocation.

[0118] FIG. 7 is a representation of a modified advertisement action frame action field and of a TXOP reservation field format defined by 802.11aa that includes HEW parameters 702. In some implementation, additional information, such as HEW parameters 702, is transported via the protocol defined by 802.11aa by means of modified or new frame formats. In some implementations, additional protocol rules are also defined as set forth above.

[0119] In some implementations, certain STAs from different BSS are allowed to transmit at the same time even in cases where the current WiFi CSMA procedure would not allow transmission. For example, "cell center" STAs 802 in FIG. 8 are allowed to transmit at the same time. Certain STAs from the different BSSs are prevented from transmitting at the same time even in cases where the current WiFi CSMA procedure would allow transmission. For example, "cell edge" STAs 804 in Figure 8 are prevented from transmitting even if allowed by the current WiFi CSMA procedure.

[0120] Referring to Figures 5 and 8, in some implementations, coordination requires identification of the STAs/APs that interfere with each other such as cell center STAs 506B-E, 506H, 802 and cell edge STAs 506A, 506F, 506G, 804, communication across APs/STAs of different BSSs to agree on the time schedule, and/or the use of a scheduling protocol that determines the schedule.

[0121] In some implementations, interfered STAs such as cell center STAs 506B-E, 506H, 802 and cell edge STAs 506A, 506F, 506G, 804 are reported by STAs to the AP. The interfered STA can be identified by its MAC address or a Partial AID (PAID) address. In some implementation, STAs report interfered STAs belonging to neighboring BSSs. In some implementations where the MAC address is not available because, for example, the address is sent at a high rate, a Partial AID may be used. However, a Partial AID may not be unique to the STA. To increases the uniqueness of the Partial AID, the neighboring APs 504A, 504B, and 504C can use disjoint PAID spaces. Access points may exchange signaling to coordinate the selection of disjoint Partial AID spaces. In some implementations, the reporting STA includes additional interference information such as signal strength and frequency of interference. In some implementations, 802.11k messaging or similar is used.

[0122] In some implementations, STAs request to be considered in one of at least two classes such as interfered or non-interfered. The request can be based on the level of interference experienced from BSS AP/STA packets even without precise identification of the interference source.

[0123] In some implementations, interfered STAs such as cell center STAs 506B-E, 506H, 802 and cell edge STAs 506A, 506F, 506G, 804 are classified by the AP based on throughput/Packet error rate or by messages sent by STAs over the air and collected by the AP. In some implementations, the messages are sent in management frames with contention or at scheduled times.

[0124] Referring back to Figure 5, a time schedule can be agreed across APs 504A, 504B, and 504C/STAs of different BSS 502A, 502B, and 502C. In some implementations, a modified 802.11aa framework is used. For example, the messages being sent across APs 504A, 504B, and 504C may include requested interval of time, a list of STAs that should be silenced during the requested time or that should adopt certain medium access procedure (may include AP), and/or the specific settings for the access procedure, such as QoS/enhanced distributed channel access (EDCA) parameters that should be used during that time, allowed Access Category, clear channel assessment parameters (CCA and energy detection threshold), maximum transmission duration, maximum amount of traffic that can be delivered, allowed power of transmission and other transmit operation modes parameters.

[0125] In some implementations where time coordination across APs 504A, 504B, and 504C is based on received information, the protocol schedules reserved time or adapts the behavior of the interfering STA. For example, if reserved time is granted based on communication across APs 504A, 504B, and 504C, the requesting AP/STAs uses the reserved time for transmission to the AP/STAs that would otherwise have experienced interference. During this time the requesting AP/STAs may access the medium with favorable access procedures. Favorable access procedures include the use of a less sensitive clear channel assessment or no clear channel assessment at all, the use of EDCA parameter settings that result in higher priority access to the medium, the use of a longer transmission, higher maximum amount of traffic delivered, higher power of transmission, and/or other favorable transmit operation modes. During this time the requesting AP/STAs may also not defer medium access upon detection of packets on the medium, as it would be requested by 802.11 medium access procedures. AP/STAs may instead drop certain detected packets and ignore them, considering the medium available for transmission. The certain packets may be identified by a Partial AID, a MAC address, and/or an explicit indication embedded in the PHY preamble.

[0126] In some implementations, interfering STAs are forbidden from accessing during the reserved time or their access is subject to less favorable procedures. Less favorable access procedures include the use of a more sensitive clear channel assessment, the use of EDCA parameter settings that result in lower priority access to the medium, the use of shorter transmission, lower maximum amount of traffic delivered, lower power of transmission and/or other less favorable transmit operation modes. During this time interfering AP/STAs may also defer medium access upon detection of certain packets on the medium. The certain packets may be all the detected packets or may be identified by a Partial AID, a MAC address (e/g referred to an interfered STA), and/or an explicit indication embedded in the PHY preamble indicating that deferral must happen.

[0127] In some implementations, if the behavior of the interfering STA is adapted to protect interfered STAs without strict time boundaries, the interfering STAs must use a more sensitive deferral to frames sent by/to interfered STAs. For frames sent by/to other STAs deferral may be weaker. In some implementations, frames sent by/to interfered STAs can be identified via Partial AID in the PHY header, a MAC address, and/or specific bits in the PHY preamble. Sensitive deferral may refer to CCA levels, EDCA parameters, duration of transmissions, and/or use of RTS/CTS. In some implementation, interfered STAs are allowed to use techniques that favor their access by indicating with one bit in the PHY header that their transmission is protected, using favorable EDCA parameters, and/or using RTS/CTS.

Frequency Coordination

[0128] FIG. 9 is an exemplary wireless communication system employing frequency coordination. In some implementations, cell center STAs 904 use the whole bandwidth (BW). Cell edge STAs 902 can only be served with BW1 while cell edge STAs 906 can only be served with BW2. Of course other arrangements are within the scope of the disclosure that reduces the likelihood of interference.

[0129] In some implementations, coordination requires identification of the STAs/APs that interfere with each other such as cell edge STAs 902, 906. In some implementations, coordination requires communication across APs/STAs of different BSS to agree on the channels schedule. In some implementations, coordination requires the use of a scheduling protocol that determines the channel schedule.

[0130] In some implementations, interfered STAs such as 'cell center' STAs and 'cell edge' STAs are reported by STAs to the AP. The interfered STA can be identified by its MAC address or a Partial AID address. In some implementation, the STA reports interfered STAs belonging to neighboring BSS and includes a channel indication. In some implementations where the MAC address is not available because, for example, the address is sent at high rate, a Partial AID may be used. However, a Partial AID may not be unique to the STA. To increases the uniqueness of the Partial AID, the neighboring APs can use disjoint PAID spaces. In some implementations, the reporting STA includes additional interference information such as signal strength and frequency of interference. In some implementations, 802.11k messaging or similar is used.

[0131] In some implementations, STAs request to be considered in one of at least two classes such as interfered or non-interfered. The request can be based on the level of interference experienced from BSS AP/STA packets even without precise identification of the interference source.

[0132] In some implementations, interfered STAs such as 'cell center' STAs and 'cell edge' STAs are classified by the AP based on throughput/Packet error rate/channel or by messages sent by STAs over the air and collected by the AP. In some implementations, the messages are sent in management frames with contention or at scheduled times.

[0133] Referring to Figure 5, a frequency schedule can be agreed across APs 504A, 504B, and 504C/STAs of different BSS 502A, 502B, and 502C. In some implementations, a modified 802.11aa framework is used. For example, the messages being sent across APs 504A, 504B, and 504C may include a requested frequency channel, a list of STAs that should be silenced on the requested channel or that should adopt certain medium access procedure (may include AP), and/or the specific settings for the access procedure, such as QoS/enhanced distributed channel access (EDCA) parameters that should be used on the requested channel, allowed Access Category, clear channel assessment parameters (CCA and energy detection threshold), maximum transmission duration, maximum amount of traffic that can be delivered, allowed power of transmission and other transmit operation modes parameters.

[0134] In some implementations where frequency coordination across APs 504A, 504B, and 504C is based on received information, the protocol schedules a reserved channel or adapts the behavior of the interfering STA. For example, if a reserved channel is granted based on communication across APs 504A, 504B, and 504C, the requesting AP/STAs uses the reserved channel for transmission to the AP/STAs that would otherwise have experienced interference. Interfering STAs are forbidden from accessing the reserved channel or their access is subject to transmission parameter limitations. For example, on the reserved channel the requesting AP/STAs may access the medium with favorable access procedures. Favorable access procedures include the use of a less sensitive clear channel assessment or no clear channel assessment at all, the use of EDCA parameter settings that result in higher priority access to the medium, the use of a longer transmission, higher maximum amount of traffic delivered, higher power of transmission, and/or other favorable transmit operation modes. On the reserved channel the requesting AP/STAs may also not defer medium access upon detection of packets on the medium, as it would be requested by 802.11 medium access procedures. AP/STAs may instead drop certain detected packets and ignore them, considering the medium available for transmission. The certain packets may be identified by a Partial AID, a MAC address, and/or an explicit indication embedded in the PHY preamble.

[0135] In some implementations, interfering STAs are forbidden from accessing the reserved channel or their access is subject to less favorable procedures. Less favorable access procedures include the use of a more sensitive clear channel assessment, the use of EDCA parameter settings that result in lower priority access to the medium, the use of shorter transmission, lower maximum amount of traffic delivered, lower power of transmission and/or other less favorable transmit operation modes. On the reserved channel interfering AP/STAs may also defer medium access upon detection of certain packets on the medium. The certain packets may be all the detected packets or may be identified by a Partial AID, a MAC address (e/g referred to an interfered STA), and/or an explicit indication embedded in the PHY preamble indicating that deferral must happen.

[0136] If the behavior of the interfering STA is adapted to protect interfered STAs without strict channel boundaries, the interfering STAs uses a lower transmission BW and/or a more sensitive deferral to frames sent by/to interfered STAs. For frames sent by/to other STAs the deferral may be weaker. In some implementations, frames sent by/to interfered STAs can be identified via Partial AID in the PHY header, a MAC address, and/or specific bits in the PHY preamble. Sensitive deferral may refer to CCA levels, EDCA parameters, duration of transmissions, and/or use of RTS/CTS. In some implementation, interfered STAs are allowed to use techniques that favor their access by indicating with one bit in the PHY header that their transmission is protected, using favorable EDCA parameters, and/or using RTS/CTS. Please note that although described separately, coordination in time and frequency may happen simultaneously.

Example High Efficiency Wireless (HEW) Access Point (AP) Coordination Protocol

[0137] Techniques and apparatus are provided herein for protocols that may allow access points (APs) to coordinate periods of time where interference can be controlled to desired levels. For example, the APs may coordinate resource usage and operation modes of APs and stations (STAs). This may useful in networks with dense deployments of multiple basic service sets (BSSs). The protocol provided herein may identify specific messaging, scheduling, and coordination. The techniques provided herein may provide enhancements, for example, to the 802.11ah scheduling and 802.11aa coordination protocols described above.

[0138] In an example implementation, using the techniques provided herein may allow APs to coordinate what frequencies the APs transmit on. According to certain aspects, the “time periods” for coordination may extend for many multiples of the beacon periods.

[0139] In a dense BSS scenario (e.g., similar to the dense BSS scenario illustrated in FIG. 5), potentially significant throughput gains may be achieved if BSSs can coordinate their transmissions for certain periods of time. During these times the BSSs can coordinate the type of traffic they send (e.g., downlink/uplink), which part of the frequency band they use, and what kind of access parameters they use.

[0140] FIG. 10 is a graph 1000 illustrating cumulative distribution functions (CDFs) 1002, 1004, 1006 for downlink throughput in a regularly spaced network, in accordance with certain aspects of the present disclosure. As shown in FIG. 10, one curve may correspond to the CDF 1304 for reuse equal to 1, where all APs send without any coordination in time or frequency. The top thirty percent (30%) of users may get very good throughput (tput), but the bottom fifty percent (50%) of users may be in outage. A second curve may correspond to the CDF 1306 for reuse equal to 1/3, where APs coordinate in frequency, but not time. The bottom fifty percent (50%) of users may no longer be in outage, but the top thirty percent (30%) may not achieve high throughput. A third curve may correspond to the CDF 1302 for a HEW scheme with 1 1/3 reuse, where the APs coordinate in both frequency and time. The bottom fifty percent (50%) may no longer be in outage and the top thirty percent (30%) may still have high throughput. In aspects, the time and frequency coordination may be performed by the APs as shown in FIGs. 8 and 9, for example. APs can use time slots (e.g., time periods) with a lower reuse factor to send to interference sensitive users. User on the cell edge get served on BW1 or BW2 during even time slots, while users closer to the AP can be served with the entire bandwidth during odd time slots.

[0141] Uplink transmissions may interfere with the downlink transmissions of neighboring overlapping BSSs (OBSSs). Hence, certain time periods (e.g., slots) may be allocated for downlink only. This may avoid interference with uplink transmissions during those times. Alternatively, certain time periods may be set aside for uplink traffic only, so that the uplink traffic does not interfere with downlink traffic during these times. In aspects, certain time periods may be uplink and downlink. In aspects, certain time periods may have different reuse factors.

[0142] According to certain aspects, certain time periods may be allocated where the AP requests that certain nodes in OBSSs do not transmit. This may allow nodes that are sensitive to interference to transmit is an environment with less interference. Conversely, the AP could request that only certain nodes from OBSSs transmit during a reserved time.

[0143] It may be desirable to have time periods where neighboring BSSs are transmitting on orthogonal frequency bands (i.e., orthogonalized) in order to reduce interference. This may be achieved in a variety of ways. In one example, a maximum bandwidth (BW) may be specified for a particular time period, and the BSSs may randomly choose a channel of this maximum BW. In another example, a maximum BW may be specified for a particular time period, and the BSSs may select a channel for transmission by starting with their primary channel and increasing the channel until the channel reaches the maximum BW specified. The BSSs may also prenegotiate which channel to use when asked to transmit on a channel of a particular size. Alternatively, a "no interference" frequency may be specified for a particular time period, in which case the BSSs may be free to send on any frequency but the one specified. The time periods where neighboring BSSs send on different frequency bands may or may not include additional restrictions on the type of traffic. For example, the time periods may be restricted to downlink only, uplink only, or uplink and downlink periods. These time periods may also have additional specifications regarding the way devices are to access the medium during that time. For example, they may be restricted to use baseline carrier sensing multiple access (CSMA) with different values of CWmin or to use a special set of enhanced distributed channel access (EDCA) parameters, etc.

[0144] It may also be beneficial to have time periods with modified deferral rules.. The deferral rules could be such that participating nodes do not need to defer to nodes that have a BSSID different from their own BSSID. Alternatively, participating nodes would not need to defer to nodes that have specific BSSIDs. These specific BSSIDs could be communicated to the other APs in the coordinating messages. The specific BSSIDs would also be communicated to the participating STAs. APs could use these time periods to allow service for users that are less sensitive to interference.

[0145] According to certain aspects, it is also possible to always allow a certain set of nodes in a BSS to forgo the normal deferral rules. For example, STAs that are far from neighboring BSSs may be allowed to forgo deferring to nodes that use a BSSID different from their own. Or, the BSSs may be allowed to forgo deferring to nodes that have a specific BSSID.

[0146] Some of these reserved time periods may also be such that APs and STAs allowed to use these time periods are granted favorable access to the medium. For example they could have less sensitive clear channel assessment levels, less stringent deferral rules, the use of more favorable EDCA parameters allowing faster access to the medium, the use of higher power, and or other favorable transmission options. This could help users of the new protocol not be adversely affected by legacy users.

[0147] Techniques and apparatus are provided herein for allowing APs to coordinate periods of time where interference may be controlled to various levels. According to certain aspects, coordination may include time synchronization, intra-AP scheduling, and the enforcement of the scheduling within the AP. In aspects, the coordination may be performed with over the air (OTA) messaging. Time synchronization and intra-AP scheduling may be performed with backhaul connection messaging.

[0148] Time synchronization may be performed in order to maintain synchronization in time between APs. According to certain aspects, time synchronization may be performed in a manner similar to social wifi (e.g., using certain methods from social wifi). For example, all nodes in a coordinating set may listen to a single (e.g., periodic) message (e.g., from a single master node) to update their clocks. According to certain aspects, a node, which may be within the coordinating set, may be selected as the "master" node. The other nodes in the set may update their clocks based on the clock of the master node. The designated master of the coordinating set may send out the synchronizing message (e.g., any message with timing information about when the message was sent). For instance, the master of the coordinating set may send out beacons at a particular interval. Other APs in the coordinating set may listen to the master's beacon and adjust their clocks based on the timing information in the beacon. According to certain aspects, the message sent by the master may not be a beacon, instead, any message having timing information about when the message was sent (e.g., according to the Master's clock) may be used. Other devices (i.e., "agents"), whether they be APs or STAs, may be used to relay the master's timing message. Therefore, multiple coordinating sets can be synchronized in time. The timing messages of nodes may all happen in a particular time window or each node may send its timing messages at an unrelated time from the other nodes.

[0149] According to certain aspects, methods (e.g., similar to 802.11aa methods) may be used for timing synchronization. For example, all nodes in a coordinating set may listen to timing messages from all their members (e.g., there may not be any master node). Each node may update its timer so that it does not lose synch with any member. Alternatively, each node may update its timer so that it stays in synch with as many members as possible. For certain systems (e.g., 802.11aa systems), it may be assumed that APs can hear the beacons of other APs they want to coordinate with. According to certain aspects, the nodes may update their timers based on a node that is furthest away in time. According to certain aspects, the nodes may update their timers to stay in synch with as many other nodes as possible. For each OBSS APs, an AP may listen to the beacon and may calculate

$$T_{offset} = TT - TR,$$

[0150] where T_{offset} is the timing offset value, TT is the value in the Timestamp field in the received Beacon frame, and TR is the Beacon frame reception time measured using the AP's TSF timer. The AP may also store T_{offset} which may be used for converting OBSS AP's time to AP's time. The AP may also perform drift adjustment. For each OBSS AP, the AP may calculate

$$T_{ClockDrift} = T_{offset,1} - T_{offset,0},$$

[0151] where $T_{ClockDrift}$ is the clock drift amount represented as twos complement, in microseconds, $T_{offset,1}$ is the T_{offset} obtained from the previous beacon reception, and $T_{offset,0}$ is the T_{offset} obtained from the current beacon reception.

[0152] According to certain aspects, if max_OBSS($T_{ClockDrift}$)>0, the AP may suspend its TSF timer for the duration of the largest $T_{ClockDrift}$.

[0153] According to certain aspects, coordinating sets may each have a Master which sends out periodic timing information (e.g., a beacon or other similar message). Nodes may belong to multiple coordinating sets. These nodes may listen to the timing messages of each master. The nodes may set their clocks so that they can stay in synch with as many masters as possible

[0154] It may be desirable to ensure that the APs can hear the messages that carry timing information so that the APs may remain in sync. For example, an AP may listen for synchronization messages during a quiet period for its STAs. According to certain aspects, the AP may send various messages in order to specify (i.e., reserve) the quiet period. Certain systems (e.g., 802.11aa systems) assume that the APs are in control of all transmissions and, hence, there may not be any uplink traffic in the BSS to interfere with a beacon reception from another AP in the coordinating set. Social wifi assumes that all nodes are listening for the timing messages. However, this may not be the case in a HEW system. In HEW, uplink transmissions may interfere with timing messages from other APs. If the AP misses beacons (e.g., due to interference from the UL transmissions), the AP may lose time synchronization with the other nodes it is coordinating with.

[0155] According to certain aspects, the AP may send a broadcast message reserving the time it will listen (listening time) to timing messages from other APs. According to certain aspects, this message may include the start times and durations that the AP wants to reserve so it can listen to timing messages. According to certain aspects, the message may be sent directly after the beacon.

[0156] According to certain aspects, the AP may send a quiet element to silence STAs in its BSS. The quiet element may define an interval during which no transmission should occur in the current channel. A quiet element may (e.g., as defined by the 802.11 standard) include the following fields: element ID, length, quiet count, quiet period, quiet duration, and quiet offset. In the case where multiple interference free periods (i.e., quiet periods) are desired, the AP may send multiple quiet elements to reserve the multiple periods. Alternatively, the quiet element itself may be modified to reserve multiple non-consecutive quiet periods. For example, a field for the number of quiet periods may be added to the quiet element as well as additional fields for quiet count, quiet period, quiet duration, and quiet offset. The multiplicity of the fields may be determined by the number of quiet periods desired.

[0157] According to certain aspects, the AP may wake sleeping users only after the reserved times have passed. The AP may wake users with target wake times (TWT). In this way, the AP may ensure that STAs do not send during the reserved periods. According to certain aspects, the AP may use a modified RAW frame or modified power save multi-poll (PSMP) message to reserve the period for listening without interference. FIG. 11 illustrates an example frame 1100 field format for RAW, in accordance with certain aspects of the present disclosure. According to certain aspects, the AP may include a group ID in the RAW frame to which no STAs belong so that the STAs sleep during the reserved times. If there are multiple time periods that the AP wants to reserve per beacon frame, then the AP may send a RAW frame before each of the multiple time periods. Alternatively, the AP may modify the RAW frame to have multiple reserved periods. For example, the AP may add additional RAW start time & RAW duration fields and a "number of reservations" field. As yet another alternative, the AP may send multiple consecutive RAW frames to reserve multiple periods for listening (e.g., 1 for each reservation needed).

[0158] According to certain aspects, the AP may send a single PSMP frame to schedule multiple STAs, for example, instead of sending direct quality of service (QoS)(+) contention free (CF)-Poll (e.g., as used in hybrid coordinated function (HCF) controlled channel access (HCCA)). This may reduce power consumption by providing an UL and DL schedule at the start of the PSMP phase so that each STA may only turn on its receiver if there is a downlink transmission time (DTT) scheduled for the STA and each STA may transmit only if it has an assigned uplink transmission time (UTT). There may be no need to perform clear channel assessment (CCA). The frame format of an example PSMP message 1200 is shown in FIG. 12. The AP may assign PSMP DTTs or UTTs to a STA ID corresponding to non-existent STAs, or other reserved STA ID, in order to make sure the medium is interference free. It can then listen to the timing messages from the other members of the coordinating set without interference from inside the BSS. If non-contiguous time reservations are desired, the PSMP message can be modified so that DTTs may be non-contiguous.

<u>Intra-AP Scheduling</u>

[0159] For intra-AP scheduling, scheduling information may be communicated across APs. One example of scheduling information to be communicated may be time allocation of reservation slot which may include: start time, where the start time is measured from (e.g., from the end of the sender's beacon time), duration of reservation, and periodicity of reservation time—if applicable. For example, the AP may specify that the reserved period will occur once during each of the next "x" beacon periods, where "x" could be 1-128. Alternatively, the AP may specify that the reserved period occurs during each beacon period until specified otherwise.

[0160] In addition to the timing of the reserved slot, another example of scheduling information that may be communicated across APs may include the type of coordinated access allowed per reservation may also be communicated across APs. According to certain aspects, the AP may reserve the listening time only for uplink, only for downlink, or for both uplink and downlink. According to certain aspects, the AP may reserve the listening period for silence from other members of the coordinated set. According to certain aspects, the AP may communicate bandwidth information for the reservation (e.g., when time coordination is paired with frequency coordination). For example, the AP may specify a particular bandwidth to reserve (i.e., for neighboring

APs not to use during the reserved time) or a maximum bandwidth for its neighbors to use during the reserved time. According to certain aspects, the AP may specify which EDCA/backoff/schedule parameters (e.g., arbitrary interframe space (AIFS), CWmin, CWmax, TXOP limit, CCA thresholds) the neighboring APs may use during the reserve time. According to certain aspects, the AP may specify access classes during the reserved listening time. For example, the AP may specify a traffic quality of service (QoS) (e.g., ACs, max amount of transmit time/bytes allowed).

[0161] According to certain aspects, only master nodes can send out scheduling information (e.g., send a reservation). According to certain aspects, there may be only one master node per coordination set. Alternatively, there may be more than one master node per coordination set, but not all nodes in the coordination set are master nodes. In another alternative, all nodes in the coordination set may send out schedule information. According to certain aspects, non-scheduling nodes (i.e., nodes that do not send out scheduling information) may send input to the master node before the master node sends the schedule.

[0162] According to certain aspects, nodes sending out the schedule (i.e., scheduling nodes) may make the schedule based on their own needs. In this case, the scheduling node(s) do not solicit input from other nodes in the coordination sets and do not request/require responses to the scheduling messages. According to certain aspects, nodes sending out the schedule may make the schedule based on input received from other nodes in the coordination set prior to sending the schedule, but may not request/require responses from the other nodes before sending the scheduling message.

[0163] According to certain aspects, nodes sending out the schedule may request/require responses from members of the coordination set. According to certain aspects, a node sending a schedule sends the scheduling to, and gets a response to the message from, each member in the coordinating set. According to certain aspects, only nodes that contest the schedule send a response. According to certain aspects, a node sending a schedule may or may not get responses from other members of the coordinating set. According to certain aspects, a node sending the scheduling message may send a single scheduling message to all the members of the coordinating set and may set aside a time period after the message to receive responses from other members of the coordinating set. According to certain aspects, the responses may be scheduled.

According to certain aspects, the response schedule may be contained in the original schedule message (e.g., the response schedule may be prenegotiated). Responders may contend for the medium (e.g., using standard 802.11 contention methods). According to certain aspects, responders may send simultaneously on different parts of the bandwidth using OFDMA. According to certain aspects, responders may send simultaneously using different spreading sequences. According to certain aspects, the scheduling node may keep sending until it receives a response.

[0164] According to certain aspects, scheduling information may be sent out at predetermined (e.g., prior to transmission of the scheduling information) times—for example, directly following the beacon period or within a predetermined recurring time slot where APs can contend to send scheduling messages. Alternatively, the scheduling messages may be sent during the same period as the timing coordination messages. This may allow the nodes in the coordinating set have already cleared the medium of interference so they can listen. If the scheduling messages are being sent out at predetermined times that are different from the timing messages, then the APs may reserve the medium for these times just as they reserved the medium for the timing messages. Alternatively, scheduling information may be sent out at times not predetermined (e.g., whenever the AP wants to send the message and has access to the medium).

[0165] According to certain aspects, any combinations of the various aspects and options described above for which nodes may send scheduling information, whether and how the scheduling is negotiable, and when the scheduling information is sent may be used.

[0166] As described above, the scheduling node may receive input from non scheduling nodes prior to scheduling. According to certain aspects, the input may specify whether extra protection is needed for that node, how much data a node has to be protected (e.g., how much data in each QoS class to be protected), what kind of protection is needed (e.g., downlink only, lower frequency reuse, complete silence from interferers, etc.), or if the current schedule provides too much or too little protected times.

[0167] According to certain aspects, non scheduling nodes in a coordination set may provide response to the scheduling messages sent from the scheduling nodes. The responses may include an ACK or NACK to the proposed reservation time. If the response includes a NACK, the response may also include the reason for the NACK (e.g., conflicts with another reserved time or too many reserved times). The response may also include an alternative reservation (e.g., alternative time for reservation, alternative duration for reservation, or alternative type of reservation).

[0168] According to certain aspects, for 802.11aa standard protocols setup, all nodes in the coordinating set may send scheduling requests. These requests may be called transmission opportunity (TxOP) advertisements. TxOP advertisements may request silence from the other nodes in the coordination set (e.g., overlapping BSSs) during the TxOP. All nodes in the coordinating set may respond to these scheduling requests. Responses may include alternate schedule suggestions. A TxOP advertisement frame may includes category, public action, dialog token, number of reported TxOP reservation, and number of pending TxOP reservations, active reservations, and TxOP reservations. The TxOP reservation field may include duration, service interval (SI), and start time. The duration subfield may specify the duration of the TxOP in units of 32 μs. The SI subfield may contain an 8-bit unsigned integer that specifies the SI of the reservation in units of milliseconds. The Start Time subfield is the offset from the next target beacon transmission time (TBTT) to the start of the first SP and may indicate the anticipated start time, expressed in microseconds, of the first TxOP after the TBTT. The response to TxOP advertisement frame may include category, public action, dialog token, status code, schedule conflict, alternative schedule, and avoidance request.

[0169] According to certain aspects, a modified TXOP frame may used by HEW APs to schedule coordination among other nodes in the coordination set. For HEW, "shared reservations" may be desirable. Additional fields may be added to the TxOP reservation frame to enumerate the type of reservation requested. For example, the fields may specify type of traffic allowed (e.g., UL, DL, or UL and DL), bandwidth info (e.g., reserved bandwidth or maximum bandwidth to use), and/or type of medium access (e.g., normal EDCA, no backoff, or only certain QoS Classes). According to certain aspects, the reservation may be longer than a normal TxOP since the reservation could be for more than a single user's data. According to certain aspects, periodicity information may be added (e.g., whether or not the reservation happens repeatedly with some periodicity).

[0170] According to certain aspects, a HEW TxOP reservation frame may include an octet for duration, an octet for SI, four octets for start frame, two bits specifying UL, DL, or UL+DL, three bits specifying type of medium access (e.g., bandwidth information), and two bits periodicity information.

[0171] According to certain aspects, the messages described above for coordination may be exchanged between APs via non-OTA methods such as backhaul communications. For example, the medium access control (MAC) message may be sent through a (wireline) "layer 2" network, such as Ethernet or similar. A bridging operation for the address translation/switching/routing may be used where messages are routed through the L2 network until the destination AP.

[0172] According to certain aspects, the MAC message may be sent encapsulated through a higher layer protocol. For example, LLC preamble may be set to an Ethertype value corresponding to a Layer 3 or above protocol dedicated to the transport of the coordination messages.

[0173] According to certain aspects, the protocol may be delegated to higher layer protocols. For example, the coordination message may not be in the form of a MAC message, instead, the MAC management entity may communicate with higher layers for the generation of messages at the higher layer protocol.

[0174] According to certain aspects, a mechanism may be in place for an AP to discover the address of a neighboring AP which is the destination of the coordination messages. For example, the AP may discover the neighboring AP address through existing OTA signaling (e.g., beacons, sniffing of frames sent by APs/STAs), through an explicit OTA discovery protocol (e.g., social WiFi or WiFi-D), programmed at deployment or set by the user though an application.

<u>Inter-AP Scheduling</u>

[0175] For inter-AP scheduling, once an AP knows the reservation times, the AP may indicate that information to its STAs. If the AP is using HCCA, it may already be in full control of the medium. If the AP is not using HCCA, there are various methods reserving the medium. According to certain aspects, information may be added to the

RAW frame. The information may include whether the reservation is for DL, UL, or DL+UL, which bandwidth the reservation is for, the type of channel access (e.g., standard access or modified deferral rules), and which EDCA parameters to use.

[0176] According to certain aspects, information may be added to the PSMP frame. The information may include which bandwidth to use, what kind of channel access to use during reservation, and what access parameters to use during reservation (e.g., which EDCA parameters). The information may be for the whole PSMP reservation, on a STA by STA basis (e.g., PSMP has a reservation per STA), or based on UL/DL intervals. According to certain aspects, a management negotiation may be performed where the AP and its STAs agree on whether the STAs are allowed to transmit on the medium when not polled by a PSMP request. According to certain aspects, the AP and STAs may agree on a time when the PSMP is expected

[0177] According to certain aspects, a management negotiation may be performed where AP and STA agree on whether the STA is allowed to transmit on the medium when not explicitly given permission to send. Explicit permission to send can be granted via a RAW, TWT, PSMP, reverse direction grant (RDG), or any other message sent by the AP which allows certain user to transmit during a given amount of time.

[0178] According to certain aspects, the RAW or PSMP frame may not be modified to indicate the reservation to the STAs. Instead, the AP may use the frames in a manner to indicate the information.

[0179] According to certain aspects, minimizing primary channel interference may help with throughput. However, the closest APs may not coordinate because coordination is done over the beacons—or other such message—on the primary channel. According to certain aspects, the AP may transmit duplicate beacons on the whole bandwidth. For dense networks, beacon range may not be of importance. According to certain aspects, APs may choose their closest APs to coordinate with regardless of primary channel, as long as operating bandwidth is the same. APs may detect and decode beacons on multiple channels—possibly simultaneously. According to certain aspects, a common coordination channel may be used. Alternatively, beacons may be sent only on the primary channel, but messages for coordination may be sent on all the channels. As another alternative, nodes may transmit coordinating messages only on their primary channels, but they may listen for coordinating messages on all their channels.

[0180] Fig. 13 illustrates example operations 1300 for coordinating access to a shared medium, in accordance with certain aspects of the present disclosure. The operations 1300 may be performed, for example, by an AP (e.g., AP 504). The operations 1300 may begin, at 1302, by synchronizing with one or more peer apparatuses based on synchronization messages detected during a listening time. According to certain aspects, the one or more peer apparatus may be in a coordinating set (e.g., a BSS) or in multiple coordinating sets. The AP and other peer apparatus may synchronize to a single time. For example, the AP may select a master, and the AP and the peer apparatus may synchronize to the master's time (e.g., clock).

[0181] According to certain aspects, the AP may transmit a message (e.g., to the one or more peer apparatuses) to reserve the listening time for listening to the synchronization messages. According to certain aspects, the message may be a quiet element, a RAW frame, or a PSMP message. According to certain aspects, the RAW frame may indicate a groupID to which no devices belong. Alternatively, the RAW frame may indicate multiple non-consecutive times to reserve for listening. According to certain aspects, the transmission time of the PSMP message may be used to indicate listening times to reserve. According to certain aspects, the PSMP message may indicate a device ID corresponding to a non-existent device. According to certain aspects, the PSMP message may indicate multiple non-consecutive times to reserve for listening to the synchronization messages.

[0182] At 1304, the AP may output, for transmission, scheduling information to the one or more peer apparatuses, the scheduling information indicating one or more time periods during which coordinated access to the shared medium is desired. According to certain aspects, the scheduling information may include a start time or a duration of the one or more time periods during which coordinated access to the shared medium is desired (e.g., in one or more additional fields included in the RAW frame or PSMP message). According to certain aspects, the scheduling information may include an indication of a type of coordinated access allowed for the one or more time periods (e.g., uplink access, downlink access, or both uplink and downlink access). According to certain aspects, the scheduling information may include information related to a bandwidth allowed during the one or more time periods (e.g., a particular bandwidth to use or a maximum bandwidth to be used). According to certain aspects, the scheduling information may include information relating to one or more types of deferral rules. For example, a modified deferral rule that allows the one or more peer apparatuses and the devices served by the apparatus to ignore packets from other peer apparatuses and devices that have certain BSS IDs. According to certain aspects, the scheduling information may include information relating to achieving favorable access to the shared medium.

[0183] At 1306, the AP may output, for transmission, at least some of the scheduling information to devices served by the apparatus. According to certain aspects, at least some of the scheduling information may identify a subset of the devices that should transmit during a scheduled time. According to certain aspects, the AP may transmit the scheduling information to the one or more peer apparatuses independently of input from the one or more peer apparatuses. According to certain aspects, the AP may solicit input from the one or more peer apparatuses prior to transmitting the scheduling information to the one or more peer apparatuses. According to certain aspects, the AP may wait to receive responses from the one or more peer apparatuses prior to transmitting the scheduling information to the one or more peer apparatuses. According to certain aspects, the AP may require responses from the one or more peer apparatus. According to certain aspects, the AP may generate the scheduling information based, at least in part, on the responses.

[0184] According to certain aspects, the AP may transmit the scheduling information to the one or more peer apparatuses following a beacon period. Alternatively, the AP may transmit the scheduling information to the one or more peer apparatuses within a predetermined recurring time period. According to certain aspects, the AP may contend to send scheduling messages within the predetermined recurring time period. According to certain aspects, the AP may transmit the scheduling information to the one or more peer apparatuses if the apparatus has access to the shared medium. According to certain aspects, the AP may transmit the scheduling information OTA. Alternatively, the AP may transmit the scheduling information via a backhaul connection.

[0185] According to certain aspects, the AP may transmit the scheduling information to the devices served by the apparatus using RAW frame or PSMP message. According to certain aspects, the RAW frame or PSMP message may indicate the one or more time periods are for downlink access, uplink access, or both; a bandwidth to use during the one or more time periods, a type of channel access to use during the one or more time periods; what deferral rules to use, or what EDCA parameters to use during the one or more time periods. According to certain aspects, the AP may transmit the scheduling information to the devices served by the apparatus using a PSMP message.

[0186] According to certain aspects, the AP may transmit the scheduling information to the one or more peer apparatuses on-primary channels. According to certain aspects, the AP may transmit duplicated scheduling information on non-primary channels. According to certain aspects, the AP may receive synchronization messages on primary channels and/or on non-primary channels. According to certain aspects, the scheduling information may identify the one or more peer apparatuses in OBSSs that should not transmit during a scheduled time.

[0187] Fig. 14 illustrates example operations 1400 for coordinating access to a shared medium, in accordance with certain aspects of the present disclosure. The operations 1400 may be performed, for example, by an AP (e.g., AP 504). The operations 1400 may begin, at 1402, by receiving, from another AP, a message to reserve a listening time for the other AP to listen to one or more synchronization messages.

[0188] At 1404, the AP may take action to ensure stations served by the AP do not interfere with synchronization messages during the listening time. At 1406, the AP may receive, from the other AP, scheduling information indicating one or more reservation periods during which coordinated access to the shared medium is desired. At 1408, the UE may take to provide coordinated access during the one or more reservation periods.

[0189] The various operations of methods described above may be performed by any suitable means capable of performing the corresponding functions. The means may include various hardware and/or software component(s) and/or module(s), including, but not limited to a circuit, an application specific integrated circuit (ASIC), or processor. Generally, where there are operations illustrated in figures, those operations may have corresponding counterpart means-plus-function components with similar numbering. For example, operations 1300 and operations 1400 illustrated in FIG. 13 and FIG. 14, respectively, correspond to means 1300A and means 1400A illustrated in FIG. 13A and FIG. 14A, respectively.

[0190] For example, means for transmitting may comprise a transmitter (e.g., the transmitter 410) and/or an antenna(s) 416 of the wireless device 402 illustrated in FIG. 4. Means for receiving may comprise a receiver (e.g., the receiver 412) and/or an antenna(s) 416 of the wireless device 402 illustrated in FIG. 4. Means for processing, means for generating, means for waiting, means for synchronizing, means for selecting, and means for contending may comprise a processing system, which may include one or more processors, such as the processor 404 illustrated in FIG. 4.

[0191] In some cases, an interface for outputting a frame may be an actual transmitter (e.g., physical RF front end) or may be an interface for receiving a frame (e.g., from a processor) and outputting that frame (e.g., to a physical RF front end) for transmission.

[0192] As used herein, the term "determining" encompasses a wide variety of actions. For example, "determining" may include calculating, computing, processing, deriving, investigating, looking up (e.g., looking up in a table, a database or another data structure), ascertaining and the like. Also, "determining" may include receiving (e.g., receiving information), accessing (e.g., accessing data in a memory) and the like. Also, "determining" may include resolving, selecting, choosing, establishing and the like. Further, a "channel width" as used herein may encompass or may also be referred to as a bandwidth in certain aspects.

[0193] As used herein, a phrase referring to "at least one of" a list of items refers to any combination of those items, including single members. As an example, "at least one of: a, b, or c" is intended to cover: a, b, c, a-b, a-c, b-c, and a-b-c.

[0194] The various operations of methods described above may be performed by any suitable means capable of performing the operations, such as various hardware and/or software component(s), circuits, and/or module(s). Generally, any operations illustrated in the Figures may be performed by corresponding functional means capable of performing the operations.

[0195] The various illustrative logical blocks, modules and circuits described in connection with the present disclosure may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array signal (FPGA) or other programmable logic device (PLD), discrete gate or transistor logic, discrete hardware components or any combination thereof designed to perform the functions described herein. A general purpose processor may be a microprocessor, but in the alternative, the processor may be any commercially available processor, controller, microcontroller or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[0196] In one or more aspects, the functions described may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Computer-readable media includes both computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A storage media may be any available media that can be accessed by a computer. By way of example, and not limitation, such computer-readable media can comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to carry or store desired program code in the form of instructions or data structures and that can be accessed by a computer. Also, any connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk, and Blu-ray® disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Thus, in some aspects, computer readable medium may comprise non-transitory computer readable medium (e.g., tangible media). In addition, in some aspects computer readable medium may comprise transitory computer readable medium (e.g., a signal). Combinations of the above should also be included within the scope of computer-readable media.

[0197] Thus, certain aspects may comprise a computer program product for performing the operations presented herein. For example, such a computer program product may comprise a computer readable medium having instructions stored (and/or encoded) thereon, the instructions being executable by one or more processors to perform the operations described herein. For certain aspects, the computer program product may include packaging material. For example, the instructions may be executed by a processor or processing, such as processor 404, and stored in a memory, such as memory 404, illustrated in FIG. 4. For example, the computer-readable medium may have computer executable instructions stored thereon for synchronizing with one or more peer apparatuses based on synchronization messages detected during a listening time, instructions for transmitting scheduling information to the one or more peer apparatuses, the scheduling information indicating one or more time periods during which coordinated access to the shared medium is desired, and instructions for transmitting at least some of the scheduling information to devices served by the apparatus.

[0198] The methods disclosed herein comprise one or more steps or actions for achieving the described method. The method steps and/or actions may be interchanged with one another without departing from the scope of the claims. In other words, unless a specific order of steps or actions is specified, the order and/or use of specific steps and/or actions may be modified without departing from the scope of the claims.

[0199] Software or instructions may also be transmitted over a transmission medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of transmission medium.

[0200] Further, it should be appreciated that modules and/or other appropriate means for performing the methods and techniques described herein can be downloaded and/or otherwise obtained by a user terminal and/or base station as applicable. For example, such a device can be coupled to a server to facilitate the transfer of means for performing the methods described herein. Alternatively, various methods described herein can be provided via storage means (e.g., RAM, ROM, a physical storage medium such as a compact disc (CD) or floppy disk, etc.), such that a user terminal and/or base station can obtain the various methods upon coupling or providing the storage means to the device. Moreover, any other suitable technique for providing the methods and techniques described herein to a device can be utilized.

[0201] It is to be understood that the claims are not limited to the precise configuration and components illustrated above. Various modifications, changes and variations may be made in the arrangement, operation and details of the methods and apparatus described above without departing from the scope of the claims.

[0202] While the foregoing is directed to aspects of the present disclosure, other and further aspects of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

CLAIMS

WHAT IS CLAIMED IS:

1. An apparatus for coordinating access to a shared medium, comprising:
   a processing system configured to synchronize with one or more peer apparatuses based on synchronization messages detected during a listening time; and
   an interface configured to:
      output, for transmission, scheduling information to the one or more peer apparatuses, the scheduling information indicating one or more time periods during which coordinated access to the shared medium is desired; and
      output, for transmission, at least some of the scheduling information to devices served by the apparatus.

2. The apparatus of claim 1, wherein the one or more peer apparatuses are in one or more coordinating sets.

3. The apparatus of claim 1, wherein the apparatus and the one or more peer apparatuses synchronize to a single time.

4. The apparatus of claim 3, wherein:
   the processing system is further configured to select one of the apparatus or one of the one or more peer apparatuses as a master, and
   the synchronization comprises setting a time of at least one of the apparatus or one or more peer apparatuses to a time of the master.

5. The apparatus of claim 1, wherein the interface is further configured to output, for transmission, a message to reserve the listening time for listening to the synchronization messages.

6. The apparatus of claim 5, wherein the message comprises a restricted access window (RAW) frame.

7. The apparatus of claim 5, wherein the message comprises a power save multi-poll (PSMP) message.

8. The apparatus of claim 1, wherein the scheduling information comprises at least one of a start time or a duration of the one or more time periods during which coordinated access to the shared medium is desired.

9. The apparatus of claim 1, wherein the scheduling information comprises an indication of a type of coordinated access allowed for the one or more time periods, wherein the type of coordinated access allowed comprises one of: uplink access, downlink access, or both uplink and downlink access.

10. The apparatus of claim 1, wherein the scheduling information comprises information related to a bandwidth allowed and a location of the bandwidth during the one or more time periods.

11. The apparatus of claim 1, wherein the scheduling information comprises information relating to at least one of:

one or more enhanced distributed channel access (EDCA) parameters or clear channel assessment (CCA) to use during the one or more time periods

12. The apparatus of claim 1, wherein the scheduling information comprises information relating to one or more types of deferral rules.

13. The apparatus of claim 12, wherein:

at least one type of the one or more types of deferral rules is a modified deferral rule, and

the modified deferral rule allows the one or more peer apparatuses and the devices served by the apparatus to ignore packets from other peer apparatuses and devices that have certain basic service set (BSS) IDs.

14. The apparatus of claim 1, wherein the outputting for transmission of the scheduling information to the one or more peer apparatuses is independent of input from the one or more peer apparatuses.

15. The apparatus of claim 1, wherein the processing system is further configured to solicit input from the one or more peer apparatuses prior to the outputting, for

transmission, the at least some of the scheduling information to the devices served by the apparatus.

16. The apparatus of claim 15, wherein the processing system is further configured to wait to receive responses from the one or more peer apparatuses prior to the outputting, for transmission, of the at least some of the scheduling information to the devices served by the apparatus.

17. The apparatus of claim 16, wherein the processing system is further configured to generate the scheduling information based, at least in part, on the responses.

18. The apparatus of claim 1, wherein the scheduling information is output for transmission to the one or more peer apparatuses following a beacon period.

19. The apparatus of claim 1, wherein the scheduling information is output for transmission to the one or more peer apparatuses within a recurring time period.

20. The apparatus of claim 19, wherein the processing system is further configured to:

contend to send the scheduling information within the recurring time period.

21. The apparatus of claim 1, wherein the scheduling information is output for transmission to the one or more peer apparatuses via an over-the-air (OTA) interface or a backhaul connection.

22. The apparatus of claim 1, wherein the at least some of the scheduling information identify a subset of the devices that should transmit during a scheduled time.

23. The apparatus of claim 1, wherein outputting, for transmission, the at least some of the scheduling information to devices served by the apparatus comprises outputting, for transmission, at least one of a restricted access window (RAW) frame or a power save multi-poll (PSMP) message.

24. The apparatus of claim 23, wherein the RAW frame or PSMP message indicates at least one of:

the one or more time periods are for downlink access, uplink access, or both;

a bandwidth to use during the one or more time periods;

a type of channel access to use during the one or more time periods;

one or more deferral rules to use during the one or more time periods; or

one or more enhanced distributed channel access (EDCA) or clear channel assessment (CCA) parameters to use during the one or more time periods.

25. The apparatus of claim 1, wherein:

the interface is configured to:

output, for transmission to the one or more peer apparatuses on primary channels, the scheduling information, and

output, for transmission to the one or more peer apparatus on non-primary channels, duplicated scheduling information.

26. The apparatus of claim 1, wherein the processing system is further configured to receive synchronization messages on at least one of primary channels or non-primary channels.

27. The apparatus of claim 1, wherein the scheduling information identify the one or more peer apparatuses in overlapping basic service sets (OBSSs) that should not transmit during a scheduled time.

28. A method for coordinating access to a shared medium by an apparatus, comprising:

synchronizing with one or more peer apparatuses based on synchronization messages detected during a listening time;

outputting, for transmission, scheduling information to the one or more peer apparatuses, the scheduling information indicating one or more time periods during which coordinated access to the shared medium is desired; and

outputting, for transmission, at least some of the scheduling information to devices served by the apparatus.

29. A computer program product comprising a computer readable medium having instructions stored thereon for:

synchronizing with one or more peer apparatuses based on synchronization messages detected during a listening time;

outputting, for transmission, scheduling information to the one or more peer apparatuses, the scheduling information indicating one or more time periods during which coordinated access to the shared medium is desired; and

outputting, for transmission, at least some of the scheduling information to devices served by the apparatus.

30. An access point (AP), comprising:

at least one antenna;

a processing system configured to synchronize with one or more peer apparatuses based on synchronization messages detected during a listening time;

a transmitter configured to:

transmit, via the at least one antenna, scheduling information to the one or more peer apparatuses, the scheduling information indicating one or more time periods during which coordinated access to the shared medium is desired; and

transmit, via the at least one antenna, at least some of the scheduling information to devices served by the apparatus.

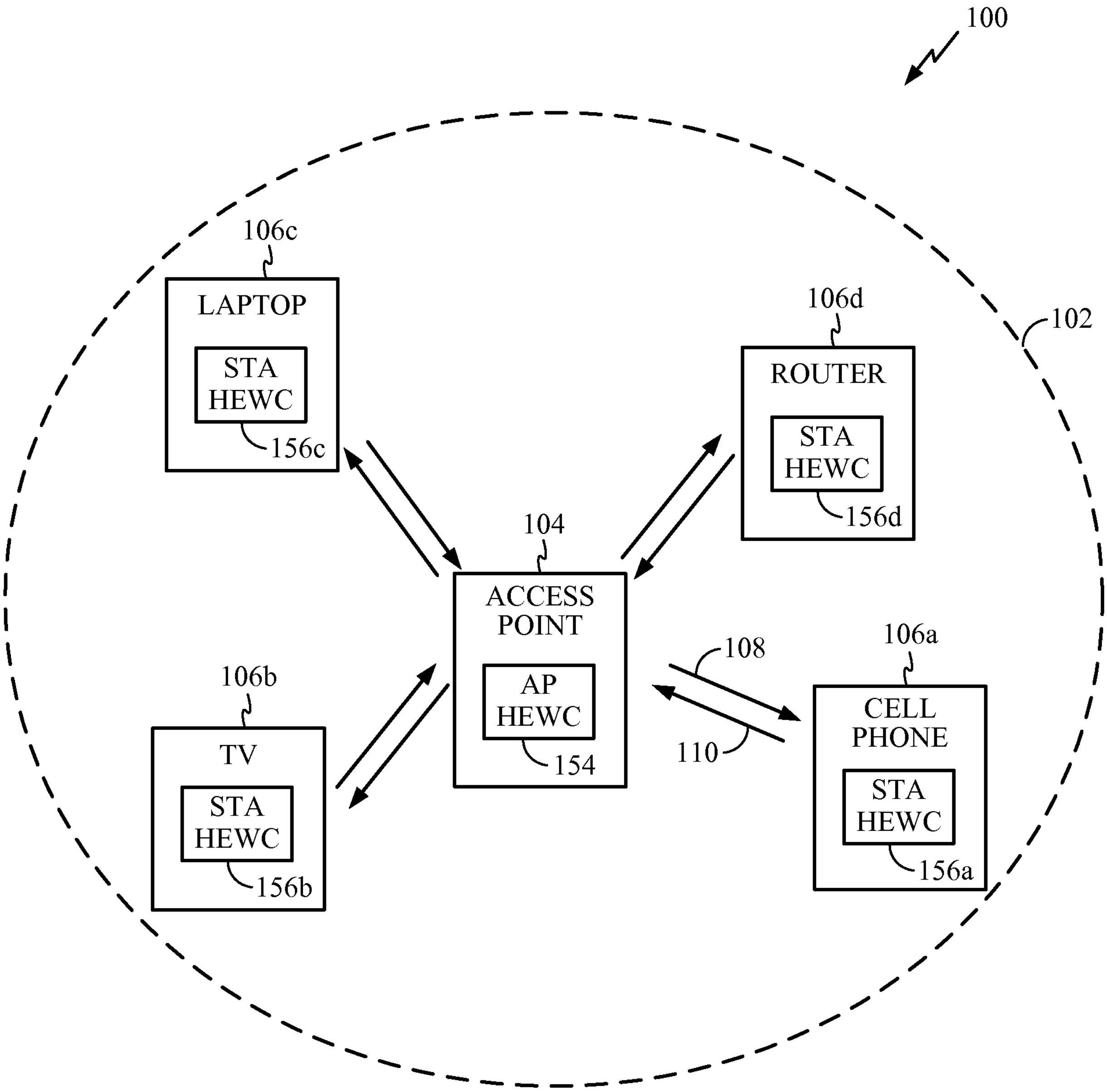

100
102
106c
LAPTOP
STA
HEWC
156c
106d
ROUTER
STA
HEWC
156d
104
ACCESS
POINT
AP
HEWC
154
108
110
106a
CELL
PHONE
STA
HEWC
156a
106b
TV
STA
HEWC
156b

FIG. 1

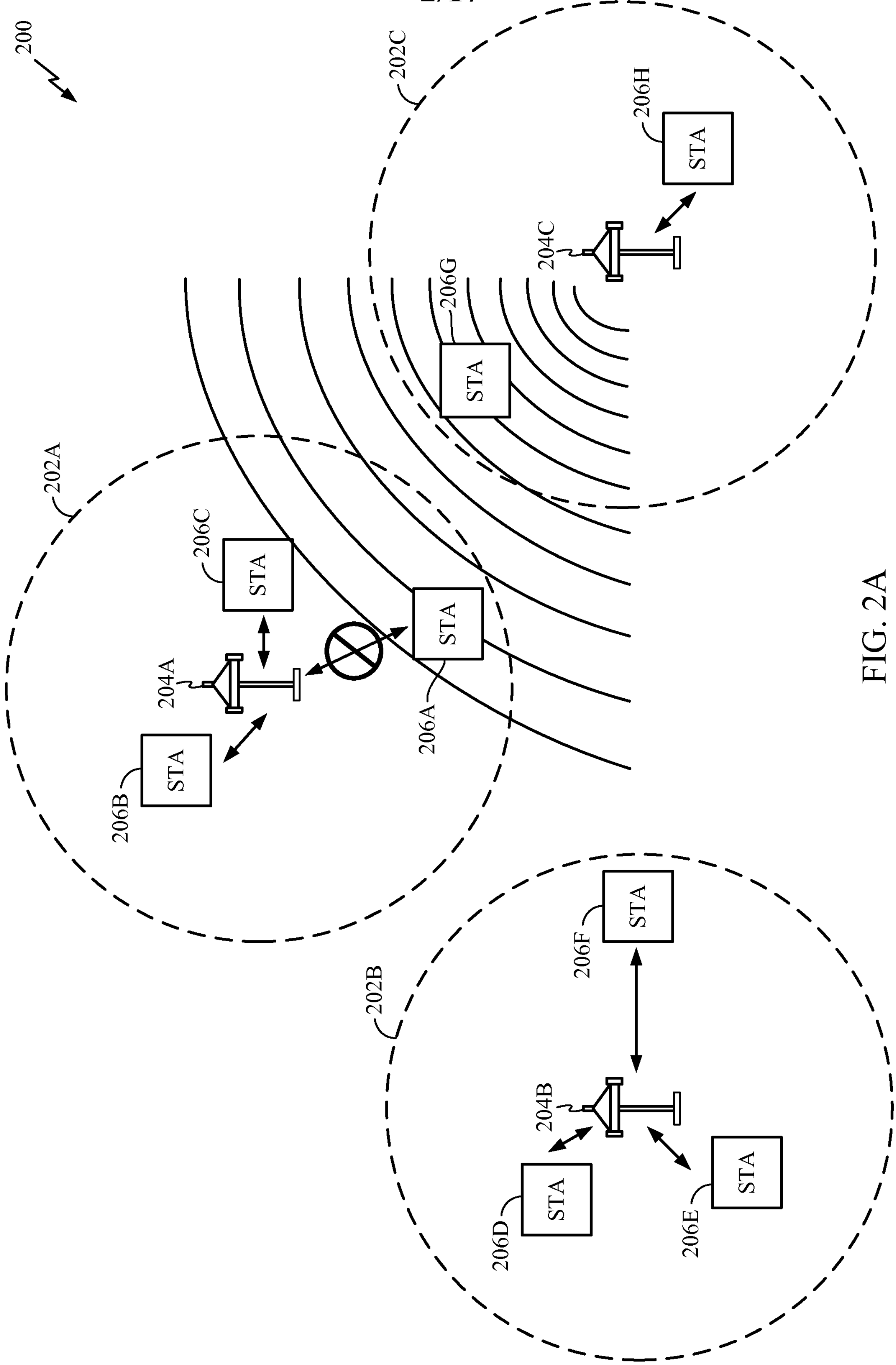

200
202A
202B
202C
204A
204B
204C
206A
206B
206C
206D
206E
206F
206G
206H
STA
STA
STA
STA
STA
STA
STA
STA

FIG. 2A

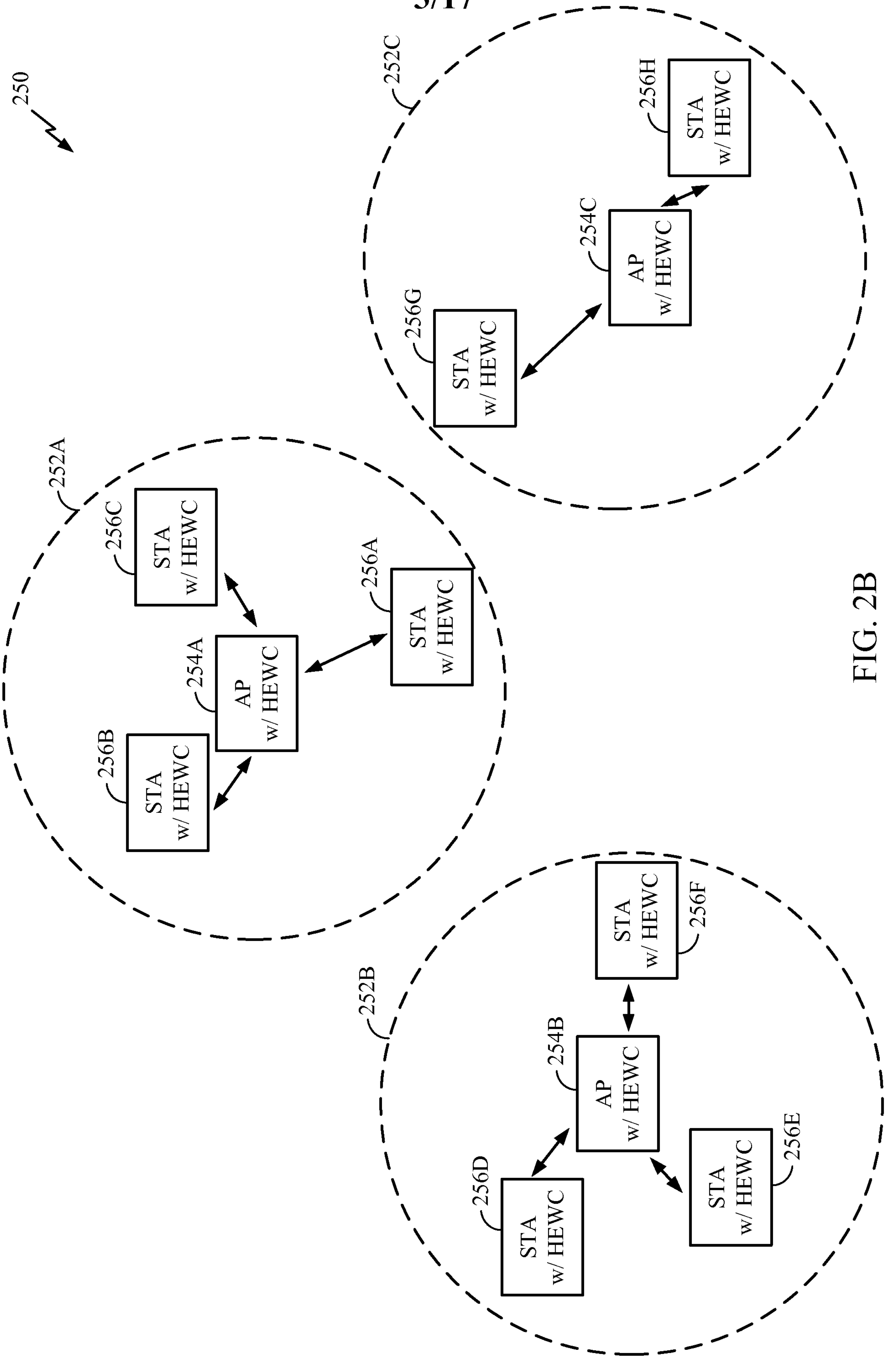

250
252A
252B
252C
254A
AP w/ HEWC
256A
STA w/ HEWC
256B
STA w/ HEWC
256C
STA w/ HEWC
254B
AP w/ HEWC
256D
STA w/ HEWC
256E
STA w/ HEWC
256F
STA w/ HEWC
254C
AP w/ HEWC
256G
STA w/ HEWC
256H
STA w/ HEWC

FIG. 2B

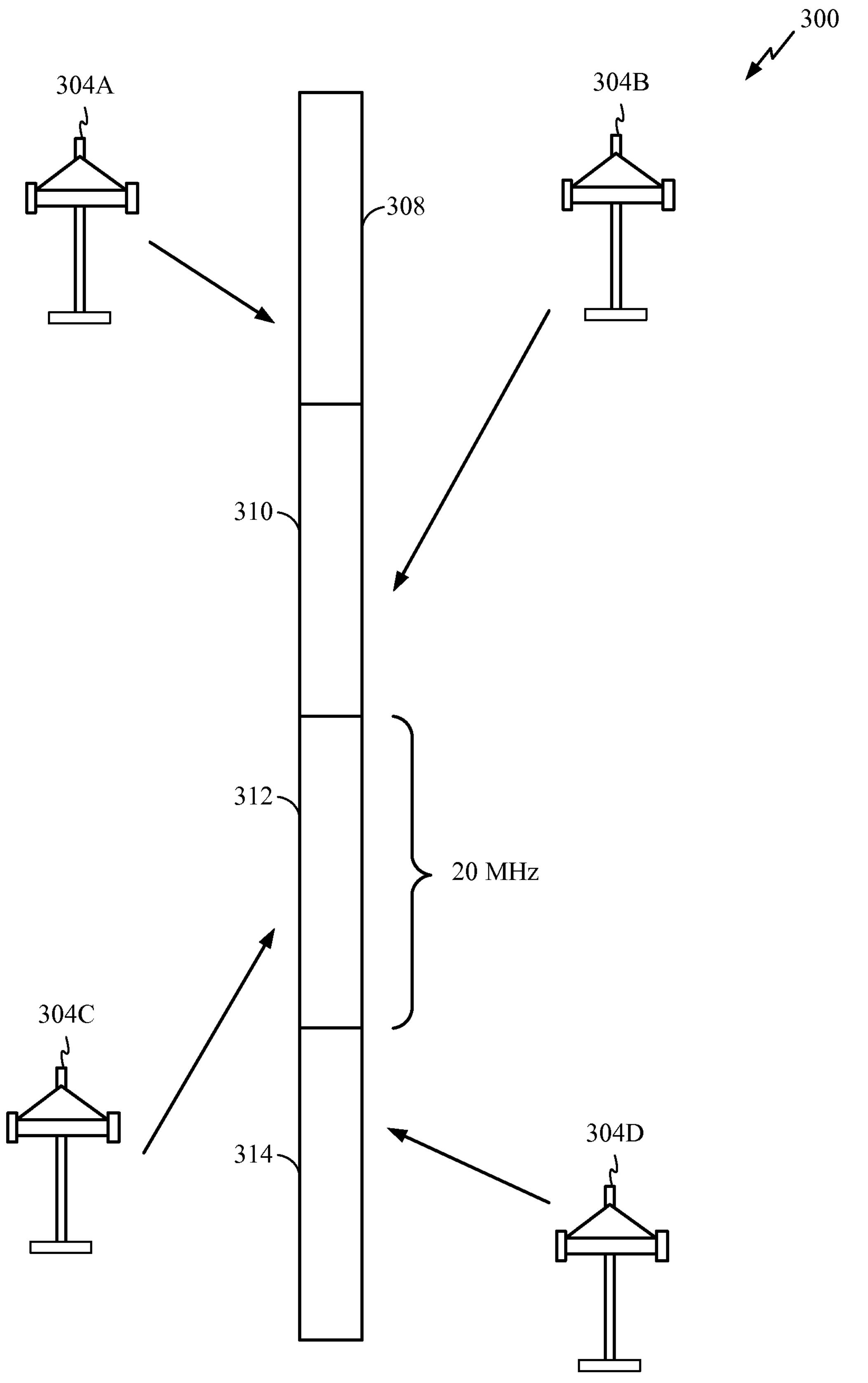


FIG. 3

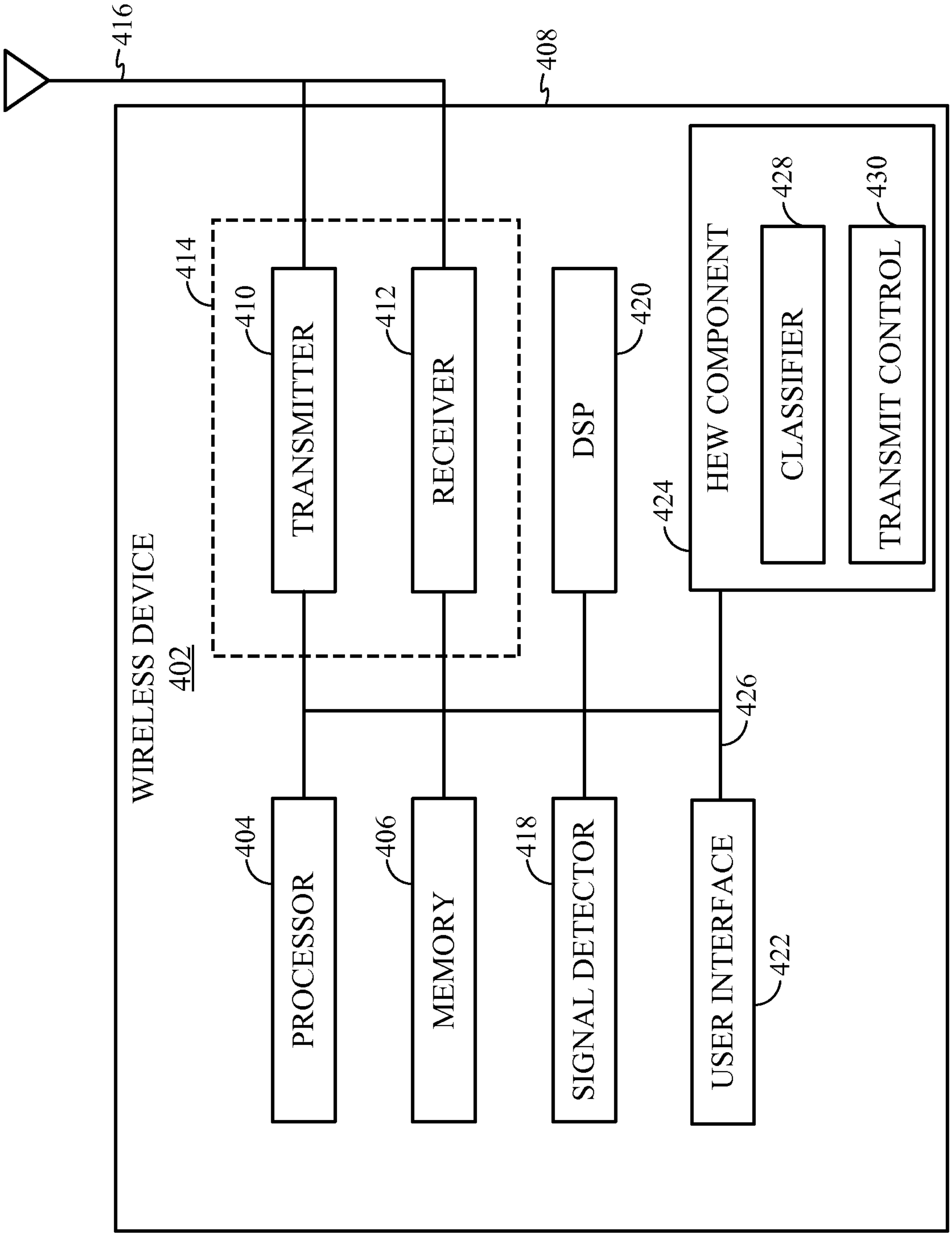

416
408
WIRELESS DEVICE
402
414
410
TRANSMITTER
412
RECEIVER
420
DSP
424
HEW COMPONENT
428
CLASSIFIER
430
TRANSMIT CONTROL
426
404
PROCESSOR
406
MEMORY
418
SIGNAL DETECTOR
422
USER INTERFACE

FIG. 4

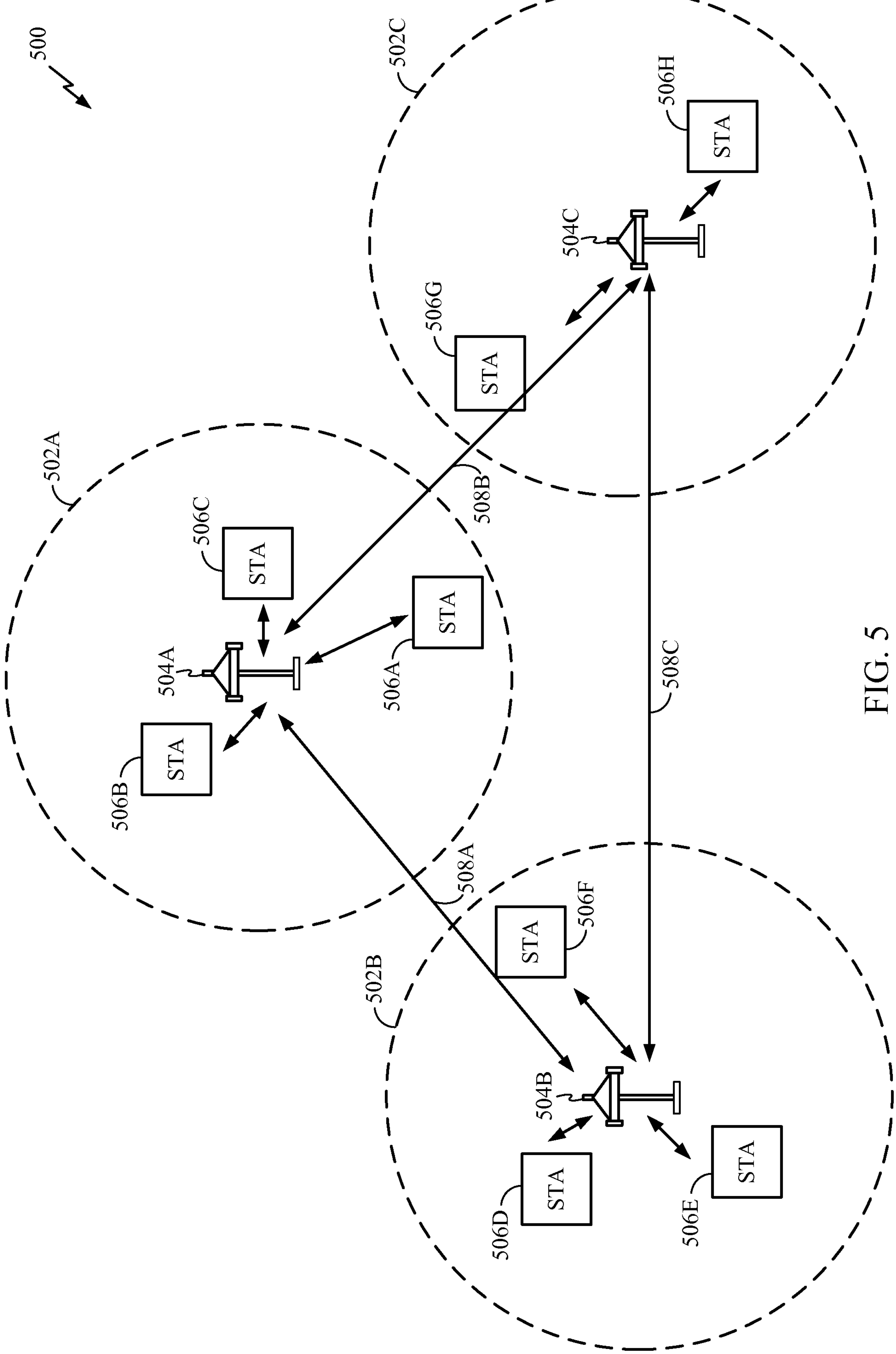

500
502A
502B
502C
504A
504B
504C
506A
506B
506C
506D
506E
506F
506G
506H
508A
508B
508C
STA
STA
STA
STA
STA
STA
STA
STA

FIG. 5

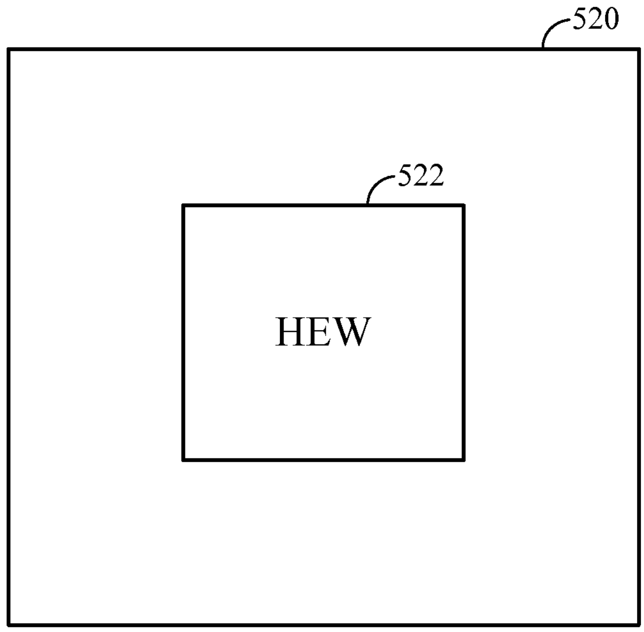


FIG. 5A

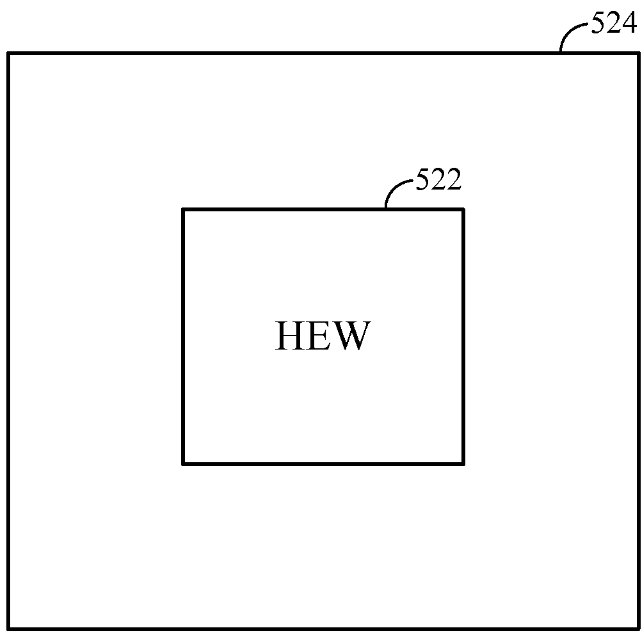


FIG. 5B

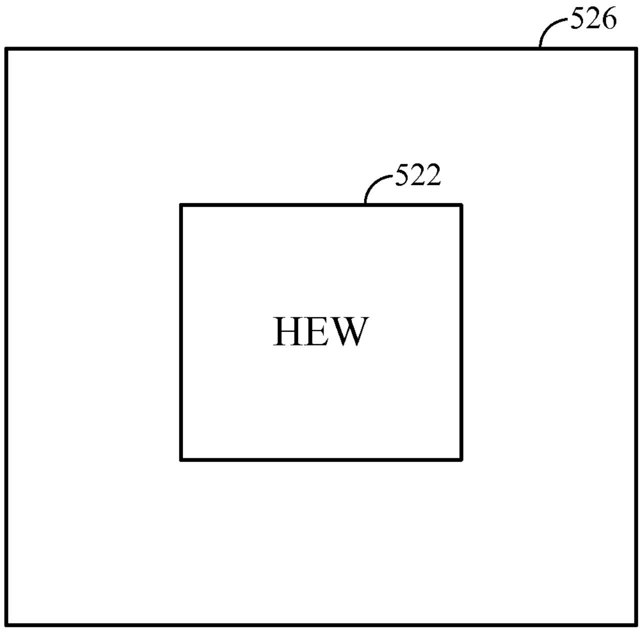


FIG. 5C

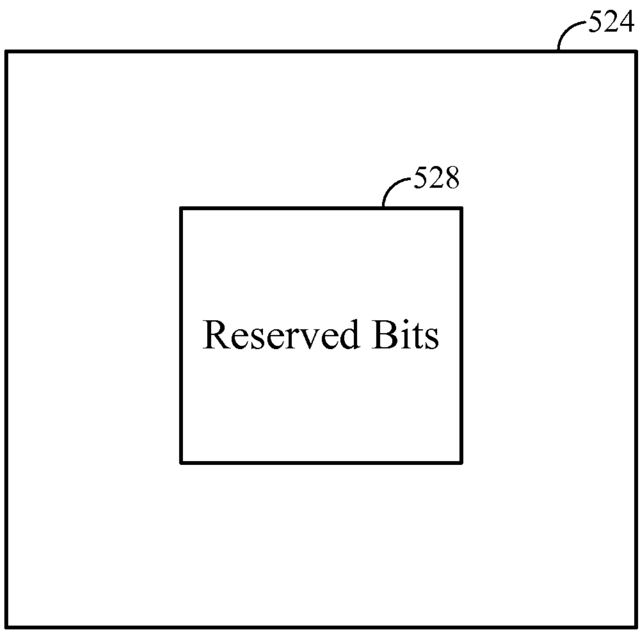
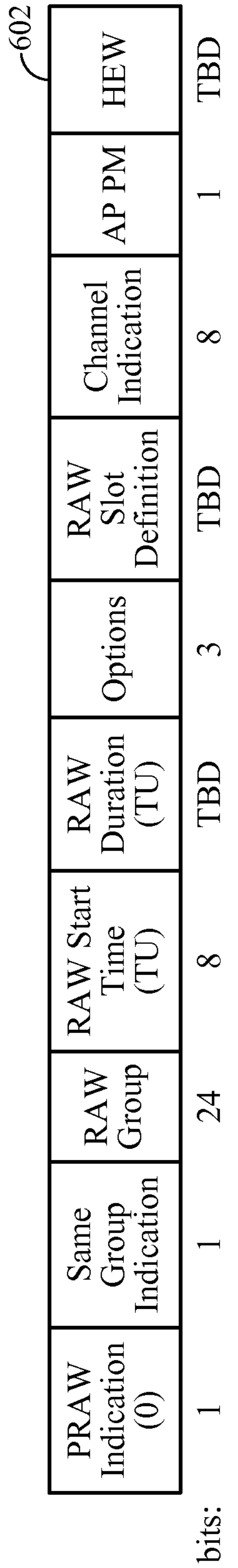
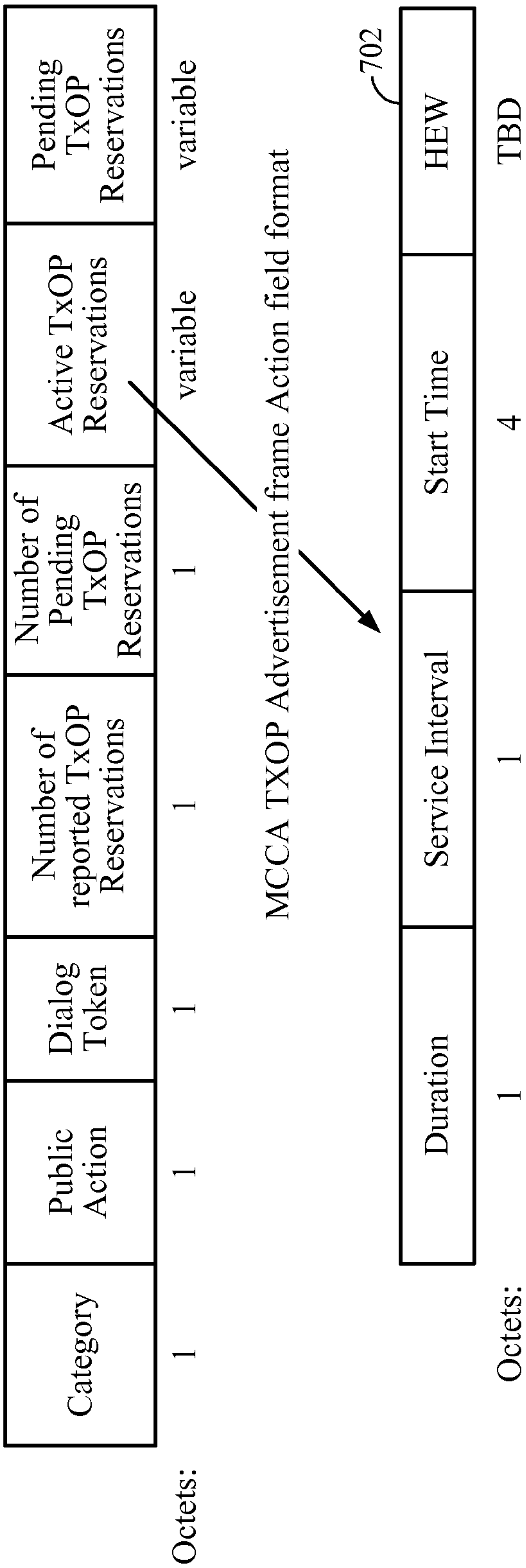


FIG. 5D



RAW N Assignment field format for RAW

FIG. 6



MCCA TXOP Advertisement frame Action field format

TXOP Reservation field format

FIG. 7

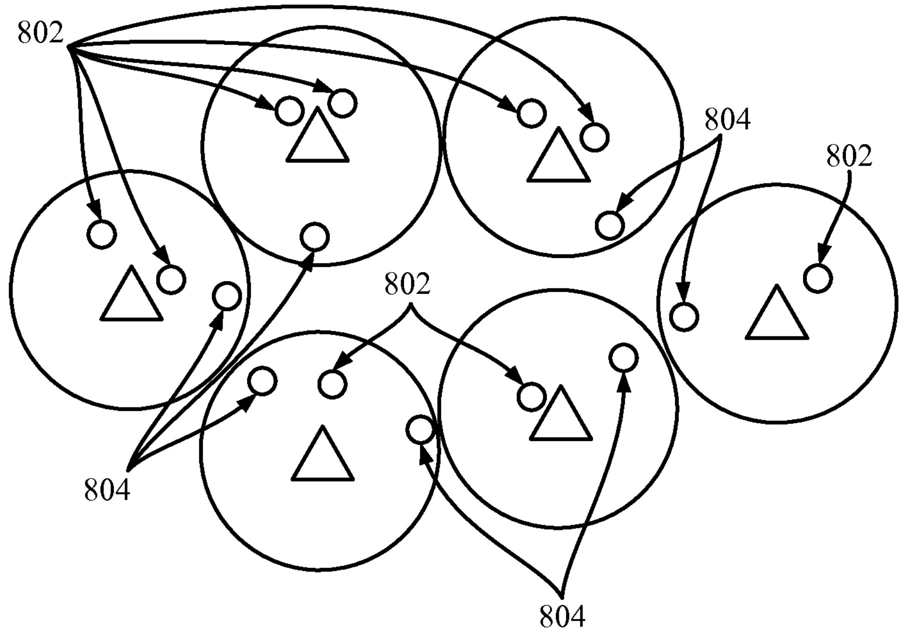


FIG. 8

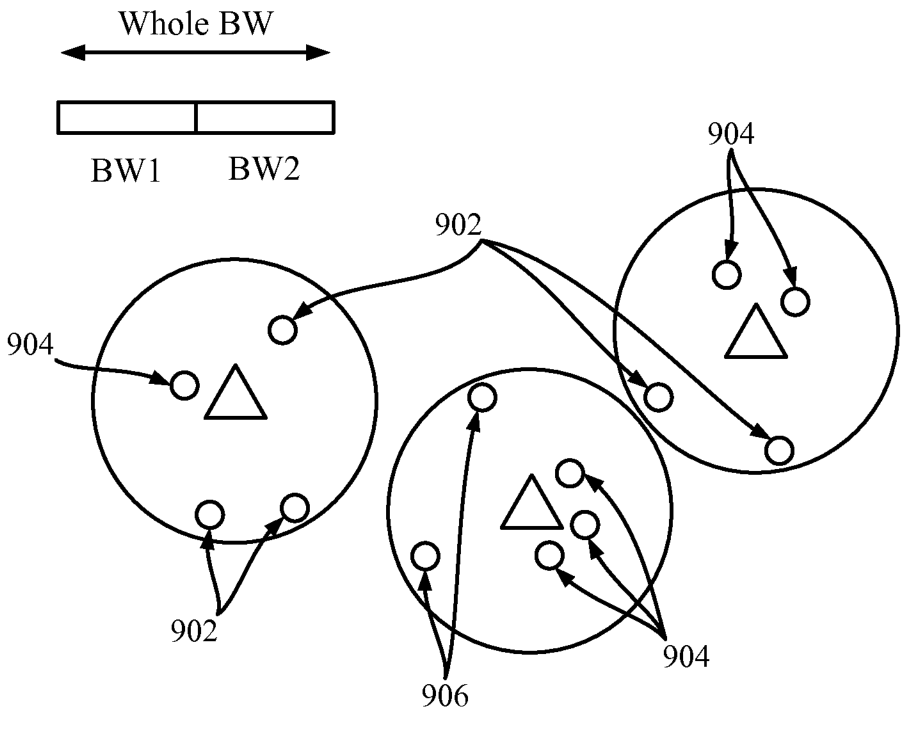


FIG. 9

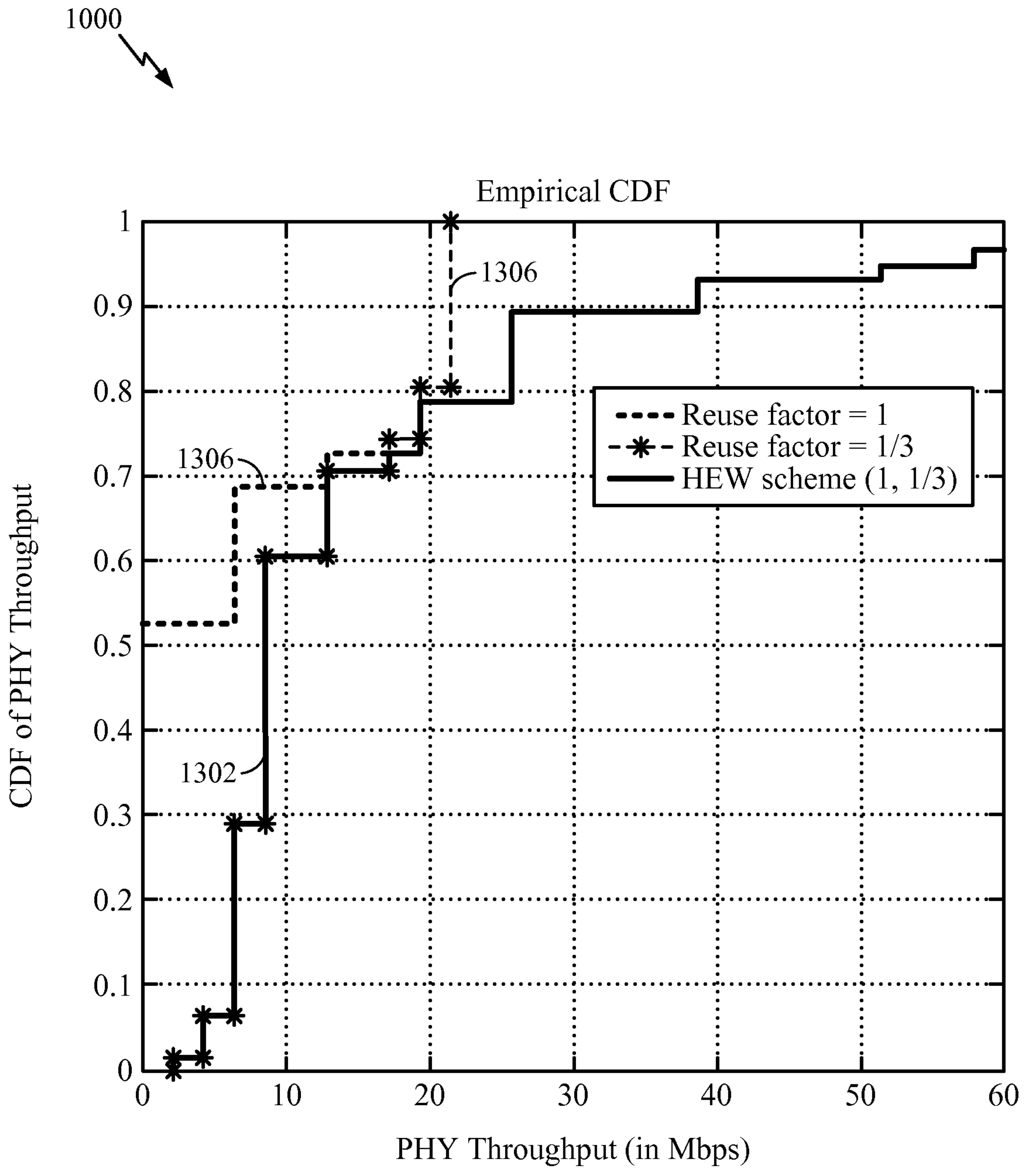

1000
Empirical CDF
CDF of PHY Throughput
PHY Throughput (in Mbps)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
1306
1306
1302
Reuse factor = 1
Reuse factor = 1/3
HEW scheme (1, 1/3)

FIG. 10

1100

	PRAW Indication (0)	Same Group Indication	RAW Group	RAW Start Time (TU)	RAW Duration (TU)	Options	RAW Slot Definition	Channel Indication	AP PM
bits:	1	1	24	8	TBD	3	TBD	8	1

RAW N Assignment field format for RAW

FIG. 11

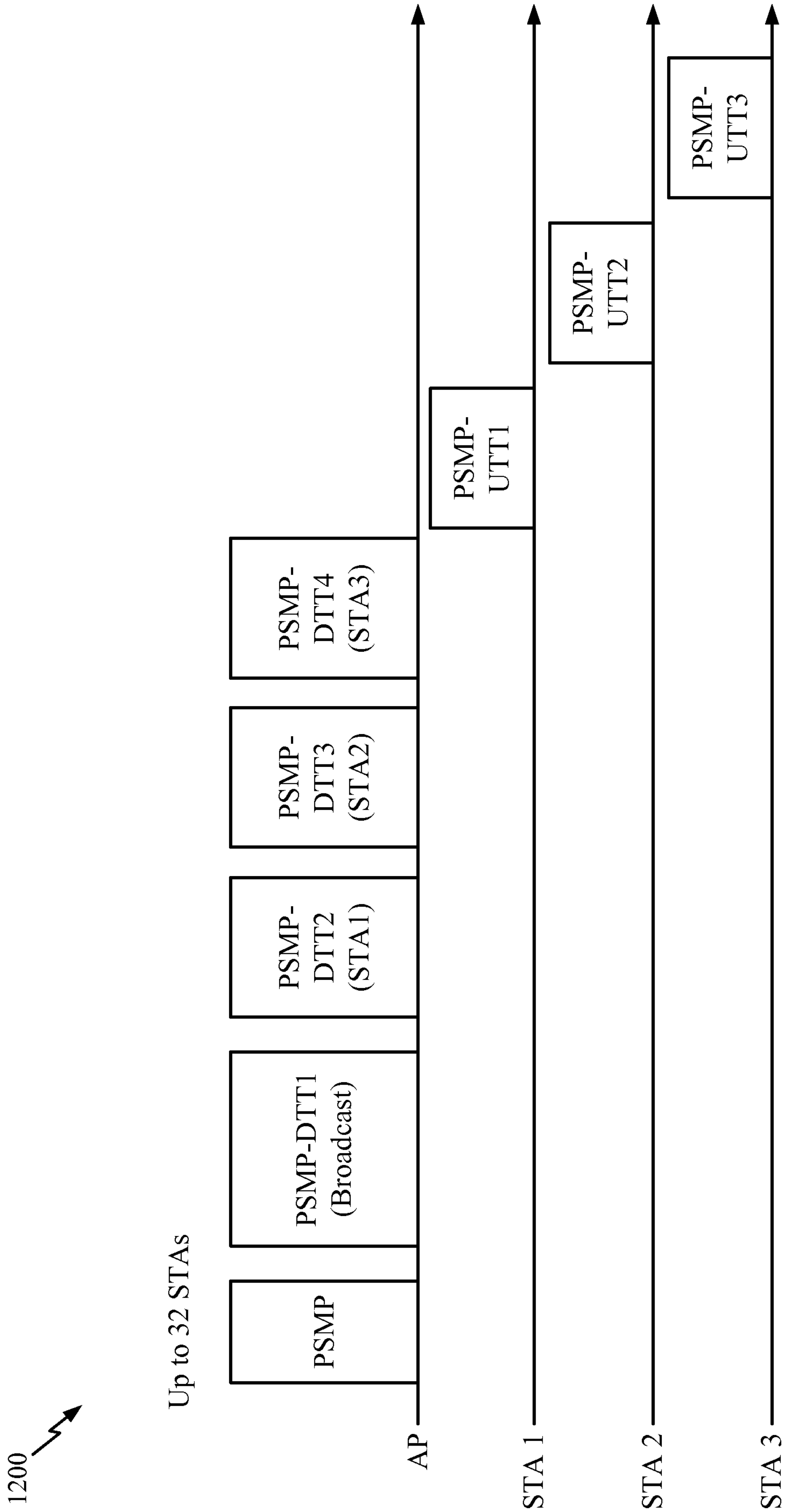

1200
Up to 32 STAs
PSMP
PSMP-DTT1 (Broadcast)
PSMP-DTT2 (STA1)
PSMP-DTT3 (STA2)
PSMP-DTT4 (STA3)
PSMP-UTT1
PSMP-UTT2
PSMP-UTT3
AP
STA 1
STA 2
STA 3

FIG. 12

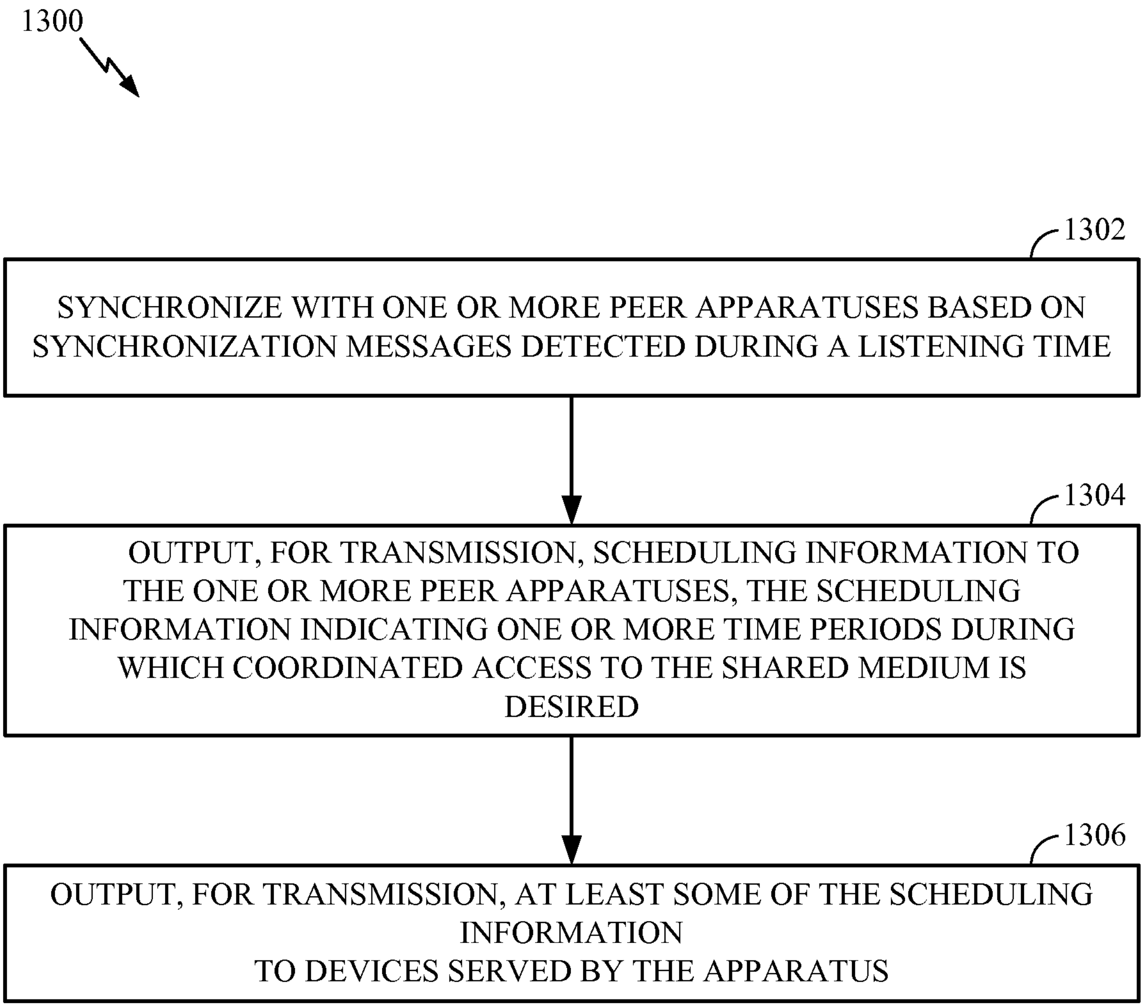

1300
1302
SYNCHRONIZE WITH ONE OR MORE PEER APPARATUSES BASED ON SYNCHRONIZATION MESSAGES DETECTED DURING A LISTENING TIME
1304
OUTPUT, FOR TRANSMISSION, SCHEDULING INFORMATION TO THE ONE OR MORE PEER APPARATUSES, THE SCHEDULING INFORMATION INDICATING ONE OR MORE TIME PERIODS DURING WHICH COORDINATED ACCESS TO THE SHARED MEDIUM IS DESIRED
1306
OUTPUT, FOR TRANSMISSION, AT LEAST SOME OF THE SCHEDULING INFORMATION TO DEVICES SERVED BY THE APPARATUS

FIG. 13

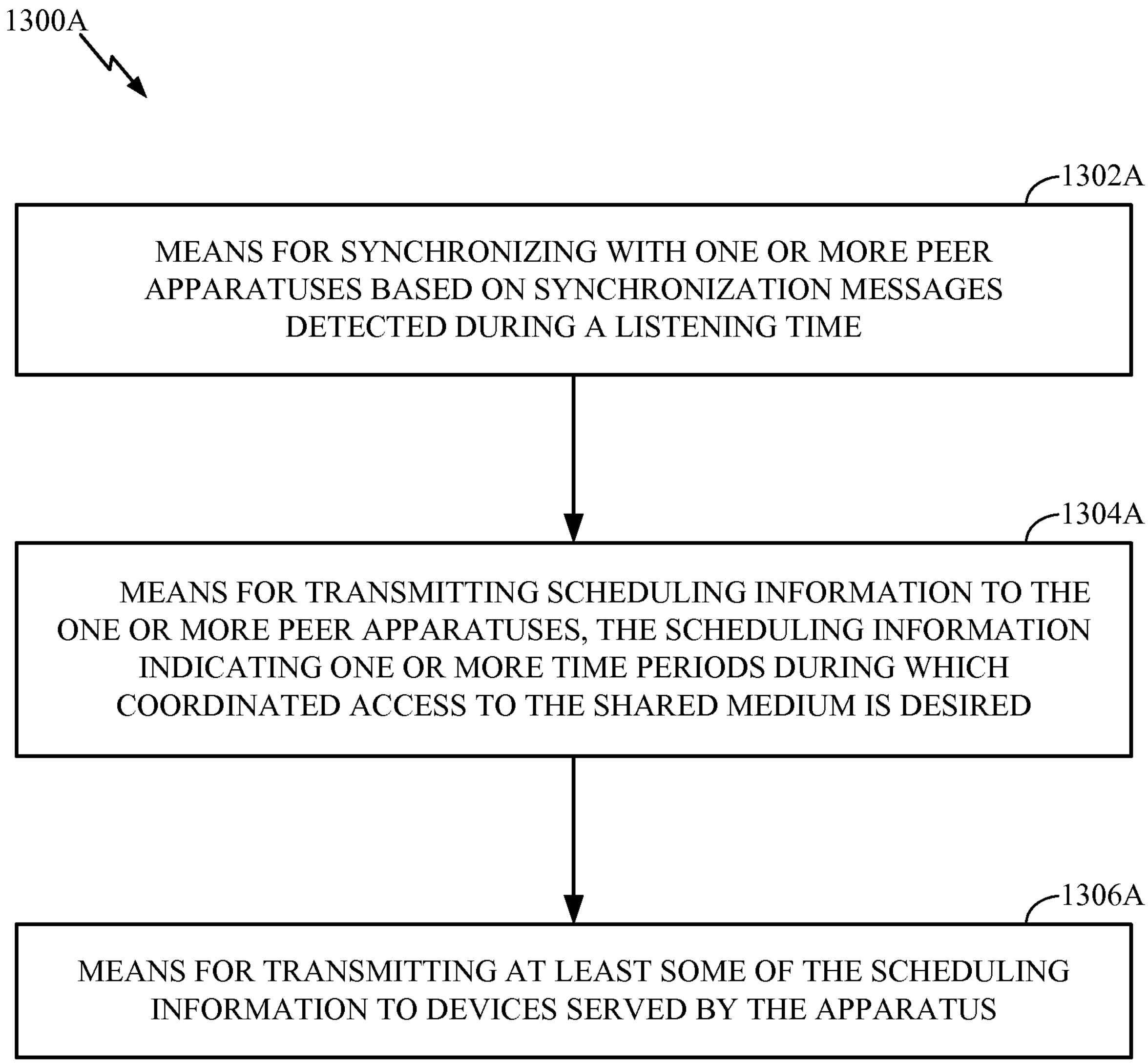

1300A
1302A
MEANS FOR SYNCHRONIZING WITH ONE OR MORE PEER APPARATUSES BASED ON SYNCHRONIZATION MESSAGES DETECTED DURING A LISTENING TIME
1304A
MEANS FOR TRANSMITTING SCHEDULING INFORMATION TO THE ONE OR MORE PEER APPARATUSES, THE SCHEDULING INFORMATION INDICATING ONE OR MORE TIME PERIODS DURING WHICH COORDINATED ACCESS TO THE SHARED MEDIUM IS DESIRED
1306A
MEANS FOR TRANSMITTING AT LEAST SOME OF THE SCHEDULING INFORMATION TO DEVICES SERVED BY THE APPARATUS

FIG. 13A

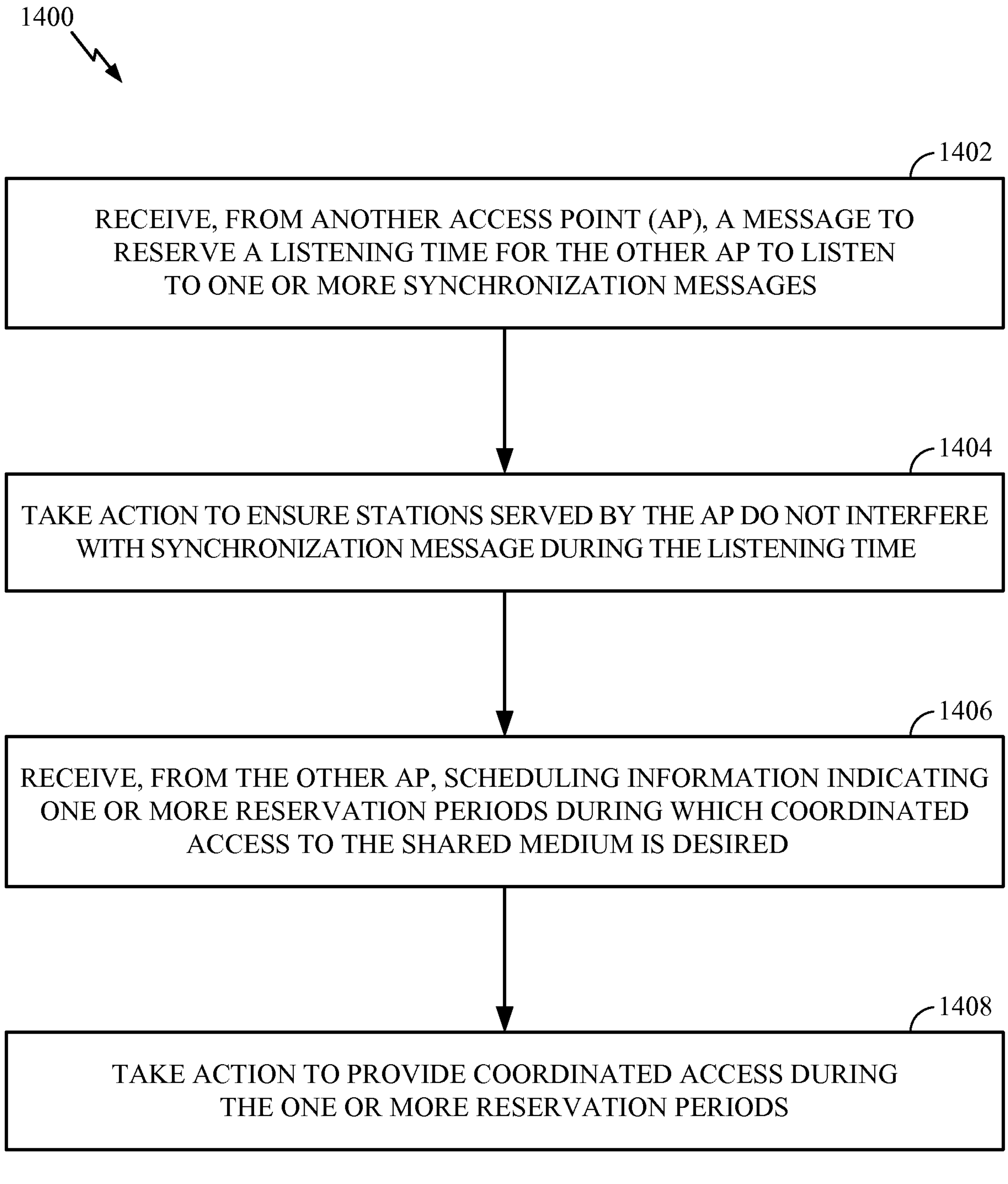

1400
1402
RECEIVE, FROM ANOTHER ACCESS POINT (AP), A MESSAGE TO RESERVE A LISTENING TIME FOR THE OTHER AP TO LISTEN TO ONE OR MORE SYNCHRONIZATION MESSAGES
1404
TAKE ACTION TO ENSURE STATIONS SERVED BY THE AP DO NOT INTERFERE WITH SYNCHRONIZATION MESSAGE DURING THE LISTENING TIME
1406
RECEIVE, FROM THE OTHER AP, SCHEDULING INFORMATION INDICATING ONE OR MORE RESERVATION PERIODS DURING WHICH COORDINATED ACCESS TO THE SHARED MEDIUM IS DESIRED
1408
TAKE ACTION TO PROVIDE COORDINATED ACCESS DURING THE ONE OR MORE RESERVATION PERIODS

FIG. 14

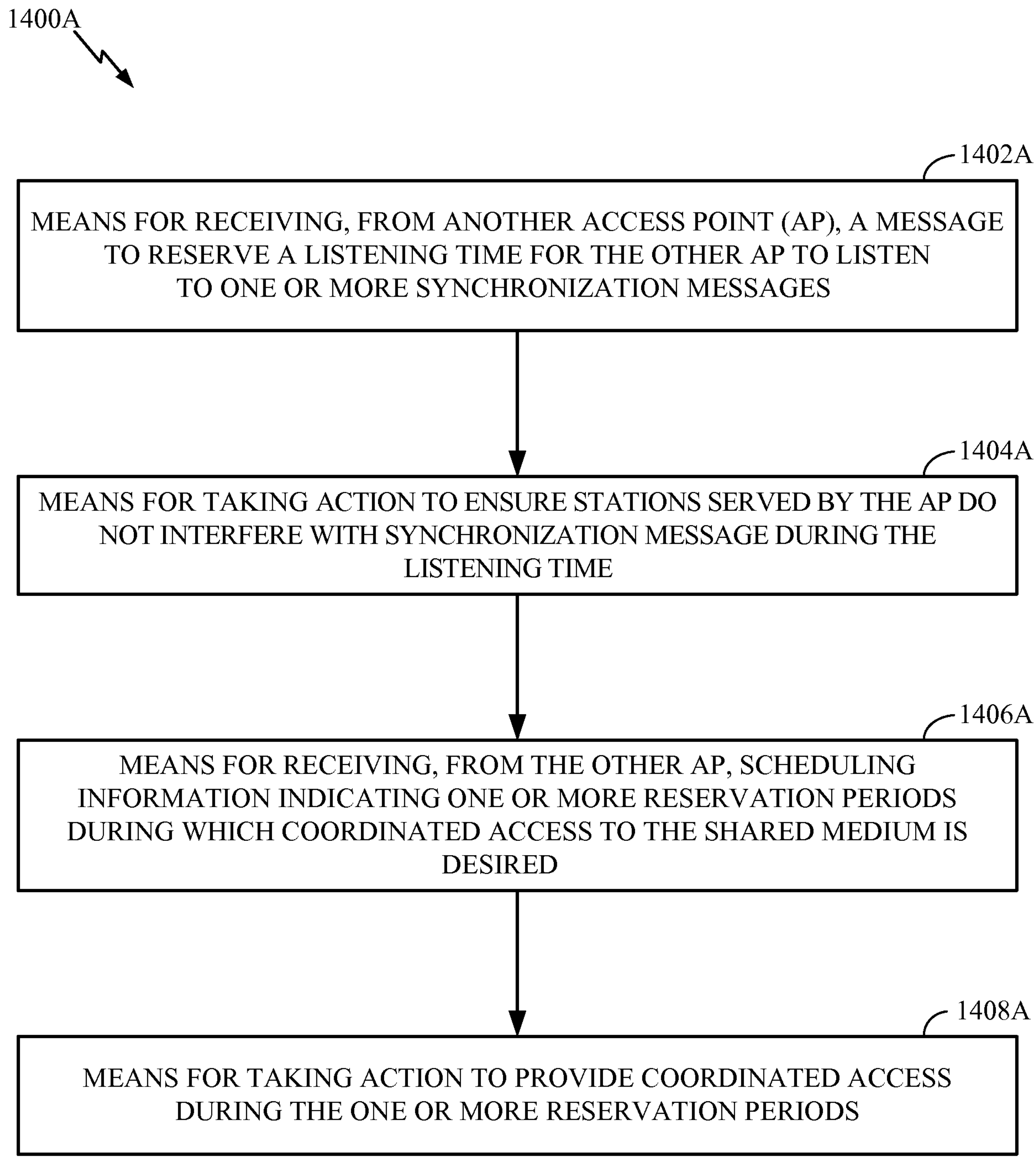

1400A
1402A
MEANS FOR RECEIVING, FROM ANOTHER ACCESS POINT (AP), A MESSAGE TO RESERVE A LISTENING TIME FOR THE OTHER AP TO LISTEN TO ONE OR MORE SYNCHRONIZATION MESSAGES
1404A
MEANS FOR TAKING ACTION TO ENSURE STATIONS SERVED BY THE AP DO NOT INTERFERE WITH SYNCHRONIZATION MESSAGE DURING THE LISTENING TIME
1406A
MEANS FOR RECEIVING, FROM THE OTHER AP, SCHEDULING INFORMATION INDICATING ONE OR MORE RESERVATION PERIODS DURING WHICH COORDINATED ACCESS TO THE SHARED MEDIUM IS DESIRED
1408A
MEANS FOR TAKING ACTION TO PROVIDE COORDINATED ACCESS DURING THE ONE OR MORE RESERVATION PERIODS

FIG. 14A

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/052923

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W56/00
ADD.

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

B. FIELDS SEARCHED

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

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

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

EPO-Internal, 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 Y	WO 2013/048499 A1 (INTEL CORP [US]; GONG MICHELLE X [US]) 4 April 2013 (2013-04-04) page 2, line 5 - line 24 page 6 - page 9; figures 1,4a,4b,4c,5	1,28-30 1-7, 28-30
Y	MAHMOOD A ET AL: "Software support for clock synchronization over IEEE 802.11 wireless LAN with open source drivers", PRECISION CLOCK SYNCHRONIZATION FOR MEASUREMENT CONTROL AND COMMUNICATION (ISPCS), 2010 INTERNATIONAL IEEE SYMPOSIUM ON, IEEE, PISCATAWAY, NJ, USA, 27 September 2010 (2010-09-27), pages 61-66, XP031780851, ISBN: 978-1-4244-5978-0 paragraph [0III]	1-7, 28-30

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

[X] See patent family annex.

* Special categories of cited documents :

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 December 2014	23/12/2014

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

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

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/052923

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	HARADA S ET AL: "Development of audio and video synchronous transmission system based on IEEE802.11a", CONSUMER COMMUNICATIONS AND NETWORKING CONFERENCE, 2004. CCNC 2004. FI RST IEEE LAS VEGAS, NV, USA 5-8 JAN. 2004, PISCATAWAY, NJ, USA,IEEE, 5 January 2004 (2004-01-05), pages 316-319, XP032165228, DOI: 10.1109/CCNC.2004.1286879 ISBN: 978-0-7803-8145-2 paragraph [III.C] -----	1-7, 28-30
Y	BRIAN HART (CISCO SYSTEMS): "Overlapping BSS ; 11-08-1250-00-00aa-overlapping-bss", IEEE DRAFT; 11-08-1250-00-00AA-OVERLAPPING-BSS, IEEE-SA MENTOR, PISCATAWAY, NJ USA, vol. 802.11aa, 31 October 2008 (2008-10-31), pages 1-16, XP017680254, [retrieved on 2008-10-31] page 6 - page 9 -----	3-5
X	US 2009/196174 A1 (JI TINGFANG [US]) 6 August 2009 (2009-08-06) paragraphs [0107], [0108]; figures 12,13,15,16 paragraphs [0054], [0010] - [0019]; figures 7-11 -----	8-27

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/052923

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-7, 28-30

   implement a master time among coordinating sets and reserve listening time for synchronisation messages

   ---

2. claims: 8-14, 18-21, 25-27

   definition of the scheduling information exchanged among access points, in particular enhanced distributed channel access or certain types of deferral rules

   ---

3. claims: 15-17, 22-24

   solicit input from peer apparatuses prior to output scheduling information to devices, identify subset of devices to transmit during a scheduled time applying a restricted access window frame or a power save multi-poll message

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2014/052923

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2013048499 A1	04-04-2013	CN 103828262 A	28-05-2014
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US 2009196174 A1	06-08-2009	AU 2009210474 A1	13-08-2009
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		UA 100721 C2	25-01-2013
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