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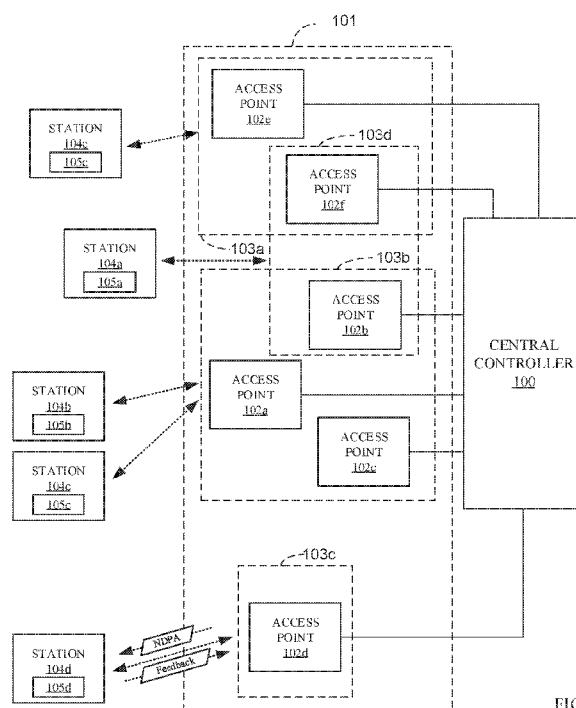


FIG. 1

(57) **Abstract:** Methods and apparatus to facilitate centralized multi-access point multi-station association in a cooperative Wi-Fi network are disclosed. An example apparatus includes a transmitter to transmit instructions to a group of access points (APs) to transmit a frame to a station (STA), the frame including group AP data related to the 5 group of APs and connectivity testing instructions related to a connectivity status of the STA to the group of APs; and an AP cluster determiner to generate a subset of the group of APs for the STA based on a response to the frame, the subset corresponding to APs whose connectivity satisfies a threshold.

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).

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METHODS AND APPARATUS TO FACILITATE CENTRALIZED MULTI-ACCESS POINT, MULTI-STATION ASSOCIATION IN A COOPERATIVE WI-FI NETWORK

FIELD OF THE DISCLOSURE

5 This disclosure relates generally to wireless fidelity (Wi-Fi) connectivity and, more particularly, to methods and apparatus to facilitate centralized multi-access point, multi-station association in a cooperative Wi-Fi network.

BACKGROUND

10 Many locations provide Wi-Fi to connect Wi-Fi enabled devices to networks such as the Internet. Wi-Fi enabled devices include personal computers, video-game consoles, mobile phones and devices, digital cameras, tablets, smart televisions, digital audio players, etc. Wi-Fi allows the Wi-Fi enabled devices to wirelessly access the Internet via a wireless local area network (WLAN). To provide Wi-Fi connectivity to a device, a Wi-Fi access point transmits a radio frequency Wi-Fi signal to the Wi-Fi enabled device within the Wi-Fi signal's range (e.g., a
15 hotspot).

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an illustration of an example central controller to facilitate centralized multi-access point, multi-station association in a cooperative Wi-Fi network.

FIG. 2 is a block diagram of the example central controller of FIG. 1.

20 FIG. 3 is a block diagram of an example AP connection determiner of FIG. 1.

FIG. 4 is a flowchart representative of example machine readable instructions that may be executed to implement the example central controller of FIG. 1.

FIG. 5 is a flowchart representative of example machine readable instructions that may be executed to implement the example station of FIG. 1.

25 FIG. 6 is a flowchart representative of example machine readable instructions that may be executed to implement the example station of FIG. 1.

FIG. 7 is an example null data packet announcement frame that may be transmitted by example access points of FIG. 1.

30 FIG. 8 is a block diagram of a processor platform structured to execute the example machine readable instructions of FIG. 4 to implement the example central controller of FIG. 2.

FIG. 9 is a block diagram of a processor platform structured to execute the example machine readable instructions of FIGS. 5-6 to implement the example AP connection determiner of FIG. 3.

The figures are not to scale. Wherever possible, the same reference numbers will be used throughout the drawing(s) and accompanying written description to refer to the same or like parts.

DETAILED DESCRIPTION

Various locations (e.g., homes, offices, coffee shops, restaurants, parks, airports, etc.) may provide Wi-Fi to Wi-Fi enabled devices (e.g., stations (STA)) to allow the Wi-Fi enabled devices to connect to the Internet, or any other network, with minimal hassle. The locations may provide one or more Wi-Fi Access Points (APs) to output Wi-Fi signals to the Wi-Fi enabled device within a range of the Wi-Fi signals (e.g., a hotspot). A Wi-Fi AP is structured to wirelessly connect a Wi-Fi enabled device to the Internet through a wireless local area network (WLAN) using Wi-Fi protocols (e.g., such as IEEE 802.11). The Wi-Fi protocol is the protocol specifying how the AP communicates with the STAs to provide access to the Internet.

In dense connectivity networks, many APs may be deployed in a given area. For example, trains, planes, conference rooms, stadiums, offices, plazas, etc. may include many APs to allow users to access the Internet at multiple locations within the space. Some conventional WLAN systems only allow a STA to communicate with a single AP at a time using Wi-Fi. Accordingly, if the Wi-Fi connection is lost, or if the STA is moved to a location outside the range of the AP, the STA needs to connect with another AP.

Other conventional WLAN systems create collaborative AP (C-AP) sets, in which an STA may be connected to a cluster of APs using different collaborative methodologies between the multiple APs (e.g., frequency channelization, channel bonding, distributed multiple input multiple output (MIMO) and beamforming (BF), etc.). The C-AP corresponds to all the APs that the STA can sense (e.g., can signal and/or successfully communicate with) based on a response to a null data packet (NDP) announcement (NDPA) transmitted by the network of APs. However, if a new STA joins the C-AP set and/or the STA moves out of the location to a neighboring location (e.g., corresponding to a neighboring C-AP set), a new C-AP set has to be formed, new connections need to be established, NDP training fields (e.g., symbols used to assist a receiver in identifying that a frame is about to start, synchronizing timers, antenna data, etc.)

have to be retransmitted for channel sounding (e.g., to evaluate the status of the wireless connection), and the NDPA needs to be restructured. Accordingly, such a conventional technique may not be network-efficient and may result in higher network overhead. Examples disclosed herein facilitate centralized access point association for multi-AP cooperative Wi-Fi networks to minimize network overhead and facilitate a soft transition (e.g., without requiring steps to reconnect to a new C-AP) of the STAs in and out of a C-AP.

Examples disclosed herein generate an extended C-AP set to facilitate a soft transition of the STAs in and out of a C-AP. The extended C-AP set is a set of APs within a location that are connected via a central controller or master AP, any combination of which may be connected to a STA. The extended C-AP set and associated STAs may include not only the APs that are successfully sensed by the STAs' receiver, but also include the APs which may not be detected by the STAs' receivers. Examples disclosed herein include transmitting augmented NDPA frames via each of the APs in the extended C-AP. The augmented NDPA frame identifies APs in the extended C-AP set, associated STAs, and other information about channel sounding and feedback reports. The augmented NDPA frame may also inform each STA of the details on training field transmission from C-AP sets (e.g., when and from what AP it can expect to receive training fields for channel sounding). In this manner, a change in STA connectivity status will not require retransmission of training fields or restructuring of NDPA frames. The STAs receive the augmented NDPA frames from APs that it can sense and process the augmented NDPA frames. In some examples, the augmented NDPA frames include instructions as to how to establish if the connection to the AP is appropriate for communication.

If the STA identifies a strong channel corresponding to the AP, the STA transmits a response (e.g., BF feedback), else the STA transmits null data or does not transmit any data. Examples disclosed herein include gathering the responses (e.g., null data/BF feedback data) to generate a C-AP for each STA connected to the extended C-AP. As the STA moves and/or as the status of the connection changes, the response (e.g., BF reports/null data) will change. Accordingly, examples disclosed herein dynamically adapt to update the C-AP for a STA connected with the extended C-AP. In this manner, STAs can transition from one cluster to another one without requiring retransmission of training fields and restructuring of NDPA frames.

FIG. 1 illustrates an example central controller 100 to facilitate centralized multi-access point, multi-station association in a cooperative Wi-Fi network. The example of FIG. 1 includes the example central controller 100, an example extended C-AP set 101, example C-AP sets 103a-d, example APs 102a-f, example STAs 104a-e, each of which includes example AP connection determiners 105a-e. Although the illustrated example of FIG. 1 includes five STAs and six APs, the example central controller 100 may facilitate communication between any number of STAs and/or APs.

The example central controller 100 of FIG. 1 facilitates communications within the example extended C-AP set 101 to the example STAs 104a-e. For example, the central controller 100 facilitates the transmission of an augmented NDPA including information of all APs 102a-f in the example extended C-AP set 101 to generate the C-AP sets 103a-d for each of the example STAs 104a-e. The augmented NDPA may include connectivity testing instructions related to testing connectivity of the STAs 104a-e to the APs 104a-e. An example augmented NDPA is further described below in conjunction with FIG. 7. The central controller 100 generates the C-AP sets 103a-d based on the responses (e.g., null data and/or BF feedback reports) from the example STAs 104a-e via the example APs 102a-f. For example, as illustrated in FIG. 1, the example central controller 100 may receive BF feedback reports for STAs 104b, 104c corresponding to APs 102a-c and null data for all other APs 102d-e in the example extended C-AP set 101. In such an example, the central controller 100 may generate a C-AP for the STAs 104b, 104c including the APs 102a-c and excluding the APs 102d-e. However, if one or both of the STAs 104b, 104c move locations and/or lose connections with one or more of the APs 102a-c, the BF feedback report and null data will change, thereby causing the example central controller 100 to reform a new C-AP set based on the new STA response. The central controller 100 may instruct the APs 102a-e to transmit the augmented NDPA based on a trigger (e.g., a timer, a loss in connection, a new STA connecting to an AP, etc.). In some examples, the central controller 100 is located in one or more of the APs 102a-f. In such an example, the AP including the example central controller 100 is the master AP where the central controller 100 facilitates communications within the example extended C-AP set 101 to the example STAs 104a-e within the master AP. In such examples, the master AP coordinates all the other APs in the example extended C-AP set 101. The example central controller 100 is further described below in conjunction with FIG. 2.

The example APs 102a-f of FIG. 1 are devices that allow the example STAs 104a-e to access a network (e.g., the Internet). The example APs 102a-f may be routers, modem-routers, and/or any other devices that provides a wireless connection to a network. For example, when the APs 102a-f is a router, the APs 102a-f provide a wireless communication link to a STA. In such an example, the APs 102a-f accesses the network through a wire connection via a modem. A modem-router combines the functionalities of the modem and the router. The APs 102a-f make up the example extended C-AP set 101 and may communicate with one of more of the example STAs 104a-e.

The example STAs 104a-e of FIG. 1 are Wi-Fi enabled computing devices. The example STAs 104a-e may be, for example, computing devices, portable devices, mobile devices, mobile telephones, smart phones, tablets, gaming systems, digital cameras, digital video recorders, televisions, set top boxes, e-book readers, and/or any other Wi-Fi enabled devices.

The example STAs 104a-e include the example AP connection determiners 105a-e of FIG. 1 to receive augmented NDPA frames from one or more of the example APs 102a-e and generate a response based on the data within the augmented NDPA (e.g., the NDPA data). The augmented NDPA data may include connectivity testing instructions on how to test the connectivity status of the STA 104a-e with the example APs 102a-e. For example, if the augmented NDPA data corresponds to a signal strength of the APs 102a-f, the example AP connection determiners 105a-e measure the signal strength between the APs 102a-f and transmit a response corresponding to the strength. For example, if the strength between the STA 104a and the APs 102f, 102b is above a threshold strength, the example AP connection determiner 105a transmits a response corresponding to the signal strength (e.g., BF report and/or null data). In some examples, the AP connection determiners 105a-e send back a response according to a multi-user Orthogonal frequency-division multiple access (OFDMA) scheme. In this manner, the training overhead and latency is reduced. The example central controller 100 controls the uplink OFDMA, where the frequency configuration for multiplexing of BF reports for each STA is identified in the augmented NDPA. Additionally, if the strength between the example STA 104a and the example APs 102a, 102c, 102d, 102e, 102f are below the threshold strength, the example AP connection determiner 105a transmits null data to one or more the example APs 102a-f. The example AP connection determiners 105a-e are further described below, in conjunction with FIG. 3.

In the illustrated example of FIG. 1, the central controller 100 has generated C-AP set 103d to include AP 102b, 102f in the example C-AP set 103d for STA 104a based on the response (e.g., BF report and/or null data) transmitted by the example AP connection determiner 105a in response to an augmented NDPA frame. However, if the example STA 104a were to move to the same or a similar location as the example STA 104d, the BF feedback report generated by the example AP connection determiner 105a would likely change to correspond to AP 102d and the null data would likely correspond to the other APs 102a-c, 102e-f. In such an example, the central controller 100 will change the C-AP set for STA 104a to the example C-AP set 103c. Because the augmented NDPAs transmitted to the STAs 104a-e include data relating to all APs 102a-f in the example extended C-AP 101 and the structure of each subsequent augmented NDPA is the same (e.g., because the augmented NDPA includes data relating to all APs 102a-f regardless of if they are sensed by a STA), a change in connectivity status allows the central controller 100 to generate a new C-AP without re-transmitting training fields and without restructuring the NDPA frame.

FIG. 2 is a block diagram of an example implementation of the example central controller 100 of FIG. 1, disclosed herein, to facilitate centralized multi-access point multi-station association in a cooperative Wi-Fi network. The example central controller 100 includes an example AP cluster determiner 200, an example transmitter 202, an example receiver 204, and an example timer 206.

The example AP cluster determiner 200 of FIG. 2 generates the example extended C-AP set 101 of FIG. 1 based on the APs within the network. Additionally, the example AP cluster determiner 200 instructs the example APs 102a-f to transmit augmented NDPA frames based on various triggers. A trigger may be based on the example timer 206, based on a new STA entering the network (e.g., via a receipt of a RTS from the new STA), based on a communication error message from one of the STAs 104a-f, etc. The example AP cluster determiner 200 determines which STAs 104a-e should be connected with which APs 102a-f based on the responses from the transmitted augmented NDPA frames. Once the determination is made, the example AP cluster determiner 200 generates C-AP sets (e.g., the example C-AP sets 103a-d) based on the determination.

The example transmitter 202 of FIG. 2 transmits the instructions (e.g., a trigger or signal) to the example APs 102a-f corresponding to a transmission of the augmented NDPA frames. In

response to receiving the instructions, the example APs 102a-f send the augmented NDPA frames to the example STAs 102a-e. Additionally, the example transmitter 202 may send C-AP set data to the C-AP set to identify that the APs are part of the C-AP for one or more STAs. The example receiver 204 of FIG. 2 receives responses to the augmented NDPA frame transmissions (e.g., BF feedback reports and/or null data corresponding to each STAs connection with each AP). In some examples, the receiver 204 receives connection error messages from one or more of the APs 102a-f when, for example, a STA has lost connection to one of more of the APs in a corresponding C-AP set. Additionally, the receiver 204 may receive a trigger identifying that a new STA has joined and/or is attempting to join the network.

The example timer 206 of FIG. 2 tracks time. In this manner, the example timer 206 is able to determine when a threshold amount of time has passed. For example, the timer 206 may initiate a start time after an augmented NDPA frame was transmitted to connected STAs and monitors the duration of time since the frame was transmitted. When the duration exceeds a threshold amount of time, the timer 206 transmits a trigger so that the example AP cluster determiner 200 can reinstruct the APs 102a-f to transmit the augmented NDPA frame to the connected STAs. In this manner, the STA to C-AP status is checked periodically or aperiodically to determine if the C-AP sets need to be updated.

FIG. 3 is a block diagram of an example implementation of the example AP connection determiners 105a of FIG. 1, disclosed herein, to facilitate centralized multi-access point multi-station association in a cooperative Wi-Fi network. Although the block diagram of FIG. 3 illustrates an example implementation of the example AP connection determiner 105a, the block diagram of FIG. 3 may be utilized in conjunction with any of the example AP connection determiner 105a-e. The example AP connection determiner 105a includes an example receiver 300, an example frame processor 302, an example connection analyzer 304, and an example transmitter 306.

The example receiver 300 of FIG. 3 receives augmented NDPA frames transmitted by the example APs 102a-f. The example frame processor 302 processes the received augmented NDPA frames to determine how to respond. For example, the frame processor 302 may process the augmented NDPA frame to determine that the frame includes data instructing the STA to measure the signal strength of a connection to each AP 102e-f in the example extended C-AP set 101, measuring the channels from all APs that can be heard (e.g., for beamforming), preform a

(CQI) calculation or Singular Value calculation on sounded channel (e.g., for channel bonding), etc.

The example connection analyzer 304 of FIG. 3 analyzes the STA's connection with the APs 102a-f based on the data (e.g., instructions) of the augmented NDPA and generates one or more responses based on the connection analysis. In some examples, the connection analyzer 304 generates one response with data corresponding to the connection analysis of each AP 102a-f. In some examples, the connection analyzer 304 generates a separate response for each of the sensed APs. For example, the connection analyzer 304 may measure the signal strength corresponding to each AP in the example extended C-AP set 101. If the connection analyzer 304 determines that the signal strengths corresponding to APs 102a-f are below a minimum strength threshold and the signal strength corresponding to AP 102f is above the minimum strength threshold, the example connection analyzer 304 may generate one response corresponding to a BF report for the example AP 102f and null data for the example APs 102a-f. Additionally or alternatively, the example connection analyzer 304 may generate a first response corresponding to the BF report for the example AP 102f, a second response corresponding to the null data for the example AP 102a, a third response corresponding to the null data for the example AP 102b, etc.

Once the example connection analyzer 304 generates the response(s), the example transmitter 306 of FIG. 3 transmits the response(s) corresponding to the connection analysis for each AP 102a-f in the example extended C-AP set 101. For example, if each AP corresponds to a different channel and the example connection analyzer 304 generated a single response for all APs 102a-f, the example transmitter 306 may transmit the single response on all channels corresponding to the APs 102a-f. If each AP corresponds to a different channel and the example connection analyzer 304 generate multiple responses (e.g., a response per AP), the example transmitter 306 will send each response on the channel corresponding to the appropriate AP. The example APs 102a-f forwards the received BF report and/or null data to the example central controller 100 to generate the example C-AP sets 103a-d, as described above.

While an example manner of implementing the example central controller 100 and the example AP connection determiner 105a of FIG. 1 is illustrated in FIGS. 2 and 3, one or more of the elements, processes and/or devices illustrated in FIGS. 2 and 3 may be combined, divided, rearranged, omitted, eliminated and/or implemented in any other way. Further, the example AP

cluster determiner 200, the example transmitter 202, the example receiver 204, the example timer 206, and/or, more generally, the example central controller 100 of FIG. 2 and the example receiver 300, the example frame processor 302, the example connection analyzer 304, the example transmitter 306, and/or more generally the example AP connection determiner 105a of FIG. 3 may be implemented by hardware, software, firmware and/or any combination of hardware, software and/or firmware. Thus, for example, any of the example AP cluster determiner 200, the example transmitter 202, the example receiver 204, the example timer 206, and/or, more generally, the example central controller 100 of FIG. 2 and the example receiver 300, the example frame processor 302, the example connection analyzer 304, the example transmitter 306, and/or more generally the example AP connection determiner 105a of FIG. 3 could be implemented by one or more analog or digital circuit(s), logic circuits, programmable processor(s), application specific integrated circuit(s) (ASIC(s)), programmable logic device(s) (PLD(s)) and/or field programmable logic device(s) (FPLD(s)). When reading any of the apparatus or system claims of this patent to cover a purely software and/or firmware implementation, at least one of the example, the example AP cluster determiner 200, the example transmitter 202, the example receiver 204, the example timer 206, and/or, more generally, the example central controller 100 of FIG. 2 and the example receiver 300, the example frame processor 302, the example connection analyzer 304, the example transmitter 306, and/or more generally the example AP connection determiner 105a of FIG. 3 is/are hereby expressly defined to include a non-transitory computer readable storage device or storage disk such as a memory, a digital versatile disk (DVD), a compact disk (CD), a Blu-ray disk, etc. including the software and/or firmware. Further still, the example central controller 100 of FIG. 2 and/or the example AP connection determiner 105a of FIG. 3 may include one or more elements, processes and/or devices in addition to, or instead of, those illustrated in FIGS. 2 and/or 3, and/or may include more than one of any or all of the illustrated elements, processes and devices.

Flowcharts representative of example machine readable instructions for implementing the example central controller 100 of FIG. 2 is shown in FIG. 4 and flowcharts representative of example machine readable instructions for implementing the example AP connection determiner 105a of FIG. 3 is shown in FIGS. 5-6. In this example, the machine readable instructions comprise a program for execution by a processor such as the processor 812, 912 shown in the example processor platform 800, 900 discussed below in connection with FIGS. 8 and 9. The

program may be embodied in software stored on a non-transitory computer readable storage medium such as a CD-ROM, a floppy disk, a hard drive, a digital versatile disk (DVD), a Blu-ray disk, or a memory associated with the processor 812, 912, but the entire program and/or parts thereof could alternatively be executed by a device other than the processor 812, 912 and/or embodied in firmware or dedicated hardware. Further, although the example program is described with reference to the flowchart illustrated in FIGS. 4-5, many other methods of implementing the example central controller 100 and/or the example AP connection determiner 105a may alternatively be used. For example, the order of execution of the blocks may be changed, and/or some of the blocks described may be changed, eliminated, or combined. Additionally or alternatively, any or all of the blocks may be implemented by one or more hardware circuits (e.g., discrete and/or integrated analog and/or digital circuitry, a Field Programmable Gate Array (FPGA), an Application Specific Integrated circuit (ASIC), a comparator, an operational-amplifier (op-amp), a logic circuit, etc.) structured to perform the corresponding operation without executing software or firmware.

As mentioned above, the example processes of FIGS. 4-6 may be implemented using coded instructions (e.g., computer and/or machine readable instructions) stored on a non-transitory computer and/or machine readable medium such as a hard disk drive, a flash memory, a read-only memory, a compact disk, a digital versatile disk, a cache, a random-access memory and/or any other storage device or storage disk in which information is stored for any duration (e.g., for extended time periods, permanently, for brief instances, for temporarily buffering, and/or for caching of the information). As used herein, the term non-transitory computer readable medium is expressly defined to include any type of computer readable storage device and/or storage disk and to exclude propagating signals and to exclude transmission media. "Including" and "comprising" (and all forms and tenses thereof) are used herein to be open ended terms. Thus, whenever a claim lists anything following any form of "include" or "comprise" (e.g., comprises, includes, comprising, including, etc.), it is to be understood that additional elements, terms, etc. may be present without falling outside the scope of the corresponding claim. As used herein, when the phrase "at least" is used as the transition term in a preamble of a claim, it is open-ended in the same manner as the term "comprising" and "including" are open ended.

FIG. 4 is an example flowchart 400 representative of example machine readable instructions that may be executed by the example central controller 100 of FIG. 2 to facilitate centralized multi-access point multi-station association in a cooperative Wi-Fi network.

Although the example flowchart 400 of FIG. 4 is described in conjunction with the example central controller 100 of FIG. 1, the flowchart 400 may be utilized by any type of central controller in any type of AP network.

At block 402, the example AP cluster determiner 200 develops a cluster of APs to generate the extended C-AP set 101. As described above, the example extended C-AP set 101 includes all APs in a particular area that are connected via the example central controller 100.

Although, the extended AP set 101 includes all of the APs that a STA may connect to within a certain location, the STA may only be capable of connecting to a subset of the APs in the extended AP set 101 at a first time. At block 404, the example transmitter 202 transmits instructions to the example APs 102a-f in the example extended C-AP set 101 to transmit augmented NDPA frames for connected STAs (e.g., the example AP connection determiner 105a of the example STAs 104a-e). The augmented NDPA may include data or other instructions (e.g., connectivity testing instructions) that are used by the example STAs 104a-e to test connections to the example APs 102e-f to generate the example C-AP sets 103a-d of FIG. 1. The augmented NDPA frames are used to determine which of the example APs 102 a-f in the example extended C-AP set 101 are capable of connecting with which STAs 104a-e. An example augmented NDPA frame is further described below in conjunction with FIG. 7.

At block 406, the example receiver 204 receives response from the STAs 104a-e via the example APs 102e-f. As described above, the responses correspond to the connection status of the STAs 104a-e to each AP 102e-f. For example, if the status corresponds to a strong connection between a STA and an AP, the response will correspond to the strong connection (e.g., BF report). If the status corresponds to a weak/no connection between a STA and an AP, the response will correspond to a weak connection (e.g., null data). The null data may be generated by the STA and/or the AP (e.g., when a response to a transmitted augmented NDPA frame is not received by the AP). At block 408, the example AP cluster determiner 200 generates the example C-AP sets 102a-d for each STA 104a-e in the example extended C-AP set 101 based on the response(s). For example, the AP cluster determiner 200 generates the example C-AP set 103a (e.g., including access points 102a-f) for the example STA 104e when

the example STA 104e responds to the augmented NDPA identifying a strong (e.g., above a threshold strength) connection with the example APs 102e-f. At block 409, the example AP cluster determiner 200 establishes a C-AP connection for each STA in the extended C-AP set 101 based on the responses by transmitting connection instructions to the example C-AP sets 103a-d in the example extended C-AP set 101. In this manner, the example C-AP sets 103a-d establish a multi-access point multi-station connection for the example STAs 104e-e.

At block 410, the example timer 206 determines if a threshold amount of time has elapsed (e.g., since the last augmented NDPA transmission). If the example timer 206 determines that the threshold amount of time has elapsed (block 410: YES), the process returns to block 404. In this manner, the example central controller 100 can recheck to see if the connection status of any of the example STAs 104a-e to determine if the status has changed. If the example timer 206 determines that the threshold amount of time has not elapsed (block 410: NO), the example receiver 204 determines if a trigger corresponding to a new STA requesting access to the extended C-AP set 101 has been received (e.g., based on a RTS received by one of the APs 102a-f in the example extended C-AP set 101) (block 412).

If the example receiver 204 determines that a trigger corresponding to a new STA requesting access to the example extended C-AP set 101 has been received (block 412: YES), the process returns to block 404 to retransmit instructions corresponding to an augmented NDPA frame so that the example central controller 100 can generate a C-AP set for the new STA. If the example receiver 204 determines that a trigger corresponding to a new STA requesting access to the example extended C-AP set 101 has not been received (block 412: NO), the example receiver 204 determines if a trigger corresponding to a connection error between any of the STAs 104a-e and an AP in a C-AP set corresponding to the STA been received (block 414). For example, initially the example STA 104c may be communicating with the example APs 102a-c in the example C-AP set 103b. In such an example, the STA 104c may lose or reduce connectivity with the example APs 102a. The example STA 104c may transmit an error signal to another AP 102b-c in the example C-AP set 103b and/or the one of the example APs 102a-c may determine that the connection has been diminished or lost. In response to one of the APs 102a-c determining the error and/or receiving the error from the STA 104b, one or more of the APs 102a-c transmit a connection error signal to the example central controller 100 to trigger a

retransmission of the augmented NDPA frames to regenerate a new C-AP set excluding the example AP 102a.

If the example receiver 204 determines that a trigger corresponding to a connection error between a STA and an AP in a C-AP set corresponding to the STA has been received (block 414: YES), the process returns to block 404 to retransmit the augmented NDPA frames to generate a new C-AP set. If the example receiver 204 determines that a trigger corresponding to a connection error between a STA and an AP in a C-AP set corresponding to the STA has not been received (block 414: NO), the process returns to block 410 until a new trigger is set (e.g., corresponding to blocks 410, 412, and 414).

FIG. 5 is an example flowchart 500 representative of example machine readable instructions that may be executed by the example AP connection determiner 105a of FIG. 3 to facilitate centralized multi-access point multi-station association in a cooperative Wi-Fi network. Although the example flowchart 500 of FIG. 5 is described in conjunction with the example AP connection determiner 105a of FIG. 1, the flowchart 500 may be utilized by any type of AP connection determiner in any type of AP network.

At block 502, the example transmitter 306 transmits a request (e.g., a RTS) to access the example extended C-AP set 101. The example transmitter 306 may transmit the request when the example STA 104a-e is within range of one of the example APs 102a-f of the example extended C-AP set 101. At block 504, the example receiver 300 receives an augmented NDPA from one or more of the example APs 102a-f in the example extended C-AP set 101. At block 506, the example frame processor 302 processes the received augmented NDPA to determine how to respond to the augmented NDPA (e.g., including data including and/or corresponding to connectivity testing instructions). As further described below in conjunction with FIG. 7, the example augmented NDPA includes various data including how to test the connectivity of the example STA 104a-c with the example APs 102a-f.

At block 508, the example connection analyzer 304 tests the connectivity of the example STA 104a-e to each of the APs 102a-f in the example extended C-AP set 101 based on the augmented NDPA. For example, the connection analyzer 304 may, based on the augmented NDPA, measure signal strength, measure the ability to hear APs on different channels, perform a CQI calculation on a sounded channel, etc. If the example connection analyzer 304 determines that the connectivity to a particular AP is satisfactory (e.g., above some threshold), the example

connection analyzer 304 generates a response corresponding to a satisfactory connection (e.g., a BF report), else the example connection analyzer 304 generates a response with null data. At block 510, the example transmitter 306 transmits a response to each AP corresponding to the received augmented NDPA. The response includes the connectivity status of the example STA 104a-c to the example APs 102e-f.

At block 512, the example transmitter 306/receiver 300 establishes a connection with a C-AP set generated by the example central controller 100 based on the transmitted response.

Because the example central controller 100 may periodically or aperiodically transmit new augmented NDPAs, at block 514, the example receiver 300 determines if an additional

augmented NDPA has been received. If the example receiver 300 determines that an additional augmented NDPA has been received (block 514: YES), the process returns to block 506 to determine how to respond to the additional augmented NDPA. If the example receiver 300 determines that an additional augmented NDPA has not been received (block 514: NO), the example connection analyzer 304 determines if a connection error has occurred with an AP in the C-AP set (e.g., the connectivity with one or more of the AP(s) in the C-AP set has been reduced and/or eliminated) (block 516).

If the example connection analyzer 304 determines that a connection error has not occurred (block 516: NO), the process returns to block 514 until an additional augmented NDPA has been received or a connection error has occurred. If the example connection analyzer 304 determines that a connection error has occurred (block 516: YES), the example transmitter transmits an error message to a connected AP(s) in the C-AP set (block 518), thereby triggering the example central controller 100 to regenerate a C-AP set for the example STA 104a-e (e.g., returning to block 504).

FIG. 6 is an example flowchart 508 representative of example machine readable instructions that may be executed by the example AP connection determiner 105a of FIG. 3 to test connectivity based on an NDPA frame. Although the example flowchart 508 of FIG. 6 is described in conjunction with the example AP connection determiner 105a of FIG. 1, the flowchart 508 may be utilized by any type of AP connection determiner in any type of AP network.

At block 600, the example connection analyzer 304 selects a first AP corresponding to the augmented NDPA frame. As described above, the augmented NDPA frame includes

instructions as to all the APs 102a-f in the example extended C-AP 101, as well as how to test the connectivity. For example, the connection analyzer 304 may, based on the augmented NDPA, measure signal strength, measure the ability to hear APs on different channels, perform a CQI calculation on a sounded channel, etc.

5 At block 602, the example connection analyzer 304 tests the connectivity of the selected AP 102a-f based on the augmented NDPA frame. For example, if the augmented NDPA frame corresponds to signal strength, the example connection analyzer 304 tests the signal strength between the example STAs and the selected AP. At block 604, the example connection analyzer 304 determines if the test results satisfy a connectivity threshold. Using the above example, if
10 the results of the signal strength test corresponds to a signal strength above a threshold value (e.g., based on user and/or manufacturer preferences), the signal strength for the selected AP satisfies the connectivity threshold.

 If the example connection analyzer 304 determines that the test results satisfy the connectivity threshold (block 604: YES), the example connection analyzer 304 generates
15 satisfactory connection data for the selected AP (block 606). In some examples, the satisfactory connection data may be, or include, channel sounding information and/or feedback reports. If the example connection analyzer 304 determines that the test results do not satisfy the connectivity threshold (block 604: NO), the example connection analyzer 304 generates unsatisfactory connection data for the selected AP (block 608). In some examples, the
20 unsatisfactory connection data may be, or include, null data.

 At block 610, the example connection analyzer 304 determines if there is a subsequent AP corresponding to the NDPA frame (e.g., identified in the NDPA frame). If the example connection analyzer 304 determines that there is a subsequent AP corresponding to the NDPA frame (block 610: YES), the example connection analyzer 304 selects the subsequent AP
25 corresponding to the augmented NDPA frame (block 612) and repeats the process until the APs 102a-f corresponding to the NDPA frame have been analyzed. If the example connection analyzer 304 determines that there is not a subsequent AP corresponding to the NDPA frame (block 610: NO), the process ends.

 FIG. 7 is an example augmented NDPA frame structure 700 used by the example APs
30 102a-f to generate connectivity data from the example STAs 104a-e to generate the example C-AP sets 103a-d. As described above, the augmented NDPA identifies the example APs 102a-f

in the example extended C-AP set 101 and the associated STAs 104a-e along with other information about channel sounding and/or feedback reports.

In the illustrated example augmented NDPA frame structure 700 of FIG. 7, k represents the total number C-APs in the example extended C-AP set 101, n represents the total number of STAs connected to the example extended C-AP set 101, n_l and n_k are the number of STA associated primarily (e.g., the AP corresponding to the strongest connection to the STA) to AP-1 and AP-K respectively, and $AP-E1, AP-E2, \dots AP-Em$ represent the m APs in the example C-AP set that may not be heard at the current active STAs. The example augmented NDPA frame structure 700 includes identifiers for the APs in a corresponding C-AP set as well as identifiers for neighboring APs not in the C-AP set. Additionally, the example augmented NDPA frame structure 700 informs the STAs 104a-e to expect the training fields from the APs 102a-f in the C-AP sets 103a-d. The NDA frame structure 700 may also inform each user to the details corresponding to the training field transmission from a C-AP set. The details may include when and from what AP the receiving STA can expect to receive training fields for channel sounding.

FIG. 8 is a block diagram of an example processor platform 800 capable of executing the instructions of FIGS. 4-5 to implement the example central controller 100 of FIGS. 1 and 2. The processor platform 800 can be, for example, a server, a personal computer, a mobile device (e.g., a cell phone, a smart phone, a tablet such as an iPadTM), a personal digital assistant (PDA), an Internet appliance, or any other type of computing device.

The processor platform 800 of the illustrated example includes a processor 812. The processor 812 of the illustrated example is hardware. For example, the processor 812 can be implemented by integrated circuits, logic circuits, microprocessors or controllers from any desired family or manufacturer.

The processor 812 of the illustrated example includes a local memory 813 (e.g., a cache). The example processor 812 of FIG. 8 executes the instructions of FIG. 4 to implement the example the example AP cluster determiner 200, the example transmitter 202, the example receiver 204, and/or the example timer 206. The processor 812 of the illustrated example is in communication with a main memory including a volatile memory 814 and a non-volatile memory 816 via a bus 818. The volatile memory 814 may be implemented by Synchronous Dynamic Random Access Memory (SDRAM), Dynamic Random Access Memory (DRAM), RAMBUS Dynamic Random Access Memory (RDRAM) and/or any other type of random

access memory device. The non-volatile memory 816 may be implemented by flash memory and/or any other desired type of memory device. Access to the main memory 814, 816 is controlled by a clock controller.

The processor platform 800 of the illustrated example also includes an interface circuit 820. The interface circuit 820 may be implemented by any type of interface standard, such as an Ethernet interface, a universal serial bus (USB), and/or a PCI express interface.

In the illustrated example, one or more input devices 822 are connected to the interface circuit 820. The input device(s) 822 permit(s) a user to enter data and commands into the processor 812. The input device(s) can be implemented by, for example, a sensor, a microphone, a camera (still or video), a keyboard, a button, a mouse, a touchscreen, a track-pad, a trackball, isopoint and/or a voice recognition system.

One or more output devices 824 are also connected to the interface circuit 820 of the illustrated example. The output devices 824 can be implemented, for example, by display devices (e.g., a light emitting diode (LED), an organic light emitting diode (OLED), a liquid crystal display, a cathode ray tube display (CRT), a touchscreen, a tactile output device, and/or speakers). The interface circuit 820 of the illustrated example, thus, typically includes a graphics driver card, a graphics driver chip or a graphics driver processor.

The interface circuit 820 of the illustrated example also includes a communication device such as a transmitter, a receiver, a transceiver, a modem and/or network interface card to facilitate exchange of data with external machines (e.g., computing devices of any kind) via a network 826 (e.g., an Ethernet connection, a digital subscriber line (DSL), a telephone line, coaxial cable, a cellular telephone system, etc.).

The processor platform 800 of the illustrated example also includes one or more mass storage devices 828 for storing software and/or data. Examples of such mass storage devices 828 include floppy disk drives, hard drive disks, compact disk drives, Blu-ray disk drives, RAID systems, and digital versatile disk (DVD) drives.

The coded instructions 832 of FIG. 4 may be stored in the mass storage device 828, in the volatile memory 814, in the non-volatile memory 816, and/or on a removable tangible computer readable storage medium such as a CD or DVD.

FIG. 9 is a block diagram of an example processor platform 900 capable of executing the instructions of FIGS. 5-6 to implement the example AP connection determiner 105a of FIGS. 1

and 3. The processor platform 900 can be, for example, a server, a personal computer, a mobile device (e.g., a cell phone, a smart phone, a tablet such as an iPadTM), a personal digital assistant (PDA), an Internet appliance, or any other type of computing device.

The processor platform 900 of the illustrated example includes a processor 912. The processor 912 of the illustrated example is hardware. For example, the processor 912 can be implemented by integrated circuits, logic circuits, microprocessors or controllers from any desired family or manufacturer.

The processor 912 of the illustrated example includes a local memory 913 (e.g., a cache). The example processor 912 of FIG. 9 executes the instructions of FIG. 7 to implement the example receiver 300, the example frame processor 302, the example connection analyzer 304, and/or the example transmitter 306. The processor 912 of the illustrated example is in communication with a main memory including a volatile memory 914 and a non-volatile memory 916 via a bus 918. The volatile memory 914 may be implemented by Synchronous Dynamic Random Access Memory (SDRAM), Dynamic Random Access Memory (DRAM), RAMBUS Dynamic Random Access Memory (RDRAM) and/or any other type of random access memory device. The non-volatile memory 916 may be implemented by flash memory and/or any other desired type of memory device. Access to the main memory 914, 916 is controlled by a clock controller.

The processor platform 900 of the illustrated example also includes an interface circuit 920. The interface circuit 920 may be implemented by any type of interface standard, such as an Ethernet interface, a universal serial bus (USB), and/or a PCI express interface.

In the illustrated example, one or more input devices 922 are connected to the interface circuit 920. The input device(s) 922 permit(s) a user to enter data and commands into the processor 912. The input device(s) can be implemented by, for example, a sensor, a microphone, a camera (still or video), a keyboard, a button, a mouse, a touchscreen, a track-pad, a trackball, isopoint and/or a voice recognition system.

One or more output devices 924 are also connected to the interface circuit 920 of the illustrated example. The output devices 924 can be implemented, for example, by display devices (e.g., a light emitting diode (LED), an organic light emitting diode (OLED), a liquid crystal display, a cathode ray tube display (CRT), a touchscreen, a tactile output device, and/or

speakers). The interface circuit 920 of the illustrated example, thus, typically includes a graphics driver card, a graphics driver chip or a graphics driver processor.

The interface circuit 920 of the illustrated example also includes a communication device such as a transmitter, a receiver, a transceiver, a modem and/or network interface card to
5 facilitate exchange of data with external machines (e.g., computing devices of any kind) via a network 926 (e.g., an Ethernet connection, a digital subscriber line (DSL), a telephone line, coaxial cable, a cellular telephone system, etc.).

The processor platform 900 of the illustrated example also includes one or more mass storage devices 928 for storing software and/or data. Examples of such mass storage devices 928
10 include floppy disk drives, hard drive disks, compact disk drives, Blu-ray disk drives, RAID systems, and digital versatile disk (DVD) drives.

The coded instructions 932 of FIGS. 5-6 may be stored in the mass storage device 928, in the volatile memory 914, in the non-volatile memory 916, and/or on a removable tangible computer readable storage medium such as a CD or DVD.

From the foregoing, it would be appreciated that methods, apparatus, and articles of
15 manufacture disclosed herein facilitate centralized multi-access point multi-station association in a cooperative Wi-Fi network. Multi-AP association may be utilized for any cooperative AP methodology when APs are to communicate jointly and in a coordinated manner to a client at any given time. Some traditional approaches may require all the APs to be detected at the STA's
20 receiver. Examples disclosed herein include neighboring AP clusters in C-AP sets to enable the user to monitor augmented NDPAs from the APs, which may not be detected successfully at the moment. In this manner, network overhead for channel sounding is reduced and a central controller to form the C-AP set to dynamically adjust as the STA's status or the interference changes in the network.

In traditional 802.11 protocols, an extended service set (ESS) is defined to include
25 multiple basic service set (BSS)/APs with the same service set identifier (SSID) to simplify the roaming, such that few message exchanges are needed when the STA moves from one AP/BSS to another, if both belong to the same ESS. However, in ESS, every user is only communicating with one AP which its beacon is received with the strongest RSSI among other APs in the ESS.

30 Using examples disclosed herein each STA is associated to all APs and may communicate

simultaneously to all APs in the associated multi-AP set based on the dynamic channel measurements.

Example 1 is an apparatus for facilitating a multi-access point multi-station association in a cooperative Wi-Fi network. Example 1 includes a transmitter to transmit instructions to a group of access points (APs) to transmit a frame to a station (STA), the frame including group AP data related to the group of APs and connectivity testing instructions related to a connectivity status of the STA to the group of APs. Example 1 further includes an AP cluster determiner to generate a subset of the group of APs for the STA based on a response to the frame, the subset corresponding to APs whose connectivity satisfies a threshold.

Example 2 includes the subject matter of Example 1, wherein the group of APs include a second subset of the group of APs that cannot be sensed by the STA.

Example 3 includes the subject matter of Example 1, further including a receiver to receive a trigger from an AP in the subset of the group of APs, the trigger corresponding to at least one of a change of the connectivity status or a request from a new AP.

Example 4 includes the subject matter of Example 3, wherein, when the receiver receives the trigger: the transmitter is to transmit second instructions to the group of APs to transmit a second frame to the STA; and the AP cluster determiner is to generate a second subset of the group of APs for the STA based on a second response to the second frame.

Example 5 includes the subject matter of Example 4, wherein the structure of the frame and the second frame is the same.

Example 6 includes the subject matter of Example 4, wherein AP cluster determiner establishes a connection between the STA and the second subset of the group of APs without retransmitting training fields or restructuring the frame.

Example 7 includes the subject matter of Examples 1-6, wherein the transmitter establishes a multi-access point multi-station association between the STA and the subset of the group of APs by transmitting instructions to the subset of the group of APs to establish a connection with the STA.

Example 8 is a method to facilitate a multi-access point multi-station association in a cooperative Wi-Fi network, the method comprising transmitting instructions to a group of access points (APs) to transmit a frame to a station (STA), the frame including group AP data related to the group of APs and connectivity testing instructions related to a connectivity status of the STA

to the group of APs. Example 8 further includes generating a subset of the group of APs for the STA based on a response to the frame, the subset corresponding to APs whose connectivity satisfies a threshold.

Example 9 includes the subject matter of Example 8, wherein the group of APs include a
5 second subset of the group of APs that cannot be sensed by the STA.

Example 10 includes the subject matter of Example 8, further including receiving a trigger from an AP in the subset of the group of APs, the trigger corresponding to at least one of a change of the connectivity status or a request from a new AP.

Example 11 includes the subject matter of Example 10, wherein, in response to receiving
10 the trigger transmitting second instructions to the group of APs to transmit a second frame to the STA; and generating a second subset of the group of APs for the STA based on a second response to the second frame.

Example 12 includes the subject matter of Example 11, wherein the structure of the frame and the second frame is the same.

Example 13 includes the subject matter of Example 11, further including establishing a
15 connection between the STA and the second subset of the group of APs without retransmitting training fields or restructuring the frame.

Example 14 includes the subject matter of Examples 8-13, further including establishing a multi-access point multi-station association between the STA and the subset of the group of
20 APs by transmitting instructions to the subset of the group of APs to establish a connection with the STA.

Example 15 is a tangible computer readable storage medium comprising instructions which, when executed, cause a machine to at least transmit instructions to a group of access points (APs) to transmit a frame to a station (STA), the frame including group AP data related to
25 the group of APs and connectivity testing instructions related to a connectivity status of the STA to the group of APs. Example 15 further includes instructions to generate a subset of the group of APs for the STA based on a response to the frame, the subset corresponding to APs whose connectivity satisfies a threshold.

Example 16 includes the subject matter of Example 15, wherein the group of APs include
30 a second subset of the group of APs that cannot be sensed by the STA.

Example 17 includes the subject matter of Example 15, wherein the instructions cause the machine to receive a trigger from an AP in the subset of the group of APs, the trigger corresponding to at least one of a change of the connectivity status or a request from a new AP.

5 Example 18 includes the subject matter of Example 17, wherein, in response to receiving the trigger, the instructions cause the machine to: transmit second instructions to the group of APs to transmit a second frame to the STA; and generate a second subset of the group of APs for the STA based on a second response to the second frame.

Example 19 includes the subject matter of Example 18, wherein the structure of the frame and the second frame is the same.

10 Example 20 includes the subject matter of Example 18, wherein the instructions cause the machine to establish a connection between the STA and the second subset of the group of APs without retransmitting training fields or restructuring the frame.

Example 21 includes the subject matter of Examples 15-20, wherein the instructions cause the machine to establish a multi-access point multi-station association between the STA and the subset of the group of APs by transmitting instructions to the subset of the group of APs to establish a connection with the STA.

Example 22 is an apparatus for facilitating a multi-access point multi-station association in a cooperative Wi-Fi network, the apparatus comprising: a receiver to receive a frame from a group of access points (APs), the frame including group AP data related to the group of APs and connectivity testing instructions related to a connectivity status to the group of APs. Example 22 further includes a connection analyzer to analyze the connectivity status to the group of APs based on the connectivity testing instructions, the analysis corresponding to a subset of APs in the group of APs whose connectivity satisfies a threshold. Example 22 further includes a transmitter to transmit a response identifying the subset of APs.

25 Example 23 includes the subject matter of Example 22, wherein the response establishes a connection with the subset of APs.

Example 24 includes the subject matter of Examples 22 or 23, wherein the connection analyzer is to determine if a connection error has occurred with a first AP of the subset.

Example 25 includes the subject matter of Example 24, wherein the transmitter is to transmit an error message to one of a second AP in the subset of APs when the connection error is determined.

Example 26 includes the subject matter of Examples 22 or 23, wherein the response includes connectivity data for the subset of APs and null data for a second subset of APs whose connectivity does not satisfy the threshold.

5 Example 27 is a method for facilitating a multi-access point multi-station association in a cooperative Wi-Fi network, the method comprising receiving a frame from a group of access points (APs), the frame including group AP data related to the group of APs and connectivity testing instructions related to a connectivity status to the group of APs. Example 27 further includes analyzing the connectivity status to the group of APs based on the connectivity testing instructions, the analysis corresponding to a subset of APs in the group of APs whose
10 connectivity satisfies a threshold. Example 27 further includes transmitting a response identifying the subset of APs.

Example 28 includes the subject matter of Example 27, wherein the response establishes a connection with the subset of APs.

15 Example 29 includes the subject matter of Examples 27 or 28, further including determining if a connection error has occurred with a first AP of the subset.

Example 30 includes the subject matter of Example 29, further including transmitting an error message to one of a second AP in the subset of APs when the connection error is determined.

20 Example 31 includes the subject matter of Examples 27 or 28, wherein the response includes connectivity data for the subset of APs and null data for a second subset of APs whose connectivity does not satisfy the threshold.

25 Example 32 is a tangible computer readable storage medium comprising instructions which, when executed cause a machine to at least receive a frame from a group of access points (APs), the frame including group AP data related to the group of APs and connectivity testing instructions related to a connectivity status to the group of APs. Example 32 further includes instructions to analyze the connectivity status to the group of APs based on the connectivity testing instructions, the analysis corresponding to a subset of APs in the group of APs whose connectivity satisfies a threshold. Example 32 further includes instructions to transmit a response identifying the subset of APs.

30 Example 33 includes the subject matter of Example 32, wherein the response establishes a connection with the subset of APs.

Example 34 includes the subject matter of Examples 32 or 33, wherein the instructions cause the machine to determine if a connection error has occurred with a first AP of the subset.

Example 35 includes the subject matter of Example 34, wherein the instructions cause the machine to transmit an error message to one of a second AP in the subset of APs when the
5 connection error is determined.

Example 36 includes the subject matter of Examples 32 or 33, wherein the response includes connectivity data for the subset of APs and null data for a second subset of APs whose connectivity does not satisfy the threshold.

Example 37 is an apparatus to facilitate a multi-access point multi-station association in a
10 cooperative Wi-Fi network, the apparatus comprising a first means for transmitting instructions to a group of access points (APs) to transmit a frame to a station (STA), the frame including group AP data related to the group of APs and connectivity testing instructions related to a connectivity status of the STA to the group of APs. Example 27 further includes a second means for generating a subset of the group of APs for the STA based on a response to the frame, the
15 subset corresponding to APs whose connectivity satisfies a threshold.

Example 38 includes the subject matter of Example 37, wherein the group of APs include a second subset of the group of APs that cannot be sensed by the STA.

Example 39 includes the subject matter of Example 37, further including a third means for receiving a trigger from an AP in the subset of the group of APs, the trigger corresponding to
20 at least one of a change of the connectivity status or a request from a new AP.

Example 40 includes the subject matter of Example 39, wherein, when the third means receives the trigger the first means includes means for transmitting second instructions to the group of APs to transmit a second frame to the STA; and the second means includes means for generating a second subset of the group of APs for the STA based on a second response to the
25 second frame.

Example 41 includes the subject matter of Example 40, wherein the structure of the frame and the second frame is the same.

Example 42 includes the subject matter of Example 40, wherein second means includes means for establishing a connection between the STA and the second subset of the group of APs
30 without retransmitting training fields or restructuring the frame.

Example 43 includes the subject matter of Examples 37-42, wherein the first means includes means for establishing a multi-access point multi-station association between the STA and the subset of the group of APs by transmitting instructions to the subset of the group of APs to establish a connection with the STA.

5 Example 44 is an apparatus for facilitating a multi-access point multi-station association in a cooperative Wi-Fi network, the apparatus comprising a first means for receiving a frame from a group of access points (APs), the frame including group AP data related to the group of APs and connectivity testing instructions related to a connectivity status to the group of APs. Example 44 further includes a second means for analyzing the connectivity status to the group of
10 APs based on the connectivity testing instructions, the analysis corresponding to a subset of APs in the group of APs whose connectivity satisfies a threshold. Example 44 further includes a third means for transmitting a response identifying the subset of APs.

Example 45 includes the subject matter of Example 44, wherein the response establishes a connection with the subset of APs.

15 Example 46 includes the subject matter of Examples 44 or 45, wherein the second means includes means for determining if a connection error has occurred with a first AP of the subset.

Example 47 includes the subject matter of Example 46, wherein the third means includes means for transmitting an error message to one of a second AP in the subset of APs when the connection error is determined.

20 Example 48 includes the subject matter of Examples 44 or 45, wherein the response includes connectivity data for the subset of APs and null data for a second subset of APs whose connectivity does not satisfy the threshold.

Although certain example methods, apparatus and articles of manufacture have been described herein, the scope of coverage of this patent is not limited thereto. On the contrary, this
25 patent covers all methods, apparatus and articles of manufacture fairly falling within the scope of the claims of this patent.

What Is Claimed Is:

1. An apparatus to facilitate a multi-access point multi-station association in a cooperative Wi-Fi network, the apparatus comprising:

a transmitter to transmit instructions to a group of access points (APs) to transmit a frame to a station (STA), the frame including group AP data related to the group of APs and connectivity testing instructions related to a connectivity status of the STA to the group of APs; and

an AP cluster determiner to generate a subset of the group of APs for the STA based on a response to the frame, the subset corresponding to APs whose connectivity satisfies a threshold.

2. The apparatus of claim 1, wherein the group of APs include a second subset of the group of APs that cannot be sensed by the STA.

3. The apparatus of claim 1, further including a receiver to receive a trigger from an AP in the subset of the group of APs, the trigger corresponding to at least one of a change of the connectivity status or a request from a new AP.

4. The apparatus of claim 3, wherein, when the receiver receives the trigger: the transmitter is to transmit second instructions to the group of APs to transmit a second frame to the STA; and

the AP cluster determiner is to generate a second subset of the group of APs for the STA based on a second response to the second frame.

5. The apparatus of claim 4, wherein the structure of the frame and the second frame is the same.

6. The apparatus of claim 4, wherein AP cluster determiner establishes a connection between the STA and the second subset of the group of APs without retransmitting training fields or restructuring the frame.

7. The apparatus of claims 1-6, wherein the transmitter establishes a multi-access point multi-station association between the STA and the subset of the group of APs by transmitting instructions to the subset of the group of APs to establish a connection with the STA.

8. A method to facilitate a multi-access point multi-station association in a cooperative Wi-Fi network, the method comprising:

transmitting instructions to a group of access points (APs) to transmit a frame to a station (STA), the frame including group AP data related to the group of APs and connectivity testing instructions related to a connectivity status of the STA to the group of APs; and

generating a subset of the group of APs for the STA based on a response to the frame, the subset corresponding to APs whose connectivity satisfies a threshold.

9. The method of claim 8, wherein the group of APs include a second subset of the group of APs that cannot be sensed by the STA.

10. The method of claim 8, further including receiving a trigger from an AP in the subset of the group of APs, the trigger corresponding to at least one of a change of the connectivity status or a request from a new AP.

11. The method of claim 10, wherein, in response to receiving the trigger: transmitting second instructions to the group of APs to transmit a second frame to the STA; and

generating a second subset of the group of APs for the STA based on a second response to the second frame.

12. The method of claim 11, wherein the structure of the frame and the second frame is the same.

13. The method of claim 11, further including establishing a connection between the STA and the second subset of the group of APs without retransmitting training fields or restructuring the frame.

14. The method of claims 8-13, further including establishing a multi-access point multi-station association between the STA and the subset of the group of APs by transmitting instructions to the subset of the group of APs to establish a connection with the STA.

15. A tangible computer readable storage medium comprising instructions which, when executed, cause a machine to at least:

transmit instructions to a group of access points (APs) to transmit a frame to a station (STA), the frame including group AP data related to the group of APs and connectivity testing instructions related to a connectivity status of the STA to the group of APs; and

generate a subset of the group of APs for the STA based on a response to the frame, the subset corresponding to APs whose connectivity satisfies a threshold.

16. The computer readable storage medium of claim 15, wherein the group of APs include a second subset of the group of APs that cannot be sensed by the STA.

17. The computer readable storage medium of claim 15, wherein the instructions cause the machine to receive a trigger from an AP in the subset of the group of APs, the trigger
5 corresponding to at least one of a change of the connectivity status or a request from a new AP.

18. The computer readable storage medium of claim 17, wherein, in response to receiving the trigger, the instructions cause the machine to:

transmit second instructions to the group of APs to transmit a second frame to the STA;
and

10 generate a second subset of the group of APs for the STA based on a second response to the second frame.

19. The computer readable storage medium of claim 18, wherein the structure of the frame and the second frame is the same.

20. The computer readable storage medium of claim 18, wherein the instructions
15 cause the machine to establish a connection between the STA and the second subset of the group of APs without retransmitting training fields or restructuring the frame.

21. The computer readable storage medium of claims 15-20, wherein the instructions cause the machine to establish a multi-access point multi-station association between the STA and the subset of the group of APs by transmitting instructions to the subset of the group of APs
20 to establish a connection with the STA.

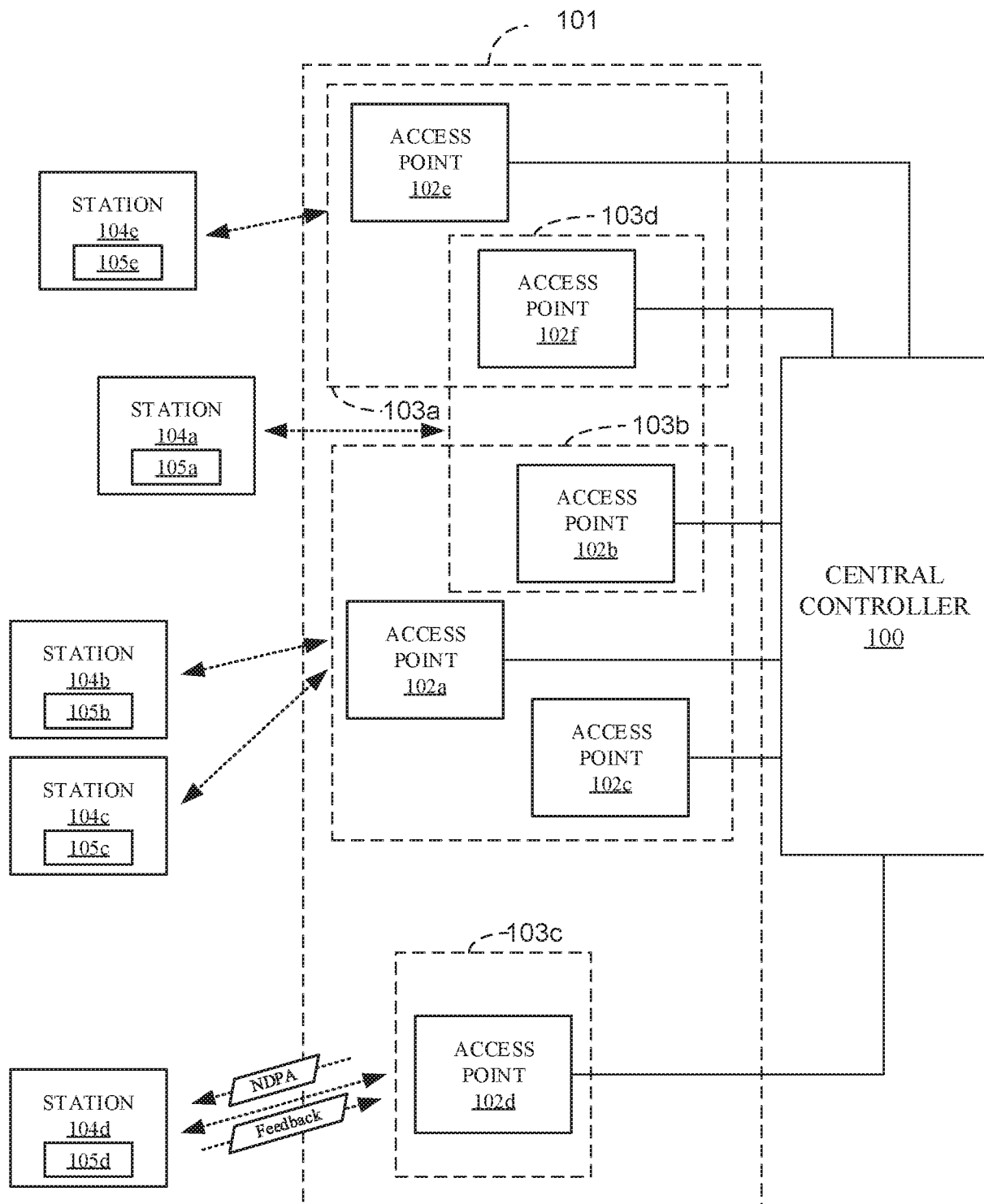


FIG. 1

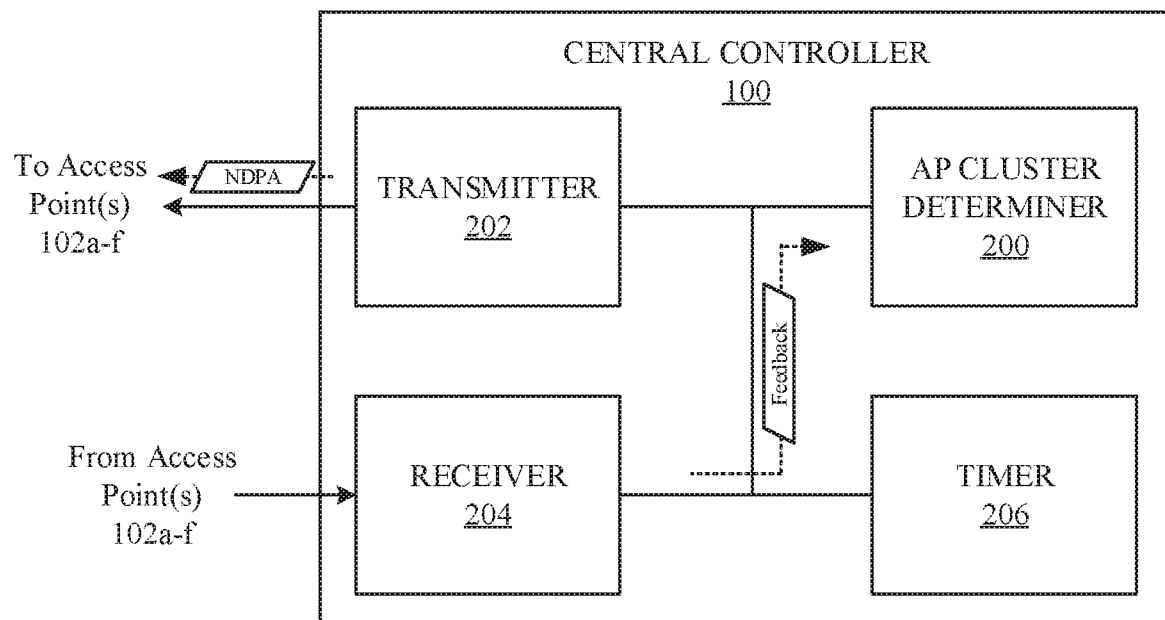


FIG. 2

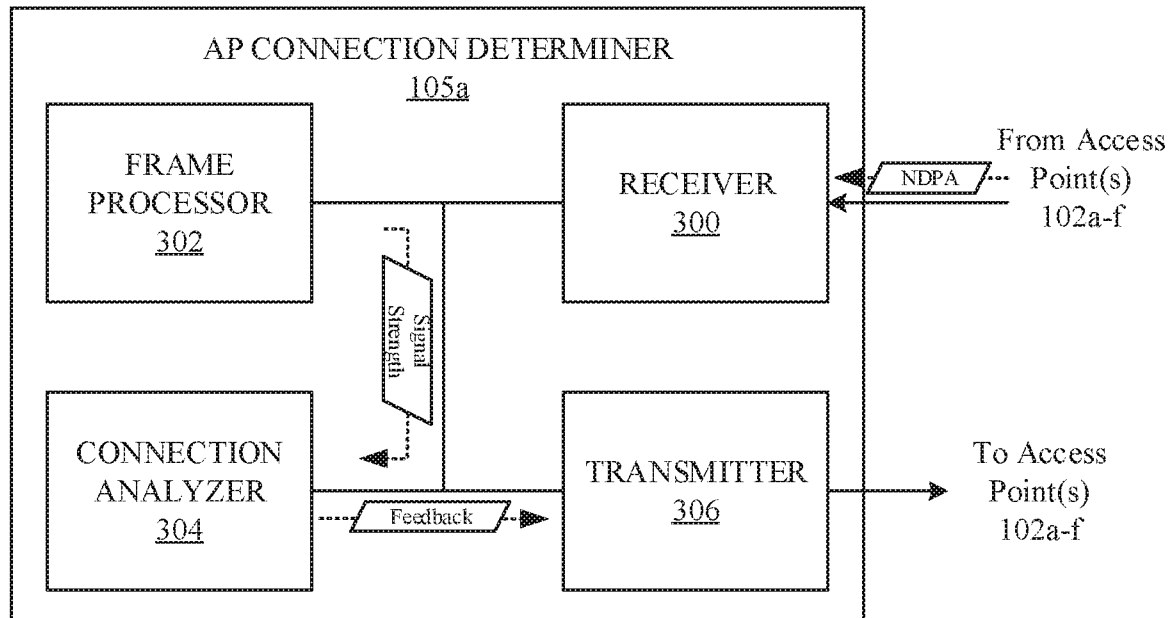


FIG. 3

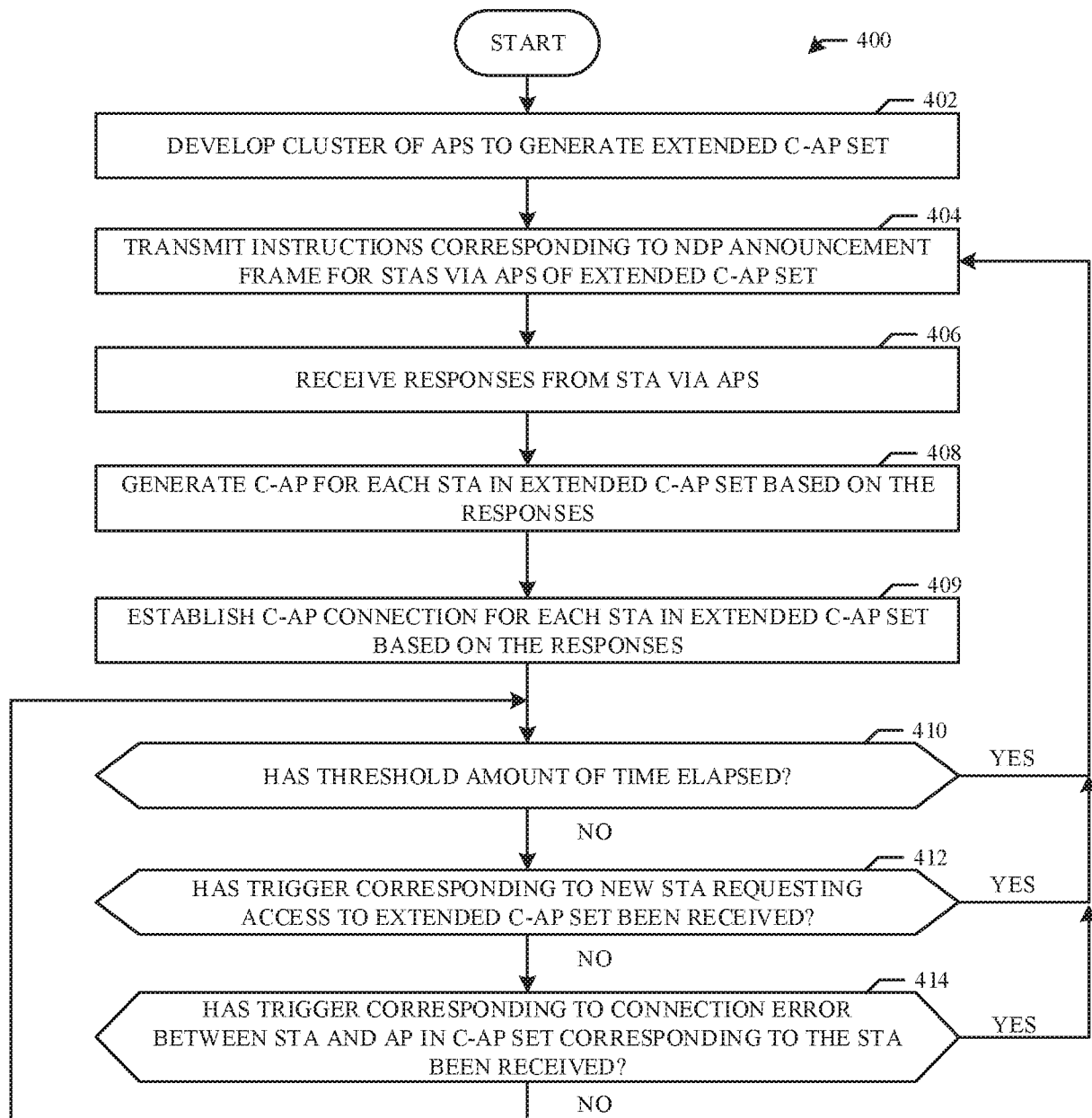


FIG. 4

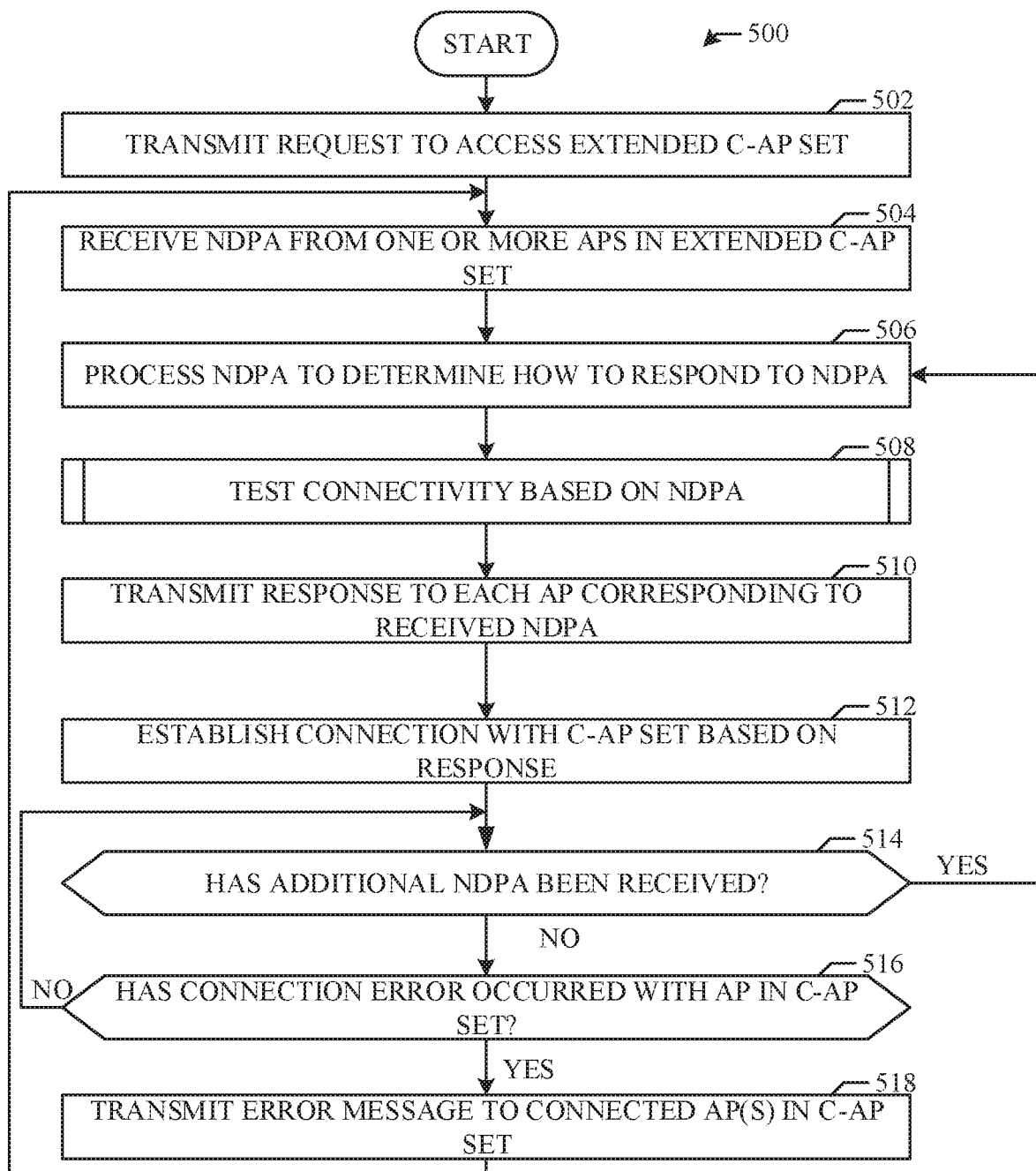


FIG. 5

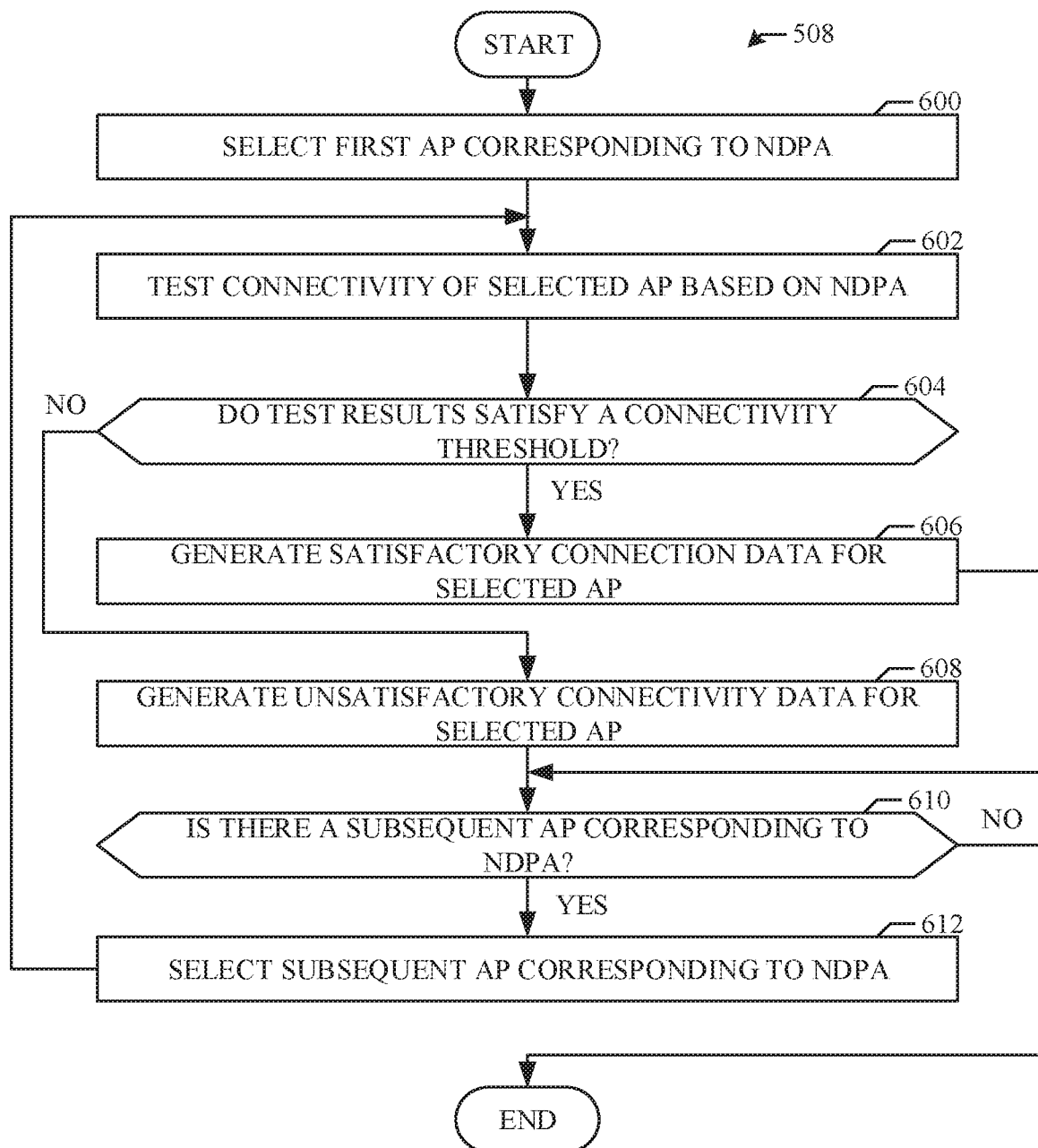


FIG. 6

700

Frame Control	RA	TA	Sounding Sequence	Feedback Type	AP-ID ₁	STA 1-1	...	STA 1-n ₁	...	AP-ID _k	STA k-1	...	STA k-n _k	AP-ID _{k1}	...	AP-ID _{Em}
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FIG. 7

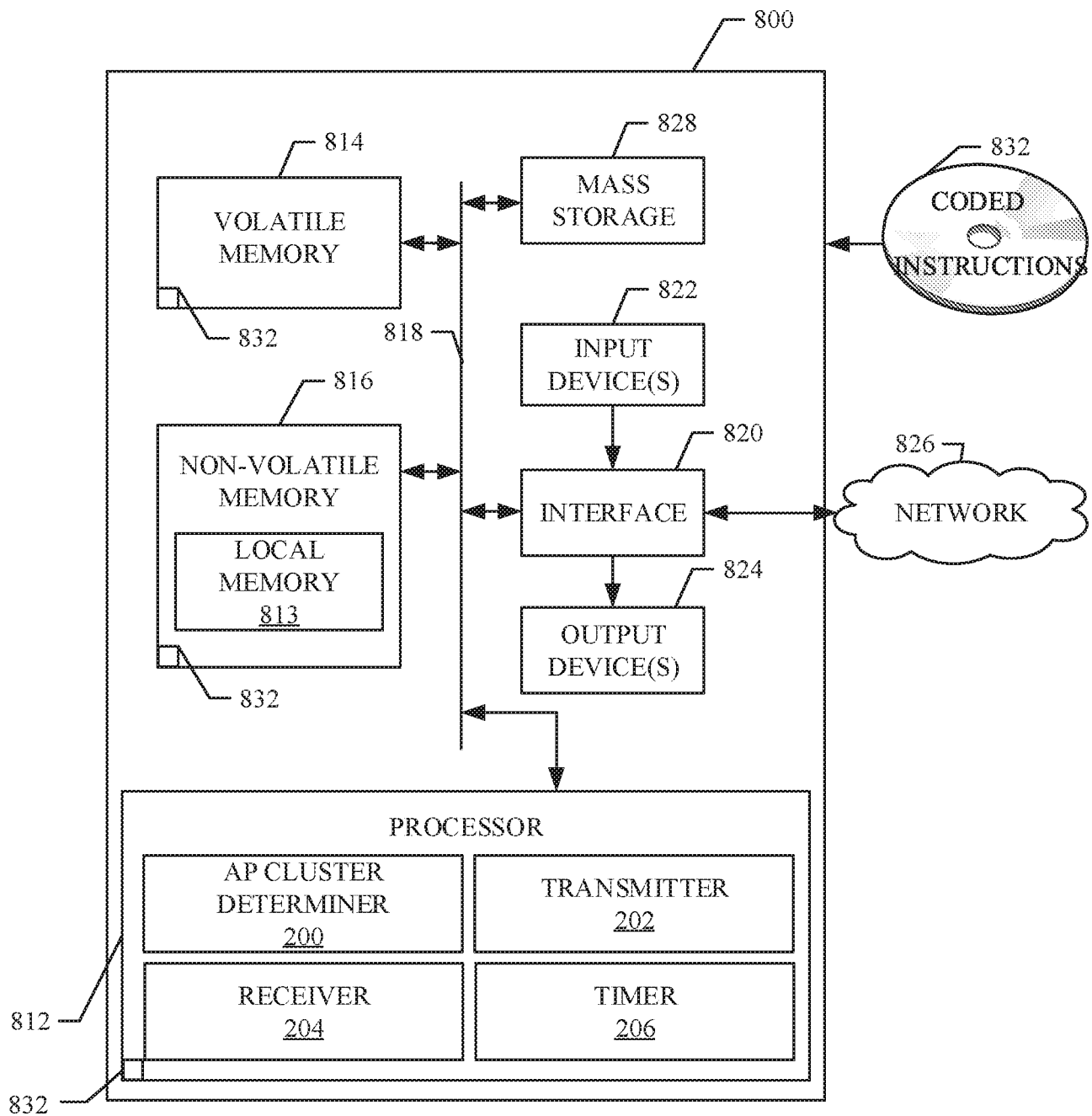


FIG. 8

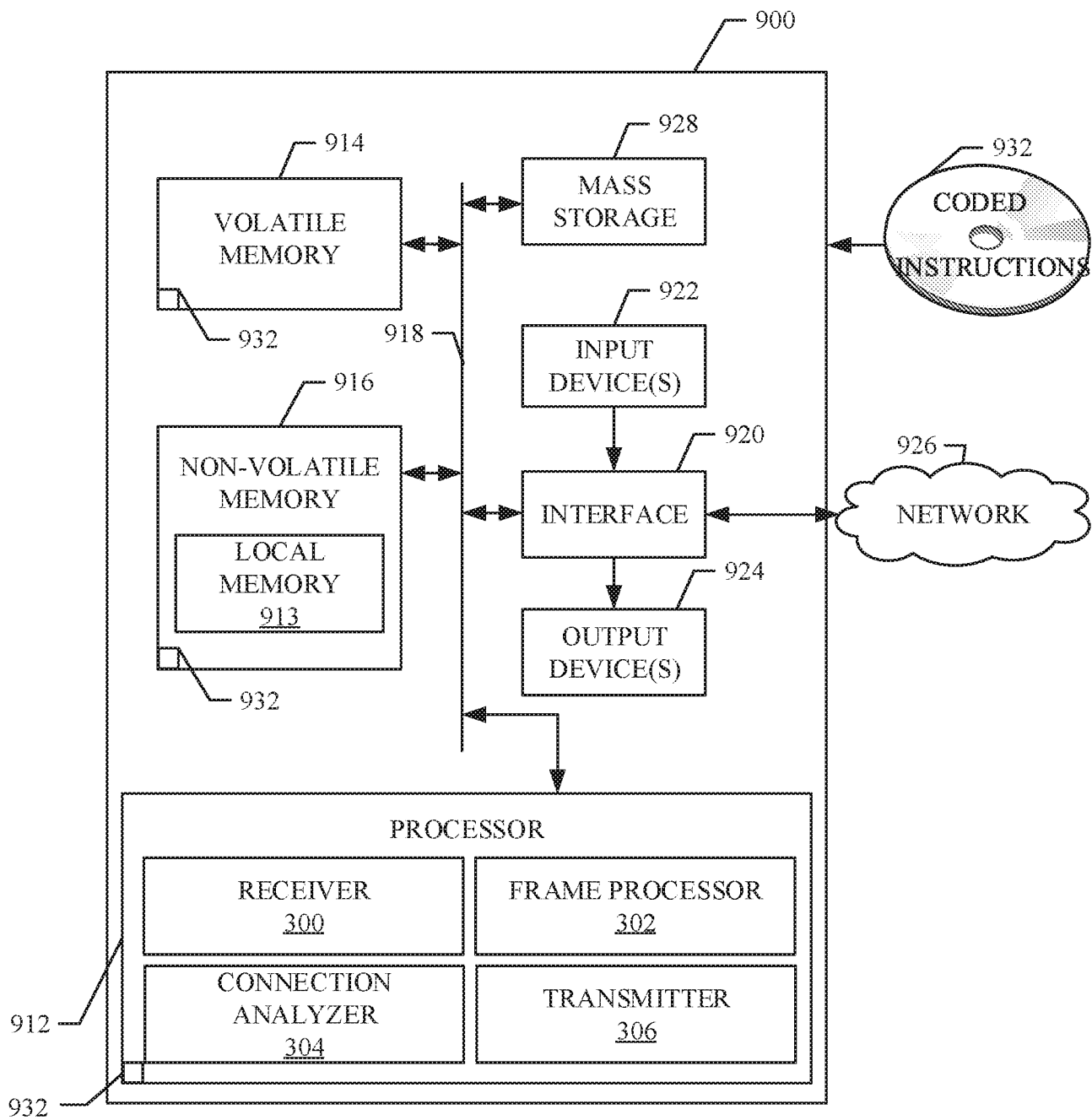


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/054084**A. CLASSIFICATION OF SUBJECT MATTER****H04W 88/12(2009.01)i, H04W 24/08(2009.01)i, H04W 84/12(2009.01)i**

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W 88/12; H04W 24/00; H04Q 7/20; H04W 36/08; H04W 24/10; H04W 48/20; H04W 8/24; H04W 24/08; H04W 84/12

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: AP, station, group AP data, frame, connectivity testing instruction, connectivity status, subset, threshold

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2016-096625 A1 (THOMSON LICENSING) 23 June 2016 See page 12, line 11 - page 13, line 19; claims 1, 6-7; and figure 3.	1-21
A	US 2014-0201383 A1 (MICROSOFT CORPORATION) 17 July 2014 See paragraphs [0046]-[0047]; and figure 6.	1-21
A	US 2005-0090259 A1 (NIKHIL JAIN et al.) 28 April 2005 See paragraphs [0055]-[0064]; and figure 4.	1-21
A	US 2011-0205910 A1 (AMJAD SOOMRO et al.) 25 August 2011 See paragraph [0051]; and figure 6.	1-21
A	US 2012-0140663 A1 (CHEOL MUN et al.) 07 June 2012 See paragraphs [0043]-[0072]; and figure 3.	1-21



Further documents are listed in the continuation of Box C.



See patent family annex.

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

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

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

"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

25 June 2018 (25.06.2018)

Date of mailing of the international search report

25 June 2018 (25.06.2018)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

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

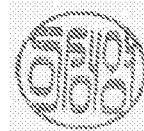


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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2017/054084

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