



(51) International Patent Classification:

H04W 74/00 (2009.01) H04W 84/12 (2009.01)

H04W 74/08 (2009.01) H04W 88/08 (2009.01)

(21) International Application Number:

PCT/US2017/039100

(22) International Filing Date:

23 June 2017 (23.06.2017)

(25) Filing Language:

English

(26) Publication Language:

English

(71) Applicant: INTEL CORPORATION [US/US]; 2200 Mission College Boulevard, Santa Clara, California 95054 (US).

(72) Inventors: MIN, Alexander W.; 5566 NW Primino Ave., Portland, Oregon 97229 (US). PARK, Minyoung; 12694 NW Milazzo Ln., Portland, Oregon 97229 (US).

(74) Agent: ZIMMERMAN, Mark C.; Hanley, Flight & Zimmerman, LLC, 150 S. Wacker Drive, Suite 2200, Chicago, Illinois 60606 (US).

(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, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,

HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, 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.

(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).

Declarations under Rule 4.17:

- as to the identity of the inventor (Rule 4.17(i))
- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))

Published:

- with international search report (Art. 21(3))

(54) Title: METHODS AND APPARATUS FOR ENABLING COMMUNICATIONS ON NON-ADJACENT SECONDARY CHANNELS IN WIRELESS LOCAL AREA NETWORK PROTOCOLS

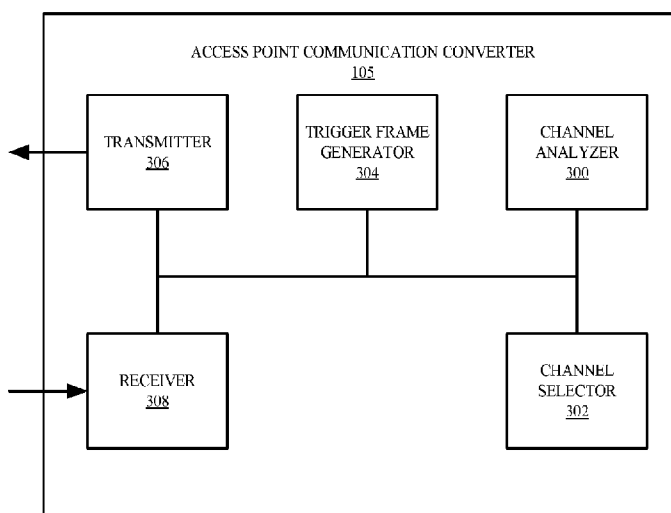


FIG. 3

(57) Abstract: Methods and apparatus for enabling communications on non-adjacent secondary channels in wireless local area network protocol are disclosed. An example apparatus includes a channel analyzer to determine an availability of a second channel that is non-adjacent to a first channel; a trigger frame generator to, when the non-adjacent second channel is idle, generate a trigger frame; and a transmitter to transmit the trigger frame on the first channel and the non-adjacent second channel; and transmit downlink data on the non-adjacent second channel.



METHODS AND APPARATUS FOR ENABLING COMMUNICATIONS ON NON-ADJACENT SECONDARY CHANNELS IN WIRELESS LOCAL AREA NETWORK PROTOCOLS

FIELD OF THE DISCLOSURE

[0001] This disclosure relates generally to wireless fidelity connectivity (Wi-Fi) and, more particularly, to methods and apparatus for enabling communications on non-adjacent secondary channels in wireless local area network protocols.

BACKGROUND

[0002] 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 access point (e.g., a hotspot) signal range. Wi-Fi is implemented using a set of media access control (MAC) and physical layer (PHY) specifications (e.g., such as the Institute of Electrical and Electronics Engineers (IEEE) 802.11 protocol).

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] FIG. 1 is an illustration of communications in using wireless local area network Wi-Fi protocols between example stations and an example Wi-Fi Access Point.

[0004] FIG. 2 is a block diagram of an example station communication converter of FIG. 1.

[0005] FIG. 3 is a block diagram of an example access point communication converter of FIG. 1.

[0006] FIGS. 4-5 are flowcharts representative of example machine readable instructions that may be executed to implement the example Access Point communication converter of FIG. 1.

[0007] FIG. 6 is a flowchart representative of example machine readable instructions that may be executed to implement the example station communication converter of FIG. 1.

[0008] FIG. 7 is a timing diagram of a downlink transmission using a traditional Wi-Fi protocol.

[0009] FIG. 8 is a timing diagram of a downlink transmission using the process of FIG. 4.

[0010] FIG. 9 is a timing diagram of a simultaneous downlink/uplink using the process of FIG. 5.

[0011] FIG. 10 is a block diagram of a processor platform structured to execute the example machine readable instructions of FIG. 6 to implement the example station communication converter of FIG. 2.

[0012] FIG. 11 is a block diagram of a processor platform structured to execute the example machine readable instructions of FIGS. 4-5 to implement the example Access Point communication converter of FIG. 3.

[0013] 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

[0014] Various locations (e.g., homes, offices, coffee shops, restaurants, parks, airports, etc.) may provide Wi-Fi to the Wi-Fi enabled devices (e.g., stations (STA)) to connect the Wi-Fi enabled devices 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 for how the AP communicates with the devices to provide access to the Internet by transmitting uplink (UL) transmissions and receiving downlink (DL) transmissions to/from the Internet.

[0015] A Wi-Fi AP and connected station(s) include various channels that may be used to facilitate the communication between the Wi-Fi AP and the station(s). In some examples, a Wi-Fi AP may utilize four channels (e.g., channel numbers 36, 40, 44 and 48, where each channel is adjacent in frequency to the subsequent channel) each having a 20 MHz channel bandwidth. In such a system, channel 36 may correspond to a primary 20 MHz channel, channel 40 may correspond to a secondary 20 MHz channel (e.g., adjacent to the primary 20 MHz channel corresponding to channel 36). Additionally, channel 36 and channel 40 may be combined (e.g., bonded), to form a primary 40 MHz channel (e.g., combining the primary and secondary 20 MHz channels corresponding to adjacent channels 36 and 40). In such examples, 20 MHz channels 44 and 48 may be combined (e.g., bonded) to form a secondary 40 MHz channel. The secondary 40 MHz channel corresponding to channels 44 and 48 is non-contiguous (e.g., non-adjacent) with the primary 20 MHz channel corresponding to channel 36). As used herein, non-adjacent and/or non-contiguous refers to the channels being separated by time and/or frequency (e.g., when two channels are non-contiguous/non-adjacent, there exists a third channel between the two channels). Additionally, the primary 20 MHz channel (e.g., corresponding to 20 MHz channel 36), secondary 20 MHz channel (e.g., corresponding to 20 MHz channel 40), and the secondary 40 MHz channel (e.g., corresponding to the 20 MHz channels 44 and 48) may be combined (e.g. bonded) to form a primary 80 MHz channel.

[0016] Traditional Wi-Fi protocols (e.g., corresponding to the 802.11 standards) mandate that APs/STAs always include the primary channel for bonding. This requirement limits the flexibility of use of the wireless spectrum and may downgrade overall throughput performance (e.g., corresponding to the rate of successful message delivery over a communication channel). Current 802.11 standards do not support non-contiguous channel bonding for single user (SU) DL transmissions (e.g., DL transmission from an AP to a single STA). For example, if a secondary 20 MHz channel (e.g., channel 40), adjacent to a primary 20 MHz channel (e.g.,

channel 36), is busy, the Wi-Fi AP cannot utilize the secondary 40 MHz channel (e.g., by combining channels 44 and 48) for SU DL transmission using such traditional Wi-Fi protocols, thereby wasting the opportunity to transmit a packet on a wider bandwidth that is available. Additionally, such traditional Wi-Fi protocols do not support simultaneous UL and DL transmissions on non-contiguous channels. Examples disclosed herein utilize a wider non-contiguous channel (e.g., by enabling transmission on secondary non-contiguous channels which are non-contiguous from the primary operating channel) and enable simultaneous UL and DL transmissions on non-contiguous channels.

[0017] Examples disclosed herein allow a transmitter (e.g., a Wi-Fi AP) to utilize wider non-contiguous secondary channels (e.g., secondary 40 MHz) for SU DL data packet transmission rather than the narrower primary channel (e.g., 20 MHz) associated with traditional Wi-Fi protocols. Examples disclosed herein include using the primary channel as a control channel that indicates that the data transmission will be transmitted in the non-contiguous secondary channel. Some examples disclosed herein include using the primary channel for UL packet reception and using a wider non-contiguous secondary channel for DL transmissions simultaneously or vice versa by leveraging the fact that the UL reception and the DL transmission are separated in frequency. For example, if an AP determines that the adjacent secondary 20 MHz channel is busy and the non-adjacent secondary 40 MHz channel is available (e.g., idle), then the AP can schedule the DL transmissions on the non-adjacent 40 MHz channel by sending a trigger frame including the DL resource allocation information prior to the packet transmission. Using examples disclosed herein, spectral efficiency is enhanced and overall throughput performance is improved.

[0018] FIG. 1 illustrates communications in using WLAN Wi-Fi protocols between example STAs 100, 102 and an example AP 104. The example of FIG. 1 includes the example STAs 100, 102, an example STA communication converter 101, the example AP 104, an example AP communication converter 105, and an example network 106. Although the illustrated example of FIG. 1 includes two STAs and one network, the AP 104 may communicate with any number of STAs and any number of networks.

[0019] The example STAs 100, 102 of FIG. 1 are Wi-Fi enabled computing devices. The example STAs 100, 102 may be, for example, a computing device, a portable device, a mobile device, a mobile telephone, a smart phone, a tablet, a gaming system, a digital camera, a digital

video recorder, a television, a set top box, an e-book reader, and/or any other Wi-Fi enabled device. The example STAs 100, 102 include the example STA communication converter 101 to connect and communicate with a Wi-Fi AP (e.g., the example AP 104) to access a network (e.g., the example network 106) using UL and DL data transmissions.

[0020] The STA communication converter 101 of FIG. 1 receives trigger frames from the example AP 104 via one of the channels (e.g., the primary 20 MHz channel, the secondary 20 MHz channel, the primary 40 MHz channel, the secondary 40 MHz channel, etc.). A trigger frame is a frame generated by the AP 104, including resource allocation information (e.g., channel number and/or bandwidth of the channel to be used for DL/UL transmission) for a subsequent DL/UL packet transmission, network allocation vector (NAV) information on a primary channel corresponding to a duration of the trigger frame, and NAV information on a non-adjacent secondary 40 MHz channel (e.g., to protect the medium until the end of the data transmission). The example STA communication converter 101 processes the trigger frames to determine the channel index and/or bandwidth corresponding to a data transmission. The example STA communication converter 101 senses the corresponding channel to determine if the corresponding channel is available (e.g., idle) and, in some examples, sends clear to send (CTS) frames to the AP when the corresponding channels are idle. When the trigger frame is to solicit UL packet transmission, the STA communication converter 101 transmits UL packet(s) using the resources indicated in the trigger frame. Additionally, the example STA communication converter 101 transmits/receives acknowledgments to/from the AP 104 in response to the completion of a data transmission. The example STA communication converter 101 are further described below in conjunction with FIG. 2.

[0021] The example AP 104 of FIG. 1 is a device that allows the example STAs 100, 102 to access wirelessly the example network 106. The example AP 104 may be a router, a modem-router, and/or any other device that provides a wireless connection to a network. A router provides a wireless communication link to a STA. The router accesses the network through a wire connection via a modem. A modem-router combines the functionalities of the modem and the router.

[0022] The example AP 104 of FIG. 1 includes the example access point communication converter 105 to facilitate communications on non-adjacent secondary channels in WLAN protocols by generating a trigger frame identifying a channel number (e.g., index) and bandwidth

(e.g., 20 MHz, 40 MHz, etc.) corresponding to a non-adjacent secondary channel to use for data transmission (e.g., DL and/or UL). Additionally, the example access point communication converter 105 transmits/receives acknowledgments to/from the example STAs 100, 102 in response to the completion of a data transmission. The example access point communication converter 105 is further described below in conjunction with FIG. 3.

[0023] The example network 106 of FIG. 1 is a system of interconnected systems exchanging data. The example network 106 may be implemented using any type of public or private network such as, but not limited to, the Internet, a telephone network, a local area network (LAN), a cable network, and/or a wireless network. To enable communication via the network 106, the example Wi-Fi AP 104 includes a communication interface that enables a connection to an Ethernet, a digital subscriber line (DSL), a telephone line, a coaxial cable, or any wireless connection, etc.

[0024] FIG. 2 is a block diagram of an example implementation of the example STA communication converter 101 of FIG. 1, disclosed herein, to facilitate communications on non-adjacent secondary channels in wireless local area network protocols. The example STA communication converter 101 includes an example receiver 200, an example trigger frame analyzer 202, and an example transmitter 204.

[0025] The example receiver 200 of FIG. 2 receives trigger frames transmitted by the example AP 104. Additionally, the example receiver 200 receives DL data packets from the AP 104 after data transmission commences. Additionally, the example receiver 200 receives ACK packets from the example AP 104 after UL transmission ceases. In some examples, the receiver 200 determines if an ACK packet has not been received within a threshold amount of time after the UL transmission ceases.

[0026] The example trigger frame analyzer 202 of FIG. 2 processes received trigger frames from the example AP 104. In some examples, the trigger frame analyzer 202 processes the trigger frame to determine if the trigger frame is destined for the STA. If the trigger frame is not destined for the STA, the example trigger frame analyzer 202 sets a NAV for the primary and secondary channels based on the resource allocation and scheduling information included in the trigger frame and/or the PHY/MAC header of the trigger frame. The NAV is a counter that identifies a duration of time where the STA 100, 102 does not need to sense any channels, thereby allowing the example STA 100, 102 to enter a low power mode to conserve energy. If

the trigger frame is destined for the STA, the example trigger frame analyzer determines whether the trigger frame corresponds to a DL packet reception and/or an UL packet transmission. If the trigger frame corresponds to a DL packet reception, the example trigger frame analyzer 202 instructs the example receiver 200 to receive the DL packets using the channel number and bandwidth identified in the trigger frame. In some examples, the trigger frame analyzer 202 verifies that the channel number(s) and bandwidth identified in the trigger frame is idle and instructs the example transmitter 204 to transmit a CTS prior to DL packet reception. If the trigger frame corresponds to an UL packet transmission, the example trigger frame analyzer 202 instructs the example transmitter 204 to transmit the UL packets using the channel number and bandwidth identified in the trigger frame.

[0027] The example transmitter 204 of FIG. 2 transmits data (e.g., packets, frames, etc.) to the example AP 104. In some examples, the transmitter 204 transmits a CTS to the example AP 104 prior to a DL reception. In some examples, the transmitter 204 transmits UL packets using the channel number and bandwidth identified in the trigger frame. Additionally, the example transmitter 204 transmits ACK packets to the example AP 104 at the end of DL packet transmission.

[0028] FIG. 3 is a block diagram of an example implementation of the example AP communication converter 105 of FIG. 1, disclosed herein, to facilitate communications on non-adjacent secondary channels in wireless local area network protocols. The example AP communication converter 105 includes an example channel analyzer 300, an example channel selector 302, an example trigger frame generator 304, an example transmitter 306, and an example receiver 308.

[0029] The example channel analyzer 300 of FIG. 3 senses the channels to determine which channels (e.g., channel numbers) are idle (e.g., the availability of the channels). In some examples, the channel analyzer 300 senses one or more secondary channels during an interval of the priority interframe space (PIFS) preceding a backoff expiration, or the start of the transmit opportunity (TXOP), and determines which transmitter channel and bandwidth to use for data transmission.

[0030] The example channel selector 302 of FIG. 3 selects a channel and bandwidth to use for data transmission (DL and/or UL of data packets to/from the example STAs 100, 102). For example, if both a secondary 20 MHz channel and a secondary 40 MHz channel are idle,

then the example channel selector 302 selects the primary 80 MHz channel (e.g., including the primary 20 MHz channel, the secondary 20 MHz channel, the secondary 40 MHz channel). If only the secondary 20 MHz channel is idle, then the channel selector 302 selects the primary 40 MHz channel (e.g., including the primary 20 MHz channel and the secondary 20 MHz channel). If only a non-adjacent secondary 40 MHz channel is idle, then the channel selector 302 determines which channel to use for a data packet transmission (e.g., either the primary 20 MHz channel or the non-adjacent secondary 40 MHz channel). The example channel selector 302 may select the channel based on one or more channel performance metrics (e.g., which channel has a higher expected throughput, which channel has a better demodulating modulation and coding scheme (MCS) value, which channel has a stronger transmit power, etc.). For example, if both the primary 20 MHz channel and the secondary 40 MHz channel are available, the example channel selector 302 may select the secondary 40 MHz (e.g., because the 40 MHz channel has a wider channel bandwidth than the 20 MHz channel, thereby leading to a higher expected throughput).

[0031] The example trigger frame generator 304 of FIG. 3 generates a trigger frame to transmit to the example STA 100, 102. As described above, a trigger frame is a frame generated by the AP 104, including resource allocation information (e.g., channel number and/or bandwidth of the channel to be used for DL/UL transmission) for a subsequent DL/UL packet transmission, NAV information on a primary channel corresponding to a duration of the trigger frame, and NAV information on a non-adjacent secondary 40 MHz channel (e.g., to protect the medium until the end of the data transmission). In some examples, the trigger frame generator 304 generates a trigger frame when the example channel selector 302 selects a non-adjacent secondary 40 MHz channel to use for data transmission.

[0032] The example transmitter 306 of FIG. 3 transmits the trigger frame to the example STAs 100, 102 using one or more of the channels and bandwidths. Additionally, the example transmitter 306 transmits downlink data on any one of the channels and bandwidths based on the channel selected by the example channel selector 302. Additionally, the example transmitter 306 transmits an acknowledgment (ACK) or a block ACK (BA) to the example STAs 100, 102 after an UL transmission. The example receiver 308 receives ACKs from the example STAs 100, 102 at the end of data transmission. In some examples, the receiver 308 determines if an ACK packet has not been received within a threshold amount of time after the end of a data

transmission. Additionally, the example receiver 308 receives UL packets from the example STAs 100, 102 during UL transmission.

[0033] While an example manner of implementing the example AP communication converter 105 and the example STA communications converter 101 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, re-arranged, omitted, eliminated and/or implemented in any other way. Further, the example receiver 200, the example trigger frame analyzer 202, the example transmitter, and/or more generally the example STA communications converter 101 of FIG. 2 and the example channel analyzer 300, the example channel selector 302, the example trigger frame generator 304, the example transmitter 306, the example receiver 308, and/or, more generally, the example AP communications converter 105 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 receiver 200, the example trigger frame analyzer 202, the example transmitter, and/or more generally the example STA communications converter 101 of FIG. 2 and the example channel analyzer 300, the example channel selector 302, the example trigger frame generator 304, the example transmitter 306, the example receiver 308, and/or, more generally, the example AP communications converter 105 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 receiver 200, the example trigger frame analyzer 202, the example transmitter, and/or more generally the example STA communications converter 101 of FIG. 2 and the example channel analyzer 300, the example channel selector 302, the example trigger frame generator 304, the example transmitter 306, the example receiver 308, and/or, more generally, the example AP communications converter 105 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 STA communications converter 101 of FIG. 2 and/or the example AP communication converter 105 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.

[0034] Flowcharts representative of example machine readable instructions for implementing the example AP communication converter 105 of FIG. 3 is shown in FIGS. 4-5 and flowcharts representative of example machine readable instructions for implementing the example STA communication converter 101 of FIG. 2 is shown in FIG. 6. In this example, the machine readable instructions comprise a program for execution by a processor such as the processor 1012, 1112 shown in the example processor platform 1000, 1100 discussed below in connection with FIGS. 10 and 11. 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 1012, 1112, but the entire program and/or parts thereof could alternatively be executed by a device other than the processor 1012, 1112 and/or embodied in firmware or dedicated hardware. Further, although the example program is described with reference to the flowchart illustrated in FIGS. 4-6, many other methods of implementing the example AP communication converter 105 and/or the example STA communication converter 101 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.

[0035] 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.

[0036] FIG. 4 is an example flowchart 400 representative of example machine readable instructions that may be executed by the example AP communication converter 105 of FIG. 3 to enable communications on SU non-adjacent secondary channels in a wireless local area network protocol.

[0037] At block 402, the example receiver 308 senses the secondary channels. For example, the receiver 308 senses the secondary channels during an interval associated with the PIFS immediately preceding the backoff expiration or the start of the TXOP and decides which channel number and bandwidth to use for transmission. At block 404, the example channel analyzer 300 determines if the adjacent secondary channel (e.g., the secondary 20 MHz channel) and the non-adjacent secondary channel (e.g., the secondary 40 MHz channel) are idle. If both the adjacent secondary and the non-adjacent secondary channels are idle, the primary 80 MHz channel may be used for DL data packet transmission because the 80 MHz channel includes the primary 40 MHz channel (e.g., the combination of the primary 20 MHz channel and the secondary 20 MHz channel) and the secondary 40 MHz channel. If the example channel analyzer 300 determines that the adjacent secondary channel and the non-adjacent secondary channels are both idle (block 404: YES), the example transmitter 306 transmits DL data packets on the primary channel (e.g., a primary 20 MHz channel), the adjacent secondary channel (e.g., a secondary 20 MHz channel), and the non-adjacent secondary channel (e.g., a non-adjacent secondary 40 MHz channel) (block 406) corresponding to a 80 MHz DL data transmission (e.g., a 80 MHz Physical Layer Convergence Protocol (PLCP) protocol data unit (PPDU)).

[0038] If the example channel analyzer 300 determines that the adjacent secondary channel and the non-adjacent secondary channels are not both idle (block 404: NO), the example channel analyzer 300 determines if the adjacent secondary channel is idle (block 408). This may occur when the non-adjacent secondary channel is not idle but the adjacent secondary channel is

idle. If the example channel analyzer 300 determines that the adjacent channel is idle (block 408: YES), then the example transmitter 306 transmits DL data packets on the primary channel (e.g., a primary 20 MHz channel) and the adjacent secondary channel (e.g., a secondary 20 MHz channel) (block 410) corresponding to a 40 MHz DL data transmission (e.g., a 40 MHz PPDU).

[0039] If the example channel analyzer 300 determines that adjacent secondary channel is not idle (block 408: NO), the example channel analyzer 300 determines if the non-adjacent secondary channel is idle (block 412). This may occur when the adjacent secondary channel is not idle but the non-adjacent secondary channel is idle. If the example channel analyzer 300 determines that the non-adjacent secondary channel is not idle (block 412: NO), the process continues to block 428, as further described below. If the example channel analyzer 300 determines that the non-adjacent secondary channel is idle (block 412: YES), the example channel selector 302 determines which channel to use for downlink transmission (e.g., the primary channel or the non-adjacent secondary channel) (block 414). As described above in conjunction with FIG. 3, the example channel selector 302 decides a channel based on one or more channel performances metrics.

[0040] If the example channel selector 302 determines that the non-adjacent secondary channel should be used (block 414: NON-ADJ. 2nd), the example trigger frame generator 304 generates a trigger frame (block 416). As described above, a trigger frame includes resource allocation information (e.g., channel number and/or bandwidth of the channel to be used for DL/UL transmission) for a subsequent DL/UL packet transmission, NAV information on a primary channel corresponding to a duration of the trigger frame, and NAV information on a non-adjacent secondary 40 MHz channel (e.g., to protect the medium until the end of the data transmission). At block 418, the example transmitter 306 transmits the trigger frame on the primary channel (e.g., the primary 20 MHz channel) and the non-adjacent secondary channel (e.g., the non-adjacent secondary 40 MHz channel).

[0041] At block 420, the example receiver 308 determines if CTS is enabled. If CTS is enabled, then the example AP communication converter 105 will receive a CTS corresponding to a channel from a STA in response to the transmission of the trigger frame. If the example receiver 308 determines that the CTS is not enabled (block 420: NO), the process continues to block 424, as further described below. If the example receiver 308 determines that the CTS is enabled (block 420: YES), the example receiver 308 determines if a CTS response has been

received on the non-adjacent secondary channel (block 422). The CTS response identifies which channel of the intended STA (e.g., one or more of the example STAs 100, 102 of FIG. 1) is ready to receive DL packets). If the example receiver 308 determines that the CTS response has been received on the non-adjacent secondary channel (block 422: YES), the example transmitter 306 transmits the DL data packets on the non-adjacent secondary channel (block 424). If the example receiver 308 determines that the CTS response has not been received on the non-adjacent secondary channel (block 422: NO), the process continues to block 428, as further described below.

[0042] If the example channel selector 302 determines that the primary channel should be used (block 414: PRIMARY), the example receiver 308 determines if CTS is enabled (block 426). If the example receiver 308 determines that the CTS is not enabled (block 426: NO), the process continues to block 430, as further explained below. If the example receiver 308 determines that the CTS is enabled (block 426: YES), the example receiver 308 determines if a CTS response has been received on the primary channel (block 428). If the example receiver 308 determines that the CTS response has been received on the primary channel (block 428: YES), the example transmitter 306 transmits the DL data packets on the primary channel (block 430). If the example receiver 308 determines that the CTS response has not been received on the primary channel (block 428: NO), the process returns to block 402 to retry identifying an appropriate channel for DL transmission.

[0043] At block 432, the example receiver 308 determines if an ACK has been received. As described above, once a STA receives the DL packets, the STA transmits an ACK to identify that the data was received. If the example receiver 308 determines that the ACK has not been received (block 432: NO), the process returns to block 402 to retry DL transmission. If the example receiver 308 determines that the ACK has been received (block 432: YES), the process ends.

[0044] FIG. 5 is an example flowchart 500 representative of example machine readable instructions that may be executed by the example AP communication converter 105 of FIG. 3 to enable simultaneous DL and UL transmissions on non-contiguous channels in a wireless local area network protocol.

[0045] At block 502, the example receiver 308 senses the secondary channels. For example, the receiver 308 senses the secondary channels during an interval associated with the

PIFS immediately preceding the backoff expiration or the start of the TXOP and decides which channel number and bandwidth to use for transmission. At block 504, the example channel analyzer 300 determines if the adjacent secondary channel (e.g., the secondary 20 MHz channel) and the non-adjacent secondary channel (e.g., the secondary 40 MHz channel) are idle. If both the adjacent secondary and the non-adjacent secondary channels are idle, the primary 80 MHz channel may be used for DL data packet transmission because the 80 MHz channel includes the primary 40 MHz channel (e.g., the combination of the primary 20 MHz channel and the secondary 20 MHz channel) and the secondary 40 MHz channel. If the example channel analyzer 300 determines that the adjacent secondary channel and the non-adjacent secondary channels are both idle (block 504: YES), the example transmitter 306 transmits DL data packets on the primary channel (e.g., a primary 20 MHz channel), the adjacent secondary channel (e.g., a secondary 20 MHz channel), and the non-adjacent secondary channel (e.g., a non-adjacent secondary 40 MHz channel) (block 506) corresponding to a 80 MHz DL data transmission (e.g., a 80 MHz PPDU).

[0046] If the example channel analyzer 300 determines that the adjacent secondary channel and the non-adjacent secondary channels are not both idle (block 504: NO), the example channel analyzer 300 determines if the adjacent secondary channel is idle (block 508). This may occur when the non-adjacent secondary channel is not idle but the adjacent secondary channel is idle. If the example channel analyzer 300 determines that the adjacent channel is idle (block 508: YES), then the example transmitter 306 transmits DL data packets on the primary channel (e.g., a primary 20 MHz channel) and the adjacent secondary channel (e.g., a secondary 20 MHz channel) (block 510) corresponding to a 40 MHz DL data transmission (e.g., a 40 MHz PPDU).

[0047] If the example channel analyzer 300 determines that adjacent secondary channel is not idle (block 508: NO), the example channel analyzer 300 determines if the non-adjacent secondary channel is idle (block 512). This may occur when the adjacent secondary channel is not idle but the non-adjacent secondary channel is idle. If the example channel analyzer 300 determines that the non-adjacent secondary channel is not idle (block 512: NO), the example transmitter 306 transmits DL data on the primary channel (block 514). If the example channel analyzer 300 determines that the non-adjacent secondary channel is not idle (block 512: YES), the example channel selector 302 determines if DL and UL data are to be transmitted

simultaneously (e.g., DL transmission for the example STA 100 and UL transmission for the example STA 102, for example) (block 516).

[0048] If the example channel selector 302 determines that DL and UL data are not to be transmitted simultaneously (block 516: NO), the example trigger frame generator 304 generates a trigger frame corresponding to DL data transmission (block 518) and the example transmitter 306 transmits the trigger frame on the primary channel (e.g., the primary 20 MHz channel) and the non-adjacent secondary channel (e.g., the non-adjacent secondary 40 MHz channel) indicating allocation of DL data transmission to the non-adjacent secondary channel (block 520). If the example channel selector 302 determines that DL and UL data are to be transmitted simultaneously (block 516: YES), the example trigger frame generator 304 generates a trigger frame corresponding to DL and UL transmission (block 522) and the example transmitter 306 transmits the trigger frame on the primary channel (e.g., the primary 20 MHz channel) and the non-adjacent secondary channel (e.g., the non-adjacent secondary 40 MHz channel) indicating (A) allocation of DL data transmission to the non-adjacent secondary channel and (B) allocation of UL data transmission to the primary channel (block 524).

[0049] At block 526, the example transmitter 306 transmits DL data on the non-adjacent secondary channel. At block 528, the example receiver 308 receives UL data on the primary channel. Alternatively, the DL data may be transmitted on the primary channel and the UL data may be received on the non-adjacent secondary channel. In some examples, during simultaneous DL and UL transmission, the example receiver 308 receives UL data from a first STA (e.g., the example STA 100) while the example transmitter 306 transmits DL data to a second STA (e.g., the example STA 102). In some examples, during simultaneous DL and UL transmission, the example receiver 308 receives UL data from a first STA (e.g., the example STA 100) while the example transmitter 306 transmits DL data to the first STA (e.g., the example STA 100). At block 530, the example transmitter 306 acknowledges receipt of the UL data (e.g., transmits an ACK to the STA corresponding to the UL) (block 530). At block 532, the example receiver 308 determines if an ACK has been received. As described above, once a STA receives the DL packets, the STA transmits an ACK to identify that the data was received. If the example receiver 308 determines that the ACK has not been received (block 532: NO), the process returns to block 502 to retry DL transmission. If the example receiver 308 determines that the ACK has been received (block 532: YES), the process ends.

[0050] FIG. 6 is an example flowchart 600 representative of example machine readable instructions that may be executed by the example STA communication converter 101 of FIG. 2 to enable communications on non-adjacent secondary channels in a wireless local area network protocol. The instructions of FIG. 6 are described in conjunction with the example STA 100 of FIG. 1. However, the instructions may be executed by any STA, including the example STA 102.

[0051] At block 602, the example receiver 200 receives a trigger frame via a primary channel. The trigger frame includes resource allocation information (e.g., channel number and/or bandwidth of the channel to be used for DL/UL transmission) for a subsequent DL/UL packet transmission, NAV information on a primary channel corresponding to a duration of the trigger frame, and NAV information on a non-adjacent secondary 40 MHz channel (e.g., to protect the medium until the end of the data transmission). At block 604, the example trigger frame analyzer 202 determines if the trigger frame is destined for the STA 100. The example trigger frame analyzer 202 may determine that the trigger frame is destined for the STA 100 based on the trigger frame and/or any other identifier corresponding to the communication between the example STA 100 and the example AP 104.

[0052] If the example trigger frame analyzer 202 determines that trigger frame is not destined for the example STA 100 (block 604: NO), the example trigger frame analyzer 202 sets a NAV on the primary and secondary channels based on the resource allocation and scheduling information of the received trigger frame (block 606). The example trigger frame analyzer 202 sets the NAV so that the example STA communication converter 101 does not need to sense a medium (e.g., perform energy detection) and/or attempt to access a channel. In this manner, the example STA communication converter 101 can enter a low power sleep state until the end of the schedule frame transmission (e.g., corresponding to the NAV counter expiring) to conserve power. If the example trigger frame analyzer 202 determines that trigger frame is destined for the example STA 100 (block 604: YES), the example trigger frame analyzer 202 processes the trigger frame to determine the DL resource allocation information in the trigger frame (block 608). In this manner, the example trigger frame analyzer 202 can determine whether the trigger frame corresponds to DL packet reception or UL packet transmission.

[0053] At block 610, the example trigger frame analyzer 202 determines if the trigger frame corresponds to a CTS frame(s) (e.g., transmitting a CTS in response to receiving a trigger

frame). In some examples, the STA 100 is configured to respond to a trigger frame with a CTS identifying which STA channels are idle (e.g., ready for transmission). In some examples, the STA 100 determines if a CTS is necessary based on the trigger frame (e.g., the trigger frame includes data corresponding to a CTS request). If the example trigger frame analyzer 202 determines that the trigger frame corresponds to a CTS frame (block 610: YES), the example transmitter 204 transmits a CTS frame identifying the idle STA channels (block 612).

[0054] At block 614, the example trigger frame analyzer 202 determines if the trigger frame corresponds to a DL packet reception. If the example trigger frame analyzer 202 determines that the trigger frame does not correspond to a DL packet reception (block 614: NO), the process continues to block 620, as further described below. If the example trigger frame analyzer 202 determines that the trigger frame corresponds to a DL packet reception (block 614: YES), the example receiver 200 senses the channel identified in the trigger frame to receive the DL packets (block 616). At block 618, the example transmitter 204 transmits an ACK to the example AP 104.

[0055] At block 620, the example trigger frame analyzer 202 determines if the trigger frame corresponds to an UL packet transmission. If the example trigger frame analyzer 202 determines that the trigger frame does not correspond to an UL packet transmission (block 620: NO), the process returns to block 602 to receive a subsequent trigger frame from the example AP 104. If the example trigger frame analyzer 202 determines that the trigger frame corresponds to an UL packet transmission (block 620: YES), the example transmitter 204 transmits UL packets using the channel identified in the trigger frame (block 622).

[0056] FIG. 7 is an example timing diagram 700 of a downlink transmission using a traditional Wi-Fi protocol for single user DL transmission. The example timing diagram 700 includes an example primary channel 702 (e.g., a primary 20 MHz channel), an example secondary channel 704 (e.g., a secondary 20 MHz channel), and an example non-contiguous secondary channel 706 (e.g., a non-contiguous 40 MHz channel).

[0057] During the PIFS, the example secondary channel 704 is busy (e.g., being used for a 20 MHz PPDU) and the non-contiguous secondary channel 706 is idle (e.g., not being used). However, such traditional Wi-Fi protocols do not allow for use of non-contiguous secondary channel transmissions for single unit DL transmissions. Accordingly, the 40 MHz bandwidth associated with the example non-contiguous secondary channel 706 is wasted. In such a

traditional timing diagram 700, the AP utilizes the example primary channel 702 to transmit a request to send (RTS), receive a CTS, and coordinate a DL PPDU to a first STA. After the AP transmits the DL PPDU, the AP receives a BA from the STA.

[0058] FIG. 8 is an example timing diagram 800 of a downlink transmission using a Wi-Fi protocol for single user DL transmission as disclosed herein. The example timing diagram 800 includes an example primary channel 802 (e.g., a primary 20 MHz channel), an example secondary channel 804 (e.g., a secondary 20 MHz channel), and an example non-contiguous secondary channel 806 (e.g., a non-contiguous 40 MHz channel). The example timing diagram 800 is described in conjunction with the STAs 100, 102 and the example AP 104 of FIG. 1.

[0059] During the PIFS, the example secondary channel 804 is busy (e.g., being used for a 20 MHz PPDU) and the non-contiguous secondary channel 806 is idle (e.g., not being used). Accordingly, the example AP 104 senses that the non-contiguous secondary channel 806 is idle and transmits a trigger frame (TF) using the example primary channel 802 and the example non-contiguous secondary channel 806. In examples where CTS is enabled and in response to transmitting the TF, the example AP 104 receives a CTS from a STA (e.g., the example STA 100) identifying that the non-contiguous secondary channel 806 is clear for DL transmission (e.g., is idle). In response to receiving the CTS, the example AP 104 commences DL transmission (e.g., 40 MHz DL PPDU) using the example non-contiguous secondary channel 806. After the AP transmits the DL PPDU, the AP receives a BA, or other ACK, from the example STA 100.

[0060] FIG. 9 is an example timing diagram 900 of a simultaneous downlink/uplink transmission using a Wi-Fi protocol as disclosed herein. The example timing diagram 900 includes an example primary channel 902 (e.g., a primary 20 MHz channel), an example secondary channel 904 (e.g., a secondary 20 MHz channel), and an example non-contiguous secondary channel 906 (e.g., a non-contiguous 40 MHz channel). The example timing diagram 900 is described in conjunction with the STAs 100, 102 and the example AP 104 of FIG. 1.

[0061] During the PIFS, the example secondary channel 904 is busy (e.g., being used for a 20 MHz PPDU) and the non-contiguous secondary channel 906 is idle (e.g., not being used). Accordingly, the example AP 104 senses that the non-contiguous secondary channel 906 is idle and transmits a trigger frame (TF) using the example primary channel 902 and the example non-contiguous secondary channel 906. The trigger frame corresponds to a DL transmission to the

example STA 100 using the example non-contiguous secondary channel 906 and an UL transmission from the example STA 102 using the example primary channel 902. After the trigger frame is transmitted to the STAs 100, 102, the example AP 104 commences DL transmission (e.g., 40 MHz DL PPDU) to the example STA 100 using the example non-contiguous secondary channel 906 and UL transmission (e.g., 20 MHz UL PPDU) to the example STA 102 using the example primary channel 902. After the data transmission is complete, the AP receives a BA, or other ACK, from the example STA 100 and transmits a BA, or other ACK, to the example STA 102.

[0062] FIG. 10 is a block diagram of an example processor platform 1000 capable of executing the instructions of FIG. 6 to implement the example STA communication converter 101 of FIGS. 1 and 3. The processor platform 1000 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.

[0063] The processor platform 1000 of the illustrated example includes a processor 1012. The processor 1012 of the illustrated example is hardware. For example, the processor 1012 can be implemented by integrated circuits, logic circuits, microprocessors or controllers from any desired family or manufacturer.

[0064] The processor 1012 of the illustrated example includes a local memory 1013 (e.g., a cache). The example processor 1012 of FIG. 10 executes the instructions of FIG. 6 to implement the example receiver 200, the example trigger frame analyzer 202, and the example transmitter 204. The processor 1012 of the illustrated example is in communication with a main memory including a volatile memory 1014 and a non-volatile memory 1016 via a bus 1018. The volatile memory 1014 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 1016 may be implemented by flash memory and/or any other desired type of memory device. Access to the main memory 1014, 1016 is controlled by a clock controller.

[0065] The processor platform 1000 of the illustrated example also includes an interface circuit 1020. The interface circuit 1020 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.

[0066] In the illustrated example, one or more input devices 1022 are connected to the interface circuit 1020. The input device(s) 1022 permit(s) a user to enter data and commands into the processor 1012. 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.

[0067] One or more output devices 1024 are also connected to the interface circuit 1020 of the illustrated example. The output devices 1024 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 1020 of the illustrated example, thus, typically includes a graphics driver card, a graphics driver chip or a graphics driver processor.

[0068] The interface circuit 1020 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 1026 (e.g., an Ethernet connection, a digital subscriber line (DSL), a telephone line, coaxial cable, a cellular telephone system, etc.).

[0069] The processor platform 1000 of the illustrated example also includes one or more mass storage devices 1028 for storing software and/or data. Examples of such mass storage devices 1028 include floppy disk drives, hard drive disks, compact disk drives, Blu-ray disk drives, RAID systems, and digital versatile disk (DVD) drives.

[0070] The coded instructions 1032 of FIG. 6 may be stored in the mass storage device 1028, in the volatile memory 1014, in the non-volatile memory 1016, and/or on a removable tangible computer readable storage medium such as a CD or DVD.

[0071] FIG. 11 is a block diagram of an example processor platform 1100 capable of executing the instructions of FIGS. 4-5 to implement the example AP communication converter 105 of FIGS. 1 and 2. The processor platform 1100 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.

[0072] The processor platform 1100 of the illustrated example includes a processor 1112. The processor 1112 of the illustrated example is hardware. For example, the processor 1112 can

be implemented by integrated circuits, logic circuits, microprocessors or controllers from any desired family or manufacturer.

[0073] The processor 1112 of the illustrated example includes a local memory 1113 (e.g., a cache). The example processor 1112 of FIG. 11 executes the instructions of FIGS. 4-5 to implement the example channel analyzer 300, the example channel selector 302, the example trigger frame generator 304, the example transmitter 306, and the example receiver 308. The processor 1112 of the illustrated example is in communication with a main memory including a volatile memory 1114 and a non-volatile memory 1116 via a bus 1118. The volatile memory 1114 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 1116 may be implemented by flash memory and/or any other desired type of memory device. Access to the main memory 1114, 1116 is controlled by a clock controller.

[0074] The processor platform 1100 of the illustrated example also includes an interface circuit 1120. The interface circuit 1120 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.

[0075] In the illustrated example, one or more input devices 1122 are connected to the interface circuit 1120. The input device(s) 1122 permit(s) a user to enter data and commands into the processor 1112. 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.

[0076] One or more output devices 1124 are also connected to the interface circuit 1120 of the illustrated example. The output devices 1124 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 1120 of the illustrated example, thus, typically includes a graphics driver card, a graphics driver chip or a graphics driver processor.

[0077] The interface circuit 1120 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 1126 (e.g., an Ethernet connection, a digital subscriber line (DSL), a telephone line, coaxial cable, a cellular telephone system, etc.).

[0078] The processor platform 1100 of the illustrated example also includes one or more mass storage devices 1128 for storing software and/or data. Examples of such mass storage devices 1128 include floppy disk drives, hard drive disks, compact disk drives, Blu-ray disk drives, RAID systems, and digital versatile disk (DVD) drives.

[0079] The coded instructions 1132 of FIGS. 4-5 may be stored in the mass storage device 1128, in the volatile memory 1114, in the non-volatile memory 1116, and/or on a removable tangible computer readable storage medium such as a CD or DVD.

[0080] From the foregoing, it would be appreciated that the above disclosed method, apparatus, and articles of manufacture enabling communications on non-adjacent secondary channels in wireless local area network protocols. Examples disclosed herein allow a transmitter (e.g., a Wi-Fi AP) to utilize wider non-contiguous secondary channels for SU DL data packet transmission rather than the narrow primary channel associated with traditional Wi-Fi protocols. Additionally, examples disclosed herein include using the primary channel for UL packet reception and using a wider non-contiguous secondary channel for DL transmissions simultaneously or vice versa by leveraging the fact that the UL reception and the DL transmission are separated in frequency. Traditional wireless communication protocols do not allow for non-contiguous SU DL data transmission or for simultaneous DL and UL transmission. Using examples disclosed herein, excess bandwidth is utilized for a more efficient wireless transmission of data packets.

[0081] Example 1 is an apparatus comprising a channel analyzer to determine an availability of a second channel that is non-adjacent to a first channel. Example 1 further includes a trigger frame generator to, when the non-adjacent second channel is idle, generate a trigger frame. Example 1 further includes a transmitter to (A) transmit the trigger frame on the first channel and the non-adjacent second channel and (B) transmit downlink data on the non-adjacent second channel.

[0082] Example 2 includes the subject matter of example 1, wherein the trigger frame includes downlink resource allocation information including a channel number and a bandwidth corresponding to the non-adjacent second channel.

[0083] Example 3 includes the subject matter of example 1, wherein the non-adjacent second channel is non-adjacent to the first channel in at least one or time or frequency.

[0084] Example 4 includes the subject matter of example 1, wherein the transmitter is to transmit the trigger frame and the downlink data to a station.

[0085] Example 5 includes the subject matter of examples 1-4, wherein the trigger frame includes uplink resource allocation information including a channel number and a bandwidth corresponding to the first channel.

[0086] Example 6 includes the subject matter of example 5, further including a receiver to receive uplink data on the first channel from a first station.

[0087] Example 7 includes the subject matter of example 6, wherein the transmitter is to transmit the downlink data on the second channel to a second station.

[0088] Example 8 includes the subject matter of examples 1-4, further including a receiver to receive a clear-to-send (CTS) from a station corresponding to the trigger frame.

[0089] Example 9 includes the subject matter of example 8, wherein the transmitter is to, when the CTS corresponds to the first channel, transmit the downlink data using the first channel.

[0090] Example 10 is a method comprising determining an availability of a second channel that is non-adjacent to a first channel. Example 10 further includes, when the non-adjacent second channel is idle, generating a trigger frame. Example 10 further includes transmitting the trigger frame on the first channel and the non-adjacent second channel. Example 10 further includes transmitting downlink data on the non-adjacent second channel.

[0091] Example 11 includes the subject matter of example 10, wherein the trigger frame includes downlink resource allocation information including a channel number and a bandwidth corresponding to the non-adjacent second channel.

[0092] Example 12 includes the subject matter of example 10, wherein the non-adjacent second channel is non-adjacent to the first channel in at least one or time or frequency.

[0093] Example 13 includes the subject matter of example 10, wherein the trigger frame and the downlink data are transmitted to a station.

[0094] Example 14 includes the subject matter of examples 10-13, wherein the trigger frame includes uplink resource allocation information including a channel number and a bandwidth corresponding to the first channel.

[0095] Example 15 includes the subject matter of example 14, further including receiving uplink data on the first channel from a first station.

[0096] Example 16 includes the subject matter of example 15, wherein the downlink data is transmitted on the second channel to a second station.

[0097] Example 17 includes the subject matter of examples 10-13, receiving a clear-to-send (CTS) from a station corresponding to the trigger frame.

[0098] Example 18 includes the subject matter of example 17, further including, when the CTS corresponds to the first channel, transmitting the downlink data using the first channel.

[0099] Example 19 is a tangible computer readable storage medium comprising instruction which, when executed, cause a machine to at least determine an availability of a second channel that is non-adjacent to a first channel. Example 19 further includes instructions to, when the non-adjacent second channel is idle, generate a trigger frame. Example 19 further includes instructions to transmit the trigger frame on the first channel and the non-adjacent second channel. Example 19 further includes instructions to transmit downlink data on the non-adjacent second channel.

[00100] Example 20 includes the subject matter of example 19, wherein the trigger frame includes downlink resource allocation information including a channel number and a bandwidth corresponding to the non-adjacent second channel.

[00101] Example 21 includes the subject matter of example 19, wherein the non-adjacent second channel is non-adjacent to the first channel in at least one or time or frequency.

[00102] Example 22 includes the subject matter of example 19, wherein instructions cause the machine to transmit the trigger frame and the downlink data to a station.

[00103] Example 23 includes the subject matter of examples 19-22, wherein the trigger frame includes uplink resource allocation information including a channel number and a bandwidth corresponding to the first channel.

[00104] Example 24 includes the subject matter of example 23, wherein instructions cause the machine to receive uplink data on the first channel from a first station.

[00105] Example 25 includes the subject matter of example 24, wherein instructions cause the machine to transmit the downlink data on the second channel to a second station.

[00106] Example 26 includes the subject matter of examples 19-22, wherein instructions cause the machine to receive a clear-to-send (CTS) from a station corresponding to the trigger frame.

[00107] Example 27 includes the subject matter of example 26, wherein instructions cause the machine to, when the CTS corresponds to the first channel, transmit the downlink data using the first channel.

[00108] Example 28 is an apparatus comprising first means for determining an availability of a second channel that is non-adjacent to a first channel. Example 28 further includes second means for, when the non-adjacent second channel is idle, generating a trigger frame. Example 28 further includes third means for transmitting the trigger frame on the first channel and the non-adjacent second channel and transmitting downlink data on the non-adjacent second channel.

[00109] Example 29 includes the subject matter of example 28, wherein the trigger frame includes downlink resource allocation information including a channel number and a bandwidth corresponding to the non-adjacent second channel.

[00110] Example 30 includes the subject matter of example 28, wherein the non-adjacent second channel is non-adjacent to the first channel in at least one or time or frequency.

[00111] Example 31 includes the subject matter of example 28, wherein the third means includes means for transmitting the trigger frame and the downlink data to a station.

[00112] Example 32 includes the subject matter of examples 28-31, wherein the trigger frame includes uplink resource allocation information including a channel number and a bandwidth corresponding to the first channel.

[00113] Example 33 includes the subject matter of example 32, further including fourth means for receiving uplink data on the first channel from a first station.

[00114] Example 34 includes the subject matter of example 33, wherein the third means includes means for transmitting the downlink data on the second channel to a second station.

[00115] Example 35 includes the subject matter of examples 28-31, further including fourth means for receiving a clear-to-send (CTS) from a station corresponding to the trigger frame.

[00116] Example 36 includes the subject matter of example 35, wherein the third means includes means for, when the CTS corresponds to the first channel, transmitting the downlink data using the first channel.

[00117] 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 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 access point for enabling communications, the access point comprising:
a channel analyzer to determine an availability of a second channel that is non-adjacent to a first channel;
a trigger frame generator to, when the non-adjacent second channel is idle, generate a trigger frame; and
a transmitter to:
transmit the trigger frame on the first channel and the non-adjacent second channel; and
transmit downlink data on the non-adjacent second channel.
2. The access point of claim 1, wherein the trigger frame includes downlink resource allocation information including a channel number and a bandwidth corresponding to the non-adjacent second channel.
3. The access point of claim 1, wherein the non-adjacent second channel is non-adjacent to the first channel in at least one of time or frequency.
4. The access point of claim 1, wherein the transmitter is to transmit the trigger frame and the downlink data to a station.
5. The access point of claims 1-4, wherein the trigger frame includes uplink resource allocation information including a channel number and a bandwidth corresponding to the first channel.
6. The access point of claim 5, further including a receiver to receive uplink data on the first channel from a first station.
7. The access point of claim 6, wherein the transmitter is to transmit the downlink data on the second channel to a second station.
8. The access point of claims 1-4, further including a receiver to receive a clear-to-send (CTS) from a station corresponding to the trigger frame.
9. The access point of claim 8, wherein the transmitter is to, when the CTS corresponds to the first channel, transmit the downlink data using the first channel.
10. A method for enabling communications, the method comprising:
determining an availability of a second channel that is non-adjacent to a first channel;
when the non-adjacent second channel is idle, generating a trigger frame;

transmitting the trigger frame on the first channel and the non-adjacent second channel;
and

transmitting downlink data on the non-adjacent second channel.

11. The method of claim 10, wherein the trigger frame includes downlink resource allocation information including a channel number and a bandwidth corresponding to the non-adjacent second channel.

12. The method of claim 10, wherein the non-adjacent second channel is non-adjacent to the first channel in at least one or time or frequency.

13. The method of claim 10, wherein the trigger frame and the downlink data are transmitted to a station.

14. The method of claim 10-13, wherein the trigger frame includes uplink resource allocation information including a channel number and a bandwidth corresponding to the first channel.

15. The method of claim 14, further including receiving uplink data on the first channel from a first station.

16. The method of claim 15, wherein the downlink data is transmitted on the second channel to a second station.

17. The method of claims 10-13, receiving a clear-to-send (CTS) from a station corresponding to the trigger frame.

18. The method of claim 17, further including, when the CTS corresponds to the first channel, transmitting the downlink data using the first channel.

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

determine an availability of a second channel that is non-adjacent to a first channel;

when the non-adjacent second channel is idle, generate a trigger frame;

transmit the trigger frame on the first channel and the non-adjacent second channel; and

transmit downlink data on the non-adjacent second channel.

20. The computer readable medium of claim 19, wherein the trigger frame includes downlink resource allocation information including a channel number and a bandwidth corresponding to the non-adjacent second channel.

21. The computer readable medium of claim 19, wherein the non-adjacent second channel is non-adjacent to the first channel in at least one or time or frequency.

22. The computer readable medium of claim 19, wherein instructions cause the machine to transmit the trigger frame and the downlink data to a station.

23. The computer readable medium of claims 19-22, wherein the trigger frame includes uplink resource allocation information including a channel number and a bandwidth corresponding to the first channel.

24. The computer readable medium of claim 23, wherein instructions cause the machine to receive uplink data on the first channel from a first station.

25. The computer readable medium of claim 24, wherein instructions cause the machine to transmit the downlink data on the second channel to a second station.

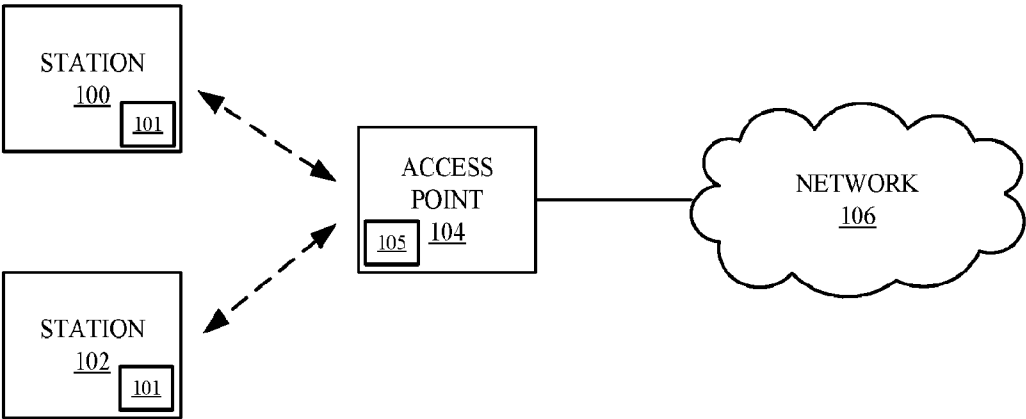


FIG. 1

2/11

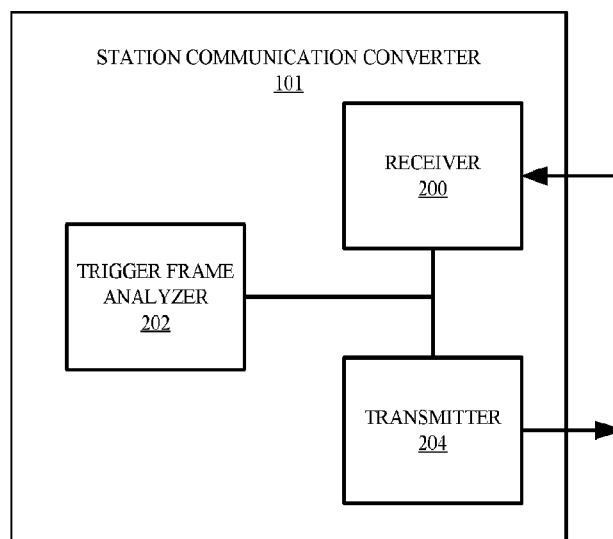


FIG. 2

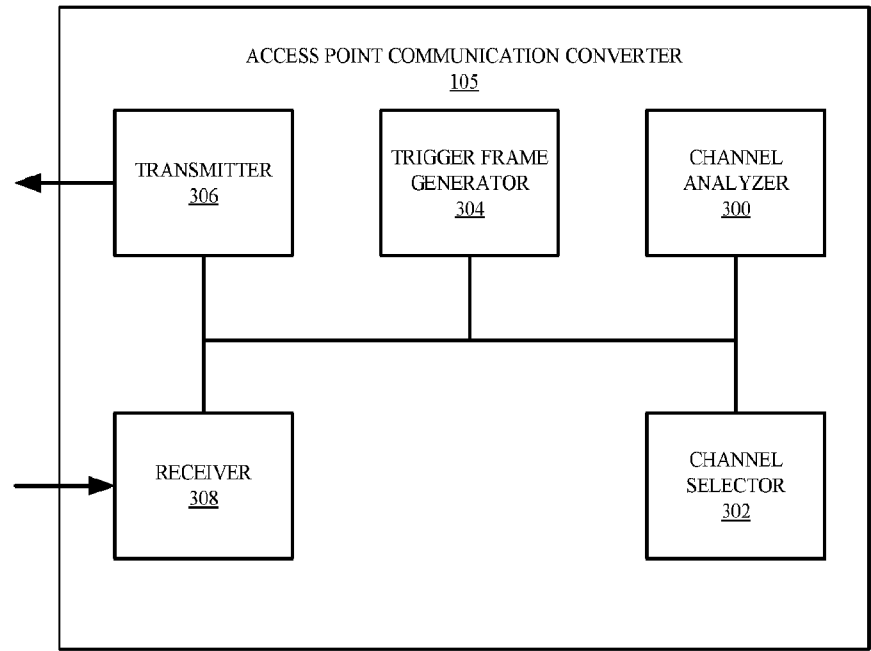


FIG. 3

4/11

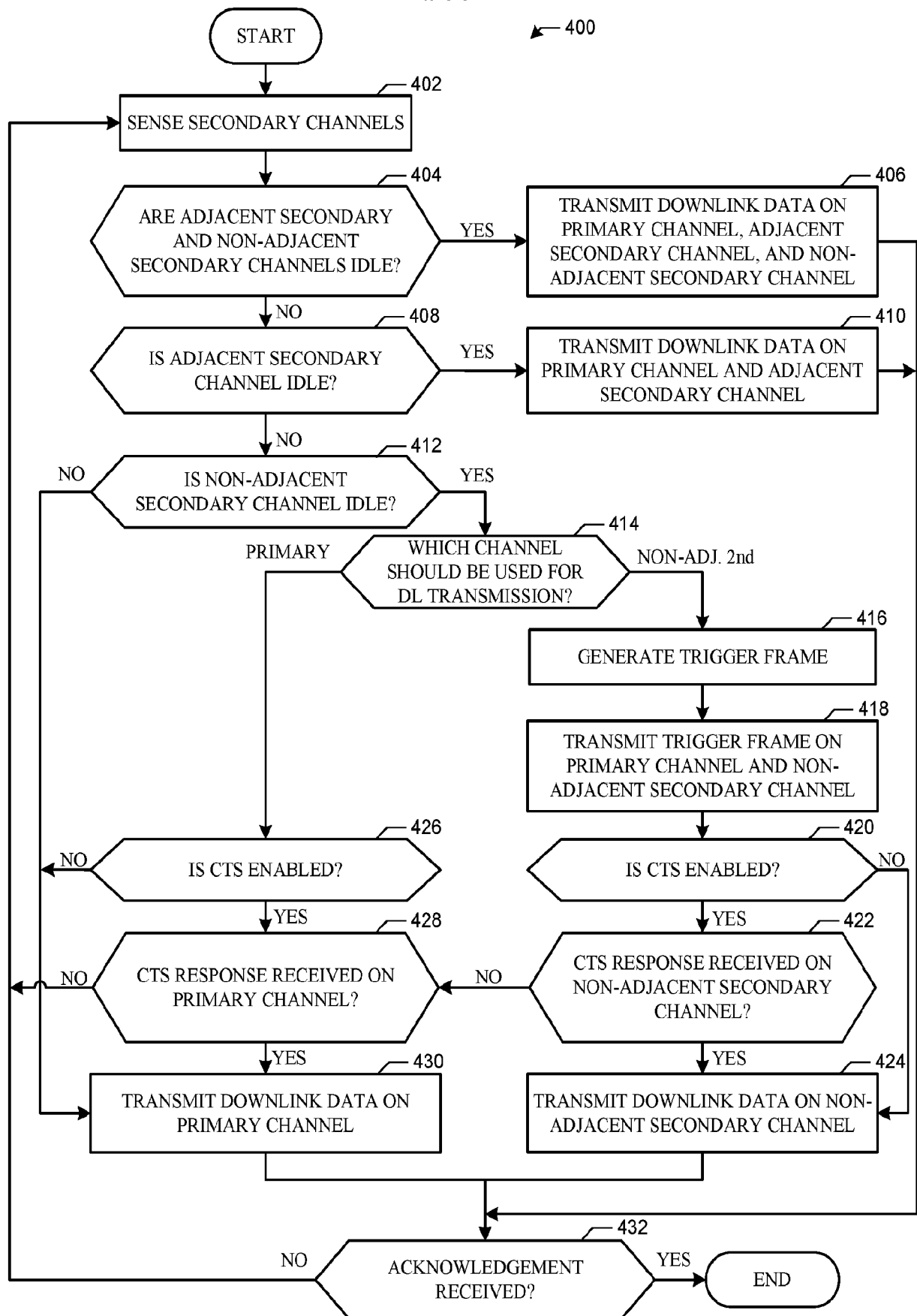


FIG. 4

5/11

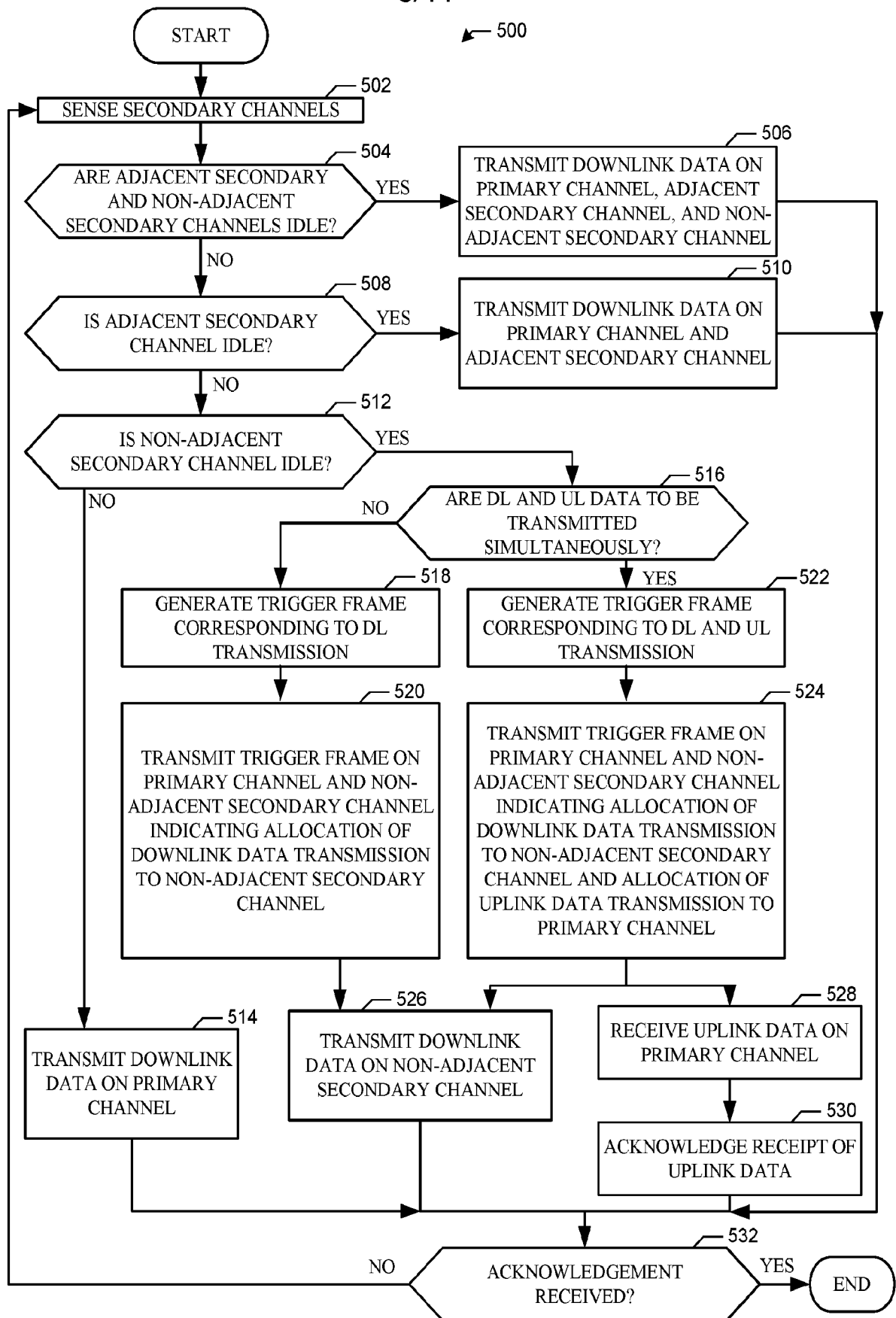


FIG. 5



7/11

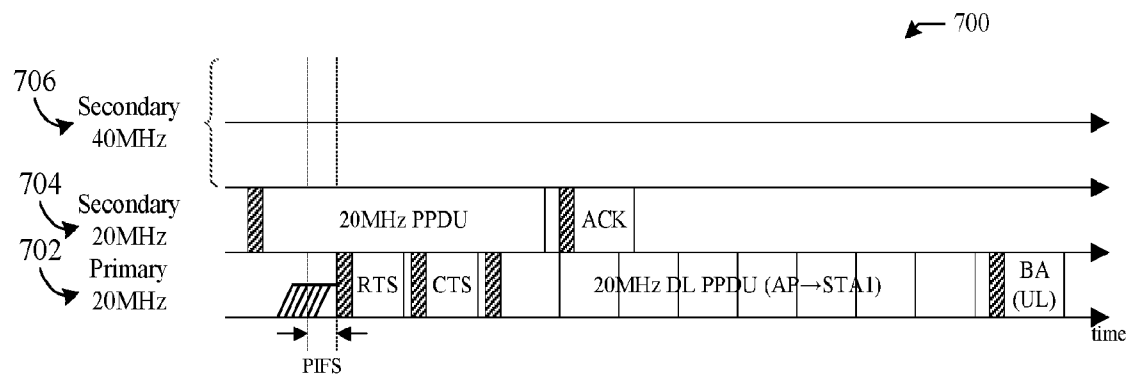


FIG. 7

8/11

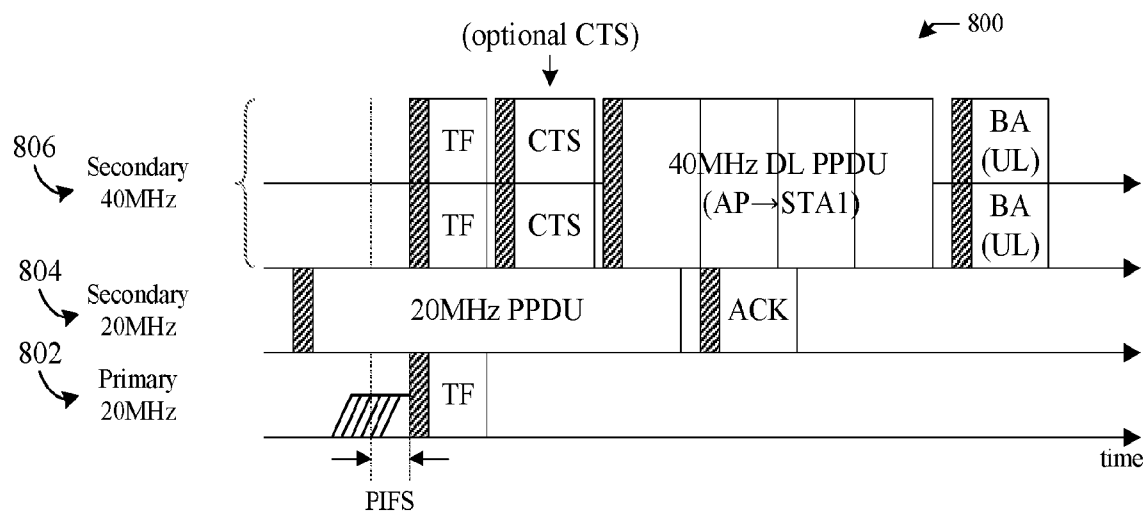


FIG. 8

9/11

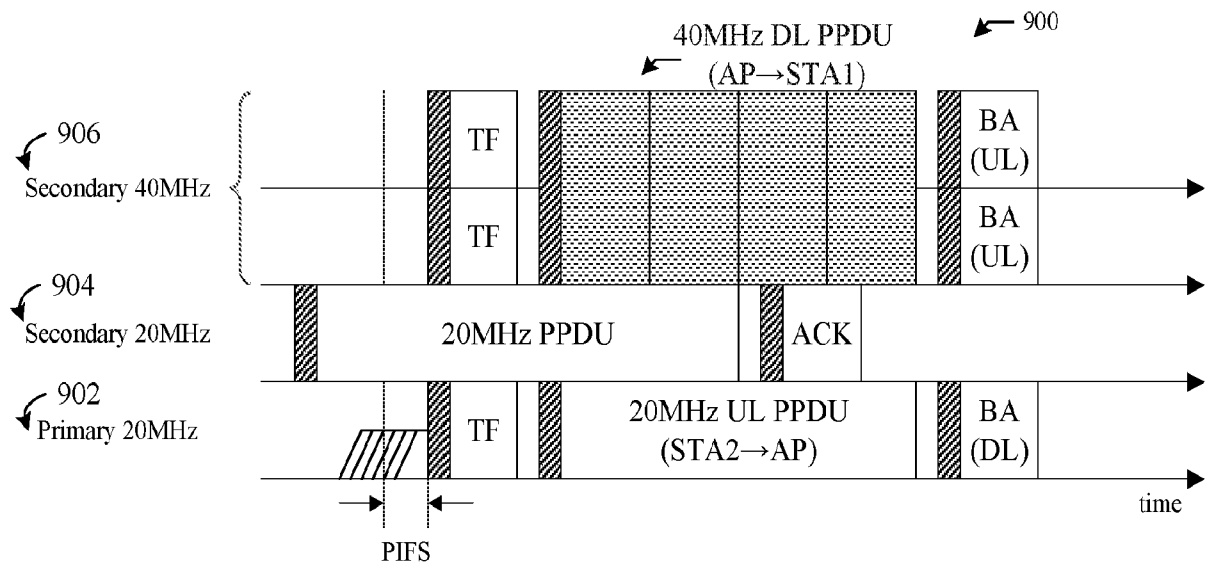


FIG. 9

10/11

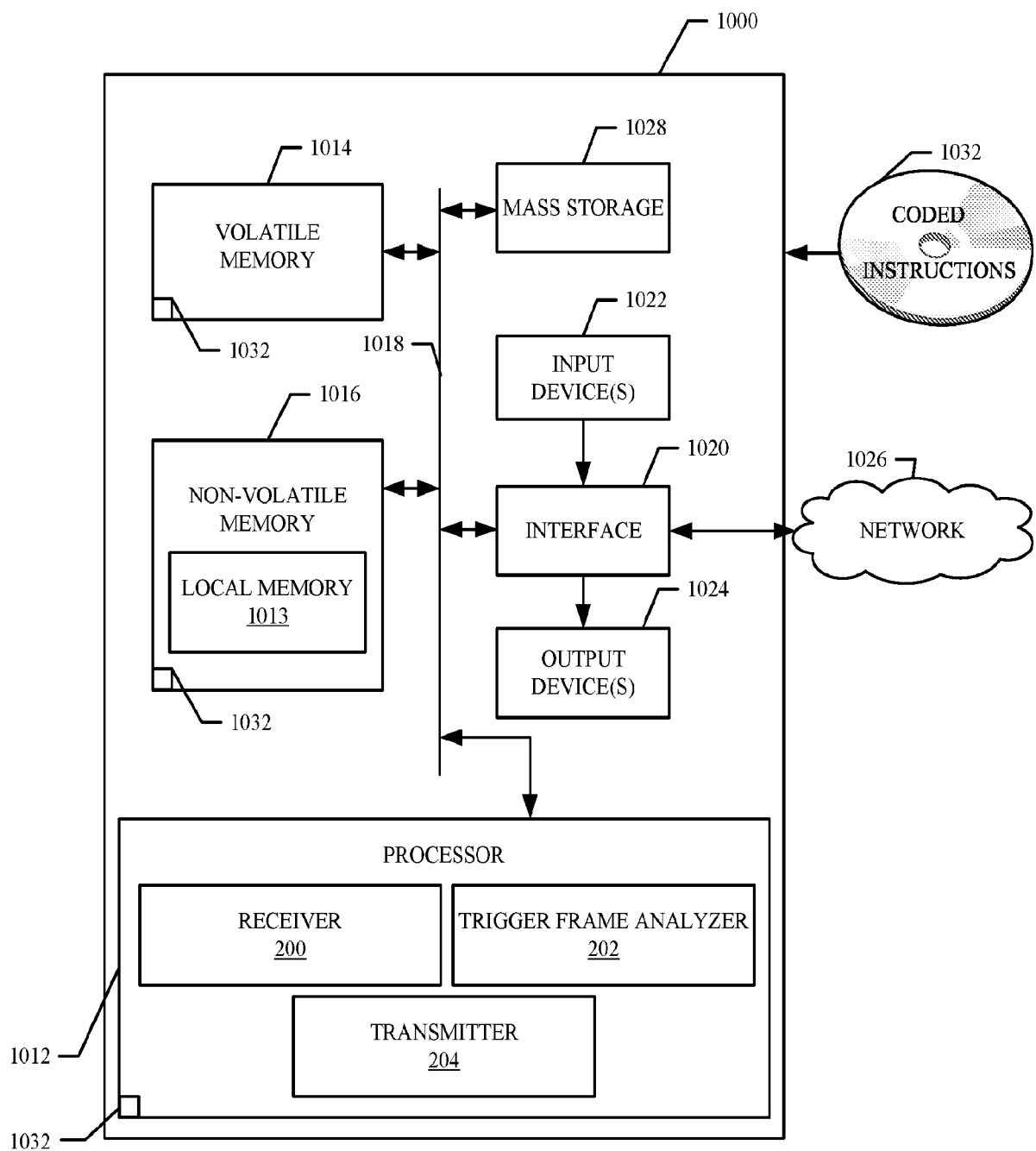


FIG. 10

11/11

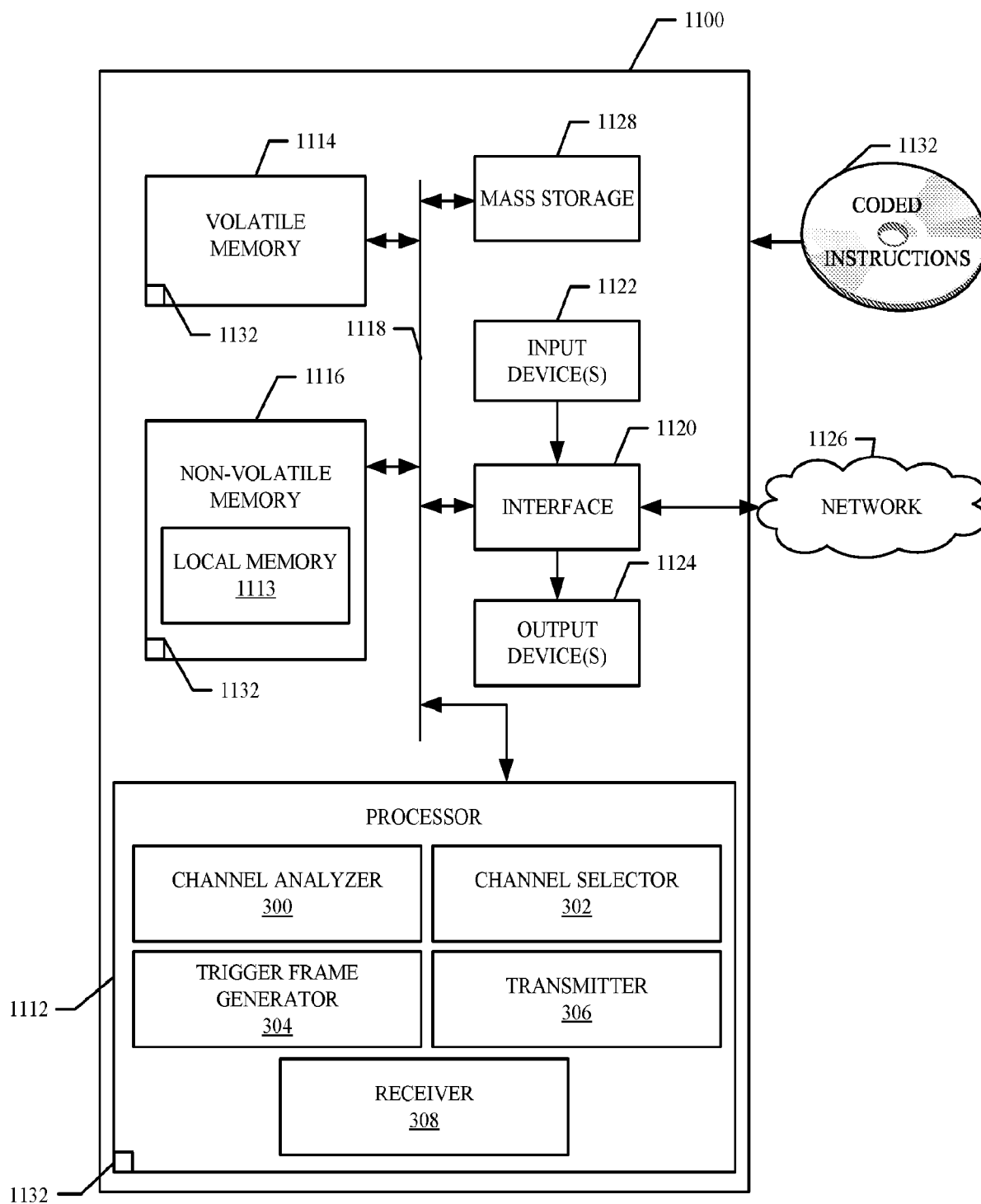


FIG. 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/039100**A. CLASSIFICATION OF SUBJECT MATTER****H04W 74/00(2009.01)i, H04W 74/08(2009.01)i, H04W 84/12(2009.01)i, H04W 88/08(2009.01)i**

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W 74/00; H04B 7/00; H04W 74/08; H04W 48/16; H04W 72/04; H04W 36/06; H04W 24/08; H04W 84/12; H04W 88/08

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: access, point, non-contiguous, channel, idle, availability, aggregation, trigger, frame, and similar terms.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2012-0082040 A1 (MICHELLE GONG et al.) 05 April 2012 See paragraph [0039]; claims 1, 13; and figure 4.	1-25
Y	US 2016-0157266 A1 (MEDIATEK INC.) 02 June 2016 See claims 12, 19-20.	1-25
A	US 2007-0191052 A1 (JARKKO KNECKT et al.) 16 August 2007 See paragraphs [0076]-[0091]; and figures 10-20.	1-25
A	US 2017-0181190 A1 (EHSAN ARYAFAR et al.) 22 June 2017 See paragraphs [0021]-[0046]; and figures 1-3.	1-25
A	US 2014-0105170 A1 (LG ELECTRONICS INC.) 17 April 2014 See paragraphs [0035]-[0057]; and figures 1-4.	1-25

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

23 March 2018 (23.03.2018)

Date of mailing of the international search report

23 March 2018 (23.03.2018)

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

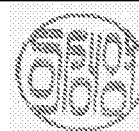


Facsimile No. +82-42-481-8578

Authorized officer

LEE, Seoung Young

Telephone No. +82-42-481-3535



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2017/039100

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2012-0082040 A1	05/04/2012	BR 112013007580 A2 CN 103250459 A CN 103250459 B CN 105792279 A EP 2622930 A1 JP 2013-543702 A JP 2015-122758 A JP 5687766 B2 JP 6038969 B2 KR 10-1560071 B1 KR 10-1560528 B1 KR 10-1629625 B1 KR 10-1666861 B1 KR 10-2013-0054453 A KR 10-2015-0038632 A KR 10-2015-0104647 A KR 10-2016-0068001 A US 2014-0369303 A1 US 8913510 B2 WO 2012-044706 A1	02/08/2016 14/08/2013 22/06/2016 20/07/2016 07/08/2013 05/12/2013 02/07/2015 18/03/2015 07/12/2016 13/10/2015 14/10/2015 13/06/2016 18/10/2016 24/05/2013 08/04/2015 15/09/2015 14/06/2016 18/12/2014 16/12/2014 05/04/2012
US 2016-0157266 A1	02/06/2016	EP 3030027 A1 EP 3030027 B1	08/06/2016 01/11/2017
US 2007-0191052 A1	16/08/2007	WO 2007-085948 A2 WO 2007-085948 A3	02/08/2007 29/11/2007
US 2017-0181190 A1	22/06/2017	None	
US 2014-0105170 A1	17/04/2014	CA 2747358 A1 CA 2747358 C US 2012-0026997 A1 US 2016-0105909 A1 US 8644281 B2 US 9247469 B2 US 9585170 B2	27/01/2012 09/06/2015 02/02/2012 14/04/2016 04/02/2014 26/01/2016 28/02/2017