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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
17 January 2019 (17.01.2019)

WIPO | PCT

(10) International Publication Number
WO 2019/014371 A1

(51) International Patent Classification:
H04W 72/12 (2009.01) *H04W 88/08* (2009.01)

(21) International Application Number:
PCT/US2018/041682

(22) International Filing Date:
11 July 2018 (11.07.2018)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/532,607 14 July 2017 (14.07.2017) US
62/561,524 21 September 2017 (21.09.2017) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, 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,

(54) Title: SERVICE PERIOD SCHEDULING

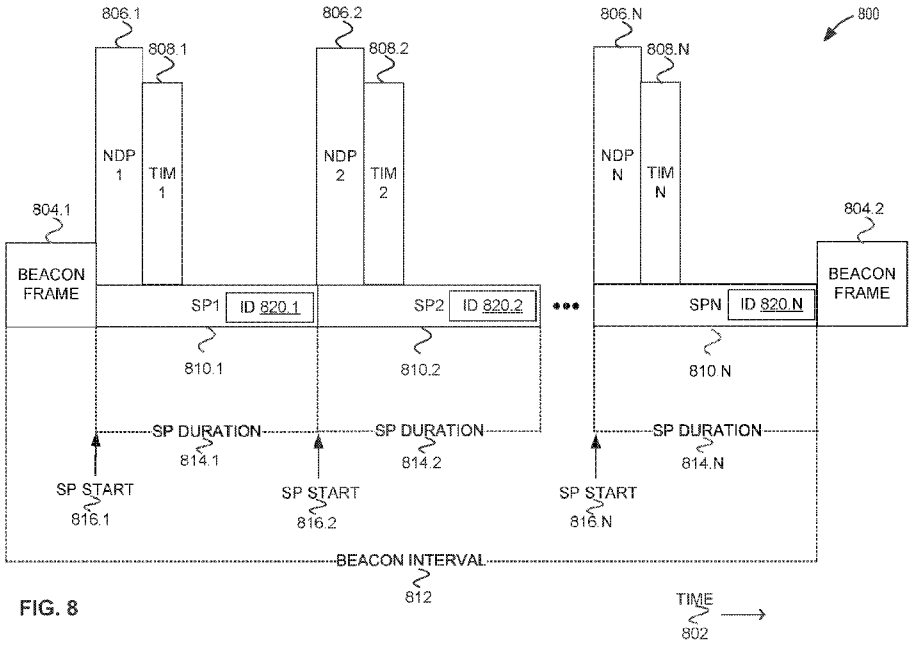


FIG. 8

(57) Abstract: Methods, computer readable media, and apparatus for scheduling service periods (SPs) are disclosed. An apparatus includes processing circuitry where the processing circuitry is configured to encode a first physical Layer Convergence Procedure (PLCP) Protocol Data Unit (PPDU), the PPDU comprising an indication of scheduled service periods (SPs) during a beacon interval (BI) and an indication of an intended transmission of a second PPDU at the start of the scheduled service periods. The processing circuitry may be configured to encode the second PPDU, the second PPDU comprising a frame or element for the HE STAs.

[Continued on next page]

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TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

SERVICE PERIOD SCHEDULING

PRIORITY CLAIM

[0001] This application claims the benefit of priority to United States Provisional Patent Application Serial No. 62/561,524, filed September 21, 2017, and United States Provisional Patent Application Serial No. 62/532,607, filed July 14, 2017, each of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] Embodiments pertain to wireless networks and wireless communications. Some embodiments relate to wireless local area networks (WLANs) and Wi-Fi networks including networks operating in accordance with the IEEE 802.11 family of standards. Some embodiments relate to IEEE 802.11ax, IEEE 6 GHz 802.11ax, and/or IEEE 802.11 extremely high-throughput (EHT).

BACKGROUND

[0003] Efficient use of the resources of a wireless local-area network (WLAN) is important to provide bandwidth and acceptable response times to the users of the WLAN. However, often there are many devices trying to share the same resources and some devices may be limited by the communication protocol they use or by their hardware bandwidth. Moreover, wireless devices may need to operate with both newer protocols and with legacy device protocols.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] The present disclosure is illustrated by way of example and not limitation in the figures of the accompanying drawings, in which like references indicate similar elements and in which:

[0005] FIG. 1 is a block diagram of a radio architecture in accordance with some embodiments;

[0006] FIG. 2 illustrates a front-end module circuitry for use in the radio architecture of FIG. 1 in accordance with some embodiments;

[0007] FIG. 3 illustrates a radio integrated circuit (IC) circuitry for use in the radio architecture of FIG. 1 in accordance with some embodiments;

[0008] FIG. 4 illustrates a baseband processing circuitry for use in the radio architecture of FIG. 1 in accordance with some embodiments;

[0009] FIG. 5 illustrates a WLAN in accordance with some embodiments;

[0010] FIG. 6 illustrates a block diagram of an example machine upon which any one or more of the techniques (e.g., methodologies) discussed herein may perform;

[0011] FIG. 7 illustrates a block diagram of an example wireless device upon which any one or more of the techniques (e.g., methodologies or operations) discussed herein may perform;

[0012] FIG. 8 illustrates a method of service period (SP) scheduling in accordance with some embodiments;

[0013] FIG. 9 illustrates target wake time (TWT) setup methods in accordance with some embodiments;

[0014] FIG. 10 illustrates a TWT element in accordance with some embodiments;

[0015] FIG. 11 illustrates a TWT element in accordance with some embodiments;

[0016] FIG. 12 illustrates a TWT element in accordance with some embodiments;

[0017] FIG. 13 illustrates a TWT element in accordance with some embodiments;

[0018] FIG. 14 illustrates a TIM element in accordance with some embodiments;

[0019] FIG. 15 illustrates a block acknowledgement frame in accordance with some embodiments;

[0020] FIG. 16 illustrates a null data packet (NDP) element in accordance with some embodiments;

[0021] FIG. 17 illustrates SP timing field and frames field in accordance with some embodiments;

[0022] FIG. 18 illustrates block acknowledgements with schedules in accordance with some embodiments;

[0023] FIG. 19 illustrates a method of service period scheduling in accordance with some embodiments; and

[0024] FIG. 20 illustrates a method of service period scheduling in accordance with some embodiments.

DESCRIPTION

[0025] The following description and the drawings sufficiently illustrate specific embodiments to enable those skilled in the art to practice them. Other embodiments may incorporate structural, logical, electrical, process, and other changes. Portions and features of some embodiments may be included in, or substituted for, those of other embodiments. Embodiments set forth in the claims encompass all available equivalents of those claims.

[0026] Some embodiments relate to methods, computer readable media, and apparatus for ordering or scheduling null data packet (NDP) feedback reports, traffic indication maps (TIMs), and other information during SPs. Some embodiments relate to methods, computer readable media, and apparatus for extending TIMs. Some embodiments relate to methods, computer readable media, and apparatus for defining SPs during beacon intervals (BI), which may be based on TWTs.

[0027] FIG. 1 is a block diagram of a radio architecture 100 in accordance with some embodiments. Radio architecture 100 may include radio front-end module (FEM) circuitry 104, radio IC circuitry 106 and baseband

processing circuitry 108. Radio architecture 100 as shown includes both Wireless Local Area Network (WLAN) functionality and Bluetooth (BT) functionality although embodiments are not so limited. In this disclosure, "WLAN" and "Wi-Fi" are used interchangeably.

[0028] FEM circuitry 104 may include a WLAN or Wi-Fi FEM circuitry 104A and a Bluetooth (BT) FEM circuitry 104B. The WLAN FEM circuitry 104A may include a receive signal path comprising circuitry configured to operate on WLAN RF signals received from one or more antennas 101, to amplify the received signals and to provide the amplified versions of the received signals to the WLAN radio IC circuitry 106A for further processing. The BT FEM circuitry 104B may include a receive signal path which may include circuitry configured to operate on BT RF signals received from one or more antennas 101, to amplify the received signals and to provide the amplified versions of the received signals to the BT radio IC circuitry 106B for further processing. FEM circuitry 104A may also include a transmit signal path which may include circuitry configured to amplify WLAN signals provided by the radio IC circuitry 106A for wireless transmission by one or more of the antennas 101. In addition, FEM circuitry 104B may also include a transmit signal path which may include circuitry configured to amplify BT signals provided by the radio IC circuitry 106B for wireless transmission by the one or more antennas. In the embodiment of FIG. 1, although FEM 104A and FEM 104B are shown as being distinct from one another, embodiments are not so limited, and include within their scope the use of an FEM (not shown) that includes a transmit path and/or a receive path for both WLAN and BT signals, or the use of one or more FEM circuitries where at least some of the FEM circuitries share transmit and/or receive signal paths for both WLAN and BT signals.

[0029] Radio IC circuitry 106 as shown may include WLAN radio IC circuitry 106A and BT radio IC circuitry 106B. The WLAN radio IC circuitry 106A may include a receive signal path which may include circuitry to down-convert WLAN RF signals received from the FEM circuitry 104A and provide baseband signals to WLAN baseband processing circuitry 108A. BT radio IC circuitry 106B may in turn include a receive signal path which may include circuitry to down-convert BT RF signals received from the FEM circuitry 104B

and provide baseband signals to BT baseband processing circuitry 108B. WLAN radio IC circuitry 106A may also include a transmit signal path which may include circuitry to up-convert WLAN baseband signals provided by the WLAN baseband processing circuitry 108A and provide WLAN RF output signals to the FEM circuitry 104A for subsequent wireless transmission by the one or more antennas 101. BT radio IC circuitry 106B may also include a transmit signal path which may include circuitry to up-convert BT baseband signals provided by the BT baseband processing circuitry 108B and provide BT RF output signals to the FEM circuitry 104B for subsequent wireless transmission by the one or more antennas 101. In the embodiment of FIG. 1, although radio IC circuitries 106A and 106B are shown as being distinct from one another, embodiments are not so limited, and include within their scope the use of a radio IC circuitry (not shown) that includes a transmit signal path and/or a receive signal path for both WLAN and BT signals, or the use of one or more radio IC circuitries where at least some of the radio IC circuitries share transmit and/or receive signal paths for both WLAN and BT signals.

[0030] Baseband processing circuity 108 may include a WLAN baseband processing circuitry 108A and a BT baseband processing circuitry 108B. The WLAN baseband processing circuitry 108A may include a memory, such as, for example, a set of RAM arrays in a Fast Fourier Transform or Inverse Fast Fourier Transform block (not shown) of the WLAN baseband processing circuitry 108A. Each of the WLAN baseband circuitry 108A and the BT baseband circuitry 108B may further include one or more processors and control logic to process the signals received from the corresponding WLAN or BT receive signal path of the radio IC circuitry 106, and to also generate corresponding WLAN or BT baseband signals for the transmit signal path of the radio IC circuitry 106. Each of the baseband processing circuitries 108A and 108B may further include physical layer (PHY) and medium access control layer (MAC) circuitry, and may further interface with application processor 111 for generation and processing of the baseband signals and for controlling operations of the radio IC circuitry 106.

[0031] Referring still to FIG. 1, according to the shown embodiment, WLAN-BT coexistence circuitry 113 may include logic providing an interface

between the WLAN baseband circuitry 108A and the BT baseband circuitry 108B to enable use cases requiring WLAN and BT coexistence. In addition, a switch 103 may be provided between the WLAN FEM circuitry 104A and the BT FEM circuitry 104B to allow switching between the WLAN and BT radios according to application needs. In addition, although the antennas 101 are depicted as being respectively connected to the WLAN FEM circuitry 104A and the BT FEM circuitry 104B, embodiments include within their scope the sharing of one or more antennas as between the WLAN and BT FEMs, or the provision of more than one antenna connected to each of FEM 104A or 104B.

[0032] In some embodiments, the front-end module circuitry 104, the radio IC circuitry 106, and baseband processing circuitry 108 may be provided on a single radio card, such as wireless radio card 102. In some other embodiments, the one or more antennas 101, the FEM circuitry 104 and the radio IC circuitry 106 may be provided on a single radio card. In some other embodiments, the radio IC circuitry 106 and the baseband processing circuitry 108 may be provided on a single chip or IC, such as IC 112.

[0033] In some embodiments, the wireless radio card 102 may include a WLAN radio card and may be configured for Wi-Fi communications, although the scope of the embodiments is not limited in this respect. In some of these embodiments, the radio architecture 100 may be configured to receive and transmit orthogonal frequency division multiplexed (OFDM) or orthogonal frequency division multiple access (OFDMA) communication signals over a multicarrier communication channel. The OFDM or OFDMA signals may comprise a plurality of orthogonal subcarriers.

[0034] In some of these multicarrier embodiments, radio architecture 100 may be part of a Wi-Fi communication station (STA) such as a wireless access point (AP), a base station or a mobile device including a Wi-Fi device. In some of these embodiments, radio architecture 100 may be configured to transmit and receive signals in accordance with specific communication standards and/or protocols, such as any of the Institute of Electrical and Electronics Engineers (IEEE) standards including, IEEE 802.11n-2009, IEEE 802.11-2012, IEEE 802.11-2016, IEEE 802.11ac, and/or IEEE 802.11ax standards and/or proposed specifications for WLANs, although the scope of embodiments is not limited in

this respect. Radio architecture 100 may also be suitable to transmit and/or receive communications in accordance with other techniques and standards.

[0035] In some embodiments, the radio architecture 100 may be configured for high-efficiency (HE) Wi-Fi (HEW) communications in accordance with the IEEE 802.11ax standard. In these embodiments, the radio architecture 100 may be configured to communicate in accordance with an OFDMA technique, although the scope of the embodiments is not limited in this respect.

[0036] In some other embodiments, the radio architecture 100 may be configured to transmit and receive signals transmitted using one or more other modulation techniques such as spread spectrum modulation (e.g., direct sequence code division multiple access (DS-CDMA) and/or frequency hopping code division multiple access (FH-CDMA)), time-division multiplexing (TDM) modulation, and/or frequency-division multiplexing (FDM) modulation, although the scope of the embodiments is not limited in this respect.

[0037] In some embodiments, as further shown in FIG. 1, the BT baseband circuitry 108B may be compliant with a Bluetooth (BT) connectivity standard such as Bluetooth, Bluetooth 4.0 or Bluetooth 5.0, or any other iteration of the Bluetooth Standard. In embodiments that include BT functionality as shown for example in Fig. 1, the radio architecture 100 may be configured to establish a BT synchronous connection oriented (SCO) link and/or a BT low energy (BT LE) link. In some of the embodiments that include functionality, the radio architecture 100 may be configured to establish an extended SCO (eSCO) link for BT communications, although the scope of the embodiments is not limited in this respect. In some of these embodiments that include a BT functionality, the radio architecture may be configured to engage in a BT Asynchronous Connection-Less (ACL) communications, although the scope of the embodiments is not limited in this respect. In some embodiments, as shown in FIG. 1, the functions of a BT radio card and WLAN radio card may be combined on a single wireless radio card, such as single wireless radio card 102, although embodiments are not so limited, and include within their scope discrete WLAN and BT radio cards

[0038] In some embodiments, the radio-architecture 100 may include other radio cards, such as a cellular radio card configured for cellular (e.g., 3GPP such as LTE, LTE-Advanced or 5G communications).

[0039] In some IEEE 802.11 embodiments, the radio architecture 100 may be configured for communication over various channel bandwidths including bandwidths having center frequencies of about 900 MHz, 2.4 GHz, 5 GHz, and bandwidths of about 1 MHz, 2 MHz, 2.5 MHz, 4 MHz, 5MHz, 8 MHz, 10 MHz, 16 MHz, 20 MHz, 40MHz, 80MHz (with contiguous bandwidths) or 80+80MHz (160MHz) (with non-contiguous bandwidths). In some embodiments, a 320 MHz channel bandwidth may be used. The scope of the embodiments is not limited with respect to the above center frequencies however.

[0040] FIG. 2 illustrates FEM circuitry 200 in accordance with some embodiments. The FEM circuitry 200 is one example of circuitry that may be suitable for use as the WLAN and/or BT FEM circuitry 104A/104B (FIG. 1), although other circuitry configurations may also be suitable.

[0041] In some embodiments, the FEM circuitry 200 may include a TX/RX switch 202 to switch between transmit mode and receive mode operation. The FEM circuitry 200 may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry 200 may include a low-noise amplifier (LNA) 206 to amplify received RF signals 203 and provide the amplified received RF signals 207 as an output (e.g., to the radio IC circuitry 106 (FIG. 1)). The transmit signal path of the circuitry 200 may include a power amplifier (PA) to amplify input RF signals 209 (e.g., provided by the radio IC circuitry 106), and one or more filters 212, such as band-pass filters (BPFs), low-pass filters (LPFs) or other types of filters, to generate RF signals 215 for subsequent transmission (e.g., by one or more of the antennas 101 (FIG. 1)).

[0042] In some dual-mode embodiments for Wi-Fi communication, the FEM circuitry 200 may be configured to operate in either the 2.4 GHz frequency spectrum or the 5 GHz frequency spectrum. In these embodiments, the receive signal path of the FEM circuitry 200 may include a receive signal path duplexer 204 to separate the signals from each spectrum as well as provide a separate

LNA 206 for each spectrum as shown. In these embodiments, the transmit signal path of the FEM circuitry 200 may also include a power amplifier 210 and a filter 212, such as a BPF, a LPF or another type of filter for each frequency spectrum and a transmit signal path duplexer 214 to provide the signals of one of the different spectrums onto a single transmit path for subsequent transmission by the one or more of the antennas 101 (FIG. 1). In some embodiments, BT communications may utilize the 2.4 GHZ signal paths and may utilize the same FEM circuitry 200 as the one used for WLAN communications.

[0043] FIG. 3 illustrates radio integrated circuit (IC) circuitry 300 in accordance with some embodiments. The radio IC circuitry 300 is one example of circuitry that may be suitable for use as the WLAN or BT radio IC circuitry 106A/106B (FIG. 1), although other circuitry configurations may also be suitable.

[0044] In some embodiments, the radio IC circuitry 300 may include a receive signal path and a transmit signal path. The receive signal path of the radio IC circuitry 300 may include at least mixer circuitry 302, such as, for example, down-conversion mixer circuitry, amplifier circuitry 306 and filter circuitry 308. The transmit signal path of the radio IC circuitry 300 may include at least filter circuitry 312 and mixer circuitry 314, such as, for example, up-conversion mixer circuitry. Radio IC circuitry 300 may also include synthesizer circuitry 304 for synthesizing a frequency 305 for use by the mixer circuitry 302 and the mixer circuitry 314. The mixer circuitry 302 and/or 314 may each, according to some embodiments, be configured to provide direct conversion functionality. The latter type of circuitry presents a much simpler architecture as compared with standard super-heterodyne mixer circuitries, and any flicker noise brought about by the same may be alleviated for example through the use of OFDM modulation. Fig. 3 illustrates only a simplified version of a radio IC circuitry, and may include, although not shown, embodiments where each of the depicted circuitries may include more than one component. For instance, mixer circuitry 320 and/or 314 may each include one or more mixers, and filter circuitries 308 and/or 312 may each include one or more filters, such as one or more BPFs and/or LPFs according to application needs. For example, when

mixer circuitries are of the direct-conversion type, they may each include two or more mixers.

[0045] In some embodiments, mixer circuitry 302 may be configured to down-convert RF signals 207 received from the FEM circuitry 104 (FIG. 1) based on the synthesized frequency 305 provided by synthesizer circuitry 304. The amplifier circuitry 306 may be configured to amplify the down-converted signals and the filter circuitry 308 may include a LPF configured to remove unwanted signals from the down-converted signals to generate output baseband signals 307. Output baseband signals 307 may be provided to the baseband processing circuitry 108 (FIG. 1) for further processing. In some embodiments, the output baseband signals 307 may be zero-frequency baseband signals, although this is not a requirement. In some embodiments, mixer circuitry 302 may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[0046] In some embodiments, the mixer circuitry 314 may be configured to up-convert input baseband signals 311 based on the synthesized frequency 305 provided by the synthesizer circuitry 304 to generate RF output signals 209 for the FEM circuitry 104. The baseband signals 311 may be provided by the baseband processing circuitry 108 and may be filtered by filter circuitry 312. The filter circuitry 312 may include a LPF or a BPF, although the scope of the embodiments is not limited in this respect.

[0047] In some embodiments, the mixer circuitry 302 and the mixer circuitry 314 may each include two or more mixers and may be arranged for quadrature down-conversion and/or up-conversion respectively with the help of synthesizer 304. In some embodiments, the mixer circuitry 302 and the mixer circuitry 314 may each include two or more mixers each configured for image rejection (e.g., Hartley image rejection). In some embodiments, the mixer circuitry 302 and the mixer circuitry 314 may be arranged for direct down-conversion and/or direct up-conversion, respectively. In some embodiments, the mixer circuitry 302 and the mixer circuitry 314 may be configured for super-heterodyne operation, although this is not a requirement.

[0048] Mixer circuitry 302 may comprise, according to one embodiment: quadrature passive mixers (e.g., for the in-phase (I) and quadrature phase (Q)

paths). In such an embodiment, RF input signal 207 from Fig. 3 may be down-converted to provide I and Q baseband output signals to be sent to the baseband processor

[0049] Quadrature passive mixers may be driven by zero and ninety-degree time-varying LO switching signals provided by a quadrature circuitry which may be configured to receive a LO frequency (f_{LO}) from a local oscillator or a synthesizer, such as LO frequency 305 of synthesizer 304 (FIG. 3). In some embodiments, the LO frequency may be the carrier frequency, while in other embodiments, the LO frequency may be a fraction of the carrier frequency (e.g., one-half the carrier frequency, one-third the carrier frequency). In some embodiments, the zero and ninety-degree time-varying switching signals may be generated by the synthesizer, although the scope of the embodiments is not limited in this respect.

[0050] In some embodiments, the LO signals may differ in duty cycle (the percentage of one period in which the LO signal is high) and/or offset (the difference between start points of the period). In some embodiments, the LO signals may have a 25% duty cycle and a 50% offset. In some embodiments, each branch of the mixer circuitry (e.g., the in-phase (I) and quadrature phase (Q) path) may operate at a 25% duty cycle, which may result in a significant reduction is power consumption.

[0051] The RF input signal 207 (FIG. 2) may comprise a balanced signal, although the scope of the embodiments is not limited in this respect. The I and Q baseband output signals may be provided to low-nose amplifier, such as amplifier circuitry 306 (FIG. 3) or to filter circuitry 308 (FIG. 3).

[0052] In some embodiments, the output baseband signals 307 and the input baseband signals 311 may be analog baseband signals, although the scope of the embodiments is not limited in this respect. In some alternate embodiments, the output baseband signals 307 and the input baseband signals 311 may be digital baseband signals. In these alternate embodiments, the radio IC circuitry may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry.

[0053] In some dual-mode embodiments, a separate radio IC circuitry may be provided for processing signals for each spectrum, or for other spectrums

not mentioned here, although the scope of the embodiments is not limited in this respect.

[0054] In some embodiments, the synthesizer circuitry 304 may be a fractional-N synthesizer or a fractional N/N+1 synthesizer, although the scope of the embodiments is not limited in this respect as other types of frequency synthesizers may be suitable. For example, synthesizer circuitry 304 may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider. According to some embodiments, the synthesizer circuitry 304 may include digital synthesizer circuitry. An advantage of using a digital synthesizer circuitry is that, although it may still include some analog components, its footprint may be scaled down much more than the footprint of an analog synthesizer circuitry. In some embodiments, frequency input into synthesizer circuity 304 may be provided by a voltage controlled oscillator (VCO), although that is not a requirement. A divider control input may further be provided by either the baseband processing circuitry 108 (FIG. 1) or the application processor 111 (FIG. 1) depending on the desired output frequency 305. In some embodiments, a divider control input (e.g., N) may be determined from a look-up table (e.g., within a Wi-Fi card) based on a channel number and a channel center frequency as determined or indicated by the application processor 111.

[0055] In some embodiments, synthesizer circuitry 304 may be configured to generate a carrier frequency as the output frequency 305, while in other embodiments, the output frequency 305 may be a fraction of the carrier frequency (e.g., one-half the carrier frequency, one-third the carrier frequency). In some embodiments, the output frequency 305 may be a LO frequency (f_{LO}).

[0056] FIG. 4 illustrates a functional block diagram of baseband processing circuitry 400 in accordance with some embodiments. The baseband processing circuitry 400 is one example of circuitry that may be suitable for use as the baseband processing circuitry 108 (FIG. 1), although other circuitry configurations may also be suitable. The baseband processing circuitry 400 may include a receive baseband processor (RX BBP) 402 for processing receive baseband signals 309 provided by the radio IC circuitry 106 (FIG. 1) and a transmit baseband processor (TX BBP) 404 for generating transmit baseband

signals 311 for the radio IC circuitry 106. The baseband processing circuitry 400 may also include control logic 406 for coordinating the operations of the baseband processing circuitry 400.

[0057] In some embodiments (e.g., when analog baseband signals are exchanged between the baseband processing circuitry 400 and the radio IC circuitry 106), the baseband processing circuitry 400 may include ADC 410 to convert analog baseband signals received from the radio IC circuitry 106 to digital baseband signals for processing by the RX BBP 402. In these embodiments, the baseband processing circuitry 400 may also include DAC 412 to convert digital baseband signals from the TX BBP 404 to analog baseband signals.

[0058] In some embodiments that communicate OFDM signals or OFDMA signals, such as through baseband processor 108A, the transmit baseband processor 404 may be configured to generate OFDM or OFDMA signals as appropriate for transmission by performing an inverse fast Fourier transform (IFFT). The receive baseband processor 402 may be configured to process received OFDM signals or OFDMA signals by performing an FFT. In some embodiments, the receive baseband processor 402 may be configured to detect the presence of an OFDM signal or OFDMA signal by performing an autocorrelation, to detect a preamble, such as a short preamble, and by performing a cross-correlation, to detect a long preamble. The preambles may be part of a predetermined frame structure for Wi-Fi communication.

[0059] Referring to FIG. 1, in some embodiments, the antennas 101 (FIG. 1) may each comprise one or more directional or omnidirectional antennas, including, for example, dipole antennas, monopole antennas, patch antennas, loop antennas, microstrip antennas or other types of antennas suitable for transmission of RF signals. In some multiple-input multiple-output (MIMO) embodiments, the antennas may be effectively separated to take advantage of spatial diversity and the different channel characteristics that may result. Antennas 101 may each include a set of phased-array antennas, although embodiments are not so limited.

[0060] Although the radio-architecture 100 is illustrated as having several separate functional elements, one or more of the functional elements may

be combined and may be implemented by combinations of software-configured elements, such as processing elements including digital signal processors (DSPs), and/or other hardware elements. For example, some elements may comprise one or more microprocessors, DSPs, field-programmable gate arrays (FPGAs), application specific integrated circuits (ASICs), radio-frequency integrated circuits (RFICs) and combinations of various hardware and logic circuitry for performing at least the functions described herein. In some embodiments, the functional elements may refer to one or more processes operating on one or more processing elements.

[0061] FIG. 5 illustrates a WLAN 500 in accordance with some embodiments. The WLAN 500 may comprise a basis service set (BSS) that may include a HE access point (AP) 502, which may be an AP, a plurality of HE (e.g., IEEE 802.11ax) stations (STAs) 504, and a plurality of legacy (e.g., IEEE 802.11n/ac) devices 506. In some embodiments, the HE STAs 504 are configured to operate in accordance with extremely-high throughput (EHT), e.g., IEEE 802.11EHT. In some embodiments, the HE APs 502 are configured to operate in accordance with extremely-high throughput (EHT), e.g., IEEE 802.11EHT.

[0062] The HE AP 502 may be an AP using the IEEE 802.11 to transmit and receive. The HE AP 502 may be a base station. The HE AP 502 may use other communications protocols as well as the IEEE 802.11 protocol. The IEEE 802.11 protocol may be IEEE 802.11ax. The IEEE 802.11 protocol may include using orthogonal frequency division multiple-access (OFDMA), time division multiple access (TDMA), and/or code division multiple access (CDMA). The IEEE 802.11 protocol may include a multiple access technique. For example, the IEEE 802.11 protocol may include space-division multiple access (SDMA) and/or multiple-user multiple-input multiple-output (MU-MIMO). There may be more than one HE AP 502 that is part of an extended service set (ESS). A controller (not illustrated) may store information that is common to the more than one HE APs 502.

[0063] The legacy devices 506 may operate in accordance with one or more of IEEE 802.11 a/b/g/n/ac/ad/af/ah/aj/ay, or another legacy wireless communication standard. The legacy devices 506 may be STAs or IEEE STAs.

The HE STAs 504 may be wireless transmit and receive devices such as cellular telephone, portable electronic wireless communication devices, smart telephone, handheld wireless device, wireless glasses, wireless watch, wireless personal device, tablet, or another device that may be transmitting and receiving using the IEEE 802.11 protocol such as IEEE 802.11ax or another wireless protocol. In some embodiments, the HE STAs 504 may be termed high efficiency (HE) stations.

[0064] The HE AP 502 may communicate with legacy devices 506 in accordance with legacy IEEE 802.11 communication techniques. In example embodiments, the HE AP 502 may also be configured to communicate with HE STAs 504 in accordance with legacy IEEE 802.11 communication techniques.

[0065] In some embodiments, a HE frame may be configurable to have the same bandwidth as a channel. The HE frame may be a physical Layer Convergence Procedure (PLCP) Protocol Data Unit (PPDU). In some embodiments, there may be different types of PPDUs that may have different fields and different physical layers and/or different media access control (MAC) layers.

[0066] The bandwidth of a channel may be 20MHz, 40MHz, or 80MHz, 160MHz, 320MHz contiguous bandwidths or an 80+80MHz (160MHz) non-contiguous bandwidth. In some embodiments, the bandwidth of a channel may be 1 MHz, 1.25MHz, 2.03MHz, 2.5MHz, 4.06 MHz, 5MHz and 10MHz, or a combination thereof or another bandwidth that is less or equal to the available bandwidth may also be used. In some embodiments the bandwidth of the channels may be based on a number of active data subcarriers. In some embodiments the bandwidth of the channels is based on 26, 52, 106, 242, 484, 996, or 2x996 active data subcarriers or tones that are spaced by 20 MHz. In some embodiments the bandwidth of the channels is 256 tones spaced by 20 MHz. In some embodiments the channels are multiple of 26 tones or a multiple of 20 MHz. In some embodiments a 20 MHz channel may comprise 242 active data subcarriers or tones, which may determine the size of a Fast Fourier Transform (FFT). An allocation of a bandwidth or a number of tones or sub-carriers may be termed a resource unit (RU) allocation in accordance with some embodiments.

[0067] In some embodiments, the 26-subcarrier RU and 52-subcarrier RU are used in the 20 MHz, 40 MHz, 80 MHz, 160 MHz and 80+80 MHz OFDMA HE PPDU formats. In some embodiments, the 106-subcarrier RU is used in the 20 MHz, 40 MHz, 80 MHz, 160 MHz and 80+80 MHz OFDMA and MU-MIMO HE PPDU formats. In some embodiments, the 242-subcarrier RU is used in the 40 MHz, 80 MHz, 160 MHz and 80+80 MHz OFDMA and MU-MIMO HE PPDU formats. In some embodiments, the 484-subcarrier RU is used in the 80 MHz, 160 MHz and 80+80 MHz OFDMA and MU-MIMO HE PPDU formats. In some embodiments, the 996-subcarrier RU is used in the 160 MHz and 80+80 MHz OFDMA and MU-MIMO HE PPDU formats.

[0068] A HE frame may be configured for transmitting a number of spatial streams, which may be in accordance with MU-MIMO and may be in accordance with OFDMA. In other embodiments, the HE AP 502, HE STA 504, and/or legacy device 506 may also implement different technologies such as code division multiple access (CDMA) 2000, CDMA 2000 1X, CDMA 2000 Evolution-Data Optimized (EV-DO), Interim Standard 2000 (IS-2000), Interim Standard 95 (IS-95), Interim Standard 856 (IS-856), Long Term Evolution (LTE), Global System for Mobile communications (GSM), Enhanced Data rates for GSM Evolution (EDGE), GSM EDGE (GERAN), IEEE 802.16 (i.e., Worldwide Interoperability for Microwave Access (WiMAX)), BlueTooth®, or other technologies.

[0069] Some embodiments relate to HE communications. In accordance with some IEEE 802.11 embodiments, e.g, IEEE 802.11ax embodiments, a HE AP 502 may operate as a master station which may be arranged to contend for a wireless medium (e.g., during a contention period) to receive exclusive control of the medium for an HE control period. In some embodiments, the HE control period may be termed a transmission opportunity (TXOP). The HE AP 502 may transmit a HE master-sync transmission, which may be a trigger frame or HE control and schedule transmission, at the beginning of the HE control period. The HE AP 502 may transmit a time duration of the TXOP and sub-channel information. During the HE control period, HE STAs 504 may communicate with the HE AP 502 in accordance with a non-contention based multiple access technique such as OFDMA or MU-MIMO. This is unlike conventional WLAN

communications in which devices communicate in accordance with a contention-based communication technique, rather than a multiple access technique. During the HE control period, the HE AP 502 may communicate with HE stations 504 using one or more HE frames. During the HE control period, the HE STAs 504 may operate on a sub-channel smaller than the operating range of the HE AP 502. During the HE control period, legacy stations refrain from communicating. The legacy stations may need to receive the communication from the HE AP 502 to defer from communicating.

[0070] In accordance with some embodiments, during the TXOP the HE STAs 504 may contend for the wireless medium with the legacy devices 506 being excluded from contending for the wireless medium during the master-sync transmission. In some embodiments the trigger frame may indicate an uplink (UL) UL-MU-MIMO and/or UL OFDMA TXOP. In some embodiments, the trigger frame may include a DL UL-MU-MIMO and/or DL OFDMA with a schedule indicated in a preamble portion of trigger frame.

[0071] In some embodiments, the multiple-access technique used during the HE TXOP may be a scheduled OFDMA technique, although this is not a requirement. In some embodiments, the multiple access technique may be a time-division multiple access (TDMA) technique or a frequency division multiple access (FDMA) technique. In some embodiments, the multiple access technique may be a space-division multiple access (SDMA) technique. In some embodiments, the multiple access technique may be a Code division multiple access (CDMA).

[0072] The HE AP 502 may also communicate with legacy stations 506 and/or HE stations 504 in accordance with legacy IEEE 802.11 communication techniques. In some embodiments, the HE AP 502 may also be configurable to communicate with HE stations 504 outside the HE TXOP in accordance with legacy IEEE 802.11 communication techniques, although this is not a requirement.

[0073] In some embodiments the HE station 504 may be a "group owner" (GO) for peer-to-peer modes of operation. A wireless device may be a HE station 502 or a HE AP 502.

[0074] In some embodiments, the HE station 504 and/or HE AP 502 may be configured to operate in accordance with IEEE 802.11mc. In example embodiments, the radio architecture of FIG. 1 is configured to implement the HE station 504 and/or the HE AP 502. In example embodiments, the front-end module circuitry of FIG. 2 is configured to implement the HE station 504 and/or the HE AP 502. In example embodiments, the radio IC circuitry of FIG. 3 is configured to implement the HE station 504 and/or the HE AP 502. In example embodiments, the base-band processing circuitry of FIG. 4 is configured to implement the HE station 504 and/or the HE AP 502.

[0075] In example embodiments, the HE stations 504, HE AP 502, an apparatus of the HE stations 504, and/or an apparatus of the HE AP 502 may include one or more of the following: the radio architecture of FIG. 1, the front-end module circuitry of FIG. 2, the radio IC circuitry of FIG. 3, and/or the base-band processing circuitry of FIG. 4.

[0076] In example embodiments, the radio architecture of FIG. 1, the front-end module circuitry of FIG. 2, the radio IC circuitry of FIG. 3, and/or the base-band processing circuitry of FIG. 4 may be configured to perform the methods and operations/functions herein described in conjunction with FIGS. 1-20.

[0077] In example embodiments, the HE station 504 and/or the HE AP 502 are configured to perform the methods and operations/functions described herein in conjunction with FIGS. 1-20. In example embodiments, an apparatus of the HE station 504 and/or an apparatus of the HE AP 502 are configured to perform the methods and functions described herein in conjunction with FIGS. 1-20. The term Wi-Fi may refer to one or more of the IEEE 802.11 communication standards. AP and STA may refer to HE access point 502 and/or HE station 504 as well as legacy devices 506.

[0078] In some embodiments, a HE AP STA may refer to a HE AP 502 and a HE STAs 504 that is operating a HE APs 502. In some embodiments, when an HE STA 504 is not operating as a HE AP, it may be referred to as a HE non-AP STA or HE non-AP. In some embodiments, HE STA 504 may be referred to as either a HE AP STA or a HE non-AP.

[0079] FIG. 6 illustrates a block diagram of an example machine 600 upon which any one or more of the techniques (e.g., methodologies) discussed herein may perform. In alternative embodiments, the machine 600 may operate as a standalone device or may be connected (e.g., networked) to other machines. In a networked deployment, the machine 600 may operate in the capacity of a server machine, a client machine, or both in server-client network environments. In an example, the machine 600 may act as a peer machine in peer-to-peer (P2P) (or other distributed) network environment. The machine 600 may be a HE AP 502, HE station 504, personal computer (PC), a tablet PC, a set-top box (STB), a personal digital assistant (PDA), a portable communications device, a mobile telephone, a smart phone, a web appliance, a network router, switch or bridge, or any machine capable of executing instructions (sequential or otherwise) that specify actions to be taken by that machine. Further, while only a single machine is illustrated, the term "machine" shall also be taken to include any collection of machines that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein, such as cloud computing, software as a service (SaaS), other computer cluster configurations.

[0080] Machine (e.g., computer system) 600 may include a hardware processor 602 (e.g., a central processing unit (CPU), a graphics processing unit (GPU), a hardware processor core, or any combination thereof), a main memory 604 and a static memory 606, some or all of which may communicate with each other via an interlink (e.g., bus) 608.

[0081] Specific examples of main memory 604 include Random Access Memory (RAM), and semiconductor memory devices, which may include, in some embodiments, storage locations in semiconductors such as registers. Specific examples of static memory 606 include non-volatile memory, such as semiconductor memory devices (e.g., Electrically Programmable Read-Only Memory (EPROM), Electrically Erasable Programmable Read-Only Memory (EEPROM)) and flash memory devices; magnetic disks, such as internal hard disks and removable disks; magneto-optical disks; RAM; and CD-ROM and DVD-ROM disks.

[0082] The machine 600 may further include a display device 610, an input device 612 (e.g., a keyboard), and a user interface (UI) navigation device 614 (e.g., a mouse). In an example, the display device 610, input device 612 and UI navigation device 614 may be a touch screen display. The machine 600 may additionally include a mass storage (e.g., drive unit) 616, a signal generation device 618 (e.g., a speaker), a network interface device 620, and one or more sensors 621, such as a global positioning system (GPS) sensor, compass, accelerometer, or other sensor. The machine 600 may include an output controller 628, such as a serial (e.g., universal serial bus (USB), parallel, or other wired or wireless (e.g., infrared(IR), near field communication (NFC), etc.) connection to communicate or control one or more peripheral devices (e.g., a printer, card reader, etc.). In some embodiments the processor 602 and/or instructions 624 may comprise processing circuitry and/or transceiver circuitry.

[0083] The storage device 616 may include a machine readable medium 622 on which is stored one or more sets of data structures or instructions 624 (e.g., software) embodying or utilized by any one or more of the techniques or functions described herein. The instructions 624 may also reside, completely or at least partially, within the main memory 604, within static memory 606, or within the hardware processor 602 during execution thereof by the machine 600. In an example, one or any combination of the hardware processor 602, the main memory 604, the static memory 606, or the storage device 616 may constitute machine readable media.

[0084] Specific examples of machine readable media may include: non-volatile memory, such as semiconductor memory devices (e.g., EPROM or EEPROM) and flash memory devices; magnetic disks, such as internal hard disks and removable disks; magneto-optical disks; RAM; and CD-ROM and DVD-ROM disks.

[0085] While the machine readable medium 622 is illustrated as a single medium, the term "machine readable medium" may include a single medium or multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) configured to store the one or more instructions 624.

[0086] An apparatus of the machine 600 may be one or more of a hardware processor 602 (e.g., a central processing unit (CPU), a graphics

processing unit (GPU), a hardware processor core, or any combination thereof), a main memory 604 and a static memory 606, sensors 621, network interface device 620, antennas 660, a display device 610, an input device 612, a UI navigation device 614, a mass storage 616, instructions 624, a signal generation device 618, and an output controller 628. The apparatus may be configured to perform one or more of the methods and/or operations disclosed herein. The apparatus may be intended as a component of the machine 600 to perform one or more of the methods and/or operations disclosed herein, and/or to perform a portion of one or more of the methods and/or operations disclosed herein. In some embodiments, the apparatus may include a pin or other means to receive power. In some embodiments, the apparatus may include power conditioning hardware.

[0087] The term "machine readable medium" may include any medium that is capable of storing, encoding, or carrying instructions for execution by the machine 600 and that cause the machine 600 to perform any one or more of the techniques of the present disclosure, or that is capable of storing, encoding or carrying data structures used by or associated with such instructions. Non-limiting machine readable medium examples may include solid-state memories, and optical and magnetic media. Specific examples of machine readable media may include: non-volatile memory, such as semiconductor memory devices (e.g., Electrically Programmable Read-Only Memory (EPROM), Electrically Erasable Programmable Read-Only Memory (EEPROM)) and flash memory devices; magnetic disks, such as internal hard disks and removable disks; magneto-optical disks; Random Access Memory (RAM); and CD-ROM and DVD-ROM disks. In some examples, machine readable media may include non-transitory machine-readable media. In some examples, machine readable media may include machine readable media that is not a transitory propagating signal.

[0088] The instructions 624 may further be transmitted or received over a communications network 626 using a transmission medium via the network interface device 620 utilizing any one of a number of transfer protocols (e.g., frame relay, internet protocol (IP), transmission control protocol (TCP), user datagram protocol (UDP), hypertext transfer protocol (HTTP), etc.). Example communication networks may include a local area network (LAN), a wide area

network (WAN), a packet data network (e.g., the Internet), mobile telephone networks (e.g., cellular networks), Plain Old Telephone (POTS) networks, and wireless data networks (e.g., Institute of Electrical and Electronics Engineers (IEEE) 802.11 family of standards known as Wi-Fi®, IEEE 802.16 family of standards known as WiMax®), IEEE 802.15.4 family of standards, a Long Term Evolution (LTE) family of standards, a Universal Mobile Telecommunications System (UMTS) family of standards, peer-to-peer (P2P) networks, among others.

[0089] In an example, the network interface device 620 may include one or more physical jacks (e.g., Ethernet, coaxial, or phone jacks) or one or more antennas to connect to the communications network 626. In an example, the network interface device 620 may include one or more antennas 660 to wirelessly communicate using at least one of single-input multiple-output (SIMO), multiple-input multiple-output (MIMO), or multiple-input single-output (MISO) techniques. In some examples, the network interface device 620 may wirelessly communicate using Multiple User MIMO techniques. The term "transmission medium" shall be taken to include any intangible medium that is capable of storing, encoding or carrying instructions for execution by the machine 600, and includes digital or analog communications signals or other intangible medium to facilitate communication of such software.

[0090] Examples, as described herein, may include, or may operate on, logic or a number of components, modules, or mechanisms. Modules are tangible entities (e.g., hardware) capable of performing specified operations and may be configured or arranged in a certain manner. In an example, circuits may be arranged (e.g., internally or with respect to external entities such as other circuits) in a specified manner as a module. In an example, the whole or part of one or more computer systems (e.g., a standalone, client or server computer system) or one or more hardware processors may be configured by firmware or software (e.g., instructions, an application portion, or an application) as a module that operates to perform specified operations. In an example, the software may reside on a machine readable medium. In an example, the software, when executed by the underlying hardware of the module, causes the hardware to perform the specified operations.

[0091] Accordingly, the term "module" is understood to encompass a tangible entity, be that an entity that is physically constructed, specifically configured (e.g., hardwired), or temporarily (e.g., transitorily) configured (e.g., programmed) to operate in a specified manner or to perform part or all of any operation described herein. Considering examples in which modules are temporarily configured, each of the modules need not be instantiated at any one moment in time. For example, where the modules comprise a general-purpose hardware processor configured using software, the general-purpose hardware processor may be configured as respective different modules at different times. Software may accordingly configure a hardware processor, for example, to constitute a particular module at one instance of time and to constitute a different module at a different instance of time.

[0092] Some embodiments may be implemented fully or partially in software and/or firmware. This software and/or firmware may take the form of instructions contained in or on a non-transitory computer-readable storage medium. Those instructions may then be read and executed by one or more processors to enable performance of the operations described herein. The instructions may be in any suitable form, such as but not limited to source code, compiled code, interpreted code, executable code, static code, dynamic code, and the like. Such a computer-readable medium may include any tangible non-transitory medium for storing information in a form readable by one or more computers, such as but not limited to read only memory (ROM); random access memory (RAM); magnetic disk storage media; optical storage media; flash memory, etc.

[0093] FIG. 7 illustrates a block diagram of an example wireless device 700 upon which any one or more of the techniques (e.g., methodologies or operations) discussed herein may perform. The wireless device 700 may be a HE device. The wireless device 700 may be a HE STA 504 and/or HE AP 502 (e.g., FIG. 5). A HE STA 504 and/or HE AP 502 may include some or all of the components shown in FIGS. 1-7. The wireless device 700 may be an example machine 600 as disclosed in conjunction with FIG. 6.

[0094] The wireless device 700 may include processing circuitry 708. The processing circuitry 708 may include a transceiver 702, physical layer

circuitry (PHY circuitry) 704, and MAC layer circuitry (MAC circuitry) 706, one or more of which may enable transmission and reception of signals to and from other wireless devices 700 (e.g., HE AP 502, HE STA 504, and/or legacy devices 506) using one or more antennas 712. As an example, the PHY circuitry 704 may perform various encoding and decoding functions that may include formation of baseband signals for transmission and decoding of received signals. As another example, the transceiver 702 may perform various transmission and reception functions such as conversion of signals between a baseband range and a Radio Frequency (RF) range.

[0095] Accordingly, the PHY circuitry 704 and the transceiver 702 may be separate components or may be part of a combined component, e.g., processing circuitry 708. In addition, some of the described functionality related to transmission and reception of signals may be performed by a combination that may include one, any or all of the PHY circuitry 704 the transceiver 702, MAC circuitry 706, memory 710, and other components or layers. The MAC circuitry 706 may control access to the wireless medium. The wireless device 700 may also include memory 710 arranged to perform the operations described herein, e.g., some of the operations described herein may be performed by instructions stored in the memory 710.

[0096] The antennas 712 (some embodiments may include only one antenna) may comprise one or more directional or omnidirectional antennas, including, for example, dipole antennas, monopole antennas, patch antennas, loop antennas, microstrip antennas or other types of antennas suitable for transmission of RF signals. In some multiple-input multiple-output (MIMO) embodiments, the antennas 712 may be effectively separated to take advantage of spatial diversity and the different channel characteristics that may result.

[0097] One or more of the memory 710, the transceiver 702, the PHY circuitry 704, the MAC circuitry 706, the antennas 712, and/or the processing circuitry 708 may be coupled with one another. Moreover, although memory 710, the transceiver 702, the PHY circuitry 704, the MAC circuitry 706, the antennas 712 are illustrated as separate components, one or more of memory 710, the transceiver 702, the PHY circuitry 704, the MAC circuitry 706, the antennas 712 may be integrated in an electronic package or chip.

[0098] In some embodiments, the wireless device 700 may be a mobile device as described in conjunction with FIG. 6. In some embodiments the wireless device 700 may be configured to operate in accordance with one or more wireless communication standards as described herein (e.g., as described in conjunction with FIGS. 1-6, IEEE 802.11). In some embodiments, the wireless device 700 may include one or more of the components as described in conjunction with FIG. 6 (e.g., display device 610, input device 612, etc.) Although the wireless device 700 is illustrated as having several separate functional elements, one or more of the functional elements may be combined and may be implemented by combinations of software-configured elements, such as processing elements including digital signal processors (DSPs), and/or other hardware elements. For example, some elements may comprise one or more microprocessors, DSPs, field-programmable gate arrays (FPGAs), application specific integrated circuits (ASICs), radio-frequency integrated circuits (RFICs) and combinations of various hardware and logic circuitry for performing at least the functions described herein. In some embodiments, the functional elements may refer to one or more processes operating on one or more processing elements.

[0099] In some embodiments, an apparatus of or used by the wireless device 700 may include various components of the wireless device 700 as shown in FIG. 7 and/or components from FIGS. 1-6. Accordingly, techniques and operations described herein that refer to the wireless device 700 may be applicable to an apparatus for a wireless device 700 (e.g., HE AP 502 and/or HE STA 504), in some embodiments. In some embodiments, the wireless device 700 is configured to decode and/or encode signals, packets, and/or frames as described herein, e.g., PPDUs.

[00100] In some embodiments, the MAC circuitry 706 may be arranged to contend for a wireless medium during a contention period to receive control of the medium for a HE TXOP and encode or decode an HE PPDU. In some embodiments, the MAC circuitry 706 may be arranged to contend for the wireless medium based on channel contention settings, a transmitting power level, and a clear channel assessment level (e.g., an energy detect level).

[00101] The PHY circuitry 704 may be arranged to transmit signals in accordance with one or more communication standards described herein. For example, the PHY circuitry 704 may be configured to transmit a HE PPDU. The PHY circuitry 704 may include circuitry for modulation/demodulation, upconversion/downconversion, filtering, amplification, etc. In some embodiments, the processing circuitry 708 may include one or more processors. The processing circuitry 708 may be configured to perform functions based on instructions being stored in a RAM or ROM, or based on special purpose circuitry. The processing circuitry 708 may include a processor such as a general purpose processor or special purpose processor. The processing circuitry 708 may implement one or more functions associated with antennas 712, the transceiver 702, the PHY circuitry 704, the MAC circuitry 706, and/or the memory 710. In some embodiments, the processing circuitry 708 may be configured to perform one or more of the functions/operations and/or methods described herein.

[00102] In mmWave technology, communication between a station (e.g., the HE stations 504 of FIG. 5 or wireless device 700) and an access point (e.g., the HE AP 502 of FIG. 5 or wireless device 700) may use associated effective wireless channels that are highly directionally dependent. To accommodate the directionality, beamforming techniques may be utilized to radiate energy in a certain direction with certain beamwidth to communicate between two devices. The directed propagation concentrates transmitted energy toward a target device in order to compensate for significant energy loss in the channel between the two communicating devices. Using directed transmission may extend the range of the millimeter-wave communication versus utilizing the same transmitted energy in omni-directional propagation.

[00103] FIG. 8 illustrates a method of service period (SP) scheduling in accordance with some embodiments. Illustrated in FIG. 8 is time 802 along a horizontal axis, beacon frames 804, null data packet (NDP) feedback report trigger 806, a traffic indication map 808, SP 810, beacon interval (BI) 812, SP duration 814, and SP start 816. The beacon frame 804 may be a beacon frame 804 that includes information such as a beacon interval, e.g., 100 ms, capability

information, service set identifier (SSI), TIM, HE capabilities, HE operation, TWT, etc.

[00104] The NDP 806 may include multiple transmissions, e.g., from an HE AP 502 and one or more HE STAs 504. The NDP 806 may include a NDP feedback report poll (NFRP) trigger frame (TF). A HE AP 502 may transmit the NFRP TF. NDP 806 may include a response to the NFRP TF. For example, NDP feedback report responses from HE STAs 504. NDP 806 may further include a multiple BA frames (or Ack frames) in an HE MU PPDU, or a Multi-STA BA frame for the HE AP 502 to acknowledge the NDP feedback report responses from the HE STAs 504. In some embodiments, the multi-STA BA frame may be the same or similar to the block acknowledgement frame 1500 as disclosed in conjunction with FIG. 15. The NDPs 806 may be transmitted at the beginning of each SP 810. The NDPs 806 may be transmitted at the beginning of each BI. The NDPs 806 may be transmitted every Nth SP 810. The NDPs 806 may be the same or similar as block acknowledgements with schedules 1800 as disclosed in conjunction with FIG. 18. The NDP 806 may include one or more additional transmissions from an HE AP 502 and/or HE STA 504. The NDP 806 may include different transmissions than the example transmissions disclosed above.

[00105] The TIMs 808 may be transmitted by a HE AP 502 to one or more HE STAs 504. The TIM 808 may be the same or similar as TIM element 1400 or another TIM element.

[00106] The SPs 810 may have IDs 820. The SPs 810 may have a SP Start 816 time and a SP duration 814. A BI 812 may be divided into a number of SPs 810, e.g., a BI 812 may be 100 ms or 100 time unites (TUs) and each SP duration 814 may be 12.5 ms or TUs. In some embodiments, one TU is 1024 μs. The IDs 820 may be integer numbers for the SPs 810. In some embodiments, the SPs 810 do not include IDs 820. In some embodiments, the SP durations 814 may all be the same duration. HE STAs 504 and/or HE APs 502 may be configured to determine SP start 816 or when to transmit and/or wake-up based on IDs 820. For example, if a HE STA 504 is scheduled for a SP 810 that has an ID 820 value of 3, then the HE STA 504 may multiply the SP duration 814 by three and add that to the SP start 816 for the first SP 810 after the beacon frame

804. The ID 820 may be a field with a number of bits, e.g., 1 to 8. The number actually represented by the bits of the field representing the ID 820 may be different than an actually number, e.g., an actually number of SPs 810 may be one more than represented by the field of the ID 820. Other offsets are possible, e.g., +2, -1, 2^x, etc. The durations of the BI 812 and SP duration 814 may be in TUs.

[00107] The BI 812 may be a duration that is indicated in the beacon frame 804 or another frame. The BI 812 may be a duration such as 10 to 500 ms. In some embodiments, the BI 812 may have a default value. The BI 812 may start after the beacon frame 804 is transmitted in some embodiments. The BI 812 may begin at a target beacon transmission time, in accordance with some embodiments. The BI 812 may begin when the beacon frame 804 is actually transmitted or the transmission of the beacon frame 804 begins, in accordance with some embodiments. In some embodiments, the HE AP 502 and HE STAs 504 transmit/receive the beacon frame 804, NDPs 806 and/or TIMs 808 in the 6 GHz to 7 GHz band.

[00108] Scheduling a NDP 806 followed by a TIM 808 may have the benefit of enabling the HE AP 502 to determine a TIM 808 based on which HE STAs 504 are actually awake and/or based on which HE STAs 504 have uplink (UL) traffic for the HE AP 502. In some embodiments, a NDP 806 may include a block acknowledgement frame 1500 as disclosed in conjunction with FIG. 15 that includes scheduling information for the HE STAs 504. Transmitting the multi-STA BA frame 1500 may have the benefit of enabling the HE AP 502 to determine a TIM 808 based on which HE STAs 504 are actually awake and/or based on which HE STAs 504 have uplink (UL) traffic for the HE AP 502.

[00109] FIG. 9 illustrates target wake time (TWT) setup methods 900 in accordance with some embodiments. Illustrated in FIG. 9 is time 902 along a horizontal axis, individual TWT method 904, broadcast TWT method 906, transmitter/receiver 908, channel 910, HE AP 502, HE STAs 504.1 through 504.N, and operations 950 along the top.

[00110] The channels 910 may be a band or sub-band of a frequency and/or a number of symbols, tones, or subcarriers. The channels 910 may be the same sub-band or different sub-bands. The channels 910 may be sub-channels

of one another. The method 904 may begin with operation 952 with a HE STA 504.N transmitting TWT request 920. The TWT request 920 may be a PPDU that includes TWT element 1000, TWT element 1100, TWT element 1200, and/or TWT element 1300. The TWT request 920 may be an individual TWT request. The HE AP 502 may receive the TWT request 920 and determine TWT response 922.

[00111] The method 904 continues at operation 954 with the HE AP 502 transmitting the TWT response 922. The TWT response 922 may be a PPDU that includes TWT element 1000, TWT element 1100, TWT element 1200, and/or TWT element 1300. The TWT response 922 may include an indication that a proposed TWT agreement is accepted by the HE AP 502. The method 904 may include additional operations where a TWT agreement is negotiated between the HE AP 502 and the HE STA 504.N, e.g., HE STA 504.N may transmit an acknowledgement of TWT response 922. As another example, the HE AP 502 may transmit the TWT request 920 to the HE STA 504. As another example, the HE AP 500 may respond with a counter offer to the HE STA 504. The TWT request 920 and/or TWT response 922 may include information as disclosed herein to indicate SPs 810, BI 812, NDP 806, and/or TIM 808 as illustrated in FIG. 8.

[00112] The method 906 begins with operation 956 with the HE AP 502 transmitting a broadcast TWT 924 to the HE STAs 504.1 through 504.N. The broadcast TWT 924 may be a PPDU that includes TWT element 1000, TWT element 1100, TWT element 1200, and/or TWT element 1300. The broadcast TWT 924 may include information as disclosed herein to indicate SPs 810, BI 812, NDP 806, and/or TIM 808 as illustrated in FIG. 8. In some embodiments, the HE STAs 504.1 through HE STA 504.N may transmit an acknowledgment to the HE AP 502. Method 906 may include one or more additional operations. For example, a HE STA 504 may transmit a counter offer or TWT request 920 in response to the broadcast TWT 924.

[00113] HE STAs 504 that are requesting a TWT agreement (e.g., transmit TWT request 920) may be termed TWT requesting STAs, in accordance with some embodiments. HE APs 502 and/or HE STA 504 that respond to requests for TWT agreements (e.g., TWT response 922) may be termed TWT

responding STAs, in accordance with some embodiments. Between the transmissions of the PPDUs, e.g., 920 and 922, there may be an interframe space, e.g., short interframe space (SIFS).

[00114] FIG. 10 illustrates a TWT element 1000 in accordance with some embodiments. Illustrated in FIG. 10 is element identification (ID) field 1002, length field 1004, control field 1006, and TWT parameter information field 1008. The element ID field 1002 may be an ID that identifies the element as a TWT element 1000. The length field 1004 may be a length of the TWT element 1000. The control field 1006 may include information regarding the control of the TWT element 1000. For example, the control field 1006 may indicate whether the TWT element 1000 is for broadcast to multiple HE STAs 504 or for an individual HE STA 1004. The TWT parameter information field 1008 may include one or more individual TWT parameter set fields and/or one or more broadcast TWT parameter set fields, in accordance with some embodiments. The TWT element 1000 may be included in an association response, re-association response, beacon frame, management frame, fast initial link setup (FILS) discovery frame, a probe response from the HE AP 502, or another frame or PPDU. The wireless devices that exchange TWT elements 1000 may be termed TWT requesting STA and TWT responding STA, in accordance with some embodiments. The TWT element 1000 may comprise one or more additional fields not indicated in FIG. 10. The TWT element 1000 may not include one or more of the illustrated fields, in accordance with some embodiments.

[00115] FIG. 11 illustrates a TWT element 1100 in accordance with some embodiments. The TWT element 1100 comprises element ID 1102, length 1104, control 1106, and TWT parameter information 1108. The element ID 1102 may be the same or similar as element ID 1002. The length 1004 may be the same or similar as length 1004. The control field 1006 may be the same or similar as control field 1006. The TWT parameter information 1008 may be the same or similar as TWT parameter information 1008. The TWT parameter information 1108 comprises two parameter sets 1101. The number of parameter sets 1110 may be different. The parameter sets 1110 may be an individual

parameter set field or a broadcast TWT parameter set field, in accordance with some embodiments.

[00116] Parameter sets 1110 may each include flow ID field 1112, start time field 1114, duration field 1116, and interval field 1118. The flow ID field 1112 may indicate a type of flow, e.g., a frame or transmission. For example, flow ID field 1112.1 may indicate NDP 806 and flow ID 1112.2 may indicate TIM 808. The flow ID 1112 may indicate other transmissions and/or periods from the HE AP 502. Start time 1114 may indicate a start of the transmission indicated by the flow ID 1112. For example, the start time may be based on the BI 812 and a time after the transmission of the beacon frame 804 or beginning of the BI 812. For example, a zero may indicate a transmission time of an interframe space after the transmission of the beacon frame 804. The start time field 1114 may indicate a TWT for the HE STA 504 or HE STAs 504. The duration field 1116 may indicate a duration of a TWT wait period of SP 810 of the transmission or period. The duration field 1116 may indicate a duration of a TWT wake duration or a SP 810. In some embodiments, the flow ID field 1112 may indicate (e.g., a value of 4) no constraints on the frames transmitted during a broadcast TWT SP, e.g., SP 810. In some embodiments, the flow ID field 1112 may indicate that the HE AP 502 transmits an NDP feedback report poll variant Trigger Frame (e.g., 806) at the beginning of the TWT SP, e.g., SP 810.1, SP 810.2, etc.

[00117] The interval field 1118 may indicate an interval between the TWT wake durations or SPs 810. The order of the parameter sets 1110 may indicate the order of the transmissions indicated by the flow ID field 1112. For example, referring to FIG. 8, parameter set 1 1110.1 may indicate NDP 806 and parameter set 2 1110.2 may indicate TIM 808. If parameter set 1 1110.1 and parameter set 2 1110.2 were ordered with parameter set 1 1110.1 being second, then it would indicate that the TIM 808 would be transmitted first and then the NDP 806. In an example, the flow ID 1112.1 may indicate a value of four (4) for NDP 806. The start time field 1114.1 may have a value of zero. The duration field 1116.1 may have a value of 12.5 ms. The interval field 1118 may have a value of 12.5 ms. The flow ID 1112.2 may be 2 for TIM 808. The start

time field 1114.2 may have a value of zero. The duration field 1116.2 may have a value of 12.5 ms. The interval field 1118 may have a value of 12.5 ms.

[00118] In some embodiments, the HE STA 504 may determine a number of SPs 810 based on a BI 812 divided by the value of the interval field 1118. For example, the BI 812 may be 100 TUs and the value of the interval field 1118 may be 12.5 ms so that there would be eight SPs 816 each of 12.5 ms duration. In some embodiments, the TWT parameter information 1108 and/or parameter sets 1110 may include a field to indicate that the frame and/or transmission indicated by the flow ID 1112 is to be transmitted at the beginning of a BI 812. In some embodiments, the one or more of the fields may include two or more fields that may be used to determine a value, e.g., the duration field 1116 may include two fields nominal minimum TWT wake duration and TWT wake interval mantissa.

[00119] FIG. 12 illustrates a TWT element 1200 in accordance with some embodiments. The TWT element 1200 comprises element ID field 1202, length field 1204, control field 1206, and TWT parameter information field 1208. The element ID field 1202 may be the same or similar as element ID field 1002. The length field 1004 may be the same or similar as length field 1004. The control field 1206 may be the same or similar as control field 1006. The TWT parameter information field 1208 may be the same or similar as TWT parameter information field 1008. The TWT parameter information field 1208 may be the same or similar to TWT parameter information field 1108. The TWT parameter information field 1208 may include BI frames field 1210.

[00120] In some embodiments BI frames field 1210 includes one or more frame fields 1212.1 through 1212.N. Each frame field 1212 may include information regarding frames (or PPDU) that are transmitted at the start of a BI 812 and/or SP 810. For example, frame 1 field 1212.1 may include information that NDP 806 will be transmitted. A frame 2 field 1212.2 may indicate that TIM 808 may be transmitted. The frame fields 1212 may include a length of the field. The BI frames field 1210 may include an element ID that identifies the field as a BI frames field 1210. In some embodiments, BI frames field 1210 includes an indication of the order the frames indicated by frame fields 1212 are transmitted. In some embodiments, the order the frames indicated by the frame fields 1212

are transmitted is based on the ordering of the frame fields 1212, e.g., first frame field 1212 is transmitted first, etc. In some embodiments, the frame fields 1212 include one or more of flow ID (e.g., 1112), start time (e.g., 1114), duration (e.g., 1116), and/or interval (e.g., 1118).

[00121] In some embodiments the BI frames 1210 includes an indication of the duration of the SPs 810 (FIG. 8) of the BI 812. The frame fields 1212, TWT parameter information 1308, and/or individual TWT parameter set 1310 may include information regarding the SPs 810, e.g., start time field 1114, duration field 1116, and interval field 1118 as disclosed in conjunction with FIG. 11. In some embodiments the frames 1212 include a flow ID field (e.g., 1112), which may indicate (e.g., a value of 4) no constraints on the frames transmitted during a broadcast TWT SP, e.g., SP 810. The HE AP 502 transmits an NDP feedback report poll variant Trigger Frame (e.g., 806) at the beginning of the TWT SP, e.g., SP 810.1, SP 810.2, etc.

[00122] In some embodiments a new element ID 1202 is used to indicate the element comprises BI frames 1210. In some embodiments, the control field 1206 includes an indication that the TWT parameter information 1208 includes BI frames 1210.

[00123] FIG. 13 illustrates a TWT element 1300 in accordance with some embodiments. The TWT element 1300 comprises element ID 1302, length 1304, control 1306, and TWT parameter information 1308. The element ID 1302 may be the same or similar as element ID 1002. The length 1304 may be the same or similar as length 1004. The control field 1306 may be the same or similar as control field 1006. The TWT parameter information 1308 may be the same or similar as TWT parameter information 1008. The TWT parameter information 1308 may include individual TWT parameter set 1310, which may be for an individual TWT negotiation. The individual TWT parameter set field 1310 may include a SP 1312. The SP field 1312 may include an identification, e.g., ID 820 (FIG. 8). The SP field 1312 may indicate a specific ID such as twenty. The SP field 1312 may indicate a specific ID per BI 812, e.g., SP2 810. The SP field 1312 may indicate every nth (e.g., 2nd, 3rd, etc.) SP 810. The SP field 1312, TWT parameter information 1308, and/or individual TWT parameter set 1310 may include information regarding the SPs 810, e.g., start time field

1114, duration field 1116, and interval field 1118 as described in conjunction with FIG. 11.

[00124] In some embodiments, the individual TWT parameter set 1310 may include a flow ID field (e.g., 1112), which may indicate (e.g., a value of 4) no constraints on the frames transmitted during a broadcast TWT SP, e.g., SP 810. The HE AP 502 transmits an NDP feedback report poll variant Trigger Frame (e.g., 806) at the beginning of the TWT SP, e.g., SP 810.1, SP 810.2, etc.

[00125] A HE AP 502 may negotiate the individual TWT parameter set 1310 with one or more HE STAs 504. The individual TWT parameter set 1310 may include a field that indicates the type of agreement is based on SP field 1312. The element ID 1302 and/or control field 1306 may include an indication that the individual TWT agreement is based on the SP field 1312.

[00126] FIG. 14 illustrates a TIM element 1400 in accordance with some embodiments. The TIM element 1400 may include one or more of the following fields element ID field 1402, length field 1404, delivery traffic indication map (DTIM) count field 1406, DTIM period field 1406, bitmap control field 1408, and partial virtual bitmap field 1410. The element ID 1402 may be an ID that identifies the element as the TIM element 1400. The length field 1404 may indicate a length of the TIM element 1400. The DTIM count field 1406 indicates how many beacon frames (e.g., 804) including a current beacon frame appear before the next DTIM. A DTIM count of 0 indicates that the current TIM is a DTIM. The DTIM count field 1406 may be reserved when the TIM element 1400 is included in a TIM frame or a fast initial link setup (FILS) discovery frame. When the TIM element 1400 is included in a TIM frame, OPS frame, or FILS discovery frame the DTIM count field 1406 and DTIM period field 1406 are reserved, in accordance with some embodiments. The bitmap control field 1408 may indicate whether one or more group addressed frames are buffered at the HE AP 502 and may indicate a bitmap offset.

[00127] The partial virtual bitmap 1410 may include STA schedules 1412.1 through 1412.N. The STA schedule 1412 may be one or more bits that indicate SPs (e.g., 810) for the corresponding HE STA 504. In accordance with some embodiments, a HE STA 504 may determine an index (e.g., 1 through N) based on information in TIM element 1400 and an association ID (AID) received

from the HE AP 502. In some embodiments, the STA schedule 1412 is three bits where the bits are set to 0 if the corresponding HE STA 504 is not scheduled to a SP (e.g., 810) corresponding to the bit. For example, if bit 1 is set to 0, then HE STA 504 is not scheduled for the current SP (e.g., 810). If bit 2 is set to 0, then HE STA 504 is not scheduled for the next SP (e.g., 810), and if bit 3 is set to 0, then HE STA 504 is not scheduled for the next SP (e.g., 810). In some embodiments, the bits may correspond to different meaning for scheduling. For example, bit 1 may indicate whether the HE STA 504 is scheduled for the current SP. Bit 2 may indicate whether the HE STA 504 is scheduled during the rest of the BI, and bit 3 may indicate whether the HE STA 504 is scheduled for a next BI.

[00128] The partial virtual bitmap 1410 field 1410 may include information regarding the SPs 810, e.g., start time field 1114, duration field 1116, and interval field 1118 as described in conjunction with FIG. 11. The TIM element 1400 may include one or more additional fields. Additionally, the TIM element 1400 may not include each of the fields disclosed in conjunction with FIG. 14.

[00129] In some embodiments the partial virtual bitmap 1410 includes a flow ID field (e.g., 1112) for one or more of the SPs (e.g., 810) for STA schedule 1412, where the flow ID field may indicate (e.g., a value of 4) no constraints on the frames transmitted during a broadcast TWT SP, e.g., SP 810. The HE AP 502 transmits an NDP feedback report poll variant Trigger Frame (e.g., 806) at the beginning of the TWT SP, e.g., SP 810.1, SP 810.2, etc.

[00130] FIG. 15 illustrates a block acknowledgement frame 1500 in accordance with some embodiments. The block acknowledgement frame 1500 may be in response to a NDP TF transmitted as part of 806. The block acknowledgment frame 1500 may include STA schedules 1512.1 through 1512.N. The STA schedule 1512 may be one or more bits that indicate SPs (e.g., 810) for the corresponding HE STA 504. A STA schedule 1512 may be included only for HE STAs 504 that responded to a NDP TF, in accordance with some embodiments. In some embodiments, there is one STA schedule 1512 for each HE STA 504 indicated in the block ack 1502.

[00131] In some embodiments, the STA schedule 1412 is three bits where the bits are set to 0 if the corresponding HE STA 504 is not scheduled to a SP (e.g., 810) corresponding to the bit. For example, if bit 1 is set to 0, then HE STA 504 is not scheduled for the current SP (e.g., 810). If bit 2 is set to 0, then HE STA 504 is not scheduled for the next SP (e.g., 810), and if bit 3 is set to 0, then HE STA 504 is not scheduled for the next SP (e.g., 810). In some embodiments, the bits may correspond to different meaning for scheduling. For example, bit 1 may indicate whether the HE STA 504 is scheduled for the current SP. Bit 2 may indicate whether the HE STA 504 is scheduled during the rest of the BI, and bit 3 may indicate whether the HE STA 504 is scheduled for a next BI. The block ack field 1502 may include information regarding the SPs 810, e.g., start time field 1114, duration field 1116, and interval field 1118 as described in conjunction with FIG. 11.

[00132] In some embodiments the block ACK 1502 include a flow ID field (e.g., 1112), which may indicate (e.g., a value of 4) no constraints on the frames transmitted during a broadcast TWT SP, e.g., SP 810. The HE AP 502 transmits an NDP feedback report poll variant Trigger Frame (e.g., 806) at the beginning of the TWT SP, e.g., SP 810.1, SP 810.2, etc.

[00133] FIG. 16 illustrates a null data packet (NDP) element 1600 in accordance with some embodiments. The NDP element 1600 may include a range of scheduled AIDs 1604, range of unassociated AIDs 1606, and a type of feedback 1608. The range of scheduled AIDs 1604 may indicate the range of AIDs that are scheduled for a next NDP trigger frame. The range of unassociated AIDs 1606 may indicate a range of response UL resource units (RUs) or resource blocks (RBs) that are available for unassociated HE STAs 504 to use. The range of unassociated AIDs 1606 may indicate a range of response UL RUs or RBs for associated HE STAs 504 that are not addressed by the range of scheduled AIDs 1604. The type of feedback field 1608 may indicate a type of feedback, e.g., whether there is UL data for the HE AP 502 at the HE STA 504. Other types of feedback may include Enhanced distributed channel access (EDCA) information, e.g., whether critical voice over internet protocol (VoIP) is waiting to be sent. The NDP element 1600 may include other fields such as an

element ID. The NDP element 1600 may not be an element but fields in a frame, e.g., a NDP TF, in accordance with some embodiments.

[00134] The NDP element 1600 may be included in an association response, re-association response, beacon frame, management frame, fast initial link setup (FILS) discovery frame, a NDP trigger frame, a probe response, or another frame or PPDU from the HE AP 502. In some embodiments, one or more of the fields of FIG. 16 are not included. In some embodiments, NDP element 1600 may include one or more additional fields.

[00135] FIG. 17 illustrates SP timing field and frames field 1700 in accordance with some embodiments. SP timing field and frames field 1700 may include TWT flow ID 1706. The TWT flow ID 1706 may be the same or similar as flow ID 1112. The SP timing 1702 may indicate the duration or timing of SPs 810. For example, SP timing 1702 may include one or more of fields start time 1114, duration 1116, and/or interval 1118. The frames field 1704 may indicate or more frames (or exchanges) that are to be transmitted at the start of a SP (e.g., 810). The frames field 1704 may be the same or similar as frame field 1212.

[00136] The SP timing field 1702 and/or the frames field 1704 may be included in an association response, re-association response, beacon frame, management frame, fast initial link setup (FILS) discovery frame, a NDP trigger frame, a probe response, or another frame or PPDU from the HE AP 502. The SP timing field 1700 may include one or more additional fields. SP timing field 1700 may not include one or more of the fields illustrated in FIG. 17.

[00137] FIG. 18 illustrates block acknowledgements with schedules 1800 in accordance with some embodiments. Illustrated in FIG. 18 time 1802, transmitter/receiver 1808, HE AP 502, HE STA 504.1 through HE STA 504.N, scheduled SPs 1820, NFRP TF 1822, NDP feedback report response 1824, BA with schedules 1826, channels 1810, and operations 1850. The channels 1810 may be a band or sub-band of a frequency or a group of sub-carriers or tones, in accordance with some embodiments. The channels 1810 may be a different channel, a same channel or be subsets of another channel 1810.

[00138] The method 1800 may begin at operation 1852 with the HE AP 502 transmitting scheduled SPs 1820. The scheduled SPs 1820 may include an indication of scheduled SPs during a BI and an indication of an intended

transmission of a PPDU at the start of the scheduled service periods. For example, HE AP 502 may encode scheduled SPs 1820 to comprise one or more of TWT element 1000, 1100, 1200, 1300, 1400, NDP element 1600, and/or SP timing field and frames field 1700. In some embodiments, the information in scheduled SPs 1820 may be encoded in NFRP TF 1822. In some embodiments, the information in scheduled SPs 1820 may be split between two PPDUs, e.g., the SP information in a first PPDU and the scheduled PPDU in a second PPDU. The scheduled SPS 1820 may be determined as a negotiation between the HE AP 502 and one or more of the HE STAs 504, in accordance with some embodiments.

[00139] The method 1800 may continue at operation 1854 with the HE AP 502 transmitting NFTP trigger frame (TF) 1822. The HE AP 502 wait until the start of a SP indicated in the scheduled SPs 1820, e.g. SP 810.1 of FIG. 8. The NFTP TF 1822 may include one or more of: a receiver address (RA) set to a broadcast address, an UL bandwidth (BW) field that indicates the bandwidth of the NDP feedback report response 1820, a carrier sense (CS) field that indicates whether HE STAs 504 should perform a CS before responding to the NFTP TF 1822, and/or a starting AID field that indicates a starting AID of HE STAs 504 that are to respond. A range of AIDs of HE STAs 504 that are to respond to the NFTP TF 1822 may be determined based on the starting AID field and the UL BW field, in accordance with some embodiments.

[00140] The NFTP TF 1822 may include a feedback type field that indicates a type of feedback, e.g., resource request. The NFTP TF 1822 may include a target RSSI field indicating a target RSSI for the NDP feedback report response 1820 to the HE AP 502. In some embodiments, NDP element 1602 may be transmitted to the HE STAs 504.1 through 504.N before operation 1852. The HE STAs 504.1 through 504.N may use the fields in the NDP element 1602 as described in conjunction with FIG. 16.

[00141] The HE STAs 504 may decode the NFRP TF 1822 and determine feedback. The method 1800 may continue at operation 1856 with the HE STAs 504 transmitting NDP feedback report response 1824. The NDP feedback report response 1824 may be transmitted on a resource block (RB) or resource unit (RU) that is determined based as disclosed above or another method. The NDP

feedback report response 1824 may be a HE trigger-based (TB) PPDU. The NDP feedback report response 1824 may transmit energy (or electro-magnetic waves) on a first set of sub-carriers or tones of the RU or RB to indicate a first response and may transmit energy on a second set of sub-carriers or tones of the RU or RB to indicate a second response. In some embodiments, there are more than two sets of sub-carriers to indicate additional responses. As an example, the HE STA 504 may transmit a HE TB PPDU and transmit energy on a set of subcarriers of the HE-LTF to indicate that the HE STA 504 would like UL resource allocations to transmit PPDUs to the HE AP 502.

[00142] In some embodiments, the NFRP TF 1822 is transmitted at the start of one or more SPs (e.g., 810) during a BI 812. For example, operations 1854, 1856, and 1856 may be during a SP (e.g., 810). The HE AP 502 may wait until the start of the SP to transmit NFRP TF 1822, and may transmit a new NFRP TF 1822 at the start of next SP or another SP.

[00143] The method 1800 may continue at operation 1858 with transmitting a BA with schedules 1826. The BA with schedules 1826 may be the same or similar to block acknowledgment 1500 as disclosed in conjunction with FIG. 15. The HE AP 502 may receive the NDP feedback report responses 1824 and based on the NDP feedback report responses 1824 determine a schedule for the HE STAs 504. For example, HE STA 1 504.1 may be scheduled for SP 810.1 (FIG. 8) and HE STA 2 504.2 may be scheduled for SP 810.2. The HE AP 502 and/or HE STAs 504 may wait a interframe space after receiving a PPDU before transmitting a response PPDU.

[00144] Operations 1854 and 1856 may be NDP 806, in accordance with some embodiments. Operation 1858 may be TIM 808. The method 1800 may include one or more additional operations. The method 1800 may not include all operations 1850 illustrated in FIG. 18. Method 1800 may be performed by an apparatus of a HE STA 504, an apparatus of a HE AP 502, a HE STA 504, and/or a HE AP 502.

[00145] FIG. 19 illustrates a method of service period scheduling 1900 in accordance with some embodiments. The method 1900 may begin at operation 1902 with encoding a first PPDU, the PPDU comprising an indication of scheduled SPs during a BI and an indication of an intended transmission of a

second PPDU at the start of the scheduled service periods. For example, HE AP 502 may encode a first PPDU to comprise one or more of TWT element 1000, 1100, 1200, 1300, 1400, NDP element 1600, and/or SP timing field and frames field 1700. In another example, the HE AP 502 may transmit scheduled SPs 1820 as disclosed in conjunction with FIG. 18. In another example, the HE AP 502 may transmit beacon frame 804.

[00146] The method 1900 may continue at operation 1904 with generating signaling to cause the HE AP to transmit the first PPDU to HE stations (STAs). For example, an apparatus of HE AP 502 may generate signaling to cause the HE AP 502 to transmit scheduled SPs 1820.

[00147] The method 1900 may continue at operation 1906 with encoding the second PPDU, the second PPDU comprising a frame or element for the HE STAs. For example, HE STA 502 may encode NFRP TF 1822, NDP 806, or TIM 808.

[00148] The method 1900 may continue at operation 1908 with generating signaling to cause the second PPDU to be transmitted at a start of a first SP of the service periods to the HE STAs. For example, HE AP 502 may wait until the start of SP 810.1 before transmitting NDP 806, TIM 808, or NFRP TF 1822.

[00149] The method 1900 may be performed by an apparatus of a HE AP 502, a HE AP 502, an apparatus of a HE STA, or an HE STA. Method 1900 may include one or more additional operations, in accordance with some embodiments. Method 1900 may omit on or more of the operations, in accordance with some embodiments.

[00150] FIG. 20 illustrates a method of service period scheduling 2000 in accordance with some embodiments. The method 2000 begins with operation 2002 with decoding a first PPDU, the PPDU including an indication of scheduled SPs during a BI and an indication of an intended transmission of a second PPDU at the start of the scheduled service periods, wherein a receiver address of the PPDU indicates a broadcast address, wherein the PPDU is from a HE AP. For example, HE STAs 504 may receive scheduled SPs 1820. In other examples, the HE STA 504 may decode a first PPDU to comprise one or more of TWT element 1000, 1100, 1200, 1300, 1400, NDP element 1600, and/or SP

timing field and frames field 1700. In another example, the HE STA 504 may decode beacon frame 804.

[00151] The method 2000 may continue at operation 2004 with waiting until a start of a first SP of the service periods. For example, HE STA 504 may wait until the start of SP 810.1. In another example, HE STA 504 may wait until the start of a SP where the HE AP 502 transmits NFRP TF 1822.

[00152] The method 2000 may continue at operation 2006 with decoding the second PPDU, where the second PPDU is to be received at the start of the first SP of the service periods. For example, HE STA 504 may decode NDP 806 or TIM 808. In another example, HE STA 504 may decode NFRP TF 1822.

[00153] The method 2000 may be performed by an apparatus of a HE AP 502, a HE AP 502, an apparatus of a HE STA, or an HE STA. Method 2000 may include one or more additional operations, in accordance with some embodiments. Method 2000 may omit on or more of the operations, in accordance with some embodiments.

[00154] The following examples pertain to further embodiments. Example 1 is an apparatus of a high-efficiency (HE) access point (AP), the apparatus including: memory; and processing circuitry coupled to the memory, the processing circuity configured to: encode a first physical Layer Convergence Procedure (PLCP) Protocol Data Unit (PPDU), the first PPDU including an indication of scheduled service periods (SPs) during a beacon interval (BI) and an indication of an intended transmission of a second PPDU at the start of the scheduled service periods; generate signaling to cause the HE AP to transmit the first PPDU to HE stations (STAs); encode the second PPDU, the second PPDU including a frame or element for the HE STAs; and generate signaling to cause the second PPDU to be transmitted at a start of a first SP of the service periods to the HE STAs.

[00155] In Example 2, the subject matter of Example 1 optionally includes where the processing circuitry is further configured to: encode the second PPDU to comprise a null data packet feedback report poll (NFRP) trigger frame (TF), the NFRP TF including an indication of association identifications (AIDs) of HE stations (STAs) and uplink (UL) resource blocks (RBs) for the HE STAs to

transmit feedback to the HE AP; and decode feedback from the HE STAs in accordance with the RBs.

[00156] In Example 3, the subject matter of Example 2 optionally includes where the processing circuitry is further configured to: encode a third PPDU, the third PPDU including a traffic indication map (TIM), the TIM indicating a schedule for the HE STAs that provided the feedback; and generate signaling to cause the third PPDU to be transmitted to the HE STAs.

[00157] In Example 4, the subject matter of any one or more of Examples 2–3 optionally include where the processing circuitry is further configured to: encode a third PPDU, the third PPDU including block acknowledgements (BAs) of the feedback and indicating a schedule for the HE STAs that provided the feedback; and generate signaling to cause the third PPDU to be transmitted to the HE STAs.

[00158] In Example 5, the subject matter of any one or more of Examples 2–4 optionally include where the processing circuitry is further configured to: encode the second PPDU to comprise an indication that the feedback is whether the HE STAs are requesting resources.

[00159] In Example 6, the subject matter of any one or more of Examples 3–5 optionally include where the schedule includes first indications indicating whether the HE STAs that provided feedback are scheduled for the first SP.

[00160] In Example 7, the subject matter of Example 6 optionally includes where the schedule further includes second indications indicating whether the HE STAs that provided feedback are scheduled for a second SP after the first SP and third indications indicating whether the HE STAs that provided feedback are scheduled for a third SP after the second SP.

[00161] In Example 8, the subject matter of any one or more of Examples 3–7 optionally include where the schedule includes indications of SP identifications for the HE STAs that provided feedback, where a corresponding SP identification of the SP identifications indicates that a corresponding HE STA of the HE STAs that provided feedback is scheduled in a SP with the corresponding SP identification.

[00162] In Example 9, the subject matter of any one or more of Examples 1–8 optionally include where the indication of the scheduled SPs includes an

indication of a duration of the scheduled SPs, and where the scheduled SPs begin an interframe space after a beacon transmission and end at the end of the BI.

[00163] In Example 10, the subject matter of Example 9 optionally includes where a number of scheduled SPs is a greatest integer that is less than a duration of the BI divided by the duration of the scheduled SPs.

[00164] In Example 11, the subject matter of any one or more of Examples 1–10 optionally include where the processing circuitry is further configured to: encode the first PPDU to comprise a broadcast TWT element, the broadcast TWT element including a flow identification (ID) that indicates the intended transmission of the second PPDU at the start of the scheduled service periods.

[00165] In Example 12, the subject matter of Example 11 optionally includes where the processing circuitry is further configured to: encode the first PPDU to further comprise another broadcast TWT element after the broadcast TWT element, the another broadcast TWT element including another flow ID that indicates the intended transmission of a third PPDU after the second PPDU.

[00166] In Example 13, the subject matter of any one or more of Examples 1–12 optionally include where the processing circuitry is further configured to: encode the first PPDU to comprise a broadcast TWT element, the broadcast TWT element including a flow identification (ID) that indicates the intended transmission of the second PPDU and a third PPDU at the start of the scheduled service periods.

[00167] In Example 14, the subject matter of any one or more of Examples 1–13 optionally include access point.

[00168] In Example 15, the subject matter of any one or more of Examples 1–14 optionally include transceiver circuitry coupled to the processing circuitry; and one or more antennas coupled to the transceiver circuitry, and where the memory is configured to store the first PPDU.

[00169] Example 16 is a non-transitory computer-readable storage medium that stores instructions for execution by one or more processors of an apparatus of a high-efficiency (HE) access point (AP), the instructions to configure the one or more processors to: encode a first physical Layer Convergence Procedure (PLCP) Protocol Data Unit (PPDU), the PPDU

including an indication of scheduled service periods (SPs) during a beacon interval (BI) and an indication of an intended transmission of a second PPDU at the start of the scheduled service periods; generate signaling to cause the HE AP to transmit the first PPDU to HE stations (STAs); encode the second PPDU, the second PPDU including a frame or element for the HE STAs; and generate signaling to cause the second PPDU to be transmitted at a start of a first SP of the service periods to the HE STAs.

[00170] In Example 17, the subject matter of Example 16 optionally includes where the instructions further configure the one or more processors to: encode the second PPDU to comprise a null data packet feedback report poll (NFRP) trigger frame (TF), the NFRP TF including an indication of association identifications (AIDs) of HE stations (STAs) and uplink (UL) resource blocks (RBs) for the HE STAs to transmit feedback to the HE AP; and decode feedback from the HE STAs in accordance with the RBs.

[00171] Example 18 is a method performed by an apparatus of a high-efficiency (HE) access point (AP), the method including: encoding a first physical Layer Convergence Procedure (PLCP) Protocol Data Unit (PPDU), the PPDU including an indication of scheduled service periods (SPs) during a beacon interval (BI) and an indication of an intended transmission of a second PPDU at the start of the scheduled service periods; generating signaling to cause the HE AP to transmit the first PPDU to HE stations (STAs); encoding the second PPDU, the second PPDU including a frame or element for the HE STAs; and generating signaling to cause the second PPDU to be transmitted at a start of a first SP of the service periods to the HE STAs.

[00172] In Example 19, the subject matter of Example 18 optionally includes where the method further includes: encoding the second PPDU to comprise a null data packet feedback report poll (NFRP) trigger frame (TF), the NFRP TF including an indication of association identifications (AIDs) of HE stations (STAs) and uplink (UL) resource blocks (RBs) for the HE STAs to transmit feedback to the HE AP; and decoding feedback from the HE STAs in accordance with the RBs.

[00173] Example 20 is an apparatus of a high-efficiency (HE) station (STA), the apparatus including: memory; and processing circuitry coupled to the

memory, the processing circuity configured to: decode a first physical Layer Convergence Procedure (PLCP) Protocol Data Unit (PPDU), the PPDU including an indication of scheduled service periods (SPs) during a beacon interval (BI) and an indication of an intended transmission of a second PPDU at the start of the scheduled service periods, where a receiver address of the PPDU indicates a broadcast address, where the PPDU is from a HE access point (AP); and decode the second PPDU, where the second PPDU is to be received at a start of the first SP of the service periods.

[00174] In Example 21, the subject matter of Example 20 optionally includes where the processing circuitry is further configured to: encode a response to the second PPDU; and generate signaling to cause the HE STA to transmit the response to the HE AP.

[00175] In Example 22, the subject matter of any one or more of Examples 20–21 optionally include where the second PPDU includes a null data packet (NDP) feedback report poll (NFRP) trigger frame (TF), and where the processing circuitry is further configured to: determine feedback in response to the NFRP TF; encode a HE trigger-based (TB) PPDU to comprise feedback to the NFRP TF; and generate signaling to cause the HE STA to transmit the response to the HE AP.

[00176] In Example 23, the subject matter of Example 22 optionally includes where the processing circuitry is further configured to: decode a third PPDU from the HE AP, the third PPDU including a schedule for the HE STA, the schedule indicating a SP where the HE STA is scheduled; wait for the SP where the HE STA is scheduled; and decode a fourth PPDU from the HE AP, the fourth PPDU to be received at a start of the SP where the HE STA is scheduled.

[00177] In Example 24, the subject matter of any one or more of Examples 20–23 optionally include transceiver circuitry coupled to the processing circuitry; and one or more antennas coupled to the transceiver circuitry, and where the memory is configured to store the first PPDU.

[00178] Example 25 is a non-transitory computer-readable storage medium that stores instructions for execution by one or more processors of an apparatus of a high-efficiency (HE) station (STA), the instructions to configure

the one or more processors to: decode a first physical Layer Convergence Procedure (PLCP) Protocol Data Unit (PPDU), the PPDU including an indication of scheduled service periods (SPs) during a beacon interval (BI) and an indication of an intended transmission of a second PPDU at the start of the scheduled service periods, where a receiver address of the PPDU indicates a broadcast address, where the PPDU is from a HE access point (AP); and decode the second PPDU, where the second PPDU is to be received at a start of the first SP of the service periods.

[00179] In Example 26, the subject matter of Example 25 optionally includes where the instructions further configure the one or more processors to: encode a response to the second PPDU; and generate signaling to cause the HE STA to transmit the response to the HE AP.

[00180] In Example 27, the subject matter of any one or more of Examples 25–26 optionally include where the second PPDU includes a null data packet (NDP) feedback report poll (NFRP) trigger frame (TF), and where the instructions further configure the one or more processors to: determine feedback in response to the NFRP TF; encode a HE trigger-based (TB) PPDU to comprise feedback to the NFRP TF; and generate signaling to cause the HE STA to transmit the response to the HE AP.

[00181] In Example 28, the subject matter of any one or more of Examples 25–27 optionally include where the instructions further configure the one or more processors to: decode a third PPDU from the HE AP, the third PPDU including a schedule for the HE STA, the schedule indicating a SP where the HE STA is scheduled; wait for the SP where the HE STA is scheduled; and decode a fourth PPDU from the HE AP, the fourth PPDU to be received at a start of the SP where the HE STA is scheduled.

[00182] Example 29 is a method performed by an apparatus of a high-efficiency (HE) station (STA), the method including: decoding a first physical Layer Convergence Procedure (PLCP) Protocol Data Unit (PPDU), the PPDU including an indication of scheduled service periods (SPs) during a beacon interval (BI) and an indication of an intended transmission of a second PPDU at the start of the scheduled service periods, where a receiver address of the PPDU indicates a broadcast address, where the PPDU is from a HE access point (AP);

and decoding the second PPDU, where the second PPDU is to be received at a start of the first SP of the service periods.

[00183] In Example 30, the subject matter of Example 29 optionally includes where the method further includes: encoding a response to the second PPDU; and generating signaling to cause the HE STA to transmit the response to the HE AP.

[00184] In Example 31, the subject matter of any one or more of Examples 29–30 optionally include where the second PPDU includes a null data packet (NDP) feedback report poll (NFRP) trigger frame (TF), and where the method further includes: determining feedback in response to the NFRP TF; encoding a HE trigger-based (TB) PPDU to comprise feedback to the NFRP TF; and generating signaling to cause the HE STA to transmit the response to the HE AP.

[00185] In Example 32, the subject matter of any one or more of Examples 29–31 optionally include where the method further includes: decoding a third PPDU from the HE AP, the third PPDU including a schedule for the HE STA, the schedule indicating a SP where the HE STA is scheduled; and decoding a fourth PPDU from the HE AP, the fourth PPDU to be received at a start of the SP where the HE STA is scheduled.

[00186] Example 33 is an apparatus of a high-efficiency (HE) station (STA), the apparatus including: means for decoding a first physical Layer Convergence Procedure (PLCP) Protocol Data Unit (PPDU), the PPDU including an indication of scheduled service periods (SPs) during a beacon interval (BI) and an indication of an intended transmission of a second PPDU at the start of the scheduled service periods, where a receiver address of the PPDU indicates a broadcast address, where the PPDU is from a HE access point (AP); and means for decoding the second PPDU, where the second PPDU is to be received at a start of the first SP of the service periods.

[00187] In Example 34, the subject matter of Example 33 optionally includes where the apparatus further includes: means for encoding a response to the second PPDU; and means for generating signaling to cause the HE STA to transmit the response to the HE AP.

[00188] In Example 35, the subject matter of any one or more of Examples 33–34 optionally include where the second PPDU includes a null data packet (NDP) feedback report poll (NFRP) trigger frame (TF), and where the apparatus further includes: means for determining feedback in response to the NFRP TF; means for encoding a HE trigger-based (TB) PPDU to comprise feedback to the NFRP TF; and means for generating signaling to cause the HE STA to transmit the response to the HE AP.

[00189] In Example 36, the subject matter of any one or more of Examples 33–35 optionally include where the apparatus further includes: means for decoding a third PPDU from the HE AP, the third PPDU including a schedule for the HE STA, the schedule indicating a SP where the HE STA is scheduled; and means for decoding a fourth PPDU from the HE AP, the fourth PPDU to be received at a start of the SP where the HE STA is scheduled.

[00190] Example 37 is an apparatus of a high-efficiency (HE) access point (AP), the apparatus including: means for encoding a first physical Layer Convergence Procedure (PLCP) Protocol Data Unit (PPDU), the PPDU including an indication of scheduled service periods (SPs) during a beacon interval (BI) and an indication of an intended transmission of a second PPDU at the start of the scheduled service periods; means for generating signaling to cause the HE AP to transmit the first PPDU to HE stations (STAs); means for encoding the second PPDU, the second PPDU including a frame or element for the HE STAs; and means for generating signaling to cause the second PPDU to be transmitted at a start of a first SP of the service periods to the HE STAs.

[00191] In Example 38, the subject matter of Example 37 optionally includes where the apparatus further includes: means for encoding the second PPDU to comprise a null data packet feedback report poll (NFRP) trigger frame (TF), the NFRP TF including an indication of association identifications (AIDs) of HE stations (STAs) and uplink (UL) resource blocks (RBs) for the HE STAs to transmit feedback to the HE AP; and means for decoding feedback from the HE STAs in accordance with the RBs.

[00192] The Abstract is provided to comply with 37 C.F.R. Section 1.72(b) requiring an abstract that will allow the reader to ascertain the nature and gist of the technical disclosure. It is submitted with the understanding that it will

not be used to limit or interpret the scope or meaning of the claims. The following claims are hereby incorporated into the detailed description, with each claim standing on its own as a separate embodiment.

AB2288-PCT 4884.952WO1

CLAIMS

What is claimed is:

1. An apparatus of a high-efficiency (HE) access point (AP), the apparatus comprising: memory; and processing circuitry coupled to the memory, the processing circuity configured to:

encode a first physical Layer Convergence Procedure (PLCP) Protocol Data Unit (PPDU), the first PPDU comprising an indication of scheduled service periods (SPs) during a beacon interval (BI) and an indication of an intended transmission of a second PPDU at the start of the scheduled service periods;

generate signaling to cause the HE AP to transmit the first PPDU to HE stations (STAs);

encode the second PPDU, the second PPDU comprising a frame or element for the HE STAs; and

generate signaling to cause the second PPDU to be transmitted at a start of a first SP of the service periods to the HE STAs.

2. The apparatus of claim 1, wherein the processing circuitry is further configured to:

encode the second PPDU to comprise a null data packet feedback report poll (NFRP) trigger frame (TF), the NFRP TF comprising an indication of association identifications (AIDs) of HE stations (STAs) and uplink (UL) resource blocks (RBs) for the HE STAs to transmit feedback to the HE AP; and

decode feedback from the HE STAs in accordance with the RBs.

3. The apparatus of claim 2, wherein the processing circuitry is further configured to:

encode a third PPDU, the third PPDU comprising a traffic indication map (TIM), the TIM indicating a schedule for the HE STAs that provided the feedback; and

generate signaling to cause the third PPDU to be transmitted to the HE STAs.

4. The apparatus of claim 2, wherein the processing circuitry is further configured to:

encode a third PPDU, the third PPDU comprising block acknowledgements (BAs) of the feedback and indicating a schedule for the HE STAs that provided the feedback; and

generate signaling to cause the third PPDU to be transmitted to the HE STAs.

5. The apparatus of claim 2, wherein the processing circuitry is further configured to:

encode the second PPDU to comprise an indication that the feedback is whether the HE STAs are requesting resources.

6. The apparatus of claim 3, wherein the schedule comprises first indications indicating whether the HE STAs that provided feedback are scheduled for the first SP.

7. The apparatus of claim 6, wherein the schedule further comprises second indications indicating whether the HE STAs that provided feedback are scheduled for a second SP after the first SP and third indications indicating whether the HE STAs that provided feedback are scheduled for a third SP after the second SP.

8. The apparatus of claim 3, wherein the schedule comprises indications of SP identifications for the HE STAs that provided feedback, wherein a corresponding SP identification of the SP identifications indicates that a corresponding HE STA of the HE STAs that provided feedback is scheduled in a SP with the corresponding SP identification.

9. The apparatus of claim 1, wherein the indication of the scheduled SPs comprises an indication of a duration of the scheduled SPs, and wherein the scheduled SPs begin an interframe space after a beacon transmission and end at the end of the BI.

10. The apparatus of claim 9, wherein a number of scheduled SPs is a greatest integer that is less than a duration of the BI divided by the duration of the scheduled SPs.

11. The apparatus of claim 1, wherein the processing circuitry is further configured to:

encode the first PPDU to comprise a broadcast TWT element, the broadcast TWT element comprising a flow identification (ID) that indicates the intended transmission of the second PPDU at the start of the scheduled service periods.

12. The apparatus of claim 11, wherein the processing circuitry is further configured to:

encode the first PPDU to further comprise another broadcast TWT element after the broadcast TWT element, the another broadcast TWT element comprising another flow ID that indicates the intended transmission of a third PPDU after the second PPDU.

13. The apparatus of claim 1, wherein the processing circuitry is further configured to:

encode the first PPDU to comprise a broadcast TWT element, the broadcast TWT element comprising a flow identification (ID) that indicates the intended transmission of the second PPDU and a third PPDU at the start of the scheduled service periods.

14. The apparatus of claim 1, wherein the HE AP is configured to communicate with the HE STAs in accordance with one or more from the following group: an Institute of Electrical and Electronic Engineers (IEEE) 802.11ax access point, an IEEE 802.11ax station, an IEEE 802.11 extremely-high efficiency (EHF) access point, an IEEE 802.11 EHF station, an IEEE 802.11 station, and an IEEE 802.11 access point.

15. The apparatus of claim 1, further comprising transceiver circuitry coupled to the processing circuitry; and one or more antennas coupled to the transceiver circuitry, and wherein the memory is configured to store the first PPDU.

16. A non-transitory computer-readable storage medium that stores instructions for execution by one or more processors of an apparatus of a high-efficiency (HE) access point (AP), the instructions to configure the one or more processors to:

encode a first physical Layer Convergence Procedure (PLCP) Protocol Data Unit (PPDU), the PPDU comprising an indication of scheduled service periods (SPs) during a beacon interval (BI) and an indication of an intended transmission of a second PPDU at the start of the scheduled service periods;

generate signaling to cause the HE AP to transmit the first PPDU to HE stations (STAs);

encode the second PPDU, the second PPDU comprising a frame or element for the HE STAs; and

generate signaling to cause the second PPDU to be transmitted at a start of a first SP of the service periods to the HE STAs.

17. The non-transitory computer-readable storage medium of claim 16, wherein the instructions further configure the one or more processors to:

encode the second PPDU to comprise a null data packet feedback report poll (NFRP) trigger frame (TF), the NFRP TF comprising an indication of association identifications (AIDs) of HE stations (STAs) and uplink (UL) resource blocks (RBs) for the HE STAs to transmit feedback to the HE AP; and

decode feedback from the HE STAs in accordance with the RBs.

18. A method performed by an apparatus of a high-efficiency (HE) access point (AP), the method comprising:

encoding a first physical Layer Convergence Procedure (PLCP) Protocol Data Unit (PPDU), the PPDU comprising an indication of scheduled service

periods (SPs) during a beacon interval (BI) and an indication of an intended transmission of a second PPDU at the start of the scheduled service periods;

generating signaling to cause the HE AP to transmit the first PPDU to HE stations (STAs);

encoding the second PPDU, the second PPDU comprising a frame or element for the HE STAs; and

generating signaling to cause the second PPDU to be transmitted at a start of a first SP of the service periods to the HE STAs.

19. The method of claim 18, wherein the method further comprises:

encoding the second PPDU to comprise a null data packet feedback report poll (NFRP) trigger frame (TF), the NFRP TF comprising an indication of association identifications (AIDs) of HE stations (STAs) and uplink (UL) resource blocks (RBs) for the HE STAs to transmit feedback to the HE AP; and

decoding feedback from the HE STAs in accordance with the RBs.

20. An apparatus of a high-efficiency (HE) station (STA), the apparatus comprising: memory; and processing circuitry coupled to the memory, the processing circuity configured to:

decode a first physical Layer Convergence Procedure (PLCP) Protocol Data Unit (PPDU), the PPDU comprising an indication of scheduled service periods (SPs) during a beacon interval (BI) and an indication of an intended transmission of a second PPDU at the start of the scheduled service periods, wherein a receiver address of the PPDU indicates a broadcast address, wherein the PPDU is from a HE access point (AP); and

decode the second PPDU, wherein the second PPDU is to be received at a start of the first SP of the service periods.

21. The apparatus of claim 20, wherein the processing circuitry is further configured to:

encode a response to the second PPDU; and

generate signaling to cause the HE STA to transmit the response to the HE AP.

22. The apparatus of claim 20, wherein the second PPDU comprises a null data packet (NDP) feedback report poll (NFRP) trigger frame (TF), and wherein the processing circuitry is further configured to:

determine feedback in response to the NFRP TF;

encode a HE trigger-based (TB) PPDU to comprise feedback to the NFRP TF; and

generate signaling to cause the HE STA to transmit the response to the HE AP.

23. The apparatus of claim 22, wherein the processing circuitry is further configured to:

decode a third PPDU from the HE AP, the third PPDU comprising a schedule for the HE STA, the schedule indicating a SP where the HE STA is scheduled; and

decode a fourth PPDU from the HE AP, the fourth PPDU to be received at a start of the SP where the HE STA is scheduled.

24. The apparatus of claim 20, wherein the processing circuitry is further configured to:

wait for the SP where the HE STA is scheduled, wherein the wait comprises reframing from transmitting packets on a same frequency band that the first PPDU was received on.

25. The apparatus of claim 20, further comprising transceiver circuitry coupled to the processing circuitry; and one or more antennas coupled to the transceiver circuitry, and wherein the memory is configured to store the first PPDU.

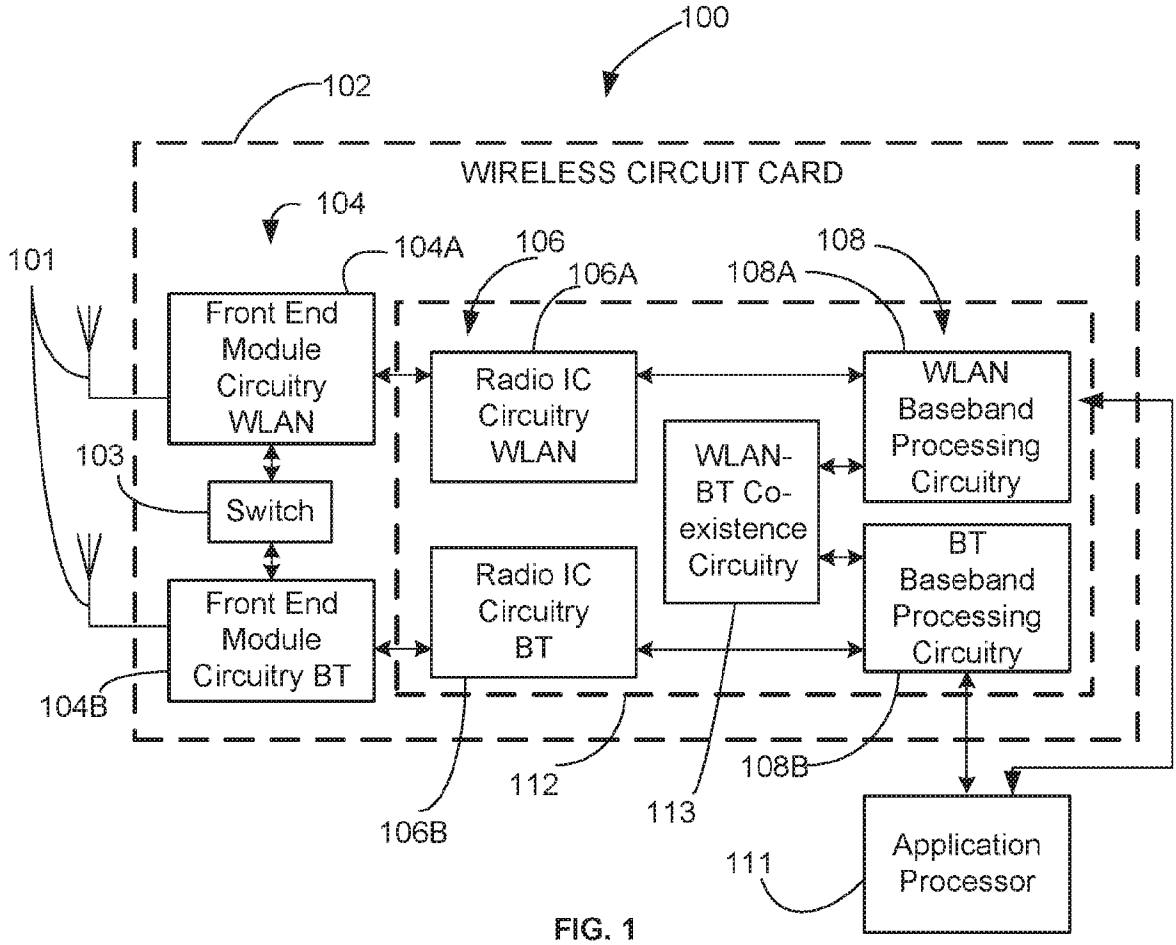

100
102
WIRELESS CIRCUIT CARD
104
101
104A
106
106A
108
108A
Front End Module Circuitry WLAN
Radio IC Circuitry WLAN
WLAN Baseband Processing Circuitry
103
Switch
WLAN-BT Co-existence Circuitry
BT Baseband Processing Circuitry
Front End Module Circuitry BT
Radio IC Circuitry BT
104B
106B
112
113
108B
Application Processor
111

FIG. 1

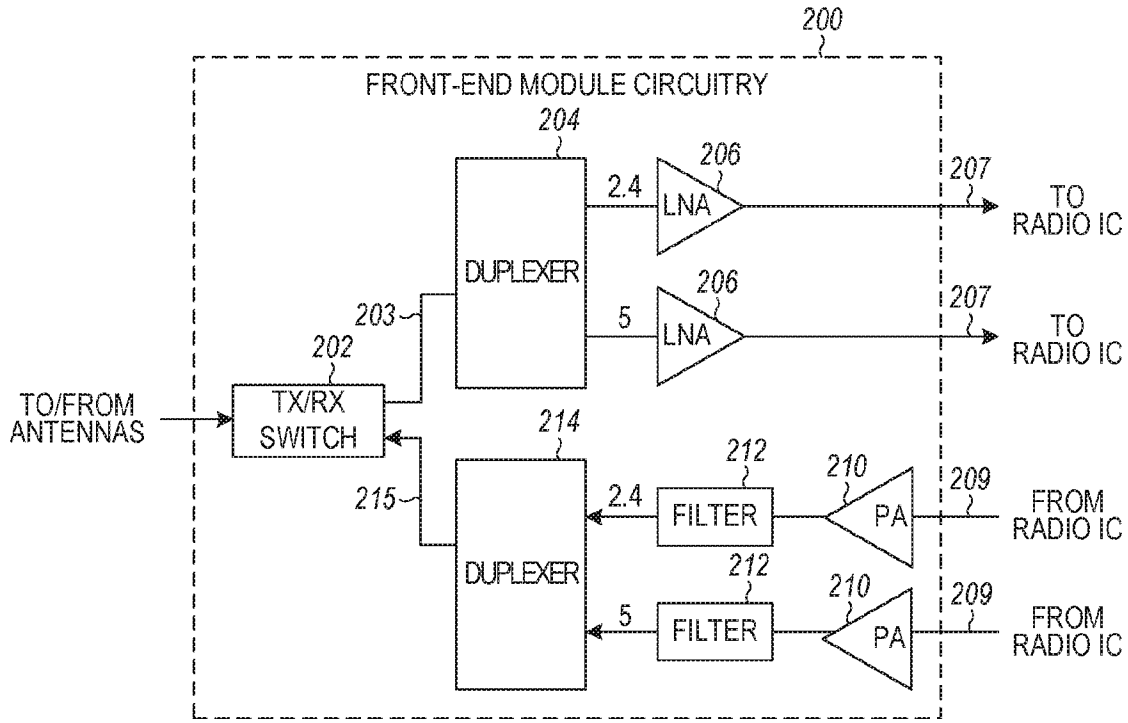

200
FRONT-END MODULE CIRCUITRY
204
206
2.4
LNA
207
TO RADIO IC
DUPLEXER
206
203
5
LNA
207
TO RADIO IC
202
TO/FROM ANTENNAS
TX/RX SWITCH
214
212
210
209
215
2.4
FILTER
PA
FROM RADIO IC
DUPLEXER
212
210
209
5
FILTER
PA
FROM RADIO IC

FIG. 2

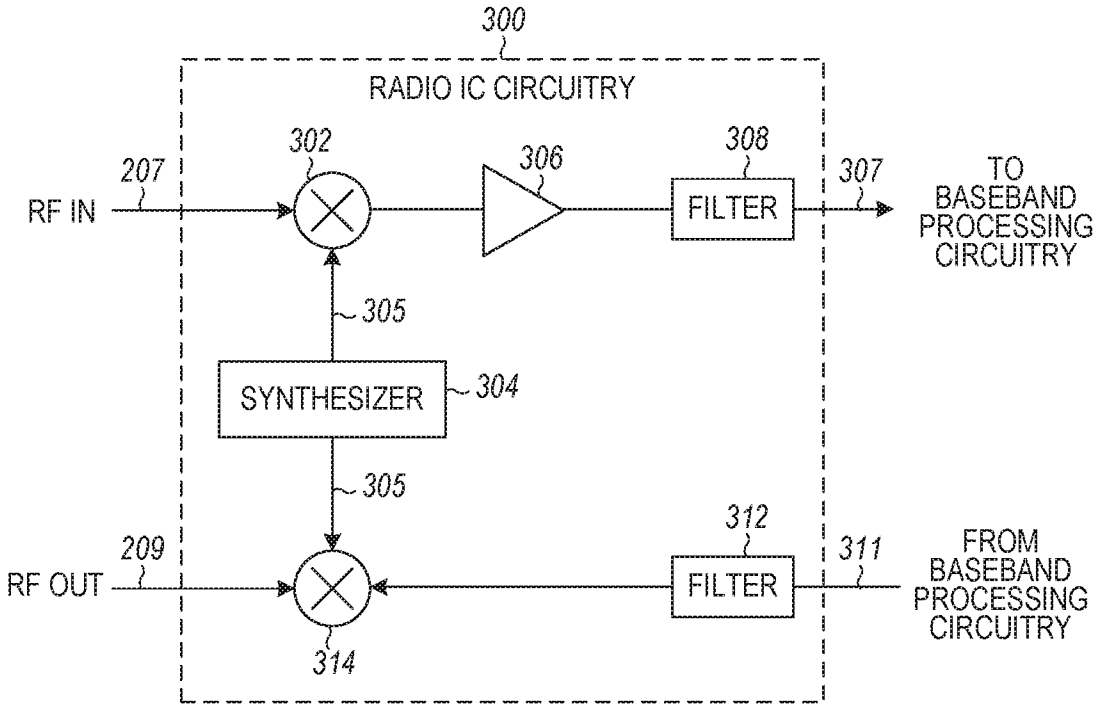

300
RADIO IC CIRCUITRY
207
RF IN
302
306
308
FILTER
307
TO BASEBAND PROCESSING CIRCUITRY
305
SYNTHESIZER
304
305
209
RF OUT
312
FILTER
311
FROM BASEBAND PROCESSING CIRCUITRY
314

FIG. 3

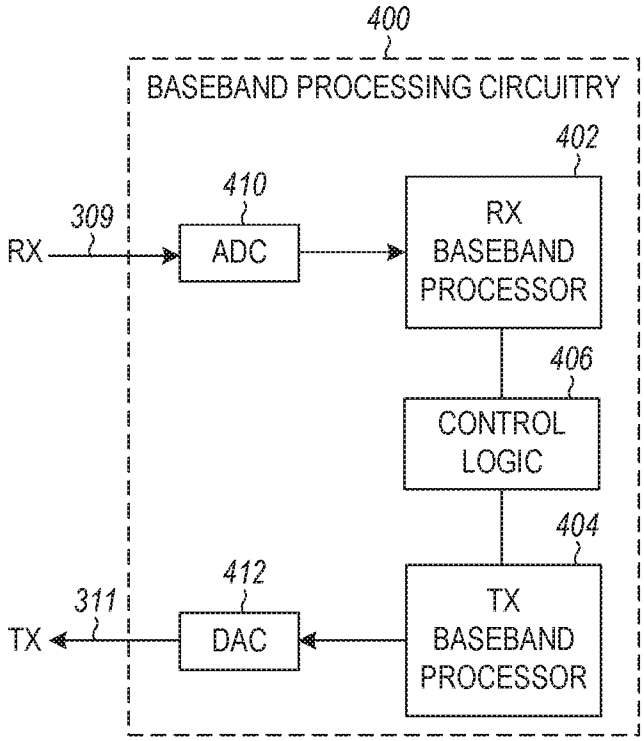

400
BASEBAND PROCESSING CIRCUITRY
402
410
309
RX
ADC
RX BASEBAND PROCESSOR
406
CONTROL LOGIC
404
412
311
TX
DAC
TX BASEBAND PROCESSOR

FIG. 4

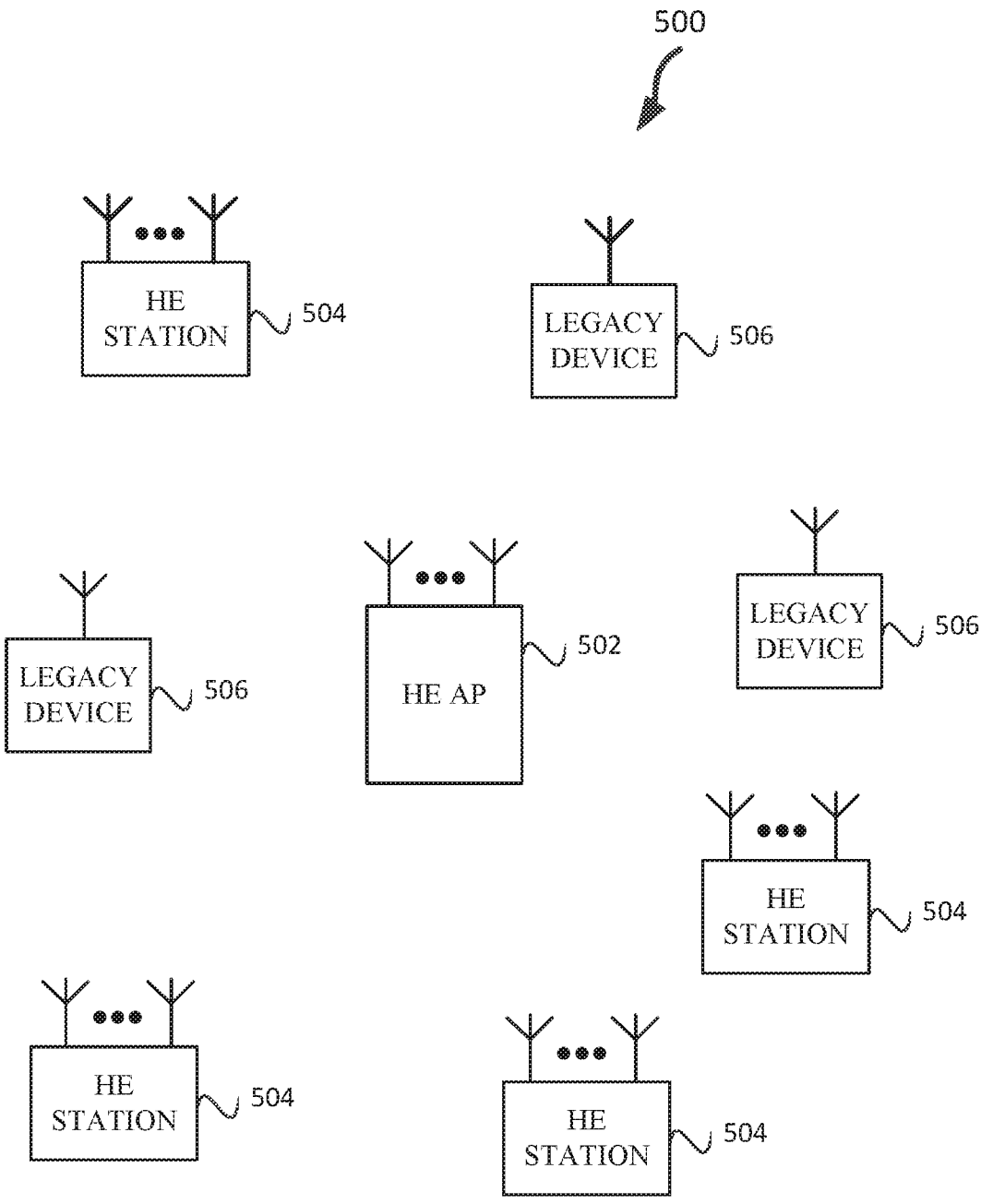

500
HE STATION
504
LEGACY DEVICE
506
LEGACY DEVICE
506
HE AP
502
LEGACY DEVICE
506
HE STATION
504
HE STATION
504
HE STATION
504
BSS

FIG. 5

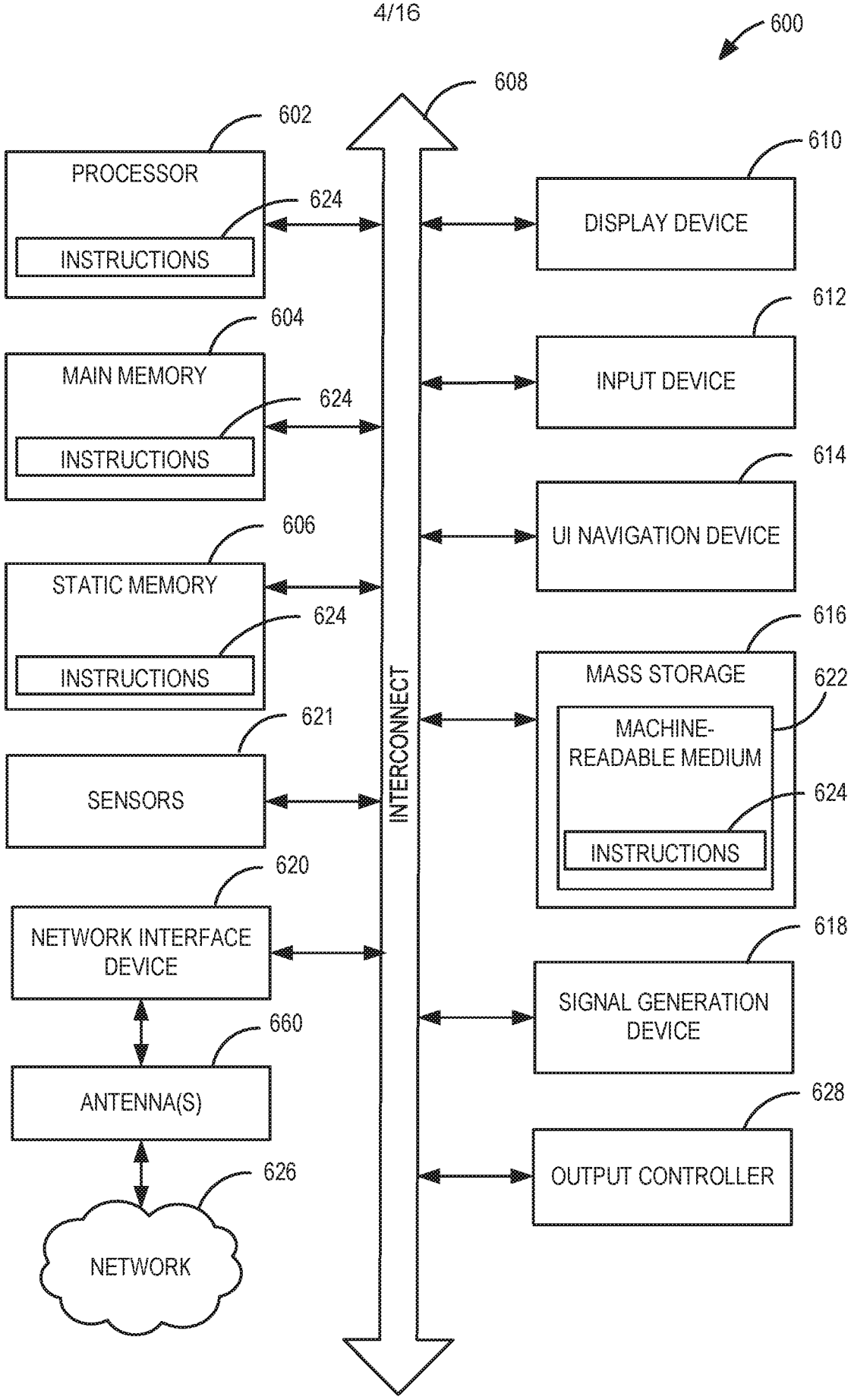

600
608
602
PROCESSOR
624
INSTRUCTIONS
604
MAIN MEMORY
624
INSTRUCTIONS
606
STATIC MEMORY
624
INSTRUCTIONS
621
SENSORS
620
NETWORK INTERFACE DEVICE
660
ANTENNA(S)
626
NETWORK
INTERCONNECT
610
DISPLAY DEVICE
612
INPUT DEVICE
614
UI NAVIGATION DEVICE
616
MASS STORAGE
622
MACHINE-READABLE MEDIUM
624
INSTRUCTIONS
618
SIGNAL GENERATION DEVICE
628
OUTPUT CONTROLLER

FIG. 6

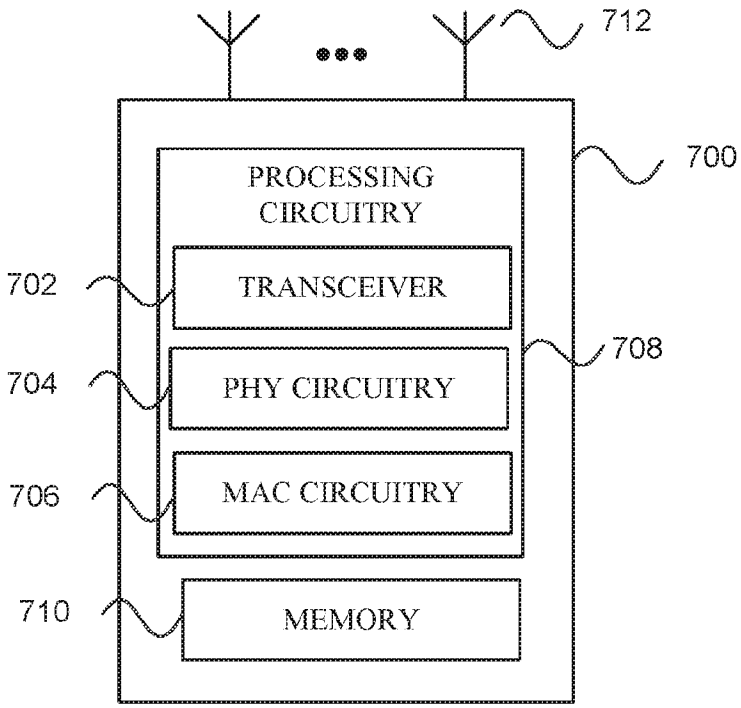

712
700
PROCESSING CIRCUITRY
TRANSCEIVER
PHY CIRCUITRY
MAC CIRCUITRY
MEMORY
702
704
706
708
710

FIG. 7

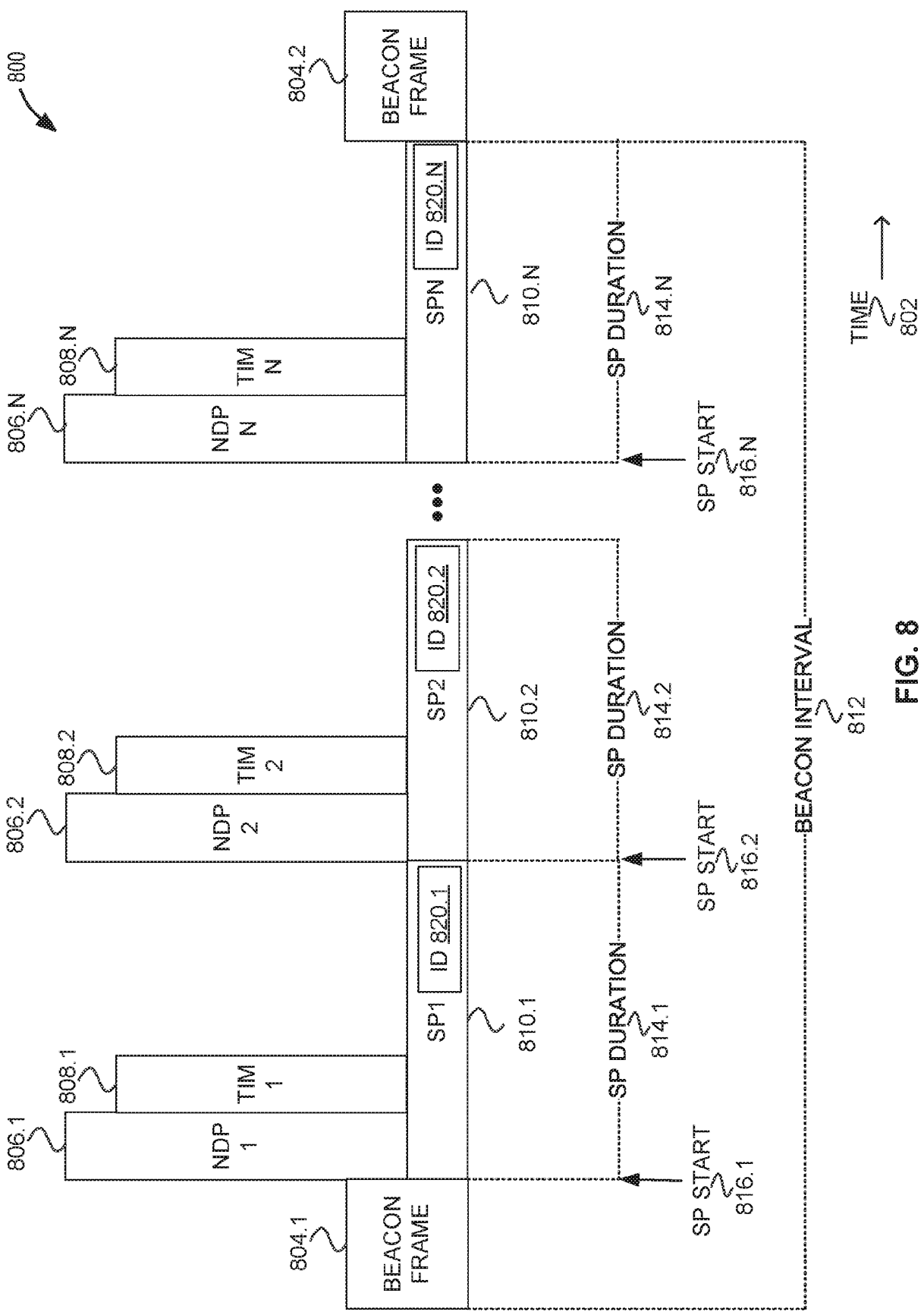

800
804.1
BEACON FRAME
804.2
BEACON FRAME
806.1
NDP 1
808.1
TIM 1
806.2
NDP 2
808.2
TIM 2
806.N
NDP N
808.N
TIM N
SP1
ID 820.1
SP2
ID 820.2
SPN
ID 820.N
810.1
810.2
810.N
SP DURATION
814.1
SP DURATION
814.2
SP DURATION
814.N
SP START
816.1
SP START
816.2
SP START
816.N
BEACON INTERVAL
812
TIME
802

FIG. 8

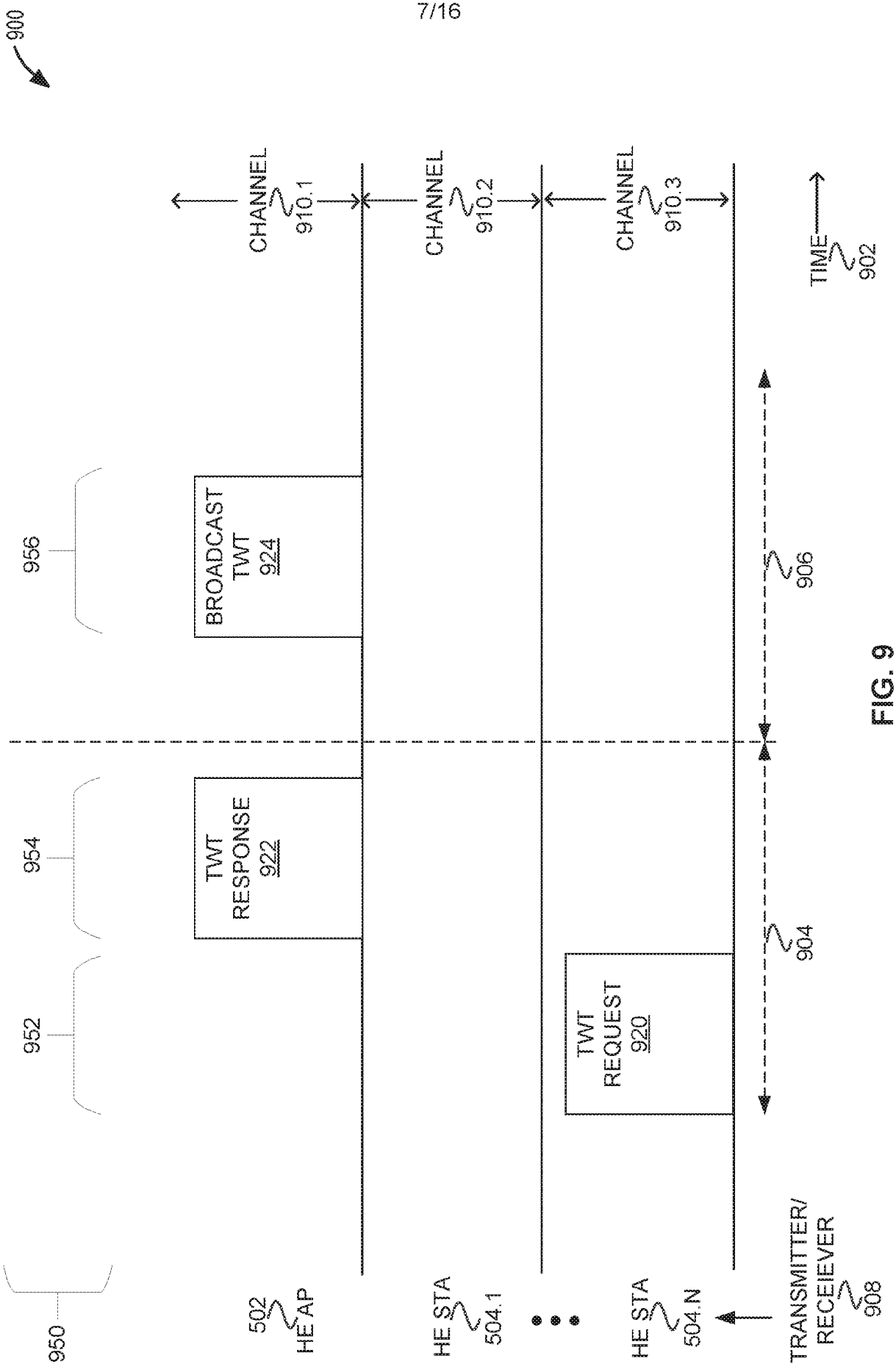

900
CHANNEL 910.1
CHANNEL 910.2
CHANNEL 910.3
TIME 902
956
BROADCAST TWT 924
954
TWT RESPONSE 922
952
TWT REQUEST 920
906
904
950
502 HE AP
HE STA 504.1
HE STA 504.N
TRANSMITTER/ RECEIEVER 908

FIG. 9

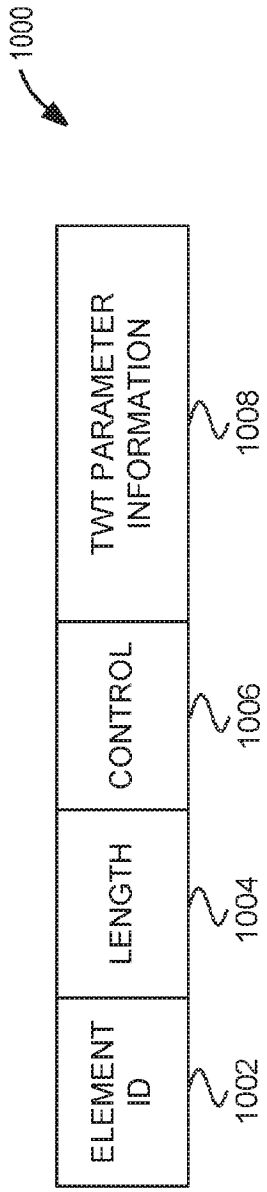

1000
ELEMENT ID
LENGTH
CONTROL
TWT PARAMETER INFORMATION
1002
1004
1006
1008

FIG. 10

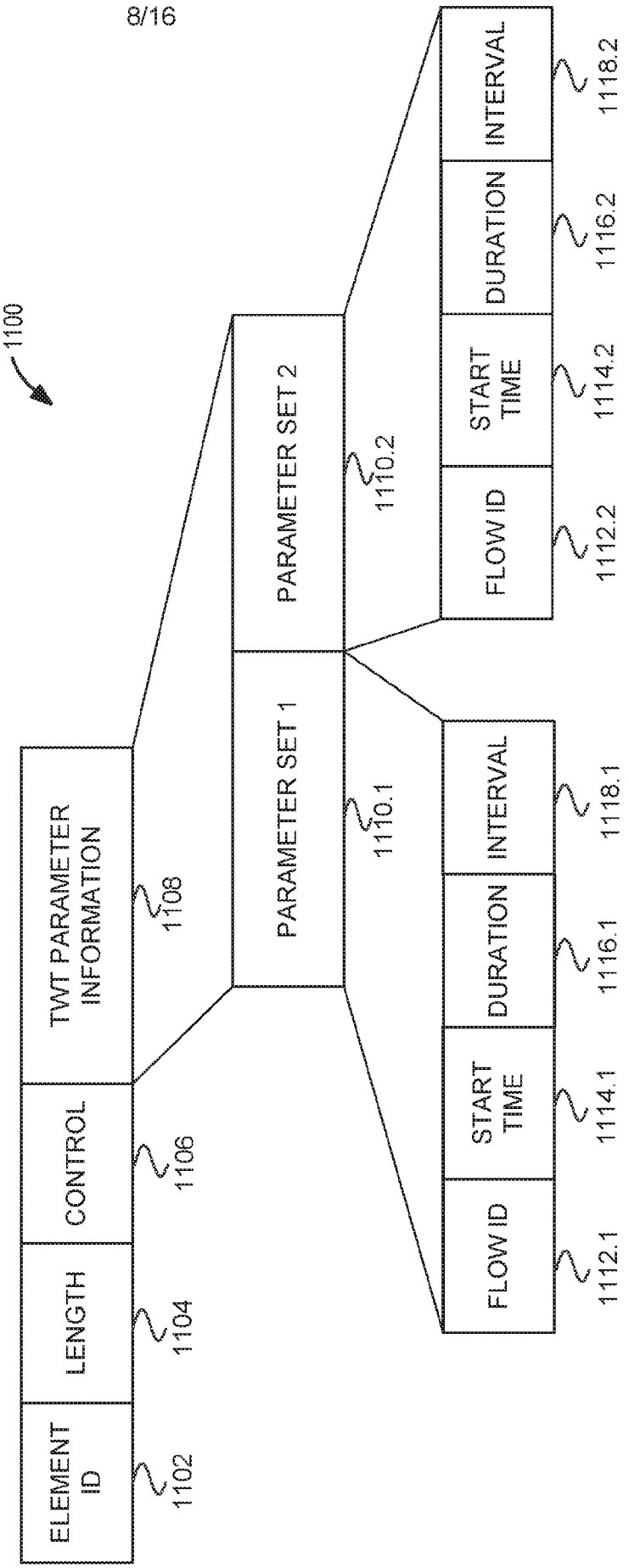

1100
ELEMENT ID
LENGTH
CONTROL
TWT PARAMETER INFORMATION
PARAMETER SET 1
PARAMETER SET 2
FLOW ID
START TIME
DURATION
INTERVAL
1102
1104
1106
1108
1110.1
1110.2
1112.1
1112.2
1114.1
1114.2
1116.1
1116.2
1118.1
1118.2

FIG. 11

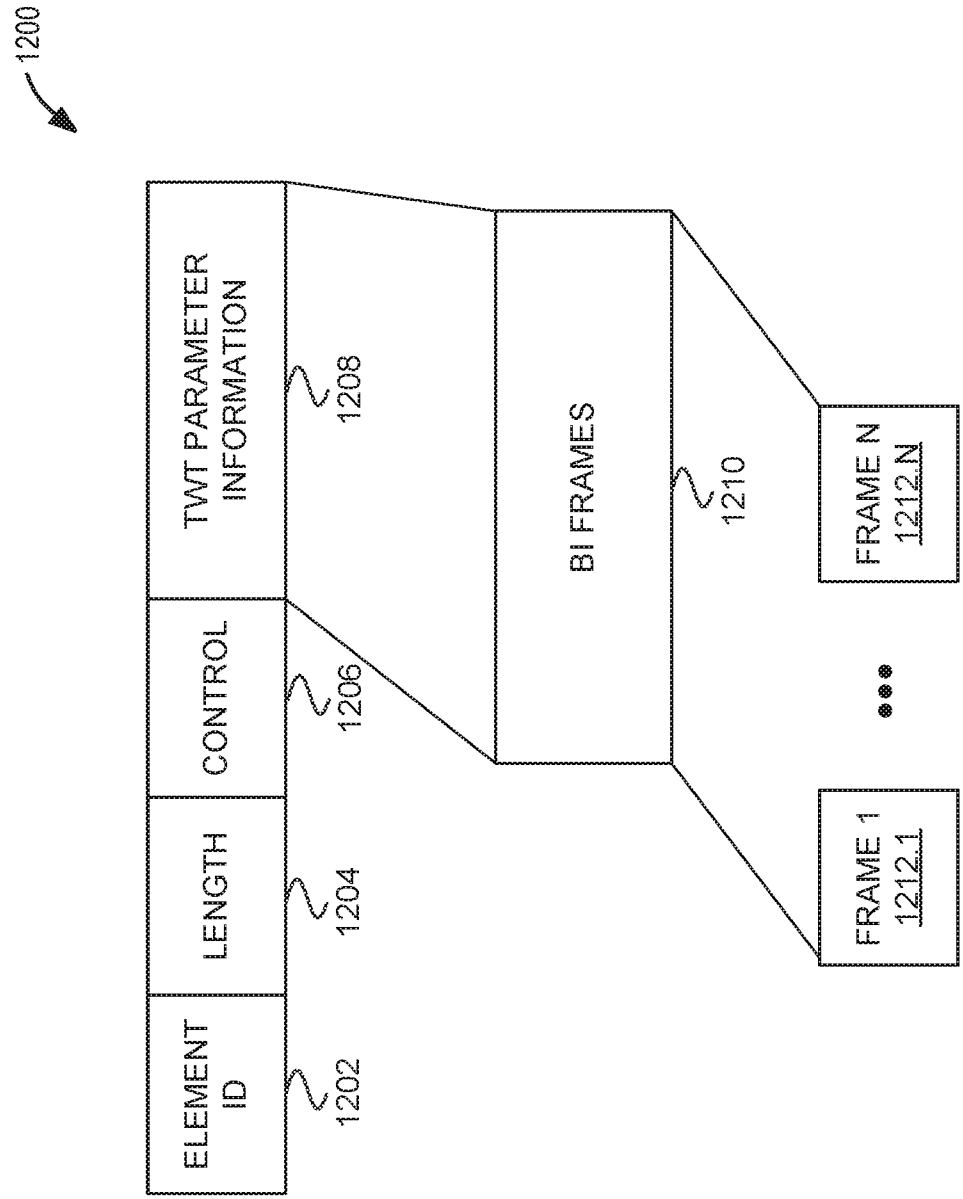

1200
ELEMENT ID
1202
LENGTH
1204
CONTROL
1206
TWT PARAMETER INFORMATION
1208
BI FRAMES
1210
FRAME 1 1212.1
FRAME N 1212.N

FIG. 12

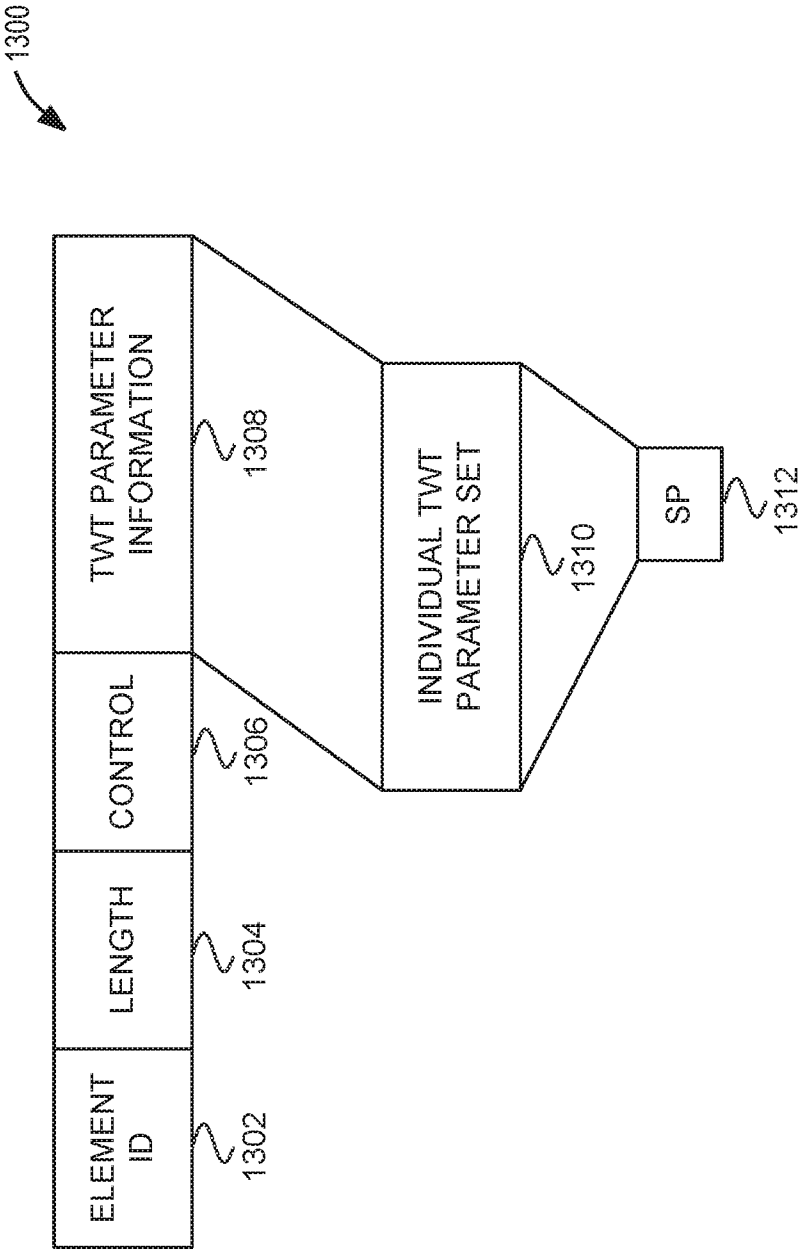

1300
ELEMENT ID
1302
LENGTH
1304
CONTROL
1306
TWT PARAMETER INFORMATION
1308
INDIVIDUAL TWT PARAMETER SET
1310
SP
1312

FIG. 13

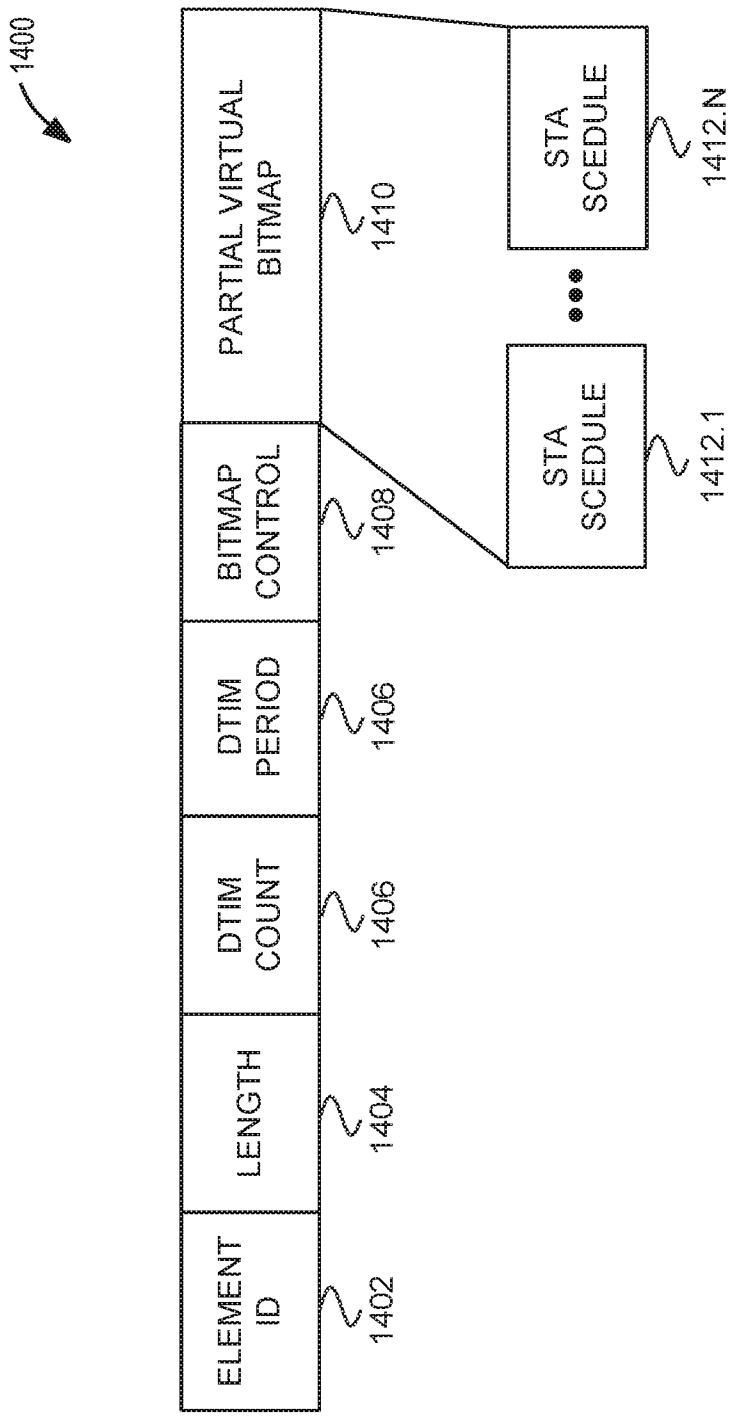

1400
ELEMENT ID
1402
LENGTH
1404
DTIM COUNT
1406
DTIM PERIOD
1406
BITMAP CONTROL
1408
PARTIAL VIRTUAL BITMAP
1410
STA SCEDULE
1412.1
STA SCEDULE
1412.N

FIG. 14

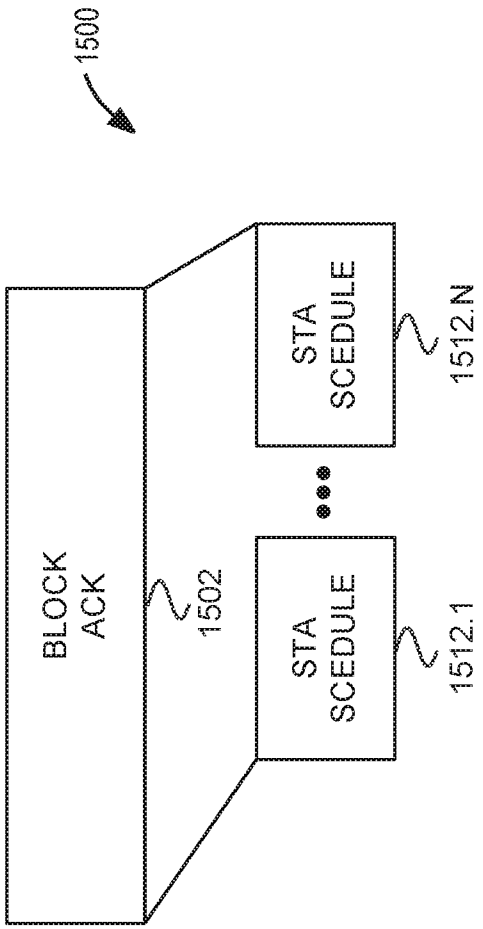


FIG. 15

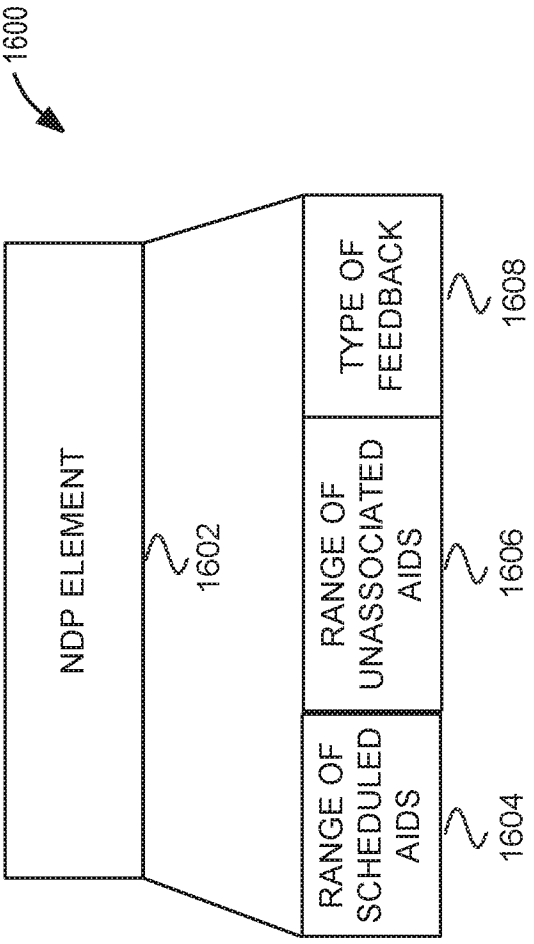

1600
NDP ELEMENT
1602
RANGE OF SCHEDULED AIDS
1604
RANGE OF UNASSOCIATED AIDS
1606
TYPE OF FEEDBACK
1608

FIG. 16

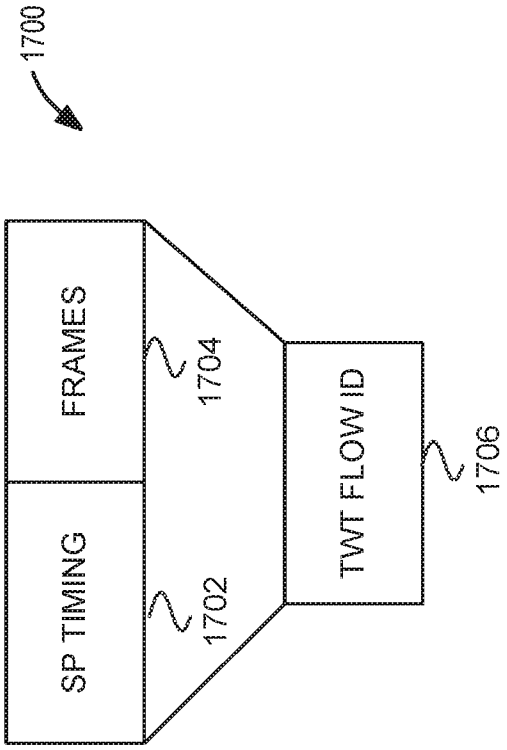

1700
SP TIMING
FRAMES
1702
1704
TWT FLOW ID
1706

FIG. 17

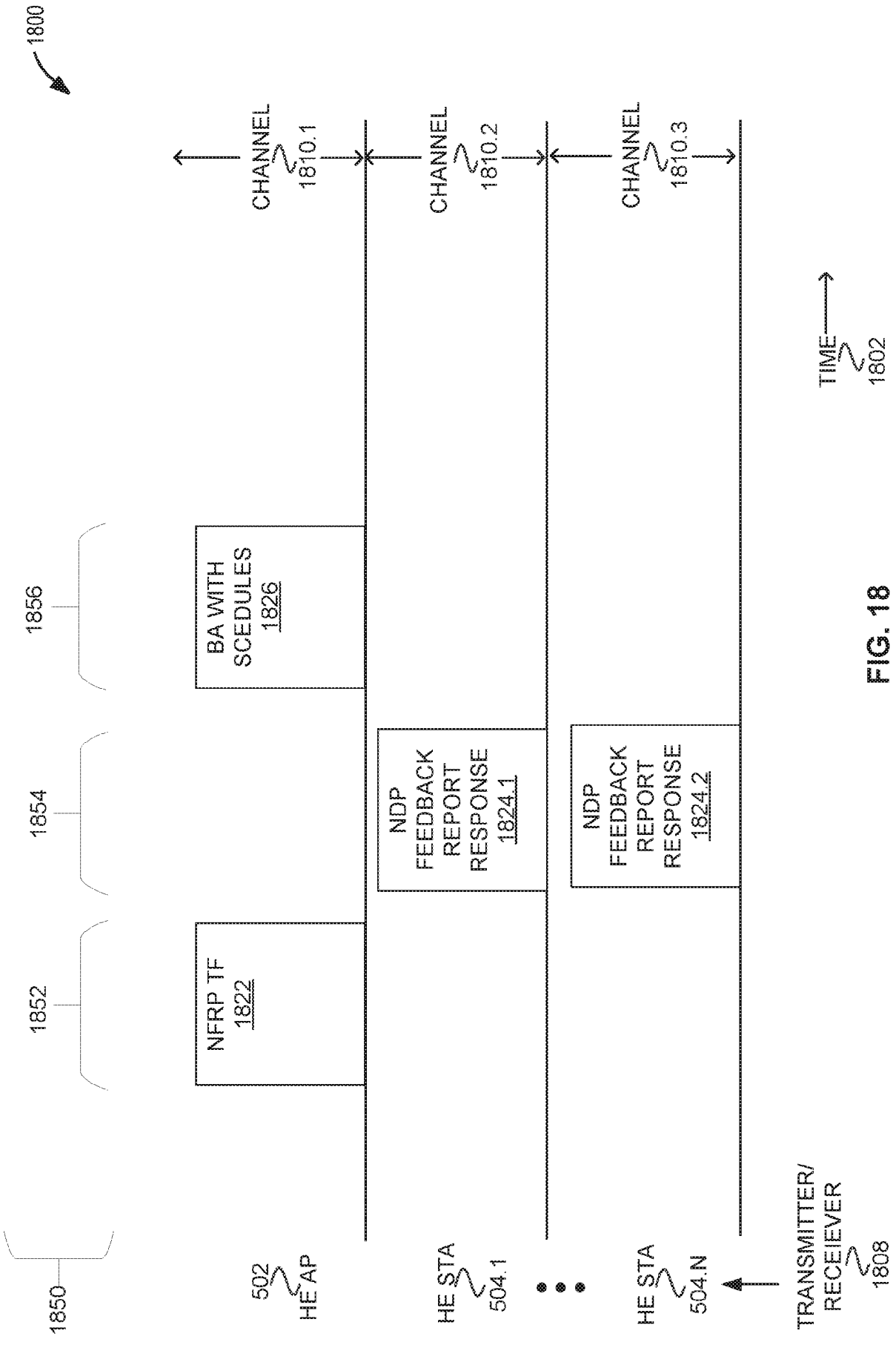

1800
CHANNEL 1810.1
CHANNEL 1810.2
CHANNEL 1810.3
TIME 1802
1856
BA WITH SCEDULES 1826
1854
NDP FEEDBACK REPORT RESPONSE 1824.1
NDP FEEDBACK REPORT RESPONSE 1824.2
1852
NFRP TF 1822
1850
502 HE AP
HE STA 504.1
HE STA 504.N
TRANSMITTER/ RECEIEVER 1808

FIG. 18

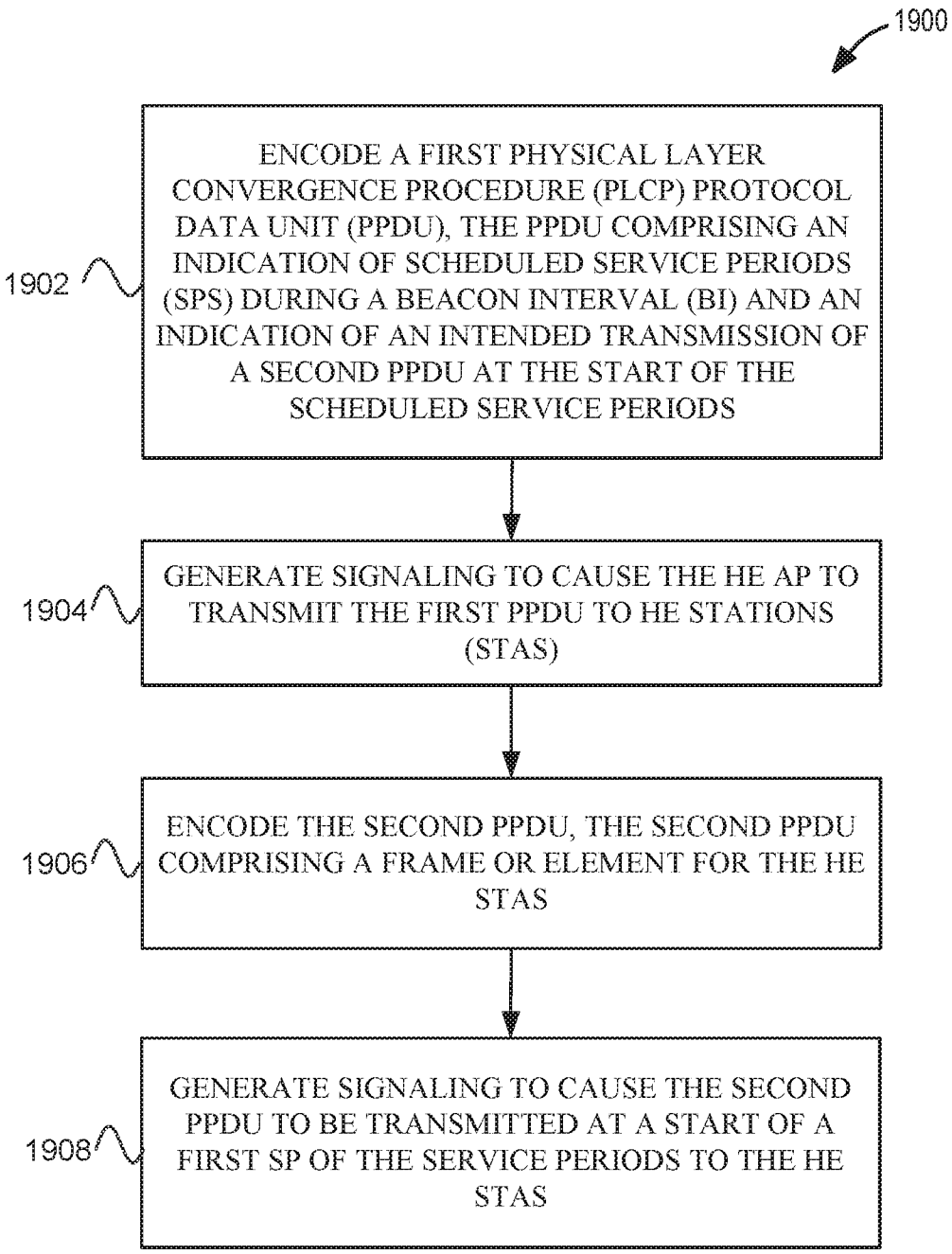

1900
ENCODE A FIRST PHYSICAL LAYER CONVERGENCE PROCEDURE (PLCP) PROTOCOL DATA UNIT (PPDU), THE PPDU COMPRISING AN INDICATION OF SCHEDULED SERVICE PERIODS (SPS) DURING A BEACON INTERVAL (BI) AND AN INDICATION OF AN INTENDED TRANSMISSION OF A SECOND PPDU AT THE START OF THE SCHEDULED SERVICE PERIODS
1902
GENERATE SIGNALING TO CAUSE THE HE AP TO TRANSMIT THE FIRST PPDU TO HE STATIONS (STAS)
1904
ENCODE THE SECOND PPDU, THE SECOND PPDU COMPRISING A FRAME OR ELEMENT FOR THE HE STAS
1906
GENERATE SIGNALING TO CAUSE THE SECOND PPDU TO BE TRANSMITTED AT A START OF A FIRST SP OF THE SERVICE PERIODS TO THE HE STAS
1908

FIG. 19

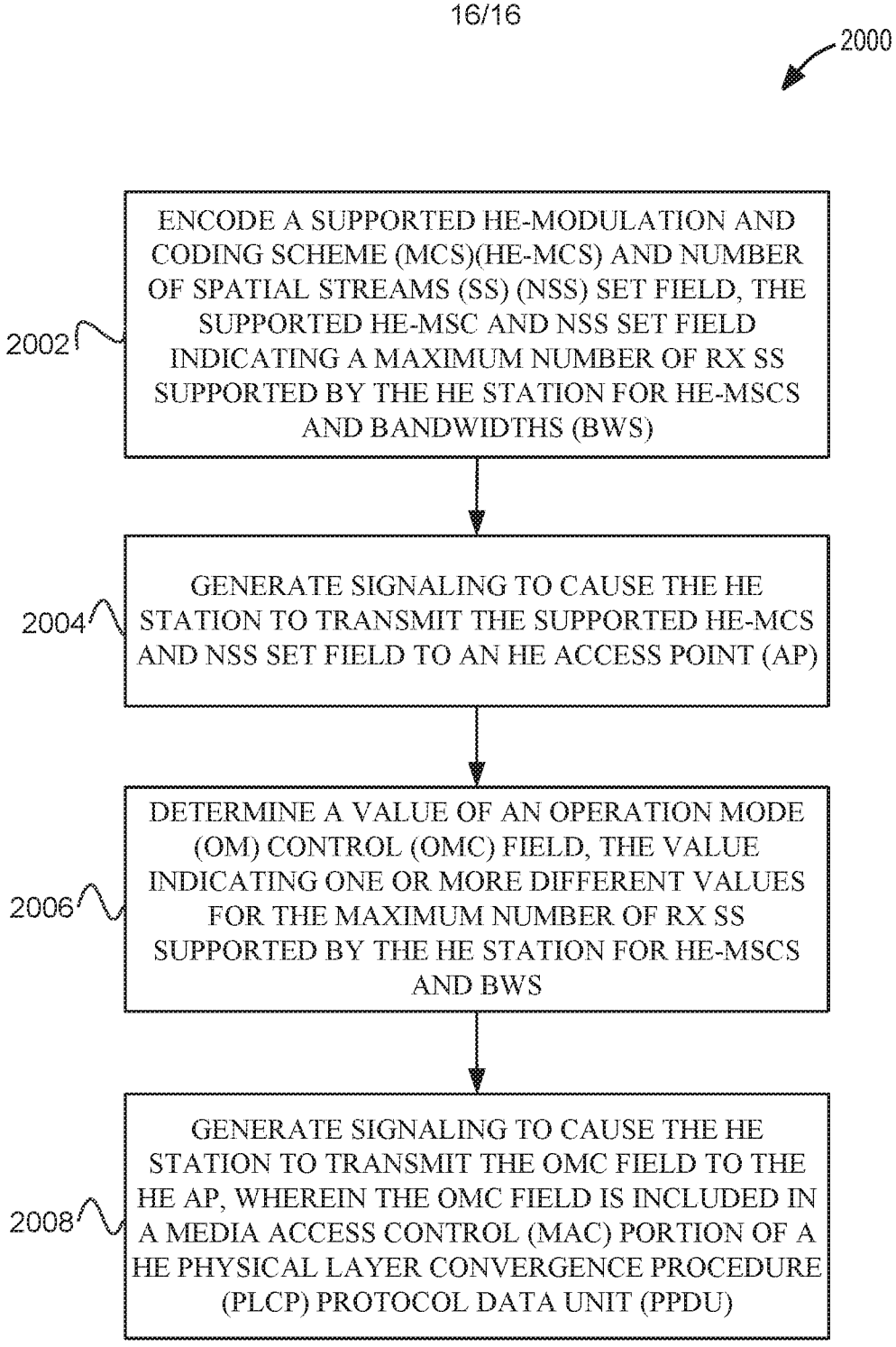

2000
ENCODE A SUPPORTED HE-MODULATION AND CODING SCHEME (MCS)(HE-MCS) AND NUMBER OF SPATIAL STREAMS (SS) (NSS) SET FIELD, THE SUPPORTED HE-MSC AND NSS SET FIELD INDICATING A MAXIMUM NUMBER OF RX SS SUPPORTED BY THE HE STATION FOR HE-MSCS AND BANDWIDTHS (BWS)
2002
GENERATE SIGNALING TO CAUSE THE HE STATION TO TRANSMIT THE SUPPORTED HE-MCS AND NSS SET FIELD TO AN HE ACCESS POINT (AP)
2004
DETERMINE A VALUE OF AN OPERATION MODE (OM) CONTROL (OMC) FIELD, THE VALUE INDICATING ONE OR MORE DIFFERENT VALUES FOR THE MAXIMUM NUMBER OF RX SS SUPPORTED BY THE HE STATION FOR HE-MSCS AND BWS
2006
GENERATE SIGNALING TO CAUSE THE HE STATION TO TRANSMIT THE OMC FIELD TO THE HE AP, WHEREIN THE OMC FIELD IS INCLUDED IN A MEDIA ACCESS CONTROL (MAC) PORTION OF A HE PHYSICAL LAYER CONVERGENCE PROCEDURE (PLCP) PROTOCOL DATA UNIT (PPDU)
2008

FIG. 20

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/041682

A. CLASSIFICATION OF SUBJECT MATTER

H04W 72/12(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 72/12; H04B 7/04; H04L 5/00; H04W 48/08; H04W 52/02; H04W 74/06; 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: PPDU, HE AP, start of the scheduled service period, TIM, NDP

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2016-0165625 A1 (LG ELECTRONICS INC.) 09 June 2016 See paragraphs [0007], [0009], [0010], [0036], [0048], [0071], [0097]-[0099], [0105], [0112]; and figures 2, 5.	1,9-10,14-16,18,20,25
Y		2-8,11-13,17,19,21-24
Y	LAURENT CARIOU et al., `Explanations for CR on 27.5.2.7 NDP feedback report', doc.: IEEE 802.11-17/0074, slide. 1-18, 16 January 2017 See slides 3, 8, 11.	2-8,17,19,21-23
Y	WO 2016-123389 A1 (QUALCOMM INCORPORATED) 04 August 2016 See paragraphs [0054], [0071]; and figure 2.	11-13
Y	US 2016-0323807 A1 (CHITTABRATA GHOSH et al.) 3 November 2016 See paragraph [0069].	24
A	US 2016-0095139 A1 (QUALCOMM INCORPORATED) 31 March 2016 See paragraphs [0060]-[0091]; and figures 3-9.	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	Date of mailing of the international search report
29 November 2018 (29.11.2018)	**30 November 2018 (30.11.2018)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2018/041682

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2018/041682

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