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(54) DYNAMIC PUNCTURING IN DYNAMIC SUBBAND OPERATION

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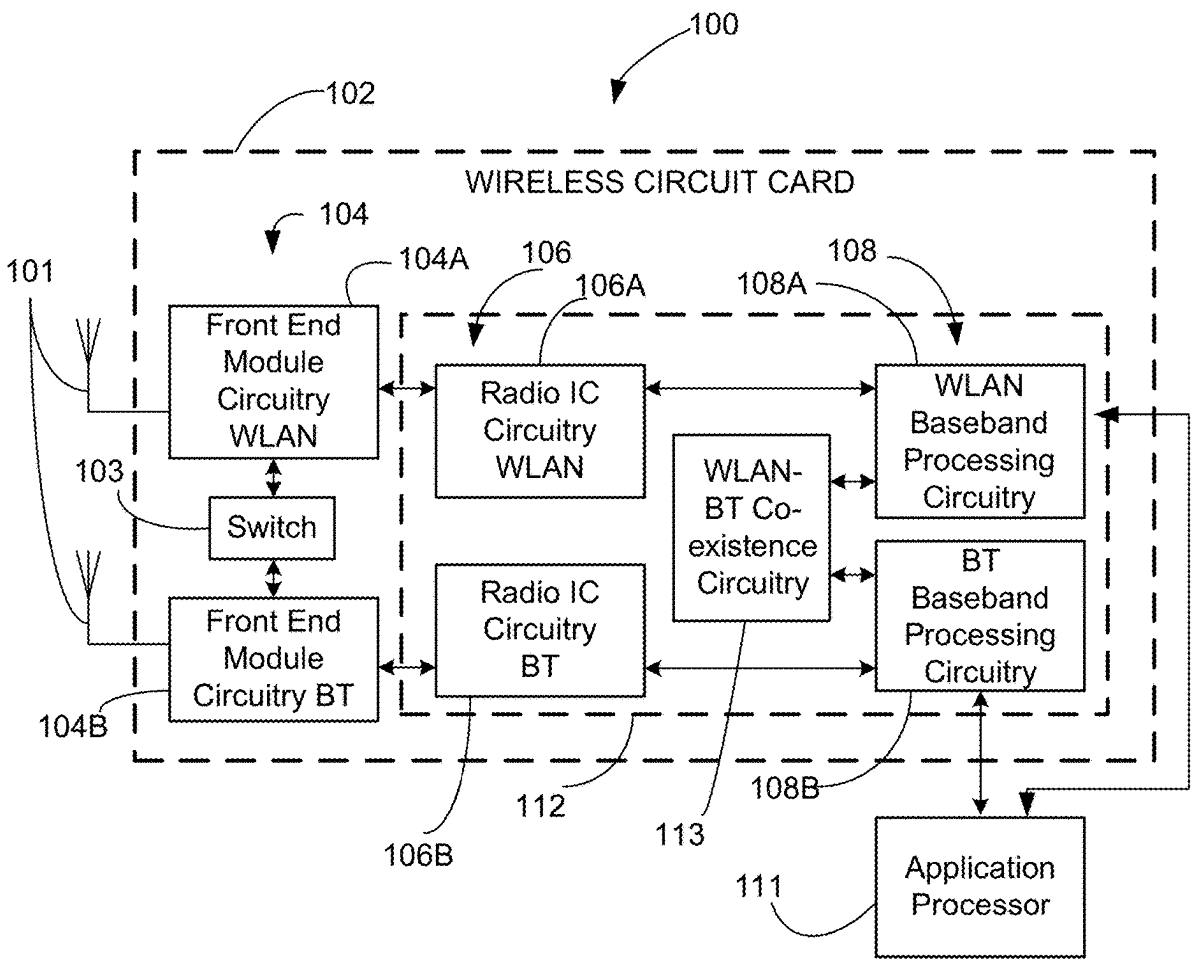
CPC ***H04L 5/006*** (2013.01); ***H04B 17/30*** (2015.01); ***H04L 1/0042*** (2013.01); ***H04L 1/0047*** (2013.01)

(57) **ABSTRACT**

Methods, apparatuses, and computer readable media for dynamic puncturing in dynamic subband operation (DSO), where a station (STA) comprises processing circuitry configured to: decode, from an access point (AP), an initial control frame (ICF), the ICF comprising a resource unit (RU) allocation field, the RU allocation field indicating an RU for the STA, the RU being outside a current operating bandwidth of the STA and within a basic service set (BSS) bandwidth of the AP. The processing circuitry further configured to move to a new operating bandwidth, the new operating bandwidth overlapping a bandwidth of the RU and outside a bandwidth of a primary channel of the AP, encode, an initial control response (ICR) frame for transmission to the AP on the RU, and monitor to a new primary channel, the new primary channel within the new operating bandwidth.



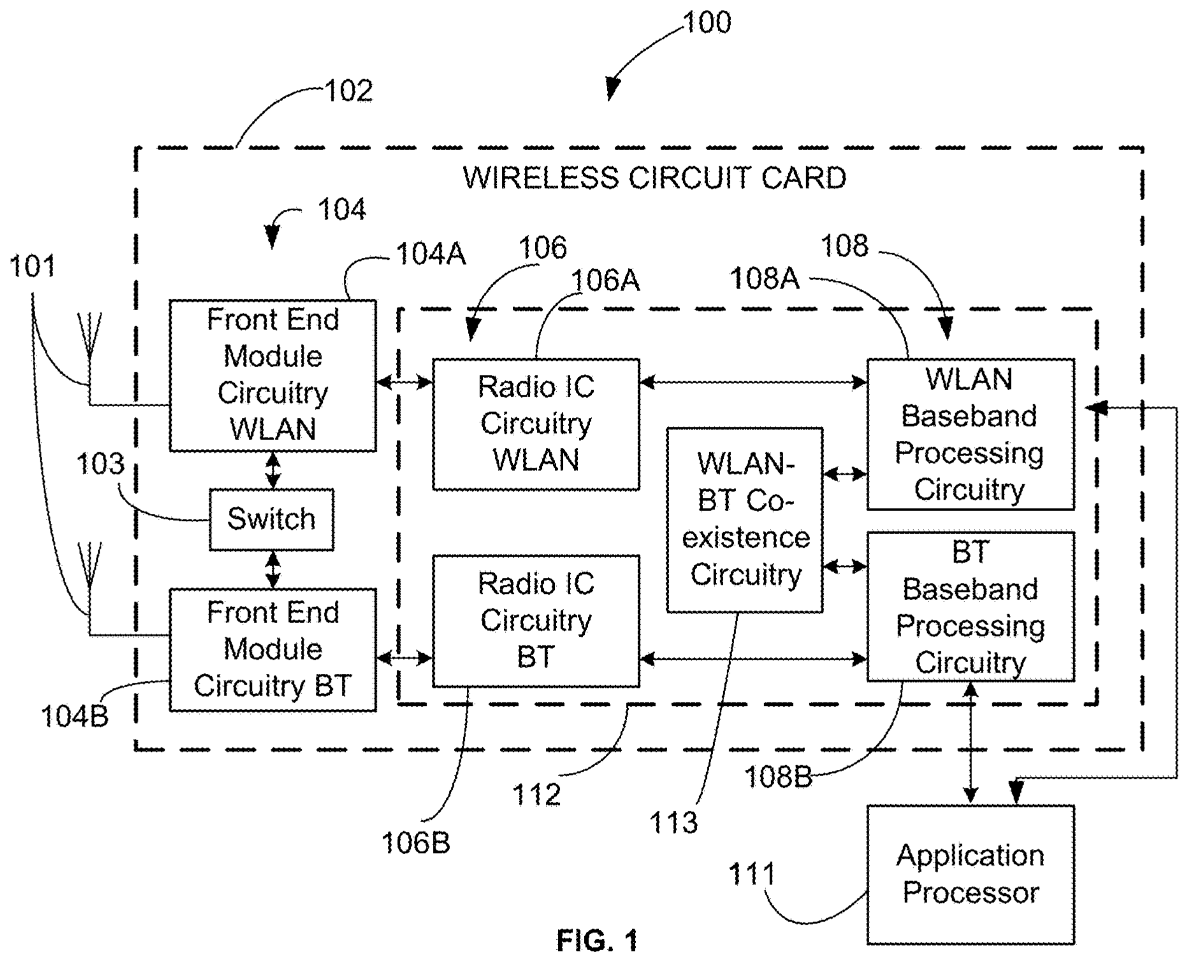

100
102
WIRELESS CIRCUIT CARD
104
101
104A
106
106A
108A
108
Front End Module Circuitry WLAN
Radio IC Circuitry WLAN
WLAN Baseband Processing Circuitry
103
Switch
WLAN-BT Co-existence Circuitry
Front End Module Circuitry BT
Radio IC Circuitry BT
BT Baseband Processing Circuitry
104B
112
108B
113
106B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

FIG. 1

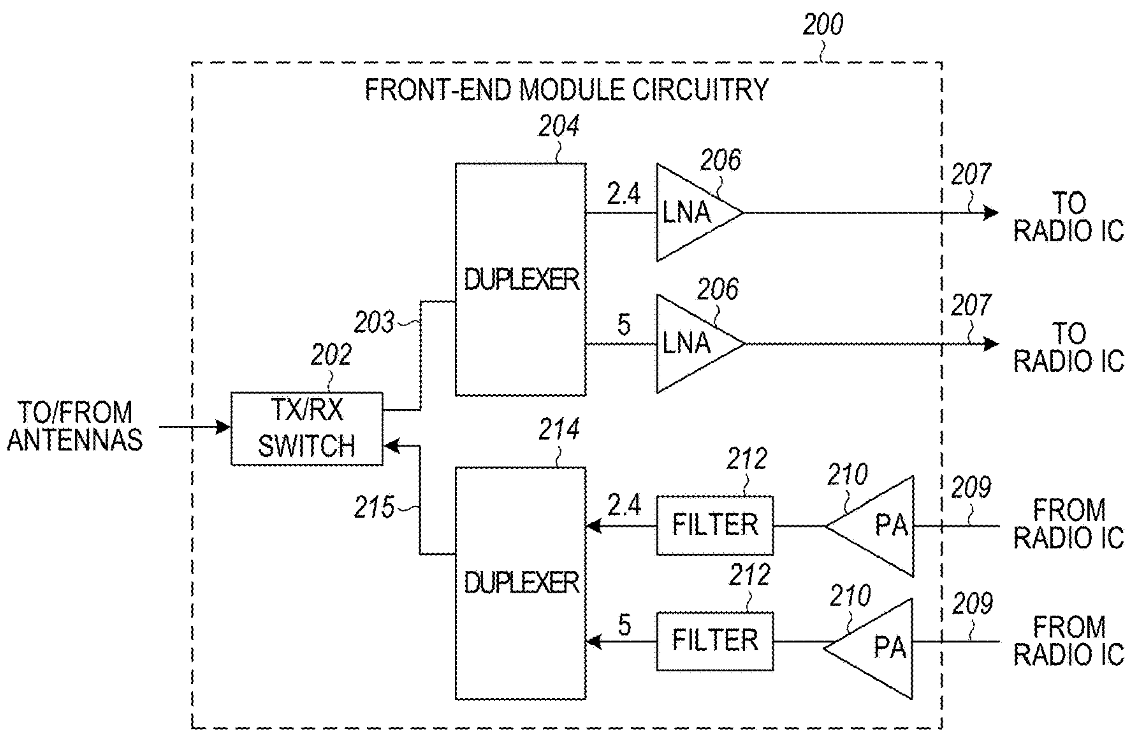

200
FRONT-END MODULE CIRCUITRY
204
206
2.4
LNA
207
TO RADIO IC
DUPLEXER
206
5
LNA
207
TO RADIO IC
203
202
TO/FROM ANTENNAS
TX/RX SWITCH
214
212
210
209
215
2.4
FILTER
PA
FROM RADIO IC
DUPLEXER
212
210
209
5
FILTER
PA
FROM RADIO IC

FIG. 2

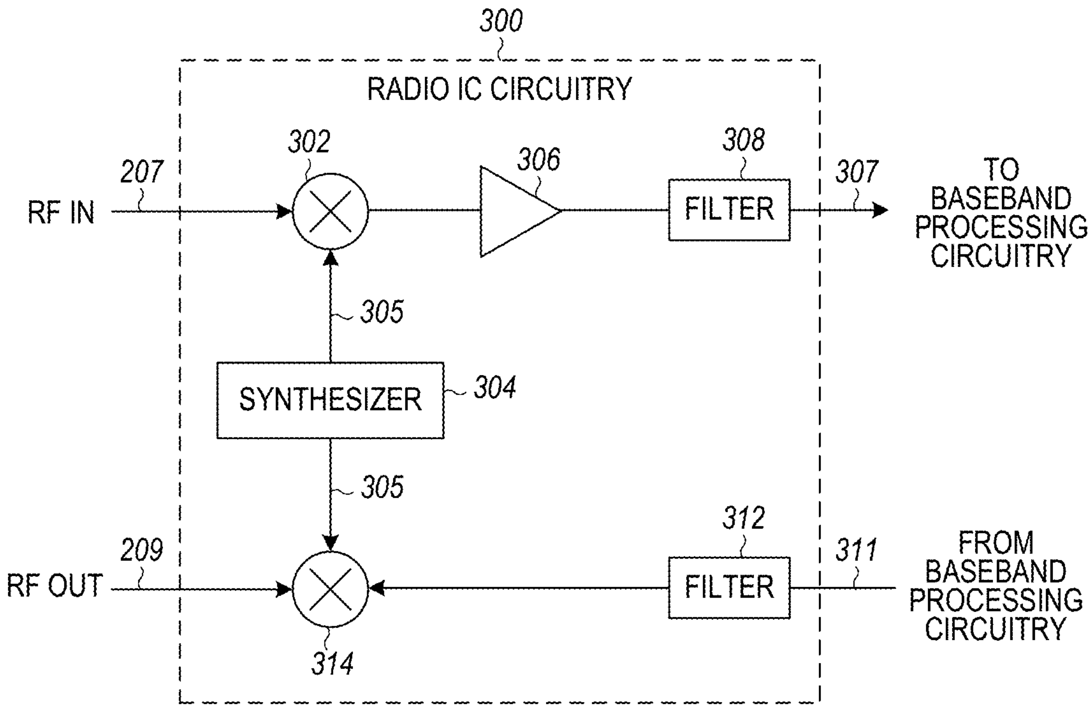

300
RADIO IC CIRCUITRY
302
306
308
207
RF IN
FILTER
307
TO BASEBAND PROCESSING CIRCUITRY
305
SYNTHESIZER
304
305
312
209
RF OUT
FILTER
311
FROM BASEBAND PROCESSING CIRCUITRY
314

FIG. 3

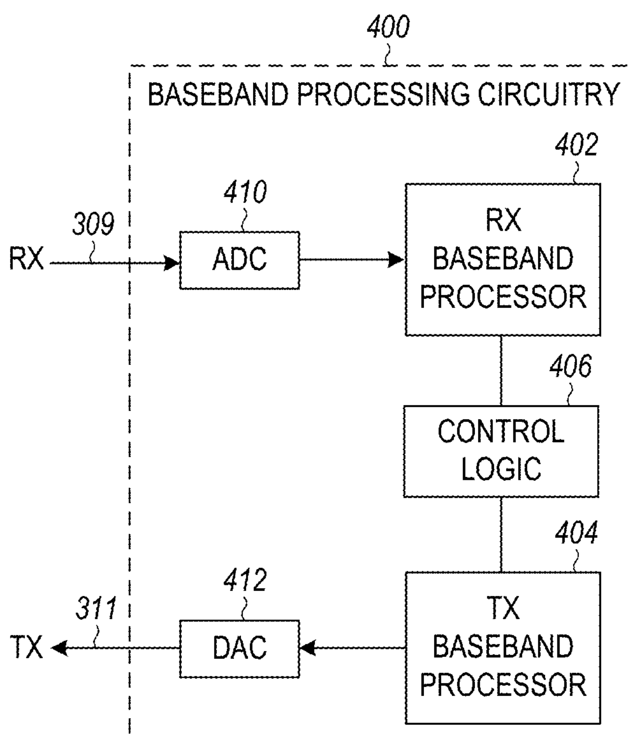

400
BASEBAND PROCESSING CIRCUITRY
402
410
309
RX
ADC
RX BASEBAND PROCESSOR
406
CONTROL LOGIC
404
412
311
TX
DAC
TX BASEBAND PROCESSOR

FIG. 4

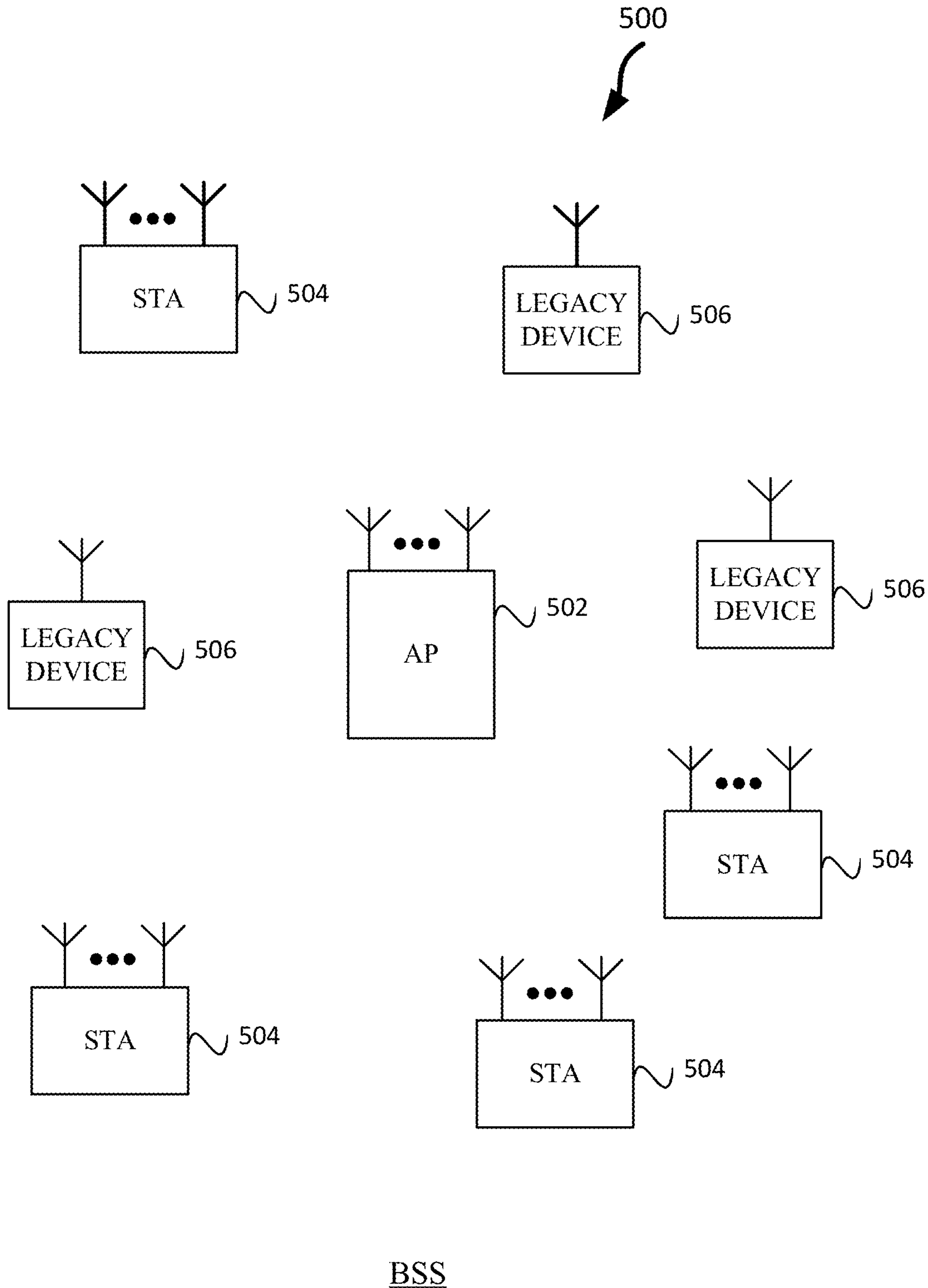

500
STA
504
LEGACY DEVICE
506
LEGACY DEVICE
506
AP
502
LEGACY DEVICE
506
STA
504
STA
504
STA
504
BSS

FIG. 5

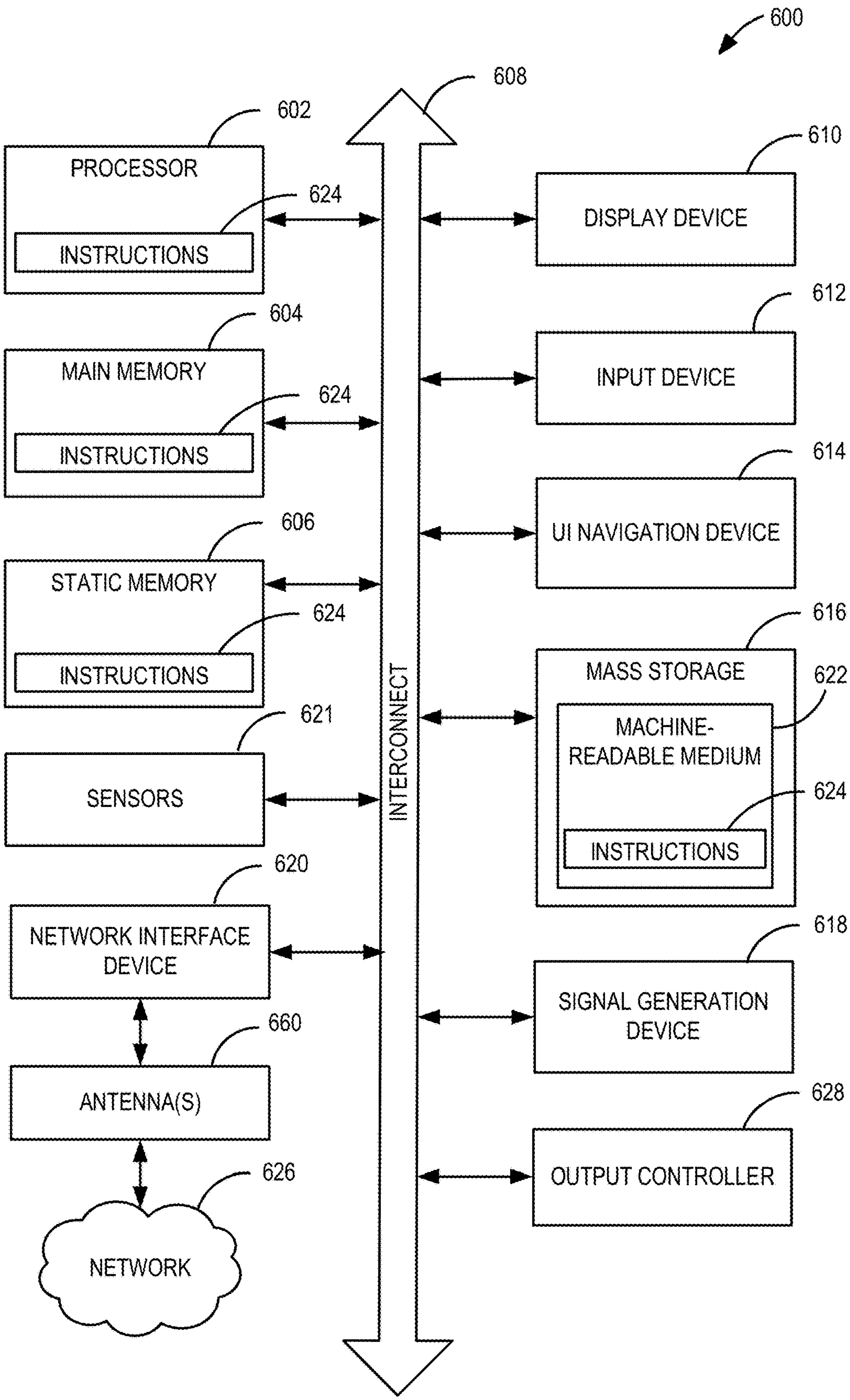

600
608
602
PROCESSOR
624
INSTRUCTIONS
604
MAIN MEMORY
624
INSTRUCTIONS
606
STATIC MEMORY
624
INSTRUCTIONS
621
SENSORS
620
NETWORK INTERFACE DEVICE
660
ANTENNA(S)
626
NETWORK
INTERCONNECT
610
DISPLAY DEVICE
612
INPUT DEVICE
614
UI NAVIGATION DEVICE
616
MASS STORAGE
622
MACHINE-READABLE MEDIUM
624
INSTRUCTIONS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

FIG. 6

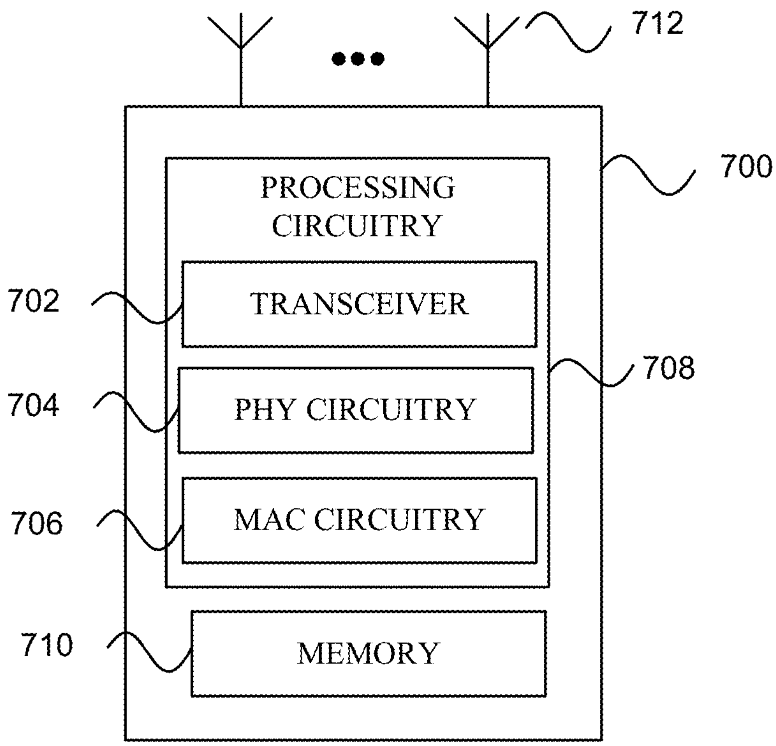

712
700
PROCESSING CIRCUITRY
702
TRANSCEIVER
708
704
PHY CIRCUITRY
706
MAC CIRCUITRY
710
MEMORY

FIG. 7

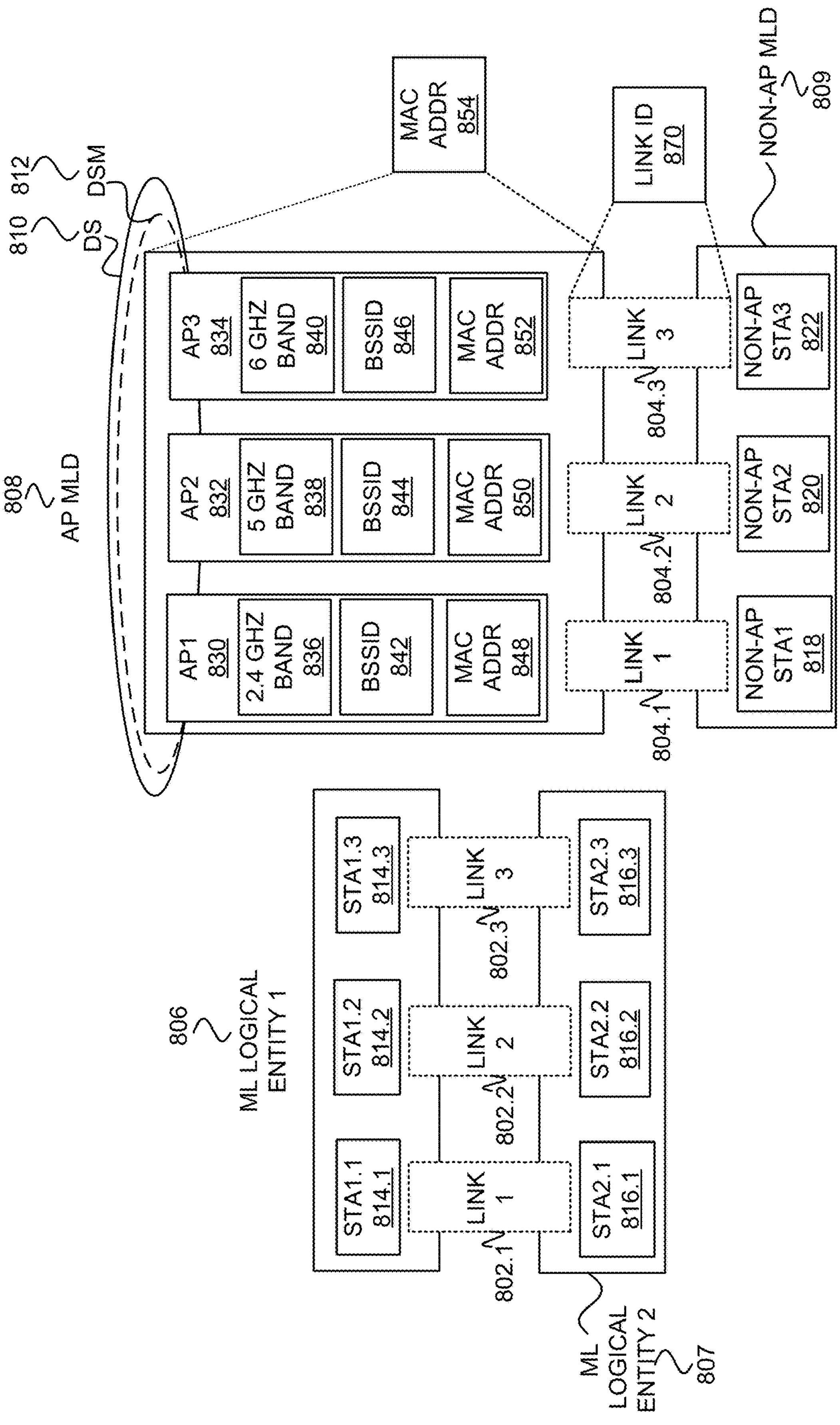

808
AP MLD
810
DS
812
DSM
MAC ADDR 854
LINK ID 870
NON-AP MLD
809
AP1 830
2.4 GHZ BAND 836
BSSID 842
MAC ADDR 848
AP2 832
5 GHZ BAND 838
BSSID 844
MAC ADDR 850
AP3 834
6 GHZ BAND 840
BSSID 846
MAC ADDR 852
LINK 1
LINK 2
LINK 3
804.1
804.2
804.3
NON-AP STA1 818
NON-AP STA2 820
NON-AP STA3 822
806
ML LOGICAL ENTITY 1
STA1.1 814.1
STA1.2 814.2
STA1.3 814.3
LINK 1
LINK 2
LINK 3
802.1
802.2
802.3
STA2.1 816.1
STA2.2 816.2
STA2.3 816.3
ML LOGICAL ENTITY 2
807

FIG. 8

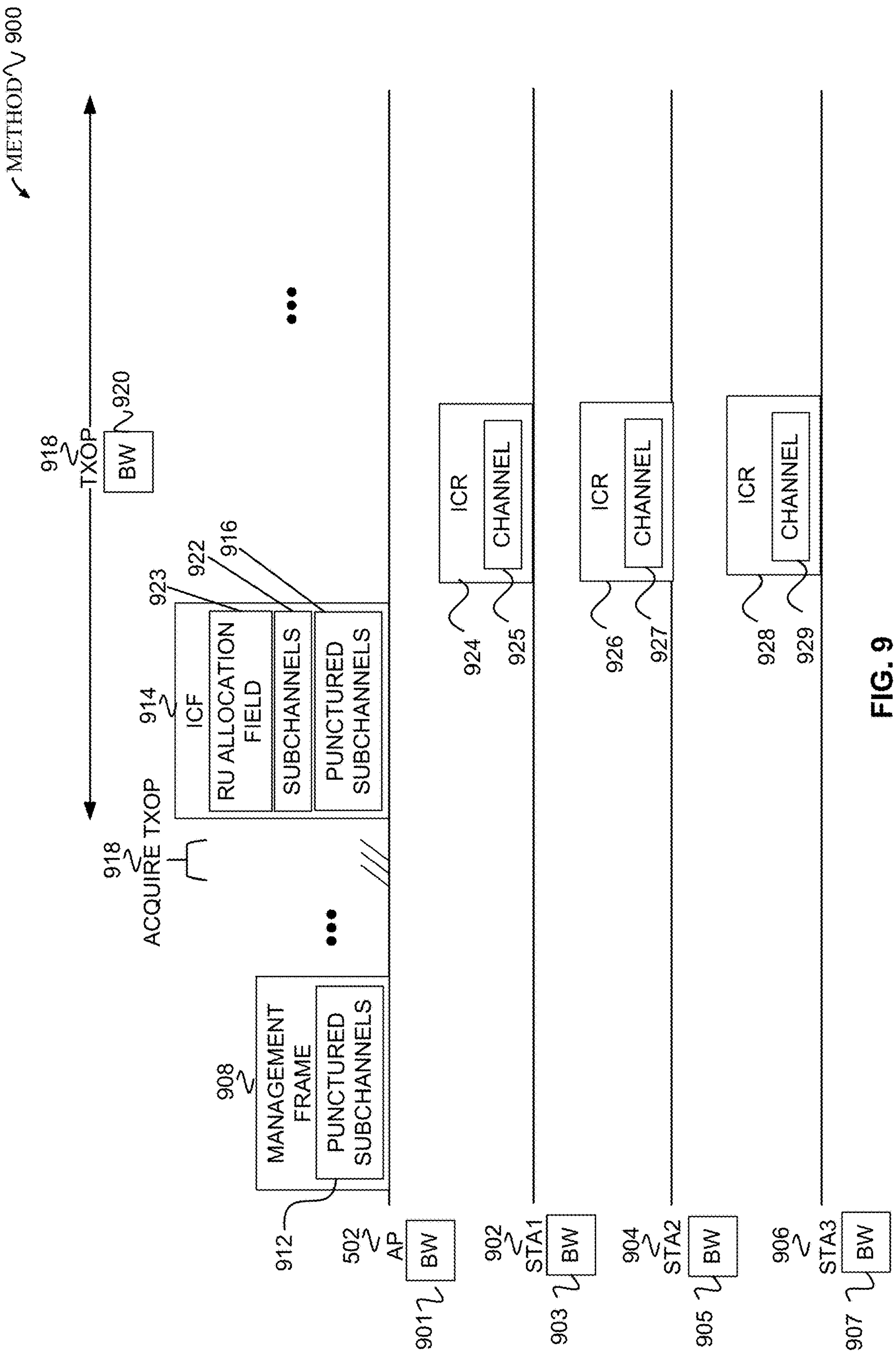

METHOD 900
918
TXOP
BW
920
918
ACQUIRE TXOP
914
ICF
RU ALLOCATION FIELD
SUBCHANNELS
PUNCTURED SUBCHANNELS
923
922
916
908
MANAGEMENT FRAME
PUNCTURED SUBCHANNELS
912
502
AP
BW
901
902
STA1
BW
903
904
STA2
BW
905
906
STA3
BW
907
ICR
CHANNEL
924
925
ICR
CHANNEL
926
927
ICR
CHANNEL
928
929

FIG. 9

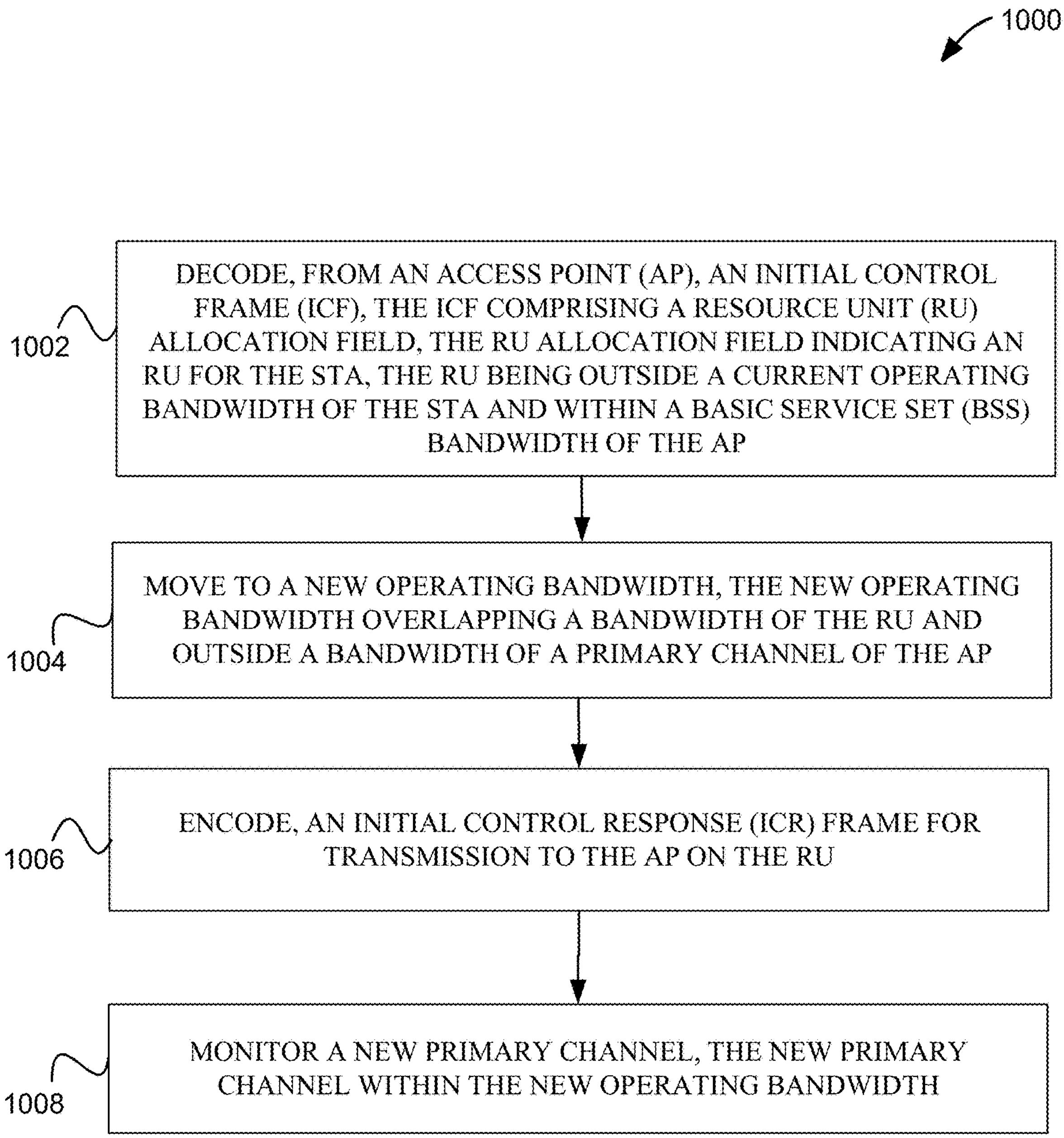

1000
1002
DECODE, FROM AN ACCESS POINT (AP), AN INITIAL CONTROL FRAME (ICF), THE ICF COMPRISING A RESOURCE UNIT (RU) ALLOCATION FIELD, THE RU ALLOCATION FIELD INDICATING AN RU FOR THE STA, THE RU BEING OUTSIDE A CURRENT OPERATING BANDWIDTH OF THE STA AND WITHIN A BASIC SERVICE SET (BSS) BANDWIDTH OF THE AP
1004
MOVE TO A NEW OPERATING BANDWIDTH, THE NEW OPERATING BANDWIDTH OVERLAPPING A BANDWIDTH OF THE RU AND OUTSIDE A BANDWIDTH OF A PRIMARY CHANNEL OF THE AP
1006
ENCODE, AN INITIAL CONTROL RESPONSE (ICR) FRAME FOR TRANSMISSION TO THE AP ON THE RU
1008
MONITOR A NEW PRIMARY CHANNEL, THE NEW PRIMARY CHANNEL WITHIN THE NEW OPERATING BANDWIDTH

FIG. 10

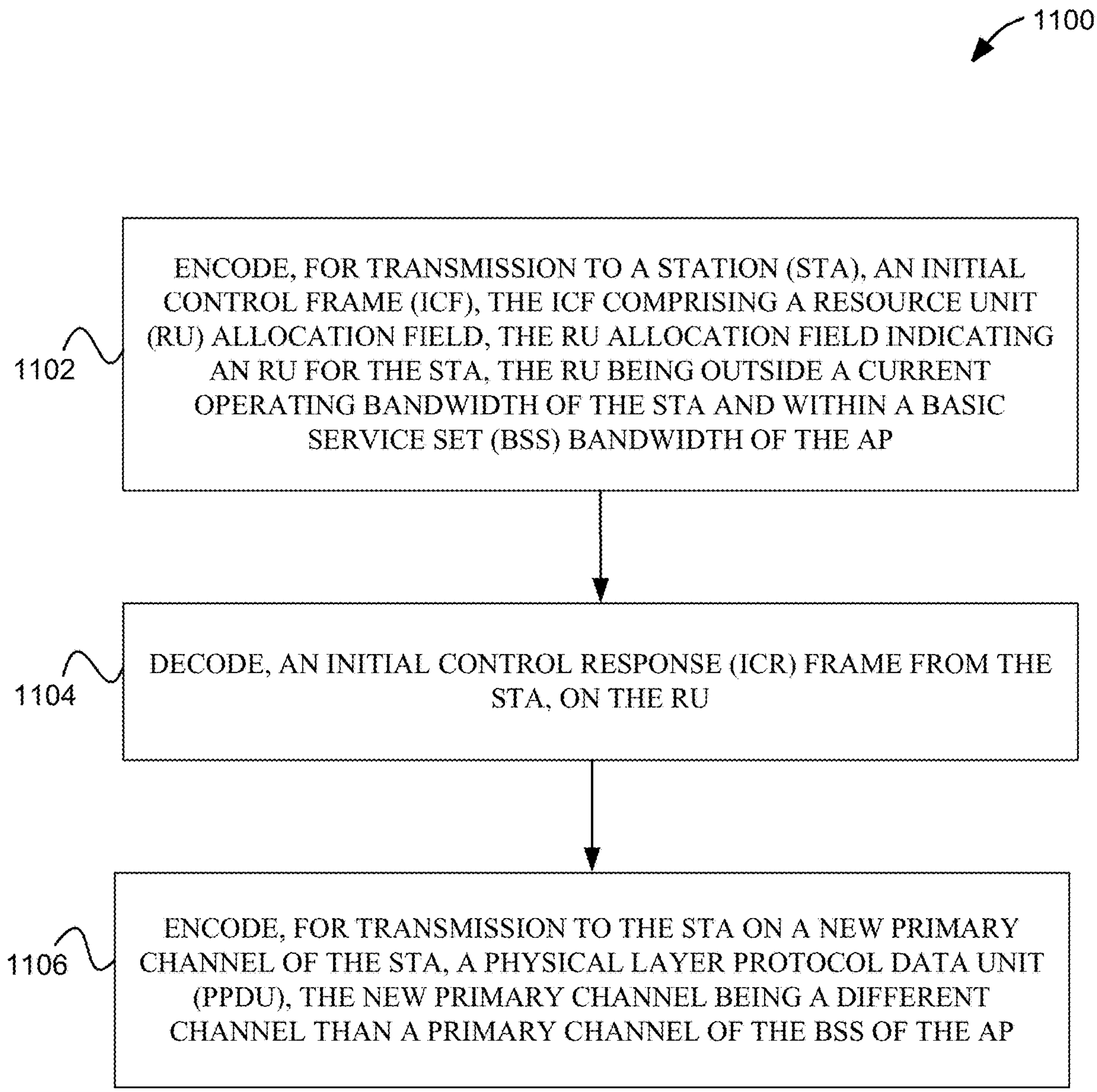

1100
1102
ENCODE, FOR TRANSMISSION TO A STATION (STA), AN INITIAL CONTROL FRAME (ICF), THE ICF COMPRISING A RESOURCE UNIT (RU) ALLOCATION FIELD, THE RU ALLOCATION FIELD INDICATING AN RU FOR THE STA, THE RU BEING OUTSIDE A CURRENT OPERATING BANDWIDTH OF THE STA AND WITHIN A BASIC SERVICE SET (BSS) BANDWIDTH OF THE AP
1104
DECODE, AN INITIAL CONTROL RESPONSE (ICR) FRAME FROM THE STA, ON THE RU
1106
ENCODE, FOR TRANSMISSION TO THE STA ON A NEW PRIMARY CHANNEL OF THE STA, A PHYSICAL LAYER PROTOCOL DATA UNIT (PPDU), THE NEW PRIMARY CHANNEL BEING A DIFFERENT CHANNEL THAN A PRIMARY CHANNEL OF THE BSS OF THE AP

FIG. 11

DYNAMIC PUNCTURING IN DYNAMIC SUBBAND OPERATION

PRIORITY CLAIM

[0001] This application claims the benefit of priority under 35 USC 119 (e) to U.S. Provisional Patent Application Ser. No. 63/643,664, filed May 7, 2024 [AG0980-Z], which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] Embodiments relate to dynamic puncturing in dynamic subband operation (DSO) and/or within a transmission opportunity (TxOP), in accordance with wireless local area networks (WLANs) and Wi-Fi networks including networks operating in accordance with different versions or generations of the IEEE 802.11 family of standards.

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 newer protocols and with legacy protocols on multiple bands and channels.

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 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 multi-link devices (MLD)s, in accordance with some embodiments;

[0013] FIG. **9** illustrates a method for dynamic puncturing in dynamic subband operation (DSO), in accordance with some embodiments;

[0014] FIG. **10** illustrates a method for dynamic puncturing in DSO, in accordance with some embodiments; and,

[0015] FIG. **11** illustrates a method for dynamic puncturing in DSO, in accordance with some embodiments.

DESCRIPTION

[0016] 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.

[0017] 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.

[0018] FEM circuitry **104** may include a WLAN or Wi-Fi FEM circuitry **104**A and a Bluetooth® (BT) FEM circuitry **104**B. The WLAN FEM circuitry **104**A 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 **106**A for further processing. The BT FEM circuitry **104**B 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 **106**B for further processing. FEM circuitry **104**A may also include a transmit signal path which may include circuitry configured to amplify WLAN signals provided by the radio IC circuitry **106**A for wireless transmission by one or more of the antennas **101**. In addition, FEM circuitry **104**B may also include a transmit signal path which may include circuitry configured to amplify BT signals provided by the radio IC circuitry **106**B for wireless transmission by the one or more antennas. In the embodiment of FIG. **1**, although FEM circuitry **104**A and FEM circuitry **104**B 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.

[0019] Radio IC circuitry **106** as shown may include WLAN radio IC circuitry **106**A and BT radio IC circuitry **106**B. The WLAN radio IC circuitry **106**A may include a receive signal path which may include circuitry to down-convert WLAN RF signals received from the FEM circuitry **104**A and provide baseband signals to WLAN baseband processing circuitry **108**A. BT radio IC circuitry **106**B may in turn include a receive signal path which may include circuitry to down-convert BT RF signals received from the FEM circuitry **104**B and provide baseband signals to BT baseband processing circuitry **108**B. WLAN radio IC circuitry **106**A may also include a transmit signal path which may include circuitry to up-convert WLAN baseband signals provided by the WLAN baseband processing circuitry **108**A and provide WLAN RF output signals to the FEM circuitry **104**A for subsequent wireless transmission by the one or more antennas **101**. BT radio IC circuitry **106**B may also include a transmit signal path which may include circuitry to up-convert BT baseband signals provided by the BT baseband processing circuitry **108**B and provide BT RF output signals to the FEM circuitry **104**B for subsequent wireless transmission by the one or more antennas **101**. In the embodiment of FIG. **1**, although radio IC circuitries **106**A and **106**B 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.

[0020] Baseband processing circuitry **108** may include a WLAN baseband processing circuitry **108**A and a BT baseband processing circuitry **108**B. The WLAN baseband processing circuitry **108**A 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 **108**A. Each of the WLAN baseband processing circuitry **108**A and the BT baseband circuitry **108**B 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 **108**A and **108**B 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**.

[0021] 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 processing circuitry **108**A and the BT baseband circuitry **108**B to enable use cases requiring WLAN and BT coexistence. In addition, a switch **103** may be provided between the WLAN FEM circuitry **104**A and the BT FEM circuitry **104**B 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 **104**A and the BT FEM circuitry **104**B, 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 circuitry **104**A or FEM circuitry **104**B.

[0022] 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**.

[0023] 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.

[0024] 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.

[0025] 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.

[0026] 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.

[0027] In some embodiments, as further shown in FIG. **1**, the BT baseband circuitry **108**B 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

[0028] 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).

[0029] 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 nine hundred MHz, 2.4 GHz, 5 GHZ, and bandwidths of about 1 MHZ, 2 MHZ, 2.5 MHz, 4 MHz, 5 MHz, 8 MHz, 10MHz, 16 MHz, 20 MHz, 40 MHz, 80 MHz (with contiguous bandwidths) or 80+80 MHz (160 MHz) (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.

[0030] 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 **104**A/**104**B (FIG. **1**), although other circuitry configurations may also be suitable.

[0031] 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**)).

[0032] 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.

[0033] 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 **106**A/**106**B (FIG. **1**), although other circuitry configurations may also be suitable.

[0034] 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 **302** 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.

[0035] 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.

[0036] 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.

[0037] 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 circuitry **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.

[0038] 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

[0039] 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 circuitry **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.

[0040] 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.

[0041] 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**).

[0042] 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.

[0043] 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.

[0044] 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**.

[0045] 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}).

[0046] 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**.

[0047] 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.

[0048] In some embodiments that communicate OFDM signals or OFDMA signals, such as through baseband processing circuitry **108**A, the TX BBP **404** may be configured to generate OFDM or OFDMA signals as appropriate for transmission by performing an inverse fast Fourier transform (IFFT). The RX BBP **402** may be configured to process received OFDM signals or OFDMA signals by performing an FFT. In some embodiments, the RX BBP **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.

[0049] 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.

[0050] 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.

[0051] FIG. **5** illustrates a WLAN **500** in accordance with some embodiments. The WLAN **500** may comprise a basis service set (BSS) that may include an access point (AP) AP **502**, a plurality of stations (STAs) STAs **504**, and a plurality of legacy devices **506**. In some embodiments, the STAs **504** and/or AP **502** are configured to operate in accordance with IEEE 802.11be extremely high throughput (EHT), WiFi 8 IEEE 802.11 ultra-high throughput (UHT), high efficiency (HE) IEEE 802.11ax, IEEE 802.11bn next generation or ultra-high reliability (UHR), and/or another IEEE 802.11 wireless communication standard. In some embodiments, the STAs **504** and/or AP **502** are configured to operate in accordance with IEEE P802.11be, and/or IEEE P802.11-REVme™, both of which are hereby included by reference in their entirety, and to operate in accordance with one or more functions described herein. In some embodiments, one or more the legacy devices **506**, STAs **504**, and/or the AP **502** may be configured to operate in accordance with one or more Wi-Fi Alliance (WFA) communication standards.

[0052] The AP **502** may use other communications protocols as well as the IEEE 802.11 protocol. The terms here may be termed differently in accordance with some embodiments. 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 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 APs **502** and may control more than one BSS, e.g., assign primary channels, colors, etc. AP **502** may be connected to the internet.

[0053] 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/ax/uht, or another legacy wireless communication standard. The legacy devices **506** may be STAs or IEEE STAs. The 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 802.11be or another wireless protocol.

[0054] The AP **502** may communicate with legacy devices **506** in accordance with legacy IEEE 802.11 communication techniques. In example embodiments, the AP **502** may also be configured to communicate with STAs **504** in accordance with legacy IEEE 802.11 communication techniques.

[0055] In some embodiments, a HE, EHT, UHT frames may be configurable to have the same bandwidth as a channel. The HE, EHT, UHT frame may be a physical Layer Convergence Procedure (PLCP) Protocol Data Unit (PPDU). In some embodiments, PPDU may be an abbreviation for physical layer 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. For example, a single user (SU) PPDU, downlink (DL) PPDU, multiple-user (MU) PPDU, extended-range (ER) SU PPDU, and/or trigger-based (TB) PPDU. In some embodiments EHT may be the same or similar as HE PPDUs.

[0056] The bandwidth of a channel may be 20 MHz, 40 MHz, or 80 MHz, 80+80 MHz, 160 MHz, 160+160 MHz, 320 MHz, 320+320 MHz, 640 MHz bandwidths. In some embodiments, the bandwidth of a channel less than 20 MHz may be 1 MHz, 1.25 MHz, 2.03 MHz, 2.5 MHz, 4.06 MHz, 5 MHz and 10 MHz, 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 2×996 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.

[0057] 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.

[0058] A HE, EHT, UHT, UHT, or UHR 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 AP **502**, 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®, low-power Bluetooth®, or other technologies.

[0059] In accordance with some IEEE 802.11 embodiments, e.g., IEEE 802.11EHT/ax/be 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 a transmission opportunity (TXOP). The AP **502** may transmit an EHT/HE trigger frame transmission, which may include a schedule for simultaneous UL/DL transmissions from

STAs **504**. The AP **502** may transmit a time duration of the TXOP and sub-channel information. During the TXOP, STAs **504** may communicate with the 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, EHT, UHR control period, the AP **502** may communicate with STAs **504** using one or more HE or EHT frames. During the TXOP, the HE STAs **504** may operate on a sub-channel smaller than the operating range of the AP **502**. During the TXOP, legacy stations refrain from communicating. The legacy stations may need to receive the communication from the HE AP **502** to defer from communicating.

[0060] In accordance with some embodiments, during the TXOP the 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 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.

[0061] In some embodiments, the multiple-access technique used during the HE or EHT 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).

[0062] The AP **502** may also communicate with legacy devices **506** and/or STAs **504** in accordance with legacy IEEE 802.11 communication techniques. In some embodiments, the AP **502** may also be configurable to communicate with STAs **504** outside the TXOP in accordance with legacy IEEE 802.11 or IEEE 802.11EHT/UHR communication techniques, although this is not a requirement.

[0063] In some embodiments the STA **504** may be a "group owner" (GO) for peer-to-peer modes of operation. A wireless device may be a STA **504** or a HE AP **502**. The STA **504** may be termed a non-access point (AP) (non-AP) STA **504**, in accordance with some embodiments.

[0064] In some embodiments, the STA **504** and/or 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 STA **504** and/or the AP **502**. In example embodiments, the front-end module circuitry of FIG. **2** is configured to implement the STA **504** and/or the AP **502**. In example embodiments, the radio IC circuitry of FIG. **3** is configured to implement the HE STA **504** and/or the AP **502**. In example embodiments, the base-band processing circuitry of FIG. **4** is configured to implement the STA **504** and/or the AP **502**.

[0065] In example embodiments, the STAs **504**, AP **502**, an apparatus of the STA **504**, and/or an apparatus of the 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**.

[0066] 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. **1-9**.

[0067] In example embodiments, the STAs **504** and/or the AP **502** are configured to perform the methods and operations/functions described herein in conjunction with FIGS. **1-9**. In example embodiments, an apparatus of the STA **504** and/or an apparatus of the AP **502** are configured to perform the methods and functions described herein in conjunction with FIGS. **1-9**. The term Wi-Fi may refer to one or more of the IEEE 802.11 communication standards. AP and STA may refer to EHT/HE access point and/or EHT/HE station as well as legacy devices **506**.

[0068] In some embodiments, a HE AP STA may refer to an AP **502** and/or STAs **504** that are operating as EHT APs **502**. In some embodiments, when a STA **504** is not operating as an AP, it may be referred to as a non-AP STA or non-AP. In some embodiments, STA **504** may be referred to as either an AP STA or a non-AP. The AP **502** may be part of, or affiliated with, an AP MLD **808**, e.g., AP1 **830**, AP2 **832**, or AP3 **834**. The STAs **504** may be part of, or affiliated with, a non-AP MLD **809**, which may be termed a ML non-AP logical entity. The BSS may be part of an extended service set (ESS), which may include multiple APs, access to the internet, and may include one or more management devices.

[0069] 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**, EVT STA **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.

[0070] 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**.

[0071] 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.

[0072] 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.

[0073] The mass storage **616** device 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 mass storage **616** device may constitute machine readable media.

[0074] 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.

[0075] 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**.

[0076] 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.

[0077] 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.

[0078] 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.

[0079] 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.

[0080] 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.

[0081] 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.

[0082] 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.

[0083] 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 or HE wireless device. The wireless device **700** may be a HE STA **504**, HE AP **502**, and/or a HE STA or HE AP. A HE STA **504**, HE AP **502**, and/or a HE AP or HE STA 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**.

[0084] 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.

[0085] 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**.

[0086] 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.

[0087] 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.

[0088] 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.

[0089] 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.

[0090] 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).

[0091] 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.

[0092] In mmWave technology, communication between a station (e.g., the HE STAs **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.

[0093] FIG. **8** illustrates multi-link devices (MLD) s **800**, in accordance with some embodiments. Illustrated in FIG. **8** is ML logical entity 1 **806**, ML logical entity 2 **807**, AP MLD **808**, and non-AP MLD **809**. The ML logical entity 1 **806** includes three STAs, STA1.1 **814.1**, STA1.2 **814.2**, and STA1.3 **814.3** that operate in accordance with link 1 **802.1**, link 2 **802.2**, and link 3 **802.3**, respectively.

[0094] The Links are different frequency bands such as 2.4 GHz band, 5 GHZ band, 6 GHz band, and so forth. ML logical entity 2 **807** includes STA2.1 **816.1**, STA2.2 **816.2**, and STA2.3 **816.3** that operate in accordance with link 1 **802.1**, link 2 **802.2**, and link 3 **802.3**, respectively. In some embodiments ML logical entity 1 **806** and ML logical entity 2 **807** operate in accordance with a mesh network. Using three links enables the ML logical entity 1 **806** and ML logical entity 2 **807** to operate using a greater bandwidth and more reliably as they can switch to using a different link if there is interference or if one link is superior due to operating conditions.

[0095] The distribution system (DS) **810** indicates how communications are distributed and the DS medium (DSM **812**) indicates the medium that is used for the DS **810**, which in this case is the wireless spectrum.

[0096] AP MLD **808** includes AP1 **830**, AP2 **832**, and AP3 **834** operating on link 1 **804.1**, link 2 **804.2**, and link 3 **804.3**, respectively. AP MLD **808** includes a MAC ADDR **854** that may be used by applications to transmit and receive data across one or more of AP1 **830**, AP2 **832**, and AP3 **834**. Each link may have an associated link ID. For example, as illustrated, link 3 **804.3** has a link ID **870**.

[0097] AP1 **830**, AP2 **832**, and AP3 **834** includes a frequency band, which are 2.4 GHz band **836**, 5 GHz band **838**, and 6 GHz band **840**, respectively. AP1 **830**, AP2 **832**, and AP3 **834** includes different BSSIDs, which are BSSID **842**, BSSID **844**, and BSSID **846**, respectively. AP1 **830**, AP2 **832**, and AP3 **834** includes different media access control (MAC) address (addr), which are MAC adder **848**, MAC addr **850**, and MAC addr **852**, respectively. The AP **502** is a AP MLD **808**, in accordance with some embodiments. The STA **504** is a non-AP MLD **809**, in accordance with some embodiments.

[0098] The non-AP MLD **809** includes non-AP STA1 **818**, non-AP STA2 **820**, and non-AP STA3 **822**. Each of the non-AP STAs may have MAC addresses and the non-AP MLD **809** may have a MAC address that is different and used by application programs where the data traffic is split up among non-AP STA1 **818**, non-AP STA2 **820**, and non-AP STA3 **822**.

[0099] The STA **504** is a non-AP STA1 **818**, non-AP STA2 **820**, or non-AP STA3 **822**, in accordance with some embodiments. The non-AP STA1 **818**, non-AP STA2 **820**, and non-AP STA3 **822** may operate as if they are associated with a BSS of AP1 **830**, AP2 **832**, or AP3 **834**, respectively, over link 1 **804.1**, link 2 **804.2**, and link 3 **804.3**, respectively.

[0100] A Multi-link device such as ML logical entity 1 **806** or ML logical entity 2 **807**, is a logical entity that contains one or more STAs **814.1**, **814.2**, **814.3**, **816.1**, **816.2**, and **816.3**. The ML logical entity 1 **806** and ML logical entity 2 **807** each has one MAC data service interface and primitives to the logical link control (LLC) and a single address associated with the interface, which can be used to communicate on the DSM **812**. Multi-link logical entity allows STAs **814**, **816** within the multi-link logical entity to have the same MAC address. In some embodiments a same MAC address is used for application layers and a different MAC address is used per link.

[0101] In infrastructure framework, AP MLD **808**, includes APs **830**, **832**, **834**, on one side, and non-AP MLD **809**, which includes non-APs STAs **818**, **820**, **822** on the other side.

[0102] ML AP device (AP MLD): is a ML logical entity, where each STA within the multi-link logical entity is an EHT AP **502**, in accordance with some embodiments. ML non-AP device (non-AP MLD) A multi-link logical entity, where each STA within the multi-link logical entity is a non-AP EHT STA **504**. AP1 **830**, AP2 **832**, and AP3 **834** may be operating on different bands and there may be fewer or more APs. There may be fewer or more STAs as part of the non-AP MLD **809**.

[0103] In some embodiments the AP MLD **808** is termed an AP MLD or MLD. In some embodiments non-AP MLD **809** is termed a MLD or a non-AP MLD. Each AP (e.g., AP1 **830**, AP2 **832**, and AP3 **834**) of the MLD sends a beacon frame that includes: a description of its capabilities, operation elements, a basic description of the other AP of the same MLD that are collocated, which may be a report in a

Reduced Neighbor Report element or another element such as a basic multi-link element. AP1 **830**, AP2 **832**, and AP3 **834** transmitting information about the other APs in beacons and probe response frames enables STAs of non-AP MLDs to discover the APs of the AP MLD.

[0104] Improved efficiency of wireless spectrum usage is a technical problem of new communication standards such as Wi-Fi 8, which may be termed ultra-high reliability (UHR) or IEEE 802.11bn. In some embodiments, when an AP **502** is operating on a wide bandwidth such as 160 MHz and has associated STAs **504** that are bandwidth (BW) limited such as operate on 20 MHz, 40 MHz, or 80 MHz, the AP **502** moves one or more of the STAs **504** to secondary channels to multiplex their transmission during a transmission opportunity (TxOP). This enables more of the wireless spectrum to be used and is, thus, a more efficient usage of the wireless spectrum.

[0105] In some embodiments, APs **502** or STAs **504** can transition STAs **504** to secondary channels during a service period (SP) where a management-level negotiation is performed; however, the negotiation may be time consuming. Some embodiments, enable an AP **502** during a TxOP to move STAs **504** to other portions of the wireless spectrum.

[0106] A non-AP STA **504** that supports is called a DSO non-AP STA **504** and s sets the DSO Supported field of the UHR MAC Capabilities Information field of the UHR Capabilities element to 1. An AP **502** that supports DSO is called a DSO AP **502** and sets the DSO Supported field of the UHR MAC Capabilities Information field of the UHR Capabilities element to 1. DSO is a mechanism where a DSO non-AP STA **504** that has an operating bandwidth narrower than the DSO AP can dynamically be allocated frequency resources outside of its current operating bandwidth within the DSO BSS bandwidth of the AP **502**, which may be on a per-TXOP basis.

[0107] FIG. **9** illustrates a method **900** for dynamic puncturing in dynamic subband operation (DSO), in accordance with some embodiments. Illustrated in FIG. **9** is STA1 **902** having BW **903**, STA2 **904** having BW **905**, STA3 having BW **907**, and AP **502** having a BW **901**.

[0108] In some embodiments, the AP **502** acquires TxOP **918** having a BW **920**, which makes the AP **502** a TxOP holder. The AP **502** may obtain or acquire the wireless medium to become the TxOP holder. The AP **502**, in accordance with DSO, sends a frame, which may be termed an Initial Control Frame (ICF) **914**, to one or more of its associated STAs **504**, which here are STA1 **902**, STA2 **904**, and STA3 **906**, which indicates the associated STAs **504** are to move to a secondary channel, which is part of the TxOP bandwidth, BW **920**.

[0109] In some embodiments, one or more of the associated STAs **504** are moved to a channel, which is part of the TxOP bandwidth, BW **920**, but outside the operating BW of the STA **504** because the STA **504** is bandwidth limited. For example, the STA1 **902** may be a 20 MHz STA **504** and the BW **920** of the TxOP may be 320 MHz.

[0110] In some embodiments, the AP **502** transmits a frame to the STA **504** at the start of the TxOP **918**. The frame may be termed an initial control frame (ICF **914**) or given another name. The ICF **914** may request that a STA **504** transition to a different mode of operation. The ICF **914** may include user fields for STAs **504** that indicate subchannels **922** for the STAs **504** to transition to. The STAs **504** transition to the indicated subchannel **922** that are identified in the ICF **914**. The subchannel **922** may be a DSO primary channel, a BW of the STA **504**, or another subchannel. Before responding with a response frame, which may be termed an initial control response (ICR **924**, **926**, **928**), on the indicated subchannel **922**. The indicated subchannels **922** may be termed a subband where a subband is one or more channels and may be indicated by a first channel and a number of channels (which may be consecutive and which may not include punctured channels.)

[0111] Following the ICF **914** ICR **924** exchange, the AP **502** is then able to schedule multiple STAs on the different subchannels of the BW **920** of the TxOP **918** by using downlink (DL) or uplink (UL) multiple user (MU) operation, or by using A-PPDU.

[0112] In some embodiments, puncturing is used. In some embodiments, there are two versions of puncturing. A static puncturing where the punctured subchannel **912**, which may be 20 MHz channels, on which there will be no transmissions, are indicated in a management frame **908** such as a beacon frames of the AP **502**. The punctured subchannels **912** may be indicated by a Disabled Subchannel Bitmap field that is included in a management frame **908** such as a beacon frame, association response frame, and so forth.

[0113] Another type of static puncturing is dynamic puncturing where the punctured subchannels **916**, which may be 20 MHz channels, are indicated in an extremely high-throughput (EHT) PPDU, which may be included in a U-SIG of the EHT PPDU. As illustrated this is an ICF **914**, but this may be another type of frame such as a MU PPDU that is not an ICF **914**. Dynamic puncturing is valid within the TxOP **918** only and can change from one TxOP **918** to another and, in some embodiments, from one PPDU and its response to another.

[0114] A technical problem is to permit operation when one or more subchannels of a BW are punctured due to regulatory reasons or are punctured for practical reasons such as a subchannel has a lot of noise, is in use by another wireless device, or the subchannel needs to remain unused for another reason.

[0115] Some embodiments address the technical problem by using dynamic puncturing and integrating dynamic puncturing with moving STAs **504** to different subchannels using ICF **914** or another mechanism.

[0116] In some embodiments, within a TxOP **918**, both DSO and dynamic puncturing are used. In some embodiments, an ICF **914** ICR **924** exchange is used at the beginning of the TxOP **918** to move STAs **504** or bandwidth-limited STAs to another part of the BW **920** of the TxOP **918**, where the BW **920** of the TxOP **918** is a BW used by the AP **502** in the acquire TxOP **910**.

[0117] The channel **925** is the channel used by STA1 **902** to transmit the ICR **924**. The channel **925** may be a primary channel of the BW **920** of the TxOP **918** or another channel such as a channel indicated in the subchannels **922**. The channel **925** may be in accordance with the punctured subchannels **912**, **916**.

[0118] The channel **927** is the channel used by STA2 **904** to transmit the ICR **926**. The channel **929** may be a primary channel of the BW **920** of the TxOP **918** or another channel such as a channel indicated in the subchannels **922**. The channel **925** may be in accordance with the punctured subchannels **912**, **916**.

[0119] The channel **929** is the channel used by STA3 **906** to transmit the ICR **924**. The channel **925** may be a primary channel of the BW **920** of the TxOP **918** or another channel such as a channel indicated in the subchannels **922**. The channel **929** may be in accordance with the punctured subchannels **912**, **916**.

[0120] The STAs **504** may be configured to transmit the ICR **924** a short interframe space (SIFS) or another inter-frame duration after receiving the ICF **914**. In some embodiments, the ICF **914** is a type of trigger frame. In some embodiments, the AP **502** ensures that during the TxOP **918** that punctured subchannels are indicated to the STA **504** (and/or other APs **502**) to ensure that the TxOP Holder (AP **502**) and Responders (STAs **504**) do not transmit on punctured subchannels **912**, **916**.

[0121] In some embodiments, the punctured subchannels **916** are not announced in the ICF **914**. In some embodiments, a DSO STA **504**, e.g., STA1 **902**, STA2 **904**, STA3 **906**, that is indicated in the subchannels **922** (e.g., that has a user field with an indicated RU), of the ICF **914**, moves to a secondary BW or channel **925**, **927**, **929**.

[0122] The DSO STA **504** moves to a secondary BW that is indicated in a RU allocation field **923** of the ICF **914**. For example, the RU allocation field **923** may indicate a DSO STA **504** and an Index of an RU, e.g., a subchannel, that occupies a BW that is equal to or lower than a max BW of the DSO STA **504** and contained within the BW **920** of the TxOP **918**, and that does not overlap with any punctured subchannels **916**. The channel **925**, **927**, **929**, may then be the RU indicated in the RU allocation field **923**. The ICF **914** may include an RU allocation field **923** for each DSO STA **504**.

[0123] When receiving the ICF **914**, the DSO STA **504** will move to the secondary BW that overlaps with the scheduled RU. For instance, if the STA1 **902** has a BW **903** capability of 80 MHz, and, within a 320 MHz ICF **914**, is scheduled on a 40 MHz RU, which is indicated in the RU allocation field **923**, STA1 **902** will be able to determine the 80 MHz channel that overlaps with the 40 MHz RU as there is a unique 80 MHz channel overlapping with any 40 MHz channel.

[0124] When moving (or tuning) to the channel **925** (outside the primary channel of the AP **502**) indicated in the RU of the RU allocation field **923**, which may be termed a secondary BW, the STA1 **902** needs to choose a temporary primary channel that it will monitor to receive frames. In some embodiments, the STA1 **902** will choose a primary channel that is contained within a 20 MHz channel that overlaps with its RU allocation, which in the current example would be within the 40 MHz indicated in the RU. In this way, the STA1 **902** is sure that it does not select a channel as a primary channel to monitor traffic that is a punctured subchannels **916**, **912**. In some embodiments, the ICF **914** does not include the punctured subchannels **916**. In some embodiments, the primary would be the first 20 MHz channel (lowest channel) of the indicated larger bandwidth of the RU indicated in the RU allocation field **923**.

[0125] When the DSO STA **504** sends the ICR **924**, **926**, **928**, after moving to the secondary BW, such as channel **929**, the DSO STA **504** shall transmit the ICR **924**, **926**, **928**, using the format indicated by the ICF **914**. If the format is TB PPDU, the DSO STA **504** will transmit the ICR **926** on the allocated RU indicated in the RU allocation field **923**, following the trigger rules.

[0126] If the format is a non-high through (HT) (non-HT) PPDU format (non-HT DUP PPDU format), the DSP STA **504** transmits the ICR **924** on all 20 MHz subchannels that overlap (or are contained within) with the allocated RU indicated in the RU allocation field **923**. The STAs **504** may transmit the ICRs **924**, **926**, **928**, a short interframe space (SIFS) or another interframe space after receiving the ICF **914**.

[0127] The AP **502** (the TxOP holder) can, in this way, ensure that no transmissions from itself of the schedules STAs (TxOP Responder) will overlap with channels that the AP **502** wants to be punctured without necessarily announcing the list of punctured channels within the ICF frame.

[0128] In some embodiments, if there is an explicit indication of punctured subchannels **912**, **916**, such as in the management frame **908** or ICF **914**, which might be advantageous to allow for other modes of operation, then the ICF **914** includes a new field in the existing or a new extended common info field such as the punctured subchannels **916** field. The punctured subchannels **916** field may be termed or named the Disabled Subchannel Bitmap which has a bit for each 20 MHz channel within the BSS BW and which is set to 1 if the channel is Disabled and to 0 otherwise, in accordance with some embodiments.

[0129] In some embodiments, the ICF is a control frame that is sent to poll one or more STAs **504** to determine their availability and/or willingness to participate during the TXOP. A STA's **504** participation might require transitioning to a different mode of operation.

[0130] In some embodiments, the STAs **504** select the new operating bandwidth based on the RU being within the new operating bandwidth and the operating bandwidth being one of: a secondary 40 MHz within a primary 160 MHz, a secondary 80 MHz within the primary 160 MHz, a secondary 160 MHz, a primary 20 MHz within the secondary 160 MHz, a primary 40 MHz within the secondary 160 MHz, a secondary 40 within the secondary 160 MHz, a primary 80 MHz within the secondary 160 MHz, a secondary 80 MHz within the secondary 160 MHz, or another bandwidth that is outside the primary channel of the AP **502**.

[0131] The method **900** may be performed by an apparatus for a STA **504**, an apparatus for a non-AP MLD **809**, an apparatus for an AP **502**, or an apparatus for an AP MLD **808**, and/or another device or apparatus disclosed herein. The method **900** may include one or more additional instructions. The method **900** may be performed in a different order. One or more of the operations of method **900** may be optional.

[0132] FIG. **10** illustrates a method **1000** for dynamic puncturing in DSO, in accordance with some embodiments. The method **1000** begins at operation **1002** with decoding, from an AP, an ICF, the ICF comprising an RU allocation field, the RU allocation field indicating an RU for the STA, the RU being outside a current operating bandwidth of the STA and within a basic service set (BSS) bandwidth of the AP. For example, STA1 **902** decodes the ICF **914**, which includes the RU allocation field **923**. The RU allocation field **923** includes an RU for STA1 **902** to transmit the ICR **924** in an UL transmission where the RU is outside the current operation bandwidth of the STA and s within the BSS bandwidth of the AP **502** or within the BW **920** of the TxOP **918**.

[0133] The method **1000** continues at operation **1004** with moving to a new operating bandwidth, the new operating bandwidth overlapping a bandwidth of the RU and outside a bandwidth of a primary channel of the AP. For example, the STA1 **902** moves to a new operating bandwidth.

[0134] The method **1000** continues at operation **1006** with encoding, an ICR frame for transmission to the AP on the RU. For example, the STA1 **902** encodes the ICR **924** frame for transmission to the AP **502** on a channel indicated by the RU allocation field **923**.

[0135] The method **1000** continues at operation **1008** with monitoring to a new primary channel, the new primary channel within the new operating bandwidth. For example, STA1 **902** selects a new primary channel as disclosed herein and monitors or transmits. STA1 **902** new operating bandwidth does not include the primary channel of the BSS of the AP **502**. Monitors indicates that the STA1 **902** is turned to the new primary channel and will decode or receive signals on the new primary channel.

[0136] The method **1000** may be performed by an apparatus for a STA **504**, an apparatus for a non-AP MLD **809**, an apparatus for an AP **502**, or an apparatus for an AP MLD **808**, and/or another device or apparatus disclosed herein. The method **1000** may include one or more additional instructions. The method **1000** may be performed in a different order. One or more of the operations of method **1000** may be optional.

[0137] FIG. **11** illustrates a method **1100** for dynamic puncturing in DSO, in accordance with some embodiments. The method **1000** begins at operation **1102** with encoding, for transmission to a STA, an ICF, the ICF comprising a RU allocation field, the RU allocation field indicating an RU for the STA, the RU being outside a current operating bandwidth of the STA and within a BSS bandwidth of the AP. For example, referring to FIG. **9**, the AP **502** encodes the ICF **914** to include one or more of the RU allocation field **923**, subchannels **922**, and punctured subchannels **916**.

[0138] The method **1100** continues at operation **1104** with decoding, an ICR frame from the STA, on the RU. For example, the STA1 **902** transmits ICR **924** in accordance with the subchannels **922** or RU allocation field **923** for STA1 **902**.

[0139] The method **1100** continues at operation **1106** with encoding, for transmission to the STA on a new primary channel of the STA, a PPDU, the new primary channel being a different channel than a primary channel of the BSS of the AP. The AP **502** of FIG. **9** may transmit a PPDU (not illustrated) on the new primary channel of the STA1 **902**.

[0140] The method **1100** may be performed by an apparatus for a STA **504**, an apparatus for a non-AP MLD **809**, an apparatus for an AP **502**, or an apparatus for an AP MLD **808**, and/or another device or apparatus disclosed herein. The method **1100** may include one or more additional instructions. The method **1100** may be performed in a different order. One or more of the operations of method **1100** may be optional.

[0141] 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.

What is claimed is:

1. An apparatus for a station (STA), the apparatus comprising memory; and processing circuitry coupled to the memory, the processing circuitry configured to:

decode, from an access point (AP), an initial control frame (ICF), the ICF comprising a resource unit (RU) allocation field, the RU allocation field indicating an RU for the STA, the RU being outside a current operating bandwidth of the STA and within a basic service set (BSS) bandwidth of the AP;

move to a new operating bandwidth, the new operating bandwidth overlapping a bandwidth of the RU and outside a bandwidth of a primary channel of the AP;

encode, an initial control response (ICR) frame for transmission to the AP on the RU; and

monitor a new primary channel, the new primary channel within the new operating bandwidth.

2. The apparatus of claim **1**, wherein the ICF further comprises a disabled subchannel bitmap, the disabled subchannel bitmap indicating 20 MHz subchannels that are disabled, and wherein the RU indicates a subband, the subband indicating a number of consecutive channels.

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

select the new primary channel from subchannels within the new operating bandwidth indicated as not disabled.

4. The apparatus of claim **2**, wherein the ICF further comprises an indication of a format for the ICR frame, the format comprising a trigger-based (TB) physical layer protocol data unit (PPDU) or a non-high through (HT) (non-HT) PPDU format, and wherein the encode further comprises:

encode the ICR frame, in accordance with the format, to comprise each 20 MHz of the RU indicated as not disabled by the disabled subchannel bitmap.

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

decode a management frame, the management frame comprising a disabled subchannel bitmap, the disabled subchannel bitmap indicating 20 MHz subchannels that are disabled.

6. The apparatus of claim **1**, wherein the ICF further comprises a plurality of RU allocation fields for other STAs, and wherein the encode further comprises:

encode, the ICR frame for transmission a short interframe space (SIFS) after receiving the ICF, wherein the STA and the other STAs simultaneously transmit ICR frames, the ICR frames comprising the ICR frame.

7. The apparatus of claim **1**, wherein the BSS bandwidth of the AP is larger than the new operating bandwidth of the STA and wherein the new primary channel is 20 MHz.

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

select the new operating bandwidth based on the RU being within the new operating bandwidth and the new operating bandwidth being one of: a secondary 40 MHz within a primary 160 MHz, a secondary 80 MHz within the primary 160 MHz, a secondary 160 MHz, a primary 20 MHz within the secondary 160 MHz, a primary 40 MHz within the secondary 160 MHz, a secondary 40 within the secondary 160 MHz, a primary 80 MHz within the secondary 160 MHz, or a secondary 80 MHz within the secondary 160 MHz.

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

decode, a physical layer protocol data unit (PPDU) from the AP, the PPDU comprising a disabled subchannel bitmap indicating 20 MHz subchannels that are disabled; and

encode, for transmission to the AP on one or more subchannels that are not indicated as disabled by the disabled subchannel bitmap, a response to the PPDU.

10. The apparatus of claim **1**, wherein the ICF further comprises an indication of a format for the ICR frame, the format comprising a trigger-based (TB) physical layer protocol data unit (PPDU) or a non-high through (HT) (non-HT) PPDU format, and wherein the encode further comprises:

encode the ICR frame, in accordance with the format, to comprise each 20 MHz of the RU.

11. The apparatus of claim **1**, wherein the BSS bandwidth of the AP is a bandwidth of transmission opportunity obtained by the AP.

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

select the new primary channel to be a first 20 MHz or lowest channel of a bandwidth of the RU.

13. The apparatus of claim **1**, wherein the STA is one of: an access point (AP), a non-AP STA, an AP of an AP of a multiple link device (MLD), or a non-AP STA of an MLD.

14. The apparatus of claim **1**, further comprising transceiver circuitry coupled to the processing circuitry, wherein the transceiver circuitry is coupled to two or more microstrip antennas for receiving signaling in accordance with a multiple-input multiple-output (MIMO) technique, or the transceiver circuitry is coupled to the processing circuitry, the transceiver circuitry coupled to two or more patch antennas for receiving signaling in accordance with a multiple-input multiple-output (MIMO) technique.

15. A non-transitory computer-readable storage medium including instructions that, when processed by one or more processors, configure a station (STA) to perform operations comprising:

decode, from an access point (AP), an initial control frame (ICF), the ICF comprising a resource unit (RU) allocation field, the RU allocation field indicating an RU for the STA, the RU being outside a current operating bandwidth of the STA and within a basic service set (BSS) bandwidth of the AP;

move to a new operating bandwidth, the new operating bandwidth overlapping a bandwidth of the RU and outside a bandwidth of a primary channel of the AP;

encode, an initial control response (ICR) frame for transmission to the AP on the RU; and

monitor a new primary channel, the new primary channel within the new operating bandwidth.

16. The non-transitory computer-readable storage medium of claim **15**, wherein the ICF further comprises a disabled subchannel bitmap, the disabled subchannel bitmap indicating 20 MHz subchannels that are disabled, and wherein the RU indicates a subband, the subband indicating a number of consecutive channels.

17. The non-transitory computer-readable storage medium of claim **16**, wherein the operations further comprise:

select the new primary channel from subchannels within the new operating bandwidth indicated as not disabled.

18. An apparatus for an access point (AP), the apparatus comprising memory; and processing circuitry coupled to the memory, the processing circuitry configured to:

encode, for transmission to a station (STA), an initial control frame (ICF), the ICF comprising a resource unit (RU) allocation field, the RU allocation field indicating an RU for the STA, the RU being outside a current operating bandwidth of the STA and within a basic service set (BSS) bandwidth of the AP;

decode, an initial control response (ICR) frame from the STA, on the RU; and

encode, for transmission to the STA on a new primary channel of the STA, a physical layer protocol data unit (PPDU), the new primary channel being a different channel than a primary channel of the BSS of the AP.

19. The apparatus of claim **18**, wherein the encode, for transmission to the STA, the ICF, further comprises encode the ICF to further comprise a disabled subchannel bitmap, the disabled subchannel bitmap indicating 20 MHz subchannels that are disabled.

20. The apparatus of claim **18**, wherein the processing circuitry is further configured to:

select the RU based on disabled subchannels within a bandwidth of the BSS of the AP, wherein the RU is selected so that the STA selects the primary channel to comprise a subchannel not disabled or punctured.

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