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PREAMBLE DESIGN ASPECTS FOR HIGH EFFICIENCY WIRELESS LOCAL AREA NETWORKS

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## **PREAMBLE DESIGN ASPECTS FOR HIGH EFFICIENCY WIRELESS LOCAL AREA NETWORKS**

### **BACKGROUND**

#### **FIELD OF THE DISCLOSURE**

**[0001]** The present disclosure, for example, relates to wireless communication systems, and more particularly to design aspects of high efficiency wireless local area networks (WLANs).

#### **DESCRIPTION OF RELATED ART**

**[0002]** Wireless communications systems are widely deployed to provide various types of communication content such as voice, video, packet data, messaging, broadcast, and so on. These systems may be multiple-access systems capable of supporting communication with multiple users by sharing the available system resources (*e.g.*, time, frequency, and power). A wireless network, for example a Wireless Local Area Network (WLAN), such as a Wi-Fi network (IEEE 802.11) may include an access point (AP) that may communicate with one or more stations (STAs) or mobile devices. The AP may be coupled to a network, such as the Internet, and enable a mobile device to communicate via the network (and/or communicate with other devices coupled to the access point).

**[0003]** A first signaling field and/or a second signaling field of a preamble used for transmitting frames in high efficiency (HE) wireless local area networks (WLANs) can be modified to improve performance and efficiency of HE WLANs.

### **SUMMARY**

**[0004]** Methods, apparatuses, and computer readable media for supporting preamble design aspects of high efficiency wireless local area networks (WLANs) are disclosed.

**[0005]** According to aspects of a first method, a transmitter, for example an AP or station, identifies a resource unit (RU) configuration for a wireless local area network (WLAN) data field of a single user (SU) transmission frame that has a fixed bandwidth. The transmitter generates a RU indicator in a WLAN signaling field of a preamble of the SU transmission

frame, the RU indicator identifying a RU size and a RU location within the WLAN data field. The transmitter then transmits the SU transmission frame.

**[0006]** An apparatus for wireless communication is described. The apparatus may include means for identifying a resource unit (RU) configuration for a WLAN data field of a single user (SU) transmission frame that has a fixed bandwidth, means for generating a RU indicator in a WLAN signaling field of a preamble of the SU transmission frame, the RU indicator identifying a RU size and a RU location within the WLAN data field, and means for transmitting the SU transmission frame.

**[0007]** A further apparatus for wireless communication is described. The apparatus may include a processor, memory in electronic communication with the processor, and instructions stored in the memory and operable, when executed by the processor, to cause the apparatus to identify a resource unit (RU) configuration for a WLAN data field of a single user (SU) transmission frame that has a fixed bandwidth, generate a RU indicator in a WLAN signaling field of a preamble of the SU transmission frame, the RU indicator identifying a RU size and a RU location within the WLAN data field, and transmit the SU transmission frame.

**[0008]** A non-transitory computer-readable medium storing code for wireless communication is described. The code may include instructions executable to identify a resource unit (RU) configuration for a WLAN data field of a single user (SU) transmission frame that has a fixed bandwidth, generate a RU indicator in a WLAN signaling field of a preamble of the SU transmission frame, the RU indicator identifying a RU size and a RU location within the WLAN data field, and transmit the SU transmission frame.

**[0009]** According to aspects of a second method, an access point (AP) identifies a first indicator identifying a number of multi-user multiple input multiple output (MU-MIMO) stations associated with a first resource unit (RU) in a first content channel of a transmission frame. The AP also generates a first common portion of a wireless local area network (WLAN) signaling field in the first content channel of the transmission frame, wherein the first common portion includes the first indicator. The AP identifies a second indicator identifying an absence of MU-MIMO stations associated with a second resource unit (RU) in a second content channel of the transmission frame. The AP generates a second common portion of the WLAN signaling field in the second content channel of the transmission frame,

wherein the second common portion includes the second indicator. The AP then transmits the transmission frame that includes the WLAN signaling field.

**[0010]** An apparatus for wireless communication is described. The apparatus may include means for identifying a first indicator identifying a number of multi-user multiple input multiple output (MU-MIMO) stations associated with a first resource unit (RU) in a first content channel of a transmission frame, means for generating a first common portion of a WLAN signaling field in the first content channel of the transmission frame, wherein the first common portion includes the first indicator, means for identifying a second indicator identifying an absence of MU-MIMO stations associated with a second resource unit (RU) in a second content channel of the transmission frame, means for generating a second common portion of the WLAN signaling field in the second content channel of the transmission frame, wherein the second common portion includes the second indicator, and means for transmitting the transmission frame that includes the WLAN signaling field.

**[0011]** A further apparatus for wireless communication is described. The apparatus may include a processor, memory in electronic communication with the processor, and instructions stored in the memory and operable, when executed by the processor, to cause the apparatus to identify a first indicator identifying a number of multi-user multiple input multiple output (MU-MIMO) stations associated with a first resource unit (RU) in a first content channel of a transmission frame, generate a first common portion of a WLAN signaling field in the first content channel of the transmission frame, wherein the first common portion includes the first indicator, identify a second indicator identifying an absence of MU-MIMO stations associated with a second resource unit (RU) in a second content channel of the transmission frame, generate a second common portion of the WLAN signaling field in the second content channel of the transmission frame, wherein the second common portion includes the second indicator, and transmit the transmission frame that includes the WLAN signaling field.

**[0012]** A non-transitory computer-readable medium storing code for wireless communication is described. The code may include instructions executable to identify a first indicator identifying a number of multi-user multiple input multiple output (MU-MIMO) stations associated with a first resource unit (RU) in a first content channel of a transmission frame, generate a first common portion of a WLAN signaling field in the first content channel

of the transmission frame, wherein the first common portion includes the first indicator, identify a second indicator identifying an absence of MU-MIMO stations associated with a second resource unit (RU) in a second content channel of the transmission frame, generate a second common portion of the WLAN signaling field in the second content channel of the transmission frame, wherein the second common portion includes the second indicator, and transmit the transmission frame that includes the WLAN signaling field.

**[0013]** According to aspects of a third method, a first station receives a transmission frame that includes a wireless local area network (WLAN) signaling field decodable by a plurality of stations. The first station identifies, in a station-specific portion of the WLAN signaling field, an order for a plurality of station-specific information blocks associated with the plurality of stations. The station then determines a number of spatial streams allocated to the first station based at least in part on the identified order for the plurality of station-specific information blocks.

**[0014]** An apparatus for wireless communication is described. The apparatus may include means for receiving, at a first station, a transmission frame that includes a WLAN signaling field decodable by a plurality of stations, means for identifying, in a station-specific portion of the WLAN signaling field, an order for a plurality of station-specific information blocks associated with the plurality of stations, and means for determining a number of spatial streams allocated to the first station based at least in part on the identified order for the plurality of station-specific information blocks.

**[0015]** A further apparatus for wireless communication is described. The apparatus may include a processor, memory in electronic communication with the processor, and instructions stored in the memory and operable, when executed by the processor, to cause the apparatus to receive, at a first station, a transmission frame that includes a WLAN signaling field decodable by a plurality of stations, identify, in a station-specific portion of the WLAN signaling field, an order for a plurality of station-specific information blocks associated with the plurality of stations, and determine a number of spatial streams allocated to the first station based at least in part on the identified order for the plurality of station-specific information blocks.

**[0016]** A non-transitory computer-readable medium storing code for wireless communication is described. The code may include instructions executable to receive, at a

first station, a transmission frame that includes a WLAN signaling field decodable by a plurality of stations, identify, in a station-specific portion of the WLAN signaling field, an order for a plurality of station-specific information blocks associated with the plurality of stations, and determine a number of spatial streams allocated to the first station based at least in part on the identified order for the plurality of station-specific information blocks.

**[0017]** According to aspects of a fourth method, a transmitter, for example an AP or station, receives a transmission frame associated with a plurality of channels, the transmission frame including a wireless local area network (WLAN) signaling field. The transmitter identifies a first number of stations associated with the WLAN signaling field for a first channel of the plurality of channels. The transmitter identifies a second number of stations associated with the WLAN signaling field for a second channel of the plurality of channels. The transmitter then determines whether a data portion of the transmission frame contains multi-user multiple input multiple output (MU-MIMO) content based at least in part on the identified first number of stations and the identified second number of stations.

**[0018]** An apparatus for wireless communication is described. The apparatus may include means for receiving a transmission frame associated with a plurality of channels, the transmission frame including a WLAN signaling field, means for identifying a first number of stations associated with the WLAN signaling field for a first channel of the plurality of channels, means for identifying a second number of stations associated with the WLAN signaling field for a second channel of the plurality of channels, and means for determining whether a data portion of the transmission frame contains multi-user multiple input multiple output (MU-MIMO) content based at least in part on the identified first number of stations and the identified second number of stations.

**[0019]** A further apparatus for wireless communication is described. The apparatus may include a processor, memory in electronic communication with the processor, and instructions stored in the memory and operable, when executed by the processor, to cause the apparatus to receive a transmission frame associated with a plurality of channels, the transmission frame including a WLAN signaling field, identify a first number of stations associated with the WLAN signaling field for a first channel of the plurality of channels, identify a second number of stations associated with the WLAN signaling field for a second channel of the plurality of channels, and determine whether a data portion of the transmission

frame contains multi-user multiple input multiple output (MU-MIMO) content based at least in part on the identified first number of stations and the identified second number of stations.

**[0020]** A non-transitory computer-readable medium storing code for wireless communication is described. The code may include instructions executable to receive a transmission frame associated with a plurality of channels, the transmission frame including a WLAN signaling field, identify a first number of stations associated with the WLAN signaling field for a first channel of the plurality of channels, identify a second number of stations associated with the WLAN signaling field for a second channel of the plurality of channels, and determine whether a data portion of the transmission frame contains multi-user multiple input multiple output (MU-MIMO) content based at least in part on the identified first number of stations and the identified second number of stations.

**[0021]** According to aspects of a fifth method, a transmitter, for example an AP or station, generates an indication that a first channel of a plurality of channels associated with a transmission frame has been punctured, the transmission frame including a wireless local area network (WLAN) signaling field. The transmitter identifies information associated with the WLAN signaling field corresponding to the punctured first channel. The transmitter then transmits the indication that the first channel has been punctured and the information associated with the WLAN signaling field in a second channel of the plurality of channels.

**[0022]** An apparatus for wireless communication is described. The apparatus may include means for generating an indication that a first channel of a plurality of channels associated with a transmission frame has been punctured, the transmission frame including a WLAN signaling field, means for identifying information associated with the WLAN signaling field corresponding to the punctured first channel, and means for transmitting the indication that the first channel has been punctured and the information associated with the WLAN signaling field in a second channel of the plurality of channels.

**[0023]** A further apparatus for wireless communication is described. The apparatus may include a processor, memory in electronic communication with the processor, and instructions stored in the memory and operable, when executed by the processor, to cause the apparatus to generate an indication that a first channel of a plurality of channels associated with a transmission frame has been punctured, the transmission frame including a WLAN signaling field, identify information associated with the WLAN signaling field corresponding

to the punctured first channel, and transmit the indication that the first channel has been punctured and the information associated with the WLAN signaling field in a second channel of the plurality of channels.

**[0024]** A non-transitory computer-readable medium storing code for wireless communication is described. The code may include instructions executable to generate an indication that a first channel of a plurality of channels associated with a transmission frame has been punctured, the transmission frame including a WLAN signaling field, identify information associated with the WLAN signaling field corresponding to the punctured first channel, and transmit the indication that the first channel has been punctured and the information associated with the WLAN signaling field in a second channel of the plurality of channels.

**[0025]** The foregoing has outlined rather broadly the features and technical advantages of examples according to the disclosure in order that the detailed description that follows may be better understood. Additional features and advantages will be described hereinafter. The conception and specific examples disclosed may be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the present disclosure. Such equivalent constructions do not depart from the scope of the appended claims. Characteristics of the concepts disclosed herein, both their organization and method of operation, together with associated advantages will be better understood from the following description when considered in connection with the accompanying figures. Each of the figures is provided for the purpose of illustration and description only, and not as a definition of the limits of the claims.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0026]** A further understanding of the nature and advantages of the present invention may be realized by reference to the following drawings. In the appended figures, similar components or features may have the same reference label. Further, various components of the same type may be distinguished by following the reference label by a dash and a second label that distinguishes among the similar components. If only the first reference label is used in the specification, the description is applicable to any one of the similar components having the same first reference label irrespective of the second reference label.

[0027] **FIG. 1** illustrates an example of a wireless communications system that supports preamble design aspects for HE WLANs in accordance with various aspects of the present disclosure;

[0028] **FIG. 2** shows an example of a WLAN protocol data unit (PDU) (e.g., a physical layer convergence PDU (PPDU)) preamble design aspects for HE WLANs in accordance with various aspects of the present disclosure;

[0029] **FIG. 3** illustrates an example of aspects of a WLAN protocol data unit for preamble design aspects for HE WLANs in accordance with various aspects of the present disclosure;

[0030] **FIGs. 4A, 4B, and 4C** illustrate examples of aspects of a WLAN protocol data unit for preamble design aspects for HE WLANs in accordance with various aspects of the present disclosure;

[0031] **FIG. 5** illustrates an example of aspects of a WLAN protocol data unit for supporting preamble design aspects for HE WLANs in accordance with various aspects of the present disclosure;

[0032] **FIG. 6** illustrates an example of aspects of a portion of a lookup table for supporting preamble design aspects for HE WLANs in accordance with various aspects of the present disclosure;

[0033] **FIG. 7** illustrates an example of aspects of a spatial configuration lookup table for supporting preamble design aspects for HE WLANs in accordance with various aspects of the present disclosure;

[0034] **FIG. 8** illustrates an example of user specific sub-fields split between two HE-SIG-B content channels, in accordance with various aspects of the present disclosure; and

[0035] **FIGs. 9A and 9B** show block diagrams of an example device for supporting preamble design aspects for HE WLANs in accordance with various aspects of the present disclosure.

#### DETAILED DESCRIPTION

[0036] In accordance with various aspects of the present disclosure, a transmitter, for example an AP or station, identifies a resource unit (RU) configuration for a wireless local

area network (WLAN) data field of a single user (SU) transmission frame that has a fixed bandwidth. The transmitter generates a RU indicator in a WLAN signaling field of a preamble of the SU transmission frame, the RU indicator identifying a RU size and a RU location within the WLAN data field. The transmitter then transmits the SU transmission frame.

**[0037]** In accordance with various aspects of the present disclosure, an access point (AP) identifies a first indicator identifying a number of multi-user multiple input multiple output (MU-MIMO) stations associated with a first resource unit (RU) in a first content channel of a transmission frame. The AP also generates a first common portion of a wireless local area network (WLAN) signaling field in the first content channel of the transmission frame, wherein the first common portion includes the first indicator. The AP identifies a second indicator identifying an absence of MU-MIMO stations associated with a second resource unit (RU) in a second content channel of the transmission frame. The AP generates a second common portion of the WLAN signaling field in the second content channel of the transmission frame, wherein the second common portion includes the second indicator. The AP then transmits the transmission frame that includes the WLAN signaling field.

**[0038]** In accordance with various aspects of the present disclosure, a first station receives a transmission frame that includes a wireless local area network (WLAN) signaling field decodable by a plurality of stations. The first station identifies, in a station-specific portion of the WLAN signaling field, an order for a plurality of station-specific information blocks associated with the plurality of stations. The station then determines a number of spatial streams allocated to the first station based at least in part on the identified order for the plurality of station-specific information blocks.

**[0039]** In accordance with various aspects of the present disclosure, a transmitter, for example an AP or station, receives a transmission frame associated with a plurality of channels, the transmission frame including a wireless local area network (WLAN) signaling field. The transmitter identifies a first number of stations associated with the WLAN signaling field for a first channel of the plurality of channels. The transmitter identifies a second number of stations associated with the WLAN signaling field for a second channel of the plurality of channels. The transmitter then determines whether a data portion of the transmission frame contains multi-user multiple input multiple output (MU-MIMO) content

based at least in part on the identified first number of stations and the identified second number of stations.

**[0040]** In accordance with various aspects of the present disclosure, a transmitter, for example an AP or station, generates an indication that a first channel of a plurality of channels associated with a transmission frame has been punctured, the transmission frame including a wireless local area network (WLAN) signaling field. The transmitter identifies information associated with the WLAN signaling field corresponding to the punctured first channel. The transmitter then transmits the indication that the first channel has been punctured and the information associated with the WLAN signaling field in a second channel of the plurality of channels.

**[0041]** These and other aspects of the disclosure are further illustrated by and described with reference to apparatus diagrams, system diagrams, and flowcharts.

**[0042]** **FIG. 1** illustrates an example of a wireless communications system 100 that supports preamble design aspects for HE WLANs in accordance with various aspects of the present disclosure. For simplicity, the wireless communications system 100 is referred to as WLAN 100 in the following discussion.

**[0043]** The WLAN 100 includes an access point (AP) 105 and stations (STAs) 110 labeled as STA\_1 through STA\_7. The STAs 110 can be mobile handsets, tablet computers, personal digital assistants (PDAs), other handheld devices, netbooks, notebook computers, tablet computers, laptops, desktop computers, display devices (e.g., TVs, computer monitors, etc.), printers, etc. While only one AP 105 is illustrated, the WLAN 100 can have multiple APs 105. STAs 110, can also be referred to as a mobile stations (MS), mobile devices, access terminals (ATs), user equipment (UEs), subscriber stations (SSs), or subscriber units. The STAs 110 associate and communicate with the AP 105 via a communication link 115. Each AP 105 has a coverage area 125 such that STAs 110 within that area are within range of the AP 105. The STAs 110 are dispersed throughout the coverage area 125. Each STA 110 is stationary, mobile, or a combination thereof.

**[0044]** Although not shown in FIG. 1, a STA 110 can be covered by more than one AP 105 and can therefore associate with multiple APs 105 at different times. A single AP 105 and an associated set of STAs 110 is referred to as a basic service set (BSS). An extended service set

(ESS) is a set of connected BSSs. A distribution system (DS) (not shown) is used to connect APs 105 in an extended service set. A coverage area 125 for an AP 105 can be divided into sectors making up only a portion of the coverage area (not shown). The WLAN 100 includes APs 105 of different types (e.g., metropolitan area, home network, etc.), with varying sizes of coverage areas and overlapping coverage areas for different technologies. Although not shown, other devices can communicate with the AP 105.

**[0045]** While the STAs 110 are capable of communicating with each other through the AP 105 using communication links 115, STAs 110 can also communicate directly with each other via direct wireless communication links 120. Direct wireless communication links can occur between STAs 110 regardless of whether any of the STAs is connected to an AP 105. Examples of direct wireless communication links 120 include Wi-Fi Direct connections, connections established by using a Wi-Fi Tunneled Direct Link Setup (TDLS) link, and other peer-to-peer (P2P) group connections.

**[0046]** The STAs 110 and APs 105 shown in FIG. 1 communicate according to the WLAN radio and baseband protocol including physical (PHY) and medium access control (MAC) layers from IEEE 802.11, and its various versions including, but not limited to, 802.11b, 802.11g, 802.11a, 802.11n, 802.11ac, 802.11ad, 802.11ah, 802.11z, 802.11ax, etc.

**[0047]** Transmissions to/from STAs 110 and APs 105 oftentimes include control information within a header that is transmitted prior to data transmissions. The information provided in a header is used by a device to decode the subsequent data. High efficiency (HE) WLAN preambles can be used to schedule multiple devices, such as STAs 110, for single-user simultaneous transmission (e.g., single-user orthogonal frequency division multiple access (SU-OFDMA)) and/or MU-MIMO transmissions (e.g., multiple input multiple output MU-MIMO). In one example an HE WLAN signaling field is used to signal a resource allocation pattern to multiple receiving STAs 110. The HE WLAN signaling field includes a common user field that is decodable by multiple STAs 110, the common user field including a resource allocation field. The resource allocation field indicates resource unit distributions to the multiple STAs 110 and indicates which resource units in a resource unit distribution correspond to MU-MIMO transmissions and which resource units correspond to OFDMA single-user transmissions. The HE WLAN signaling field also includes, subsequent to the common user field, dedicated user fields that are assigned to certain STAs 110. The order in

which the dedicated user fields are generated corresponds to the allocated resource units (e.g., the first dedicated user field corresponds to the first allocated resource unit). The HE WLAN signaling field is transmitted with a WLAN preamble to the multiple STAs 110.

**[0048]** FIG. 2 shows an example of a WLAN protocol data unit (PDU) 200 (e.g., a physical layer convergence PDU (PPDU)) preamble design aspects for HE WLANs in accordance with various aspects of the present disclosure. WLAN PDU 200 illustrates aspects of a transmission between a STA 110 and an AP 105, as described above with reference to FIG. 1.

**[0049]** In this example, the WLAN protocol data unit 200 includes a physical (PHY) layer header 205 and a data field 220 (e.g., a MAC protocol data unit (MPDU) or physical layer service data unit (PSDU)). The PHY layer header 205 includes a legacy WLAN preamble 210 and a high efficiency WLAN preamble 215. The preambles and data field are transmitted in the following order: legacy WLAN preamble 210, high efficiency WLAN preamble 215, data field 220.

**[0050]** The WLAN protocol data unit 200 is transmitted over a radio frequency spectrum band, which in some examples may include a plurality of sub-bands. In some examples, the radio frequency spectrum band may have a bandwidth of 80 MHz, and each of the sub-bands may have a bandwidth of 20 MHz. The legacy WLAN preamble 210 includes legacy short training field (STF) (L-STF) information, legacy long training field (LTF) (L-LTF) information, and legacy signaling (L-SIG) information. When the radio frequency spectrum band includes multiple sub-bands, the L-STF, L-LTF, and L-SIG information is duplicated and transmitted in each of the plurality of sub-bands. The legacy preamble is used for packet detection, automatic gain control, channel estimation, etc. The legacy preamble is also used to maintain compatibility with legacy devices.

**[0051]** The high efficiency WLAN preamble 215 includes any of: a repeated legacy WLAN field (e.g., an RL-SIG field), a first WLAN signaling field (e.g., a first high efficiency WLAN signaling field such as HE-SIG-A), a second WLAN signaling field (e.g., a second high efficiency WLAN signaling field such as HE-SIG-B), a WLAN STF (e.g., a high efficiency WLAN STF), and at least one WLAN LTF (e.g., at least one high efficiency WLAN LTF). The high efficiency WLAN preamble 215 enables an AP to simultaneously transmit to multiple stations (e.g., MU-MIMO) and also enables an AP to allocate resources

to multiple stations for uplink/downlink transmissions (e.g., SU-OFDMA). The high efficiency WLAN preamble 215 uses a common signaling field and one or more dedicated (e.g., station-specific) signaling fields to schedule resources and to indicate the scheduling to other WLAN devices. A device uses the scheduling to determine which resource units associated with the frequency spectrum utilized by data field 220 have been allocated to the device for forthcoming communications.

**[0052]** FIG. 3 illustrates an example of aspects of a WLAN protocol data unit 300 for preamble design aspects for HE WLANs in accordance with various aspects of the present disclosure. WLAN protocol data unit 300 illustrates aspects of a transmission between a STA 110 and a AP 105, as described above with reference to FIGs. 1-2. WLAN protocol data unit 300 includes a first WLAN signaling field 305, a second WLAN signaling field 310, a high efficiency STF 315, a high efficiency LTF 320, and a data field 325. The first WLAN signaling field 305 includes an HE-SIG-A 330 that is repeated across multiple subbands. The data field 325 includes data portions 335 that have been allocated to different devices. For instance, data portion 335-a is allocated to a first device, data portion 335-b to a second device, data portion 335-c to a first group of devices, and data portion 335-d to a second group of devices.

**[0053]** The first WLAN signaling field 305 includes high efficiency WLAN signaling information usable by APs and stations other than a number of APs or stations identified to receive or transmit communications in the WLAN protocol data unit 300. The first WLAN signaling field 305 also includes information usable by the identified number of APs or stations to decode the second WLAN signaling field 310. When the radio frequency spectrum band includes a plurality of sub-bands, the information (e.g., HE-SIG-A 330-a) included in the first WLAN signaling field 305 is duplicated and transmitted in each sub-band of the first WLAN signaling field 305, (e.g., HE-SIG-A 330-b to 330-d).

**[0054]** The second WLAN signaling field 310 includes high efficiency WLAN signaling information usable by a number of APs or stations identified to transmit or receive communications in the WLAN protocol data unit 300. More specifically, the second WLAN signaling field 310 includes information usable by the number of APs or stations to transmit/encode or receive/decode data in the data field 220. The second WLAN signaling field 310 can be encoded separately from the first WLAN signaling field 305. The second

WLAN signaling field 310 includes a common block field 340 that signals information to a group of devices, such as high efficiency STAs within range of an AP, and user blocks 345-a to 345-c that signal information specific to specific high efficiency STAs. The common block includes a resource allocation field 350 that signals to the high efficiency device how the data field 325 is partitioned amongst devices (e.g., partitions the data field into resource units), which of the resource units are associated with SU-OFDMA and which are associated with MU-MIMO. Furthermore, the order of the user blocks 345 provides a link between the device associated with the user block 345 and the resource unit that has been allocated to the device. As an example, the resource allocation field 350 partitions the data field into nine regions (e.g., 20MHz data region is partitioned into nine sub-regions that each span 26 tones). The STA addressed in the first user block corresponds to the first 26 tones, the second STA addressed in the second user block corresponds to the next 26 tones, etc. The common block may also include other fields, such as a LTF.

**[0055]** FIGs. 4A illustrates an example of aspects of a WLAN protocol data unit 400 for preamble design aspects for HE WLANs in accordance with various aspects of the present disclosure. WLAN protocol data unit 400 illustrates aspects of a transmission between a STA 110 and a AP 105, as described above with reference to FIGs. 1-2. WLAN protocol data unit 400 includes a first WLAN signaling field 305-a, a high efficiency STF 315-a, a high efficiency LTF 320-a, and a data field 325-a. The first WLAN signaling field 305-a includes an HE-SIG-A 330 that is repeated across multiple subbands. The data field 325 may include data portions that have been allocated to different devices.

**[0056]** A transmission sent in the HE extended range PPDU format may be sent in environments where using a longer range transmission is desirable, e.g. this format may be used for communication with internet of thing (IoT) devices, sensors, etc. A HE extended range PPDU may also have a simpler structure and be more robust as compared to one or more other HE PPDU formats that may be used for SU transmissions. For example, a HE extended range PPDU format may use a repeated HE-SIG-A field in its preamble to provide for more robust reception. A HE extended range PPDU may also be configured to allow for the signaling of smaller resource units (RUs).

**[0057]** In contrast to a generic SU HE PPDU that may select among several different bandwidths or have a varying bandwidth (as signaled in the HE preamble), a HE extended

range PPDU for SU transmissions may use a fixed bandwidth, e.g. 20 MHz, that may be smaller than the bandwidth available for the generic SU HE PPDU, e.g. where the SU HE PPDU bandwidth is 40 MHz, 80 MHz, or 160 MHz. Using a smaller, fixed bandwidth may allow for transmissions to be sent with a higher power than if the same amount of power were spread across a larger bandwidth, e.g. 40 MHz, 80 MHz, or 160 MHz, increasing range and robustness for the transmissions. For example, the power for the preamble of the HE extended range PPDU may be increased or boosted 3 dB above the transmission power of a generic SU HE PPDU. In some case, just the power of the preamble may be boosted by the transmitter to increase the likelihood of successful reception and decoding. In other examples, the entire PPDU may be boosted, e.g. by 3 dB. In other examples, the HE extended range PPDU may also boost the power of the transmitted preamble when using a larger bandwidth, such as a 40 MHz, 80 MHz, or 160 MHz bandwidth.

**[0058]** FIG. 4B illustrates an example 401 of aspects of a WLAN protocol data unit for preamble design aspects for HE WLANs in accordance with various aspects of the present disclosure. In the SU HE extended range PPDU in a 20 MHz band illustrated in FIG. 4B, transmissions to individual users may be allocated to one or more RUs within a tone unit of a PPDU. A size of a RU may be constrained to be one of 106 or 242 tones. In one example of a PPDU, all 242 tones may be allocated to a user for a SU transmission as a single 242-tone RU 435. In another PPDU, 106 tones may be allocated as a first 106-tone RU 430 to a first user for SU transmission, which may be located in one of two positions. 106 tones may also be allocated as a second 106-tone RU 430 in this example. Thus, 3 different RU positions may be available for RU allocation, which may be indicated by a minimum of 2 bits of an RU allocation field 415.

**[0059]** FIG. 4C illustrates an example 402 of aspects of a WLAN protocol data unit for preamble design aspects for HE WLANs in accordance with various aspects of the present disclosure. In the SU HE extended range PPDU in a 20 MHz band illustrated in FIG. 4C, transmissions to individual users may be allocated to one or more RUs within a tone unit of a PPDU. A size of a RU may be constrained to be one of 52, 106, or 242 tones. In one example of a PPDU, all 242 tones may be allocated to a user for a SU transmission as a single 242-tone RU 450. In another PPDU, 106 tones may be allocated as a first 106-tone RU 445 to a first user for SU transmission, which may be located in one of two positions. 106 tones

may also be allocated as a second 106-tone RU 445 in this example. In yet another PPDU, 52 tones may be allocated as a first 52-tone RU 440 to a first user for SU transmission, which may be located in one of four positions. 52 tones may also be allocated as a second 52-tone RU 440, as a third 52-tone RU 440, and as a fourth 52-tone RU 440 in this example, for up to 4 different users. Thus, 7 different RU positions may be available for RU allocation, which may be indicated by a minimum of 3 bits of an RU allocation field 415.

**[0060]** Thus, to maintain simplicity and reduce overhead, the number of combinations of RU sizes and locations may be limited to a maximum of 4 possibilities (for a 2 bit allocation as described above in reference to FIG. 4B) or a maximum of 8 possibilities (for a 3 bit allocation as described above in reference to FIG. 4C) for the HE extended range PPDU, meaning that 2 or 3 bits in the SIG-A field of the PPDU preamble may be used to identify, for a given RU, which of 3 or 7, respectively, possible RU sizes and locations are allocated. Where the bandwidth is fixed, for example to 20 MHz, additional bits are not needed in the SIG-A field of the PPDU preamble to identify the bandwidth used, simplifying the preamble.

**[0061]** In some examples, the RU allocation field 415 may only be used in an example where the bandwidth of PPDU is indicated by the BW field 410 to be 20 MHz. The 2 bits of the BW field 410 may be used to indicate that the PPDU uses one of four different bandwidths. Where the BW field 410 indicates a bandwidth of 20 MHz (or another predetermined bandwidth according to other examples), the recipient of the PPDU may assume that the HE-SIG-A field 305-a contains the RU allocation field 415 following the BW field 410, and the RU allocation field 415 may be followed by an MCS field 420 and a Nsts field 425, as illustrated in FIG. 4A. Where the BW field 410 indicates a bandwidth other than 20 MHz (or the other predetermined bandwidth), for example 40 MHz, 80 MHz, or 160 MHz, then the recipient of the PPDU may assume that the HE-SIG-A field 305-a contains MCS field 420 following the BW field 410, and that the RU allocation field 415 has been omitted. Although the BW field 410, RU allocation field 415, MCS field 420, and Nsts field 425 are illustrated as falling one immediately after the other, intermediate fields may exist, or the fields may be rearranged to occur at differing positions.

**[0062]** In some instances, the HE-SIG-A field 305-a where the BW field 410 indicates a higher bandwidth, e.g. 40 MHz, 80 MHz, or 160 MHz, the HE-SIG-A field for the SU HE extended range PPDU may have the same format as for a non-extended range format PPDU,

e.g. the HE-SIG-A field for the SU HE PPDU. Maintaining a similar format for the HE-SIG-A field for certain bandwidths of the SU extended range HE PPDU as the SU HE PPDU may increase simplicity of implementation.

**[0063]** Where an RU allocation field 415 in the HE-SIG-A field 305-a (e.g. in the case where BW field 410 indicates a 20 MHz bandwidth), then additional bits in the HE-SIG-A field may be needed. For example, the size of the HE-SIG-A field 305-a may be constrained, such that introducing bits in an RU allocation field 415 may push the size of the field over that constraint. As described above, the size of the RU allocation field 415 may be 2 bits in some examples. In such case, the size of the MCS field may be limited to 2 bits, for example where the size of the MCS field 420 in the absence of an RU allocation field 415 would otherwise be 4 bits. Thus, the MCS values indicated by the MCS field 420 may be MCS0, MCS1, MCS2, and MCS3. In an example the four MCSs may correspond to a BPSK 1/2 MCS, a QPSK 1/2 MCS, a QPSK 3/4 MCS, and a 16-QAM 1/2 MCS, respectively.

**[0064]** As also described above, the size of the RU allocation field 415 may be 3 bits in some examples. In such case, the size of the MCS field may be limited to 1 bit. Thus, in one example, the MCS values indicated by the MCS field 420 may be MCS0 and MCS1. In an example the two MCSs may correspond to a BPSK 1/2 MCS and a QPSK 1/2 MCS, respectively. Thus, 1 bit may be used in the SIG-A field of the preamble to identify whether a first MCS or a second MCS is used to modulate and code the PPDU data; and 2 bits may be used in the SIG-A field of the preamble to identify whether a first, a second, a third, or a fourth MCS is used to modulate and code the PPDU data. In other examples, the MCS field may be omitted, such that MCS0 is used where the BW is indicated to be 20 MHz.

**[0065]** In other example, the number of spatial streams (Nsts) may also be limited so that the RU allocation field 415 may be used, or to provide further reserved bits to be used for other purposes. Thus, , Nsts may be limited to two options, e.g. Nsts=0 or Nsts=1, and the SIG-A field may have a Nsts field 425 that may contain a single bit to indicate the number of spatial streams, Nsts. In other examples the Nsts field 425 may have 2 bits to indicate up to 4 spatial streams, or 3 bits to indicate up to 8 spatial streams. In other examples, the Nsts field 425 may be omitted, such that a single stream is used where the BW is indicated to be 20 MHz.

**[0066]** As described above, limiting the number of bits used for MCS field 420 and Nsts field 425 may also decrease the complexity that a receiver needs to handle and decoding, thus decreasing the power consumption at the receiver and decreasing the amount of testing that may need to be performed, even if the extra reserved bits created by limiting the size of such fields are not used for implementing other features.

**[0067]** FIG. 5 illustrates an example of aspects of a WLAN protocol data unit 500 for supporting preamble design aspects for HE WLANs in accordance with various aspects of the present disclosure. WLAN protocol data unit 400 illustrates aspects of a transmission between a STA 110 and a AP 105, as described above with reference to FIGs. 1-2. WLAN protocol data unit 400 includes an HE-SIG-B field 310-a, which is an example of a second WLAN signaling field 310. HE-SIG-B field 310-a includes two content channels 405-a and 405-b including control information. In one example, a device decodes both channels to acquire all of the content signaled in the HE-SIG-B field 310-a. Furthermore, a device that receives a user block within a frequency band associated with a stream 405 also received data within the same frequency band. The common portion (*e.g.* the information in common block fields 340-a and 340-b) and dedicated portion (*e.g.*, user blocks 345-d and 345-e) for every other 20 MHz channel are signaled together. User blocks 345-d and 345-e each include per user information for MU-MIMO users in user blocks and per-user information for SU users in user blocks. The dedicated portion, which includes per user information, including user blocks 345-d and 345-e, may be dynamically allocated between channels during load balancing.

**[0068]** For example, 8 MU-MIMO users may be allocated RUs in channel 405-a and channel 405-b. RUs may be allocated by the common portion 340-a of the HE-SIG-B field 310-a to 5 MU-MIMO users of the 8 MU-MIMO users. The dedicated portion 345-d of the HE-SIG-B field 310-a may then provide information, once decoded by a station that is one of the 5 MU-MIMO users, that identifies where data for that station is found in the data portion associated with the channel 405-a of the transmission frame. Similarly, RUs may be allocated by the common portion 340-b of the HE-SIG-B field 310-a to 5 MU-MIMO users of the 8 MU-MIMO users. The dedicated portion 345-e of the HE-SIG-B field 310-a may then provide information, once decoded by a station that is one of the 3 MU-MIMO users,

that identifies where data for that station is found in the data portion associated with the channel 405-b of the transmission frame (e.g. PPDU).

**[0069]** To perform load balancing, a transmitter, e.g. an AP or station, may split up a number of MU-MIMO users in different ways. For WLAN protocol data unit 500, 8 MU-MIMO users are split with 5 MU-MIMO users, which are allocated RUs of 484 tones associated with the first channel 405-a, and 3 MU-MIMO, which are allocated RUs of 484 tones associated with the second channel 405-b. In other examples, a user may be allocated RUs that are larger than the maximum RU size for a single channel. For example where the maximum RU size for a channel is 242 tones, an allocated RU for 1 or more MU-MIMO users may be 484 tones spanning two channels (e.g., two 20 MHz channels making a 40 MHz allocation). For these larger allocations, e.g. where the RU size is 484 tones or larger, a number of MU-MIMO users may be split between a first channel and a second channel, for example from 1 to 8 MU-MIMO users. However, for purposes of load balancing, where it may be desirable to balance RU allocations between a first channel and a second channel, it may assist load balancing to provide the ability to allocate zero or no MU-MIMO users to a channel. For example, where a first channel already has a number of blocks allocated to SU transmissions for a number of users, and a second channel has no such blocks allocated to SU transmissions, for purposes of load balancing, the transmitter may then allocated zero or no MU-MIMO blocks to the first channel, and each of the remaining MU-MIMO blocks for MU-MIMO users to the second channel.

**[0070]** FIG. 6 illustrates an example of aspects of a portion of a lookup table 600 for supporting preamble design aspects for HE WLANs in accordance with various aspects of the present disclosure. Lookup table 600 is a portion of a lookup table, specifically rows that contain RU allocations of at least 102 tones, that may be used to signal RU allocation signaling in a common block field of a HE-SIG-B field of a HE PPDU as described above. Lookup table 600 may indicate the location of the SIG-B dedicated content for large SU allocations, and allows for loading balancing in the case of large RU sizes, e.g. 484 tones or larger. To provide the ability to transmit no or zero MU-MIMO blocks for a RU size of 484 tones or larger, a lookup table that indicates a number of MU-MIMO users associated with a RU may be modified by adding rows to the table. In particular a row 605 may be added so that, in addition to signaling that there are 1 through 8 MU-MIMO user blocks transmitted in

a particular SIG-B content channel associated with the 484 tone RU allocation, that an indication of an absence of a MU-MIMO user block transmitted in the said SIG-B content channel with the 484 tone allocation, i.e. there is no MU-MIMO user block transmitted with the 484 tone allocation for that channel. Similarly, a row 610 may be added so that, in addition to signaling that there are 1 through 8 MU-MIMO user blocks transmitted with a SIG-B content channel with the 996 tone RU allocation, that an indication of an absence of a MU-MIMO user block in the said SIG-B content channel associated with the 996 tone allocation, i.e. there is no MU-MIMO user block transmitted with the 996 tone allocation for that channel. In other examples, the RU size may vary, such that the additional rows may be used where a RU allocation span multiple channels and an indication of zero or an absence of MU-MIMO user blocks may be indicated for a the large RU allocation. It should be noted that where the allocation size is less than 484 tones, according to this example, additional rows may not be needed in the lookup table 600 because only a single channel will be used, and load balancing between 2 or more channels will not take place.

**[0071]** FIG. 7 illustrates an example of aspects of a spatial configuration lookup table 700 for supporting preamble design aspects for HE WLANs in accordance with various aspects of the present disclosure. A user field for an MU-MIMO allocation, e.g. in a HE-SIG-B field, may include a spatial configuration subfield of 4 bits indicating the number of spatial streams for each multiplexed STA, the index of the spatial stream, and the total number of spatial streams. Column Nuser indicates the number of users; Nuser may be indicated in the common portion (e.g. common block 340) of a HE-SIG-B field. Given Nuser, index of the spatial stream, the total number of spatial stream allocated, and an index of the user/station as determined by an order that the user/station appears in a dedicated portion of a second WLAN signaling field 310 (e.g. a HE-SIG-B field), the number of spatial stream associated with the particular user/station may be determined. The index of the spatial stream and total number of spatial streams allocated may be communicated explicitly. However, the index of the user/station needs to be determined based on the order in which it appears in the dedicated portion, as explained further below. Thus, the index may be implicitly determined based on the order, reducing overhead for explicit communication of the index.

**[0072]** In a transmission frame, e.g. a HE MU PPDU transmission frame using MU-MIMO RU allocations, the order of the dedicated portions 345 of a second WLAN signaling field

310 may be used to determine a number of spatial streams ( $N_{sts}$ ) allocated to a particular user/station that has received the transmission frame. A station may receive a transmission frame that includes a second WLAN signaling field 310. The station may then decode the dedicated portions 345 of the second WLAN signaling field 310 and determine an order for the various stations or users in the MU-MIMO allocation along with the station that has received the transmission frame. The order may be predetermined for the station. For example, the station (when an AP is the transmitter) may determine that the order is based on the identity of the station according to the order that it appears in the dedicated portion 345 based on frequency, e.g. proceeding from the lowest subcarrier frequency to the highest subcarrier frequency (or vice-versa). In one example, the station may determine the order of stations appearing in the dedicated portion 345 without regard to whether a particular channel is dedicated as a primary channel (e.g. the primary 20 MHz channel) or a secondary channel (e.g. the secondary 20 MHz channel). In another example, the station may determine the order based on frequency, but first for the primary channel, followed by the secondary channel. For example, the station may proceed from the lowest subcarrier frequency to the highest subcarrier frequency (or vice-versa) for the primary channel, followed by the lowest subcarrier frequency to the highest subcarrier frequency (or vice-versa) for the secondary channel. Thus, the station may determine the order of stations having data communicated in the dedicated portion 345.

**[0073]** Having determined the order for each station in the dedicated portion, a user/station may determine its own index based on where the station appears in the order. That index may then be used in conjunction with spatial configuration lookup table 700 to determine the number of spatial streams for that station. For example, if  $N_{user} = 3$ , there are a total number of spatial streams equal to 8, and the station has determined that its index is equal to 2, then the number of spatial streams associated with the user/station is 3, corresponding to entry 705.

**[0074]** In some examples for supporting preamble design aspects for HE WLANs in accordance with various aspects of the present disclosure, a station may differentiate between SU and MU-MIMO allocations. Decoding and combining both SIG-B content channels may be used to distinguish between SU and MU-MIMO allocations. Due to load balancing as described above with reference to FIG. 5,  $N_{user}$  may be one as indicated by a common

portion 340 in a HE-SIG-B field for a large MU-MIMO allocation. Because the content of the SU and MU dedicated portions of a HE-SIG-B field may be different, Nuser indications in a first SIGB content channel need to be combined with the content in a second SIGB content channel. Through combining, if Nuser for the first content channel plus Nuser for the second content channel is greater than 1 (for the same RU), then the content is MU-MIMO dedicated content. If Nuser for the first content channel plus Nuser for the second content channel is not greater than 1 (for the same RU), the content is SU dedicated content.

**[0075]** In other examples for supporting preamble design aspects for HE WLANs in accordance with various aspects of the present disclosure, HE-SIG-B compressed mode 800 may be used. The compressed mode may be used for MU-MIMO utilizing a full bandwidth. In such case, no RU signal information is transmitted in a HE\_SIG-B field. Instead, user specific sub-fields are split between the two HE-SIG-B content channels, as illustrated in FIG. 8. In the compressed mode, a number of MU-MIMO users needs to be indicated. To accomplish this, a field in the SIG-A field corresponding to the number of SIG-B symbols may be re-interpreted or repurposed, and the number of SIG-B symbols derived from the number of MU-MIMO users. The number of MU-MIMO users may be computed from the number of SIG-B symbols, which could lead to ambiguity in the case where a high MCS is used. Thus, the number of MU-MIMO users may instead be indicated in a common portion of a HE-SIG-B field. This increases overhead because CRC and tail bits are also added to the common portion of the HE-SIG-B field.

**[0076]** In other examples for supporting preamble design aspects for HE WLANs in accordance with various aspects of the present disclosure, an HE-SIG-B design may use channel bonding. According to an example, SIG-B may not be transmitted in a channel that has been punctured, for example a 20 MHz channel. This may be regardless of whether the preamble in the transmission frame prior to the SIG-B field has been transmitted or not. The SIG-B transmission format may be determined for secondary 20 MHz channels that are not transmitted, or other such channels that are not transmitted. When a second 20 MHz channel is not transmitted, there may be multiple options to transmit such information.

**[0077]** In a first example, information/contents of the SIG-B that was found in the secondary 20 MHz channel may be transmitted on the primary 20 MHz channel. In such case

an indication of the puncturing of the 20 MHz channel may be signaled in the SIG-A field, for example by including an indicator.

**[0078]** In a second example, information/contents of the SIG-B that was found in the secondary 20 MHz channel may be decoded from a 4th 20 MHz channel. In such case an indication of the SIG-B decoding may be signaled in the SIG-A field, for example by including an indicator.

**[0079]** In other examples for supporting preamble design aspects for HE WLANs in accordance with various aspects of the present disclosure, an HE-SIG-B design may be different when other 20 MHz channels are punctured. In such case, a common portion of a SIG-B field may be affected since some 20 MHz channel are absent.

**[0080]** In a first example, RU allocation for the punctured 20 MHz channels are not transmitted. A size of the common portion of the SIG-B field may be modified depending on the number and location of the punctured channels. In addition, a common portion size may be different between the two SIGB content channels. An explicit indication of punctured channels may be indicated in the SIG-A field.

**[0081]** In a second example, a special or dedicated RU allocation bit sequence may be used to indicate that a 20 MHz channel is punctured. The indication may be made by adding an additional entry in a RU allocation table. A size of the common portion may be unchanged for either content channel. According to this example an explicit indication of the punctured 20 MHz channel may not be needed, though the additional RU allocation bit sequence may result in additional overhead in the common portion of the SIG-B field.

**[0082]** In these examples, the SIG-B dedicated portion, as opposed to the common portion, may be relatively unaffected. SIG-B duplicated structure may be maintained, while the dedicated content for punctured channels are not transmitted.

**[0083]** **FIGs. 9A and 9B** show block diagrams of an example device for supporting preamble design aspects for HE WLANs in accordance with various aspects of the present disclosure.

**[0084]** **FIG. 9A** shows a block diagram 900-a of an example wireless device 990 that supports preamble design aspects for HE WLANs in accordance with various aspects of the

present disclosure, and with respect to FIGs. 1-8. The wireless device 990, which may be an example of a STA 110 or an AP 105, includes a resource unit signaling manager 930, a MU-MIMO load balancer 935, a spatial stream determiner 940, a content type determiner 945, and a punctured channel manager 950. The processor 905, memory 910, transceiver(s) 920, the resource unit signaling manager 930, MU-MIMO load balancer 935, spatial stream determiner 940, content type determiner 945, and punctured channel manager 950 are communicatively coupled with a bus 955, which enables communication between these components. The antenna(s) 925 are communicatively coupled with the transceiver(s) 920.

**[0085]** The processor 905 is an intelligent hardware device, such as a central processing unit (CPU), a microcontroller, an application-specific integrated circuit (ASIC), *etc.* The processor 905 processes information received through the transceiver(s) 920 and information to be sent to the transceiver(s) 920 for transmission through the antenna(s) 925.

**[0086]** The memory 910 stores computer-readable, computer-executable software (SW) code 915 containing instructions that, when executed, cause the processor 905 or another one of the components of the wireless device 990 to perform various functions described herein.

**[0087]** The transceiver(s) 920 communicate bi-directionally with other wireless devices, such as APs 105, STAs 110, or other devices. The transceiver(s) 920 include a modem to modulate packets and frames and provide the modulated packets to the antenna(s) 925 for transmission. The modem is additionally used to demodulate packets received from the antenna(s) 925.

**[0088]** The resource unit signaling manager 930, MU-MIMO load balancer 935, spatial stream determiner 940, content type determiner 945, and punctured channel manager 950 implement the features described with reference to FIGs. 1-8B, as further explained below.

**[0089]** The resource unit signaling manager 930 can identify a resource unit (RU) configuration for a WLAN data field of a SU transmission frame that has a fixed bandwidth. The resource unit signaling manager 930 can then generate a RU indicator in a WLAN signaling field of a preamble of the SU transmission frame, where the RU indicator identifies a RU size and a RU location within the WLAN data field. The resource unit signaling manager 930 can, in some examples together with transceivers 920 and/or antenna(s) 925, transmit the SU transmission frame.

**[0090]** The MU-MIMO load balancer 935 can identify a first indicator identifying a number of MU-MIMO stations associated with a first RU in a first content channel of a transmission frame. The MU-MIMO load balancer 935 can also identify a second indicator identifying an absence of MU-MIMO stations associated with a second RU in a second content channel of the transmission frame. The MU-MIMO load balancer 935 may then generate a first common portion of a WLAN signaling field in the first content channel of the transmission frame, wherein the first common portion includes the first indicator, and generate a second common portion of the WLAN signaling field in the second content channel of the transmission frame, wherein the second common portion includes the second indicator. The MU-MIMO load balancer 935 can, in some examples together with transceivers 920 and/or antenna(s) 925, transmit the SU transmission frame that includes the WLAN signaling field.

**[0091]** The spatial stream determiner 940 can receive a transmission frame that includes a WLAN signaling field decodable by a plurality of stations. In some examples the spatial stream determiner 940 receives the transmission frame together with transceivers 920 and/or antenna(s) 925. The spatial stream determiner 940 may identify, in a station-specific portion of the WLAN signaling field, an order for a plurality of station-specific information blocks associated with the plurality of stations. The spatial stream determiner 940 may then determine a number of spatial streams allocated to the first station based at least in part on the identified order for the plurality of station-specific information blocks.

**[0092]** The content type determiner 945 may receive a transmission frame associated with a plurality of channels, the transmission frame including a WLAN signaling field. In some examples the content type determiner 945 receives the transmission frame together with transceivers 920 and/or antenna(s) 925. The content type determiner 945 can identify a first number of stations associated with the WLAN signaling field for a first channel of the plurality of channels, and identify a second number of stations associated with the WLAN signaling field for a second channel of the plurality of channels. The content type determiner 945 may then determine whether a data portion of the transmission frame contains MU-MIMO content based at least in part on the identified first number of stations and the identified second number of stations.

**[0093]** The punctured channel manager 950 can generate an indication that a first channel of a plurality of channels associated with a transmission frame has been punctured, the transmission frame including a WLAN signaling field. The punctured channel manager 950 can identify information associated with the WLAN signaling field corresponding to the punctured first channel, then transmit the indication that the first channel has been punctured and the information associated with the WLAN signaling field in a second channel of the plurality of channels. In some examples, the punctured channel manager 950 operates together with transceivers 920 and/or antenna(s) 925 to transmit the indication and the information associated with the WLAN signaling field in the second channel.

**[0094]** Again, FIG. 9A shows only one possible implementation of a device executing the features of FIGS. 1-8B. While the components of FIG. 9A are shown as discrete hardware blocks (*e.g.*, ASICs, field programmable gate arrays (FPGAs), semi-custom integrated circuits, *etc.*) for purposes of clarity, it will be understood that each of the components may also be implemented by multiple hardware blocks adapted to execute some or all of the applicable features in hardware. Alternatively, features of two or more of the components of FIG. 9A may be implemented by a single, consolidated hardware block. For example, a single transceiver 920 chip may implement the processor 905, memory 910, resource unit signaling manager 930, MU-MIMO load balancer 935, spatial stream determiner 940, content type determiner 945, and punctured channel manager 950.

**[0095]** In still other examples, the features of each component may also be implemented, in whole or in part, with instructions embodied in a memory, formatted to be executed by one or more general or application-specific processors. For example, **FIG. 9B** shows a block diagram 900-b of another example of a wireless device 990-a in which the features of the resource unit signaling manager 930-a, MU-MIMO load balancer 935-a, spatial stream determiner 940-a, content type determiner 945-a, and punctured channel manager 950-a are implemented as computer-readable code stored on memory 910-a and executed by one or more processors 905-a. Other combinations of hardware/software may be used to perform the features of one or more of the components of FIGS. 9A-9B.

**[0096]** The detailed description set forth above in connection with the appended drawings describes examples and does not represent the only examples that may be implemented or that are within the scope of the claims. The terms “example” and “exemplary,” when used in

this description, mean "serving as an example, instance, or illustration," and not "preferred" or "advantageous over other examples." The detailed description includes specific details for the purpose of providing an understanding of the described techniques. These techniques, however, may be practiced without these specific details. In some instances, well-known structures and apparatuses are shown in block diagram form in order to avoid obscuring the concepts of the described examples.

**[0097]** Information and signals may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the above description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

**[0098]** The various illustrative blocks and components described in connection with the disclosure herein may be implemented or performed with a general-purpose processor, a digital signal processor (DSP), an ASIC, an FPGA or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, *e.g.*, a combination of a DSP and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

**[0099]** The functions described herein may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Other examples and implementations are within the scope and spirit of the disclosure and appended claims. For example, due to the nature of software, functions described above can be implemented using software executed by a processor, hardware, firmware, hardwiring, or combinations of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations. As used herein, including in the claims, the term "and/or," when used in a

list of two or more items, means that any one of the listed items can be employed by itself, or any combination of two or more of the listed items can be employed. For example, if a composition is described as containing components A, B, and/or C, the composition can contain A alone; B alone; C alone; A and B in combination; A and C in combination; B and C in combination; or A, B, and C in combination. Also, as used herein, including in the claims, “or” as used in a list of items (for example, a list of items prefaced by a phrase such as “at least one of” or “one or more of”) indicates a disjunctive list such that, for example, a list of “at least one of A, B, or C” means A or B or C or AB or AC or BC or ABC (*i.e.*, A and B and C).

**[0100]** Computer-readable media includes both computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A storage medium may be any available medium that can be accessed by a general purpose or special purpose computer. By way of example, and not limitation, computer-readable media can comprise RAM, ROM, EEPROM, flash memory, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to carry or store desired program code means in the form of instructions or data structures and that can be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor. Also, any connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, include compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and Blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above are also included within the scope of computer-readable media.

**[0101]** The previous description of the disclosure is provided to enable a person skilled in the art to make or use the disclosure. Various modifications to the disclosure will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is

not to be limited to the examples and designs described herein but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.

## CLAIMS

**What is claimed is:**

1           1.       A method for wireless communication, comprising:  
2           identifying a resource unit (RU) configuration for a wireless local area  
3 network (WLAN) data field of a single user (SU) transmission frame that has a fixed  
4 bandwidth;  
5           generating a RU indicator in a WLAN signaling field of a preamble of the SU  
6 transmission frame, the RU indicator identifying a RU size and a RU location within the  
7 WLAN data field; and  
8           transmitting the SU transmission frame.

1           2.       A method for wireless communication, comprising:  
2           identifying a first indicator identifying a number of multi-user multiple input  
3 multiple output (MU-MIMO) stations associated with a first resource unit (RU) in a first  
4 content channel of a transmission frame;  
5           generating a first common portion of a wireless local area network (WLAN)  
6 signaling field in the first content channel of the transmission frame, wherein the first  
7 common portion includes the first indicator;  
8           identifying a second indicator identifying an absence of MU-MIMO stations  
9 associated with a second resource unit (RU) in a second content channel of the transmission  
10 frame;  
11          generating a second common portion of the WLAN signaling field in the  
12 second content channel of the transmission frame, wherein the second common portion  
13 includes the second indicator; and  
14          transmitting the transmission frame that includes the WLAN signaling field.

1           3.       A method for wireless communication, comprising:  
2           receiving, at a first station, a transmission frame that includes a wireless local  
3 area network (WLAN) signaling field decodable by a plurality of stations;  
4           identifying, in a station-specific portion of the WLAN signaling field, an order  
5 for a plurality of station-specific information blocks associated with the plurality of stations;  
6 and

7                   determining a number of spatial streams allocated to the first station based at  
8   least in part on the identified order for the plurality of station-specific information blocks.

1                   4.       A method for wireless communication, comprising:  
2                   receiving a transmission frame associated with a plurality of channels, the  
3   transmission frame including a wireless local area network (WLAN) signaling field;  
4                   identifying a first number of stations associated with the WLAN signaling  
5   field for a first channel of the plurality of channels;  
6                   identifying a second number of stations associated with the WLAN signaling  
7   field for a second channel of the plurality of channels; and  
8                   determining whether a data portion of the transmission frame contains multi-  
9   user multiple input multiple output (MU-MIMO) content based at least in part on the  
10   identified first number of stations and the identified second number of stations.

1                   5.       A method for wireless communication, comprising:  
2                   generating an indication that a first channel of a plurality of channels  
3   associated with a transmission frame has been punctured, the transmission frame including a  
4   wireless local area network (WLAN) signaling field;  
5                   identifying information associated with the WLAN signaling field  
6   corresponding to the punctured first channel; and  
7                   transmitting the indication that the first channel has been punctured and the  
8   information associated with the WLAN signaling field in a second channel of the plurality of  
9   channels.

1                   6.       An apparatus, comprising:  
2                   a memory; and  
3                   a processor coupled with the memory and configured to execute instructions  
4   stored on the memory to perform the steps recited in any of claims 1-5.

1                   7.       An apparatus, comprising:  
2                   means for performing the method steps recited in any of claims 1-5.

3

1                   8.       A computer program comprising executable instructions for causing at  
2 least one computer to perform a method according to any of claims 1-5 when executed.

1                   9.       A non-transitory computer-readable medium comprising instructions  
2 that, when executed, causes an apparatus to perform a method according to any of claims 1-5.

### ABSTRACT OF THE DISCLOSURE

Methods, apparatuses, and computer readable media for resource allocation signaling in a high efficiency wireless local area network (WLAN) are disclosed. An access point (AP) may generate a resource unit (RU) size indicator in a first WLAN signaling field, the RU size indicator decodable by a set of stations. The AP may also generate a common user field in a second WLAN signaling field, such that a size of the common user field may be based on the RU size indicator of the first WLAN signaling field. The AP may generate, subsequent to the common user field in the second WLAN signaling field, a station-specific field, such that a position of the a station-specific field corresponds to one or more RUs associated with the a station-specific field. The AP may then transmit a WLAN preamble that includes the first WLAN signaling field followed by the second WLAN signaling field.

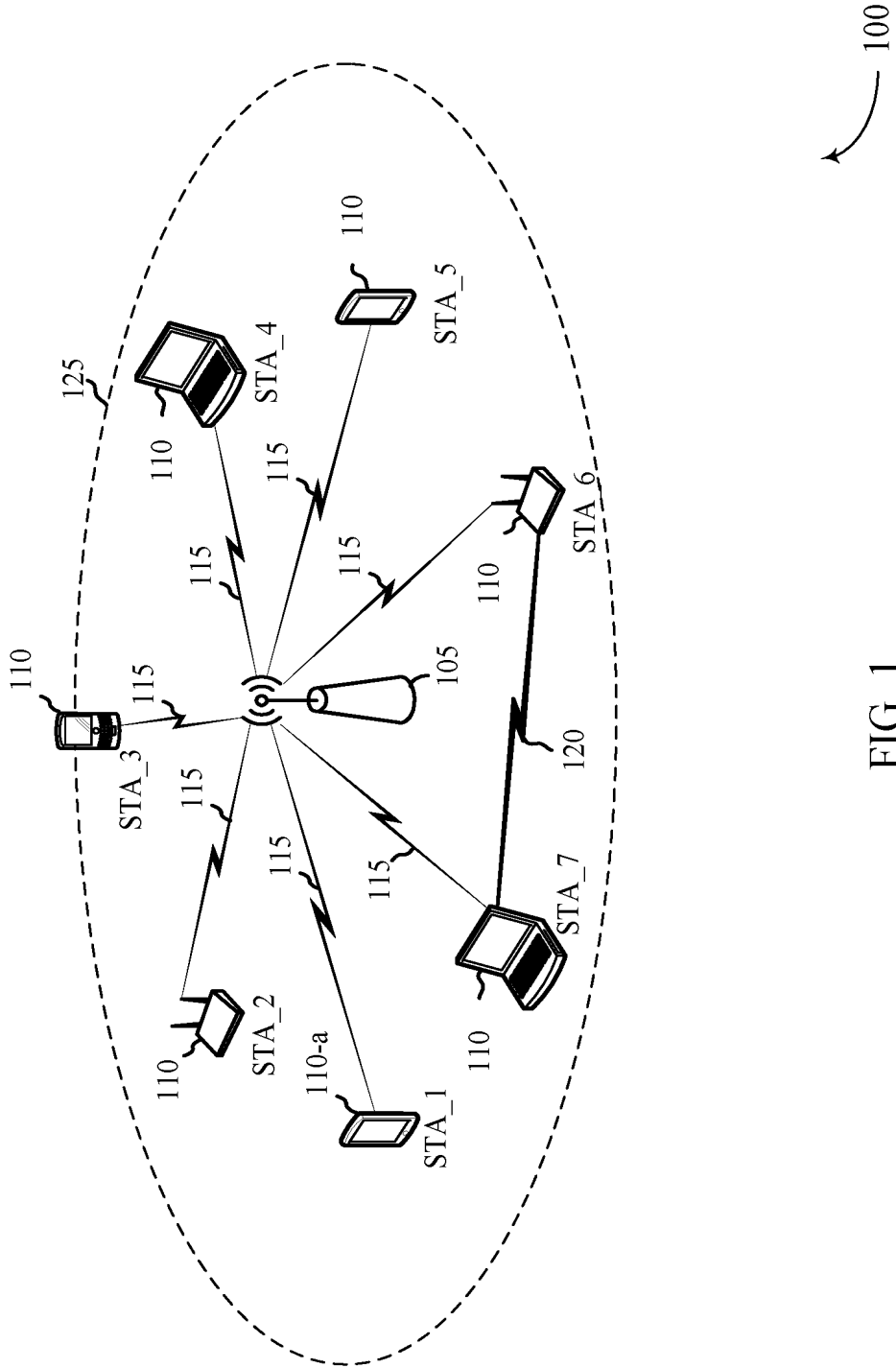


FIG. 1

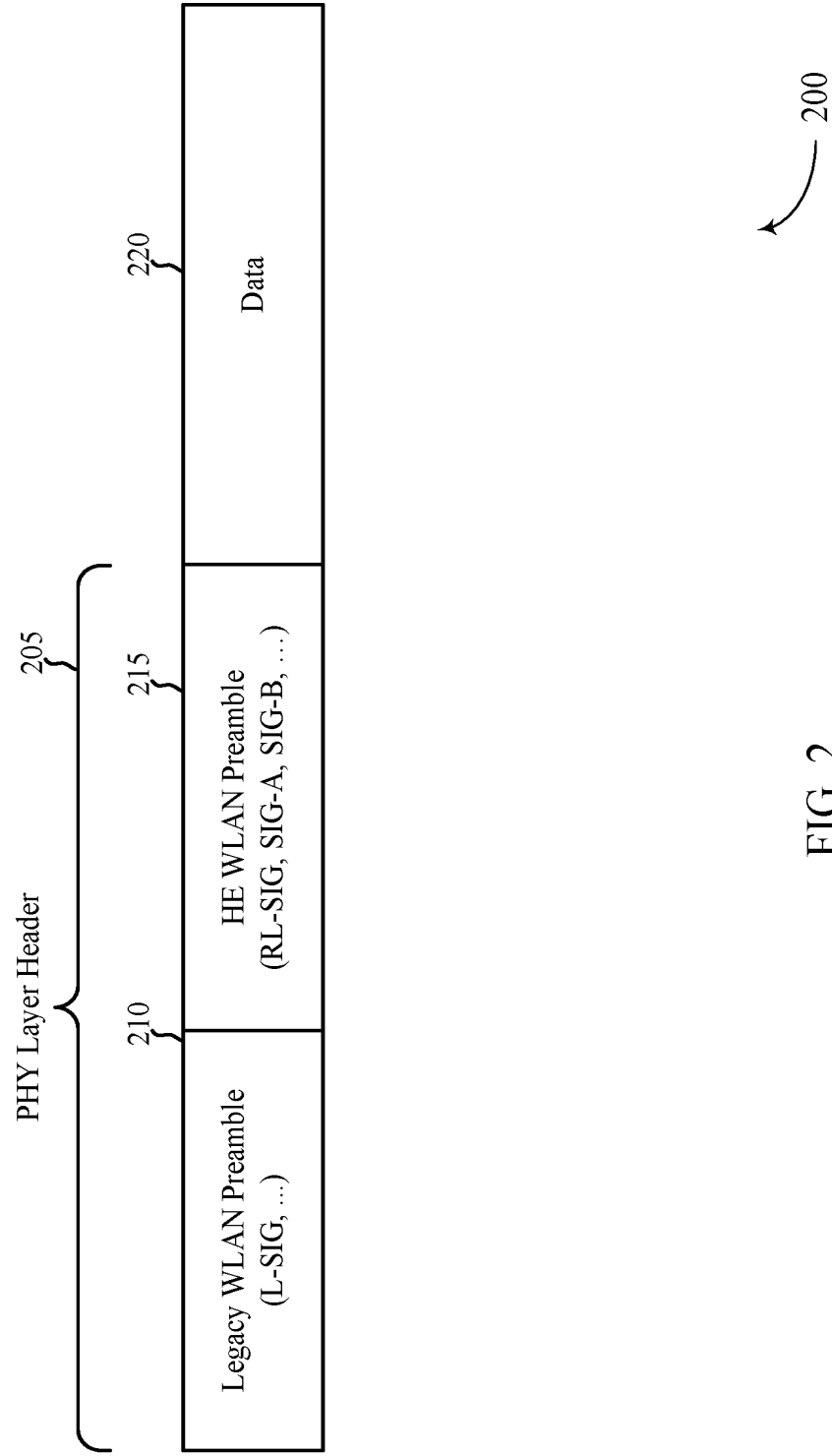


FIG. 2

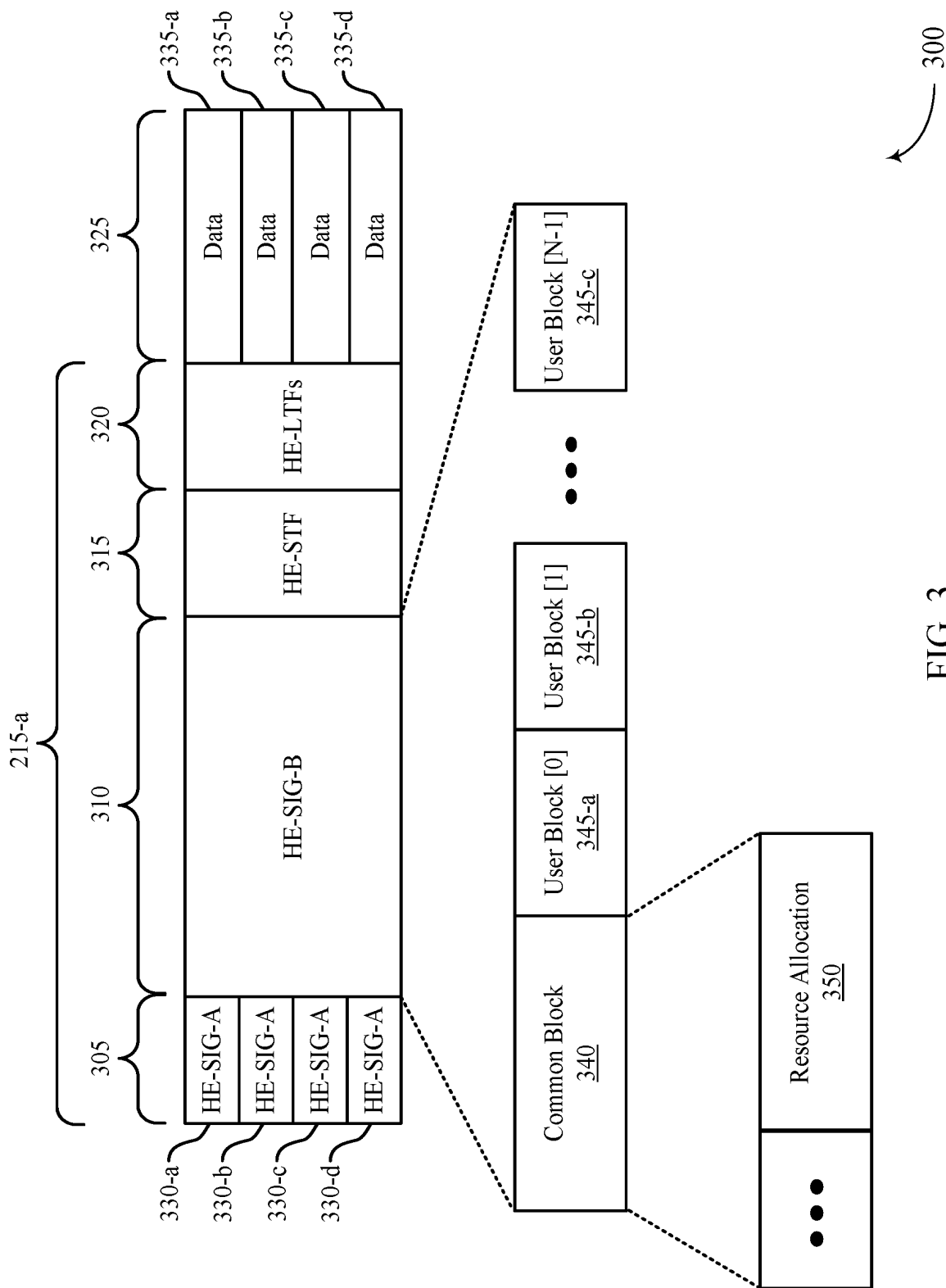


FIG. 3

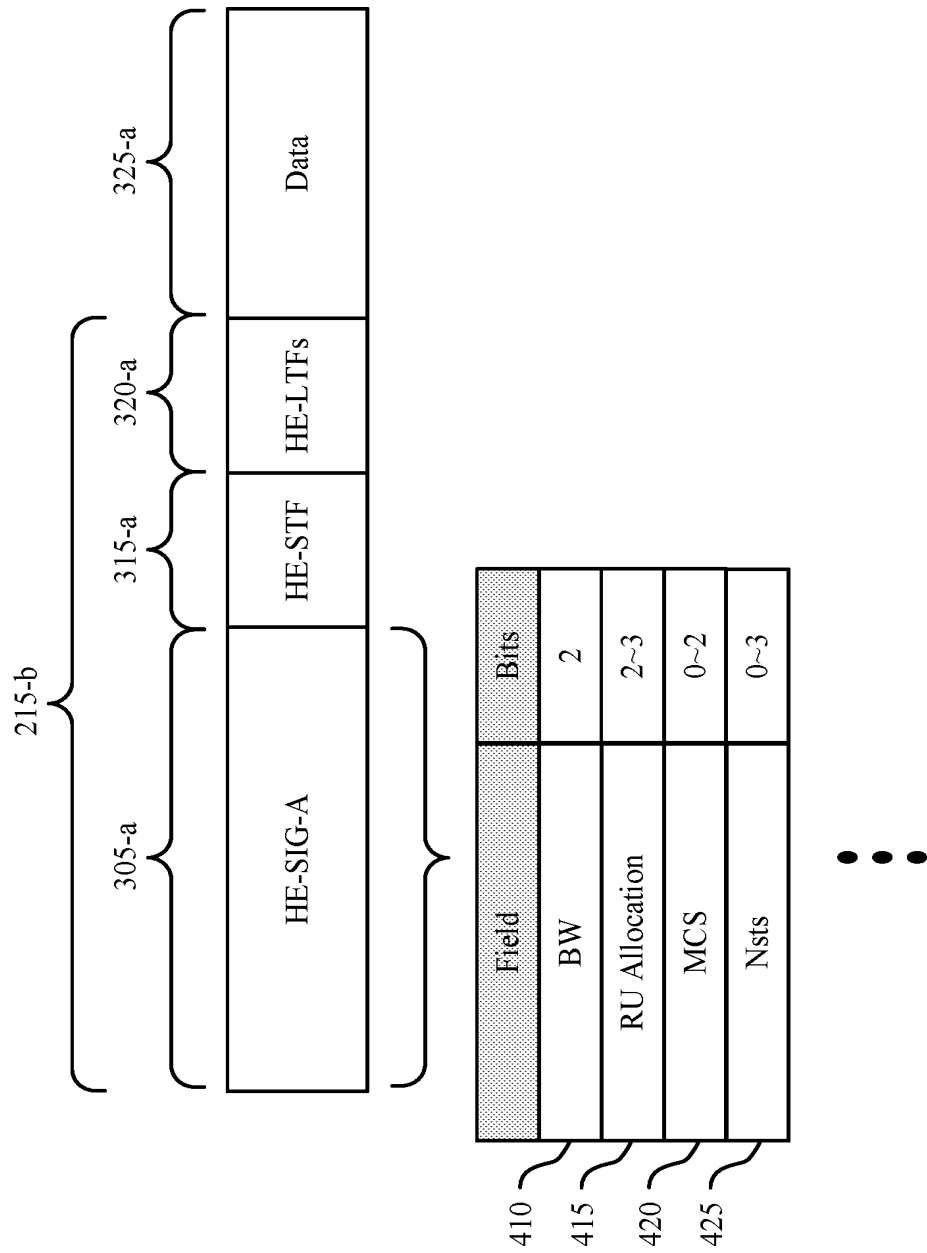
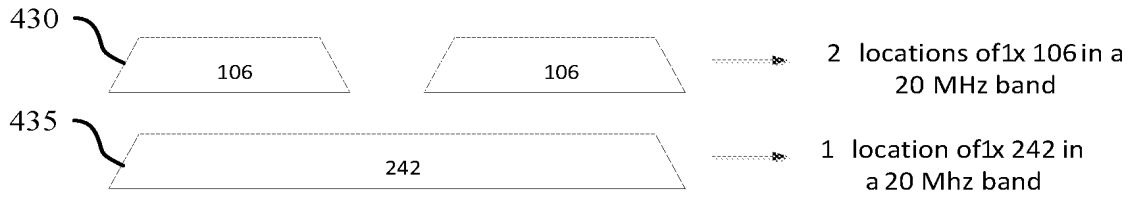
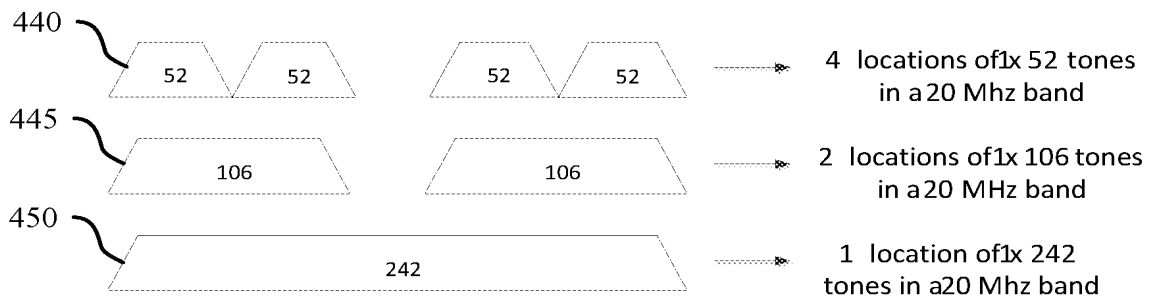


FIG. 4A



401

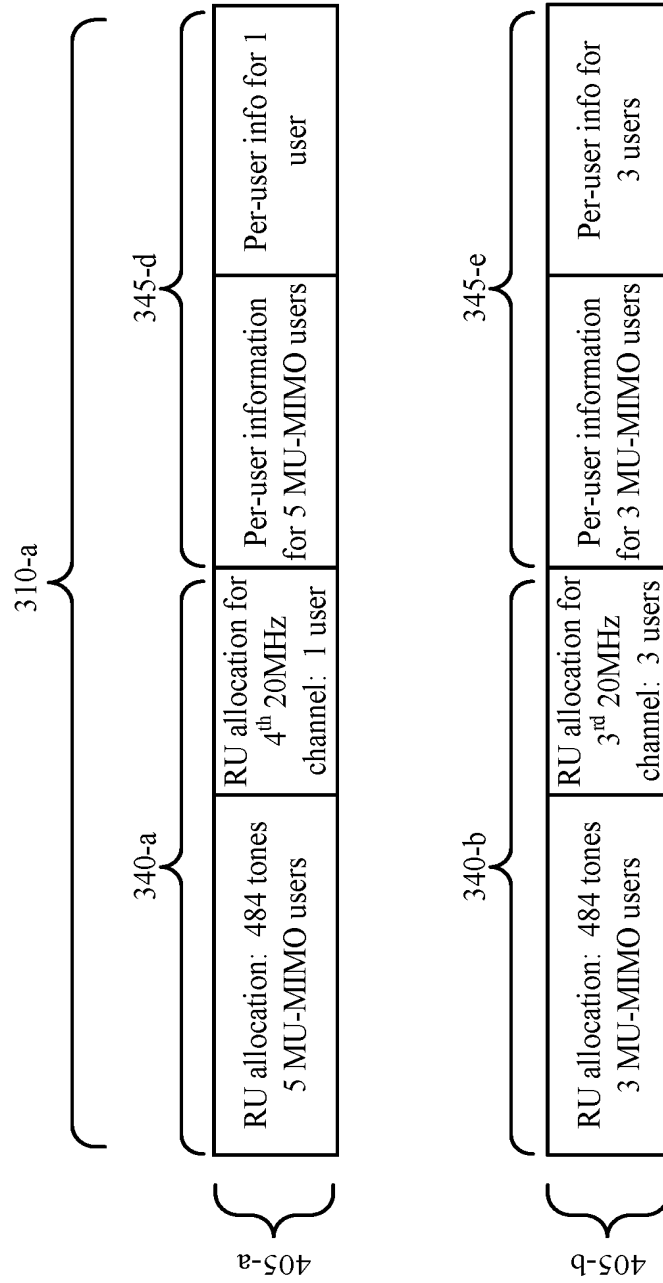
FIG. 4B



402

FIG. 4C





500

FIG. 5

#1	#2	#3	#4	#5	#6	#7	#8	#9	Num of entries
26	26	26	26	26	106				8
26	26	52		26	106				8
52	26	26	26	26	106				8
52	52			26	106				8
	106			26	26	26	26	26	8
	106			26	26	26	52		8
	106			26	52		26	26	8
	106			26	52		52		8
	106			26	106				64
				242					8
				484					8+1
				996					8+1
				2*996					8

605  
610

600

FIG. 6

Nuser	B0...B3	Nsts [1]	Nsts [2]	Nsts [3]	Nsts [4]	Nsts [5]	Nsts [6]	Nsts [7]	Nsts [8]	Number of Entries
2	0000~0011	1~4	1							10
	0100~0110	2~4	2							
	0111~1000	3~4	3							
	1001	4	4							
3	0000~0011	1~4	1	1						13
	0100~0110	2~4	2	1						
	0111~1000	3~4	3	1	705					
	1001~1011	2~4	2	2						
	1100	3	3	2						
4	0000~0011	1~4	1	1	1					11
	0100~0110	2~4	2	1	1					
	0111	3	3	1	1					
	1000~1001	2~3	2	2	1					
	1010	2	2	2	2					
5	0000~0011	1~4	1	1	1	1				6
	0100~0101	2~3	2	1	1	1				
6	0000~0010	1~3	1	1	1	1	1			4
	0011	2	2	1	1	1	1			
7	0000~0001	1~2	1	1	1	1	1	1		2
8	0000	1	1	1	1	1	1	1	1	1

700

FIG. 7

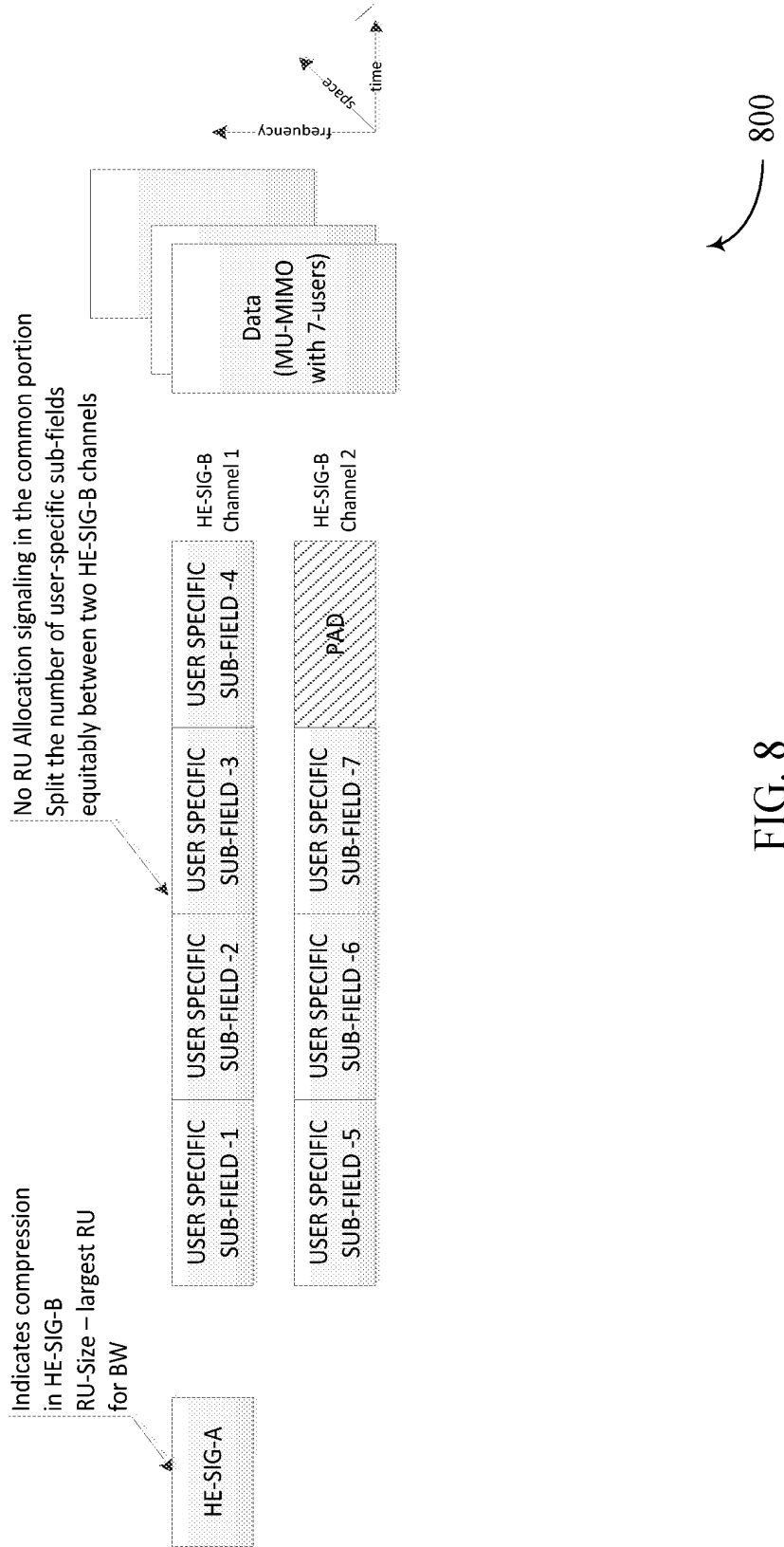


FIG. 8

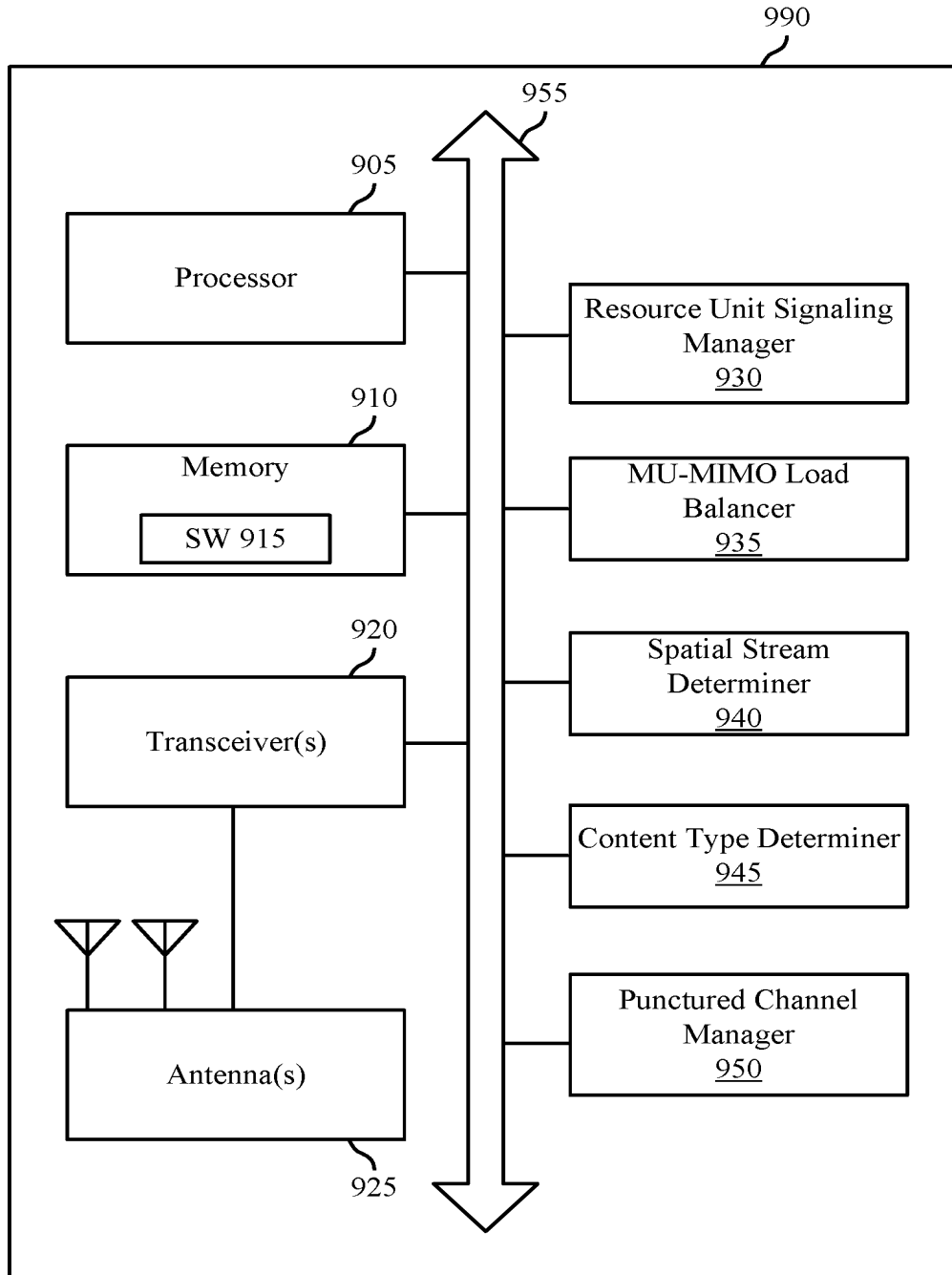


FIG. 9A

900-a



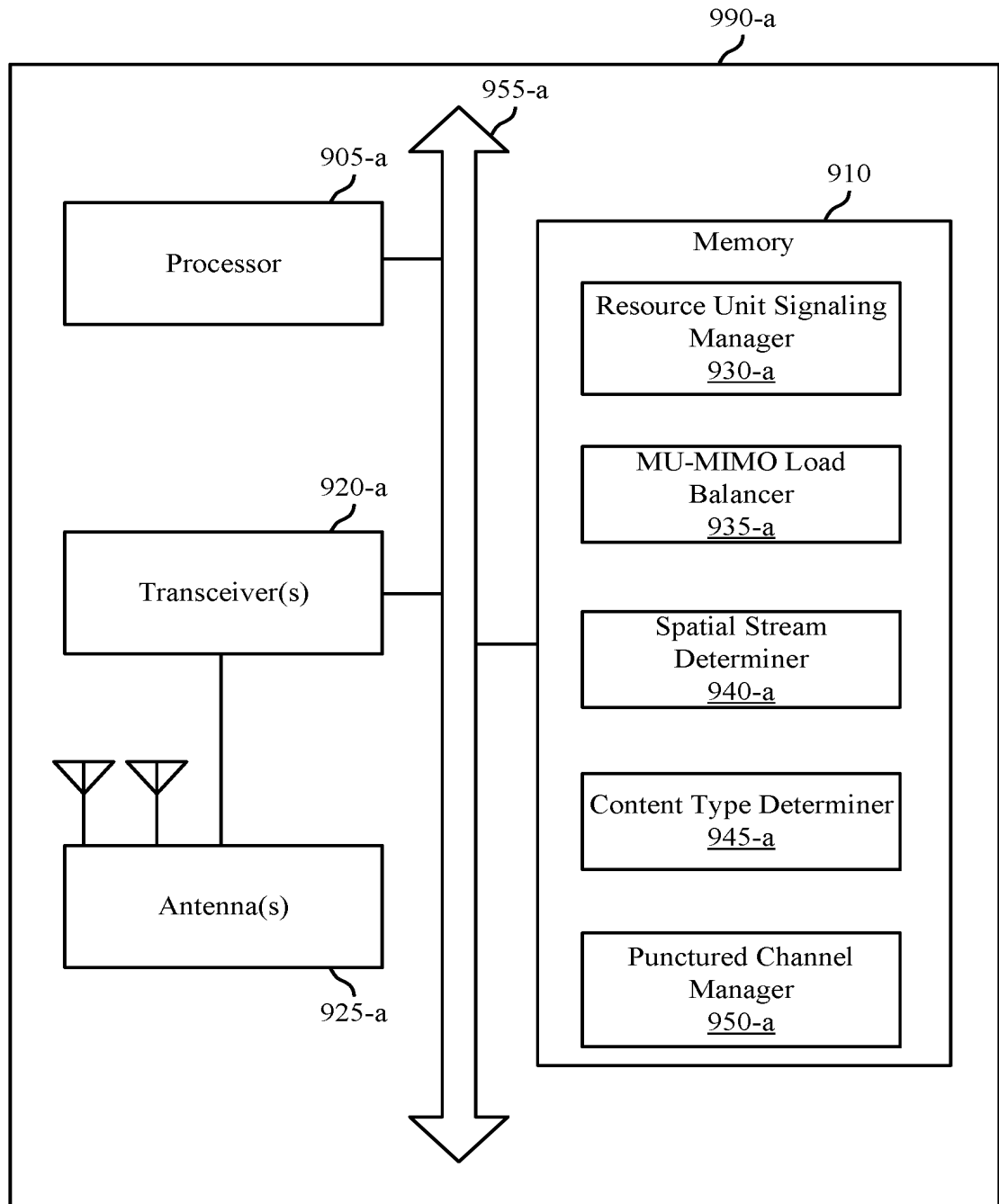


FIG. 9B

900-b