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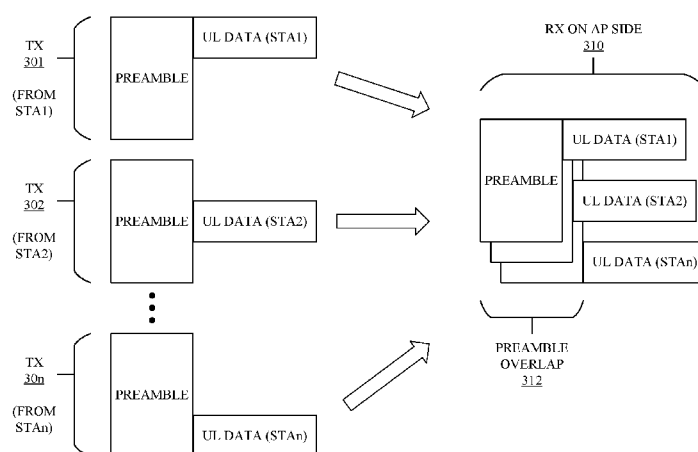


FIG. 3

(57) Abstract: Presently disclosed are systems and methods for preamble construction in uplink multi-user (MU) orthogonal frequency division multiple access (OFDMA) networks. One embodiment takes the form of a method that includes a wireless station receiving an uplink resource scheduling message having a resource allocation and the wireless station further receiving transmission power-level estimation parameters; determining an uplink data transmission power based on the received transmission power-level estimation parameters; determining a fractional preamble transmission power level based on the received uplink resource scheduling message; transmitting the preamble at the determined fractional preamble transmission power level; and transmitting the uplink data at the allocated power level.

## **SYSTEMS AND METHODS FOR PREAMBLE CONSTRUCTION IN UPLINK MULTI-USER ORTHOGONAL FREQUENCY DIVISION MULTIPLE ACCESS NETWORKS**

### **CROSS-REFERENCE TO RELATED APPLICATION**

[0001] The present application is a non-provisional filing of, and claims benefit under 35 U.S.C. §119(e) from, U.S. Provisional Patent Application Serial No. 62/306,486, entitled “Systems and Method for Preamble Construction in Uplink Multi-User Orthogonal Frequency Division Multiple Access Networks”, filed March, 10, 2016, the entirety of which is incorporated herein by reference.

### **TECHNICAL FIELD**

[0002] This disclosure relates to systems and methods for preamble construction in uplink multi-user (MU) orthogonal frequency division multiple access (OFDMA) networks such as Institute of Electrical and Electronics Engineers (IEEE) 802.11ax wireless local area networks (WLANs), including various approaches with respect to the common preamble for trigger-based MU OFDMA networks such as 802.11ax WLANs.

### **BACKGROUND**

[0003] Countless devices and networks around the globe operate according to one or more IEEE 802.11 standards for engaging in wireless communications. These communications typically occur in the 2.4-GHz and 5-GHz bands, though other bands are used as well. Recently, discussions and investigations are ongoing in the industry with respect to MU use cases.

### **OVERVIEW OF DISCLOSED EMBODIMENTS**

[0004] Presently disclosed are systems and methods for implementing uplink MU OFDMA networks.

[0005] One embodiment takes the form of a method comprising: a wireless station receiving an uplink resource scheduling message having a resource allocation; the wireless station further receiving transmission power-level estimation parameters; the wireless station determining an

uplink data transmission power based on the received transmission power-level estimation parameters; the wireless station determining a fractional preamble-transmission power level based on the received uplink resource scheduling message; the wireless station transmitting the preamble at the determined fractional preamble-transmission power level; and the wireless station transmitting the uplink data at the determined uplink data transmission power level.

[0006] In some embodiments, the fractional preamble-transmission power level is based on an estimated number of other wireless stations transmitting per the resource scheduling message. In other embodiments, the fractional preamble-transmission power level is based on a ratio of resource units allocated to the wireless station to a total number of resource units. In some embodiments, the fractional preamble-transmission power level is based on a ratio of both i) resource units allocated to the wireless station and ii) an unallocated resource unit to a total number of resource units. The unallocated resource unit may be to the left, the right, or both the left and right of the allocated resource units. In other embodiments, the wireless station determines unallocated RUs to be those unallocated RUs that are adjacent in frequency to the allocated RU.

[0007] In some embodiments, determining the fractional preamble-transmission power level is based on a field of the resource scheduling message, wherein the field indicates a pre-set fractional level, a zero level, or a full-power level. The field of the resource scheduling message may be set responsive to arrival times of transmissions from the wireless station at an access point, received power levels of transmissions from the wireless station at an access point, or a determined location of the wireless station.

[0008] Moreover, any of the variations and permutations described in this disclosure can be implemented with respect to any embodiments, including with respect to any method embodiments and with respect to any system embodiments. Furthermore, this flexibility and cross-applicability of embodiments is present in spite of the use of slightly different language (e.g., process, method, steps, functions, set of functions, and the like) to describe and or characterize such embodiments.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

[0009] FIG. 1 depicts an example tone plan, in accordance with at least one embodiment.

[0010] FIG. 2 depicts multiple different types of preamble format signaling, in accordance with at least one embodiment.

[0011] FIG. 3 depicts an example preamble-overlap scenario, in accordance with at least one embodiment.

[0012] FIG. 4 depicts an example wireless-communication device, in accordance with at least one embodiment.

[0013] FIG. 5 depicts an example wireless-communication device, in accordance with at least one embodiment.

[0014] FIG. 6A depicts a first method, in accordance with at least one embodiment.

[0015] FIG. 6B depicts a second method, in accordance with at least one embodiment.

[0016] FIG. 6C depicts a third method, in accordance with at least one embodiment.

[0017] FIG. 6D depicts a method performed by a wireless station, in accordance with at least one embodiment.

[0018] Moreover, before proceeding with this disclosure, it is noted that the entities, connections, arrangements, and the like that are depicted in—and described in connection with—the various figures are presented by way of example and not by way of limitation. As such, any and all statements or other indications as to what a particular figure “depicts,” what a particular element or entity in a particular figure “is” or “has,” and any and all similar statements—that may in isolation and out of context be read as absolute and therefore limiting—can only properly be read as being constructively preceded by a clause such as “In at least one embodiment....” And it is for reasons akin to brevity and clarity of presentation that this implied leading clause is not repeated *ad nauseum* in the below detailed description of the drawings.

## DETAILED DESCRIPTION

### 1. WLAN Background

#### 1.1. Overview of WLAN Systems

[0019] A WLAN in Infrastructure Basic Service Set (BSS) mode has an Access Point (AP) for the BSS and one or more stations (STAs) (e.g., client devices) associated with the AP. See, e.g. IEEE Std 802.11™-2012: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications. The AP typically has access or interface to a Distribution System (DS) or another type of wired/wireless network that carries traffic in and out of the BSS. Traffic to STAs that originates from outside the BSS arrives through the AP and is delivered to the STAs. Traffic originating from STAs to destinations outside the BSS is sent to the AP to be delivered to the respective destinations. Traffic between STAs within the BSS may also be sent through the AP where the source STA sends traffic to the AP and the AP delivers the traffic to the destination STA. Such traffic between STAs within a BSS is really peer-to-peer traffic. Such peer-to-peer traffic may also be sent directly between the source and destination STAs with a direct link setup (DLS) using an 802.11e DLS or an 802.11z tunneled DLS (TDLS). A WLAN using an Independent BSS (IBSS) mode has no AP, and compatible devices simply communicate directly with each other. This mode of communication is referred to as an “ad-hoc” mode of communication.

[0020] Using the 802.11ac infrastructure mode of operation, the AP may transmit a beacon on a fixed channel, usually the primary channel. This channel may be 20 megahertz (MHz) wide, and is the operating channel of the BSS. This channel is also used by the STAs to establish a connection with the AP. The fundamental channel-access mechanism in an 802.11 system is Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA). In this mode of operation, every STA, including the AP, will sense the primary channel. If the channel is detected to be busy, the STA backs off. Hence only one STA may transmit at any given time in a given BSS.

[0021] In 802.11n, High Throughput (HT) STAs may also use a 40-MHz-wide channel for communication. This is achieved by combining the primary 20-MHz-wide channel with an adjacent 20-MHz-wide channel to form a 40-MHz-wide contiguous channel.

**[0022]** In 802.11ac, Very High Throughput (VHT) STAs may support 20-MHz-wide channels, 40-MHz-wide channels, 80-MHz-wide channels, and 160-MHz-wide channels. See, e.g., IEEE P802.11ac™/D1.0: Part 11, Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications, Amendment 5: Enhancements for Very High Throughput for Operation in Bands below 6 GHz. The 40-MHz-wide channels and the 80-MHz-wide channels are formed by combining contiguous 20-MHz-wide channels in a manner that is similar to what is described above in connection with 802.11n. A 160-MHz-wide channel may be formed either by combining 8 contiguous 20-MHz-wide channels, or by combining 2 non-contiguous 80-MHz-wide channels in what is also referred to at times as an “80+80 configuration.” For the 80+80 configuration, the data, after channel encoding, is passed through a segment parser that divides it into two streams. Inverse Fast Fourier Transform (IFFT) processing and time-domain processing are performed on each stream separately. The streams are then mapped on to the two channels, and the data is transmitted. At the receiver, this mechanism is reversed, and the combined data is delivered to the MAC of the receiver.

**[0023]** Sub-1-gigahertz (GHz) modes of operation are supported by 802.11af (See e.g., IEEE 802.11 af: Part 11, Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, Amendment 5: Television White Spaces (TVWS) Operation,) and 802.11ah (See e.g., IEEE 802.11 ah/D5.0: Part 11, Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, Amendment 2: Sub 1 GHz License Exempt Operation,). For these specifications, the channel operating bandwidths, as well as the carriers, are reduced relative to those used in 802.11n, and 802.11ac. 802.11af supports 5-MHz, 10-MHz, and 20-MHz bandwidths in the TV White Space (TVWS) spectrum, and 802.11ah supports 1-MHz, 2-MHz, 4-MHz, 8-MHz, and 16-MHz bandwidths using non-TVWS spectrum. A possible use case for 802.11ah is support for Meter Type Control (MTC) devices in a macro coverage area. MTC devices may have limited capabilities including support for only limited bandwidths, but also include a requirement for a very long battery life.

**[0024]** WLAN systems—such as 802.11n, 802.11ac, 802.11af, and 802.11ah—that support multiple channels and multiple channel widths include a channel that is designated as the primary channel. The primary channel may, but does not necessarily, have a bandwidth equal to the largest common operating bandwidth supported by all STAs in the BSS. The bandwidth of the primary

channel is therefore limited by the STA (among the STAs that are operating in a BSS) that supports the smallest bandwidth operating mode (as the maximum supported channel-bandwidth operating mode for the particular STA). In the example of 802.11ah, the primary channel may be 1 MHz wide if there are STAs (e.g., MTC-type devices) that only support a 1-MHz channel-bandwidth operating mode even if the AP and other STAs in the BSS support, e.g., a 2-MHz, a 4-MHz, an 8-MHz, a 16-MHz, and/or one or more other channel-bandwidth operating modes in excess of the 1-MHz channel-bandwidth operating mode. All carrier sensing, as well as NAV settings, depend on the status of the primary channel; i.e., if the primary channel is busy, for example, due to a STA that supports only a 1-MHz operating mode currently transmitting to the AP, then the entire available frequency bands are considered busy even though majority of it stays idle and available.

[0025] In the United States, the available frequency bands that can be used for 802.11ah are from 902 MHz to 928 MHz. In Korea, it is from 917.5 MHz to 923.5 MHz; and in Japan, it is from 916.5 MHz to 927.5 MHz. The total bandwidth available for 802.11ah is between 6 and 26 MHz depending on the country code.

## **1.2. Introduction of High Efficiency WLAN Study Group and TGax**

[0026] The IEEE 802.11 High Efficiency WLAN (HEW) Study Group (SG) was created to explore ways to enhance the quality of service that is experienced by a broad spectrum of wireless users in many usage scenarios including high-density scenarios in the 2.4-GHz and 5-GHz bands. New use cases that support dense deployments of APs and STAs—as well as associated Radio Resource Management (RRM) technologies—are considered by the HEW SG.

[0027] Potential applications for HEW include emerging usage scenarios such as data delivery for stadium events and other high-user-density scenarios such as train stations and enterprise/retail environments; additional examples include applications having heightened dependence on video delivery, as well as wireless services for medical applications. And certainly other examples could be listed here.

[0028] The IEEE Standard board approved the IEEE 802.11ax Task Group (TGax) based on a Project Authorization Request (PAR) (See, e.g., IEEE 802.11-14/165r0: 802.11 HEW SG Proposed SG PAR, Jan 2014, <https://mentor.ieee.org/802.11/dcn/14/11-14-0165-01-0hew-802->

11-hew-sg-proposedpar.docx.) and Criteria for Standards Development (CSD) (See, e.g., IEEE 802.11-14/169ro: 802.11 IEEE 802.11 HEW SG Proposed CSD, <https://mentor.ieee.org/802.11/dcn/14/11-14-0169-01-0hew-ieee-802-11-hew-sg-proposedcsd.docx>.) that were developed in the HEW SG. In TGax standard meetings, several contributions showed that the measured traffic for a variety of applications has a large likelihood of involving short packets, and there are network applications that may also generate short packets, such as:

- Virtual office;
- Transmit power control (TPC) acknowledgement (ACK);
- Video streaming ACK;
- Device/Controller (mice, keyboards, game controls, etc.);
- Access: probe request/response;
- Network selection: probe requests, Access Network Query Protocol (ANQP); and
- Network management: control frames.

**[0029]** Also, many contributions in 802.11ax have proposed the introduction of MU features that include uplink (UL) and downlink (DL) OFDMA and UL and DL MU multiple-in-multiple-out (MU-MIMO). Such features involve addressing how to multiplex UL random access for various different purposes.

#### **1.2.1. UL Multi-User Operation**

**[0030]** In 802.11ax, a UL MU Physical Layer Convergence Protocol (PLCP) Protocol Data Unit (PPDU) is defined, which may be MU-MIMO or OFDMA. This PPDU is sent as a response to a trigger frame sent by the AP. The trigger frame allocates different STAs to different resources (in the case of OFDMA: a specific Resource Unit). In some embodiments, the AP sends, to the wireless stations, transmission power-level estimation parameters. Each wireless station determines an uplink data transmission power level for its respective data packet based on the

received transmission power-level estimation parameters. In some embodiments, the transmission power-level estimation parameters include a target received signal strength indicator (RSSI) value and the transmission power of the access point. Each wireless station determines the uplink data transmission power to achieve the target RSSI value at the access point for its respective data packet transmission. In one embodiment, therefore, the AP implicitly signals the transmit power that is to be used in the full and partial bandwidth regions frequency spectrum.

**[0031]** As an example, in a 20-MHz-wide channel, the 802.11ax Specification Framework Document (SFD) proposes the following OFDMA building blocks:

- 26-tone with 2 pilots, 52-tone with 4 pilot and 106-tone with 4 pilots and with 7 DC Nulls and (6,5) guard tones, and at locations shown in FIG. 1, in which various sections of the tone plan 100 are labeled in various colors to account for being limited to black-and-white line drawings in this disclosure, and where “W” represents “WHITE,” “GR” represents “GREEN,” “YEL” represents “YELLOW,” and “ORG” represents “ORANGE.” Those of skill in the art are familiar with such tone plans.
- An OFDMA PPDU can carry a mix of different tone unit sizes within each 242-tone-unit boundary.
- See e.g., IEEE 802.11-15/0132r13, Specification Framework for TGax, Nov 2015.

And similar building blocks are defined in the 802.11ax SFD for 40-MHz-wide channels, 80-MHz-wide channels, 160-MHz-wide channels, and the above-mentioned 80+80.

### **1.2.2. Preamble Formats for High Efficiency PPDU (HE-PPDU)**

**[0032]** The preamble structure before the HE-Short Training Field (HE-STF) defines the transmission format. There are only three pre-HE-STF preamble formats defined:

- Single-User (SU) format (mandatory) / Trigger-based UL format
- Extended-range SU format

- MU format (mandatory)

The signaling of the three preamble formats is illustrated in FIG. 2, which depicts the SU format 202, the extended-range SU format 204, and the MU format 206. When the L-SIG length is set to  $\text{mod}3=1$ , this indicates that what follows is in the SU format, as shown at 202. When the L-SIG length is set to  $\text{mod}3=2$ , this indicates that what follows is either in the extended-range SU format, as shown at 204, or in the MU format, which is shown at 206. These last two cases are distinguished from one another in that QBPSK on HE-SIG-A2 indicates the extended-range SU format, whereas BPSK on HE-SIG-A2 indicates that what is being used is the MU format.

[0033] Thus, it can be seen in FIG. 2 that there are three different preamble structures that can precede the HE-STF: the SU format as shown at 202, the extended-range SU format as shown at 204, and the MU format as shown at 206. It can also be seen that all three preamble structures start with the L-SIG/L-R-SIG field followed in succession by the HE-SIG-A1 field and the HE-SIG-A2 field. In the case of the SU format 202, the very next field is the HE-STF. However, in the extended-range SU format 204, there are also the HE-SIG-A3 field and then the HE-SIG-A4 field prior to the HE-STF. In the case of the MU format 206, an HE-SIG-B field is present between the HE-SIG-A2 field and the HE-STF.

## 2. Introductions to Embodiments of Solutions

[0034] In this disclosure we address the following problems:

### 2.1. Problem 1: Common-Preamble Overlap

[0035] For Trigger based UL PPDU, the 64pt Fast Fourier Transform (FFT) preamble is defined by the following fields, which may be common to all STAs:

- L-STF
- L-LTF
- L-SIG/R-L-SIG
- HE-SIG-A1

- HE-SIG-A2

In the case of UL MU OFDMA transmission, each user is sending their respective data using partial bandwidth, presenting a question as to how to structure this part of the preamble, which, if sent by multiple STAs, may result in overlap that may impact the received power, the Automatic Gain Control (AGC), and synchronization. An example of such preamble overlap is depicted in FIG. 3, which shows an example preamble-overlap scenario 300 that involves  $n$  different transmissions: a transmission 301 from a first STA (i.e., STA1), a transmission 302 from a second STA (i.e., STA2), all the way down to a transmission 30 $n$  from the  $n$ th station (i.e., STAn). The receipt of these transmissions 301-30 $n$  is generally shown at 310 in FIG. 3, and the overlap of the preambles sent as part of the respective transmissions is shown generally at 312. It is noted that, with respect to the respective UL data in the respective transmissions 301-30 $n$ , STA1, STA2, ..., STAn use different, non-overlapping partial-bandwidth segments that are respectively labeled UL DATA (STA1), UL DATA (STA2), ..., UL DATA (STAn).

[0036] Three approaches for addressing the above-described common-preamble-overlap problem are described below.

### 2.1.1. Solution 1: Using a Full-Band Common Preamble from all STAs

[0037] In this solution, all STAs send a full-band common preamble to the AP and then send partial-band UL OFDMA HE-SIG and data. Problems with this method include the following:

- The common SIG from all STAs received by the AP may be synchronized at the AP location. However, packets synchronized at the AP may not be synchronized at other STAs in the BSS, resulting in other STAs being unable to decode the packets.
- The combined power levels for the preamble may be different from the combined power levels for the HE-STF / HE-LTF and HE-Data. As such, TPC methods may need to take this into account.

### **2.1.2. Solution 2: Defining Narrow-Band Common Preamble**

[0038] In this solution, all STAs send a narrow-band common preamble, and the transmission from different users is synchronized in such a way that they add up to the full common preamble. Problems with this method include the following:

- Preamble must be designed such that all the legacy device can detect it as if it originated from a single AP or STA.
- Timing synchronization becomes very important. Also, timing synchronization at the AP may result in poor timing synchronization at other STAs in the BSS.
- There may be empty band, with no scheduled transmission, and hence no STAs would transmit preamble on it.

### **2.1.3. Solution 3: No Common Preamble**

[0039] Because the AP has scheduled the uplink transmission, it knows all the SIG information already, and thus the AP may not need the STAs to transmit that information again. However, it may be advantageous to instruct STAs to not send the common preamble in order to save the overhead. The “Proposed Solutions” section below provides further details with respect to the overall solutions listed above, and addresses each problem that is listed above with respect to the various different solutions.

## **2.2. Example Scenario**

[0040] FIG. 4 depicts an example scenario that includes an AP and multiple STAs, in accordance with at least one embodiment. The example scenario 400 includes an AP 400, a STA 410, a STA 420, a STA 430, and a STA 440. In the depicted example, the STA 410 is a tablet computer, the STA 420 is a smartphone, the STA 430 is a laptop computer, and the STA 440 is a personal digital assistant (PDA). In the depicted example, each of the STAs 410-440 receive data from the AP 402 over a DL as shown at 411, 421, 431, and 441, and each of the STAs also transmit data to the AP 402 over an UL as shown at 412, 422, 432, and 442. The STAs 410-440 could be the STA1-STAn that are depicted in and described in connection with FIG. 3. The STAs 410-440

may communicate with the AP 402 (and perhaps with one another) using any suitable wireless protocol, including any IEEE 802.11 protocol.

### **2.3. Example Wireless-Communication Device**

[0041] FIG. 5 depicts an example wireless-communication device, in accordance with at least one embodiment. The device 500 could be an AP, a STA, and/or any other wireless-communication device. Thus, any of the APs, STAs, and/or other computing-and-communication devices described herein (e.g., the AP 402, the STAs 410-440, etc.) could have a structure similar to the example structure that is described in connection with FIG. 5.

[0042] As shown in FIG. 5, the example device 500 includes a communication interface 502, a processor 504, data storage 506 containing program instructions 508, and an optional user interface 510, all of which are communicatively connected by a system bus 512. Other device architectures could be used as well, as the provided and described architecture is presented herein by way of example and not limitation.

[0043] The communication interface 502 may include one or more wireless-communication interfaces (for communicating according to, e.g., LTE, Wi Fi (i.e., any one or more IEEE 802.11 protocols), Bluetooth, and/or the like) and/or one or more wired-communication interfaces (for communicating according to, e.g., Ethernet, USB, and/or the like). As such, the communication interface 502 may include any necessary hardware (e.g., chipsets, antennas, Ethernet cards, etc.), any necessary firmware, and any necessary software for conducting one or more forms of communication with one or more other entities as described herein.

[0044] The processor 504 may include one or more processors of any type deemed suitable by those of skill in the relevant art, some examples including a general-purpose microprocessor and a dedicated digital signal processor (DSP).

[0045] The data storage 506 may take the form of any non-transitory computer-readable medium or combination of such media, some examples including flash memory, read-only memory (ROM), and random-access memory (RAM) to name but a few, as any one or more types of non-transitory data-storage technology deemed suitable by those of skill in the relevant art could

be used. The data storage 506 contains program instructions 508 that are executable by the processor 504 for carrying out various functions described herein.

[0046] When present, the optional user interface 510 may include one or more input devices (a.k.a. components and the like) and/or one or more output devices (a.k.a. components and the like). With respect to input devices, the optional user interface 510 may include one or more touchscreens, buttons, switches, knobs, microphones, and the like. With respect to output devices, the optional user interface 510 may include one or more displays, speakers, light emitting diodes (LEDs), and the like. Moreover, one or more components (e.g., an interactive touchscreen-and-display component) of the optional user interface 510 could provide both user-input and user-output functionality. And certainly other user-interface components could be used in a given context, as known to those of skill in the art.

### **3. Various Embodiments**

#### **3.1. Embodiment Group 1.1: Using a Full-Band Common Preamble from all STAs**

[0047] In this group of embodiments, each STA that is transmitting in UL-OFDMA uses a full-bandwidth L preamble (64pt FFT for 20 MHz) followed by partial-band transmission of HE-STF, HE-LTF, and HE-Data using the HE numerology for the HE-STF, HE-LTF, and HE-Data (256pt FFT for 20MHz).

##### **3.1.1. Embodiment 1.1.1: Power Suppression for Legacy Preamble**

[0048] In UL MU-OFDMA, each STA transmits the data part or the partial-bandwidth part at a power that is proportionate to the bandwidth allocated. If each STA sends the full bandwidth part, i.e. the common preamble, with full power, the AP will receive the common-preamble with the power level, which is N times larger than the power level at which the AP will receive the data part, where N is the number of transmitting STAs. To ensure that packets have the same power throughout the packet, this group of embodiments involves power suppression for the full-bandwidth portion.

[0049] FIG. 6A depicts a first method, in accordance with an embodiment. In the first method, the suppression levels in various scenarios of the UL-OFDMA are selected such that there are no sudden fluctuations in power level in the frame, which is more suitable for the hardware.

[0050] In an embodiment, the method 600 of FIG. 6A is followed:

1. Multiple STAs indicate the presence of data using a buffer status report (BSR) frame. (At 602)
  - a. This may be based on AP polling or may be based on an UL MU\_OFDMA random-access transmission.
2. The AP schedules a set of STAs to transmit in the uplink. (At 604)
  - a. The scheduling is done using the trigger frame with the signaling and allocation done using the HE-SIG-B field.
  - b. It also indicates allocated RUs for each STA.
  - c. Each STA may have one or more RUs allocated to itself.
  - d. If one or more of the RUs are unallocated, this is implicitly indicated in the same trigger frame.
3. Using this scheduling information, each STA generates an identical preamble, including identical L-SIG, RL-SIG, HE-SIG-A1, and HE-SIG-A2. (At 606)
  - a. If all of the RUs in the UL-MU-OFDMA system are allocated and one of the STAs is assigned a given RU  $x$  out of the 9 RU, that STA computes the power level for the common preamble at  $x/9$  power of the regular common preamble.
    - i. When all of the STAs are transmitting simultaneously with these computed power levels, the AP receives the common preamble with combined power levels similar to the rest of the packet.

- ii. In one embodiment, the AP implicitly signals the transmit power that is to be used in the full/partial bandwidth region. The STA may implicitly adjust its transmit power by estimating the number of STAs that will be transmitting from the resource-allocation information and then adjust its power accordingly. For example, if the allocation is  $\{\text{STAA}, \text{STAB}, \text{STAC}, \text{STAD}\} = [52\ 52\ 26\ 104]$  and the partial bandwidth transmit power is set to  $\{\text{Pa}, \text{Pb}, \text{Pc}, \text{Pd}\}$  then each STA may scale its common-preamble power by  $\{2/9, 2/9, 1/9, 4/9\}$  in one method or  $\{1/4, 1/4, 1/4, 1/4\}$  in another method. And other examples could be listed as well.
- b. If one or more of the RUs in the UL-MU-OFDMA system are not allocated to any STA, another STA computes an adjustment to the power levels to cover for the difference. A resource unit that is either to the left or the right of each other may be referred to as ‘adjacent in frequency.’ For example, a RU to the left of an allocated RU has a lower frequency than the allocated RU and is adjacent to (i.e., having a tone index one less than) the allocated RU. Similarly, a RU to the right of (i.e., having a tone index one more than) an allocated RU has a higher frequency than the allocated RU and is also adjacent to the allocated RU. In some embodiments, a wireless station determines that the unallocated RUs are those unallocated RUs that are adjacent in frequency to the allocated RUs. In some embodiments, a wireless station determines that the unallocated RUs are those that are adjacent and to the left of the allocated RU, or that the unallocated RUs are those that are adjacent and to the right of the allocated RU.
  - i. This may be done by the STA with the RU allocated to the to the left of (i.e., having tone index less than (e.g., one less than)) unallocated RUs.

- ii. This may be done by the STA with the RU allocated to the to the right of (i.e., having tone index greater than (e.g., one greater than)) unallocated RUs.
- iii. This may be done by the STA that is indicated by the AP in the SIG-B field of the trigger frame.
- iv. Each STA may use power  $\frac{AllocatedRU}{TotalRU}$  for the full-bandwidth common Preamble portion. AllocatedRU is all RUs allocated to that STA in the MU-Uplink Frame
  - 1. This may be indicated explicitly in the trigger frame.
  - 2. This may be inferred by a given STA by the number of RUs that are allocated based on information in the trigger frame.
- c. The STA transmits the UL-MU-OFDMA frame with appropriately set transmit powers. (At 608)
- d. AP and other listening STA receive the full band portion and rest of the packet with similar lower levels and decode it.

### **3.1.2. Embodiment 1.1.2: Use of Two-Level TPC for Full-Band Common-Preamble Transmission**

**[0051]** In UL MU-OFDMA, it is necessary for the AP to set the transmit power of each STA in order to ensure that the packets arrive at the AP at approximately the same power level. This is typically implemented by using AP-directed TPC with the transmit power levels specified in the trigger frame.

**[0052]** In at least one embodiment, the AP specifies a separate transmit power level, one for the full bandwidth (64-pt FFT) region of the frame and one for the partial bandwidth (256-pt FFT) region of the frame. This allows the AP to set the received power of the overlapped full bandwidth region of the frame to a level that is suitable based on its hardware.

[0053] FIG. 6B depicts a second method, in accordance with an embodiment. In the second method, the method 610 of FIG. 6B is followed:

1. The STAs indicate the presence of data using a buffer status report (BSR) frame. (At 612)
  - a. This may be based on AP polling or may be based on an UL MU\_OFDMA random access transmission.
2. The AP schedules a set of STAs to transmit in the uplink. (At 614)
  - a. The scheduling is done using the trigger frame with the signaling and allocation communicated to the STAs using the HE-SIG-B field.
  - b. The common HE-SIG-B field indicates the OFDMA numerology used, e.g., 9 resource units of 26 tones each.
  - c. The HE-SIG-B field indicates the user-specific information including the specific STAs to be scheduled in each resource.
    - i. Each user-specific information field may contain the two TPC levels that indicate the transmit power to be used by the STA during the full-bandwidth and partial-bandwidth regions of the UL MU OFDMA frame.
      1. The full-bandwidth transmit power may be set to a lower value to ensure that the target receive power for the AP is met. This transmit power level may be set as a function of the number of STAs scheduled in the UL MU transmission.
3. In one embodiment, the AP may explicitly signal the transmit power to be used in each region. The STA transmits the UL-MU-OFDMA frame with appropriately set transmit powers. (At 616) In another embodiment, rather than explicitly setting the transmit power, the transmit power may be implicitly determined, by providing the wireless station with estimated

transmission power parameters that include a target RSSI level at the receiving access point and the power level of the access point transmission.

### **3.1.3. Embodiment 1.1.3: Select M/N STA to Transmit the Common Preamble**

**[0054]** One problem with multiple STAs transmitting the full-bandwidth region of the UL MU-MIMO frame is that the L-STF may appear to have been transmitted through a large delay spread channel, reducing its effectiveness. To mitigate this effect, the AP may specify that a subset of STAs only transmit the full-bandwidth region and others only transmit the partial-bandwidth region. This subset may be based on the following criterion:

1. Arrival time at the AP: The arrival time of the start of the packet at the AP (including any timing adjustments) is within a desired limit.
2. Received power at the AP: The received power at the AP is approximately the same.
3. Location in the BSS: The location of the STAs within the BSS are such that all STAs in neighboring BSSs overhear the transmission. In one example, the STAs are located at the equivalent of the four cardinal points.

**[0055]** Alternatively, the AP may only schedule STAs with packets that arrive within a precise window. The AP may perform some timing adjustment and trigger packet padding to ensure that this criterion is satisfied.

**[0056]** The STAs that are permitted/instructed to transmit the full-bandwidth region may be indicated or signaled in the trigger frame. A flag within the user specific HE-SIG-B frame may indicate this.

**[0057]** FIG. 6C depicts a third method, in accordance with an embodiment. The following method 620 of FIG. 6C may be followed:

1. To select the STAs that transmit the preamble, the AP may request each STA to transmit a list of OBSS STAs it overhears. (At 622)

- a. This may be by polling each STA or may be based on an UL MU-OFDMA random access transmission.
2. The AP may then select a subset of STAs that are overheard by all the STAs in the network. (At 624)
3. The STAs in the BSS may indicate the presence of data using a buffer status report (BSR) frame. (At 626)
  - a. This may be based on AP polling or may be based on an UL MU-OFDMA random access transmission.
4. The AP schedules a set of STAs to transmit in the uplink. (At 628)
  - a. The scheduling is done using the trigger frame with the signaling and allocation done using the HE-SIG-B field.
  - b. The common HE-SIG-B field indicates the OFDMA numerology used e.g. 9 resource units of 26 tones each.
  - c. The HE-SIG-B field indicates the user specific information including the specific STAs to be scheduled in each resource.
  - d. Each user specific information field may be a flag that indicates if the full bandwidth region of the UL MU OFDMA frame of the OFDMA frame should be transmitted.
5. The STA transmits the UL-MU-OFDMA frame with appropriately set transmit powers.

#### **3.1.4. Embodiment 1.1.4: Orthogonal HE-SIG-A1/2**

1. In trigger based UL-MU transmission, if STAs have different HE-SIG-A information to be sent in same 20MHz bandwidth, the HE-SIG-A fields may be orthogonalized in time, code, or space for the different STAs.

2. In at least one embodiment, an orthogonal domain (code, space, time) is assigned by the AP for each RU. Hence, if a STA transmits UL-OFDMA data on a specific RU, it may use the specific orthogonal domain for HE-SIG-A corresponding to that RU.
  - a. The AP may use in the trigger frame to indicate which orthogonal domain may be used by resources.
3. In other scheme a pre-defined orthogonal domain may be assigned by the AP for each associated STA.
  - a. Different domains may be assigned and detected using blind detection.
  - b. An orthogonal domain may be associated with specific resource.
  - c. An orthogonal domain may be associated with specific STA.

#### **3.1.4.1. Random Request for Uplink**

**[0058]** If HE-SIG-A1/2 is made orthogonal in code, it may create an opportunity for random request for uplink by a STA which is not part of current transmission. The same is also possible if HE-SIG-A1/2 is orthogonal in frequency and one of the RU is unallocated.

**[0059]** In at least one embodiment, the following procedure is used:

1. AP sends a trigger frame identifying the STA and corresponding RUs.
2. If each STA has unique code assigned,
  - a. STA may be able to use that code to send information such as its buffer status during the orthogonal transmission HE-SIG-A1/2.
3. If each RU has unique code assigned, and STA observes an unallocated RU:
  - a. STA may use the code for that RU to send information such as buffer status in uplink.

- b. In this case, STA may also include STA ID / PAID 4 if HE-SIG-A1/2 is orthogonal in frequency domain and one of the RU is unallocated.
  - c. STA may send information such as buffer status in uplink on that unallocated orthogonal resource.
  - d. In this case, STA may also include STA ID / PAID
4. This buffer report and STA ID /PAID may be used by AP or EBSS AP to allocate resources more efficiently in following frames.

### **3.2. Embodiment 1.2: Defining Narrow-Band Common Preamble**

[0060] In at least one embodiment, each STA sends part of the common-preamble only on the sub-carriers corresponding to RUs that have transmission scheduled. This is designed in such a way that an AP or other listening STA receives a complete common preamble.

- 1. Preamble includes sub-carriers that are distributed between different STAs.
- 2. To achieve seamless reception that is transparent as to the origin of the common preamble, all the common preamble fields, identical frequency domain, are generated by each STA.
  - a. This includes L-STF, L-LTF, L-SIG/R==L-SIG, HE-SIG-A1, HE-SIG-A2.
- 3. After generation of all the sub-carriers, suppression and null sub-carriers are identified.
- 4. As the sub-carrier spacing is different between HE RU allocations and the common portion of the preamble, a mapping is defined between 64pt FFT (1x) numerology and RU allocations.
  - a. For example: Each allocated RU may correspond to 7 1x sub-carriers.

5. STA identifies the sub-carriers to be transmitted depending on the allocated RUs and then nulls the rest of the sub-carriers that are not allocated to an STA.
6. If an RU is not allocated to any STA (unallocated RU), STA with RU adjacent to unallocated RU allocation may transmit the sub-carriers corresponding to the unallocated RU.
7. The AP may indicate which STA must transmit a portion of the common preamble in unallocated RU.
8. An algorithm may be specified (instead of explicit signaling by AP) to correctly identify the STA to transmit on unallocated RU for the common-preamble portion.

### **3.3. Embodiment 1.3: No Common-Preamble**

**[0061]** This is the simplest and no-overhead solution to the problem. AP may indicate to STA that no preamble is required as all the information to decode the packet is already available at the AP. In the trigger frame sent to start the transmission the AP may send a flag indicating if we should use a common-preamble or not. This may be especially useful, when AP detects no energy or signal from STA other than it is associated with. This may be an indication of few or no hidden nodes.

**[0062]** In at least one embodiment, the following procedure is used:

1. AP groups STA for the MU-UpLink transmission
2. AP determines whether common-preamble should be used to increase the protection for hidden nodes.
3. AP sends a trigger frame identifying the STA and corresponding RUs. Along with the trigger frame it also sends a bit indicating that STA may or may not send the common-preamble.

4. STA receives this trigger frame. Depending on the indication bit, they either send only HE-preamble or HE-preamble followed by a common-preamble.
5. This procedure may reduce overhead. This may be especially beneficial for smaller packets.

#### **4. Alternative Embodiments from Perspective of Wireless Stations and Access Points**

[0063] It may be noted that embodiments disclosed herein may alternatively be described from a reference point of either a wireless station or an access point.

[0064] FIG. 6D depicts a method performed by a wireless station. In particular, FIG. 6D depicts the method 630. The method 630 comprises a wireless station receiving an uplink resource scheduling message having a resource allocation and an allocated transmission power level (at 632); the wireless station determining a fractional preamble-transmission power level based on the received uplink resource scheduling message (at 634); the wireless station transmitting the preamble at the determined fractional preamble-transmission power level (at 636); and the wireless station transmitting the uplink data at the allocated power level (at 638).

[0065] In some embodiments, at 632, rather than receiving an allocated transmission power level in the resource scheduling message, the access point sends transmission power-level estimation parameters to the wireless station, and the wireless station determines an uplink data transmission power level based on the received transmission power-level estimation parameters. Example transmission power-level estimation parameters may include a target RSSI value and the power level of the access point transmission. The wireless station then determines the allocated transmission power level for the uplink data. A determined preamble transmission fraction may then be applied to determined power level for the uplink data, thus the wireless station transmits the preamble at a fraction of the determined uplink data transmission power level and transmits the uplink data at the determined uplink data transmission power level.

[0066] In one such embodiment, determining the fractional preamble-transmission power level based on the received uplink resource scheduling message comprises determining a number of other wireless stations transmitting and dividing the determined uplink data transmission power

level by the number of other wireless stations. In some embodiments, the number of other wireless stations is an estimation of the number of other wireless stations.

[0067] In one embodiment, determining the fractional preamble-transmission power level comprises determining a ratio of resource units (RUs) allocated to the wireless station to a total of RUs available.

[0068] In one embodiment, determining the fractional transmission-preamble power level comprises determining a ratio of both i) RUs allocated to the wireless station and ii) an unallocated RU to a total of RUs available. In one such embodiment, the unallocated RU is to the left of the RU allocated to the wireless station. In another such embodiment, the unallocated RU is to the right of the RU allocated to the wireless station. In such embodiments, determining the fractional transmission-preamble power level based on the unallocated RU is in response to a field in the uplink resource scheduling message.

[0069] In one embodiment, determining the fractional preamble power level comprises setting the fractional preamble-transmission power level according to a field of the uplink resource scheduling message.

[0070] In one embodiment, the field of the uplink resource scheduling message indicates the fractional preamble-transmission power level is zero.

[0071] In one embodiment, the field of the uplink resource scheduling message indicates the fractional preamble-transmission power level is equal to the determined uplink transmission power level. In one such embodiment, the field of the uplink resource scheduling message is set responsive to an arrival time of a transmission from the wireless station at an access point. In another such embodiment, the field of the uplink resource scheduling message is set responsive to a received power level of a transmission from the wireless station at an access point. In another such embodiment, the field of the uplink resource scheduling message is set responsive to a determined location of the wireless station.

[0072] In one embodiment, the preamble comprises identical L-SIG, R-L-SIG, HE-SIG-A1, and HE-SIG-A2 fields as a second preamble transmitted by a second wireless station transmitting per the resource scheduling message.

[0073] One embodiment takes the form of a wireless station comprising: a wireless-communication interface; a processor; and data storage containing instructions executable by the processor for causing the AP to carry out a set of functions, the set of functions including: the wireless station receiving an uplink resource scheduling message having a resource allocation and the wireless station further receiving transmission power-level estimation parameters; the wireless station determining an uplink data transmission power based on the received transmission power-level estimation parameters; the wireless station determining a fractional preamble-transmission power level based on the received uplink resource scheduling message; the wireless station transmitting the preamble at the determined fractional preamble-transmission power level; and the wireless station transmitting the uplink data at determined uplink data transmission power level.

[0074] Alternatively, some embodiments may be described from the reference point of an access point. One such embodiment takes the form of a method that includes receiving respective indications of presence of uplink (UL) data from respective different wireless stations via respective buffer status report (BSR) frames; scheduling the wireless stations to transmit in the UL according to a UL-transmission schedule using a HE-SIG-B field of a trigger frame, the transmission schedule allocating resource units (RUs) for the respective different wireless stations; receiving identical Physical Layer Convergence Protocol (PLCP) headers from the wireless stations according to the UL-transmission schedule, each identical PLCP header transmitted at a station-specific power, wherein the station-specific power level is based on an RU allocation that is specific to the corresponding wireless station and as a fractional part of a regular PLCP-header power level; and receiving the UL data from the different wireless stations.

[0075] One embodiment takes the form of a method that includes an access point (AP) receiving respective indications of presence of uplink (UL) data from respective different wireless stations via respective buffer status report (BSR) frames; the AP scheduling the wireless stations to transmit in the UL according to a UL-transmission schedule; and the AP receiving identical Physical Layer Convergence Protocol (PLCP) headers from the wireless stations according to the UL-transmission schedule, each identical PLCP header comprising identical L-SIG, R-L-SIG, HE-SIG-A1, and HE-SIG-A2 fields.

[0076] One embodiment takes the form of an AP comprising a wireless-communication interface; a processor; and data storage containing instructions executable by the processor for causing the AP to carry out at least the functions listed in the preceding paragraph.

[0077] In at least one embodiment, the AP receives the respective indications based on AP polling.

[0078] In at least one embodiment, the AP receives the respective indications based on UL MU OFDMA random-access transmission.

[0079] In at least one embodiment, the AP schedules the wireless stations to transmit in the UL according to the UL-transmission schedule using a trigger frame.

[0080] In at least one embodiment, the AP carries out signaling and allocation using an HE-SIG-B field.

[0081] In at least one embodiment, the UL-transmission schedule indicates which resource units (RUs) are allocated to which wireless stations. In at least one such embodiment, each wireless station is allocated at least one RU by the UL-transmission schedule. In at least one other such embodiment, each wireless station transmits its respective identical PLCP header at a station-specific power level. In at least one such embodiment, each station-specific power level is based on an RU allocation that is specific to the corresponding wireless station and as a fractional part of a regular PLCP-header power level.

[0082] In at least one embodiment, each wireless station adjusts its respective transmit power based at least in part on an estimation of a number of wireless stations that will be transmitting, wherein the estimation is based on the UL-transmission schedule.

[0083] In at least one embodiment, at least one RU is unallocated. In at least one such embodiment, a particular one of the wireless stations adjusts its respective transmission power level to account for the at least one unallocated RU. In at least one such embodiment, the particular wireless station is the wireless station that has been allocated an RU to the left of the at least one unallocated RU. In at least one other such embodiment, the particular wireless station is the wireless station that has been allocated an RU to the right of the at least one unallocated RU. In at

least one other such embodiment, the particular wireless station is indicated in an HE-SIG-B field of a trigger frame.

**[0084]** One embodiment takes the form of a method comprising a wireless station transmitting to an access point (AP) an indication of presence of uplink (UL) data via a buffer status report (BSR) frame; the wireless station receiving from the AP a UL-transmission schedule; and the wireless station transmitting to the AP a PLCP header that is identical to a PLCP header transmitted to the AP by at least one other wireless station, each identical PLCP header comprising identical L-SIG, R-L-SIG, HE-SIG-A1, and HE-SIG-A2 fields.

**[0085]** One embodiment takes the form of a wireless station comprising a wireless-communication interface; a processor; and data storage containing instructions executable by the processor for causing the wireless station to carry out at least the functions listed in the preceding paragraph.

**[0086]** In at least one embodiment, the wireless station transmits the indication to the AP responsive to AP polling.

**[0087]** In at least one embodiment, the wireless station transmits the indication to the AP as a UL MU orthogonal frequency division multiple access (OFDMA) random-access transmission.

**[0088]** In at least one embodiment, the wireless station receives the UL-transmission schedule from the AP in a trigger frame.

**[0089]** In at least one embodiment, the UL-transmission schedule indicates which one or more RUs are allocated to the wireless stations.

**[0090]** In at least one embodiment, the wireless terminal computes a station-specific power level, wherein the wireless station transmits its PLCP header at the computed station-specific power level. In at least one such embodiment, the station-specific power level is based on the RU allocation to the wireless station and is computed as a fractional part of a regular PLCP-header power level. In at least one other such embodiment, the station-specific power level is based at least in part on an estimation by the wireless station of a number of wireless stations that will be transmitting, wherein the estimation is based on the UL-transmission schedule.

**[0091]** In at least one embodiment, at least one RU is unallocated, and the station-specific power level is adjusted by the wireless station to account for the at least one unallocated RU. In at least one such embodiment, the wireless station adjusts its station-specific power level responsive to determining that the wireless station has been allocated an RU to the left of the at least one unallocated RU. In at least one other such embodiment, the wireless station adjusts its station-specific power level responsive to determining that the wireless station has been allocated an RU to the right of the at least one unallocated RU. In at least one such embodiment, the wireless station adjusts its station-specific power level responsive to determining that the wireless station has been indicated in an HE-SIG-B field of a trigger frame.

**[0092]** In at least one embodiment, the AP scheduling the wireless stations to transmit in the UL according to a UL-transmission schedule comprises the AP instructing a first subset of the wireless stations to transmit a full-bandwidth region and not a partial-bandwidth region, and further instructing a second subset of the wireless stations to the partial-bandwidth region and not the full-bandwidth region. In at least one such embodiment, the AP selects the first and second subset based at least in part on one or more of arrival time at the AP, received power at the AP, and location in a basic service set (BSS) that includes the AP. In at least one other such embodiment, the AP instructs the first and second subsets of wireless stations in a trigger frame. In at least one such embodiment, the AP uses user-specific flags in an HE-SIG-B field of the trigger frame to instruct the first and second subsets of wireless stations. In at least one embodiment, the AP selects the first and second subset based on lists from the wireless stations of OBSS wireless stations detected by the respective wireless stations.

**[0093]** In at least one embodiment, different wireless stations use respective HE-SIG-A fields that are orthogonalized in one or more domain. In at least one such embodiment, the AP assigns respective orthogonal domains on a per-resource-unit (RU) basis.

**[0094]** One embodiment takes the form of a method comprising a wireless station transmitting in uplink (UL) orthogonal frequency division multiple access (OFDMA) at least in part by: making a full-bandwidth transmission of a PLCP header; and making a partial-bandwidth post-PLCP-header transmission that comprises a high-efficiency (HE) short training field (STF) (HE-STF).

[0095] In at least one embodiment, the partial-bandwidth post-PLCP-header transmission further comprises a HE long training field (LTF) (HE-LTF).

[0096] In at least one embodiment, the partial-bandwidth post-PLCP-header transmission further comprises HE-Data.

[0097] In at least one embodiment, the wireless station receives a bandwidth allocation from an access point (AP), wherein the wireless station makes the partial-bandwidth post-PLCP-header transmission at a power level that is proportionate to the bandwidth allocation with respect to a total-bandwidth allocation.

[0098] In at least one embodiment, making the full-bandwidth transmission of the PLCP header comprises making a power-suppressed full-bandwidth transmission of the PLCP header. In at least one such embodiment, making the power-suppressed full-bandwidth transmission of the PLCP header comprises selecting a transmission power level for transmitting the PLCP header so as to avoid sudden fluctuations in power level in a frame.

## **5. Notes on Embodiments**

[0099] Although the features and elements of the present invention are described in the preferred embodiments in particular combinations, each feature or element can be used alone without the other features and elements of the preferred embodiments or in various combinations with or without other features and elements of the present invention.

[0100] Although the solutions described herein consider 802.11 specific protocols, it is understood that the solutions described herein are not restricted to this scenario and are applicable to other wireless systems as well.

[0101] Although Short Inter-Frame Space (SIFS) is used to indicate various inter-frame spacing in the examples of the designs and procedures, all other inter-frame spacing such as Reduced Inter-Frame Space (RIFS) or other agreed-upon time intervals could be applied in the same solutions.

## CLAIMS

What is claimed is:

1. A method comprising:

a wireless station receiving an uplink resource scheduling message having a resource allocation and further receiving transmission power-level estimation parameters;

the wireless station determining an uplink data transmission power based on the received transmission power-level estimation parameters;

the wireless station determining a fractional preamble-transmission power level based on the received uplink resource scheduling message and the determined uplink data transmission power level;

the wireless station transmitting the preamble at the determined fractional preamble-transmission power level; and

the wireless station transmitting the uplink data at the determined uplink data transmission power level.

2. The method of claim 1, wherein determining the fractional preamble-transmission power level based on the received uplink resource scheduling message comprises determining a number of other wireless stations transmitting and dividing the determined uplink data transmission power level by the number of other wireless stations.

3. The method of any of claims 1-2, wherein the number of other wireless stations is an estimated number of other wireless stations transmitting.

4. The method of any of claims 1-3, wherein determining the fractional preamble-transmission power level comprises determining a ratio of resource units (RUs) allocated to the wireless station to a total of RUs available.

5. The method of any of claims 1-4, wherein the transmission power-level estimation parameters are a target RSSI value at an access point and an actual transmission power level of a transmission from the access point to the wireless station.
6. The method of any of claims 1-5, wherein determining the fractional transmission-preamble power level comprises determining a ratio of both i) RUs allocated to the wireless station and ii) an unallocated RU to a total of RUs available.
7. The method of claim 6, wherein determining the fractional transmission-preamble power level based on the unallocated RU is in response to a field in the uplink resource scheduling message.
8. The method of any of claims 1-7, wherein determining the fractional preamble power level comprises setting the fractional preamble-transmission power level according to a field of the uplink resource scheduling message.
9. The method of claim 8, wherein the field of the uplink resource scheduling message indicates the fractional preamble-transmission power level is zero.
10. The method of claim 8, wherein the field of the uplink resource scheduling message indicates the fractional preamble-transmission power level is equal to the determined data uplink transmission power level.
11. The method of any of claims 8-10, wherein the field of the uplink resource scheduling message is set responsive to an arrival time of a transmission from the wireless station at an access point.
12. The method of any of claims 8-11, wherein the field of the uplink resource scheduling message is set responsive to a received power level of a transmission from the wireless station at an access point.
13. The method of any of claims 8-12, wherein the field of the uplink resource scheduling message is set responsive to a determined location of the wireless station.

14. The method of any of claims 1-13, wherein the preamble comprises identical L-SIG, R-L-SIG, HE-SIG-A1, and HE-SIG-A2 fields as a second preamble transmitted by a second wireless station transmitting per the resource scheduling message.

15. A wireless station comprising:

a wireless-communication interface;

a processor; and

data storage containing instructions executable by the processor for causing the AP to carry out a set of functions, the set of functions including:

a wireless station receiving an uplink resource scheduling message having a resource allocation and receiving transmission power-level estimation parameters;

the wireless station determining an uplink data transmission power based on the received transmission power-level estimation parameters;

the wireless station determining a fractional preamble-transmission power level based on the received uplink resource scheduling message and the determined uplink data transmission power level;

the wireless station transmitting the preamble at the determined fractional preamble-transmission power level; and

the wireless station transmitting the uplink data at the determined uplink data transmission power level.

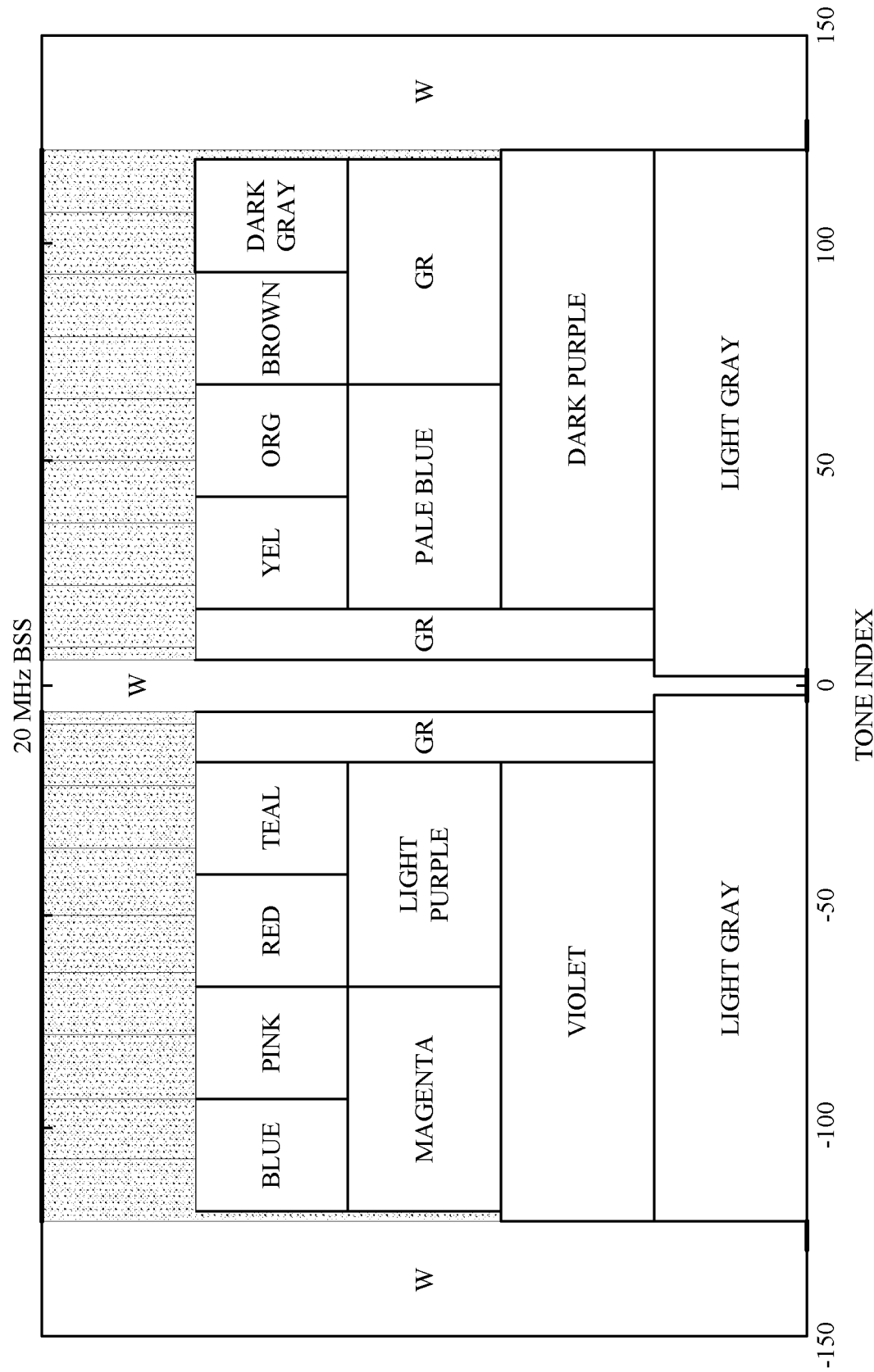


FIG. 1

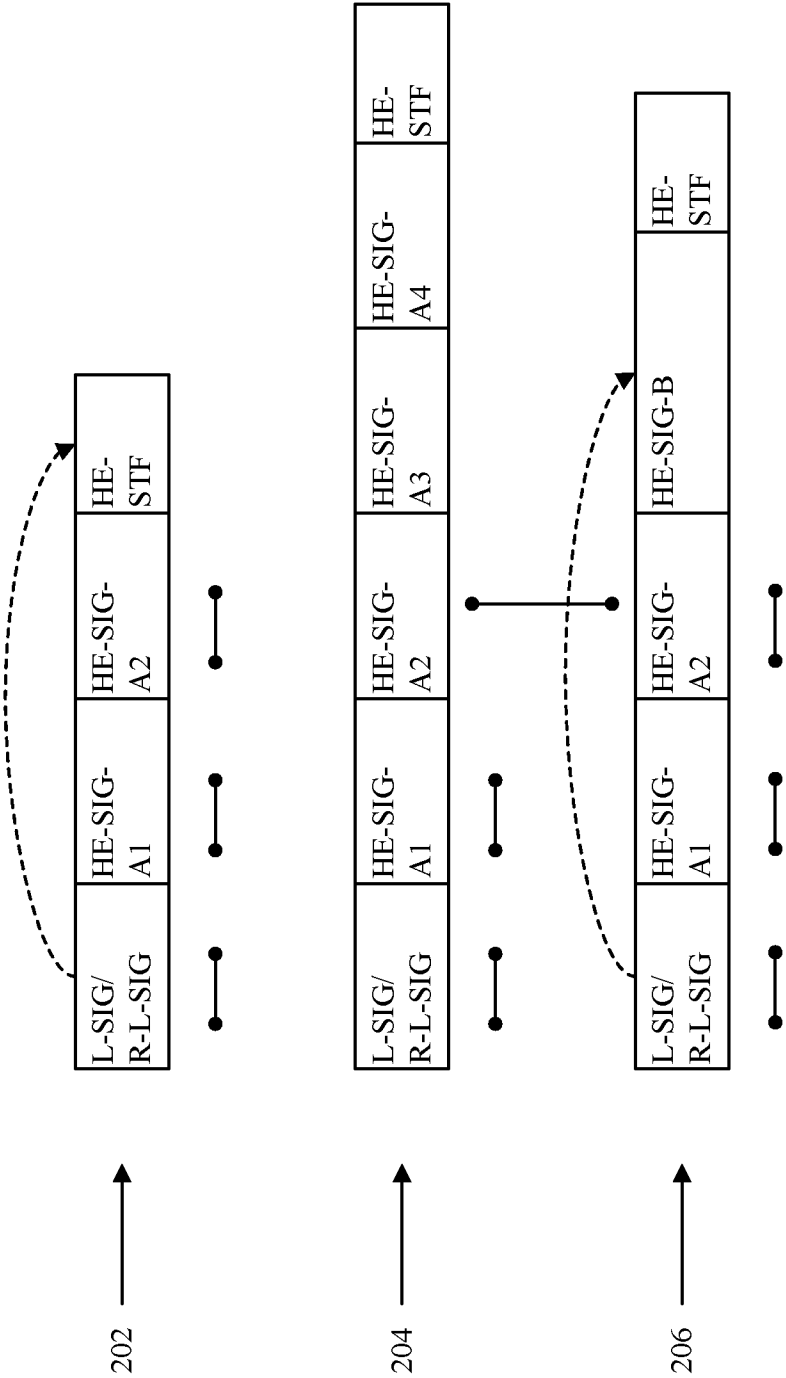


FIG. 2

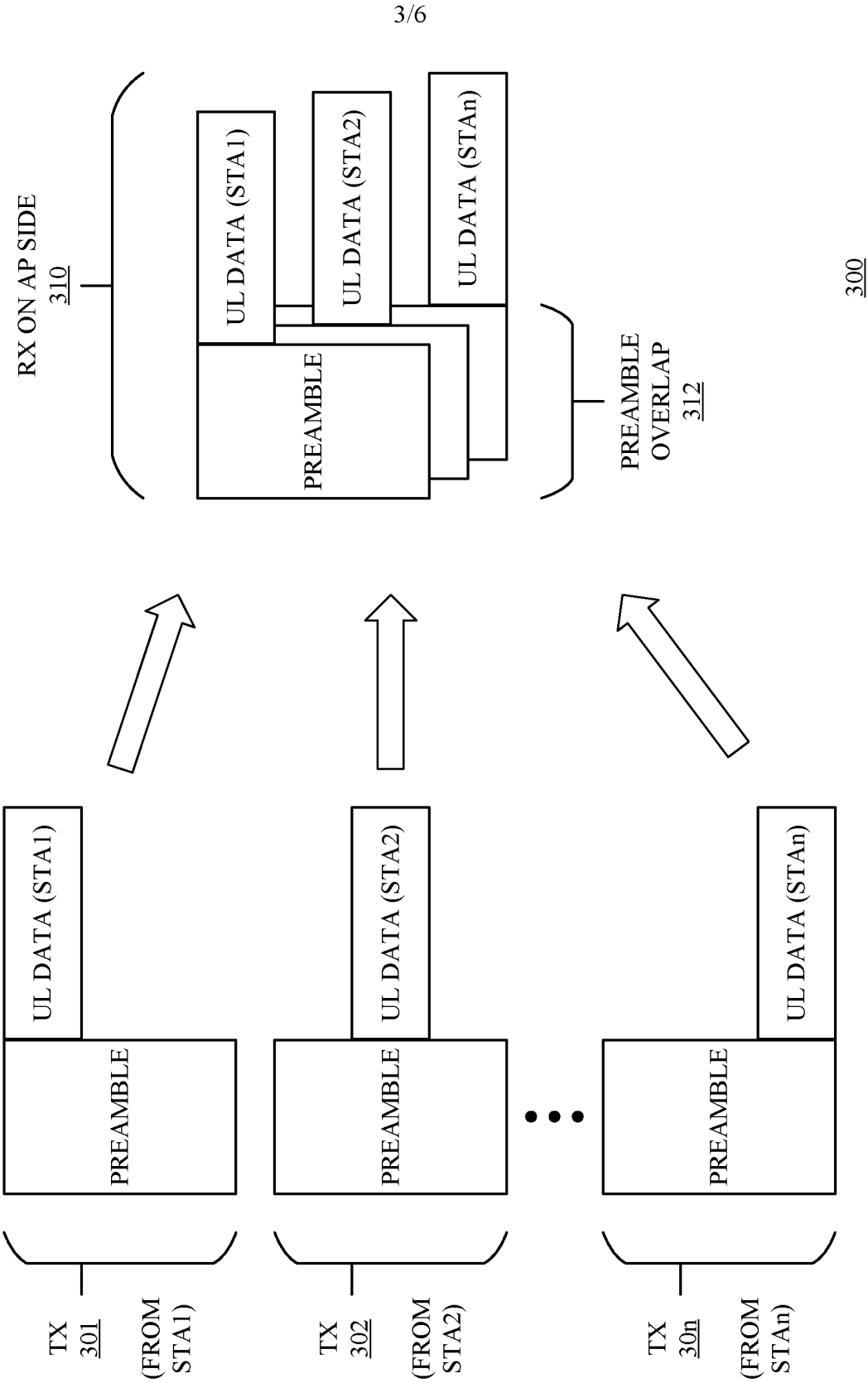


FIG. 3

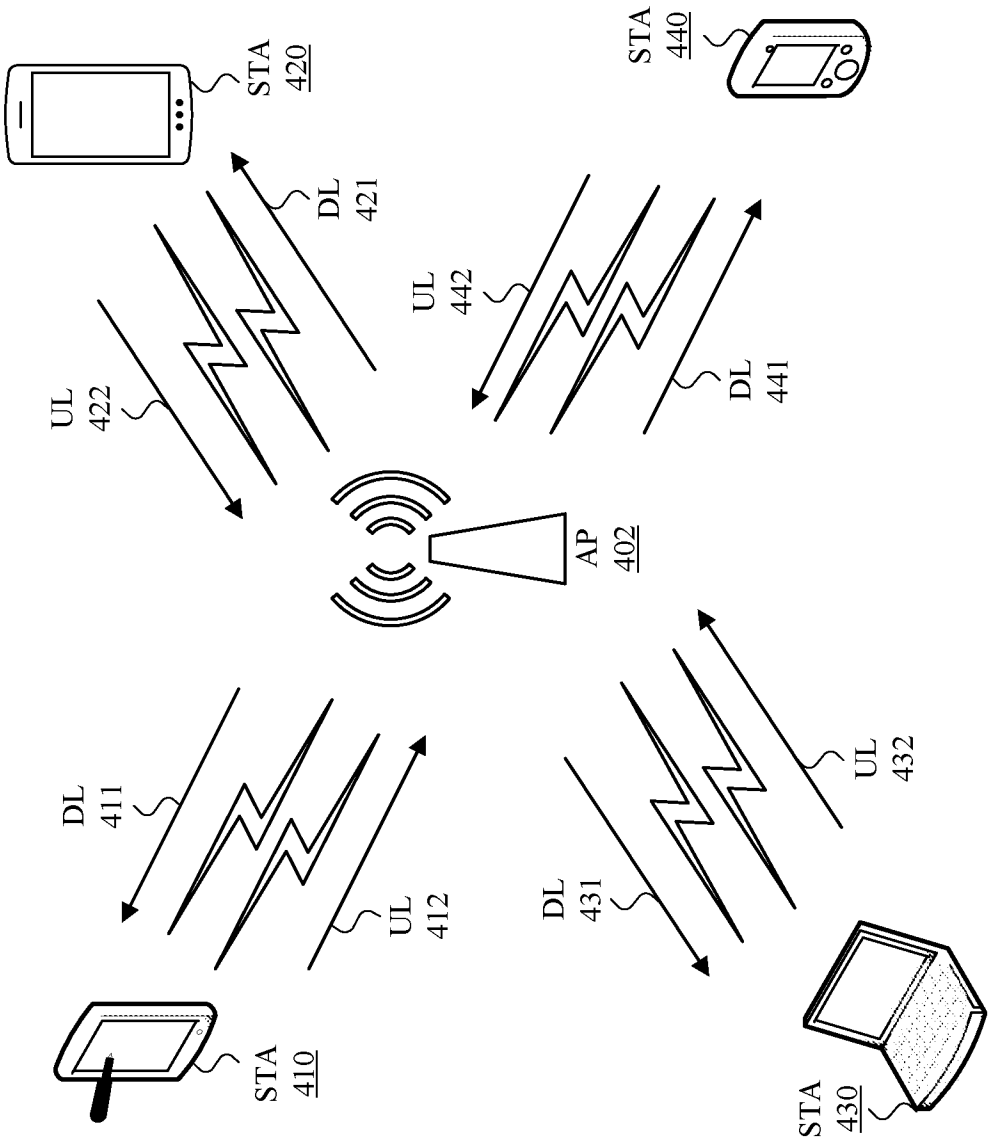


FIG. 4

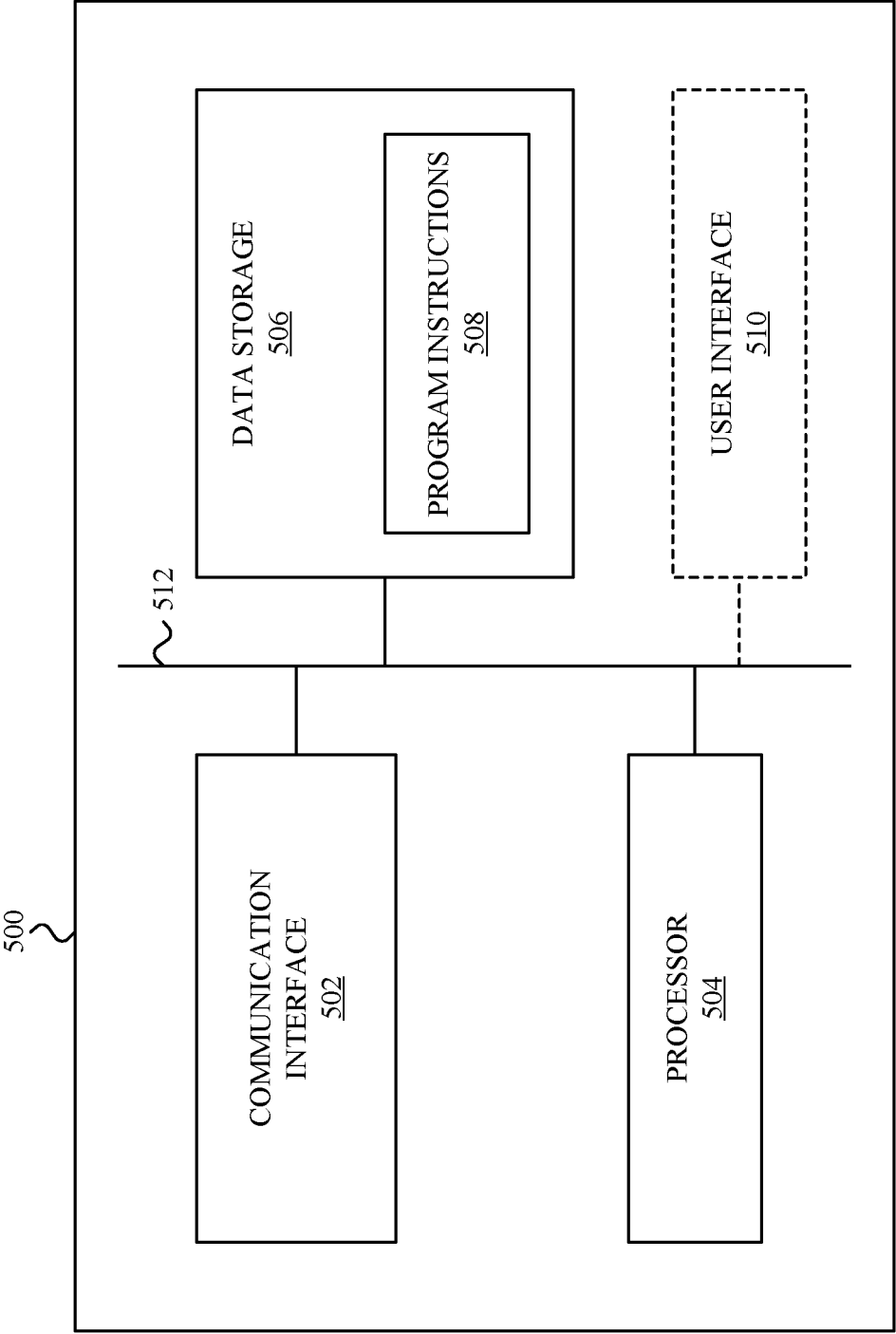
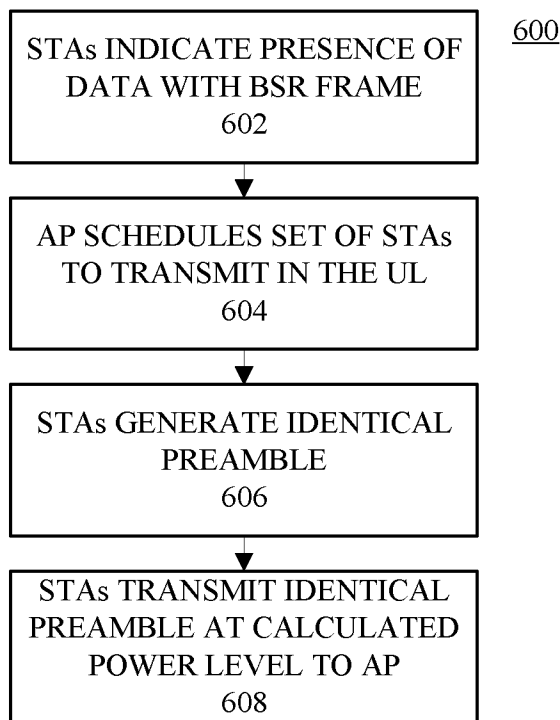
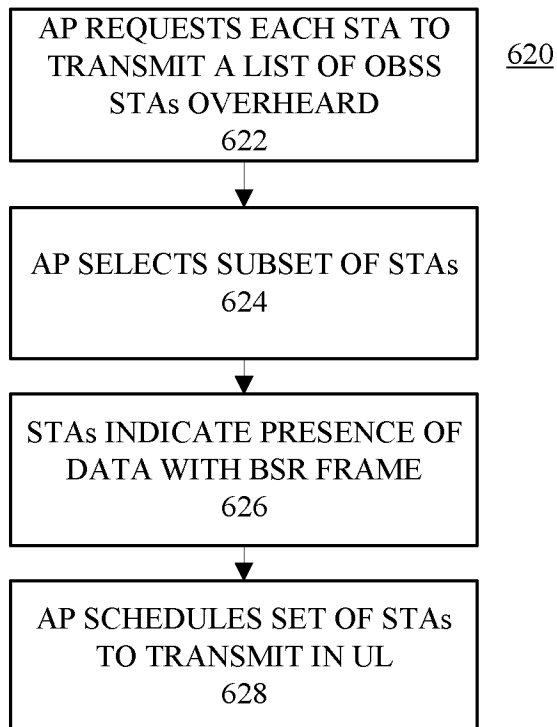
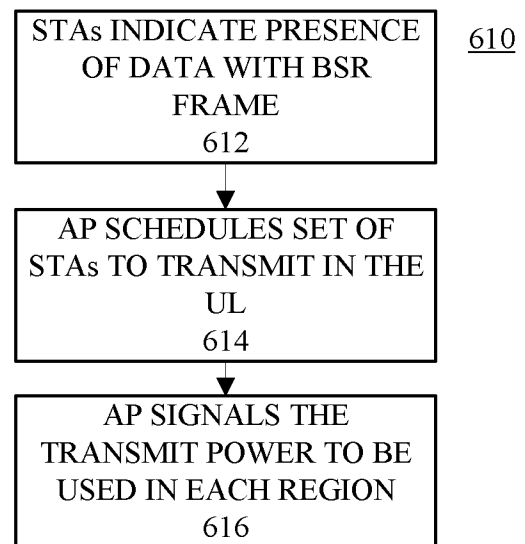
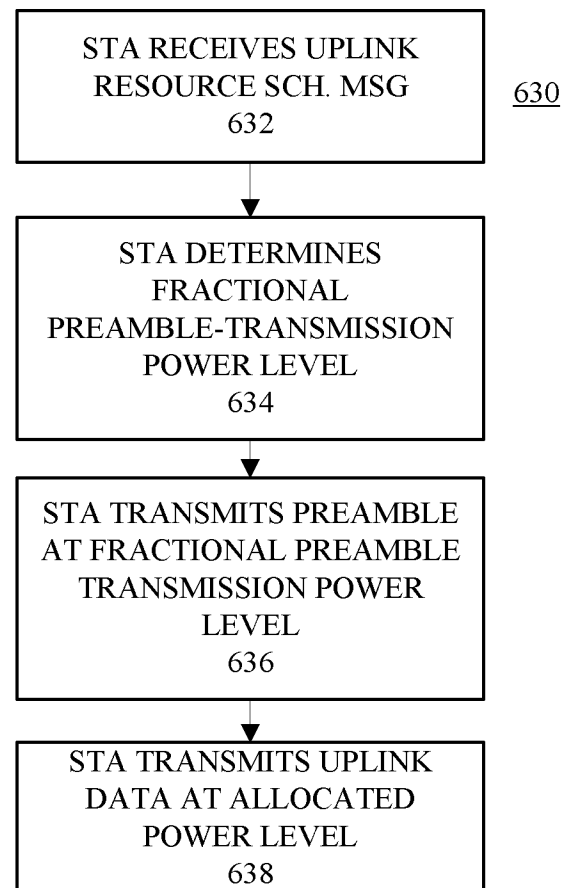


FIG. 5

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**FIG. 6A****FIG. 6C****FIG. 6B****FIG. 6D**

## INTERNATIONAL SEARCH REPORT

International application No  
PCT/US2017/021399

A. CLASSIFICATION OF SUBJECT MATTER  
INV. H04W52/14 H04W52/32 H04W52/34 H04W52/50  
ADD.

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

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
H04W

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

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

EPO-Internal, WPI Data, INSPEC

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

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|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
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Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

22 May 2017

Date of mailing of the international search report

31/05/2017

Name and mailing address of the ISA/

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## INTERNATIONAL SEARCH REPORT

International application No  
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| C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT |                                                                                                                                                                                                                                                                                                                                                                                                                             |                       |
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Information on patent family members

International application No

PCT/US2017/021399

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