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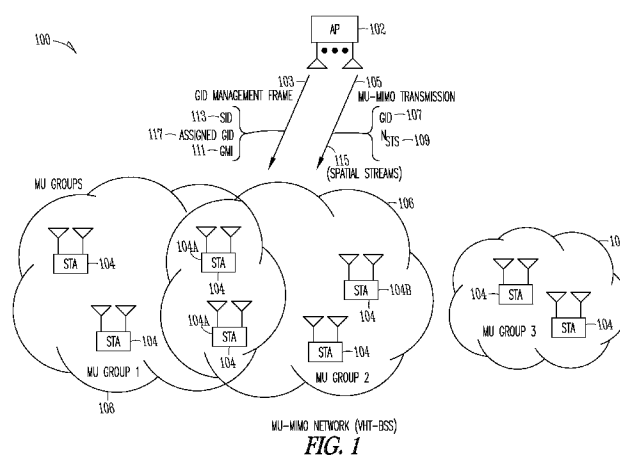


FIG. 1

(57) Abstract: Embodiments of a MU-MIMO access point, user station and method for multi-user group management are generally described herein. In some embodiments, a MU-MIMO access point may assign a MU group identifier (GID) and a group member index (GMI) to each of a plurality of associated user stations. The MU-MIMO access point may transmit a MU-MIMO transmission that includes a plurality of spatial streams. The MU-MIMO transmission may be destined for the user stations of a single MU group indicated by a GID that is included within the MU-MIMO transmission. A subset of the spatial streams may be intended for each user station of the indicated MU group that is identified by the GID transmitted within the MU-MIMO transmission. A user station may use its assigned GMI along with an N_{sts} field in the MU-MIMO transmission to determine which of the spatial streams to demodulate.

MU-MIMO ACCESS POINT AND USER STATION INCLUDING
METHODS FOR MULTI-USER GROUP MANAGEMENT

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PRIORITY CLAIM

[0001] This application claims priority to U.S. Patent Application Serial
No. 12/975,614, filed on December 22, 2010, which is incorporated herein by
10 reference in its entirety.

TECHNICAL FIELD

[0002] Embodiments pertain to wireless communications. Some
15 embodiments relate to multi-user (MU) multiple-input multiple-output (MIMO)
(MU-MIMO) communication techniques. Some embodiments pertain to very-
high throughput (VHT) basic service sets (BSSs) configured to operate in
accordance with an IEEE 802.11 standard, such as the IEEE 802.11ac draft
standard.

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BACKGROUND

[0003] MIMO communication techniques allow for the communication
of more than one spatial data stream. MU-MIMO techniques exploit the
25 availability of multiple independent radio terminals in order to enhance the
communication capabilities of each individual terminal. MU-MIMO techniques
use a space-division multiple access (SDMA) technique to allow a terminal to
transmit to or receive from multiple terminals in the same frequency band
simultaneously.

30 [0004] Since a MU-MIMO transmission can include a limited number of
spatial data streams, one issue with MU-MIMO communications is managing
the various terminals for configuring MU-MIMO transmissions. Thus, there are

general needs for MU-MIMO access points, user stations and methods for managing user stations for MU-MIMO communications.

BRIEF DESCRIPTION OF THE DRAWINGS

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[0005] FIG. 1 illustrates a MU-MIMO network in accordance with some embodiments;

[0006] FIG. 2 is a functional block diagram of a MU-MIMO access point in accordance with some embodiments;

10 [0007] FIG. 3 is a functional block diagram of a user station in accordance with some embodiments;

[0008] FIG. 4 is an illustration of a MU-MIMO transmission in accordance with some embodiments;

[0009] FIG. 5 illustrates MU group identifier (GID) signaling in accordance with some embodiments;

15 [0010] FIG. 6 illustrates a GID management frame with a fixed-length frame format in accordance with some embodiments; and

[0011] FIG. 7 illustrates a GID management frame with a variable-length frame format in accordance with some embodiments.

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DETAILED DESCRIPTION

[0012] The following description and the drawings sufficiently illustrate specific embodiments to enable those skilled in the art to practice them. Other
25 embodiments may incorporate structural, logical, electrical, process, and other changes. Portions and features of some embodiments may be included in, or substituted for, those of other embodiments. Embodiments set forth in the claims encompass all available equivalents of those claims.

[0013] FIG. 1 illustrates a MU-MIMO network 100 in accordance with
30 some embodiments. MU-MIMO network 100 may include a MU-MIMO access point (AP) 102 and a plurality of associated user stations (STA) 104. The access point 102 and at least some of the user stations 104 may be configured for MU-MIMO communications in which the MU-MIMO access point 102 may transmit

MU-MIMO transmissions for reception by the MU-MIMO configured user stations 104.

[0014] In accordance with embodiments, the MU-MIMO access point 102 may manage groups of two or more user stations 104 for MU-MIMO communications in which user stations 104 are assigned to one or more MU groups 106 for receipt of a MU-MIMO transmission 105. These embodiments are described in more detail below.

[0015] In accordance with embodiments, the MU-MIMO access point 102 may assign a MU group identifier (GID) 117 and a group member index (GMI) 111 to each of a plurality of associated user stations 104. Each GID 117 may be assigned to a different MU group 106 of two or more of the associated user stations 104. The assigned GMI 111 may indicate an ordinate position of a user station 104 in an assigned MU group 106. The MU-MIMO access point 102 may also be configured to transmit a MU-MIMO transmission 105 that includes a plurality of spatial streams 115 and one of the assigned GIDs 107. The MU-MIMO transmission 105 may be destined for user stations 104 of a single MU group 106 that is indicated by the GID 107 that is included within the MU-MIMO transmission 105. In these embodiments, a subset (i.e., one or more) of the spatial streams 115 may be intended for each user station 104 of the MU group 106 that is identified by the GID 107 transmitted within the MU-MIMO transmission 105. The GID 107, 117 and the GMI 111 may be integer values.

[0016] The MU-MIMO transmission 105 may be a single transmission (e.g., a single packet such as a PPDU) comprising a plurality of frames that are intended for more than one user station 104. The MU-MIMO transmission 105 may include two or more spatial streams 115. In accordance with embodiments, the GID 107 transmitted within a MU-MIMO transmission 105 may indicate for which MU group 106 of user stations 104 the MU-MIMO transmission 105 is intended. As described in more detail below, a user station's assigned GMI 111 may be used by a user station 104 of the MU group 106 to determine which subset of the spatial streams 115 is intended for the user station 104.

[0017] The MU-MIMO access point 102 may utilize a downlink (DL) SDMA technique to transmit at least the portion of the MU-MIMO transmission 105 that includes the one or more spatial streams 115. In some embodiments, the

MU-MIMO network 100 may be a very-high throughout (VHT) base station service set (BSS) configured to operate in accordance with one of the IEEE 802.11 standards or proposed/draft standards, such as the IEEE 802.11ac proposed/draft standard.

5 **[0018]** In accordance with embodiments, based on the GID 107 received within the MU-MIMO transmission 105, a user station 104 may be configured to determine whether or not it is a member of the MU group to determine if it needs to demodulate one or more of the spatial streams 115 of a received MU-MIMO transmission 105. Based on the GMI 111 previously assigned to the user station
10 104, the user station 104 may further determine which subset of the one or more of the spatial streams 115 in the MU-MIMO transmission 105 to demodulate.

[0019] For example, user station 104B may be assigned a GID value of two and a GMI value of three. In these embodiments, when the user station 104B receives a MU-MIMO transmission 105 that includes a GID value of two, it may
15 determine that the received MU-MIMO transmission 105 is intended for the members of its MU-MIMO group and therefore that one or more of the spatial streams 115 of the MU-MIMO transmission 105 may be demodulated. The user station 104B may use its assigned GMI value of three to determine which subset of the spatial streams 115 in the MU-MIMO transmission 105 to demodulate.

20 These embodiments are described in more detail below.

[0020] In some embodiments, the MU-MIMO access point 102 may be configured to assign one or more GIDs 117 to a single user station 104 or update the one or more GIDs 117 of a single user station 104 by transmitting a GID management frame 103. GID management frame 103 may be intended for a
25 single user station 104 and may include a station ID (SID) 113, one or more assigned GIDs 117, and a GMI 111 for each assigned GID 117. These embodiments are discussed in more detail below.

[0021] In some embodiments, the MU-MIMO access point 102 may also include a number of spatial streams (N_{sts}) field 109 within the MU-MIMO
30 transmission 105. The N_{sts} field 109 may indicate the number of spatial streams 115 (e.g., space-time streams) that a particular user station 104 is to demodulate. A user station 104 may be configured to use the assigned GMI 111 that is associated with the GID 107 of a MU-MIMO transmission 105 to determine

which portion of the N_{sts} field 109 to read. The portion of the N_{sts} field 109 may indicate to the user station 104 which subset of the spatial streams 115 of the MU-MIMO transmission 105 to demodulate.

[0022] In some embodiments, the GMI 111 assigned to a user station 104
5 may indicate the order of the spatial streams 115 to demodulate. For example, a GMI of two may indicate to a user station 104 to demodulate the subset of spatial streams 115 indicated in a second position of the N_{sts} field 109.

[0023] Although FIG. 1 illustrates that MU groups 106 include user
10 stations 104 that are geographically nearer to each other, this is for illustrative purposes only and is not a requirement as user stations 104 selected for a MU group 106 may be geographically dispersed. In accordance with embodiments, user stations 104 need only be separated by an inch or so to be able to receive through different spatial channels.

[0024] FIG. 2 is a functional block diagram of a MU-MIMO access point
15 200 in accordance with some embodiments. The MU-MIMO access point 200 may be suitable for use as MU-MIMO access point 102 (FIG. 1). The MU-MIMO access point 200 may include, among other things, physical-layer (PHY) circuitry 204 for communicating with user stations 104 (FIG. 1) in accordance with MU-MIMO techniques. The MU-MIMO access point 200 may be
20 configured for transmitting a MU-MIMO transmission 105 (FIG. 1) using a plurality of spatially separate antennas 201.

[0025] In accordance with embodiments, the MU-MIMO access point
200 may maintain a MU group assignment table 206 to identify the user stations of each MU group 106 (FIG. 1). In some embodiments, the MU group
25 assignment table 206 may include GIDs 207 that are assigned to each user station 104 and a GMI 211 associated with each assigned GID 207. Table 206 may use a station ID (SID) 205 to identify each user station 104 of an assigned group. The station ID 205 may be a MAC address of the user station 104 although other identifiers may be used to uniquely identify each user station 104
30 that is associated with the MU-MIMO access point 200.

[0026] In some embodiments, the MU-MIMO access point 200 may include an assignment block 208 to select associated user stations 104 for assignment to a MU group 106 and to assign a GID 207 to the user stations 104

of the selected MU group 106. In some embodiments, the station ID 205 may be an association ID or a receiver MAC address, although this is not a requirement.

[0027] In accordance with embodiments, the MU-MIMO access point 200 may select user stations 104 for assignment to one or more MU groups 106 and may assign one GID 207 for each assigned MU group 106. Each MU group 106 of user stations 104 may be assigned a different GID 207. Some user stations, such as user stations 104A, may belong to more than one MU group 106.

[0028] In accordance with some embodiments, the MU-MIMO access point 200 may queue traffic for each MU group 106 of user stations 104 based on the assigned GIDs 207. In these embodiments, the MU-MIMO access point 200 may select one of the GIDs 207 for which traffic has been queued and generate a MU-MIMO transmission 105 for the user stations 104 of the selected GID 207. The MU-MIMO transmission 105 may be configured to include the selected GID 207 and to include the traffic queued for the user stations 104 of the selected GID 207.

[0029] In some embodiments, the MU-MIMO access point 200 may include queue block 210 to queue traffic and select a GID 207 for which traffic is queued. The PHY-layer circuitry 204 may be configured to generate the MU-MIMO transmission 105 for the stations of the selected MU group 106. In some embodiments, the MU-MIMO access point 200 may segregate the traffic queued for the user stations 104 of the selected MU group 106 for transmission within one or more spatial streams 115. The MU-MIMO access point 200 may also include the N_{sts} field 109 (FIG. 1) in the preamble to indicate which subset of the spatial streams of the MU-MIMO transmission 105 each user station 104 of the selected MU group 106 is to demodulate based on each user station's GMI 211.

[0030] In some embodiments, the MU-MIMO access point 200 may select user stations 104 for assignment to a MU group 106 based on channel characteristics. In these embodiments, user stations 104 with similar channel characteristics may be assigned to the same MU group 106. In some embodiments, the MU-MIMO access point 200 may group user stations 104 into MU groups 106 for efficient traffic distribution to multiple users simultaneously with a MU-MIMO transmission. The MU-MIMO access point 200 may group

user stations 104 in various combinations with other stations for increased flexibility in creating MU-MIMO transmissions.

[0031] In some embodiments, the MU-MIMO access point 200 may add user stations 104 to MU groups 106, may remove user stations 104 from MU groups 106, and may delete MU groups 106 as traffic patterns change and as channel characteristics change. These embodiments are described in more detail below.

[0032] As mentioned above, in some embodiments, the MU-MIMO access point 200 may be configured to assign one or more GIDs 207 to a single user station 104 or update the one or more GIDs 207 of a single user station 104 by transmitting a GID management frame 103 (FIG. 1). The GID management frame 103 may include an assignment of one or more GIDs 207 and an assignment of a GMI 211 for each of the one or more assigned GIDs 207 assigned to a particular user station 104. The GID management frame 103 may be a unicast frame that is addressed to the single user station 104. In some embodiments, the GID management frame 103 may include a station identifier, such as an SID 205, indicating which user station 104 that the GID management frame 103 is intended for.

[0033] Accordingly, a single GID management frame 103 may be used to assign more than one GID 207 to a user station 104 (i.e., since a user station 104 may be a member of more than one MU group 106) as well as to assign a GMI 211 for each assigned GID 207. In this way, an individual user station 104 can be added to or deleted from a MU group 106 without affecting the membership of other user stations 104 of the MU group 106.

[0034] In some embodiments, physical-layer circuitry 204 may be an IEEE 802.11ac PHY, such as a WiFi radio, and may be configured for DL SDMA transmissions. Although the term 'access point' has been used to describe MU-MIMO access point 200, the term 'base station' may also be suitable. Although the MU-MIMO access point 200 is illustrated as having several separate functional elements, one or more of the functional elements may be combined and may be implemented by combinations of software-configured elements, such as processing elements including digital signal processors (DSPs), and/or other hardware elements. For example, some elements may

comprise one or more microprocessors, DSPs, application specific integrated circuits (ASICs), radio-frequency integrated circuits (RFICs) and combinations of various hardware and logic circuitry for performing at least the functions described herein. In some embodiments, the functional elements of the MU-

5 MIMO access point 200 may refer to one or more processes operating on one or more processing elements.

[0035] In some embodiments, the MU-MIMO access point 200 may configure the MU-MIMO transmission 105 for transmission over a channel bandwidth comprising a primary access channel having a fixed bandwidth and a
10 secondary channel of variable bandwidth. The primary access channel may have a bandwidth of 20 MHz and the secondary channel may have a bandwidth of up to seven 20 MHz portions of bandwidth to achieve a total or maximum channel bandwidth of up to 160 MHz. The preamble of the MU-MIMO transmission 105 may be transmitted on each 20 MHz portion of the channel bandwidth.

15 [0036] In some embodiments, MU-MIMO access point 200 may utilize a carrier-sense multiple access/collision avoidance (CSMA/CA) protocol for channel access. In these embodiments, the access channel that wins the transmission opportunity (TXOP) may be the primary access channel. In some embodiments, the primary and the secondary channels comprise non-contiguous
20 portions of spectrum. In other embodiments, the primary and the secondary channels comprise contiguous portions of spectrum.

[0037] FIG. 3 is a functional block diagram of a user station 300 in accordance with some embodiments. The user station 300 may be suitable for use as any of the user stations 104 illustrated in FIG. 1. User station 300 may
25 include, among other things, a GID table 302 and physical-layer (PHY) circuitry 304. Physical-layer circuitry 304 may be configured to communicate with a MU-MIMO access point, such as MU-MIMO access point 102 (FIG. 1) and may use a plurality of spatially separated antennas 301. The user station 300 may be configured to maintain the GID table 302 therein to identify each of the one or
30 more assigned GIDs 117 (FIG. 1) as well as to identify a GMI 111 (FIG. 1) associated with each assigned GID 117. In response to receipt of GID management frame 103 (FIG. 1), the user station 300 may update the information in its GID table 302.

[0038] In these embodiments, upon receipt of a MU-MIMO transmission 105 (FIG. 1), the user station 300 may be configured to index the GID 117 received in the MU-MIMO transmission 105 in its GID table 302 to determine whether or not it is a member of the MU group 106 indicated by the value of the GID 117. When the user station 300 is a member of the MU group 106 indicated by the GID 117 received in the MU-MIMO transmission 105, the user station 300 may identify the GMI 111 associated with GID 117 from the GID table 302. Based on the associated GMI 111, the user station 300 may then determine which subset of the one or more of the spatial streams 115 (FIG. 1) to demodulate based on the N_{sts} field 109 (FIG. 1) in the received MU-MIMO transmission 105.

[0039] In this way, the GID table 302 may be used as a look-up-table (LUT) to determine whether or not the user station 300 is a member of a particular MU group and to look up the GMI 111 that is associated with a MU group 106 in which it is a member. Accordingly, the user station 300 can determine whether or not it needs to demodulate a subsequent portion of a MU-MIMO transmission 105 that includes the one or more spatial streams 115. Furthermore, a user station 104 may determine which subset of the spatial streams 115 of the MU-MIMO transmission 105 to demodulate. In this way, the user station 300 does not need to expend the energy by demodulating subsequent portions of MU-MIMO transmission 105 that are not intended for it.

[0040] In some embodiments, the GID 107 and the N_{sts} field 109 are included within a preamble of the MU-MIMO transmission 105 that is configured to be receivable by all of the associated user stations 104. In these embodiments, the N_{sts} field 109 and the GID 107 may both be within the same signaling field, although this is not a requirement.

[0041] Although the user station 300 is illustrated as having several separate functional elements, one or more of the functional elements may be combined and may be implemented by combinations of software-configured elements, such as processing elements including digital signal processors (DSPs), and/or other hardware elements. For example, some elements may comprise one or more microprocessors, DSPs, application specific integrated circuits (ASICs), radio-frequency integrated circuits (RFICs) and combinations

of various hardware and logic circuitry for performing at least the functions described herein. In some embodiments, the functional elements of the user station 300 may refer to one or more processes operating on one or more processing elements.

5 **[0042]** FIG. 4 is an illustration of a MU-MIMO transmission 400 in accordance with some embodiments. The MU-MIMO transmission 400 may be suitable for use as MU-MIMO transmission 105 (FIG. 1). The MU-MIMO transmission 400 may include an initial portion 410 which may comprise its preamble, and a subsequent portion 412 which may include the one or more
10 spatial streams 115. As illustrated in FIG. 4, the preamble of the MU-MIMO transmission 400 may include a VHT signaling field, such as VHT-SIG-A field 406. The GID 107 and the N_{sts} field 109 may be included within the VHT-SIG-A field 406 of the MU-MIMO transmission 400 as shown.

[0043] The MU-MIMO transmission 400 may also include legacy
15 training fields (L-TFs) 402, non-HT signal field (L-SIG) 404, VHT training fields (VHT-TFs) 408, VHT-SIG B fields 414, service fields 415 and data fields 416. Each data field 416 may correspond to one of the spatial streams 115 of the PPDU.

[0044] The MU-MIMO access point 102 (FIG. 1) may be configured to
20 transmit the initial portion 410 that comprises the preamble in non-directional (e.g., substantially omnidirectional) fashion. The access point 102 may be configured to transmit the subsequent portion 412 of the MU-MIMO transmission 400 that includes the plurality of spatial streams 115 in a directional fashion.

25 **[0045]** In these embodiments, the initial portion 410 that includes the VHT-SIG-A field 406 (which includes the GID 107 and the N_{sts} field 109) that is transmitted in the non-directional fashion may be configured to be received by all associated user stations 104 (FIG. 1). The subsequent portion 412 that includes the plurality of spatial streams 115, when transmitted in a directional
30 fashion, may be beamformed or precoded as described in more detail below.

[0046] A user station 104 may be configured to use an assigned GMI 111 (FIG. 1) that is associated with the GID 107 (FIG. 1) of the MU-MIMO transmission 400 (read from the GID table 302 (FIG. 3)) to determine which

portion of the N_{sts} field 109 (FIG. 1) to read. The portion of the N_{sts} field 109 may indicate to the user station 104 which subset of the spatial streams 115 of the MU-MIMO transmission 400 to demodulate. In some embodiments, the user station 104 may be configured to use the assigned GMI 111 to determine which
5 three-bit portion of the N_{sts} field 109 to read.

[0047] In some of these embodiments, the MU-MIMO access point 102 may apply beamforming techniques for the transmission of the subsequent portion 412. Beamforming coefficients for each spatial stream 115 may be based on channel characteristics of the user stations 104 of the MU group 106 that are
10 to receive a particular spatial stream 115. The use of different beamforming coefficients for each spatial stream 115 allows each user station 104 of the MU group 106 to separate the different spatial streams 115 using signal processing techniques.

[0048] In some embodiments, the MU-MIMO access point 102 may
15 precode the subsequent portion 412 using codewords based on a codebook (e.g., a precoding matrix) for beamforming. In these embodiments, channel estimation may be performed based on pilot signals transmitted by the MU-MIMO access point 102. Based on the channel information, a codeword that results in the maximum signal-noise-ratio (SNR) and a channel quality indicator (CQI) value
20 corresponding to the codeword may be determined by a user station 104. The codeword and CQI may be fed back to the MU-MIMO access point 102 and the MU-MIMO access point 102 may configure the MU-MIMO transmission 400 for the user stations 104 of a selected MU group 106 based on the codewords and the CQI values. In some embodiments, the MU-MIMO transmission 400
25 may be configured based on the codewords and the CQI values so that a predetermined performance metric of the system is achieved or maximized. In these embodiments, at least the subsequent portion 412 of the MU-MIMO transmission 400 may be transmitted with a plurality of spatially separate antennas 201 (FIG. 2).

30 [0049] In some embodiments, a user station, such as user station 300 (FIG. 3), may refrain from demodulating the subsequent portion 412 of the MU-MIMO transmission 400 when the GID 107 included in the MU-MIMO transmission 400 is not assigned to the user station 300 that receives the MU-

MIMO transmission 400. In these embodiments, the MU-MIMO transmission 400 may be discarded since it was not intended for that particular user station 300.

5 **[0050]** In some embodiments, the MU-MIMO access point 102 may create a unique MU group 106 for each possible combination of user stations 104. This may result in a large number of MU groups 106 and a large GID table 302 when there is a high number of user stations 104 associated with the MU-MIMO access point 102 (i.e., because each user station 104 would be included in many MU groups 106).

10 **[0051]** In other embodiments, multiple combinations of user stations 104 may use the same GID to reduce the size of the GID table 302. When multiple user station combinations use the same GID, user stations 104 receiving a MU-MIMO transmission 400 may end up demodulating spatial streams 115 that are not intended for that user station 104. These frames may be discarded. These
15 embodiments that use many multiple user-station combinations may provide a trade-off between slightly increased power consumption for a reduction in the size of the GID table 302. In some embodiments, a MU group 106 may include a single user station 104.

20 **[0052]** In accordance with embodiments, the number of spatial streams 115 that may be included in the MU-MIMO transmission 400 may depend on, among other things, the number of antennas 201 (FIG. 2) used by the MU-MIMO access point 102 for transmitting the MU-MIMO transmission 400. For example, when eight antennas 201 are used, up to eight spatial streams 115 may be transmitted.

25 **[0053]** In some embodiments, the MU-MIMO transmission 400 may include a channel bandwidth parameter 418 to indicate the channel bandwidth used, a space-time block coding parameter 420, and a modulation and coding parameter (not separately illustrated) to indicate a modulation and coding scheme of subsequent portions of the MU-MIMO transmission 400 as
30 transmitted over the channel bandwidth. In some embodiments, the MU-MIMO transmission 400 may indicate which 20 MHz portions of the spectrum comprise the channel bandwidth of the MU-MIMO transmission 400.

[0054] FIG. 5 illustrates MU-GID signaling in accordance with some embodiments. An access point 502 may correspond to MU-MIMO access point 102 (FIG. 1) and user station (STA) 504 may correspond to one of user stations 104 (FIG. 1). As described above, the access point 502 may transmit a GID management frame 503 to assign one or more GIDs 117 (FIG. 1) to user station 504 or update the one or more GIDs 117 of the user station 504. GID management frame 503 may correspond to GID management frame 103 (FIG. 1). After transmitting the GID management frame 503 to the user station 504, the access point 502 may be configured to delay transmitting of a MU-MIMO transmission 505 that includes a GID 107 (FIG. 1) that was assigned or updated by the GID management frame 503.

[0055] In these embodiments, the MU-MIMO transmission 505 that is delayed includes the GID that was assigned to user station 504 (i.e., that had one of its GIDs assigned or updated). This delay may be used to accommodate any processing delay of user station 504 associated with, for example, decrypting the GID management frame 503 and installing updates to the GID table 302 (FIG. 3).

[0056] In some embodiments, the delay may be a MU group addition delay 507 and may follow the receipt of an acknowledgement (ACK) 506 from the user station 504. The ACK 506 may be transmitted by the user station 504 to acknowledge receipt of the GID management frame 503. In some embodiments, MU group addition delay 507 may be a fixed or predetermined amount. In other embodiments, the MU group addition delay 507 may be determined based on delay amounts provided by user stations 104 associated with the MU-MIMO access point 102 (e.g., when a user station 504 joins the VHT BSS).

[0057] In some embodiments, each user station 104 may provide a delay amount associated with installing or updating its GID table 302. The provided delay amount may be an upper bound on a station's processing delay. The access point 502 may utilize a greatest of these delay amounts (i.e., from the user station with the greatest delay) as the MU group addition delay 507. In some embodiments, the delay amount may be provided by a user station 104 during association in a field of an association request frame, although this is not a requirement.

[0058] In some alternate embodiments, as illustrated in FIG. 5, after transmitting the GID management frame 503 to the user station 504, the access point 502 may delay transmitting the MU-MIMO transmission 505 until receipt of a GID assignment confirmation frame 508 from the user station 504 for which the GID management frame 503 was intended. In these embodiments, user stations 104 may be configured to transmit a GID assignment confirmation frame 508 to the MU-MIMO access point 502 when a user station 504 has successfully installed or updated its GID table 302 based on the received GID management frame 503.

10 [0059] In some embodiments, the access point 502 may update entries for a particular user station 104 listed in its MU group assignment table 206 (FIG. 2) after transmitting the GID management frame 503. The access point 502 may wait until an ACK 506 is received from the user station 504 before transmitting the MU-MIMO transmission 505 to the user station 504 using the updated table 206 to ensure that the user station 504 received the GID management frame 503. In some alternate embodiments, the access point 502 may wait until a GID assignment confirmation frame 508 is received from the user station 504 before transmitting the MU-MIMO transmission 505 using the updated table 206 to ensure that the user station 504 has installed or updated its GID table 302.

[0060] In some embodiments, the access point 502 may wait until the ACK 506 is received from the user station 504 before the access point 502 updates its table 206. In some embodiments, the access point 502 may wait until a GID assignment confirmation frame 508 is received from the user station 504 before the access point 502 updates its table 206.

[0061] FIG. 6 illustrates a GID management frame 603 with a fixed-length frame format 600 in accordance with some embodiments. GID management frame 603 may be suitable for use as GID management frame 103 (FIG. 1) and may have a fixed-length frame format 600. In these embodiments, the GID management frame 603 may be configured to provide a full-table update to a user station's GID table 302 (FIG. 3). In these embodiments, the GID management frame 603 may include a membership bitmap field 602 and a GMI lookup table field 604. The membership bitmap field 602 may comprise a bitmap

in which each bit of the bitmap represents whether or not the user station 300 (FIG. 3) is a member of a corresponding MU group. The position of each bit of the bitmap of the membership bitmap field 602 may be indexed by the GID. The GMI lookup table field 604 may indicate the GMI for the user station 300 for an associated GID (i.e., for a corresponding MU group).

[0062] In the bitmap of the membership bitmap field 602, a bit that is set to one may indicate that the user station 300 is a member of the group indicated by the position of the bit. For each bit that is set to one in the membership bitmap field 602, the corresponding bit in the GMI lookup table field 604 indicates the GMI value for the associated GID. In response to receipt of the GID management frame 603, the user station 300 may update its GID table 302 (FIG. 3) based on the information in the membership bitmap field 602 and the corresponding information in the GMI lookup table field 604.

[0063] For example, the bit that is set to one in the fourth position of the membership bitmap field 602 (as shown in FIG. 6) indicates that the user station 300 (for which the GID management frame 603 is intended) is assigned to be a member of the fourth MU group (i.e., GID = 4). The corresponding GMI of two in the GMI lookup table field 604 indicates that the user station 300 should look at the second portion of the N_{sts} field 109 (e.g., B16 to B18 of the VHT-SIG-A field 406 (FIG. 4)) for the number and order of the spatial streams 115 (FIG. 1) to demodulate. Each two bits of the GMI lookup table field 604 may indicate the GMI of the user station for a corresponding MU group. In this way, the user station 300 can determine which subset of the spatial streams 115 to demodulate based on a portion of the N_{sts} field 109.

[0064] In some embodiments, the membership bitmap field 602 may be eight octets long and the GMI lookup table field 604 may be sixteen octets long, although this is not a requirement. There may be sixty-four GID management fields, each of which contains one bit to indicate the membership status of a user station in the corresponding MU group and two bits to indicate the group member index (GMI) of a station in the corresponding MU group.

[0065] FIG. 7 illustrates a GID management frame 703 with a variable-length frame format 700 in accordance with some embodiments. GID management frame 703 may be suitable for use as GID management frame 103

(FIG. 1) and may have a variable-length frame format 700. In these embodiments, a GID management frame 703, when configured in accordance with the variable-length frame format 700, may provide additions, deletions or changes to a user station's GID table 302 (FIG. 3). In response to receipt of the
5 GID management frame 703, the user station 300 (FIG. 3) may update its GID table 302.

[0066] In these variable-length frame format embodiments, the GID management frame 703 may include a field 702 to indicate the number of entries to be added to the GID table 302 followed by one or more fields 704 to indicate
10 which entries are to be added (e.g., one octet per entry). In these embodiments, the GID management frame 703 may also include a field 706 to indicate the number of entries to be deleted followed by a number of fields 708 to indicate which entries are to be deleted (e.g., one octet per entry). In these variable-length frame format embodiments, each add entry element of field 704 may include a
15 GID 710 of the MU group to which the user station 300 is being added or for which the station's GMI is being changed as well as the new GMI 712 associated with that GID 710. Each delete entry element of field 708 may include the GID of the MU group from which the user station 300 is being removed.

20 [0067] Embodiments may be implemented in one or a combination of hardware, firmware and software. Embodiments may also be implemented as instructions stored on a computer-readable storage device, which may be read and executed by at least one processor to perform the operations described herein. A computer-readable storage device may include any non-transitory
25 mechanism for storing information in a form readable by a machine (e.g., a computer). For example, a computer-readable storage device may include read-only memory (ROM), random-access memory (RAM), magnetic disk storage media, optical storage media, flash-memory devices, and other storage devices and media. In some embodiments, the machine may include one or more
30 processors and may be configured with instructions stored on a computer-readable storage device.

[0068] The Abstract is provided to comply with 37 C.F.R. Section 1.72(b) requiring an abstract that will allow the reader to ascertain the nature and

gist of the technical disclosure. It is submitted with the understanding that it will not be used to limit or interpret the scope or meaning of the claims. The following claims are hereby incorporated into the detailed description, with each claim standing on its own as a separate embodiment.

5

CLAIMS

What is claimed is:

- 5 1. A MU-MIMO access point configured to:
assign a multi-user (MU) group identifier (GID) and a group member
index (GMI) to each of a plurality of associated user stations, each GID being
assigned to a different MU group of two or more of the associated user stations,
the assigned GMI indicating a user station's ordinate position in an assigned MU
10 group; and
transmit a MU-MIMO transmission that includes a plurality of spatial
streams and one of the assigned GIDs,
wherein a subset of the spatial streams is intended for each user station of
the MU group that is identified by the GID transmitted within the MU-MIMO
15 transmission.
2. The access point of claim 1 wherein based on the GID transmitted
within the MU-MIMO transmission, a user station is configured to determine
whether or not to demodulate one or more of the spatial streams of the MU-
20 MIMO transmission, and
wherein based on the GMI previously assigned to the user station, the
user station is configured to determine which subset of the one or more of the
spatial streams in the MU-MIMO transmission to demodulate.
- 25 3. The access point of claim 2 further configured to include a number of
spatial streams (N_{sts}) field within the MU-MIMO transmission, the N_{sts} field
indicating a number of the spatial streams that each user station is to demodulate,
wherein the user station is configured to use an assigned GMI that is
associated with the GID of the MU-MIMO transmission to determine which
30 portion of the N_{sts} field to read,
wherein a portion of the N_{sts} field indicates to the user station which
subset of the spatial streams of the MU-MIMO transmission to demodulate, and

wherein the GID and the N_{sts} field are included within a preamble of the MU-MIMO transmission that is configured to be receivable by the associated user stations.

5 4. The access point of claim 3 wherein each of the associated user stations are configured to maintain a GID table therein to identify each of the one or more assigned GIDs and to identify a GMI associated with each assigned GID.

10 5. The access point of claim 3 wherein the preamble of a MU-MIMO transmission includes a very-high-throughput signaling-A (VHT-SIG-A) field, and
 wherein the GID and the N_{sts} field are included within the VHT-SIG-A field.

15 6. The access point of claim 3 wherein the access point is configured to transmit an initial portion that includes the preamble in non-directional fashion, and
 wherein a subsequent portion of the MU-MIMO transmission that
20 includes the plurality of spatial streams is transmitted in a directional fashion.

 7. The access point of claim 1 further configured to assign one or more GIDs to a single user station by transmitting a GID management frame to the single user station,

25 wherein the GID management frame includes an assignment of one or more GIDs and an assignment of a GMI for each of the one or more assigned GIDs, and

 wherein the GID management frame is a unicast frame that is addressed to the single user station.

30 8. The access point of claim 7 wherein after transmitting the GID management frame to a user station, the access point is configured to delay

transmitting of a MU-MIMO transmission that includes a GID that was assigned or updated by the GID management frame.

9. The access point of claim 7 wherein after transmitting the GID management frame to a user station, the access point is configured to delay transmitting a MU-MIMO transmission until receipt of a GID assignment confirmation frame from the user station.

10. The access point of claim 7 further configured to configure the GID management frame to have a fixed-length frame format,
wherein the GID management frame having the fixed-length frame format is configured to provide a full-table update to a user station's GID table,
wherein the GID management frame is configured to include a membership bitmap field and a GMI lookup table field,
wherein the membership bitmap field comprises a bitmap wherein each bit of the bitmap represents whether the user station is a member of a corresponding MU group,
wherein a position of each bit of the bitmap is indexed by the GID, and
wherein the GMI lookup table field indicates the GMI for the user station for an associated GID.

11. The access point of claim 7 further configures the GID management frame to have a variable-length frame format,
wherein the GID management frame, when configured in accordance with the variable-length frame format, is configured to provide additions, deletions or changes to a user station's GID table.

12. The access point of claim 7 further configured to select user stations for assignment to one or more of the MU groups,
wherein the user stations are selected for assignment to a MU group based on at least one of channel characteristics or efficient traffic distribution.

13. The access point of claim 7 wherein the access point is further configured to:

- 5 maintain a MU group assignment table;
 queue traffic for MU groups of user stations;
 select one MU group for which two or more user stations that are
members of the group have queued traffic; and
 generate a MU-MIMO transmission for the user stations of the selected
10 MU group,
 wherein the MU-MIMO transmission is configured to include the GID of
the selected MU group and to include the traffic queued for the user stations of
the selected MU group.

- 15 14. A user station for reception of multi-user (MU) multiple-input
multiple-output (MIMO) transmissions, configured to:
 receive a group identifier (GID) management frame from an access point
assigning the user station to one or more multi-user (MU) groups, each group
identified by a group identifier (GID) and assigning the user station a group
20 member index (GMI) for each assigned MU group, the assigned GMI indicating
the user station's ordinate position in the assigned MU group;
 receive a MU-MIMO transmission that includes a plurality of spatial
streams and a GID; and
 determine whether or not to demodulate one or more of the spatial
25 streams of the MU-MIMO transmission based on the GID received within the
MU-MIMO transmission.

15. The user station of claim 14 wherein when the user station determines
to demodulate one or more of the spatial streams, the user station further
30 configured to determine which subset of the one or more of the spatial streams in
the MU-MIMO transmission to demodulate based on the GMI assigned to the
user station associated with the GID within the MU-MIMO transmission.

16. The user station of claim 15 further configured to update a GID table based on the GID management frame.

wherein the GID table includes a GID for each MU group that the user station is a member of, and a GMI for each GID.

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17. The user station of claim 16 wherein the MU-MIMO transmission includes a number of spatial streams (N_{sts}) field, the N_{sts} field indicating a number of the spatial streams that the user station is to demodulate,

wherein the user station is configured to use an assigned GMI that is associated with the GID of the MU-MIMO transmission to determine which portion of the N_{sts} field to read,

wherein the portion of the N_{sts} field indicates to the user station which subset of the spatial streams of the MU-MIMO transmission to demodulate.

18. A very-high throughput (VHT) basic service set (BSS) comprising a multi-user (MU) multiple-input multiple-output (MIMO) access point and a plurality of associated user stations, wherein the MU-MIMO access point is configured to:

assign a user station to one or more MU groups, each MU group identified by a group identifier (GID);

assign the user station a group member index (GMI) for each MU group of which the user station is a member and where the assigned GMI indicates the user station's ordinate position in the MU group; and

transmit a MU-MIMO transmission that includes a plurality of spatial streams and one of the assigned GIDs,

wherein a subset of the spatial streams is intended for each user station of the MU group that is identified by the GID transmitted within the MU-MIMO transmission.

19. The VHT-BSS of claim 18 wherein based on the GID transmitted within the MU-MIMO transmission, each user station is configured to determine whether or not to demodulate one or more of the spatial streams of the MU-MIMO transmission, and

wherein when a user station determines to demodulate one or more of the spatial streams, the user station is configured to determine which subset of the one or more of the spatial streams in the MU-MIMO transmission to demodulate based on the GMI.

5

20. The VHT-BSS of claim 19 wherein the access point configures the MU-MIMO transmission for transmission over a channel bandwidth comprising a primary channel having a fixed bandwidth and a secondary channel of variable bandwidth,

10 wherein the primary channel has a bandwidth of a 20 MHz and the secondary channel has a bandwidth of up to seven 20 MHz portions to achieve a total channel bandwidth of up to 160 MHz, and

wherein a preamble of the MU-MIMO transmission that includes the GID and the GMI is transmitted on each 20 MHz portion of the channel

15 bandwidth.

21. The VHT-BSS of claim 19 wherein the access point is configured to assign one or more GIDs to a single user station by transmitting a GID management frame to the single user station,

20 wherein the GID management frame includes an assignment of one or more GIDs and an assignment of a GMI for each of the one or more assigned GIDs, and

wherein the GID management frame is a unicast frame that is addressed to the single user station.

25

22. A method performed by a multi-user (MU) multiple-input multiple-output (MIMO) access point, the method comprising:

assigning a multi-user (MU) group identifier (GID) and a group member index (GMI) to each of a plurality of associated user stations, each GID being
30 assigned to a different MU group of two or more of the associated user stations, the assigned GMI indicating a user station's ordinate position in an assigned MU group; and

transmitting a MU-MIMO transmission that includes a plurality of spatial streams and one of the assigned GIDs,

wherein a subset of the spatial streams is intended for each user station of the MU group that is identified by the GID transmitted within the MU-MIMO transmission.

23. The method of claim 22 wherein based on the GID transmitted within the MU-MIMO transmission, a user station is configured to determine whether or not to demodulate one or more of the spatial streams of the MU-MIMO transmission, and

wherein based on the GMI previously assigned to the user station, the user station is configured to determine which subset of the one or more of the spatial streams in the MU-MIMO transmission to demodulate.

24. The method of claim 23 further comprising including a number of spatial streams (N_{sts}) field within the MU-MIMO transmission, the N_{sts} field indicating a number of the spatial streams that the user station is to demodulate, wherein the user station is configured to use an assigned GMI that is associated with the GID of the MU-MIMO transmission to determine which portion of the N_{sts} field to read,

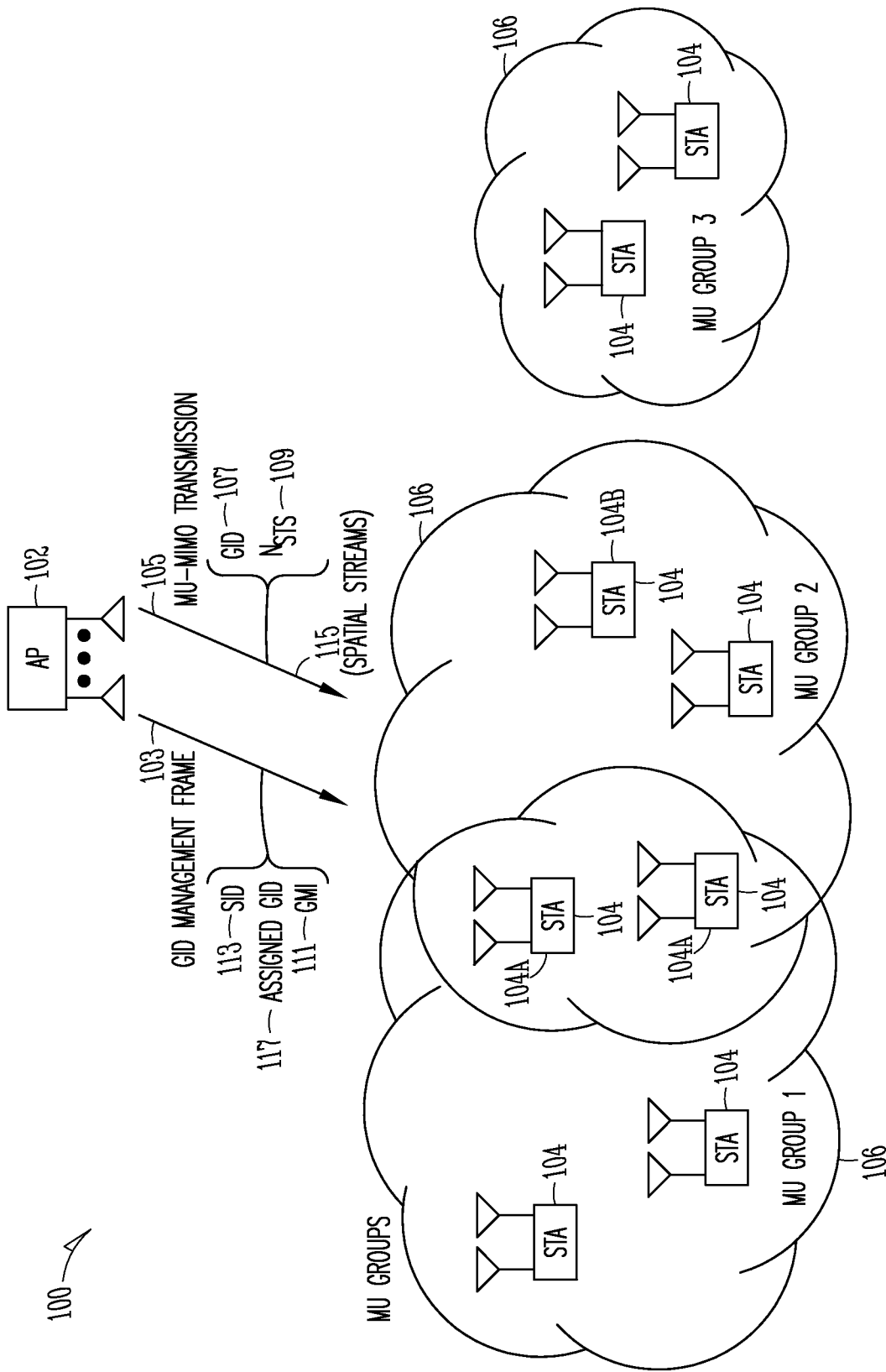
wherein the portion of the N_{sts} field indicates to the user station which subset of the spatial streams of the MU-MIMO transmission to demodulate, and

wherein the GID and the N_{sts} field are included within a preamble of the MU-MIMO transmission that is configured to be receivable by the associated user stations.

25. The method of claim 24 further comprising assigning one or more GIDs to a single user station by transmitting a GID management frame to the single user station,

wherein the GID management frame includes an assignment of one or more GIDs and an assignment of a GMI for each of the one or more assigned GIDs, and

wherein the GID management frame is a unicast frame that is addressed to the single user station.



MU-MIMO NETWORK (VHT-BSS)

FIG. 1

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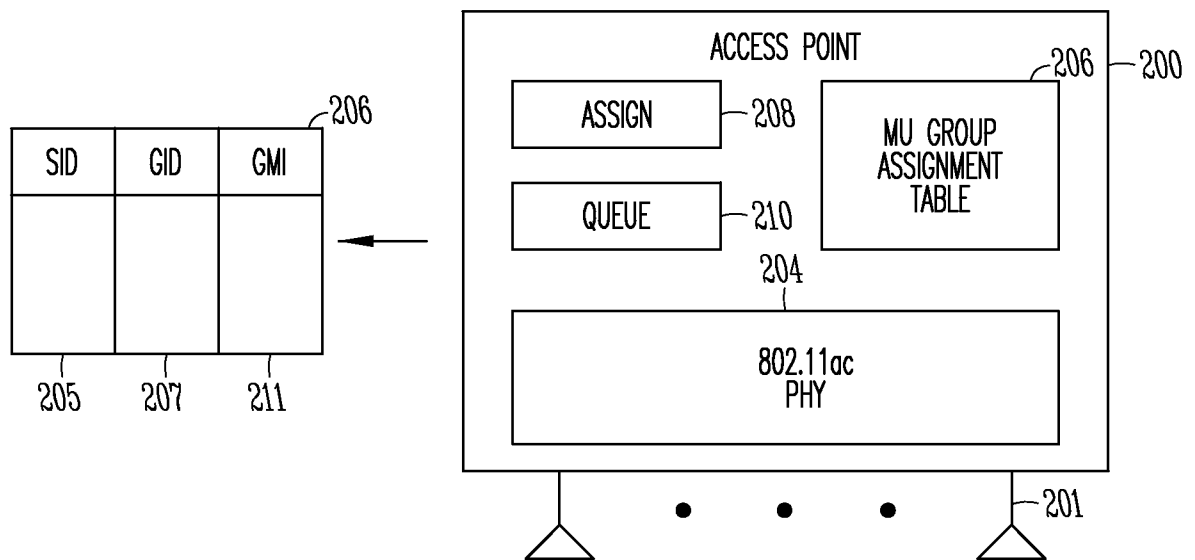


FIG. 2

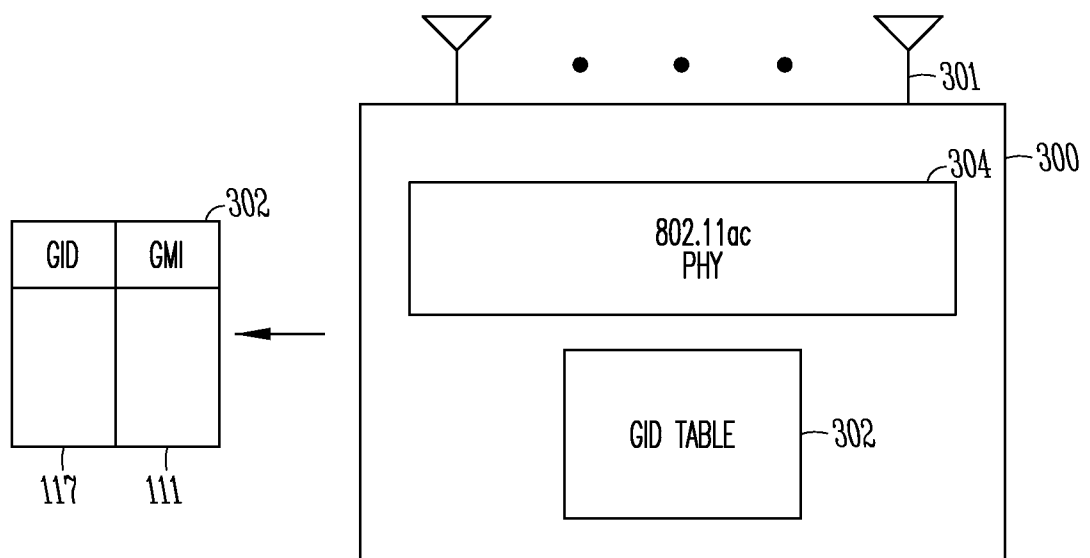
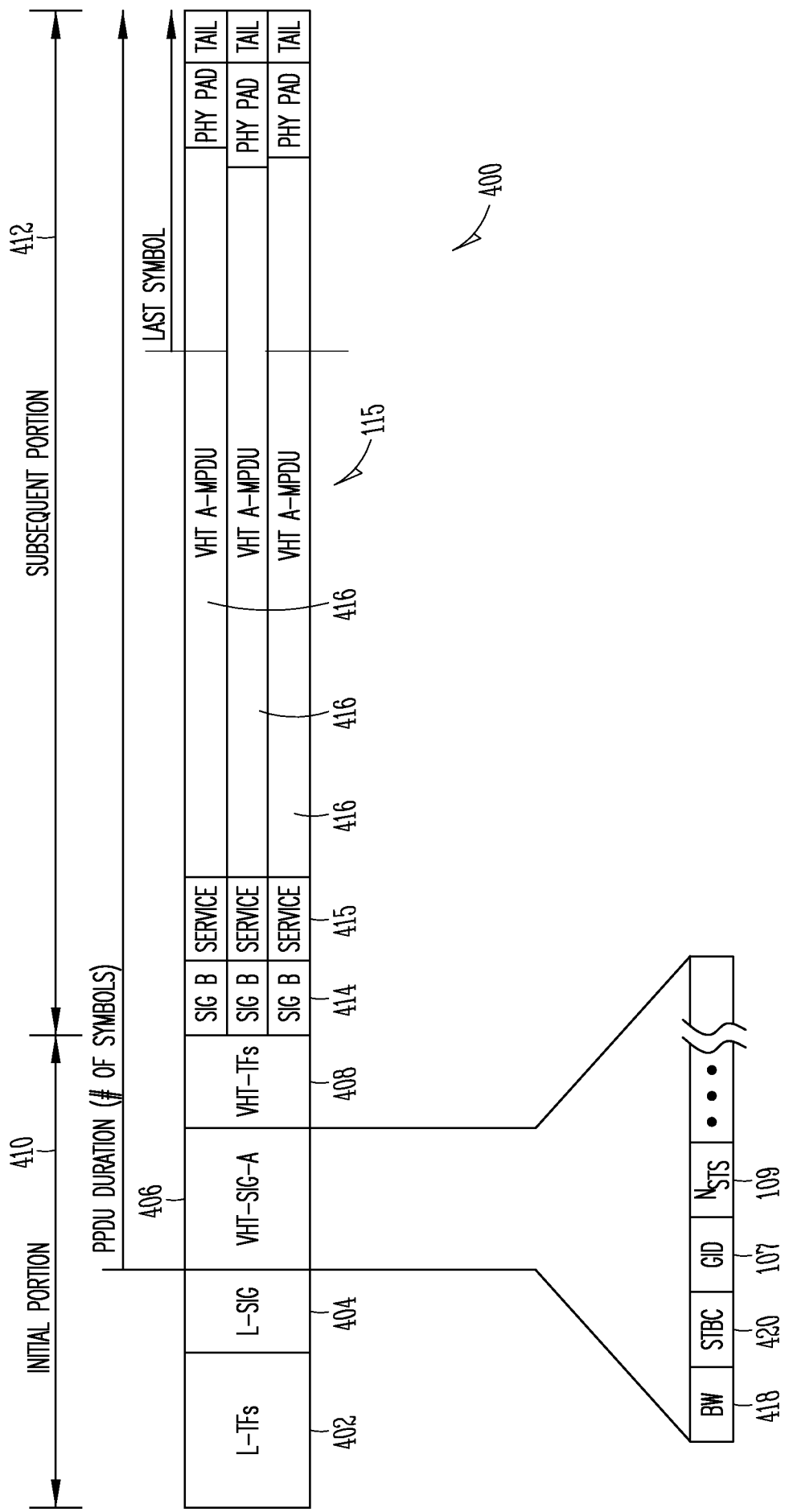
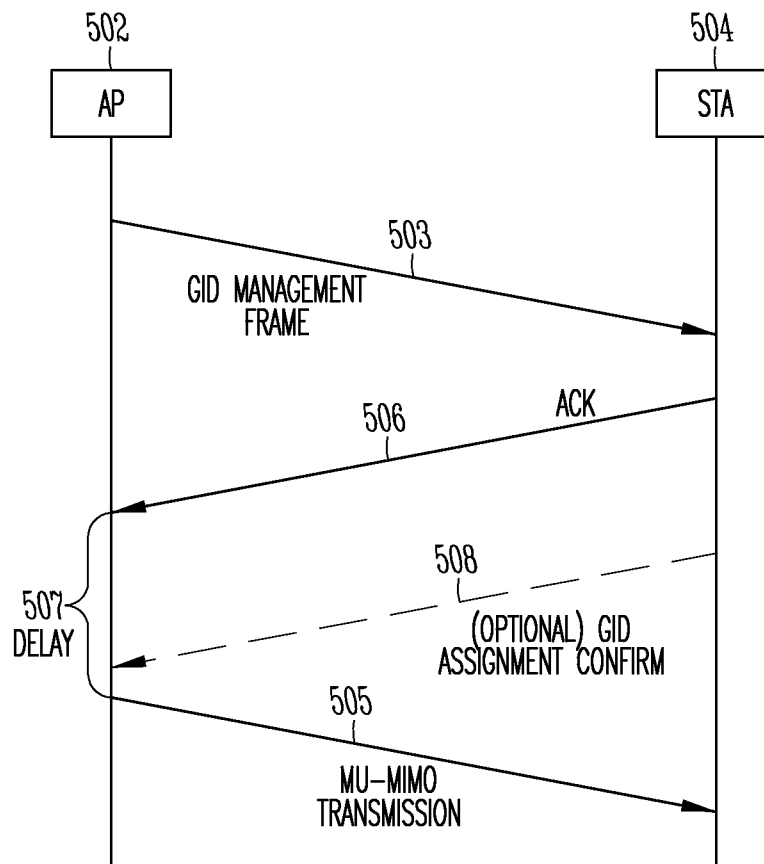


FIG. 3

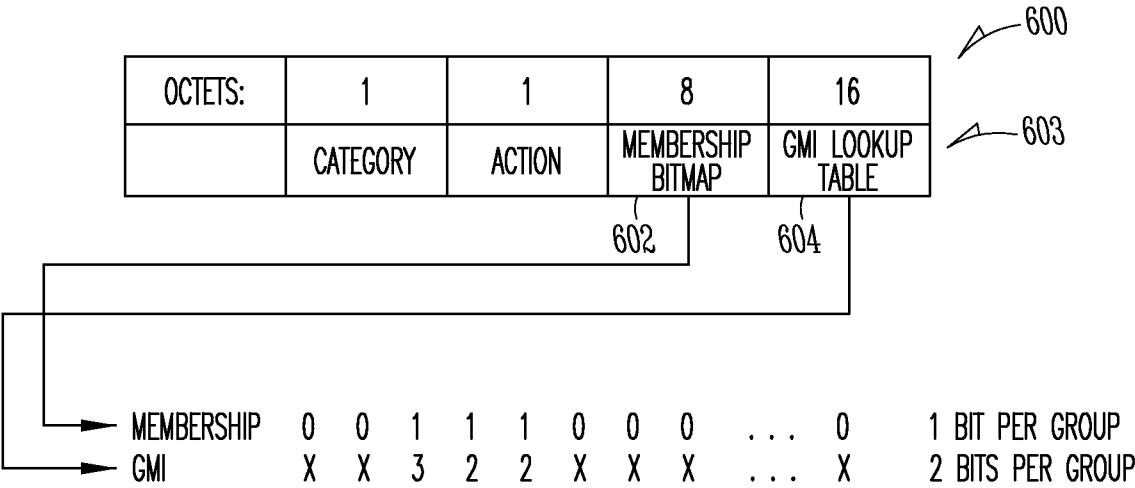


MU-MIMO TRANSMISSION
FIG. 4

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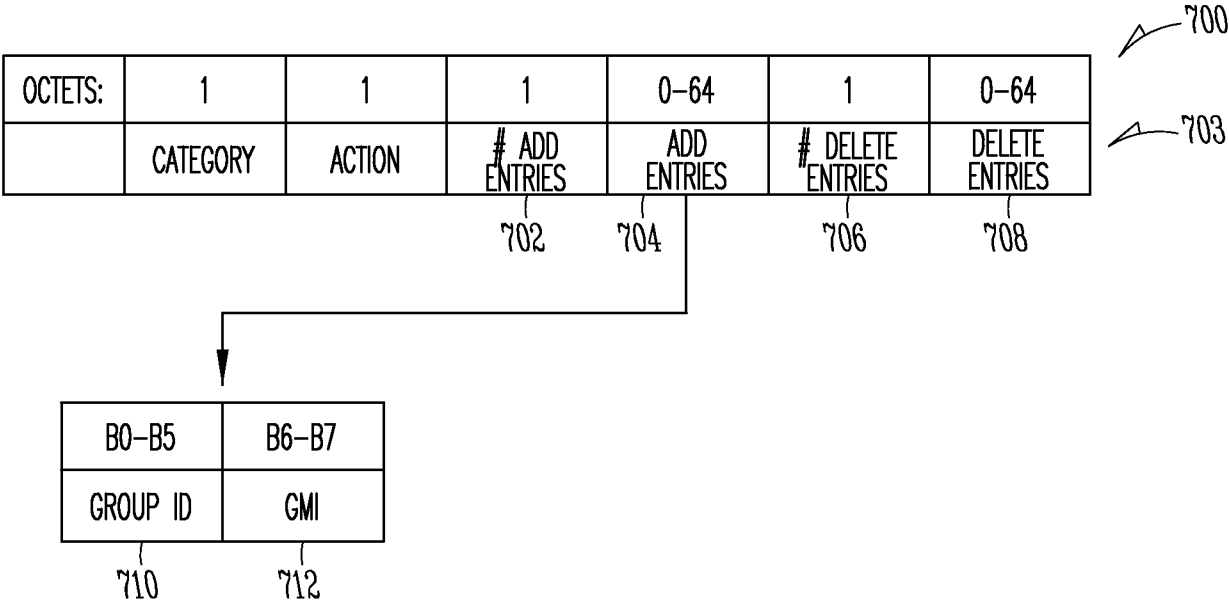
MU-GID ASSIGNMENT
SIGNALING**FIG. 5**

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GID MANAGEMENT FRAME FIXED-LENGTH FRAME FORMAT

FIG. 6



GID MANAGEMENT FRAME VARIABLE-LENGTH FORMAT

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2011/063049**A. CLASSIFICATION OF SUBJECT MATTER****H04B 7/04(2006.01)i**

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04B 7/04; H04Q 7/34

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: MU-MIMO, group ID, group index

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2001-517044 A (Telefonaktiebolaget LM Ericsson) 02 October 2001 See abstract; paragraphs [13]-[18], [36]-[39]; claims 1-7, 24 and figures 3, 4.	1-25
A	Tomoya Tandai et al. 'An efficient uplink multiuser MIMO protocol in IEEE 802.11 WLANs', IEEE, 2009 See III. PROPOSED UPLINK MU-MIMO PROTOCOL.	1-25
A	Qinghua Li et al. 'MIMO Techniques in WiMAX and LTE: A Feature Overview', In : IEEE Communications Magazine, May 2010 See MU-MIMO and Reference signal for multi-antenna operation.	1-25

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

* Special categories of cited documents:

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

28 MARCH 2012 (28.03.2012)

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2011/063049

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