

Methods and Apparatus for Signaling in High Efficiency Wireless Local Area Networks

The following documents and standards descriptions are hereby incorporated into the present disclosure as if fully set forth herein:

The OFDMA structure for 802.11ax consists of the following building blocks:

1. 26-tone RU consisting of 24 data tones and 2 pilot tones as defined for the S1G 1 MHz mode in 802.11ah
 - Possible locations of the 26-tone RUs are fixed as shown in Figure 1, Figure 2 and Figure 3 for 20 MHz, 40 MHz and 80 MHz OFDMA PPDUs, respectively.
2. 52-tone RU consisting of 48 data tones and 4 pilot tones as defined in 802.11a
 - Possible locations of the 52-tone RUs are fixed as shown in Figure 1, Figure 2 and Figure 3 for 20 MHz, 40 MHz and 80 MHz OFDMA PPDUs, respectively.
3. 106-tone RU consisting of 102 data tones and 4 pilot tones
 - Interleaver parameter following that of VHT 40 MHz mode in 802.11ac, except that $N_{col} = 17$
 - Possible locations of the TBD1-tone RUs are fixed as shown in Figure 1, Figure 2 and Figure 3 for 20 MHz, 40 MHz and 80 MHz OFDMA PPDUs, respectively.
4. 242-tone RU consisting of 234 data tones and 8 pilot tones as defined for the VHT 80 MHz mode in 802.11ac
 - Possible locations of the 242-tone RUs are fixed as shown in Figure 2 and Figure 3 for 40 MHz and 80 MHz OFDMA PPDUs, respectively
5. 484-tone RU consisting of 468 data tones and 16 pilot tones as defined for the VHT 160 MHz mode in 802.11ac
 - Possible locations of the 484-tone RUs are fixed as shown in Figure 3 for 80 MHz OFDMA PPDUs.

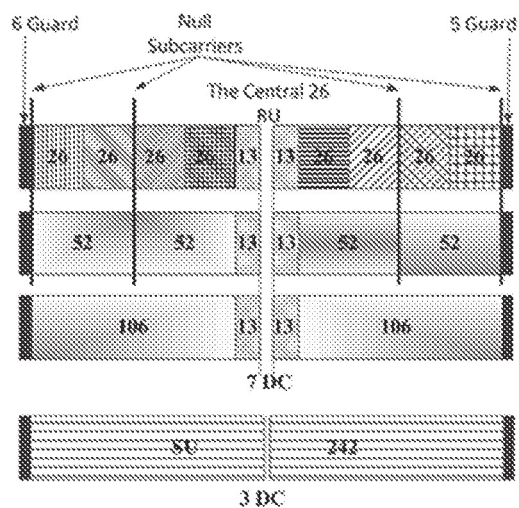


Figure 1 - Possible RU locations in a 20 MHz OFDMA PPDU

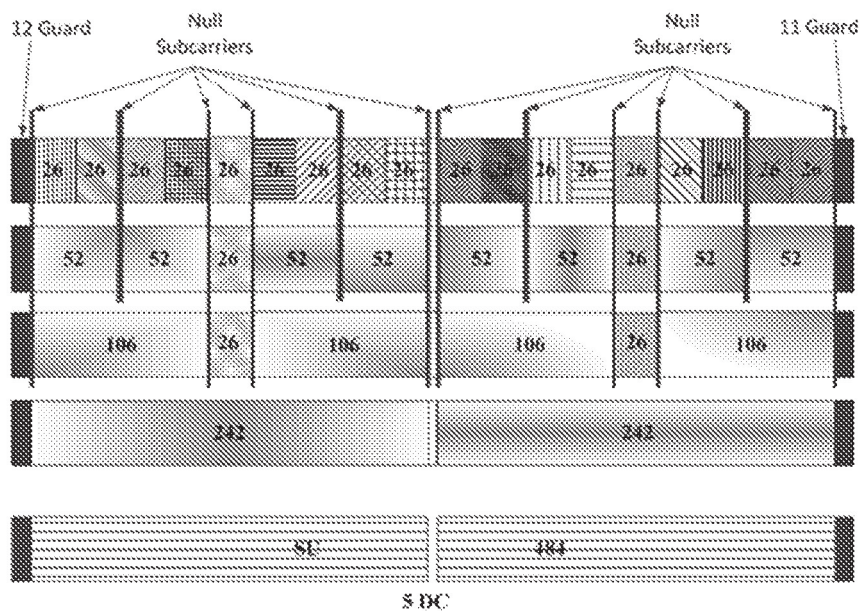


Figure 2 - Possible RU locations in a 40 MHz OFDMA PPDU

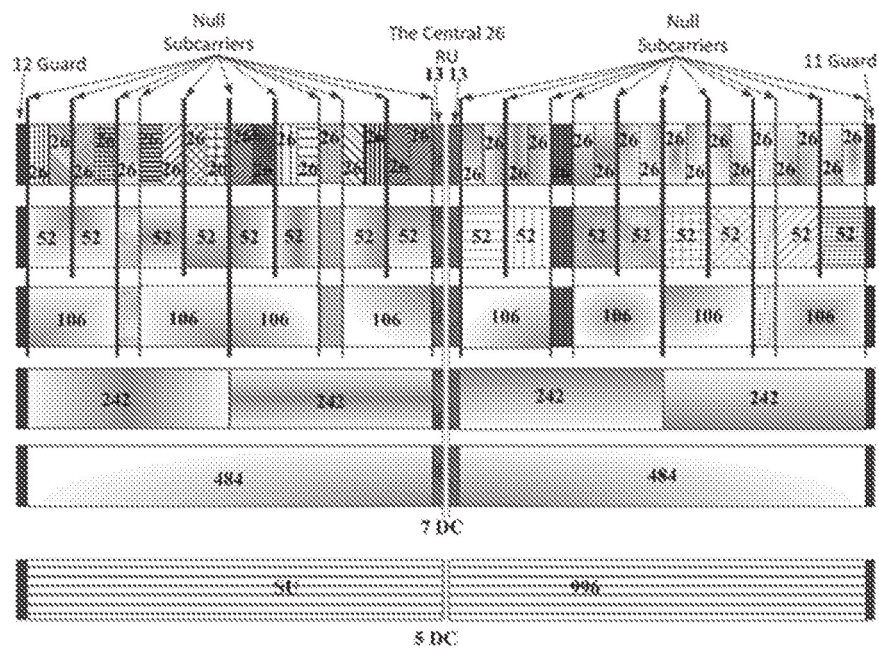


Figure 3 - Possible RU locations in an 80 MHz OFDMA PPDU

An OFDMA PPDU can carry a mix of different resource unit sizes within each 242 resource unit boundary.

The format of the HE MU PPDU is defined as in Figure 4. This format is used for MU transmission that is not a response of a Trigger frame. An HE-SIG-B field is present in this format.

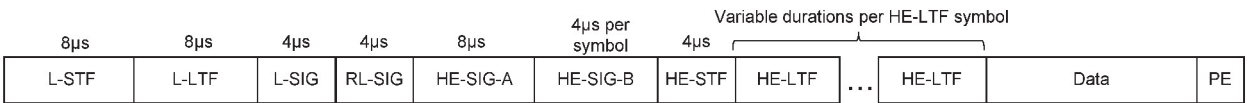


Figure 4 HE MU PPDU format

The HE-SIG-B field is separately encoded on each 20 MHz band. The encoding structure in one such 20 MHz band is shown in Figure 5. It consists of a Common Block field followed by a User Specific field.

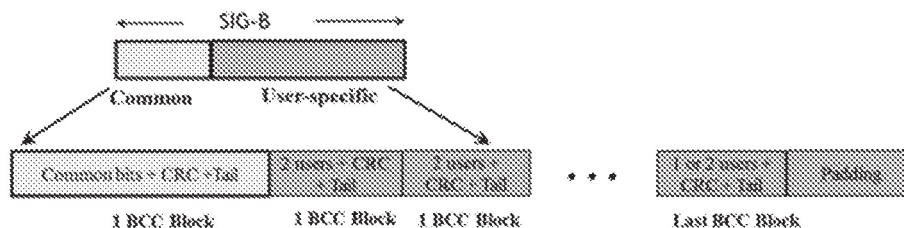


Figure 5 HE-SIG-B field encoding structure in each 20 MHz

The Common Block field contains information regarding the resource unit allocation such as the RU arrangement in frequency domain, the RUs allocated for MU-MIMO and the number of users in MU-MIMO allocations.

The User Specific field consists of multiple User Block fields. Each User Block field contains information for two STAs to decode their payloads. The last User Block field may contain information for only one STA, if the number of user fields indicated by the RU allocation signaling in the common block is odd.

For 20 MHz and 40 MHz PPDU, the Common Block field and the User field for a STA are transmitted in the same 20 MHz band as the STA's data.

For an 80 MHz PPDU, the default frequency mapping of the Common Block field and User Specific fields is shown in Figure 6. The HE-SIG-B field content in the 1st and 3rd 20 MHz bands from top are identical. The information carried in either of these bands is called HE-SIG-B content channel 1. HE-SIG-B content channel 1 carries signaling information for all STAs whose payloads occupy some tones in A242 or C242. Similarly, the HE-SIG-B contents on the 2nd and 4th 20 MHz bands are identical. The information carried in either of these bands is called HE-SIG-B content channel 2. HE-SIG-B content channel 2 carries signaling information for all STAs whose payloads occupy some tones in B242 or D242.

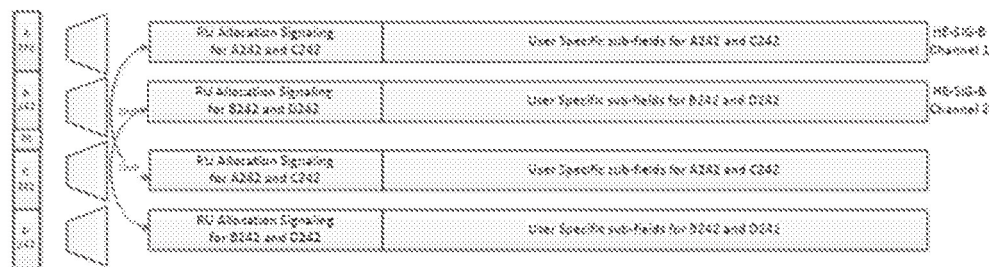


Figure 6 Default mapping of the two HE-SIG-B channels and their duplication in an 80 MHz PPDU

For a 160 MHz PPDU, the default frequency mapping of the Common Block field and User Specific fields is shown in Figure 7. The HE-SIG-B content in the 1st, 3rd, 5th and 7th 20 MHz bands from top are all identical. The information carried in any of these bands is called HE-SIG-B content channel 1. HE-SIG-B content channel 1 carries signaling information for all STAs whose payloads occupy some tones in A1-242 or C1-242 or A2-242 or C2-242. Similarly, the HE-SIG-B contents in the 2nd, 4th, 6th and 8th 20 MHz bands from top are identical. The information carried in any of these bands is called HE-SIG-B content

channel 2. HE-SIG-B content channel 2 carries signaling information for all STAs whose payloads occupy some tones in B1-242 or D1-242 or B2-242 or D2-242.



Figure 7 Default mapping of the two HE-SIG-B channels and their duplication in a 160 MHz PPDU

For MU-MIMO allocation of RU size > 20 MHz, the User Block subfields are dynamically split between the two HE-SIG-B content channels (1/2) and the split is decided by the AP (on a per case basis).

A resource allocation index signaled in the common portion of HE-SIG-B channel carries the following information:

- RU Arrangement
- If MU-MIMO Capable RUs carry MU-MIMO
- Number of users multiplexed using MU-MIMO

A transmitted resource allocation index will differ when different RU arrangements are used or when for the same RU arrangement, different number of users multiplexed using MU-MIMO. Since up to 8 users can be multiplexed in an MU-MIMO allocation, 8 indices indicating different # of users for a MU-MIMO capable RU within the same RU arrangement. The tabulated indices encoding jointly the RU arrangements and the number of users for a MU-MIMO index is shown in Figure 8. For example, as shown in Figure 8, Index 3 & 4 – Indicate an RU arrangement [106 26 106] over a channel: Index 3 – refers to SU transmissions in the RU while index 4 – refers to MU MIMO in the first 106 RU with 2 users and SU in the remaining RUs. There are total of 64 different indices that refer to the same [106 26 106] RU arrangement, each with differing # of users in either of the MU-MIMO capable 106 tone RU. For the different RU sizes and arrangements possible, a total of 175 different indices can be signaled and would require 8 signaling bits and is carried in the common information portion of the HE-SIG-B channel as illustrated in Figure 9.

	#1	#2	#3	#4	#5	#6	#7	#8	#9	Num User
1	26	26	26	26	26	26	26	26	26	1
2	52		52		26	52		52		1
3		106			26		106			64
66	52		26	26	26	26	26	26	26	1
67	26	26		52	26	26	26	26	26	1
68	26	26	26	26	26		52	26	26	1
69	26	26	26	26	26	26	26		52	1
70	52		52		26	26	26	26	26	1
71	52		26	26	26		52	26	26	1
72	52		26	26	26	26	26		52	1
73	26	26		52	26		52	26	26	1
74	26	26		52	26	26	26		52	1
75	26	26	26	26	26		52		52	1
76	52		52		26		52	26	26	1
77	52		52		26	26	26		52	1
78	52		26	26	26		52		52	1
79	26	26		52	26		52		52	1
87		106			26	26	26	26	26	8
95		106			26	26	26		52	8
103		106			26		52	26	26	8
111		106			26		52		52	8
119	26	26	26	26	26			106		8
127	26	26		52	26			106		8
135	52		26	26	26			106		8
143	52		52		26			106		8
151					242					8
159					484					8
167					996					8
175					2*996					8

Figure 8 Signaling the RU arrangement along with the number of users for MU-MIMO resources.
Indicating jointly the RU arrangement and the number of MU-MIMO users in an MU-MIMO resource results in the compact common information field. The per-user signaling portion follows the common information portion for the HE-SIG-B channel and carries information necessary to identify users as well as the decoding information for the data PPDU for the users. It admits both STAID and GroupID addressing for MU-MIMO. An arrangement of the per-user information element where each user is identified by an STAID is shown in Figure 9.

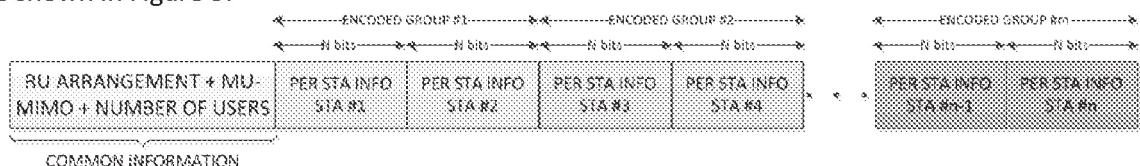


Figure 9 Arrangement of common information containing both RU arrangement and the number of users for MU-MIMO RUs in a HE-SIG-B Channel

The number of RU allocation sub-fields in the HE-SIG-B common block field depends on the total PPDU bandwidth

- In the default mode, for 20 MHz and 40 MHz PPDU, each *HE-SIG-B content channel* contains one RU allocation sub-field followed by multiple user fields. The position of the user-field in the user-specific field together with the 8-bit RU allocation sub-field indicates the RU assignment to the user.
- In the default mode for the 80 MHz PPDU, each HE-SIG-B content channel contains two RU allocation sub-fields for a total of 16 bits of RU allocation signaling, one each for the RUs in the two 20MHz segments of the *HE-SIG-B content channel*. The user fields corresponding to the first RU allocation signaling field are followed by the user fields indicated by the second RU allocation signaling field in the user specific field.
- In the default mode for the 160 MHz PPDU, each HE-SIG-B content channel contains four RU allocation signaling fields for a total of 32 bits of RU allocation signaling, one each for the RUs in the four 20 MHz segments of the *HE-SIG-B content channel*. The user fields for each of the 20MHz segments in the content channel are arranged by the order in which their RU allocation signaling fields appear in the common field

A user field for an MU-MIMO allocation includes a Spatial Configuration sub-field consisting of 4 bits that indicates the number of spatial streams for each STA and the total number of spatial streams in the MU-MIMO allocation. The subfield shown in Table 1 is constructed by using the entries corresponding to the value of number of users (Nuser) multiplexed using MU-MIMO in an RU. When MU-MIMO is used in an RU of size ≤ 20 MHz, the number of users (Nuser) in an MU-MIMO allocation is equal to the number of user-fields per RU signalled for the RU in the RU allocation sub-field of an HE-SIG-B Common block field. For a given value of Nuser, the four bits of the spatial configuration sub-field are used as follows: An STA whose STA-ID matches the 11-bit ID signalled in the user field for an MU-MIMO allocation derives the number of spatial streams allocated to it using the row corresponding to the signalled 4-bit spatial configuration subfield and the column corresponding to the position of the user-field in the user-specific field. The starting stream index for the STA is computed by summing the Nsts in the columns prior to the column indicated by the STA's user-field position.

Table 1 Spatial Configuration subfield encoding

Nuser	B0...B3	Nsts [1]	Nsts [2]	Nsts [3]	Nsts [4]	Nsts [5]	Nsts [6]	Nsts [7]	Nsts [8]	Total Nsts	Number of Entries
2	0000~0011	1~4	1							2~5	10
	0100~0110	2~4	2							4~6	
	0111~1000	3~4	3							6~7	
	1001	4	4							8	
3	0000~0011	1~4	1	1						3~6	13

	0100~0110	2~4	2	1						5~7	
	0111~1000	3~4	3	1						7~8	
	1001~1011	2~4	2	2						6~8	
	1100	3	3	2						8	
4	0000~0011	1~4	1	1	1					4~7	11
	0100~0110	2~4	2	1	1					6~8	
	0111	3	3	1	1					8	
	1000~1001	2~3	2	2	1					7~8	
	1010	2	2	2	2					8	
5	0000~0011	1~4	1	1	1	1				5~8	6
	0100~0101	2~3	2	1	1	1				7~8	
6	0000~0010	1~3	1	1	1	1	1			6~8	4
	0011	2	2	1	1	1	1			8	
7	0000~0001	1~2	1	1	1	1	1	1		7~8	2
8	0000	1	1	1	1	1	1	1	1	8	1

A description of example embodiments is provided on the follow pages.

The text and figures are provided solely as examples to aid the reader in understanding the invention. They are not intended and are not to be construed as limiting the scope of this invention in any manner. Although certain embodiments and examples have been provided, it will be apparent to those skilled in the art based on the disclosures herein that changes in the

embodiments and examples shown may be made without departing from the scope of this invention.

This invention covers the methods and apparatus required to enable signaling of orthogonal frequency division multiple access (OFDMA) and multi-user MIMO (MU-MIMO) allocations to different users addressed in a packet based wireless systems like IEEE 802.11.

The invention shows methods of enabling OFDMA and MU-MIMO in a packet in the latest version of the IEEE 802.11 standard known as 11ax currently under development. The flexibility in signaling and the acceptable overhead play a key role in determining efficient signaling mechanism for multi-user packets. We adapt and modify some legacy signaling elements to support OFDMA and MU-MIMO together in one DL MU packet.

In an embodiment of the current invention, when MU-MIMO is used in RUs of size > 20MHz, the number of users (Nuser) in an MU-MIMO allocation is computed as the sum of the number of user-fields per RU indicated for the RU by the 8-bit RU allocation sub-field in each HE-SIG-B content channel. When RUs of size > 20 MHz are signaled in the common portion, the user fields corresponding the same MU-MIMO allocations could be split into two HE-SIG-B content channels. The user-field positions are logically continuous with the user-field in the second HE-SIG-B content channel updating its position (and therefore, column index) from that of the last user-field in the first HE-SIG-B content channel.

When RU sizes whose width span larger than 20MHz are signaled, AP can divide the per-user content blocks between allocated channels dynamically based on load in each allocated channel, different RU allocation signaling indices are signaled in the common information of the two content channels which refer to the same allocation size, but indicate number of per-user content blocks carried in the corresponding content channel i.e., transmit per-user content blocks for the subset of users indicated in the common portion as shown in Figure 10.

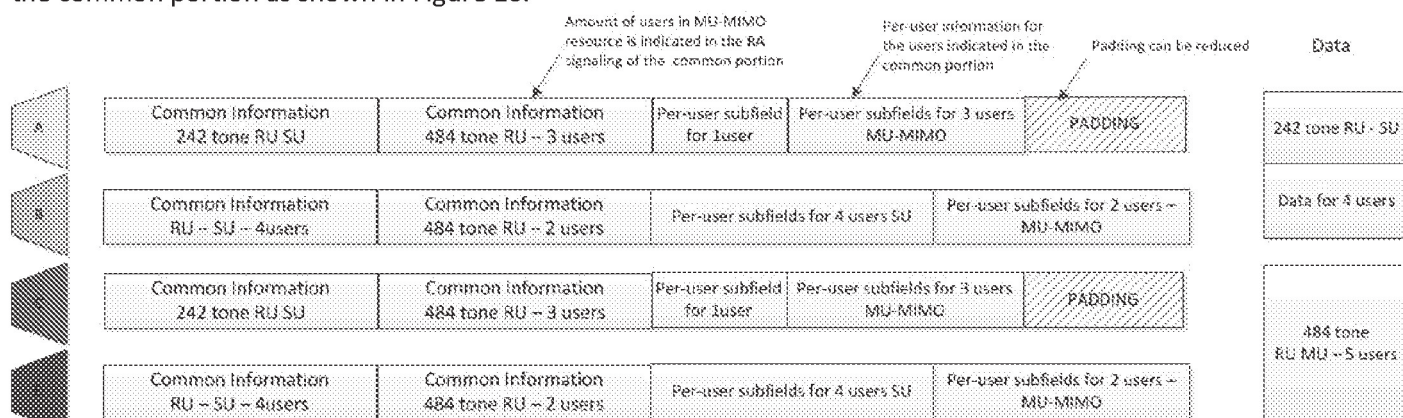


Figure 10 Illustration of load-balancing with MU-MIMO for RUs > 20MHz BW

The AP on its own decides whether load balancing is used or not for RUs > 242. When used, STA looks at the allocation in each HE-SIG-B content channel and interprets the user-fields that follow appropriately. When not used, STA will have to know that load balancing is not used in order to interpret

the spatial allocation sub-field in the user-field.

In an embodiment of the current invention, an indication for null allocation in the RU allocation sub-field table is used to signal that no load balancing is used or no user-fields corresponding to the RUs >242 tones are present in the content channel. The STA on receiving the null allocation sets the Number of user fields in the content channel to zero and the Nuser is computed based on the users in only the content channel where the index corresponding to RU size > 242 tones is signaled. When used in either of the HE-SIG-B content channel, the other content channel will have to indicate an index corresponding to an RU size > 242 tones. For example, the RU allocation index 11111111 signals a null allocation in the common portion as shown in in the Figure 11.

8 bit indices	RU size	Number of users
11 001yyy	484	8
11 010yyy	996	8
11 011yyy	2*996	8
11 111111	Null Allocation	1

← No load balancing is used

Figure 11 Null Allocation Index for RU signaling

In another embodiment of the current invention, a null allocation for each RU size can be encoded in an index individually. For example 11101000 could indicate a null allocation for a 484 tone RU, 11110000 could indicate a null allocation for a 996 tone RU and 11111000 could indicate a null allocation for a 2*996 tone RU. When these null allocations are signaled, they signal both the RU size and the fact that there are no user fields corresponding to the RU in the HE-SIG-B content channel in which it is carried.

Signaling the central 26 tone

Each content channel carries 16 bits, 8 bits of RU allocation signaling for each of the 2 corresponding 242 tone RUs

In an embodiment of the current invention, the central 26 tone RU in an 80MHz MU PPDU is signaled using 1 bit separately in one content channel which also carries the corresponding user field. By convention, the signaling bit is carried in HE-SIG-B channel-1. Therefore, a total of 17 bits RU signaling in HE-SIG-B content channel-1 and 16 bits RU signaling is carried in HE-SIG-B content channel-2 as shown in Figure 12.

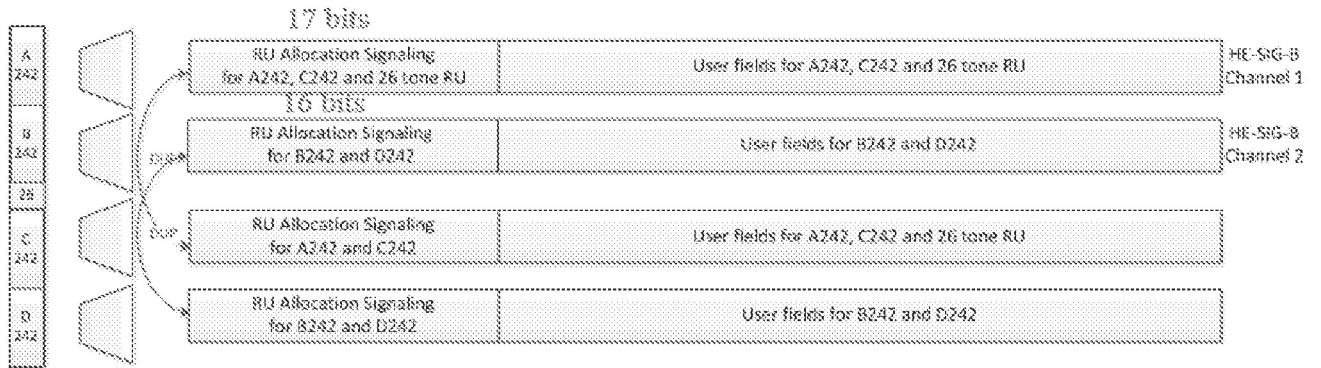


Figure 12 Signaling for the central 26 tone RU in a 80MHz MU PPDU

- We can repeat the RU signaling for the central 26 tone RU in both content channels

In an embodiment for the current invention, for a 160MHz PPDU, the central 26 tone RU corresponding to the constituent 80MHz segments are signaled using 1 bit separately. By convention, one in HE-SIG-B channel-1 and the other in HE-SIG-B channel-2. A total of 33 bits RU signaling per HE-SIG-B content channel as shown in Figure 13.



Figure 13 Signaling for the central 26 tone RU in a 160MHz MU PPDU

In another embodiment of the current invention, the use of central 26 tone RU in 80MHz PPDU or the two central 26 tone RUs in the 160MHz PPDU is not signaled in the HE-SIG-B common. Instead, the transmission of the user field corresponding to the central 26 tone is carried after the user fields corresponding to the signaled RU-allocation index in the HE-SIG-B common. For 80 MHz PPDU, the user

field corresponding to the central 26-tone RU is carried in either of the two content channels. In some cases, the user field corresponding to the central 26-tone RU in an 80MHz PPDU is carried in both content channels. For 160MHz PPDU, the user field corresponding to the central 26 tone RU in the 80MHz primary is carried in HE-SIG-B content channel -1 and the other in HE-SIG-B content channel 2.

In an embodiment of the current invention, a null allocation is indicated in the user-field subfields. It may be done by indicating a null STA-ID or an STA-ID determined that by the AP that is not yet allocated. The null allocation may be indicated by signaling a zero spatial transmit streams to the user. A user field corresponding to the central 26-tone RU is always carried.

In an embodiment of the current invention, STAs maintain a binary hypothesis on the number of user-fields that follow : $N_{userfields}$ or $N_{userfields} + 1$ in either or each of the content channel. After decoding the $N_{userfields}$ signaled by the RU allocation, the STA attempts to decode another user-field if there are at least as many bits corresponding to an user-field in the content channel. If the STA-ID matches the ID of the STA and CRC checks out, the STA will proceed to decode the data in the central 26 tone RU.

In an embodiment of the current invention, the STA will have only one allocation in an MU PPDU. STA can stop decoding HE-SIG-B if the STA-ID in the user-specific sub-field matches its own ID.

TXOP Duration:

Currently, HE-SIG-A has a field identified as TXOP duration. The details and the bitwidth are TBD. TXOP duration is also carried in the MAC header with a bit width of 15 bits. It is unlikely that HE-SIG-A has room for 15 bits. So some compression is required.

Compression requires that the duration field be re-quantized to the new bitwidth.

The most use of the TXOP duration field in PPDU header is for a MU-PPDU where the STAs don't have to decode any MPDU if it is not allocated to them. Giving the duration field in the HE-SIG field helps for spatial re-use, power-saving etc., For SU transmissions, 11ax STAs can decode the MPDU and get the full duration from the MAC header. Power-save and spatial re-use are not affected because the first MAC header in the A-MPDU gives the duration field.

In an embodiment of the current invention, in a MU PPDU, the 15 bit duration field is carried in the common portion of HE-SIG-B. The common portion of HE-SIG-B currently carries RU allocation signaling and the TXOP duration.

In an embodiment of the current invention, the 15 bits of the TXOP duration may be split between HE-SIG-A and HE-SIG-B for an MU PPDU.

In an embodiment of the current invention, 5 bits of TXOP duration is carried in HE-SIG-A followed by 10 bits of TXOP duration in the common portion of HE-SIG-B.



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