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Title	**Replacement Text for 8.3.5.7, OFDMA2 PHY**
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Re:	802.16a/D2
Abstract	
Purpose	Replacement text for 8.3.5.7, OFDMA2 PHY
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8.3.5.7 OFDMA2 PHY (Optional)

This optional PHY Mode shares many similarities with the OFDMA PHY (8.3.5.6), but is optimized for TDD duplex operation and adaptive antenna operation. As such, it contains a few key differences to enable support for multiple simultaneous users on the same OFDM symbols and frequencies (within a cell) resulting from the spatial division multiple access (SDMA) capability of adaptive antenna arrays under the AAS option of the Standard. The scheduler can take advantage of the additional spatial degree of freedom at the system level, but the specific implementation is outside the scope of this air interface specification.

In this PHY mode, symbol data is assigned to adjacent OFDM carriers as indicated in the framing comments in this section. With OFDMA (8.3.5.6), the framing figures depict logical sub-channels since the carriers are actually distributed across the available frequency spectrum to mitigate against frequency selective fading. With OFDMA2, frequency selective fading is mitigated via spatial processing. Also, an additional superframe structure is defined to address transmission of preambles when using multiple antennas for adaptive array processing.

8.3.5.7.1 OFDMA2 Slot Definition

8.3.5.7.1.1 PHY Burst

The SS's transmission of a block of data is called a UL PHY Burst, and the BS's transmission of a block of data is called a DL PHY Burst.

A PHY burst is composed of sub-channels in a group of contiguous OFDM symbols. With a single beam, sub-channels within a PHY burst can be assigned to one SS or partitioned amongst multiple SSs. By using multiple spatial beams through adaptive array processing, PHY bursts can be transmitted to multiple subscribers simultaneously. This is depicted in Figure 1. As an example, for a single beam, all sub-channels can be allocated to a single SS, and so given N spatial beams, N SSs can be provided full rate links simultaneously.

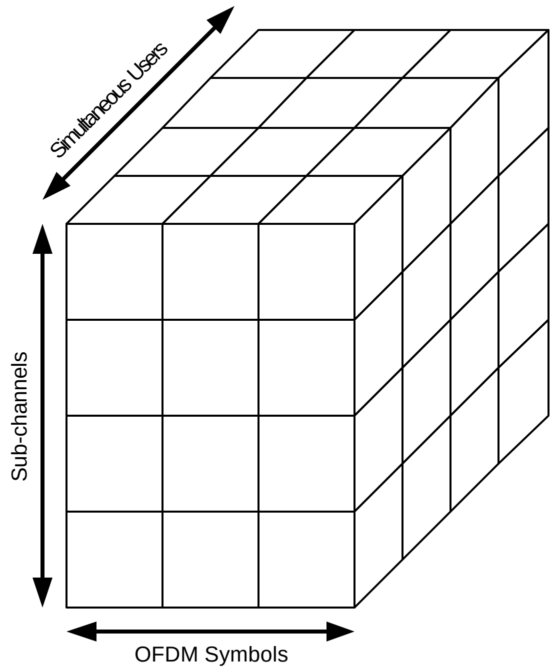

Figure 1: Illustration of OFDMA2 PHY Burst Allocation

8.3.5.7.1.2 OFDMA2 Data Mapping

Per Figure 1, once the user plane been chosen, MAC data shall be mapped to a sub-channel – OFDM symbol plane PHY burst using the following algorithm:

1) Segment the data into blocks sized to fit into one FEC block.
2) Each FEC block spans one OFDMA2 sub-channel in the sub-channel axis and three OFDM symbols in the time axis. Map the FEC blocks such that the lowest numbered FEC block occupies the lowest numbered sub-channel, and the lowest numbered byte of the FEC block occupies the lowest numbered OFDM symbol.
3) Continue the mapping such that the OFDMA2 sub-channel index is increased for each FEC block mapped. When the last available sub-channel is reached, continue the mapping from the lowest numbered OFDMA2 sub-channel in the next OFDM symbol.

8.3.5.7.2 OFDMA2 DL/UL-MAPs

For broadcast operations, the frame control information is transmitted at the beginning of each frame in the access channels. For unicast operations, the frame control information is transmitted at the beginning of each superframe (see 8.3.5.7.7). The first FEC block of the DL frame, labeled the DL Frame Prefix, shall contain information about the frame control information and beginning of the DL MAP.

The DL Frame Prefix is used to provide information about where to demodulate the frame control information (structure of the transmitted symbols) and how to demodulate it (pertinent PHY parameters). The DL Frame Prefix is defined in Table 1.

Table 1: OFDMA2 DL Frame Prefix Definition

Syntax	Size	Notes
DL_Frame_Prefix_Format() {		
Rate_ID	8 bits	
DL_Information_Message_Rectangle() {		
No_OFDM_Symbols	10 bits	
No_Sub_Channels	6 bits	
}		
Prefix_CS	8 bits	
}		

The fields in Table 1 are defined as:

Rate_ID

Enumerated field that describes the modulation/coding of the DL-MAP message. Encoding values of the Rate_ID field are defined in Table 200.

No_OFDM_Symbols

Indicates the number of OFDM symbols for the DL_MAP message starting from the first symbol of the frame.

No_Sub_Channels

Indicates the number of sub-channels for the DL_MAP message starting from sub-channel 0.

Prefix_CS

An 8-bit checksum for the DL-Frame prefix fields, with the generator polynomial: $g(D) = D^8 + D^2 + D + 1$.

The remaining bytes of the first FEC block may contain the beginning of the frame control information (DL MAP).

8.3.5.7.2.1 DL-MAP PHY synchronization field

The format of the PHY Synchronization Field of the DL-MAP message, as described in 6.2.2.3.2, is given in Table 2. The Frame Duration Codes are given in Table 180. The frame number is incremented by 1 each frame and eventually wraps around to zero.

Table 2: OFDMA2 Synchronization Field

Syntax	Size	Notes
PHY_synchronization_field() {		
Frame duration code()	8 bits	
Frame number	24 bits	
Allocation_Start_Time	32 bits	
}		

A BS shall generate DL-MAP messages in the format shown in Table 2, including the following parameter:

Allocation Start Time

The effective start time of the uplink allocation defined in units of mini-slots. The start time is relative to the start of a frame in which the DL-MAP message is transmitted.

8.3.5.7.2.2 DL-MAP_Information_Element Format

The OFDMA2 DL-MAP Information Element defines the sub-channels and OFDM symbols for a PHY burst and the associated DIUC. The format is defined in Table 3.

Table 3: OFDMA DL-MAP_Information_Element format

Syntax	Size	Notes
DL-MAP_Information_Element() {		
DIUC	4 bits	
OFDM Symbol Offset	10 bits	
Sub-channel Offset	8 bits	
No. OFDM Symbols	10 bits	
No. Sub-channels	6 bits	
}		

DIUC

Downlink interval usage code used for the burst.

OFDM Symbol offset

The offset of the OFDM symbol in which the burst starts, measured in OFDM symbols from the start of the MAC frame.

Sub-channel offset

The lowest index OFDM sub-channel used for carrying the burst, starting from sub-channel 0.

No. OFDM Symbols

The number of OFDM symbols that are used (fully or partially) to carry the DL PHY Burst.

No. of sub-channels

The number OFDMA sub-channels with subsequent indexes, used to carry the burst.

8.3.5.7.2.3 UL MAP Information Element Format

8.3.5.7.2.3.1 Normal allocation UL MAP Information Element Format

The OFDMA2 UL-MAP Information Element defines a two-dimensional allocation pattern for the UL bursts. Information elements define uplink bandwidth allocations. Each UL-MAP message shall contain at least one Information Element that marks the end of the last allocated burst. The Information Elements shall be in strict chronological order within the UL-MAP. A UIUC shall be used to define the type of uplink access and the burst type associated with that access. A Burst Descriptor shall be specified in the UCD for each UIUC to be used in the UL-MAP. The format of the UL-MAP IE is defined in Table 4.

Table 4 – OFDMA2 UL-MAP_Information Element Format

Syntax	**Size (bits)**	**Notes**
UL-MAP_Information_Element() {		
CID	16	
UIUC	4	
OFDM symbol offset	10	
Sub-channel offset	6	
Number OFDM symbols	10	
Number sub-channels	6	
}		

CID (Connection Identifier)
Represents the assignment of the IE.

UIUC
Uplink interval usage code used for the burst.

OFDM Symbol offset
The offset of the OFDM symbol in which the burst starts, the offset value is defined in units of OFDM symbols and is relevant to the Allocation Start Time field given in the UL-MAP message.

Sub-channel offset
The lowest index OFDMA2 sub-channel used for carrying the burst, starting from sub-channel 0.

Number of OFDM symbols
The number of OFDM symbols that are used to carry the UL Burst.

Number of sub-channels
The number OFDMA2 sub-channels with subsequent indexes, used to carry the burst. UIUC extension. The uplink interface usage code extension used for the burst.

8.3.5.7.2.3.2 CDMA allocation UL-MAP Information Element Format

For compliance with OFDMA, this element is as defined in 8.3.5.6.2.3.2.

8.3.5.7.2.4 DIUC Allocation

Table 5 defines the DIUC encoding that should be used in the DL-MAP Information Elements.

Table 5: —OFDMA2 DIUC values

DIUC	Usage
0-12	Different burst profiles
13	Gap
14	End of map
15	Extended DIUC

8.3.5.7.2.5 UIUC Allocation

Table 6 defines the UIUC encoding that should be used in the UL-MAP Information Elements.

Table 6: OFDMA2 UIUC Values

UIUC	Usage
0	Reserved
1-9	Different burst profiles
10	Null Information Element
11	Empty
12	CDMA Ranging Allocation
13	Reserved
14	CDMA Allocation Information Element
15	Extended UIUC

When an extension code (UIUC = 15) is specified, a sub-code extension is required. As specified in Table 224, a sub-code of 0x00 indicates that the information element is an OFDMA2 power control information element. As specified in Table Table 7, sub-codes 0x01 through 0x09 indicate that the information element is for AAS.

Table 7: OFDMA2 AAS UL-MAP_Information Element Format

Syntax	Size (bits)	Notes
UL-MAP_Information_Element() {		
CID	16	
UIUC	4	UIUC = 15
UIUC extension	4	Sub-code = 0x01 – 0x09
OFDM symbol offset	10	
Sub-channel offset	6	
Number OFDM symbols	10	
Number sub-channels	6	
}		

CID (Connection Identifier)

Represents the assignment of the IE.

UIUC

Uplink interval usage code used for the burst.

UIUC Extension

Uplink interval extended usage code used for the burst. The sub-code value is the UIUC burst profile value Table 6.

OFDM Symbol offset

The offset of the OFDM symbol in which the burst starts, the offset value is defined in units of OFDM symbols and is relevant to the Allocation Start Time field given in the UL-MAP message.

Sub-channel offset

The lowest index OFDMA2 sub-channel used for carrying the burst, starting from sub-channel 0.

Number of OFDM Symbols

The number of OFDM symbols that are used to carry the UL Burst.

Number of sub-channels

The number OFDMA2 sub-channels with subsequent indexes, used to carry the burst.

The CID used in the Information Element should be the Basic CID of the SS.

8.3.5.7.3 OFDMA2 Carrier Allocations

For OFDMA2, Fs = BW x 8/7.

For compatibility with OFDMA (8.3.5.6) the DC carriers, guard tones, and pilots are defined as in 8.3.5.6.3.

8.3.5.7.3.1 Downlink

8.3.5.7.3.1.1 Assignment of Pilots

Pilots are mapped to carrier locations as defined in 8.3.5.7.3.1.1.

8.3.5.7.3.1.2 Partitioning of Data Carriers into Sub-channels

After mapping the pilots, the remaining carriers are used for data. To allocate the data carriers to sub-channels, the remaining carriers are partitioned into equal numbers of contiguous carriers.

8.3.5.7.3.2 Uplink

Five pilots are added to each subchannel assignment, such that there are 53 carriers per subchannel. These five pilots are assigned to locations {5, 16, 27, 38, 49} within each 53 carrier block.

8.3.5.7.4 Channel Coding

8.3.5.7.4.1 Uplink Scrambling (Randomization) Initialization

The scrambler (see clause 8.3.5.2.2.1) is initialized with the vector created as shown in Figure 2.

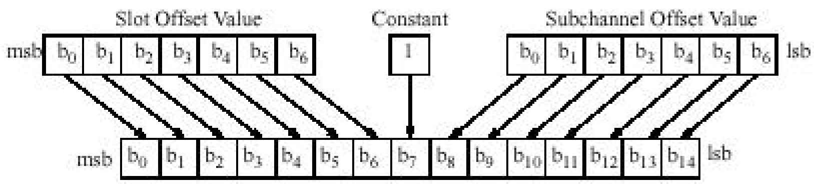

Figure 2: OFDMA2 Scrambler (Randomizer) Initialization

8.3.5.7.4.2 FEC

8.3.5.7.4.2.1 Concatenated Reed Solomon and Convolutional Coding

The encoding is performed by first passing the data in blocks through an RS encoder and then a tail biting convolutional encoder. Six schemes are defined, as shown in Table 8. The channel coding options for 64 QAM modulation are optional. All other channel coding options are mandatory.

Table 8: Channel Coding per Modulation

Modulation	Uncoded Block Size (Bytes)	Overall Coding Rate	Coded Block Size (Bytes)	RS Code	CC Code Rate
QPSK	18	1/2	36	(24,18,3)	2/3
QPSK	26	~3/4	36	(30,26,2)	5/6
16 QAM	36	1/2	72	(48,36,6)	2/3
16 QAM	54	3/4	72	(60,54,3)	5/6
64 QAM	72	2/3	108	(81,72,4)	3/4
64 QAM	82	~3/4	108	(90,82,4)	5/6

8.3.5.7.4.2.2 Turbo Product Codes (optional)

Same as 8.3.5.6.4.2.2

8.3.5.7.4.2.3 Interleaving

Same as 8.3.5.6.4.2.3

8.3.5.7.5 Control Mechanisms

8.3.5.7.5.1 Ranging

The ranging is the process of acquiring the correct timing offset and power corrections such that the SS's transmissions are aligned to a symbol that marks the beginning of a burst(s) boundary with the required power.

- The SS, after acquiring downstream synchronization and upstream transmission parameters, shall choose randomly a Ranging Slot (with the use of a binary truncated exponent algorithm to avoid possible re-collisions) as the time to perform the ranging, then it chooses randomly a Ranging Code (from the Initial Ranging domain) and sends it to the BS (as a CDMA code).

- Upon detection of the CDMA code, the BS can form a beam to the corresponding SS. However, the BS cannot tell which SS sent the CDMA ranging request, therefore upon successfully receiving a CDMA Ranging Code, the BS broadcasts a Ranging Response message that advertises the received Ranging Code as well as the ranging slot (i.e. OFDM symbol number, sub-channel, etc.) where the CDMA Ranging code has been identified. This information is used by the SS that sent the CDMA ranging code to identify the Ranging Response message that corresponds to its ranging request. The Ranging Response message contains all the needed adjustment (e.g., time, power and possibly frequency corrections) and a status notification.

- Upon receiving Ranging Response message with continue status, the SS shall continue the ranging process as done on the first entry with ranging codes randomly chosen from the Maintenance Ranging domain.

8.3.5.7.5.1.1 Initial-Ranging Transmissions
Same as 8.3.5.6.1.1.

8.3.5.7.5.1.2 Maintenance-Ranging and Bandwidth-Request Transmissions
Same as 8.3.5.6.5.1.2.

8.3.5.7.5.1.3 Ranging Codes
Same as 8.3.5.6.5.1.3.

8.3.5.7.5.1.4 Ranging Pilot Modulation
Same as 8.3.5.6.5.1.4.

8.3.5.7.5.2 Preamble Structure

8.3.5.7.5.2.1 Downlink Preamble

In the first frame of every superframe (or 6^{th} frame), 5 preamble slots are transmitted consisting of 2 synchronization slots, 2 link initiation slots and one channel estimation slot having the following form

CP+S1+CP+S2+CP+S3+CP+S4+CP+S5

where the synchronization slots S1 and S4 are Walsh-Hadamard codes, link initiation slots S2 and S3 are Kasami sequences, and the Channel Estimation slot S5 is a unique16 element Hadamard codeword that is transmitted to each CPE. The link initiation slots are unique to each CPE and the synchronization sequence is common to all CPE's.

The Hadamard codes are defined by the recursion relation $H_2 = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$,

$$H_{n+2} = \begin{bmatrix} H_n & H_n \\ H_n & -H_n \end{bmatrix}.$$

8.3.5.7.5.2.2 Uplink Preamble

The length of the preamble depends upon the number of antennas. Since multiple antennas are economically implemented at the base, the preamble on the uplink will vary depending on the number of antennas at the base.

The uplink preamble is transmitted in the beginning of every superframe and has the following structure:

CP+S1+CP+S2+CP+S3+CP+S4

Where 16 symbols are transmitted from each CPE during each slot. The codeword transmitted over the four slots is a length 64 QPSK Hadamard codeword of the following form:

H_j+iH_k = [S1 S2 S3 S4]

where H_j is the jth row of the Hadamard matrix, $0<j,k<65$, and the 4x16 sequences are concatenated to form the Hadamard codes. Each of the users transmitting on a particular partition has a different Hadamard codeword combination.

The Hadamard codes are defined by the recursion relation $H_2 = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$,

$$H_{n+2} = \begin{bmatrix} H_n & H_n \\ H_n & -H_n \end{bmatrix}.$$

8.3.5.7.6 Frame structure

8.3.5.7.6.1 Downlink

The transmission of the DL is performed on the sub-channels of the OFDM symbol. The number of sub-channels needed for the different transmissions (modulation and coding) and their mapping is defined in the DL-MAP message. The mapping of the sub-channels is performed in a two-dimensional grid, involving the sub-channels in the frequency domain and OFDM symbols in the time domain, as explained in 8.3.5.7.1.2. The additional beamforming capability permits simultaneous mappings to multiple SSs.

8.3.5.7.6.2 Uplink

For a given subscriber, the allocation for a user UL transmission is a number of sub-channels over a number of OFDM symbols. The number of symbols in a frame shall be equal to 3N, where N is a positive integer. The smallest allocation, a basic allocation, is one sub-channel for a duration of 3 OFDM symbols (N=1). Larger allocations are called extended allocations. With beamforming, multiple simultaneous UL transmissions are permitted. A dedicated sub-channel shall be provided for ranging and random access. The highest and lowest sub-channels (in regards to frequency) shall be used for this purpose. With beamforming, multiple simultaneous SSs may use the access channel without necessarily causing a collision.

8.3.5.7.7 Superframe Structure

A superframe structure is defined to address transmission of preambles when using multiple antennas for adaptive array processing. A superframe consists of 1+M frames. The first frame in a superframe is used for the uplink and downlink preambles to allow access into the partition, synchronization, and channel estimation. The slot structure for the preamble slot is described in the preamble section. The proceeding M frames in the superframe (after the first frame) are used for data traffic only.

Each superframe on neighboring contiguous groups of 48 subcarriers is staggered by one frame as shown in Figure 3. This produces a raster pattern in the time frequency group plane that allows synchronization to be done in every frame.

Users enter the network on the access channel and are assigned to a sub-channel that consists of 48 contiguous subcarriers. Multiple users are assigned to each sub-channel and transmit and receive simultaneously with one another. On the downlink slots, all users are transmitted to simultaneously. On the uplink slots, all users assigned to a sub-channel transmit simultaneously.

The length of the control frame is motivated by the need to perform channel estimation and beamforming in a single frame. The number of symbols required for channel estimation in multiple antenna systems can be large (up to a frame) if there are a large number of transmit antennas. The superframe structure is motivated by the need for frequency diversity and time diversity as well as accurate channel estimation. The control frame is transmitted across frequency and time in a raster pattern while the remaining frames are data frames. The raster pattern in time allows a new SS to begin transmitting at any frame thus permitting low latency. The raster pattern in frequency gives frequency diversity so that SS's experiencing fades at one frequency can enter on another frequency. The raster pattern thereby gives diversity in both frequency and time. The first and last sub-channels (in frequency) are available as control frames for all time. This superframe structure can be applied as shown in Figure 3.

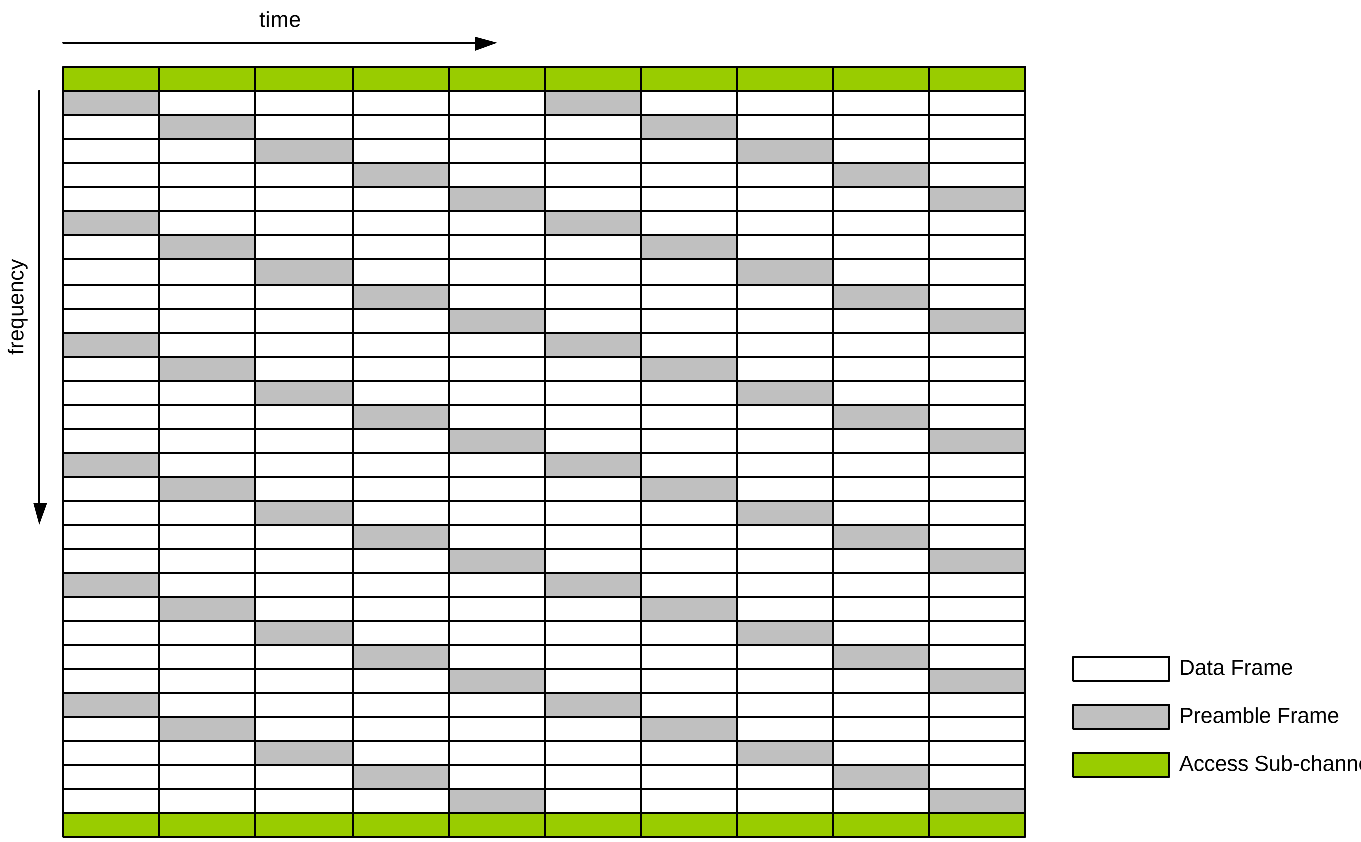

Figure 3 Example of Superframe Structure