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Re:	Call for contributions issued in document 802.16e-03/02
Abstract	This document presents the modifications for the OFDMA PHY/MAC layers, which adapts them to function/function better in a mobile environment.
Purpose	To be integrated into P802.16e-03/07r1 2003 draft document
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OFDMA Modification for Mobility

Introduction

The following contribution brings the details of the changes to the OFDMA system, which will allow it to work in a very fast mobility (up to 200Km/h in the 2.7GHz band) scenario as well as in a frequency reuse of 1 scenario. The system will also support better granularity (down to 6bytes).

Normative Text

The following text provides instruction and normative text that should be inserted to 80216e-03_07r1 draft.
In order to have one readable section, some of the relevant section in 80216e-03_07r1 where replaced and moved into a new section. The instructions defines the specific editorial changes.

Do the following deletions:

[remove from 80216e-03_07r1 section 8.5.4.3 up to 8.5.4.7 from page 26 line 22 to page 28 line 27]
[remove from 80216e-03_07r1 section 8.5.6.4 from page 32 line 44 to page 35 line 56]

Do the following additions:
[push clause 8.5.10 and all subsequent clauses 8.5.x down by one, and insert a new clause 8.5.10]

8.5.10 Frequency Reuse of 1 for OFDMA

This clause defines extensions of OFDMA system for working in deployment scenarios with frequency reuse of 1.
The text provided defines the necessary modification of the prior OFDMA sections to support the frequency reuse 1 scenario, all other OFDMA definitions, when not redefined are as defined in the prior sections.

8.5.10.1 Introduction

The definition of an OFDMA system as defined in the above section is well suited to work with deployment scenarios with frequency reuse factor >1, but in order to satisfy requirement of reliability, coverage, capacity, spectral efficiency, location base service and mobility the system can be configured to work in a reuse of 1, which means the same RF frequency is allocated to all sectors in the cell. In this case a new scheme of work must be introduced in order to achieve the needed performance. A scenario using a reuse of 1 is given in Figure 1:

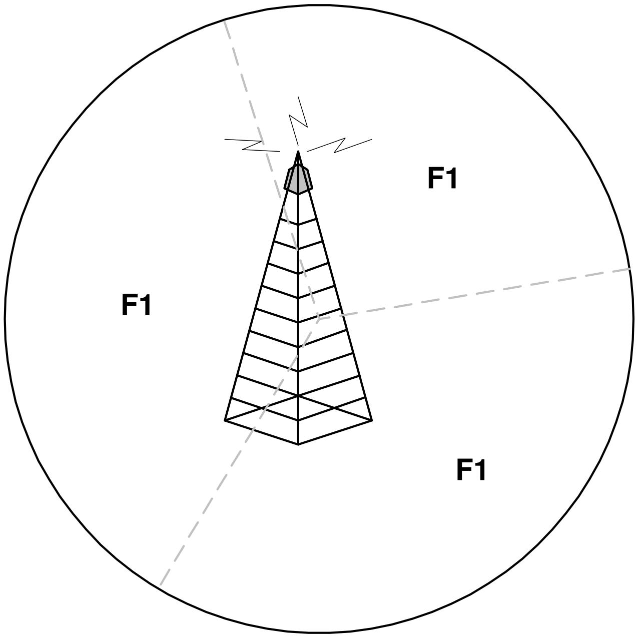

Figure 1: Reuse of 1 configuration, 3 sectors per cell

There are three options of operation in the reuse of 1 scenario:

- Asynchronous configuration- in this configuration every base-station uses its own permutation, the frame lengths and starting times are not synchronized among the base-stations. Therefore orthogonality is kept within the base-station but not between base-stations. In this scenario the base-stations could be synchronized or not to the same reference clock. This mode will introduce interference between base-station (sub-carriers from different sub-channels collide in a controlled way, determined by the different permutations). This configuration could be easily used as an independent low-cost hot spot deployment (as an example).
- Synchronous configuration - in this configuration all base-stations use the same reference clock (for example, by using GPS), the frame durations and starting times are also synchronized among the base-stations but still each base station uses different permutations. Therefore the time/frequency orthogonality is kept between and within the base-stations operation but still interference between the same sub-channels of different base-station occurs. Due to the time synchronization in this scenario and the long symbol duration of the OFDMA symbol, fast handoff as well as soft handoff is possible. This configuration could be used as an independent base-stations deployment with a controlled interference level (as an example).
- Coordinated Synchronous configuration - in this configuration all base-stations work in the synchronous mode but use also the same permutations. An upper layer is responsible for the handling of sub-channels allocations within the sectors of the base-station, making sure that better handling of the bandwidth is achieved and the system could handle and balance load between the sectors and within the system. This mode is identical in performance as the regular coverage scenarios [1], beside the fact that the bandwidth allocated to each sector is only a portion of the overall bandwidth, but when using the load balancing additional system gain is achieved. This configuration could be used as a full scale system deployment, with a common backbone (as an example).

The preferred scenario is of course the Coordinated Synchronous mode (when using this configuration with different permutations per base-station we get the synchronous mode, and if we do not use a synchronized clock between the base stations as well we end up with the asynchronous mode of operation); the configuration of the base-station sectors are presented in Figure 2

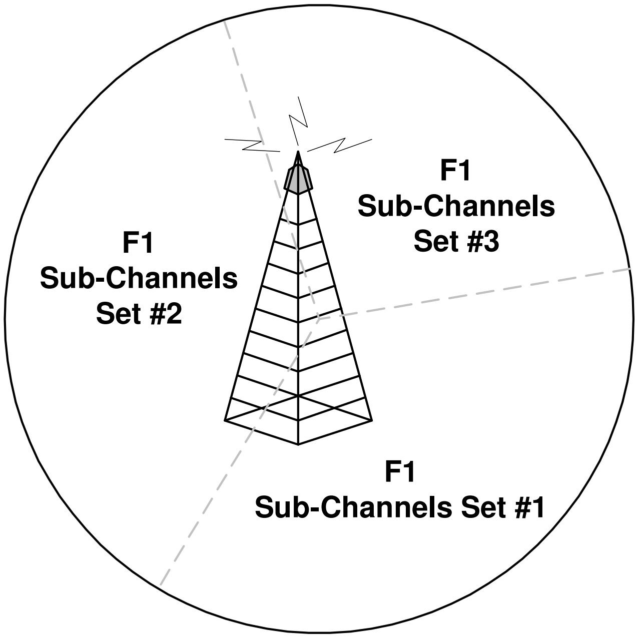

Figure 2: Reuse of 1 configuration using sub-channalization, 3 sectors per cell

8.5.10.2 Interoperability

Interoperability with the regular OFDMA systems can be done using the TDMA scheme in the time domain, or using the FDMA scheme in the frequency domain.

8.5.10.3 Downlink

The downlink supports up to 3 sectors and includes a preamble which begins the transmission, this preamble divides the used carriers into 6 sections, each 2 sections are used by a single sector, the motivation of this split is to allow the usage of 6 different preambles in the Space-Time Coding mode (STC).

A downlink period will follow Figure 3:

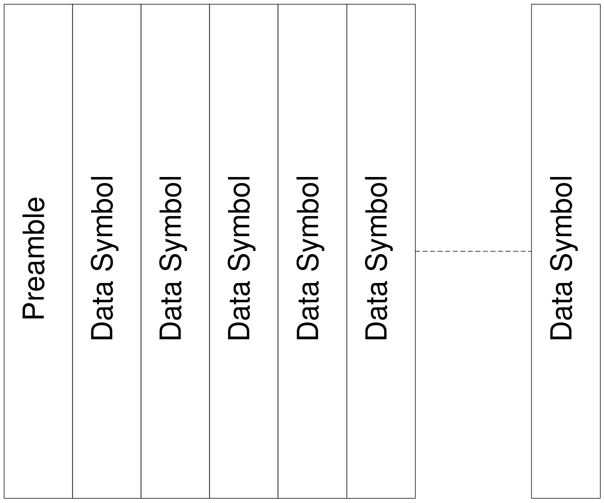

Figure 3: Downlink transmission basic structure

8.5.10.3.1 Preamble

The first symbol of the down link transmission is the preamble; there are 6 types of preambles. The preamble types are defined by allocation of different sub-carriers for each one of them; those sub-carriers are modulated after that using a non-boosted BPSK modulation with a specific Pseudo-Noise (PN) code.

The preambles are defined using the following formula:

$$Preamble_n = n + 6 * k$$

where:

$Preamble_n$ - specifies all carriers allocated to the specific preamble

n - specifies the number of the preamble indexed 0..5

k - is a running index 0..283/284 (the index is used while carrier number is ≤1702 – overall used carrier index)

Each sector uses 2 types of preamble out of the 6 sets in the following manner:

- Sector 1 uses preamble 0 and 3
- Sector 2 uses preamble 1 and 4
- Sector 3 uses preamble 2 and 5

Therefore each sector eventually modulates each 3'rd carrier, Figure 4 depicts as an example the preamble of sector 1:

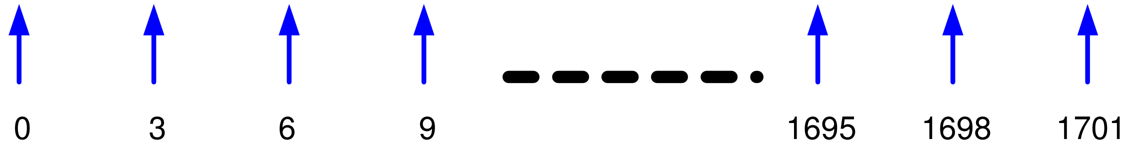

Figure 4: Downlink basic structure

The PN series modulating the pilots is the one defined in section 8.5.9.4.3. The initialization sequence for each preamble type is given in Table 1

Preamble Type (PNId)	PRBS Initialization	Wk (partial)
0	[01010101010]	010101010100000…
1	[00011101010]	000111010100000101…
2	[10011010011]	10011010011111001…

Table 1: Initialization sequence for the preamble PRBS

The modulation used on the preamble is in section 8.5.9.4.3.1, therefore the number of combination of PNId and preambles types are 9.

8.5.10.3.2 Symbol Structure

The symbol structure is constructed using pilots, data and zero carriers. The symbol is first allocated with the appropriate pilots and with zero carriers, and then all the remaining carriers are used as data carriers (these will be divided into sub-channels).

There are 6 possible allocations of pilots, in regular transmission each sector shall use 2 allocations each, in STC mode each antenna uses one out of those two, Table 2 summarizes the parameters of the symbol:

Parameter			Value	Remark
Number of DC Carriers			1	Index 1024
Number of Guard Carriers, Left			173	
Number of Guard Carriers, Right			172	
Number of Used Carriers (N_{used})			1702	Number of all carriers used within a symbol, including all allocated pilots for each sector
Number of fixed Pilots	Sector 1	Antenna 0	28	0,39,72,144,216,288,360,432,504,576, ,645,648,720,792,864,936,1008,1017,1080,1152, ,1224,1296,1368,1407,1440,1512,1584,1656
		Antenna 1	28	36,108,180,252,261,324,396,468,540,612, ,651,684,756,828,900,972,1044,1116,1143,1188, ,1260,1332,1404,1419,1476,1548,1620,1692
	Sector 2	Antenna 0	28	12,84,156,228,300,330,372,444,516,588, ,660,726,732,804,876,948,1020,1092,1155,1164, ,1236,1308,1380,1452,1461,1524,1596,1668
		Antenna 1	27	48,120,192,264,336,342,408,480,552,624, ,696,768,840,849,912,984,1056,1128,1158,1200, ,1272,1344,1416,1488,1530,1560,1632
	Sector 3	Antenna 0	28	24,96,168,240,312,351,384,456,528,600, ,672,744,816,855,888,960,1032,1104,1176,1185, ,1248,1320,1392,1464,1536,1545,1608,1680
		Antenna 1	27	60,132,204,276,348,420,492,522,564,636, ,708,780,852,918,924,996,1068,1140,1206,1212, ,1284,1356,1428,1500,1572,1644,1701

Number of data carriers	1536	
Number of data carriers per sub-channel	48	
Number of Sub-Channels	32	

Table 2: Initialization sequence for the preamble PRBS

The pilots' allocations are derived from the following formula:

$$Pilots_{n,k} = 12*n + 36*k + 72*i$$

where:

$Pilots_{n,k}$ - pilots indices allocated for sector n and antenna k

i - is a running index 0..26/27 (the index is used while carrier number is ≤1702 – overall used carriers index)

For regular transmission, each sector uses both types of antenna pilots for its transmission, therefore:

- Sector 1 uses 56 pilots
- Sector 2 uses 55 pilots
- Sector 1 uses 55 pilots

Figure 5 depicts as an example of the symbol allocation for sector 1:

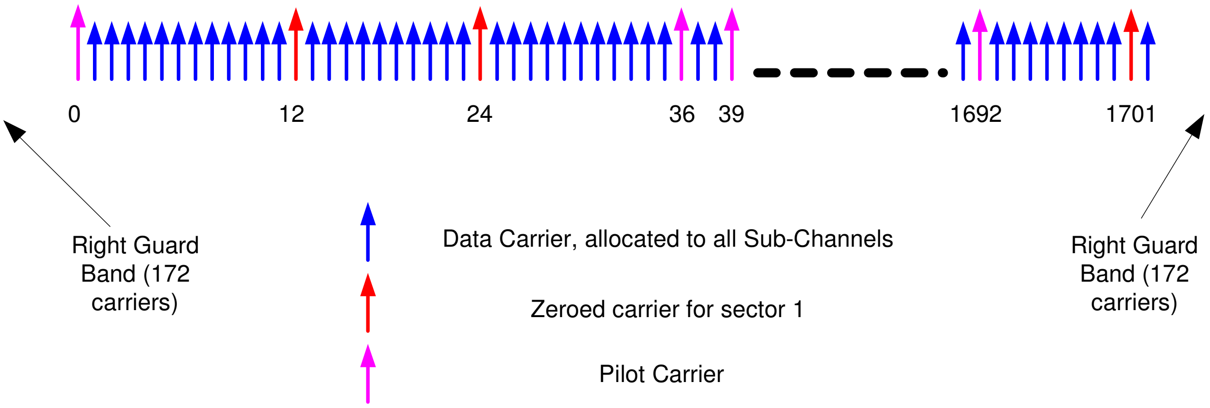

Figure 5: Downlink symbol structure for sector 1

The PN series modulating the pilots is the one defined in section 8.5.9.4.3.
The initialization sequence for each Sector type is given in Table 3

PNId	Initialization B
0	[10111000101]
1	[01000101010]
2	[11001010111]

Table 3: Initialization sequence for the PRBS used to modulate the symbol pilots

The modulation used on the preamble is in section 8.5.9.4.3.

8.5.10.3.2.1 Downlink Sub-Channels carrier allocation

Each Sub-Channel is composed of 48 carriers, and is an independent entity in the base-band processing (each sub-channel data is randomized, encoded and interleaved separately, therefore it can be decoded separately).

The sub-channel indices are formulated using a Reed-Solomon series, and is allocated out of the data sub-carriers domain. The data sub-carriers domain includes 48*32=1536 carriers, which are the remaining carriers after removing from the carrier's domain (0-2047) all possible pilots and zero carriers (including the DC carrier).

After allocating the data sub-carriers domain the procedure specified in section 8.5.6.1.2.

8.5.10.3.3 Allocation of sub-channels for DL Frame Prefix, and logical sub-channel numbering

The minimal allocation of sub-channels for a sector (if the sector is used) is 3 sub-channels, these sub-channels are always modulated using QPSK and has coding rate of 1/2. The data enclosed in those sub-channels, called the DL Frame Prefix, is specified in section 8.5.10.3.3.1, for sector 1 Sub-channels 0-2 are used as the basic allocated Sub-Channels, for Sector 2 Sub-channels 11-13, for sector 3 Sub-channels 22-24, Figure 6 depicts this structure

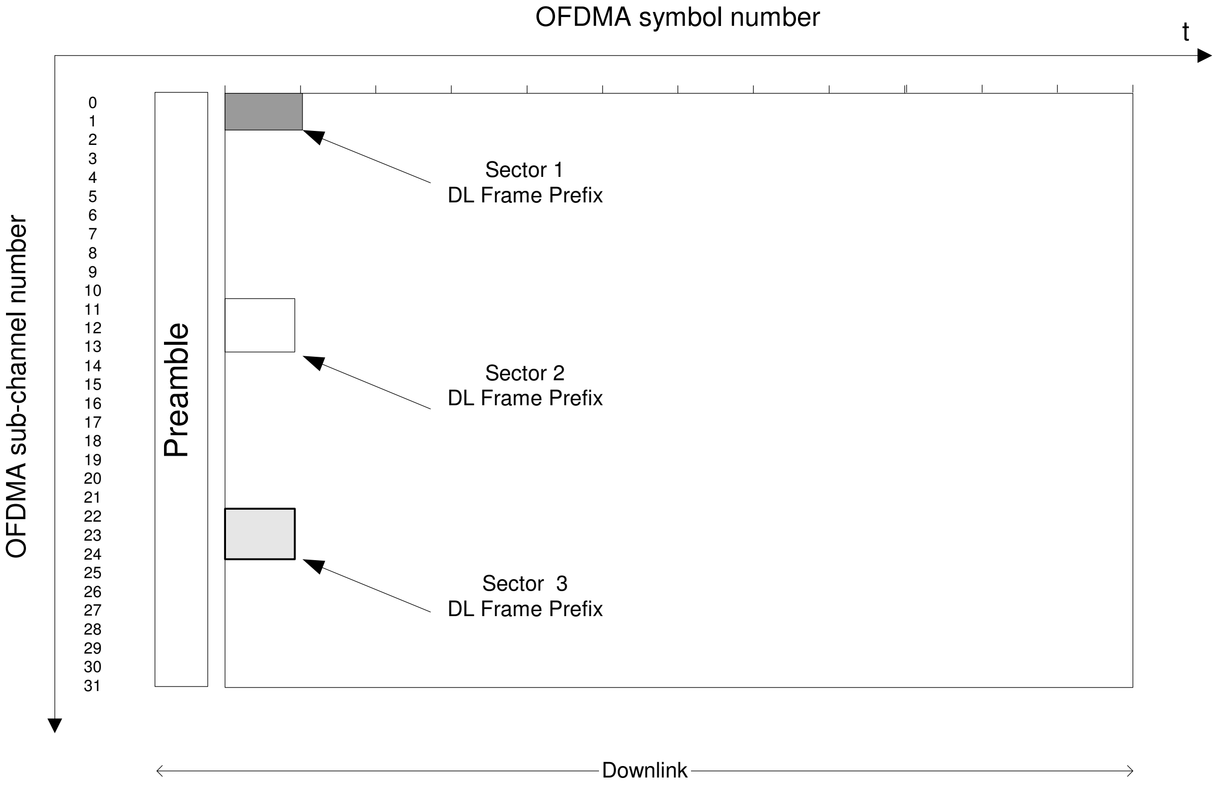

Figure 6: DL Frame Prefix sub-channel allocation for all 3 sectors

After decoding the DL Frame Prefix the SU has the knowledge of how many and which sub-channels are allocated to the sector. In order to observe the allocation of the sub-channels as a contiguous block of allocation the sub-channels shall be renumbered, the renumbering shall start from the DL Frame Prefix sub-channels (renumbered to values 0..2), then continue numbering the sub-channels in a cyclic manner to the last allocated sub-channel and from the first allocated sub-channel to the DL Frame Prefix Sub-Channels, Figure 7 gives an example of such renumbering for sector 2.

	Physical Enumeration	Logical Enumeration (Renumbered)
	SC 7	SC 7
DL Frame Prefix	SC 11	SC 0
DL Frame Prefix	SC 12	SC 1
DL Frame Prefix	SC 13	SC 2
	SC 14	SC 3
	SC 18	SC 4
	SC 27	SC 5
	SC 31	SC 6

Figure 7: Example of renumbering the allocated sub-channels for sector 2

8.5.10.3.3.1 DL_Frame_Prefix

The DL_Frame_Prefix is a data structure transmitted at the beginning of each frame and contains information regarding the current frame.
The DL_Frame_Prefix is always transmitted using QPSK-1/2 with the mandatory coding scheme.

Table 4 defines the structure of DL_Frame_Prefix.

Syntax	Size	Notes
DL_Frame_Prefix_Format() {		
Ranging_Change_Indication	1 bits	
DL_Map_Length	7 bits	
Sub_Channel_Bitmap	32 bits	
Prefix_CS	8 bits	
}		

Table 4: OFDMA DL Frame Prefix format

DL_Map_Length

Defines the length in slots of the DL_Map message that follows immediately the DL_Frame_Prefix.

Ranging_Change_Indication

A flag that indicates whether this frame contains a change of the allocation of Periodic Ranging/BW Request UL regions comparing to the previous frame. A value of ‘1’ means that a change has occurred, and value of ‘0’ means that the allocations of Periodic Ranging/BW Request regions in the current frame are the same as in the previous frame.

Sub_Channel_Bitmap

An 32-bit field that defines a bitmap representing the sub-channels which are allocated to this sector. Each bit represent a sub-channel with same enumerated value, a value ‘1’ means that the sub-channel represented by the bit is allocated to the sector.

Prefix_CS

An 8-bit checksum for the DL-Frame prefix fields. The generator polynomial shall be: $g(x) = x^8 + x^2 + x + 1$.

8.5.10.4 Uplink

The following section defines the uplink transmission and symbol structure.
The uplink follows the downlink model, therefore it also supports up to 3 sectors. Two formats of transmission in the uplink are supported:

- Regular Sub-Channel of 53 carriers (32 Sub-Channels overall)
- Mini Sub-Channel of 21/22 carriers (80 mini Sub-Channels overall)

Each transmission uses 48 symbols as their minimal block of processing, each new transmission commences with a preamble (which is modulated on the allocated Sub-Channels only), allocations of sub-channels to users are done with the granularity of one Sub-Channel / mini Sub-Channel.

8.5.10.4.1 Symbol Structure

The symbols structure supported in the uplink are specified hereafter.

8.5.10.4.1.1 Symbol Structure for regular Sub-Channel

The symbol structure shall follow section 8.5.6.1.

8.5.10.4.1.2 Symbol Structure for mini Sub-Channel

The regular Sub-Channel in the DL shall be further divided to create the mini sub-channels, every to adjunct sub-channels (where the first one is the even sub-channel) shall be divided into 5 mini sub-channels. The 106 carriers will be divided into 5 groups, 4 of them containing 21 carriers and the last containing 22 carriers. In each mini sub-channel 16 carriers are allocated for data and the rest are allocated as pilots.

The carriers which obey the following formula, are allocated to one mini sub-channel:

$$\mathrm{mod}(Carrier(j,i),5) = k$$

where:

$Carrier(j,i)$ - defines carrier j of sub-channel i, as defined in 8.5.6.1.2

k - defines mini sub-channel k, 0..4.

The overall numbering of the mini sub-channels shall start from the first two sub-channels divided into 5 mini sub-channels and follow each two adjunct sub-channels which are divided, for a total of 80 mini sub-channels numbered 0..79.

Figure 8 and Figure 9 depict the mini sub-channel organization:

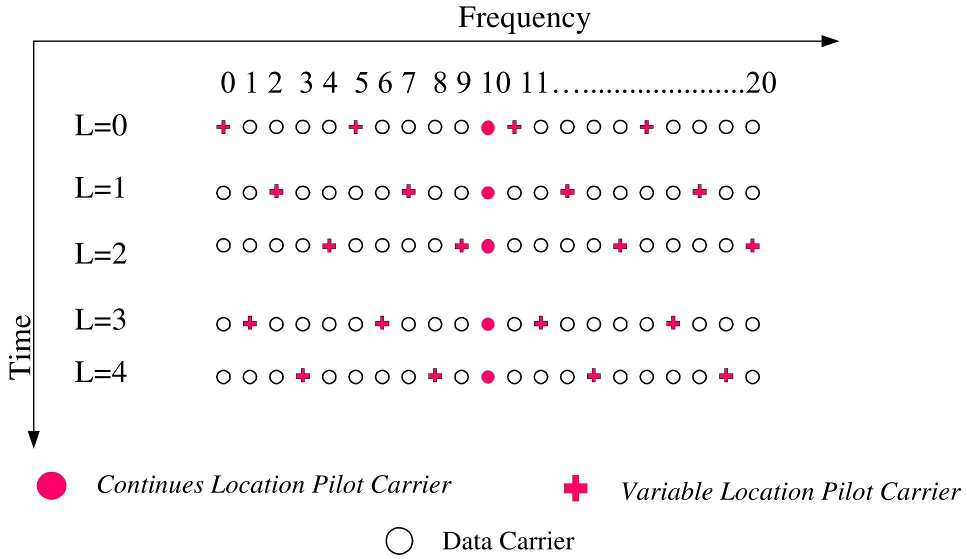

Figure 8: Mini Sub-Channel (of 21 carriers) izationorgan and structure

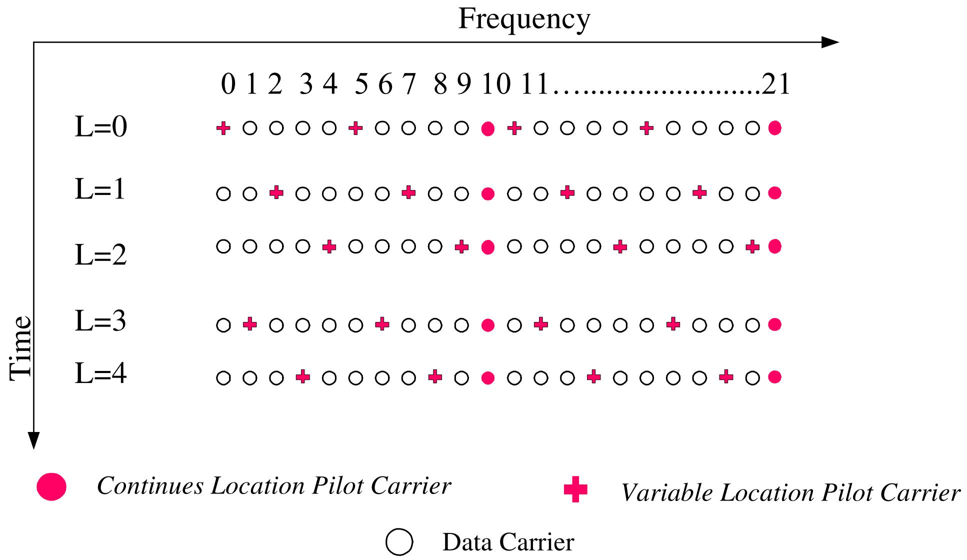

Figure 9: Mini Sub-Channel (of 21 carriers) organization and structure

The structure proposed will enable a module 5 frame structure, with maximum frequency diversity.

8.5.10.4.1.3 Burst Structure using regular sub-channels

The burst structure consists of the preamble and one time symbol following it as the basic structure. Allocating more sub-channels or/and time symbols could expand the burst; in any case the preamble is transmitted at the beginning of the burst on all allocated sub-channels. This is depicted in Figure 10

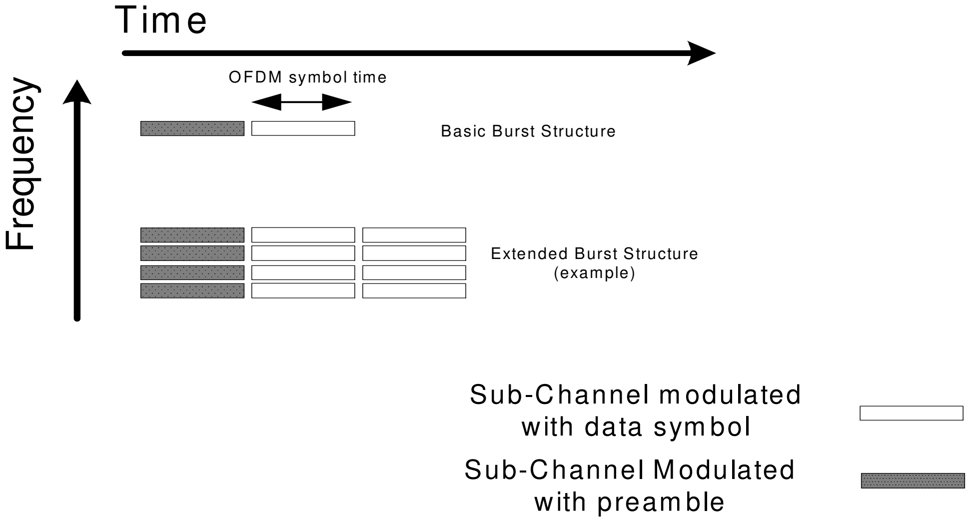

Figure 10: Burst Structure using regular sub-channel

8.5.10.4.1.4 Burst Structure using mini sub-channels

The burst structure consists of the preamble and 3 time symbols following it as the basic structure. Allocating more sub-channels or/and multiples of 3 time symbols could expand the burst; in any case the preamble is transmitted at the beginning of the burst on all allocated mini sub-channels. This is depicted in Figure 11

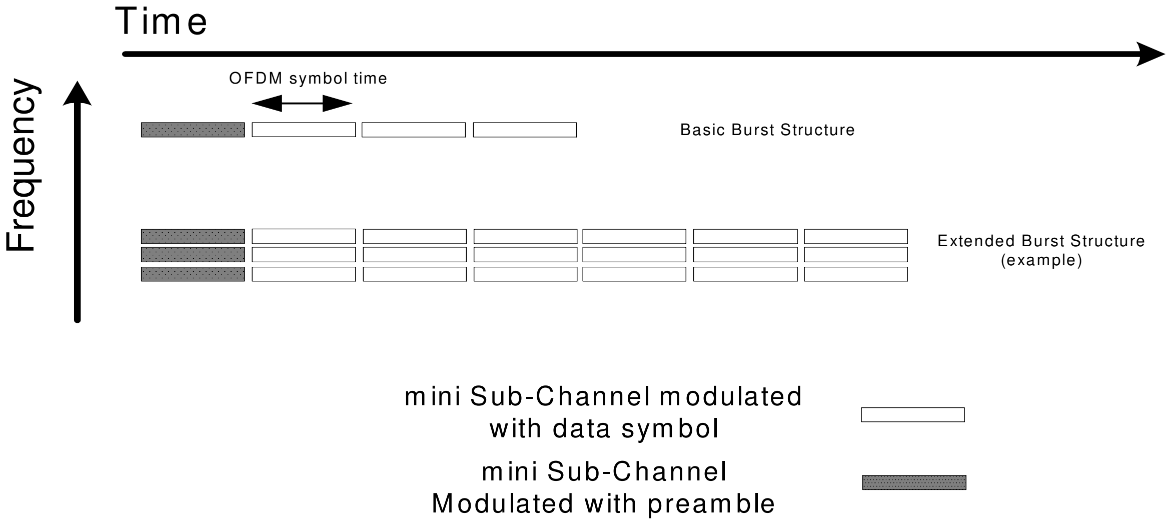

Figure 11: Burst Structure using mini sub-channel

8.5.10.5 Channel Coding

Channel coding includes the following processes:

- Randomization
- Encoding
- Bit-Interleaving
- Modulation

These processes are performed in the uplink and downlink in the same manner.

8.5.10.5.1 Randomization

As in section 8.5.9.1.

8.5.10.5.2 Encoding

The coding method used as the mandatory scheme will be the tail biting convolutional encoding specified in section 8.5.9.2.1 and the optional modes of encoding in sections 8.5.9.2.2 and 8.5.9.2.2 shall be also supported.

The encoding block size shall depend on the number of sub-channels/mini sub-channels allocated and the modulation specified for the current transmission.

Concatenation of a number of sub-channels/mini sub-channels shall be performed when using QPSK modulation in order to make larger blocks of coding where it is possible, with the limitation of not passing the largest block under the same coding rate (the block defined by 64QAM modulation). Table 5 specifies the concatenation of sub-channels for different allocations and modulations. In the following sections parameters for encoding 64QAM rate 1/2 is given in the tables, these should be used for the concatenated case of the QPSK only, because there is no use of this combination of modulation and coding rate.

Number of Sub-Channel / mini Sub-Channels allocated	Modulation	Sub-Channels concatenated	Remarks
1	QPSK	1	When using 1 Sub-channel concatenation is not performed
2	QPSK	2	Using the 16QAM configuration
3	QPSK	3	Using the 64QAM configuration
4	QPSK	2,2	Using twice the 16QAM configuration
5	QPSK	3,2	Using the 64QAM then the 16QAM configuration
6	QPSK	3,3	Using twice the 64QAM configuration
n>6 (mod(n,3)=1)	QPSK	3,..,3,2,2	Using 64QAM, last two encoding done with 16QAM configuration
n>6 (mod(n,3)=2)	QPSK	3,..,3,3,2	Using 64QAM, last encoding done with 16QAM configuration

n>6 (mod(n,3)=0)	QPSK	3,..,3,3,3	Using only the 64QAM configuration
Not relevant	16QAM	1	Concatenation is never performed
Not relevant	64QAM	1	

Table 5: Encoding Sub-Channel concatenation for different allocations and modulations

8.5.10.5.2.1 Tail-Biting Convolutional Encoding

The convolutional encoding scheme is specified in section 8.5.9.2.1 (without the RS encoding part).
Table 6 defines the basic sizes of the useful data payloads to be encoded in relation with the selected modulation type and encoding rate.

	QPSK		**16 QAM**		**64 QAM**		
Encoding rate	R=1/2	R=3/4	R=1/2	R=3/4	R=1/2	R=2/3	R=3/4
Data payload in 48 symbols	6 bytes	9 bytes	12 bytes	18 bytes	18 bytes	24 Bytes	27 bytes

Table 6: useful data payload for a sub-channel

8.5.10.5.2.2 Block Turbo Code (BTC)

The BTC scheme is specified in section 8.5.9.2.2.
The parameters used for the encoding process shall follow TBD

8.5.10.5.2.3 Convolutional Turbo Code (CTC)

The CTC scheme is specified in section 8.5.9.2.3.
The parameters used for the encoding process shall follow TBD

Modulation	Data Block Size (Bytes)	Data Block Size (Bytes)	Code Rate	N	P0	P1	P2	P3
QPSK	6	12	1/2	24	5	0	0	0
QPSK	9	12	3/4	36	11	18	0	18
16QAM	12	24	1/2	48	13	24	0	24
16QAM	18	24	3/4	72	11	6	0	6
64QAM	18	24	1/2	72	11	6	0	6
64QAM	27	36	2/3	96	7	48	24	72
64QAM	27	36	3/4	108	11	54	56	2

8.5.10.5.3 Bit-Interleaving

Using the same scheme as defined in section 8.5.9.3 with the parameters defined in Table 7:

Modulation	Coded Bits per Bit Interleaved Block (N_{cbps})	Modulo used (d)
QPSK	96	16
16 QAM	192	16
64 QAM	288	16

Table 7: Bit-Interleaver Block Sizes

8.5.10.5.4 Modulation

As in section 8.5.9.4.

8.5.10.6 STC mode

The STC mode of operation is based on the PHY layer defined in sections 8.5.10.38.5.10.4, **Error! Reference source not found.**

8.5.10.6.1 STC Encoding/Decoding

As defined in sections 8.5.8.2 and 8.5.8.3.

8.5.10.6.2 Downlink

The changes between the regular mode and the STC mode are in the usage of the Preambles and the structure of the symbol, all other elements remain the same.

8.5.10.6.2.1 Preamble

For each sector as defined in previous sections, two antennas are used to transmit the STC signal. Therefore from the definition in section 8.5.10.3.1, the following applies:

Each sector uses 2 types of preamble (one for each antenna) out of the 6 sets in the following manner:
- Sector 1 - preamble 0 used by antenna 0, preamble 3 used by antenna 1
- Sector 1 - preamble 0 used by antenna 1, preamble 4 used by antenna 1
- Sector 1 - preamble 0 used by antenna 2, preamble 5 used by antenna 1

The same PN series as defined in that section is also used in the STC mode.

8.5.10.6.2.2 Symbol Structure

The same symbol structure defined in section 8.5.10.3.18.5.10.3.2 shall apply for the STC mode, the amount of pilots allocated to each antenna and their details are also specified in that section (antenna shall use a subset of the pilots used by the sector).

8.5.10.6.3 Downlink

Not changed compared to the regular mode of operation.

8.5.10.6.4 Channel coding

As defined in 8.5.10.5.

8.5.10.7 2K OFDMA Soft Handoff

A 2K OFDMA system may use a soft handoff scheme for dealing with problems of fading and attenuations at the cell boundary for MSS performing handoff. In such scenarios, the MSS may not be able to communicate satisfactorily with the serving BS and the target BS.

Such cases may force the MSS to perform hard handoff, i.e. break the connection with the serving BS and go and perform re-attachment to the target BS. During the hard handoff process, the MSS will not be able to receive any data until a completion of the registration process with the target BS.

The 2K OFDMA system can improve the hard handoff process by using a soft handoff process, in which, the MSS is able to continuously receive data transmission at the cell boundary from the serving BS and from the target BS simultaneously.

8.5.10.7.1 Soft Handoff Procedures

TBD

8.5.10.7.2 Soft Handoff Messages

TBD

References

[1] IEEE C802.16e-03/22r1 “Coverage simulations for OFMDA PHY mode”
[2] IEEE Std 802.16-2001 “Part 16: Air Interface for Fixed Broadband Wireless Access Systems”
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