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Re:	Contribution on comments to IEEE 802.16e-03/07r6
Abstract	Contribution elaborating on possible extension of the 802.16d OFDMA PHY layer
Purpose	To be integrated into IEEE 802.16e-03/07r7 document
Notice	
Release	
Patent Policy and Procedures	

Applying scalability for the OFDMA PHY layer

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1 Introduction

The OFDMA PHY defined in the 802.16d uses a 2K FFT for its operation. This configuration shows good performance for channels using high bandwidth allocation (as will be shown in the document). In order to extend its performance for lower bandwidth channels it is recommended to apply some scalability to the 802.l6d OFDMA PHY. This document shall elaborate on a simple and effective way to make these changes.

2 Evaluation of performance

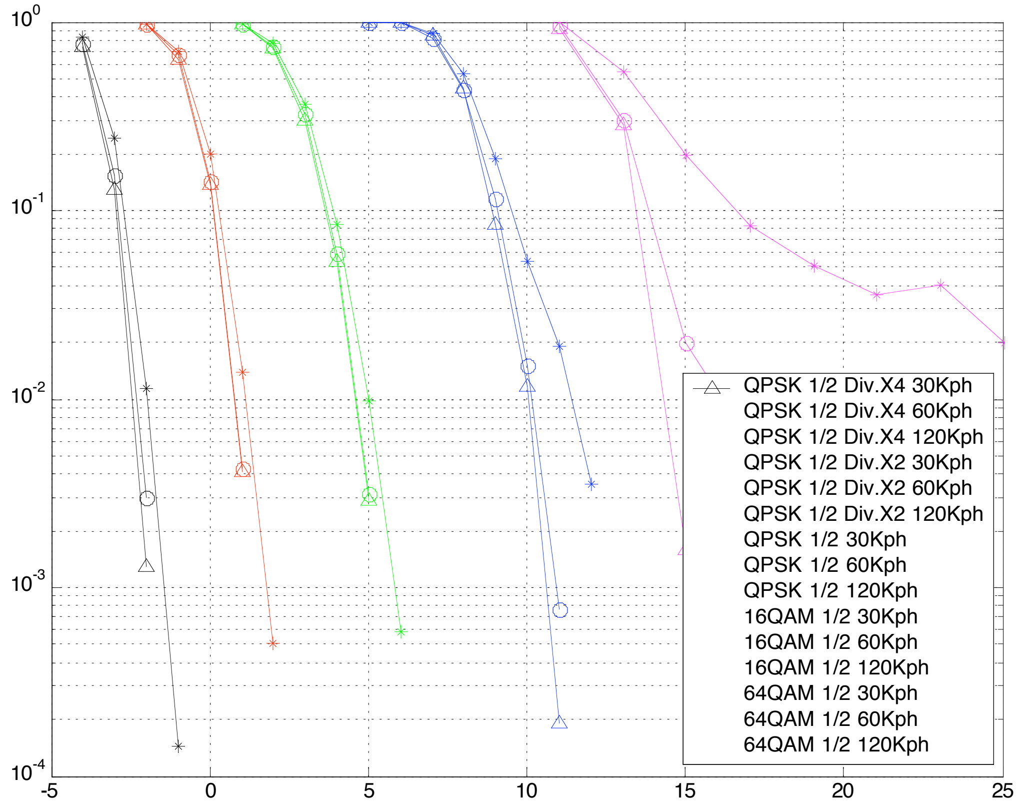
The current PHY performance was evaluated in former documents:

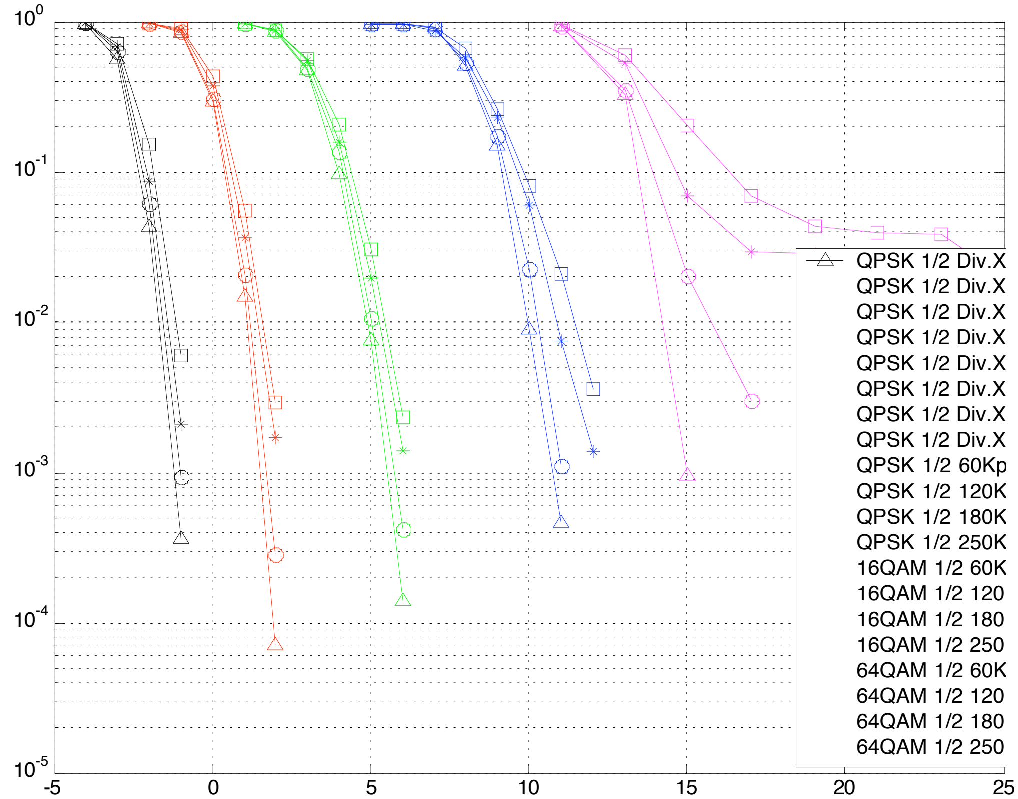
- IEEE C802.16d-03/78r1 - Coverage/Capacity simulations for OFDMA PHY in with ITU-T channel model
- IEEE C802.16e-04/16 - Coverage/Capacity simulations for OFDMA PHY in ITU-T channel model including MRC, STC, AAS results

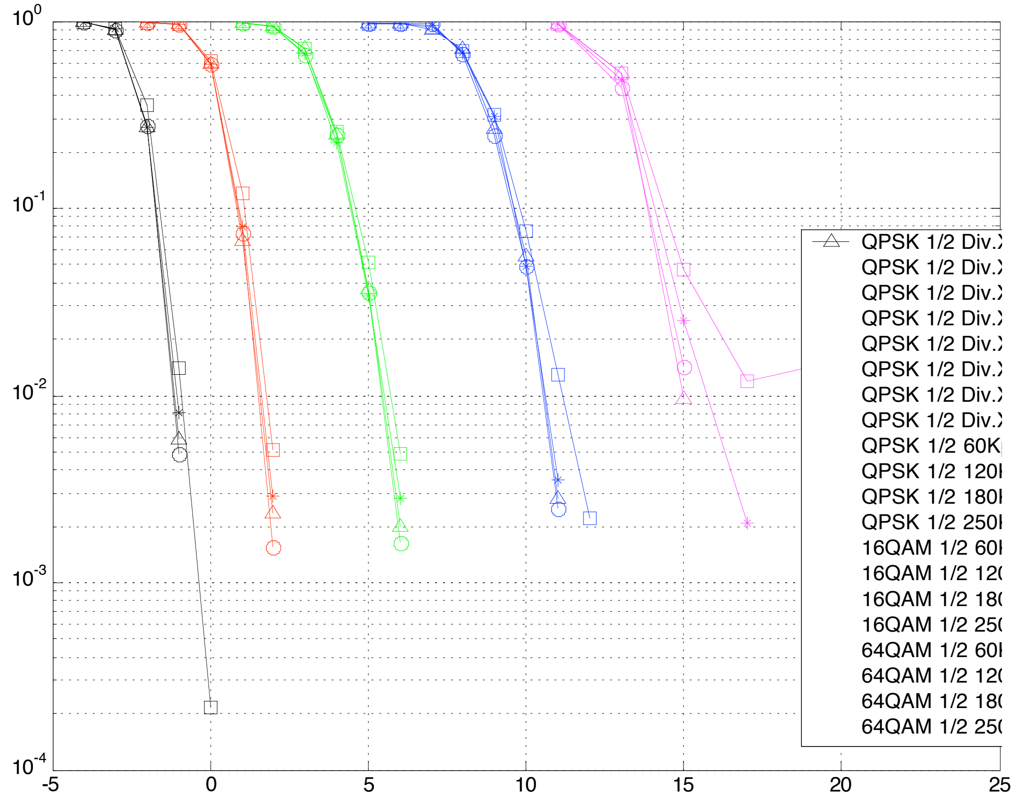
The performance of the PHY layer has shown very good performance even for high mobility (especially for high channel bandwidth >= 5MHz). Some of the results are reproduced hereafter for convenience and for further analysis; the simulation environment included the following:

- DL PUSC/FUSC models of the IEEE802.16d OFDMA PHY
- Real channel estimation process
- Block sizes of 384-576bits (depending on modulation)
- Covolutional Turbo Code scheme using code rate _
- Phase noise model with a power of -85dBc/Hz flat up to 10KHz and then reducing 20dB/dec up to -120
- ITU-B model for vehicular speeds

The following graphs presents the performance of the PHY for 2.5,5,10MHZ channel bandwidth (title of the graph describes the scenario, legend describes the different modulations and speeds tested).


10^0
10^-1
10^-2
10^-3
10^-4
-5
0
5
10
15
20
25
QPSK 1/2 Div.X4 30Kph
QPSK 1/2 Div.X4 60Kph
QPSK 1/2 Div.X4 120Kph
QPSK 1/2 Div.X2 30Kph
QPSK 1/2 Div.X2 60Kph
QPSK 1/2 Div.X2 120Kph
QPSK 1/2 30Kph
QPSK 1/2 60Kph
QPSK 1/2 120Kph
16QAM 1/2 30Kph
16QAM 1/2 60Kph
16QAM 1/2 120Kph
64QAM 1/2 30Kph
64QAM 1/2 60Kph
64QAM 1/2 120Kph


10^0
10^-1
10^-2
10^-3
10^-4
10^-5
-5
0
5
10
15
20
25
QPSK 1/2 Div.X
QPSK 1/2 Div.X
QPSK 1/2 Div.X
QPSK 1/2 Div.X
QPSK 1/2 Div.X
QPSK 1/2 Div.X
QPSK 1/2 Div.X
QPSK 1/2 Div.X
QPSK 1/2 60Kp
QPSK 1/2 120K
QPSK 1/2 180K
QPSK 1/2 250K
16QAM 1/2 60K
16QAM 1/2 120
16QAM 1/2 180
16QAM 1/2 250
64QAM 1/2 60K
64QAM 1/2 120
64QAM 1/2 180
64QAM 1/2 250



The performance for 10MHz channel BW shows clearly that the PHY supports speeds of up to 250Kmph even for 16QAM and 180Kph for 64QAM with a small degradation. For lower bandwidth the maximum speed declines but the 2K mode can support very high mobility with lower modulations (where for higher modulations some degradation is noticeable).

Taking the performance of the PHY into consideration and the IEEE802.16d definition to support bandwidths starting from 1.25MHz, it is evident that for the IEEE802.16e some additions to standard are appropriate to support very high mobility better for low channel bandwidth allocations.

3 Suggested modifications (Scalability)

A possible solution to the requirements of the IEEE802.16e and the actual OFDMA PHY defined for IEEE802.16d is to use smaller FFT sizes in order to compensate on the large symbol times for lower bandwidths enforced by the 2K FFT. The solution can include adding a configuration of the current OFDMA PHY to be used with 1K or/and 512 FFT size.
Scaling the performance of the 2K mode in the graphs shown before it could be deducted that the performance of the 2K mode FFT for 10MHz will be reproduced by a 512 FFT sizes for 2.5MHz (and so on).

These new definitions for 1K/512 FFT size could be easily incorporated as optional elements of the OFDMA PHY by changing some basic parameters. The major thing to be changed is the definition of the symbol structure for these FFT sizes (duplicating table 247 and 247a – new addition).

4 Specific text changes

[Add the following text at the end of section 8.4.1]

The mandatory OFDMA PHY mode that shall be supported by all SS is based on a 2048-FFT. Other FFT sizes may optionally be employed as well. These FFT sizes are scalable to the channel BW in which they are being used, i.e., 512-FFT for 5 MHz channel BW or less and 1024-FFT for 10 MHz channel BW or less. Any configuration shall use the 2048-FFT for at least one frame duration every one second.

[Add the following text in section 8.4.6.1.1 just before table 246]
For FFT size other than 2048-FFT, only the first k elements of table 246 shall be used to modulate the DL preamble sub-carriers, where k is the number of carriers

[Add the following table in section 8.4.6.1.2]

Table 247— 2048-FFT OFDMA downlink carrier allocations

Parameter	Value	Comments
Number of DC Subcarriers	1	Index 1024
Number of Guard Subcarriers, Left	172	
Number of Guard Subcarriers, Right	173	
Number of Used Subcarriers (Nused)	1703	Number of all subcarriers used within a symbol, including all possible allocated pilots and the DC carrier.
Pilots		
VariableSet #0	24	0,72,144,216,288,360,432,504,576,648,720, 792,864,936,1008,1080,1152,1224,1296,1368, 1440,1512,1584,1656
ConstantSet #0	4	39,645,1017,1407
VariableSet #1	24	36,108,180,252,324,396,468,540,612,684,756, 828,900,972,1044,1116,1188,1260,1332,1404, 1476,1548,1620,1692
ConstantSet #1	4	261,,651,1143,1419
VariableSet #2	24	48,120,192,264,336,408,480,552,624,696,768,840, 912,984,1056,1128,1200,1272,1344,1416, 1488,1560,1632
ConstantSet #2	4	330,726,1155,1461
VariableSet #3	24	12,84,156,228,300,372,444,516,588,660,732, 804,876,948,1020,1092,1164,1236,1308,1380, 1452,1524,1596,1668
ConstantSet #3	4	342,849,1158,1530
VariableSet #4	24	24,96,168,240,312,384,456,528,600,672,744,816, 888,960,1032,1104,1176,1248,1320,1392,1464, 1536,1608,1680
ConstantSet #4	4	351,855,1185,1545
VariableSet #5	23	60,132,204,276,348,420,492,564,636,,708,780,852, 924,996,1068,1140,1212,1284,1356,1428,1500, 1572,1644
ConstantSet #5	4	522,918,1206,1701
Number of data subcarriers	1536	
Number of data subcarriers per subchannel	48	
Number of Subchannels	32	
PermutationBase		3, 18, 2, 8, 16, 10, 11, 15, 26, 22, 6, 9, 27, 20, 25, 1, 29, 7, 21, 5, 28, 31, 23, 17, 4, 24, 0, 13, 12, 19, 14, 30

Table 247a— 1024-FFT OFDMA downlink carrier allocations

Parameter	Value	Comments
Number of DC Subcarriers	1	Index 512
Number of Guard Subcarriers, Left	86	
Number of Guard Subcarriers, Right	87	
Number of Used Subcarriers (Nused)	851	Number of all subcarriers used within a symbol, including all possible allocated pilots and the DC carrier.
Pilots		
VariableSet #0	12	0,72,144,216,288,360,432,504,576,648,720, 792
ConstantSet #0	2	39,645
VariableSet #1	12	36,108,180,252,324,396,468,540,612,684,756, 828
ConstantSet #1	2	261, 651
VariableSet #2	12	48,120,192,264,336,408,480,552,624,696,768,840
ConstantSet #2	2	330,726
VariableSet #3	12	12,84,156,228,300,372,444,516,588,660,732, 804
ConstantSet #3	2	342,848
VariableSet #4	12	24,96,168,240,312,384,456,528,600,672,744,816
ConstantSet #4	2	351,850
VariableSet #5	11	60,132,204,276,348,420,492,564,636,708,780
ConstantSet #5	1	522
Number of data subcarriers	768	
Number of data subcarriers per subchannel	48	
Number of Subchannels	16	
PermutationBase		6, 14, 2, 3, 10, 8, 11, 15, 9, 1, 13, 12, 5, 7, 4, 0

Table 247b— 512-FFT OFDMA downlink carrier allocations

Parameter	Value	Comments
Number of DC Subcarriers	1	Index 256
Number of Guard Subcarriers, Left	43	
Number of Guard Subcarriers, Right	43	
Number of Used Subcarriers (Nused)	426	Number of all subcarriers used within a symbol, including all possible allocated pilots and the DC carrier.
Pilots		
VariableSet #0	6	0,72,144,216,288,360
ConstantSet #0	1	39
VariableSet #1	6	36,108,180,252,324,396
ConstantSet #1	1	261
VariableSet #2	6	48,120,192,264,336,408
ConstantSet #2	1	330
VariableSet #3	6	12,84,156,228,300,372
ConstantSet #3	1	342

VariableSet #4	6	24,96,168,240,312,384
ConstantSet #4	1	351
VariableSet #5	6	60,132,204,276,348
ConstantSet #5	1	420
Number of data subcarriers	384	
Number of data subcarriers per subchannel	48	
Number of Subchannels	8	
PermutationBase		7,4,0,2,1,5,3,6

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Table 247c— 2048-FFT OFDMA downlink carrier allocations

Parameter	Value	Comments
Number of DC Subcarriers	1	index 1024
Number of Guard Subcarriers, Left	183	
Number of Guard Subcarriers, Right	184	
Number of Used Subcarriers (Nused) including all possible allocated pilots and the DC carrier.	1681	Number of all subcarriers used within a symbol
renumbering sequence	6, 108, 37, 81, 31, 100, 42, 116, 32, 107, 30, 93, 54, 78, 10, 75, 50, 111, 58, 106, 23, 105, 16, 117, 39, 95, 7, 115, 25, 119, 53, 71, 22, 98, 28, 79, 17, 63, 27, 72, 29, 86, 5, 101, 49, 104, 9, 68, 1, 73, 36, 74, 43, 62, 20, 84, 52, 64, 34, 60, 66, 48, 97, 21, 91, 40, 102, 56, 92, 47, 90, 33, 114, 18, 70, 15, 110, 51, 118, 46, 83, 45, 76, 57, 99, 35, 67, 55, 85, 59, 113, 11, 82, 38, 88, 19, 77, 3, 87, 12, 89, 26, 65, 41, 109, 44, 69, 8, 61, 13, 96, 14, 103, 2, 80, 24, 112, 4, 94, 0	used to renumber clusters before allocation to subcchannels:
Number of carriers per cluster	14	Number of all subcarriers used within a symbol,
Number of clusters	120	
Number of carriers per subchannel	24	
Number of subchannels	60	
PermutationBase12 (for 12 subchannels)	6,9,4,8,10,11,5,2,7,3,1,0	
PermutationBase8 (for 8 subchannels)	7,4,0,2,1,5,3,6	

[Add the following table in section 8.4.6.1.2]

Table 247d— 1024-FFT OFDMA downlink carrier allocations

Parameter	**Value**	**Comments**
Number of DC Subcarriers	1	index 512
Number of Guard Subcarriers, Left	91	
Number of Guard Subcarriers, Right	92	
Number of Used Subcarriers (Nused) including all possible allocated pilots and the DC carrier.	841	Number of all subcarriers used within a symbol
renumbering sequence	6, 48, 37, 21, 31, 40, 42, 56, 32, 47, 30, 33, 54, 18, 10, 15, 50, 51, 58, 46, 23, 45, 16, 57, 39, 35, 7, 55, 25, 59, 53, 11, 22, 38, 28, 19, 17, 3, 27, 12, 29, 26, 5, 41, 49, 44, 9, 8, 1, 13, 36, 14, 43, 2, 20, 24, 52, 4, 34, 0	used to renumber clusters before allocation to subchannels:
Number of carriers per cluster	14	Number of all subcarriers used within a symbol,
Number of clusters	60	
Number of carries per subchannel	24	
Number of subchannels	30	
PermutationBase6 (for 6 subchannels)	3,2,6,4,5,1	
PermutationBase4 (for 4 subchannels)	3,4,2,1	

Table 247e— 512-FFT OFDMA downlink carrier allocations

Parameter	Value	Comments
Number of DC Subcarriers	1	index 256
Number of Guard Subcarriers, Left	45	
Number of Guard Subcarriers, Right	46	
Number of Used Subcarriers (Nused) including all possible allocated pilots and the DC carrier.	421	Number of all subcarriers used within a symbol
renumbering sequence	12, 13, 26, 9, 5, 15, 21, 6, 28, 4, 2, 7, 10, 18, 29, 17, 16, 3, 20, 24, 14, 8, 23, 1, 25, 27, 22, 19, 11, 0	used to renumber clusters before allocation to subchannels:
Number of carriers per cluster	14	Number of all subcarriers used within a symbol,
Number of clusters	30	
Number of carries per subchannel	24	

Number of subchannels	15	
PermutationBase6 (for 6 subchannels)	3,1,2	
PermutationBase4 (for 4 subchannels)	3,4,2,1	

[Add the following table in section 8.4.6. 2]

UL parameters for the 2K mode are reproduced here (assuming some changes accepted during the letter ballot)

Parameter	Value	Comments
Number of DC Subcarriers	1	index 1024
Number of Guard Subcarriers, Left	183	
Number of Guard Subcarriers, Right	184	
Number of Used Subcarriers (Nused) including all possible allocated pilots and the DC carrier.	1681	Number of all subcarriers used within a symbol
PermutationBase0	12, 26, 66, 18, 33, 15, 65, 5, 6, 19, 46, 42, 61, 24, 40, 35, 41, 48, 68, 44, 16, 7, 32, 2, 38, 9, 58, 56, 30, 47, 55, 17, 20, 59, 69, 57, 43, 3, 51, 36, 54, 4, 64, 63, 50, 23, 27, 8, 45, 29, 34, 28, 21, 1, 25, 53, 62, 37, 67, 31, 60, 11, 13, 39, 22, 14, 52, 49, 10, 0,	used to allocate tiles to subchannels
Number of carriers per tile	4	Number of all subcarriers used within a tile
Number of tiles	420	
Number of tiles per subchannel	6	
Number of subchannels	70	

A table for a 1K FFT UL :

Parameter	Value	Comments
Number of DC Subcarriers	1	index 512
Number of Guard Subcarriers, Left	91	
Number of Guard Subcarriers, Right	92	
Number of Used Subcarriers (Nused) including all possible allocated pilots and the DC carrier.	841	Number of all subcarriers used within a symbol
PermutationBase0	11,19,12,32,33,9,30,7,4,2,13,8,17,23,27, 5,15,34,22,14,21,1,0,24,3,26,29,31,20,25, 16,10,6,28,18	used to allocate tiles to subchannels
Number of carriers per tile	4	Number of all subcarriers used within a tile

Number of tiles	210	
Number of tiles per subchannel	6	
Number of subchannels	35	

A table for a 512 FFT UL:

Parameter	Value	Comments
Number of DC Subcarriers	1	index 512
Number of Guard Subcarriers, Left	51	
Number of Guard Subcarriers, Right	52	
Number of Used Subcarriers (Nused) including all possible allocated pilots and the DC carrier.	409	Number of all subcarriers used within a symbol
PermutationBase0	11,15,10,2,12,9,8,14,16,4,0,5,13,3,6,7,1	used to allocate tiles to subchannels
Number of carriers per tile	4	Number of all subcarriers used within a tile
Number of tiles	102	
Number of tiles per subchannel	6	
Number of subchannels	17	

5 Conclusion

The performance of the IEEE802.16d OFDMA PHY layer has been presented, the performance achieved for high bandwidth are very good and deteriorated for lower bandwidth.
A simple and straight forward way has been shown to add a 1K and 512 FFT sizes to the OFDMA PHY layer to cope with high mobility demands when low channel bandwidth are allocated.
It is recommended that the IEEE802.16e WG will consider these changes to be added to the current draft.