Project	IEEE 802.16 Broadband Wireless Access Working Group < <u>http://ieee802.org/16</u> >		
Title	FFT size and subchannelization for scalability		
Date Submitted	2004-05-15		
Source(s)	Jeong-Heon Kim, Jiho Jang, Panyuh Joo, Jaeho Jeon, Soon Young Yoon	jeongheon.kim@samsung.com jiho.jang@samsung.com panyuh@samsung.com	
	Samsung Electronics Co., Ltd. Dong Suwon P.O.Box 105 416, Maetan-3dong, Yeongtong-gu, Suwon-city, Gyeonggi-do, Korea 442-600	jhjeon@samsung.com soon.young.yoon@samsung.com	

Re:	Contribution supporting Sponsor ballot	
Abstract	System parameters to support public cellular operation and scalability	
Purpose	Adopting of proposed system parameters into P802.16e	
Notice	This document has been prepared to assist IEEE 802.16. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.	
Release	The contributor grants a free, irrevocable license to the IEEE to incorporate material contained in this contribution, and any modifications thereof, in the creation of an IEEE Standards publication; to copyright in the IEEE's name any IEEE Standards publication even though it may include portions of this contribution; and at the IEEE's sole discretion to permit others to reproduce in whole or in part the resulting IEEE Standards publication. The contributor also acknowledges and accepts that this contribution may be made public by IEEE 802.16.	
Patent Policy and Procedures	The contributor is familiar with the IEEE 802.16 Patent Policy and Procedures (Version 1.0) < <u>http://ieee802.org/16/ipr/patents/policy.html</u> >, including the statement "IEEE standards may include the known use of patent(s), including patent applications, if there is technical justification in the opinion of the standards-developing committee and provided the IEEE receives assurance from the patent holder that it will license applicants under reasonable terms and conditions for the purpose of implementing the standard."	
	Early disclosure to the Working Group of patent information that might be relevant to the standard is essential to reduce the possibility for delays in the development process and increase the likelihood that the draft publication will be approved for publication. Please notify the Chair <mailto:r.b.marks@ieee.org> as early as possible, in written or electronic form, of any patents (granted or under application) that may cover technology that is under consideration by or has been approved by IEEE 802.16. The Chair will disclose this notification via the IEEE 802.16 web site <http: 16="" ieee802.org="" ipr="" notices="" patents="">.</http:></mailto:r.b.marks@ieee.org>	

FFT size and subchannelization for scalability

Problem Definition and Proposed Solutions

In order to operate the system specified in IEEE 802.16e/D2 in a public cellular network supporting full mobility, the basic system parameters i.e., system bandwidth, FFT size, and subchannelization should be modified or included in [1].

The solution falls into three categories:

Bandwidth

To meet the requirements from service providers who would like to deploy a high speed public cellular network, the system bandwidths 1.25 and 2.5MHz options should be included.

FFT Size

In order to support full mobility with low overhead for CP duration, the FFT size corresponding to the bandwidth should be scalable, i.e., 128-FFT for 1.25 MHz BW, 256-FFT for 2.5 MHz BW, 512-FFT for 5 MHz, 1024-FFT for 10 MHz BW, and 2048-FFT for 20 MHz BW.

Subchannelization

In order to support various FFT sizes for corresponding bandwidths, the subchannelization for downlink and uplink should be modified accordingly.

Suggested change to the standard

(1) In '8.4.1 Introduction', CHANGE the paragraph in page 72 line 21 as "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., <u>128-FFT for 1.25 MHz</u> channel BW, <u>256-FFT for 2.5 MHz channel BW</u>, <u>512- FFT for 5 MHz channel BW</u> or less and 1024-FFT for 10 MHz channel BW or less."

(2) ADD the <u>Table 1</u>~<u>Table 5</u> at section '8.4.6.1.4 Additional optional symbol structure for FUSC'.

Parameters	Value	<u>Comments</u>
Number of DC Subcarriers	<u>1</u>	
Number of Guard Subcarriers, Left	<u>910</u>	
Number of Guard Subcarriers, Right	<u>109</u>	
Number of Used Subcarriers (N _{used})	108 <u>109</u>	

Table 1. Optional 128-FFT OFDMA downlink carrier allocations

(including all possible allocated pilots and the DC carrier)		
Number of Pilot Subcarriers	<u>12</u>	
Pilot Subcarrier Index	<u>9k+3m+1,</u> for k=0,1,,11 and m=[symbol index] mod 3	Symbol of index 0 is the first optional FUSC data symbol in the downlink.
Number of Data Subcarriers	<u>96</u>	
Number of Bands	3	
Number of Bins per Band	4	
Number of Data Subcarriers per Subchannel	<u>48</u>	

Table 2. Optional 256-FFT OFDMA downlink carrier allocations

Parameters	Value	Comments
Number of DC Subcarriers	<u>1</u>	
Number of Guard Subcarriers, Left	<u> 1920</u>	
Number of Guard Subcarriers, Right	20<u>19</u>	
<u>Number of Used Subcarriers (N_{used})</u>	216 217	
(including all possible allocated pilots and the DC carrier)		
Number of Pilot Subcarriers	<u>24</u>	
Pilot Subcarrier Index	9k+3m+1, for k=0,1,,23 and m=[symbol index] mod 3	Symbol of index 0 is the first optional FUSC data symbol in the downlink.
Number of Data Subcarriers	<u>192</u>	
Number of Bands	6	
Number of Bins per Band	4	
Number of Data Subcarriers per Subchannel	<u>48</u>	

Table 3. Optional 512-FFT OFDMA downlink carrier allocations

Parameters	Value	<u>Comments</u>
Number of DC Subcarriers	<u>1</u>	

Number of Guard Subcarriers, Left	39 <u>40</u>	
Number of Guard Subcarriers, Right	40 <u>39</u>	
<u>Number of Used Subcarriers (N_{used})</u>	<u>432433</u>	
(including all possible allocated pilots and the DC carrier)		
Number of Pilot Subcarriers	<u>48</u>	
Pilot Subcarrier Index	9k+3m+1, for k=0,1,,47 and m=[symbol index] mod 3	Symbol of index 0 is the first optional FUSC data symbol in the downlink.
Number of Data Subcarriers	<u>384</u>	
Number of Bands	12	
Number of Bins per Band	4	
Number of Data Subcarriers per Subchannel	<u>48</u>	

Table 4. Optional 1024-FFT OFDMA downlink carrier allocations

Parameters	Value	Comments
Number of DC Subcarriers	<u>1</u>	
Number of Guard Subcarriers, Left	79<u>80</u>	
Number of Guard Subcarriers, Right	80<u>79</u>	
Number of Used Subcarriers (<i>N</i> _{used})	864 865	
(including all possible allocated pilots and the DC carrier)		
Number of Pilot Subcarriers	<u>96</u>	
Pilot Subcarrier Index	9k+3m+1, for k=0,1,,95 and m=[symbol index] mod 3	Symbol of index 0 is the first optional FUSC data symbol in the downlink.
Number of Data Subcarriers	<u>768</u>	
Number of Bands	24	
Number of Bins per Band	4	
Number of Data Subcarriers per Subchannel	<u>48</u>	

Table 5. Optional 2048-FFT OFDMA downlink carrier allocations

Parameters	Value	<u>Comments</u>
Number of DC Subcarriers	<u>1</u>	
Number of Guard Subcarriers, Left	159 <u>160</u>	
Number of Guard Subcarriers, Right	160<u>159</u>	
<u>Number of Used Subcarriers (N_{used})</u>	1728 <u>1729</u>	
(including all possible allocated pilots and the DC carrier)		
Number of Pilot Subcarriers	<u>192</u>	
Pilot Subcarrier Index	9k+3m+1, for k=0,1,,191 and m=[symbol index] mod 3	Symbol of index 0 is the first optional FUSC data symbol in the downlink.
Number of Data Subcarriers	<u>1536</u>	
Number of Bands	4 8	
Number of Bins per Band	4	
Number of Data Subcarriers per Subchannel	<u>48</u>	

(3) REPLACE section '8.4.6.1.4.1 Downlink subchannel subcarrier allocation" with the following text:

To allocate the diversity subchannels, the whole data tones in a symbol are partitioned into groups of contiguous data subcarriers. Each subchannel consists of one subcarrier from each of these groups. The number of groups is therefore equal to number of data subcarriers per subchannel, and its value is 48. The number of the subcarriers in a group is equal to the number of subchannels, say N_s . As shown in Table 6, N_s is determined by FFT size. The exact partitioning into subchannels is according to Equation (1), called DL permutation formula.

$$Carrier(s,m) = \begin{cases} N_s \times k + [s + P_{1,c_1}(k') + P_{2,c_2}(k')] & 0 < c_1, c_2 < N_s \\ N_s \times k + [s + P_{1,c_1}(k')] & c_1 \neq 0, c_2 = 0 \\ N_s \times k + [s + P_{2,c_2}(k')] & c_1 = 0, c_2 \neq 0 \\ N_s \times k + s, & c_1 = 0, c_2 = 0 \end{cases}$$
(1)

where

Carrier(s, m) = subcarrier index of *m*-th subcarrier in subchannel *s*

 $k = (m + s * 23) \mod 48$, $k' = k \mod (N_s - 1)$

 $\underline{m} = \text{subcarrier-in-subchannel index from the set } [0 \sim 47]$

<u>*s* = index number of a subchannel from the set $[0 \sim N_s-1]$ </u>

 $\underline{P}_{1,c1}(j) = j$ -th element of the sequence obtained by rotating basic permutation sequence \underline{P}_1 cyclically to the left \underline{c}_1 times. See Table 6.

<u> $P_{2,c2}(j) = j$ -th element of the sequence obtained by rotating basic permutation sequence P_2 cyclically to the left c_2 times. See Table 6.</u>

$$\underline{\mathbf{c}_1 = ID_{cell} \mod \mathbf{N}_{\underline{s}}, \mathbf{c}_2 = \lfloor ID_{cell} / \mathbf{N}_{\underline{s}} \rfloor, \ 0 \le c_1, c_2 < N_s$$

In Equation (1), the operation in [] is done over $GF(N_s)$. In $GF(2^n)$, addition is binary XOR operation. For example, 13 + 4 in $GF(2^n)$ is $[(1101)_2 \text{ XOR } (0100)_2] = (1001)_2 = 9$, where $(x)_2$ represents binary expansion of x.

After allocating the subcarriers for each subchannel the data subcarriers per subchannel are enumerated. This enumeration sets the order to which the mapping of the data onto the subcarriers shall be performed.

 $subcarrier(n) = (n + 23 \cdot c) \mod 48$

where,

<u>n : is a running index 0...47</u>

c : IDcell mod 48

FFT size	<u>N</u> s	Basic permutation sequences		
<u>128</u>	<u>2</u>	<u>GF(2)</u>	\underline{P}_1 \underline{P}_2	1 1
<u>256</u>	<u>4</u>	<u>GF(4)</u>	<u>P</u> ₁ P ₂	<u>1.2.3</u> 1.3.2
<u>512</u>	<u>8</u>	<u>GF (8)</u>	<u>P</u> ₁ <u>P</u> ₂	<u>1, 2, 4, 3, 6, 7, 5</u> <u>1, 4, 6, 5, 2, 3, 7</u>
<u>1024</u>	<u>16</u>	<u>GF (16)</u>	<u>P</u> ₁ <u>P</u> ₂	<u>1, 2, 4, 8, 3, 6, 12, 11, 5, 10, 7, 14, 15, 13, 9</u> <u>1, 4, 3, 12, 5, 7, 15, 9, 2, 8, 6, 11, 10, 14, 13</u>
<u>2048</u>	<u>32</u>	<u>GF (32)</u>	<u>P</u> 1	<u>1, 2, 4, 8, 16, 5, 10, 20, 13, 26, 17, 7, 14, 28, 29, 31, 27, 19, 3,</u> <u>6, 12, 24, 21, 15, 30, 25, 23, 11, 22, 9, 18</u>
			<u>P</u> ₂	<u>1, 4, 16, 10, 13, 17, 14, 29, 27, 3, 12, 21, 30, 23, 22, 18, 2, 8, 5, 20, 26, 7, 28, 31, 19, 6, 24, 15, 25, 11, 9</u>

(4) ADD <u>Table 7</u>~<u>Table 11</u> at section '8.4.6.2.4 Additional optional symbol structure for PUSC'.

Table 7. Optional 128-FFT OFDMA uplink carrier allocations

Parameters	Value
Number of DC Subcarriers	<u>1</u>
Number of Guard Subcarriers, Left	9 <u>10</u>

Number of Guard Subcarriers, Right	10 9
<u>Number of Used Subcarriers (N_{used}) (including all</u>	108 <u>109</u>
possible allocated pilots and the DC carrier)	
Number of Subchannels	<u>6</u>
Number of Tiles	36
Number of Subcarriers per Tile	3
Tiles per Subchannel	<u>6</u>
Number of Data Subcarriers per Subchannel	48

Table 8. Optional 256-FFT OFDMA uplink carrier allocations

Parameters	Value
Number of DC Subcarriers	<u>1</u>
Number of Guard Subcarriers, Left	<u>+920</u>
Number of Guard Subcarriers, Right	20<u>19</u>
Number of Used Subcarriers (N _{used}) (including all	216 217
possible allocated pilots and the DC carrier)	
Number of Subchannels	<u>12</u>
Number of Tiles	<u>72</u>
Number of Subcarriers per Tile	3
Tiles per Subchannel	<u>6</u>
Number of Data Subcarriers per Subchannel	<u>48</u>

Table 9. Optional 512-FFT OFDMA uplink carrier allocations

Parameters	Value
Number of DC Subcarriers	<u>1</u>
Number of Guard Subcarriers, Left	39<u>40</u>
Number of Guard Subcarriers, Right	40 <u>39</u>
Number of Used Subcarriers (N_{used}) (including all	4 <u>32</u> <u>433</u>
possible allocated pilots and the DC carrier)	
Number of Subchannels	<u>24</u>
Number of Tiles	<u>144</u>
Number of Subcarriers per Tile	<u>3</u>

<u>Tiles per Subchannel</u>	<u>6</u>
Number of Data Subcarriers per Subchannel	<u>48</u>

Table 10. Optional 1024-FFT OFDMA uplink carrier allocations

Parameters	Value
Number of DC Subcarriers	1
Number of Guard Subcarriers, Left	79<u>80</u>
Number of Guard Subcarriers, Right	80<u>79</u>
<u>Number of Used Subcarriers (N_{used}) (including all</u>	864 <u>865</u>
possible allocated pilots and the DC carrier)	
Number of Subchannels	<u>48</u>
Number of Tiles	<u>288</u>
Number of Subcarriers per Tile	<u>3</u>
Tiles per Subchannel	<u>6</u>
Number of Data Subcarriers per Subchannel	<u>48</u>

Table 11. Optional 2048-FFT OFDMA uplink carrier allocations

Parameters	Value
Number of DC Subcarriers	<u>1</u>
Number of Guard Subcarriers, Left	<u>+59160</u>
Number of Guard Subcarriers, Right	160<u>159</u>
<u>Number of Used Subcarriers (N_{used}) (including all</u>	1728 <u>1729</u>
possible allocated pilots and the DC carrier)	
Number of Subchannels	<u>96</u>
Number of Tiles	<u>576</u>
Number of Subcarriers per Tile	3
Tiles per Subchannel	<u>6</u>
Number of Data Subcarriers per Subchannel	48

(5) REPLACE section '8.4.6.2.4.2 Partitioning of subcarriers into subchannels in the uplink" with the following text:

To allocate the subchannels, N_{used} subcarriers are partitioned into tiles which is 3x3 frequency-time block containing 9 tones(1 pilot tones and 8 data tones). The whole frequency bands are partitioned into groups of

2004-05-15

contiguous tiles. Each subchannel consists of 6 tiles each of which is chosen from different groups. Let us denote the number of tiles in a group by N_s . N_s is different according to FFT size.

There are 18 groups in the whole frequency band and the number of tiles in a group is $N_{s.}$ In order to make a subchannel, 6 groups at equal distance(3 groups away from each) are chosen and each of 6 tiles is selected from each group.

The exact partitioning into subchannels is according to Equation (2), called UL permutation formula.

$$Tile(s,m) = \begin{cases} 3N_s \cdot m + N_s \cdot S + [s' + P_{1,c_1}(m') + P_{2,c_2}(m')], & 0 < c_1, c_2 < N_s \\ 3N_s \cdot m + N_s \cdot S + [s' + P_{1,c_1}(m')], & c_1 \neq 0, c_2 = 0 \\ 3N_s \cdot m + N_s \cdot S + [s' + P_{2,c_2}(m')], & c_1 = 0, c_2 \neq 0 \\ 3N_s \cdot m + N_s \cdot S + s', & c_1 = 0, c_2 = 0 \end{cases}$$
(2)

where

 $\underline{Tile(s, m)} = \text{tile index of } m\text{-th tile in subchannel } s.$

 $S = \lfloor s / N_s \rfloor_{\star} s' = s \mod N_s$

<u> $m = \text{tile-in-subchannel index from the set [0 ~ 5], } m' = m \mod(N_s - 1)$ </u>

<u>*s*</u> = index number of a subchannel from the set $[0 \sim 3N_s - 1]$

<u> $P_{1,c_l}(j) = j$ -th element of the sequence obtained by rotating basic permutation sequence P_l cyclically to the left c_l times. See Table 6</u>

<u>P_{2,c2}(j)= *j*-th element of the sequence obtained by rotating basic permutation sequence P_2 cyclically to the left c_2 times. See Table 6</u>

 $\underline{c_1 = ID_{cell} \text{ mod } N_s, c_2 = = \lfloor ID_{cell} / N_s \rfloor}$

In Equation (4), the operation in [] is over $GF(2^n)$. In $GF(2^n)$, addition is binary XOR operation. For example, 13 + 4 in $GF(2^n)$ is $[(1101)_2 \text{ XOR } (0100)_2] = (1001)_2 = 9$, where $(x)_2$ represents binary expansion of x.

After allocating the tiles for each subchannel the data subcarriers per subchannel are enumerated by the following process:

1. Starting from the first symbol at the lowest subcarrier from the lowest tile and continuing in an ascending manner through the subcarriers in the same symbol and going to next symbol at the lowest data subcarrier, and so on, data subcarriers shall be indexed from 0 to 47.

2. The enumeration of the subcarriers will follow equation below. This enumeration sets the order to which the mapping of the data onto the subcarriers shall be performed.

 $subcarrier(n) = (n + 23 \cdot c) \mod 48$

where,

n: is a running index 0...47

 $c: ID_{cell} \mod 48$

(6) ADD the following tables at 'Section 8.4.6.3 Optional permutations for AAS and AMC subchannels'

Table 12. 128-FFT OFDMA AMC carrier allocations

Parameters	Value	Comments
Number of DC Subcarriers	<u>1</u>	
Number of Guard Subcarriers, Left	<u>10</u>	
Number of Guard Subcarriers, Right	<u>9</u>	
<u>Number of Used Subcarriers (N_{used})</u>	<u>109</u>	
(including all possible allocated pilots and the DC carrier)		
Number of Pilot Subcarriers	<u>12</u>	
Pilot Subcarrier Index	<u>9k+3m+1,</u> for k=0,1,,11 and m=[symbol index] mod 3	Symbol of index 0 is the first AMC data symbol in the downlink or uplink.
Number of Data Subcarriers	<u>96</u>	
Number of Bands	<u>3</u>	
Number of Bins per Band	<u>4</u>	
Number of Data Subcarriers per Subchannel	<u>48</u>	

Table 13. 256-FFT OFDMA AMC carrier allocations

Parameters	Value	<u>Comments</u>
Number of DC Subcarriers	<u>1</u>	
Number of Guard Subcarriers, Left	<u>20</u>	
Number of Guard Subcarriers, Right	<u>19</u>	
<u>Number of Used Subcarriers (N_{used})</u>	<u>217</u>	
(including all possible allocated pilots and the DC carrier)		
Number of Pilot Subcarriers	<u>24</u>	
Pilot Subcarrier Index	9k+3m+1, for k=0,1,,23 and m=[symbol index] mod 3	Symbol of index 0 is the first AMC data symbol in the downlink or uplink.
Number of Data Subcarriers	<u>192</u>	

Number of Bands	<u>6</u>	
Number of Bins per Band	<u>4</u>	
Number of Data Subcarriers per Subchannel	<u>48</u>	

Table 14. 512-FFT OFDMA AMC carrier allocations

Parameters	Value	Comments
Number of DC Subcarriers	<u>1</u>	
Number of Guard Subcarriers, Left	<u>40</u>	
Number of Guard Subcarriers, Right	<u>39</u>	
<u>Number of Used Subcarriers (N_{used})</u>	<u>433</u>	
(including all possible allocated		
pilots and the DC carrier)		
Number of Pilot Subcarriers	<u>48</u>	
Pilot Subcarrier Index	<u>9k+3m+1,</u>	Symbol of index 0 is the first
	for k=0,1,,47 and	AMC data symbol in the
	m=[symbol index] mod 3	<u>downlink or uplink.</u>
Number of Data Subcarriers	<u>384</u>	
Number of Bands	<u>12</u>	
Number of Bins per Band	<u>4</u>	
Number of Data Subcarriers per Subchannel	<u>48</u>	

Table 15. 1024-FFT OFDMA AMC carrier allocations

Parameters	Value	<u>Comments</u>
Number of DC Subcarriers	<u>1</u>	
Number of Guard Subcarriers, Left	<u>80</u>	
Number of Guard Subcarriers, Right	<u>79</u>	
<u>Number of Used Subcarriers (N_{used})</u>	<u>865</u>	
(including all possible allocated pilots and the DC carrier)		
Number of Pilot Subcarriers	<u>96</u>	
Pilot Subcarrier Index	<u>9k+3m+1,</u>	Symbol of index 0 is the first AMC data symbol in the

	<u>for k=0,1,,95 and</u> <u>m=[symbol index] mod 3</u>	downlink or uplink.
Number of Data Subcarriers	<u>768</u>	
Number of Bands	<u>24</u>	
Number of Bins per Band	<u>4</u>	
Number of Data Subcarriers per Subchannel	<u>48</u>	

Table 16. 2048-FFT OFDMA AMC carrier allocations

Parameters	Value	Comments
Number of DC Subcarriers	<u>1</u>	
Number of Guard Subcarriers, Left	<u>160</u>	
Number of Guard Subcarriers, Right	<u>159</u>	
<u>Number of Used Subcarriers (N_{used})</u>	<u>1729</u>	
(including all possible allocated pilots and the DC carrier)		
Number of Pilot Subcarriers	<u>192</u>	
Pilot Subcarrier Index	9k+3m+1, for k=0,1,,191 and m=[symbol index] mod 3	Symbol of index 0 is the first AMC data symbol in the downlink or uplink.
Number of Data Subcarriers	<u>1536</u>	
Number of Bands	<u>48</u>	
Number of Bins per Band	<u>4</u>	
Number of Data Subcarriers per Subchannel	<u>48</u>	

(7) ADD the following text at the end of the 'Section 8.4.6.3 Optional permutations for AAS and AMC subchannels'

There are four types of AMC subchannels which are different in the collection of 6 bins in a band. In the first type(default type), the available bins in a band are enumerated by starting from the lowest bin in the first symbol to the last bin in the symbol and then going to the lowest bin in the next symbol and so on. A subchannel consists of 6 consecutive bins in this enumeration. In the other types, the shapes of an AMC subchannel are shown in figure 228. In all the types, the index of the subchannels in a band is increased along bins and then symbols which is a similar procedure shown in (a) of Figure 228.

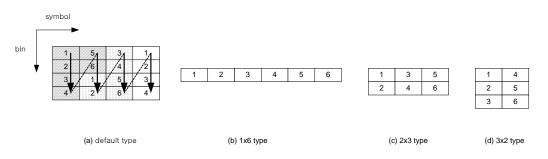


Figure 228 types of AMC subchannel

References

[1] IEEE P802.16-REVe/D2-2004 Amendment for Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Band.