Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**FFT size and subchannelization for scalability**
Date Submitted	**2004-05-07**
Source(s)	Jeong-Heon Kim, Jiho Jang, Panyuh Joo, Jaeho Jeon Samsung Electronics Co., Ltd. Dong Suwon P.O.Box 105 416, Maetan-3dong, Yeongtong-gu, Suwon-city, Gyeonggi-do, Korea 442-600 jeongheon.kim@samsung.com jiho.jang@samsung.com panyuh@samsung.com jhjeon@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	
Release	
Patent Policy and Procedures	

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., 128-FFT for 1.25 MHz channel BW, 256-FFT for 2.5 MHz channel BW, 512- FFT for 5 MHz channel BW or less and 1024-FFT for 10 MHz channel BW or less."

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

Table 1. Optional 128-FFT OFDMA downlink carrier allocations

Parameters	Value	Comments
Number of DC Subcarriers	1	
Number of Guard Subcarriers, Left	9	
Number of Guard Subcarriers, Right	10	

Number of Used Subcarriers (N_{used})	108	
Number of Pilot Subcarriers	12	
Pilot Subcarrier Index	9k+3m+1, for k=0,1,……,11 and m=[symbol index] mod 3	Symbol of index 0 is the first data symbol in the downlink.
Number of Data Subcarriers	96	
Number of Bands	3	
Number of Bins per Band	4	
Number of Data Subcarriers per Subchannel	48	

Table 2. Optional 256-FFT OFDMA downlink carrier allocations

Parameters	Value	Comments
Number of DC Subcarriers	1	
Number of Guard Subcarriers, Left	19	
Number of Guard Subcarriers, Right	20	
Number of Used Subcarriers (N_{used})	216	
Number of Pilot Subcarriers	24	
Pilot Subcarrier Index	9k+3m+1, for k=0,1,……,23 and m=[symbol index] mod 3	Symbol of index 0 is the first data symbol in the downlink.
Number of Data Subcarriers	192	
Number of Bands	6	
Number of Bins per Band	4	
Number of Data Subcarriers per Subchannel	48	

Table 3. Optional 512-FFT OFDMA downlink carrier allocations

Parameters	Value	Comments
Number of DC Subcarriers	1	
Number of Guard Subcarriers, Left	39	
Number of Guard Subcarriers, Right	40	

Number of Used Subcarriers (N_{used})	432	
Number of Pilot Subcarriers	48	
Pilot Subcarrier Index	9k+3m+1, for k=0,1,……,47 and m=[symbol index] mod 3	Symbol of index 0 is the first data symbol in the downlink.
Number of Data Subcarriers	384	
Number of Bands	12	
Number of Bins per Band	4	
Number of Data Subcarriers per Subchannel	48	

Table 4. Optional 1024-FFT OFDMA downlink carrier allocations

Parameters	Value	Comments
Number of DC Subcarriers	1	
Number of Guard Subcarriers, Left	79	
Number of Guard Subcarriers, Right	80	
Number of Used Subcarriers (N_{used})	864	
Number of Pilot Subcarriers	96	
Pilot Subcarrier Index	9k+3m+1, for k=0,1,……,95 and m=[symbol index] mod 3	Symbol of index 0 is the first data symbol in the downlink.
Number of Data Subcarriers	768	
Number of Bands	24	
Number of Bins per Band	4	
Number of Data Subcarriers per Subchannel	48	

Table 5. Optional 2048-FFT OFDMA downlink carrier allocations

Parameters	Value	Comments
Number of DC Subcarriers	1	
Number of Guard Subcarriers, Left	159	
Number of Guard Subcarriers, Right	160	

Number of Used Subcarriers (N_{used})	1728	
Number of Pilot Subcarriers	192	
Pilot Subcarrier Index	9k+3m+1, for k=0,1,……,191 and m=[symbol index] mod 3	Symbol of index 0 is the first data symbol in the downlink.
Number of Data Subcarriers	1536	
Number of Bands	48	
Number of Bins per Band	4	
Number of Data Subcarriers per Subchannel	48	

(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.

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

where

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

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

m = subcarrier-in-subchannel index from the set [0 ~ 47]

s = index number of a subchannel from the set [0 ~ N_s-1]

$P_{1,c1}(j)$ = *j*-th element of the sequence obtained by rotating basic permutation sequence P_1 cyclically to the left c_1 times. See Table 6.

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

$c_1 = ID_{cell} \bmod N_s$, $c_2 = \lfloor ID_{cell} / N_s \rfloor$, $0 \le c_1, c_2 < N_s$

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 $[(1101)_2$ **XOR** $(0100)_2] = (1001)_2 = 9$, where $(x)_2$ represents binary expansion of x.

Table 6 – Basic permutation sequences for diversity subcarrier allocations

FFT size	N_s	Basic permutation sequences		
128	2	GF(2)	P_1	1
			P_2	1
256	4	GF(4)	P_1	1,2,3
			P_2	1,3,2
512	8	GF (8)	P_1	1, 2, 4, 3, 6, 7, 5
			P_2	1, 4, 6, 5, 2, 3, 7
1024	16	GF (16)	P_1	1, 2, 4, 8, 3, 6, 12, 11, 5, 10, 7, 14, 15, 13, 9
			P_2	1, 4, 3, 12, 5, 7, 15, 9, 2, 8, 6, 11, 10, 14, 13
2048	32	GF (32)	P_1	1, 2, 4, 8, 16, 5, 10, 20, 13, 26, 17, 7, 14, 28, 29, 31, 27, 19, 3, 6, 12, 24, 21, 15, 30, 25, 23, 11, 22, 9, 18
			P_2	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

(4) ADD Table 7~Table 11 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	1
Number of Guard Subcarriers, Left	9
Number of Guard Subcarriers, Right	10
Number of Used Subcarriers (N_{used})	108
Number of Subchannels	6
Number of Tiles	36
Number of Subcarriers per Tile	3
Tiles per Subchannel	6
Number of Data Subcarriers per Subchannel	48

Table 8. Optional 256-FFT OFDMA uplink carrier allocations

Parameters	Value
Number of DC Subcarriers	1

Number of Guard Subcarriers, Left	19
Number of Guard Subcarriers, Right	20
Number of Used Subcarriers (N_{used})	216
Number of Subchannels	12
Number of Tiles	72
Number of Subcarriers per Tile	3
Tiles per Subchannel	6
Number of Data Subcarriers per Subchannel	48

Table 9. Optional 512-FFT OFDMA uplink carrier allocations

Parameters	Value
Number of DC Subcarriers	1
Number of Guard Subcarriers, Left	39
Number of Guard Subcarriers, Right	40
Number of Used Subcarriers (N_{used})	432
Number of Subchannels	24
Number of Tiles	144
Number of Subcarriers per Tile	3
Tiles per Subchannel	6
Number of Data Subcarriers per Subchannel	48

Table 10. Optional 1024-FFT OFDMA uplink carrier allocations

Parameters	Value
Number of DC Subcarriers	1
Number of Guard Subcarriers, Left	79
Number of Guard Subcarriers, Right	80
Number of Used Subcarriers (N_{used})	864
Number of Subchannels	48
Number of Tiles	288
Number of Subcarriers per Tile	3
Tiles per Subchannel	6

Number of Data Subcarriers per Subchannel	48

Table 11. Optional 2048-FFT OFDMA uplink carrier allocations

Parameters	Value
Number of DC Subcarriers	1
Number of Guard Subcarriers, Left	159
Number of Guard Subcarriers, Right	160
Number of Used Subcarriers (N_{used})	1728
Number of Subchannels	96
Number of Tiles	576
Number of Subcarriers per Tile	3
Tiles per Subchannel	6
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 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.

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

where

Tile(s, m) = tile index of *m*-th tile in subchannel *s*.

$S = \lfloor s / N_s \rfloor$, $s' = s \bmod N_s$

m = tile-in-subchannel index from the set [0 ~ 5], $m' = m \bmod (N_s - 1)$

s = index number of a subchannel from the set [0 ~ $3N_s$ -1]

$P_{1,c_1}(j)$= *j*-th element of the sequence obtained by rotating basic permutation sequence P_1 cyclically to the left c_1 times. See Table 6

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

$c_1 = ID_{cell} \bmod N_S$, $c_2 = = \lfloor ID_{cell} / N_S \rfloor$

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 $[(1101)_2$ **XOR** $(0100)_2] = (1001)_2 = 9$, where $(x)_2$ represents binary expansion of x.

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.