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| Title | **FFT size and subchannelization for scalability** |
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| 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 two categories:

### *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., 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) ADD the Table 1~Table 3 at section '8.4.6.1.4 Additional optional symbol structure for FUSC'.

**Table 1. 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 ( $N_{used}$ ) (including all possible allocated pilots and the DC carrier) | 433 | |
| Number of Pilot Subcarriers | 48 | |
| Pilot Subcarrier Index | 9k+3m+1,<br>for k=0,1,……,47 and<br>m=[symbol index] mod 3 | Symbol index 0 is the first symbol from which the diversity subchannelization is applied. |
| Number of Data Subcarriers | 384 | |
| Number of Data Subcarriers per Subchannel | 48 | |

**Table 2. 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 ( $N_{used}$ ) (including all possible allocated pilots and the DC carrier) | 865 | |
| Number of Pilot Subcarriers | 96 | |
| Pilot Subcarrier Index | 9k+3m+1, for k=0,1,……,95 and m=[symbol index] mod 3 | Symbol index 0 is the first symbol from which the diversity subchannelization is applied. |
| Number of Data Subcarriers | 768 | |
| Number of Data Subcarriers per Subchannel | 48 | |

**Table 3. 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 ( $N_{used}$ ) (including all possible allocated pilots and the DC carrier) | 1729 | |
| Number of Pilot Subcarriers | 192 | |
| Pilot Subcarrier Index | 9k+3m+1, for k=0,1,……,191 and m=[symbol index] mod 3 | Symbol index 0 is the first symbol from which the diversity subchannelization is applied. |
| Number of Data Subcarriers | 1536 | |
| Number of Data Subcarriers per Subchannel | 48 | |

(2) 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 4, $N_s$ is determined by FFT size. The exact partitioning into subchannels is according to Equation (1), called DL permutation formula.

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

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 4.

$P_{2,c2}(j)$ = *j*-th element of the sequence obtained by rotating basic permutation sequence $P_2$ cyclically to the left $c_2$ times. See Table 4.

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

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 4 – Basic permutation sequences for diversity subcarrier allocations**

| FFT size | $N_s$ | Basic permutation sequences | | |
|---|---|---|---|---|
| 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 |

(3) ADD Table 5 ~ Table 7at section '8.4.6.2.4 Additional optional symbol structure for PUSC'.

**Table 5. Optional 512-FFT OFDMA uplink subcarrier allocations**

| Parameters | Value |
|---|---|
| Number of DC Subcarriers | 1 |
| Number of Guard Subcarriers, Left | 39 |
| Number of Guard Subcarriers, Right | 40 |
| Number of Used Subcarriers ( $N_{used}$ ) (including all possible allocated pilots and the DC carrier) | 433 |
| 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 6. Optional 1024-FFT OFDMA uplink subcarrier allocations**

| Parameters | Value |
|---|---|
| Number of DC Subcarriers | 1 |
| Number of Guard Subcarriers, Left | 79 |
| Number of Guard Subcarriers, Right | 80 |
| Number of Used Subcarriers ( $N_{used}$ ) (including all possible allocated pilots and the DC carrier) | 865 |
| 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 7. Optional 2048-FFT OFDMA uplink subcarrier allocations**

| Parameters | Value |
|---|---|
| Number of DC Subcarriers | 1 |
| Number of Guard Subcarriers, Left | 159 |

| | |
|---|---|
| Number of Guard Subcarriers, Right | 160 |
| Number of Used Subcarriers ( $N_{used}$ ) (including all possible allocated pilots and the DC carrier) | 1729 |
| 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 |

(4) 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]

$P_{1,c1}$(j)= *j*-th element of the sequence obtained by rotating basic permutation sequence $P_1$ cyclically to the left $c_1$ times. See Table 4

$P_{2,c2}$(j)= *j*-th element of the sequence obtained by rotating basic permutation sequence $P_2$ cyclically to the left $c_2$ times. See Table 4

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

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.

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

**Table 8. 512-FFT OFDMA AMC 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 ( $N_{used}$ ) (including all possible allocated pilots and the DC carrier) | 433 | |
| Number of Pilot Subcarriers | 48 | |
| Pilot Subcarrier Index | 9k+3m+1,<br>for k=0,1,……,47 and<br>m=[symbol index] mod 3 | Symbol of index 0 is the first AMC data symbol in the downlink or uplink. |
| Number of Data Subcarriers | 384 | |
| Number of Bands | 12 | |
| Number of Bins per Band | 4 | |
| Number of Data Subcarriers per Subchannel | 48 | |

**Table 9. 1024-FFT OFDMA AMC 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 ( $N_{used}$ ) (including all possible allocated pilots and the DC carrier) | 865 | |
| Number of Pilot Subcarriers | 96 | |
| Pilot Subcarrier Index | 9k+3m+1, | Symbol of index 0 is the first |

| | | |
|---|---|---|
| | for k=0,1,……,95 and<br>m=[symbol index] mod 3 | AMC data symbol in the downlink or uplink. |
| Number of Data Subcarriers | 768 | |
| Number of Bands | 24 | |
| Number of Bins per Band | 4 | |
| Number of Data Subcarriers per Subchannel | 48 | |

**Table 10. 2048-FFT OFDMA AMC 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 ( $N_{used}$ ) (including all possible allocated pilots and the DC carrier) | 1729 | |
| Number of Pilot Subcarriers | 192 | |
| Pilot Subcarrier Index | 9k+3m+1,<br>for k=0,1,……,191 and<br>m=[symbol index] mod 3 | Symbol of index 0 is the first AMC data symbol in the downlink or uplink. |
| Number of Data Subcarriers | 1536 | |
| Number of Bands | 48 | |
| Number of Bins per Band | 4 | |
| Number of Data Subcarriers per Subchannel | 48 | |

## References

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

[2] IEEE P802.16-REVd/D5-2004 Air Interface for Fixed Broadband Wireless Access Systems