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Re:	IEEE 802.16e D4 Draft
Abstract	Proposal of operating mode identification to improve the flexibility and efficiency of the system
Purpose	To incorporate the changes here proposed into the 802.16e D5 draft.
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Operating Mode Identification

1 Background

In IEEE 802.16e/D4 [1], the FCH and DL-MAP should be delivered using PUSC symbol structure only. However, transmitting FCH and DL-MAP using PUSC symbol structure has the limitation of spectral efficiency by 1/3.

One of the Sprint's requirements is that each sector uses whole frequency bandwidth (10MHz for example), but neighboring sectors uses different FAs. Figure A-1 depicts an example of the operation scenario. PUSC with all subchannels may be used for each sector in this case, but optional FUSC symbol structure is superior to the PUSC with all subchannels in terms of spectral efficiency and performance (See Appendix). In addition, if the downlink TD_ZONE_IE is used to switch the subchannelization scheme for the downlink bursts from PUSC to optional FUSC, the overhead may increase.

The method of operating mode identification which enables SSs to obtain the symbol structure used for FCH and DL-MAP before receiving the FCH can be a good solution for flexible system deployment and minimizing the overhead. In this contribution, we propose operating mode identification (OMI) method which will improve the flexibility and efficiency of the system.

2 Proposed Solution

METHOD 1: using multiple sequences for common SYNC symbol

OMI can be supported using multiple sequences for the common SYNC symbol. When multiple sequences for the common SYNC symbol are used, each of sequences can be mapped for each of operating modes. For example, with 4 sequences for common SYNC symbol, we can distinguish 4 operating mode such as common sequence 0 for PUSC, common sequence 1 for FUSC, common sequence 2 for optional FUSC, and common sequence 3 for AMC symbol structure. The four kinds of operating modes each of which defines symbol structure for FCH and DL-MAP are listed in Table 1. ~~The sequences for common SYNC symbol is TBD.~~ PN like binary sequences can used for the common SYNC symbol.

Table 1 – Operating mode configuration

Sequence index for common SYNC symbol	Operating mode
0 (default)	PUSC
1	FUSC
2	Optional FUSC
3	AMC

METHOD 2: using cyclic time shift of current preamble (legacy preamble)

When the current preamble is cyclically delayed in time by N samples, the transmitted waveform s(t) becomes as following:

$$s(t) = \mathrm{Re}\left\{ e^{j2\pi f_c t} \cdot \left(\sum_{\substack{k=-(N_{used}-1)/2 \\ k \neq 0}}^{k=(N_{used}-1)/2} c_k \cdot e^{j2\pi Nk/N_{FFT}} \cdot e^{j2\pi k\Delta f(t-T_g)} \right) \right\} \quad (1)$$

where c_k are the preamble tone values, and t is the time elapsed since the beginning of the OFDMA symbol with $0 < t < T_s$.

In case when the preamble is cyclically shifted in time domain by n/4 of OFDMA symbol for n=0,1,2,3 (see Table 2), 4 types of symbol structure can be differentiated. The method of operating mode identification using cyclic time shift of current preamble does not have any impacts on the existing preamble structure. Four types of operating modes each of which defines symbol structure for FCH are listed in Table 2.

Table 2 – Operating mode configuration

n (index for delay in time)	Operating mode
0 (default)	PUSC
1	FUSC
2	Optional FUSC
3	AMC

Comments:

The complexity of MSS in scanning the operating mode does not increase since the operating mode may be fixed to use a specific symbol structure corresponding to the strategy of cell deployment. Also, the implementation of MSS to support all the kinds of symbol structures can be easily done by only adding a control logic which has the rules of mapping the modulated symbols into physical subcarriers according to the symbol structure.

3 Proposed Text Change

-----------------Start text ---------------------------

8.4.4.3 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 and is mapped to the FCH. Table 266a defines the structure of DL_Frame_Prefix.

Table 266a–OFDMA downlink Frame Prefix format

Syntax	Size	Notes
DL_Frame_Prefix_Format( ) {		
Used subchannel bitmap	6 bits	Bit #0: Subchannel group 0 Bit #1: Subchannel group 1 Bit #2: Subchannel group 2 Bit #3: Subchannel group 3 Bit #4: Subchannel group 4 Bit #5: Subchannel group 5 When FUSC, optional FUSC or AMC symbol structure is used for FCH which is defined by common preamble, all subchannels shall be used with all 1's for the 'used subchannel bitmap'
Ranging_Change_Indication	1 bit	
Repetition_Coding_Indication	2 bits	00 – No repetition coding on DL-MAP 01 – Repetition coding of 2 used on DL-MAP 10 – Repetition coding of 4 used on DL-MAP 11 – Repetition coding of 6 used on DL-MAP
Coding_Indication	3 bits	0b000 – CC encoding used on DL-MAP 0b001 – BTC encoding used on DL-MAP 0b010 – CTC encoding used on DL-MAP 0b011 – ZT CC used on DL-MAP 0b100 to 0b111 – reserved
DL-MAP_Length	8 bits	
Reserved	4 bits	Shall be set to 0
}		

8.4.4.4 DL Frame Prefix

In PUSC, any segment used shall be allocated at least the same amount of subchannels in subchannel group #0. The first 4 slots in the downlink part of the segment contain the FCH as defined in 8.4.4.2. These slots contain 48 bits modulated by QPSK with coding rate 1/2 and repetition coding of 4. The basic allocated subchannel sets for Segments 0, 1, and 2 are Subchannel Group #0, #2, #4 respectively. Figure 220 depicts this structure.
In FUSC, optional FUSC, and AMC which are defined by the common preamble for the operating mode identification, the FCH shall be transmitted using QPSK rate 1/2 with four repetitions using the designated symbol structure (e.g. PUSC, FUSC, optional FUSC or AMC).

The information about symbol structure for FCH and DL-MAP shall be transmitted by the following method.

METHOD 1:

For the common SYNC symbol, four sequences in frequency domain are used each of which represents one of four types of operating mode as in Table aaa. The operating modes each of which defines symbol structure for FCH and DL-MAP. The sequences for common SYNC symbol is in Table aaa-1.

Table aaa – Operating mode configuration

Sequence index for common SYNC symbol	Operating mode
0 (default)	PUSC
1	FUSC
2	Optional FUSC
3	AMC

Table aaa-1. Sequences for common SYNC symbol

FFT size	Sequence index	Sequence	PAPR (dB)
1024	0	473A0B21CE9537F3A0B20316AC873A0B21CE9537 8C5F4DFCE9537F3A0B21CE9537F3A0B20316AC80 C5F4DE316AC873A0B20316AC800	3.32
	1	126F5E749BC062A6F5E75643F9D26F5E749BC062 D90A18A9BC062A6F5E749BC062A6F5E75643F9D 590A18B643F9D26F5E75643F9D50	3.32
	2	D04D5A3013417384D5A31ECBE8C7B2A5CFECBE 8C04D5A31ECBE8C04D5A3013417384D5A31ECBE 8C04D5A30134173FB2A5CE13417398	3.37
	3	85180F65461426D180F64B9EBD92E7F09AB9EBD9 5180F64B9EBD95180F65461426D180F64B9EBD95 180F65461426AE7F09B461426C8	3.37
512	0	5642862D90FE75642862A6F018B642862D90FE749 BD79D590FE740	3.17
	1	0317D378C5AB20317D37F3A54DE317D378C5AB2 1CE82C80C5AB210	3.17
	2	74603D9518509AB9FC26D18509AB9FC26AE7AF6 4B9FC26D18509A8	3.21
	3	213568C04D05CFECA97384D05CFECA973FB2FA3 1ECA97384D05CF8	3.21
128	0	590A18B643F9D0	2.89
	1	0C5F4DE316AC80	2.89
	2	518509AB9FC268	2.95
	3	04D05CFECA9738	2.95

METHOD 2:

When the preamble is cyclically delayed in time by N samples, the transmitted waveform s(t) becomes as following:

$$s(t) = \mathrm{Re}\left\{ e^{j2\pi f_c t} \cdot \left(\sum_{\substack{k=-(N_{used}-1)/2 \\ k \neq 0}}^{k=(N_{used}-1)/2} c_k \cdot e^{j2\pi Nk/N_{FFT}} \cdot e^{j2\pi k\Delta f(t-T_g)} \right) \right\} \quad \text{(xxx)}$$

where c_k are the preamble tone values, and t is the time elapsed since the beginning of the OFDMA symbol with $0 < t < T_s$. In case when the preamble is cyclically shifted in time domain by n/4 of OFDMA symbol for n=0,1,2,3 (see Table bbb), 4 types of symbol structure can be differentiated. Four types of operating modes each of which defines symbol structure for FCH and DL-MAP are listed in Table bbb.

Table bbb – Operating mode configuration

n (index for delay in time)	Operating mode
0 (default)	PUSC
1	FUSC
2	Optional FUSC
3	AMC

-----------------End text ---------------------------

4 References

[1] IEEE P802.16-REVe/D4-2004 Amendment for Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Band.

APPENDIX

Reasonings for Proposal of Operating mode identification

In the current standard, the FCH and DL-MAP should be delivered using PUSC symbol structure only. However, transmitting FCH and DL-MAP using PUSC has the limitation of spectral efficiency by 1/3.

One of the Sprint's requirements is that each sector uses whole frequency bandwidth of 10MHz but neighboring sectors uses different FAs. Figure A-1 depicts an example of the operation scenario. In case of 3-sectored cell deployment using whole frequency bandwidth as in Figure A-1, optional FUSC symbol structure is the most beneficial in terms of spectral efficiency and performance. Moreover, AAS supporting BS may prefer the AMC subchannel structure.

1. FUSC or Optional FUSC (O-FUSC) is beneficial in terms of spectral efficiency because they use the whole bandwidth, comparing with the PUSC which uses only a third of the bandwidth.
2. Comparing with PUSC with all subchannels, O-FUSC has the gain of spectral efficiency by about 6.7 percents since O-FUSC uses 768 data subcarriers while PUSC with all subchannels uses 720 data subcarriers in case of 1024-FFT size.
3. Comparing with PUSC with all subchannels, O-FUSC has the gain of signal to interference ratio (SIR) about 1.5dB in slightly loaded case since the hit property of subcarriers in a subchannel for O-FUSC is much better than that for PUSC (see Figure A-2).
4. Comparing with PUSC with all subchannels, O-FUSC has more diversity gain in frequency domain since the subcarriers are distributed within the whole bandwidth for O-FUSC while the subcarriers are distributed within the limited bandwidth for PUSC with all subchannels.
5. In AAS systems using beamforming, AMC subchannel structure is preferred since energy concentration into narrow frequency band is easier to implement and yields more gain than spreading out the total energy into wideband.
6. If the downlink TD_ZONE_IE is used to switch the subchannelization scheme for the downlink bursts from PUSC to optional FUSC, the overhead may increase.

Consequently, it is crucial that the FCH is flexibly configured according to the preferred system deployment and system capability to support advanced technology. The use of optional FUSC symbol structure in the case of cell deployment as in Figure A-1 has great benefits. The method of operating mode identification which enables SSs to obtain the symbol structure used for FCH and DL-MAP before receiving the FCH can be a good solution for flexible system deployment and minimizing the overhead.

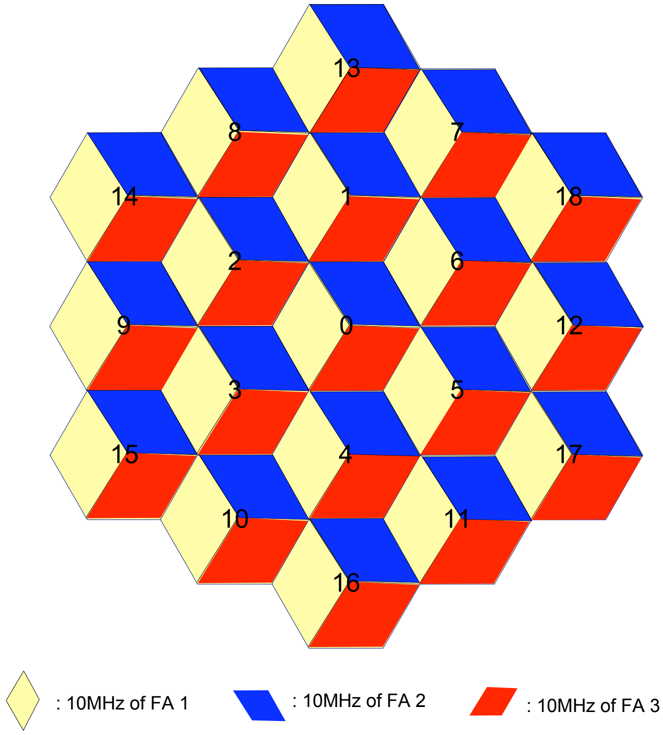
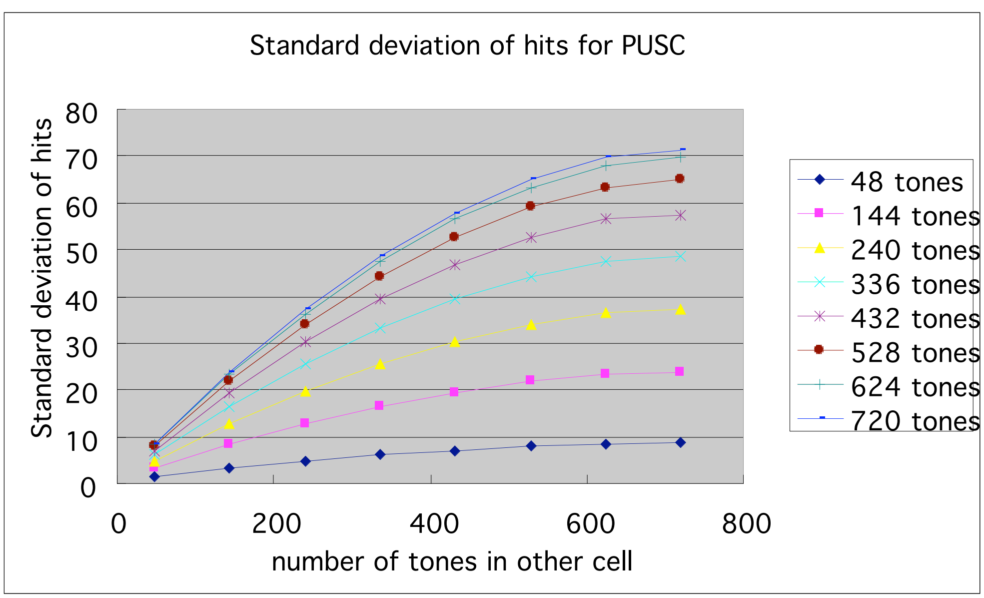
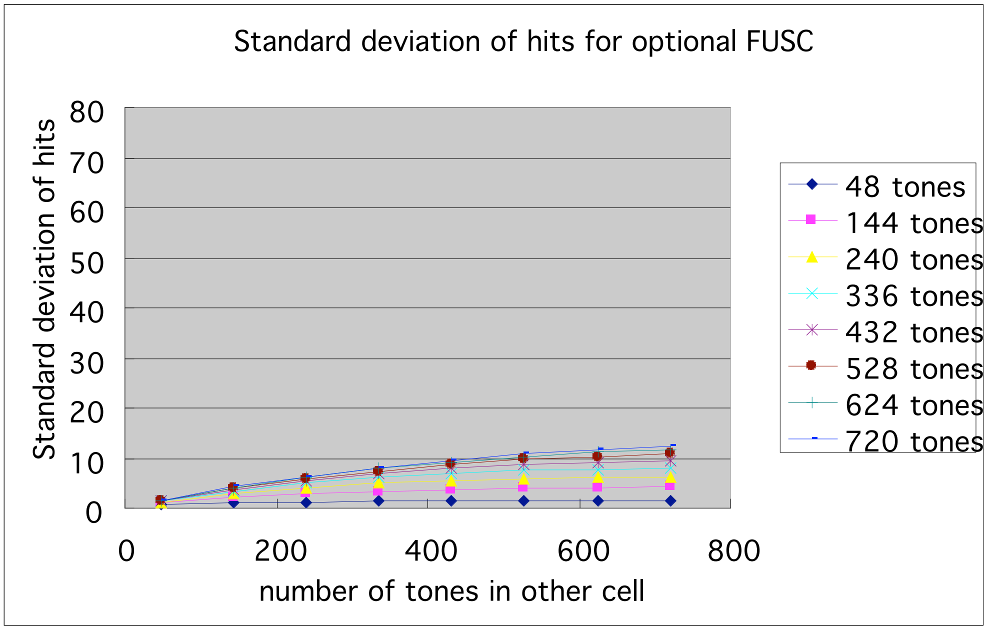


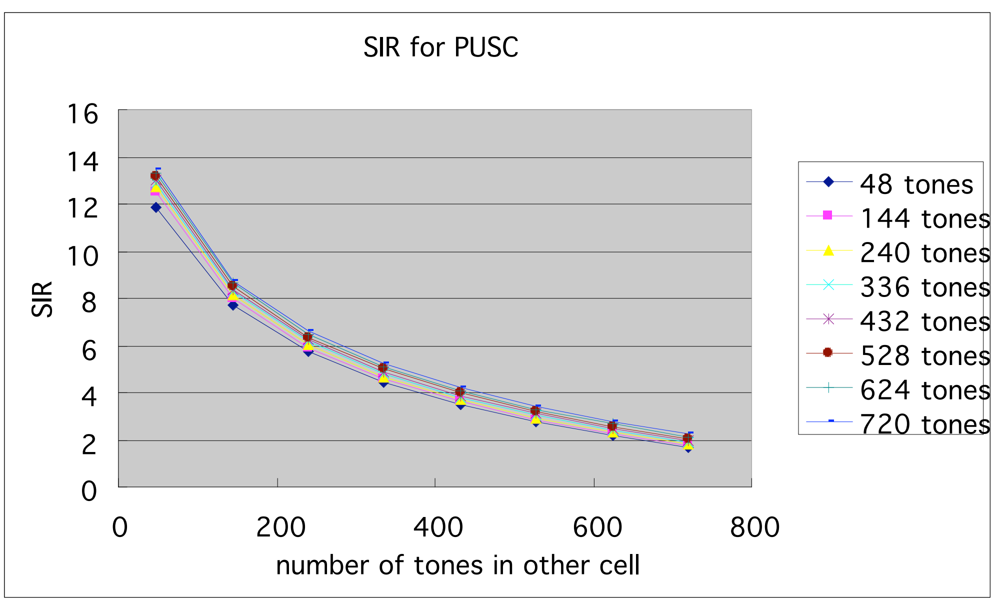
Figure A-1. Example of 3-sectored cell deployment using whole bandwidth for each sector



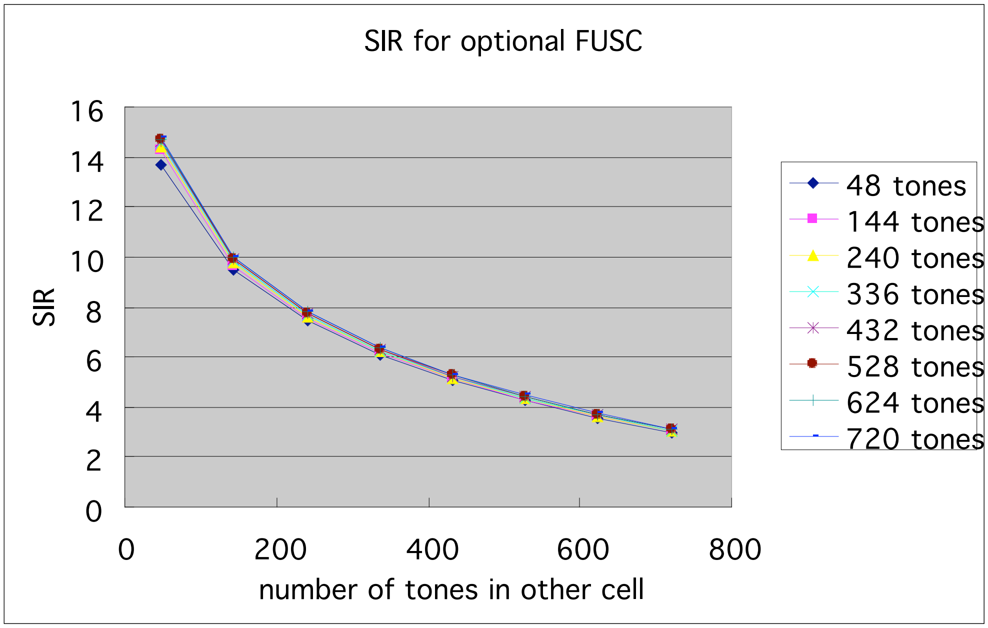
(a)


Standard deviation of hits for optional FUSC
Standard deviation of hits
80
70
60
50
40
30
20
10
0
0
200
400
600
800
number of tones in other cell
48 tones
144 tones
240 tones
336 tones
432 tones
528 tones
624 tones
720 tones

(b)


SIR for PUSC
SIR
16
14
12
10
8
6
4
2
0
0
200
400
600
800
number of tones in other cell
48 tones
144 tones
240 tones
336 tones
432 tones
528 tones
624 tones
720 tones

(c)



(d)

Figure A-2. Standard deviation of hits and SIR for optional FUSC and PUSC with all subchannels