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Re:	IEEE 802.16e D4 Draft
Abstract	Addition of a common SYNC symbol to aid in fast cell search.
Purpose	To incorporate the changes here proposed into the 802.16e D5 draft.
Notice	
Release	
Patent Policy and	

Procedures	include the known use of patent(s), including patent applications, provided the IEEE receives assurance from the patent holder or applicant with respect to patents essential for compliance with both mandatory and optional portions of 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:chair@wirelessman.org> as early as possible, in written or electronic form, if patented technology (or technology under patent application) might be incorporated into a draft standard being developed within the IEEE 802.16 Working Group. The Chair will disclose this notification via the IEEE 802.16 web site <http://ieee802.org/16/ipr/patents/notices>.

A Common SYNC Symbol for FFT sizes other than 2048

1 Background

In IEEE 802.16e/D4 [1], section 8.4.6.1.1 describes the preamble for scalable OFDMA as "*For FFT size other than 2048-FFT, only the first k elements of table 307 shall used to modulate the DL preamble subcarriers, where k is the number of carriers*." The preamble structure in the current standard [1] using the truncated preamble sequence from that of 2048-FFT has a serious problem in initial frame synchronization at cell edge.

At the stage of initial network entry and when the synchronization is lost, SSs should search the starting point of preamble for frame synchronization. Usually, the frame synchronization can be done in time domain exploiting the time repetitive pattern of the preamble by constructing the preamble with regular zero insertion in frequency domain. For example, when every other subcarriers is used for preamble, there are exact 2 replicas in time domain and the frame synchronization can be easily achieved by using the delay multiplier technique as (1).

$$\hat{n} = \arg\max_{n} \frac{\left| \sum_{n=0}^{(N_{FFT}/2)-1} r^{*}(n+l)\, r(n+l+N_{FFT}/2) \right|^{2}}{\sum_{n=0}^{(N_{FFT}/2)-1} \left| r^{*}(n+l)\, r(n+l+N_{FFT}/2) \right|^{2}} \qquad (1)$$

When there are 3 replicas in time domain (as in current preamble), the frame synchronization may be done using the equation (2)

$$\hat{n} = \arg\max_{n} \frac{\left| \sum_{n=0}^{2\cdot\lceil N_{FFT}/3\rceil-1} r^{*}(n+l)\, r(n+l+\lceil N_{FFT}/3\rceil) \right|^{2}}{\sum_{n=0}^{2\cdot\lceil N_{FFT}/3\rceil-1} \left| r^{*}(n+l)\, r(n+l+\lceil N_{FFT}/3\rceil) \right|^{2}} \qquad (2)$$

However, in the current standard, each sector of the same cell uses disjoint set of subcarriers for preamble, and each set of subcarriers is organized with every third subcarriers. An SS at cell edge may receive several preambles from all the neighboring cells and in that case the time repetition property of the preamble cannot be maintained anymore. When the SS receives the composite preamble, which may be seen as a new preamble organized with all subcarriers, the SS cannot exploit the time repetition property to achieve frame synchronization.

Table 1 shows the performance of the probabilities for detection, miss, and false alarm with the configurations of current preamble structure. In the simulation, we assume 3 cell deployment, and the SS is located at edge point between cells as in Figure 1. Each BS uses disjoint set of subcarriers for transmitting preamble as in [1]. Path loss is assumed to be identical for all cells and ITU vehicular-A fading channel model is used. Log normal shadowing is also included with a value of standard deviation of 10dB and 2dB. The simulation results show that the delay multiplier technique does not work for the current preamble structure, especially at small FFT sizes.

Table 1. Performance of initial frame synchronization with the current preamble structure

FFT sizes and CP ratio	STD of Shadowing	Detection	Miss-Detection	False-Alarm
2K-FFT, CP=1/8	2dB	72.7 %	14.9 %	12.4 %
	10dB	91.9 %	4.6 %	3.5 %
1K-FFT, CP=1/8	2dB	77.1 %	14.3 %	8.6 %
	10dB	94.0 %	4.0 %	2.0 %
512-FFT, CP=1/8	2dB	47.0 %	32.5 %	20.5 %
	10dB	77.6 %	10.5 %	11.9 %
128-FFT, CP=1/8	2dB	18.0 %	58.4 %	23.6 %
	10dB	54.7 %	22.1 %	23.2 %

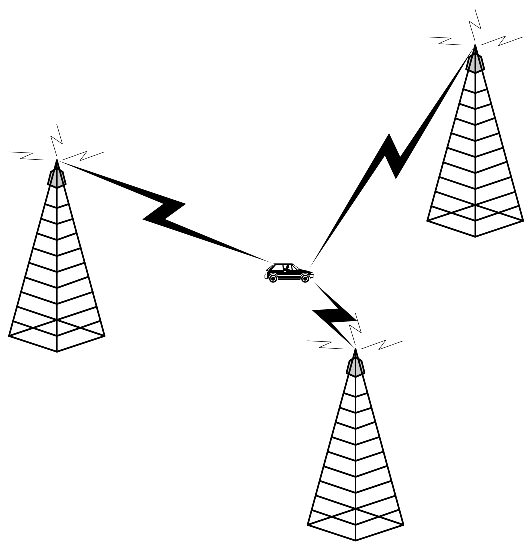

Figure 1. Simulation environment – SS's location

We have also simulated on the SIR distribution in another environment (see Figure 2), where adjacent two cells are transmitting signals simultaneously with the same frequency band. In this simulation, the log normal shadowing is set as 8.9dB, and path loss according to geometry is considered. From the simulations, the probability that SIR is distributed between -3dB and +3dB is found to be 23.5 percents. This means that the use of the delay multiplier technique with current preamble structure may yield failure probability more than 20 percents.

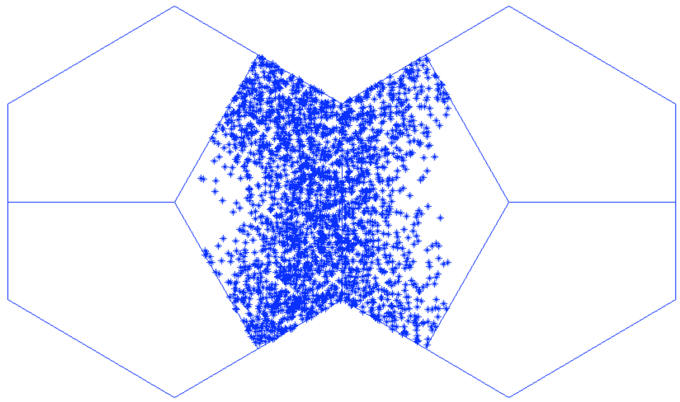

Figure 2. Simulation environment – SIR distribution in 2 cell case

Thus with the current preamble structure, the SS should search the position of preamble by using the time domain correlation of the whole waveforms for cell/sector ID or by using the brute force method where frequency domain correlation of the sequence is required after FFT at every sample point.

Table 2 shows the computational complexity for several frame synchronization algorithms. In the table, we can see that the complexity can be greatly reduced by delay multiplier technique.

Table 2-a. Complexity comparison for initial frame synchronization

(frequency offset estimation is not included)

	Delay multiplier	Time domain waveform correlation	Brute force search
Number of FFTs	1 FFT	1 FFT	NxM FFTs
Number of complex multipliers	$NxM + 114xN_{SEQ}$	$N^2xMx114$	$114xN_{SEQ}$

N=Number of samples in an OFDMA symbol, $N=N_{FFT}+N_{CP}$

M=Number of symbols in a frame

N_{SEQ}=Sequence length of cell specific preamble

Table 2-b. Example of complexity for initial frame synchronization

(N_{FFT}=1024, N_{CP}=128, M=42, N_{SEQ}=284)

	Delay multiplier	Time domain waveform correlation	Brute force search
Number of FFTs	1 FFT	1 FFT	48,384 FFTs
Number of complex multipliers	80,760	$6.35x10^9$	32,376

To solve the problem in the current preamble, in this contribution, we propose a common SYNC symbol for FFT sizes other than 2048 to acquire easy frame synchronization, and cell search. The addition of the common SYNC symbol will improve initial synchronization and cell search thereby greatly reducing the power consumption of the mobile.

2 Proposed Solution

The concept of common SYNC symbol is accepted in preamble ad-hoc group, but the location and mandatory/optional feature are not agreed. In [2], the common SYNC symbol is located in the last symbol of downlink sub-frame. In this case, even if the synchronization for the common SYNC symbol may be obtained with the delay multiplier technique, SSs should search the position of legacy preamble with time domain correlation or brute force method. Since the TTG/RTG, frame duration and downlink/uplink duration ratio are unknown before decoding DCD, the time interval between common SYNC symbol and the legacy preamble cannot be estimated. Therefore, if the common SYNC symbol is positioned as post-amble, then the post-amble is no more helpful for the initial frame synchronization and cell search.

In this contribution, a common SYNC symbol is located at the very first OFDMA symbol in a downlink sub-frame. ~~and~~ All the BSs shall use the same sequence in frequency domain for the common SYNC symbol, and the subcarriers used for transmitting preamble should be the same for all BSs. The current preamble in the standard [1] (legacy preamble) appear at the second OFDMA symbol which is used for cell search and channel estimation. When the BS is equipped with multiple antennas, the common SYNC symbol shall be transmitted only by antenna 0. Figure 3 depicts the time domain structure proposed in this contribution. Figure 4 depicts the frequency domain structure of the common SYNC symbol proposed in this contribution.

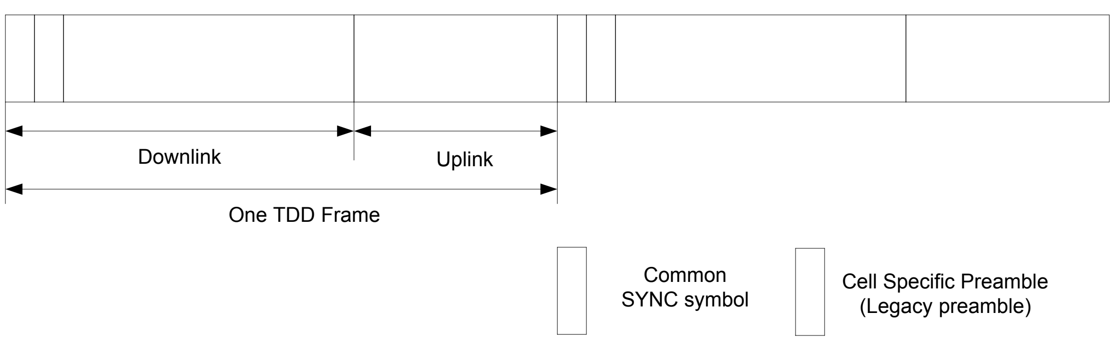

Figure 3. Proposed preamble structure (time domain)

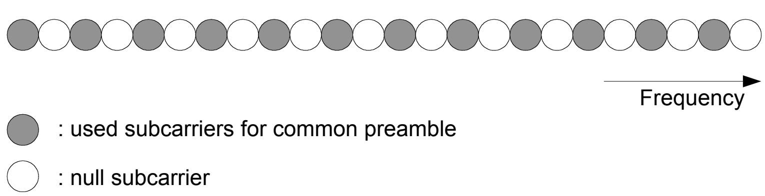

Figure 4. Common SYNC symbol structure (frequency domain)

For the common SYNC symbol, only even subcarriers are used for all the cells and sectors with the same sequence in frequency domain. The repetition pattern of preamble in time domain shows 2 replicas, which is desirable for good synchronization for time and frequency. Since the sequence used for common SYNC symbol is known for all SSs, the fine tuning for time and frequency synchronization can be easily done. ~~The sequence for the common SYNC symbol is TBD.~~ PN like binary sequence can be used for the common SYNC symbol.

Table 3 shows the performance of the probabilities for detection, miss, and false alarm with the proposed common SYNC symbol and delay multiplier technique. In the simulation, we assume 3 cell deployment, and the SS is located at edge point between cells as in Figure 1. Each BS uses the same set of subcarriers for transmitting preamble. All other conditions are the same as in the previous simulation in Table 1. The simulation results show that the detection probability is high enough for initial frame synchronization even at small FFT sizes by using the delay multiplier technique.

Table 3. Performance of initial frame synchronization with the proposed common SYNC symbol

FFT sizes and CP ratio	STD of Shadowing	Detection	Miss-Detection	False-Alarm
2K-FFT, CP=1/8	2dB	100 %	0 %	0 %
	10dB	98.86 %	0.96 %	0.18 %
1K-FFT, CP=1/8	2dB	100 %	0 %	0 %
	10dB	98.28 %	1.44 %	0.28 %
512-FFT, CP=1/8	2dB	99.4 %	0 %	0.6 %
	10dB	97.7 %	1.6 %	0.7 %
128-FFT, CP=1/8	2dB	96.3 %	2.2 %	1.5 %
	10dB	92.4 %	3.3 %	4.3 %

3 Proposed Text Change

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

8.4.6.1.1 Preamble

For FFT size other than 2048, ~~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.~~ the downlink preamble consists of common SYNC symbol and cell specific preamble as shown in Figure aaa. The common SYNC symbol is located at the very first OFDMA symbol in a downlink sub-frame followed by cell specific preamble. All the BSs shall use the same sequence in frequency domain for the common SYNC symbol, and the subcarriers used for transmitting preamble should be the same for all BSs. When the BS is equipped with multiple antennas, the common SYNC symbol shall be transmitted only by antenna 0.

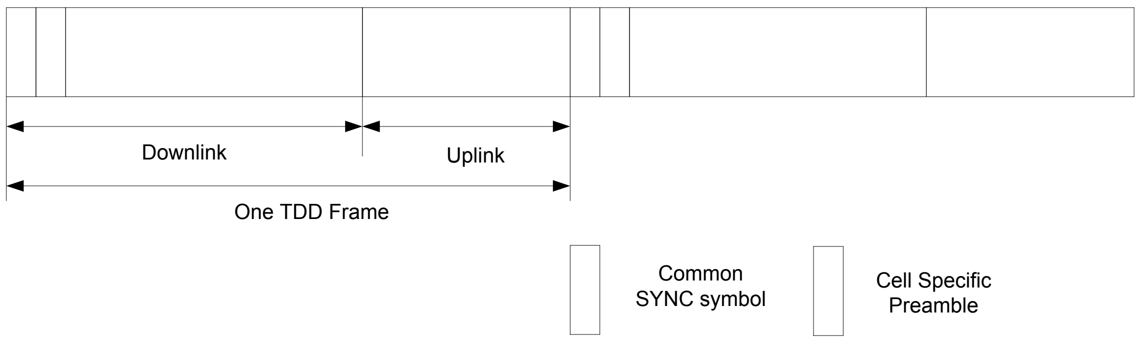

Figure aaa. Preamble structure (time domain)

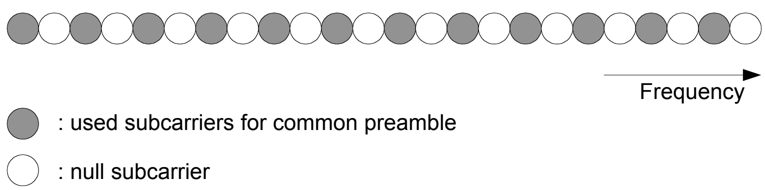

Figure bbb. Common SYNC symbol structure (frequency domain)

~~The sequence for the common SYNC symbol is TBD.~~

~~Table ccc. (place holder for the sequence of common SYNC symbol)~~

~~FFT size~~	~~1024~~	~~512~~	~~128~~
~~Length of sequence~~	~~512~~	~~256~~	~~64~~

The sequence for the common SYNC symbol is in Table ccc.

Table ccc. The sequence of common SYNC symbol

FFT size	Sequence	PAPR (dB)
1024	473A0B21CE9537F3A0B20316AC873A0B21CE95378C5F 4DFCE9537F3A0B21CE9537F3A0B20316AC80C5F4DE31 6AC873A0B20316AC800	3.32
512	5642862D90FE75642862A6F018B642862D90FE749BD79 D590FE740	3.17
128	590A18B643F9D0	2.89

-----------------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.

[2] "Common SYNC symbol for OFDMA," C80216e-04_261.doc, Wen Tong et. al.