802.16e 시스템에서 동기화를 위하여 hybrid detection 을 이용한 Initial ranging detection 향상과 time offset 계산

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Initial Ranging and Detection Enhacement and Time Offset Calculation for Synchronization in 802.16e Systems by Hybrid Detection Method

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Abstract - Initial Ranging Detection and Synchronization is suggested for IEEE 802.16e OFDMA Systems.However ranging is vulnerable to the channel selectivity and other user's interference at low SNR. This paper presents enhanced ranging scheme that improves ranging detection process using the combine multiple FFT blocks and cope with channel selectivity and other user's interference at low SNR. Based on the ranging detection timing offset is calculated for synchronization.

1.Introduction

Initial ranging is proposed for OFDMA based uplink systems for uplink synchronization. A sub channel is composed of a code set that is spread over multiple subcarriers. Each user transmits ranging signal through randomly selected subchannels. Base Station identify each user's ranging signal and time offset by multiplying all ranging code set and finds maximum decision variables for all possible time offset values. Non-coherent methods used for ranging detection show limits in the channel with frequency selectivity, as channel phase variations are not removed efficiently[4]. A ranging scheme using generalized Chirp Like Polyphase sequences with optimal correlation properties is suggested to overcome high Peak-to-average power ratio(PAPR) in time domain[6] but it has problems with low SNR and frequency selectivity.

In this paper, ranging detection scheme, which employs hybrid detection scheme with the modified GCL sequences, is proposed..

2. Back Ground

2.1 Conventional OFDMA Ranging System Model

In the IEEE 802.16e, a group of sub-carriers are allotted for uplink ranging. Multiple users are associated with base station (BS) by sending unique ranging symbol sequences. Each ranging signal arrives at BS with different properties due to its distance and mobility. Exploiting various time offset and received power among different users, BS performs initial uplink synchronization and transmission power adjustment.

Consider an OFDMA system with N sub-carriers. Among them K sub-carriers are allocated for ranging process. The ith mobile station (MS) sends ranging signals with its unique ranging code set $C_i = \{c_1, c_2, \ldots, c_k\}$ then BS detects the ranging signal by the conjugated code set multiplied with $\exp(2\pi f_j \Delta n)$ to corresponding subcarriers. The exponential part is for compensation of transmission delay. The frequency domain received signal is given by

$$R(f) = \sum_k [(C_i(f_k) C_i^*(f_k) H(f_k) + N(f_k) C_i^*(f_k)) \times \exp(2\pi f_k (\Delta n - n_{off}))]$$

$$\sum_k [H(f_k) + N(f_k) C_i^*(f_k)) \times \exp(2\pi f_k (\Delta n - n_{off}))],$$
$$when\, n_{off} = \Delta n \quad (1)$$

Where, $N(f_k)$ is additive white gaussian noise (AWGN) with variance $N_o/2$, converted to frequency domain and $H(f_k)$ denotes channel impulse response of the K^{th} subcarrier. The time offset caaused by transmission is traced by transmission is traced by adjusting Δn, which maximize $R(f)$. This uplink synchronization process is defined as initail ranging.

2.2 GCL Polyphase Sequence

The ranging code set is defined as a subset of Pseudo Noise (PN) sequences generated by generation polynomial $G(x) = 1 + x + x^4 + x^7 + x^{15}$. It provides 227 different code sets when 144 subcarriers are alloted for ranging. However, it bears inherent high time-domain PAPR. Thus, the GCL sequences, which are non-binary unit-amplitude sequences are suggested as a substitution for PN sequences. The GCL sequences adopted for ranging is expressed as

$$S(k) = \exp\left\{ -j2\pi\mu \frac{k(k+1)}{2N_G} \right\} \qquad (2)$$

Where k=0,1,...,N_G-1 and μ=1,2,...,N_G-1. The prime number N_G is total length of the sequence and μ is chosen from 1 to N_G. GCL sequence has the similar properties with PN sequences while having much favorable PAPR.

Property 1: Constant Amplitude (its N_G-point FFT as well)
Property 2: Ideal autocorrelation
Property 3: Constant crosscorrelation value $1/N_G$ between any two GCL sequences with μ_1 and μ_2, when $|\mu_1 - \mu_2|$, μ_1 and μ_2 are relatively prime to N_G.

3. Proposed Method

3.1 Proposed Ranging Detection Algorithm

The scheme with non-coherent detection shows limits in the channel with high frequency selectivity, since channel phase variations are not removed efficiently. Remaining channel component $H(f_k)$,which is complex value, degrades the ranging performance in the fading environment. Since the summation of irregular complex values might cancels its components while the summation of real values is accumulated without loss, we will show $|H(f_k)^3|$ is more desirable rather than $H(f_k)$. It can be achieved with slight but novel modification of GCL sequences and ranging structure.

The modified GCL sequences is given by

$$\acute{S}(k) = \exp\left\{-j2\pi\mu\frac{1}{2N_G}\frac{k}{2}(\frac{k}{2}+1)\right\},\ when\, k\, is\, even$$
$$= \exp\left\{2\pi\mu j\frac{(k+1)}{2N_G}\right\},\ when\ k\, is\, odd \qquad (3)$$

Where k=0,1,...,N_G-1 and μ=1,2,...,N_G-1.

Suppose even k and odd k be 2p and 2p+1, respectively. Then $\acute{S}(k)$ is represented as

$$\acute{S}(k) = \begin{cases} E'_{ven}(k) = \exp\left\{-j2\pi\mu\frac{p(p+1)}{2N_G}\right\},\ when\, k = 2p \\ \acute{O}_{dd}(k) = \exp\left\{j2\pi\mu\frac{2(p+1)}{2N_G}\right\},\ when\, k = 2p+1 \end{cases} \qquad (4)$$

Even part of the modified GCL sequences $E'_{ven}(k)$ is as same as original GCL sequences, and if we multiply $E'_{ven}(k)$ and conjugate of $\acute{O}_{dd}(k)$

$$E'_{ven}(k) \times (\acute{O}_{dd}(k))^* = \exp\left\{-j2\pi\mu\frac{(p+1)(p+2)}{2N_G}\right\} \qquad (5)$$

Here (5) is equivalent to (2) with the substitution of k by p+1. Both modified GCL sequences have the half length of the original sequence length N_G. The first one is used for differential detection using multiple FFT blocks and the second one is for non-coherent detection, respectively.

3.2 Proposed Ranging System Model

Each MS sends ranging signal with its ranging sequences according to (4). On the other hand BS multiplies its adjacent subcarriers with conjugation, such that $(\acute{O}_{dd}(k-1))^* \times E'_{ven}(k) \times (\acute{O}_{dd}(k))^*$. Then, the received signal $\acute{R}(f)$ is given by

$$\acute{R}(f) = \sum_{k/2}\begin{bmatrix} \{\acute{O}_{dd}(f_{odd\ k-1})H(f_{odd\ k-1}) + N(f_{odd\ k-1})\}^* \\ \{E'_{ven}(f_{even\ k})H(f_{even\ k}) + N(f_{even\ k})\} \\ \{\acute{O}_{dd}(f_{odd\ k})H(f_{odd\ k}) + N(f_{odd\ k})\}^* \end{bmatrix}$$
$$= \sum_{k/2}\begin{bmatrix} \acute{O}_{dd}(f_{odd\ k-1})^* E'_{ven}(f_{even\ k})\acute{O}_{dd}(f_{odd\ k})^* \\ H^*(f_{odd\ k-1})H(f_{even\ k})H^*(f_{odd\ k}) + etc \end{bmatrix}$$
$$= \sum_{k/2}\left[S(f_{k+1})|H(f_{even\ k})|^3 + etc\right],$$
$$when\, f_{odd\, k-1}, f_{even\ k}\, \text{and}\, f_{odd\ k}\, are\, adjacent \qquad (6)$$

It can be assumed that adjacent sub-carriers of OFDMA have similar channel response even with severe frequency selectivity[7]. Thus, we can assume $H^*(f_{k-1})H(f_k)H^*(f_{k+1})$ as $|H(f_k)|^3$.

Now the time offset value for OFDMA uplink synchronization is given by

$$(\Delta n)_{time\, offset} = \arg_{\Delta n}\max R$$

Where R

$$= \acute{R}(f) \times S^*(f)\exp(2\pi f_{even\ k}(\Delta n - n_{off}))$$
$$\equiv \sum_{k/2}\left[S(f_k)S^*(f)|H(f_{even\ k})|^3\exp(2\pi f_{even\ k}(\Delta n - n_{off})) + etc\right]$$
$$= \sum_{k/2}\left[|H(f_{even\ k})|^3\exp(2\pi f_{even\ k}(\Delta n - n_{off})) + etc\right] \qquad (7)$$

BS can detect time offset by adjusting Δn which maximize R as conventional algorithm. However, there hardly exist a possibility that summation components $|H(f_k)|^3$ are cancelled out since they are almost real values.

3.3 Combining Multiple FFT Blocks

Multiple FFT blocks demodulate the received ranging signals with different size from N to $N/2^{k/2}$. To form a decision variable, the norm value of differential FFT outputs are combined after differential decoding. We will use the even part of GCL codes for differential detection. $R(f)$ of each FFT blocks are shown as

$$R(f) = \begin{cases} \sum_{k/2}\left[|H(f_{even\, k})|^3 + \acute{N}(f)C^*(f)) \times \exp(2\pi f_{even\, k}(\Delta n - n_{off}))\right], \\ \qquad \text{for } N - pt\, FFT \\ \sum_{k/2}\left[|H(f_{even\, k})|^3 + \acute{N}(f)C^*(f)) \times \exp(2^2\pi f_{even\, k}(\Delta n - n_{off}))\right], \\ \qquad \text{for } N/2 - pt\, FFT \\ \qquad \vdots \\ \sum_{k/2}\left[|H(f_{even\, k})|^3 + \acute{N}(f)C^*(f)) \times \exp(2^{(k/2)+1}\pi f_{even\, k}(\Delta n - n_{off}))\right], \\ \qquad \text{for } N/2^{k/2} - pt\, FFT \end{cases} \qquad ..(8)$$

Combing multiple FFT blocks is beneficial in the low SNR regions, since noise is averaged by summation of multiple FFT blocks, while ranging signal remains the same time offset with periodic replicas.

3.Simulation Results

Simulation parameters are chosen by [8]. 144 subcarriers of total 1024 carriers are alloted for the uplink ranging. One OFDM symbol is 115.2 usec including 12.8 usec of cyclic prefix. To consider high mobility with severe frequency selectivity, delay model is chosen. Three FFT blocks , 1024-point, 512-point and 256 point, are combined. Table below shows mean time error defined by $E[|t_{estimation} - t_{delay}|]$, which refers the average difference between the actual transmission delay and the estimated transmission delay. The conventional detection algorithm does not work in here theoretically. So, it needs other supplementary techniques such as power boosting. Yet. the Mean time error of the proposed differential detection shows stable results.

<Table 1> Mean Time Error (μsec)

SNR (dB)	-3	-2	-1	0	1	2
(a)	6.64	6.42	6.30	6.57	6.48	6.54
(b)	0.39	0.25	0.10	0.5	0.02	0.03

3.Conclusion

The algorithm is presented for ranging detection in IEEE802.16e system. Differential detection algorithm with combined multiple FFT blocks for ranging using the properties of similarity of adjacent channels and the performance degradation due to channel selectivity is overcome.

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