

An Efficient Timing and Frequency Synchronization Algorithm for OFDMA/TDD Mode in Downlink of IEEE 802.16-2004

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Abstract—Timing and frequency synchronization is the important task in receiver. In this paper, an efficient timing and carrier frequency offset (CFO) estimation algorithm for orthogonal frequency division multiple access/ time division duplexing (OFDMA/TDD) mode in IEEE 802.16-2004 standard (WiMAX) is represented. This method has high performance and jointly estimates timing error and CFO. The performance is evaluated in multipath fading channel. This algorithm can be easily used for other OFDM based systems which receiver knows preamble by itself.

Keywords—timing synchronization, carrier frequency offset estimation, IEEE 802.16, multipath fading channel.

I. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) has so applications in broadband communication systems such as wireless metropolitan area network (WiMAX) [1]-[2]. OFDM systems are very sensitive to timing and frequency errors as all the tasks in receiver will be feckless with imperfect synchronization [3]. Thus timing and frequency synchronization in OFDM systems are very important task. Timing error and CFO lead to inter-symbol interference (ISI) and inter-carrier interference (ICI) respectively. There are some methods that we can use them based on qualifications and features of preamble [4]-[6]. There are some methods which do not use preamble that are based on cyclic prefix (CP) [7]-[8]. Synchronization algorithms for orthogonal frequency division multiple access (OFDMA)-based systems in downlink are the same as Synchronization algorithms for OFDM-based systems. Actually in downlink, each receiver should estimate timing offset and related CFO by itself. But in uplink, base station should estimate a vector of CFOs related to all of the active users [9]. Therefore synchronization in uplink is more difficult than downlink. We can't use the previous methods in OFDMA mode in WiMAX, because of the preamble features. We should modify these methods for WiMAX preamble to use them in downlink transmission. The first symbol of downlink transition is preamble. The preamble of OFDMA mode in

WiMAX has size of 2048 in time domain, which makes use of boosted BPSK modulation with specific pseudo-noise (PN) code [1]. Accordingly, there are 114 different preamble signals. Each of them is served at a particular segment of a cell. Each cell is divided to three segments: 0, 1, and 2. The preamble carrier-sets are defined using equation (1) [1]:

$$\text{Preamble carrier set}_n = n + 3k \quad (1)$$

n and k are the number of preamble carrier set indexed 0, 1, 2 and a running index 0, 1,..., 567 respectively. Each segment uses a preamble composed of a carrier set out of the three available carrier set in the following manner [1]:

- Segment 0 uses preamble carrier set 0
- Segment 1 uses preamble carrier set 1
- Segment 2 uses preamble carrier set 2.

Therefore each segment eventually modulates each third subcarrier. Fig. 1 depicts the preamble segment 1 [1]. Thus we have 3 blocks (A, B, and C) with length of 682 in time domain that they are not same to each other, but they have good cross correlation. This matter is because of 2048 is not divisible to 3. Blocks A, B, and C begin from 0 to 681, 682 to 1363, and 1366 to 2047 respectively. In [10] some methods are modified for this preamble. In WiMAX, the user situated in a cell is known by IDcell and number of segment and has its own preamble.

The rest of this paper is organized as follow: we propose a metric method that do timing synchronization and can estimate CFO by knowing preamble in receiver. The proposed method has high performance even in low SNR versus Reddy algorithm [6]. In section II, system model is presented in multipath channel. In section III, Reddy algorithm is explained. In section IV, the proposed timing metric is presented. In section V, simulation results is

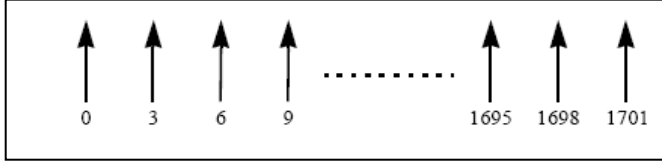


Figure1. Downlink preamble structure [1].

demonstrated and finally the conclusion is given in section VI.

II. SYSTEM MODEL

The transmitted samples in baseband OFDM modulation can be written as:

$$s[n] = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} C_k e^{j \frac{2\pi n k}{N}}; -N_g \leq n \leq N-1 \quad (2)$$

where N is IFFT length. N_g , C_k , and n are cyclic prefix length, preamble data in subcarrier k , and timing sample index respectively. We concentrate on preamble symbol. n th sample of received signal is given by:

$$r[n] = e^{j \frac{2\pi \epsilon n}{N}} \sum_{l=1}^L h[l] s[n-l] + v[n]; -N_g \leq n \leq N-1 \quad (3)$$

Where ϵ and $v[n]$ are the carrier frequency offset normalized to the subcarrier spacing and zero mean complex AWGN respectively. $h[l]$ represents the channel impulse response and l is the index for the multipath.

III. THE REDDY ALGORITHM

The Reddy algorithm is one of the most important algorithms that the receiver knows the preamble. The Reddy algorithm is presented for timing and frequency synchronization in this section. The modified timing metric is given by [10]:

$$M(d) = \frac{|P(d)|^2}{(R(d))^2} \quad (4)$$

where

$$P(d) = \sum_{n=0}^{G-1} (r[n+d]s[n+N_g])^* (r[n+d+M]s[n+N_g]) \quad (5)$$

and

$$R(d) = \sum_{n=0}^{G-1} |r[n+M+d]|^2 \quad (6)$$

A^* means conjugate A . $G = \lfloor \frac{N}{3} \rfloor$, where $\lfloor B \rfloor$, means floor(B). If $M = G$, correlation between blocks A and B and if $M = 2G + 2$ (or $M = N - G$), correlation between blocks A and C will be considered.

IV. THE PROPOSED ALGORITHM FOR TIMING METRIC

By knowing the preamble in receiver, we propose a timing metric that has good performance even in low SNR and use it to estimate the CFO. The proposed timing metric is given by:

$$M(d) = \frac{|P'(d)| |P''(d)|}{R(d)} \quad (7)$$

where

$$P'(d) = \sum_{n=0}^{G-1} r^*[n+d]s[n+N_g], \quad (8)$$

and

$$P''(d) = \sum_{n=0}^{G-1} r[n+M+d]s^*[n+M+N_g], \quad (9)$$

and

$$R(d) = (\sum_{n=0}^{G-1} |r[n+d]|^2) (\sum_{n=0}^{G-1} |r[n+M+d]|^2), \quad (10)$$

If $M = G$, correlation between blocks A by A and B by B from received preamble and save preamble and if $M = 2G + 2$, correlation between blocks A by A and C by C from received preamble and save preamble will be considered. The index of maximum of metric shows the start of symbol. By regarding to Fig. 2 and Fig. 3 it can be seen if $M = G$, timing metric has a peak at start of symbol and has a smaller peak than in G samples later too. But if $M = 2G + 2$, timing metric has just one peak at start of preamble. By selecting the maximum of metric as beginning of symbol, we use this index (d_{opt}) to estimate CFO. CFO estimator is given by:

$$\hat{\epsilon} = \frac{N}{2\pi M} \angle (P'(d_{opt})P''(d_{opt})). \quad (10)$$

$\angle$ means measured angle. In fixed WiMAX, we have CFO because of the change in environment and

mismatching between transmitter and receiver oscillators. Thus CFO is smaller than subcarrier spacing. CFO has two parts, fractional and integer[5]. we compensate the fractional part of CFO by multiplying the received signal by $e^{\frac{-j2\pi\epsilon n}{N}}$. In this paper, integer CFO will not be considered.

V. SIMULATION RESULTS

OFDM system with 2048 subcarriers and 256 samples for CP and Rayleigh multipath channel with 8 paths by power of each path equal 0, -1, -2, -3, -4, -5, -6, and -7 in dB, is considered. The performance of proposed algorithm is evaluated by computer simulations. Fig. 2 and Fig. 3 indicate timing metric with $2\pi\epsilon = 3$ and SNR=0 dB for proposed algorithm. Fig. 4 also runs for Reddy algorithm in these qualifications. The largest peak is the first of symbol. We can see that proposed timing metric has better performance for symbol detecting. Table 1 indicates comparison of CFOs estimation between two algorithms with various CFOs in SNR=0 dB. Simulation results show that if $M = G$, then estimation of CFOs are accurated of where $M = 2G + 2$. Therefore the paper result based on $M = G$. Regarding to table 1, the proposed method has better performance. Fig. 5 indicates comparison estimation of CFO ($2\pi\epsilon = 3$) in various SNR between two algorithms. Based on Fig. 5, the proposed algorithm has the better performance than Reddy algorithm.

VI. CONCLUSION

In this paper, we proposed an algorithm for timing metric that can be used for CFO estimation. This algorithm can be used for downlink in OFDM(A)-based systems that preamble is known by receiver. We compare the performance of the proposed algorithm with Reddy algorithm. Simulation results indicate that the proposed algorithm has high performance even in low SNR in multipath fading channel.

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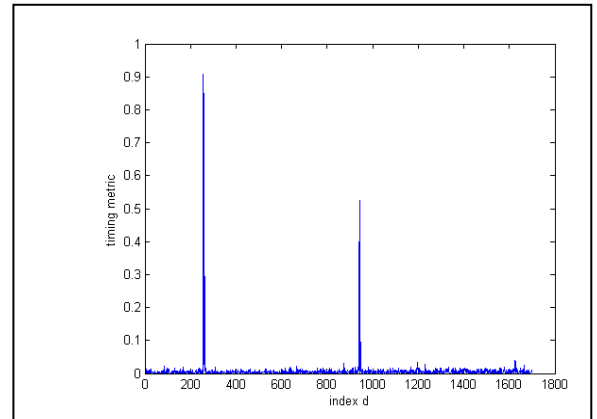


Figure 2. Proposed Timing metric with M=G.

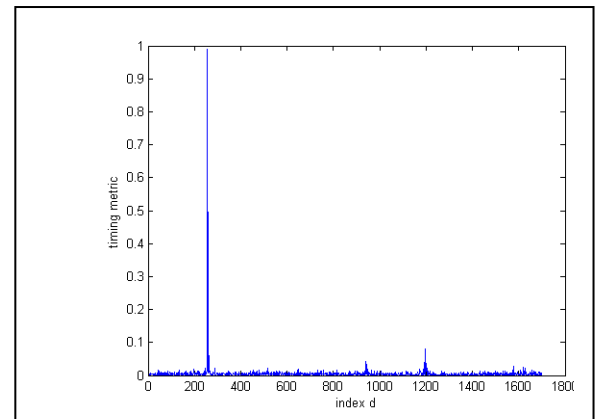


Figure 3. Proposed Timing metric with M=2G+2.

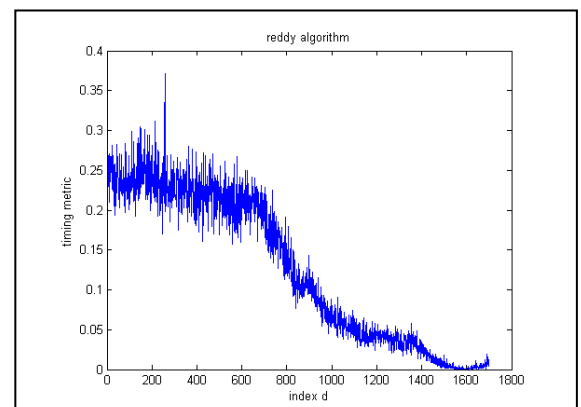


Figure 4. Reddy timing metric with M = G.

Table 1. Estimated CFO for SNR=0 dB.

$2\pi\epsilon$ [rad]	-3	-2	-1	0	1	2	3	4
Proposed algorithm	-2.988	-1.979	-0.995	0.001	0.997	2.006	2.978	4.001
Reddy algorithm	-2.976	-2.024	-1.017	0.015	0.988	1.976	3.035	3.997

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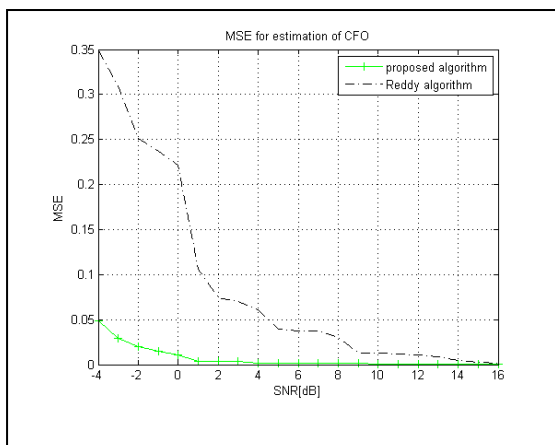


Figure 5. Estimated CFO for $2\pi\epsilon = 3$.

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