FUZZY BASED ADAPTIVE WEIGHTED MULTIUSER INTERFERENCE CANCELLATION IN OFDMA SYSTEMS

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Abstract

Orthogonal Frequency-Division Multiple Access (OFDMA) is a multi-user version of the Orthogonal frequency-division multiplexing (OFDM). OFDMA is used in the mobility mode of IEEE 802.16 WirelessMAN Air Interface standard, commonly referred to as WiMAX. Multiple access is achieved in OFDMA by assigning subsets of subcarriers to individual users [1], [2]. The performance of these systems depend on the orthogonality between the transmitted subcarriers alloted to different users. The important advantages of OFDMA are that it enables orthogonality in the uplink by synchronizing users in time and frequency and multipath mitigation without using equalizers and training sequences. However, the orthogonality between codes is often disturbed by the carrier frequency offset due to the Doppler effect in fading channels, time delay due to multipath components and poor synchronization at the receiver.

Key Words: OFDMA, CFO, MUI, BER

I Introduction

The recent very high demand for multimedia services in wireless communication systems requires high transmission rates. But this swill result in frequency selective fading and and inter-symbol interference. Orthogonal Frequency Division Multiplexing (OFDM) is a communication technology used in WLANS. The basic idea of OFDM is to divide the available spectrum into several orthogonal sub channels so that each narrowband subchannel experiences almost flat fading allowing subchannels in the frequency domain thus increasing the transmission rate [1]-[2].

Frequency division multiple access (FDMA) method that assigns sets of subcarriers to different users has been a popular basic multiple access scheme for OFDM. This technique is called as PFDMA. In OFDMA distinct sub-carriers are assigned to different users for simultaneous transmission. Multiple users share the bandwidth simultaneously. Hence the users and the base station in the OFDMA system are required to be synchronous in frequency domain.

In the uplink ie from the mobile user to the base station, offsets in the frequency assigned between users occurs whenever their local oscillators are misadjusted and/or due to a frequency shift in their carrier frequency in fading channels. This offset is called carrier frequency offset (CFO), CFO introduces not only inter-carrier interference (ICI) and ISI but also multiple user interference (MUI) between the users in the uplink of the OFDMA system. An adaptive MUI cancellation for uplink of OFDMA system has been proposed in this paper [1]-[2].

2. Literature Surveys

Recent literature addresses the issue of multiuser interference in the uplink of OFDMA systems due to other user carrier frequency offset.

The first method of uplink CFP compensation is to estimate the CFO values and give them as feedback to the transmitter so as to enable it to adjust the transmitter frequency [4]-[5]. However this feedback requires additional signaling.

Interference cancellation at the base station receiver to cancel the CFO in the frequency domain using circular convolution were also studied [5]-[8]. Manohar et al proposed weighted MUI cancellation technique where the basic principle is to estimate the MUI interference and to multiply the optimized weights and then subtract it from the required users signal. However in this method, the weights are not adaptive [9].

In this paper, an adaptive weighted MUI cancellation technique has been proposed for FDMA systems where the weights chosen to cancel the MUI are adaptive depending the mobility characteristics of the mobile channels. A multistage adaptive weighted interference cancellation scheme has been proposed to cancel the mulituser interference due to carrier frequency offset in the uplink of OFDMA systems has been proposed. Monte Carlo simulation has been used with 95% confidence interval. Simulations have been carried out to simulate the Bit Error Rate (BER) performance of the proposed scheme in Rayleigh fading channels. It has found from the simulations that BER performance is better that that of the proposed schemes available in the literature. The issues of complexity have also been discussed.

The paper is organized as follows: We start with basic discrete model Section III. We present our proposed multistage MUI cancellation in Section IV. Simulation results are presented in Section V. Conclusion and future extensions are given in Section VI.

3. System Model

The system model for the proposed work is the uplink of OFDMA system. It is assumed that there are N subcarriers in each OFDM symbol and one carrier is allocated to only one user [1]-[2]. Distinct sub-carriers are assigned to distinct users for simultaneous transmission. The uplink consists of K users. The data of each user in the frequency domain is converted to time domain by taking IDFT on the input. Then guard interval is added to the time domain samples. The time domain sequence of the ith user on the kth subcarrier is given by

$$x_n^{(i)} = \frac{1}{N}\sum_{k \in S_i} X_k^{(i)} e^{\frac{j2\pi nk}{N}}, \quad -N_g \le n \le N-1 \quad (1)$$

where S_i is the set of subcarriers assigned to each user and Ng is the length of the guard interval and is assumed to be longer than the maximum delay spread of the channel. Let h(n) denote the impulse response of the frequency selective fading channel. The time domain sequence of the ith user after passing through the channel is given by

$$s_n^{(i)} = x_n^{(i)} * h_n^{(i)} \quad (2)$$

The received signal at the base station with CFO is given by

$$r_n = \sum_{i=1_i}^{K} s_n^{(i)} e^{\frac{j2\pi n \varepsilon_i}{N}} + W_n \quad (3)$$

where $\varepsilon_{i,}$ i=1,….K denotes the ith users's residual CFO and wn is the the AWGN with zero mean and variance σ^2 . CFO compensation in the time domain is done by multiplying the received signal by the CFO compensation value given by

$$y_n^{(i)} = r_n e^{\frac{-j2\pi n \varepsilon_i}{N}}, \quad 0 \le n \le N-1 \quad (4)$$

The guard interval is removed and then DFT is performed to get the put in the frequency domain. The output of the DFT block corresponding to the ith user on the kth subcarrier is given by [7]

$$Y_k^{(i)} = H_k^{(i)} X_k^{(i)} + \sum_{\substack{l=1 \\ l \ne i}}^{K} \sum_{q \in S_i} \rho_{kq}^{(i),(l)} H_q^{(l)} X_q^{(l)} + W_k^{(i)} \quad (5)$$

where $$\rho_k^{(i)} = \frac{\sin \pi(k - q + \delta_{li})}{N \sin \frac{\pi}{N}(k - q + \delta_{li})} e^{-j(1-1/N)\pi(k-q+\delta_{li})} \quad (6)$$

and

$$\delta_{li} = \varepsilon_l - \varepsilon_i \quad (7)$$

The first term in the equation (5) is the desired signal, the second term is the multiuser interference due to CFO and the third term is the AWGN term. This MUI can be cancelled to get the desired users signal using many interference cancellation techniques [8]-[9]. In this paper, an adaptive MUI cancellation technique has been proposed for the uplink of OFDMA systems.

4. Proposed MUI Cancellation

The performance of the system is severely degraded when different carrier frequency offsets of the users occur. The desired user offset can be compensated but the others users' carriers are always misaligned and the MUI affects the reception. An offset compensation of all the users at the base station is not possible. To reduce the effects of the CFO in a multiple access system an adaptive MUI cancellation schemes has been proposed in the frequency domain.

Many linear and nonlinear multiuser detectors have been proposed to alleviate the UAI and the near far problem [3]. The interference cancellation techniques can be broadly broken into successive and parallel schemes for canceling MUII. The Parallel interference Cancellation (PIC) scheme simultaneously removes the MUI from each user's received signal. Another promising suboptimal detector with acceptable delay is the partial parallel interference cancellation (PPIC). With this receiver, only part of the previously estimated signal is removed from the received signal input to the next stage [3]. The performance is better when the MUI is weighted and then removed form the desired users signal.

Adaptive Multistage PPIC (AMPPIC) detector is a multistage detector in which the cancellation weights are not constant but adaptively obtained from Fuzzy Inference System (FIS) based on the principle of Fuzzy logic. As the MUI or the back ground noise increases, the performance of the uplink of the OFDMA system becomes worse. So the cancellation weight should be set to a small value. However, if the interference due to CFO decreases, the weight should be set to a large value. Hence the optimal weight becomes larger as the number of users K decreases.

The optimal weight obtained from FIS is related to the number of users K and Energy to Noise density ratio (Eb/No) of each user. The amount of multiple user interference depends on the total CFO values of all interferers. So, a parameter called the effective number of users who are interferers for the desired ith user is defined as

$$U_{eff,i} = \frac{\sum_{\substack{k=1 \\ k \neq i}}^{K} \varepsilon_k}{\varepsilon_i} \qquad (8)$$

As Ueff increases, the Signal to Interference ratio (SIR) of the desired user decreases. Under this condition, the BER of the desired user increases. For this case, in an multistage AMPPIC detector, a small cancellation weight should be selected for the next stage. Thus the weights if chosen adaptively based on the number of users and CFO values of the users, the BER performance of the system can be greatly improved.

The fuzzy inference system (FIS) is a decision-making logic that uses a set of fuzzy IF-THEN rules. The optimal weights are determined by the FIS with sufficient rules. These fuzzy rules are formed by matching input-output pairs through an adaptive procedure. Five and Six Gaussian membership functions are chosen to cover the universe of discourse of two inputs Ueff,i and Eb/Noi and one output weight λi, respectively shown in Table 1. Five linguistic terms, negative low (NEL), zero (ZE), positive low (POL), positive medium (POM), positive high (OPH), are chosen to cover the universe of discourse of the Eb/No of the desired user. Five terms very few (VEF), few (FE), medium (MED), many (MA), great many (GMA), are chosen to cover the universe of discourse for the effective number of users. Six terms almost zero (AZ), small (S), medium (MED), large (L), very large (VL), and almost one (AO), are chosen to cover the discourse of cancellation weights.

Table 1. Rule Base For FIS

Eb/No	Ueff VF	F	MED	M	GM
NL	MED	S	AZ	AZ	AZ
ZE	H	MED	S	S	AZ
PL	ONE	H	MED	S	AZ
PM	ONE	VH	H	MED	AZ
PH	ONE	VH	H	MED	S

The Gaussian membership function of the fuzzy set Fi in each interval [Ci-, Cj+] of the universe of discourse can be expressed by

$$\mu_F^a(x_b) = \exp\left[-\frac{(x_b - \bar{x}_b^a)^2}{2(\sigma_b^1)^2}\right] \qquad (9)$$

where a=1,2,3,4,5 and b=1,2,3. x_b takes values in the interval [Ci-, Cj+]. x_b^a and σ_b are the mean and the standard deviation of the Gaussian membership function. The fuzzy control rules of a two input- single output fuzzy system are framed as

R j : IF Eb/No_i is F_2 a1 AND

Ueff,i is F_2 a2 , THEN $w_k = F_3$ a3 where F_2 a1 , F_2 a2 and F_2 a3 are the linguistic terms of the input variables $Ueff_{,i}$ and Eb/No_i and the output variable wi respectively. a1 ,a2 =1,2,3,4,5 a3 = 1,2,3,4,5,6 and the index of rule j = 1,2,………..25. The defuzzification method is the centroid calculation. Thus the adaptive principle of determining the partial weights can be followed for a multistage AMPPIC detector for MUI cancellation. The optimal cancellation weights of the latter stages should be larger than those of the front stages.

5. Results and Discussion

Monte Carlo simulations have been run with a confidence interval of 95% to compare the performance of the OFDMA system with the proposed MUI cancellation with adaptive weights. The following parameters are chosen for the system simulation. The number of subcarriers N=64, Number of users K=4, SNR = 20 dB, CFO values for the 4 users [-1 - 0.25 0.25 -0.13]. the AWGN is assumed to have zero mean and unit variance. 2 stages of MUI cancellation are performed. A two ray Rayleigh fading channel is considered.

Fig.1 and Fig.2 show the BER performance of the uplink of the OFDMA system with 4 users and CFO values as mentioned with BPSK modulation and 4 QAM respectively. It is seen from the graphs, that Single user detection (SUD) has the highest BER because of the no compensation and very high interference. The second method is CLJL [6] uses circular convolution method. The BER performance using this method is better than that of the SUD because of the CFO compensation in the frequency domain.

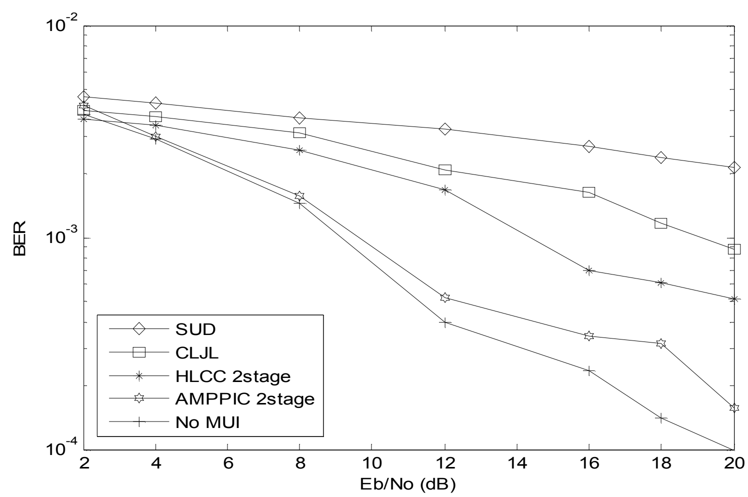

Fig.1 BER performance comparison of different detectors with K=4, CFO values for the 5 users [-1 - 0.25 0.25 -0.13] with BPSK modulation

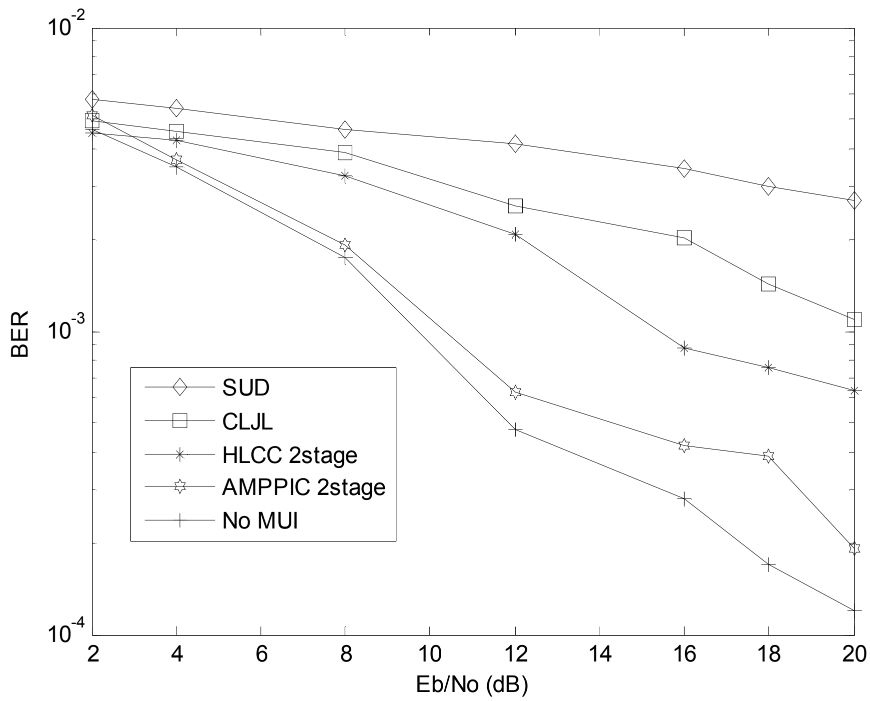

Fig.2 BER performance comparison of different detectors with K=4, CFO values for the 5 users [-1 - 0.25 0.25 -0.13] with 4 QAM

However it shows poor performance compared to that of the HLCC method [8]-[9] which employs both CFO compensation and MUI cancellation. Our proposed method of MUI cancellation show better BER performance compared to the methods available in the literature due to the reason that here both CFO compensation and adaptive MUI cancellation are applied. The complexity of the proposed detector depends on the number of stages and the number of users. As the number of stage and number of users increase, the complexity in computations raise.

6. Conclusion

In this paper, an adaptive weighted MUI cancellation technique has been proposed for OFDMA systems where the weights chosen to cancel the MUI due to carrier frequency offsets are adaptive depending the mobility characteristics of the mobile channels. Simulations have been carried out to simulate the Bit Error Rate (BER) performance of the proposed scheme in Rayleigh fading channels. It has found from the simulations that BER performance is better that that of the proposed schemes available in the literature. The performance analysis of the proposed method with channel coding may be carried out as future work.

Reference

[1] I. Koffman and V. Roman, "Broadband wireless access solutions based on OFDM access in IEEE 802.16," IEEE Commun. Mag., vol.4, no.4, pp.96–103, April 2002.

[2] J. Qiang, H. Harada, H. Wakana, and P. Zhang, "Subband selection and handover of OFDMA system over frequency selective channel," IEICE Trans. Commun., vol.E88-B, no.4, pp.1718–1724, April 2005.

[3] S. Verdù, MultiUser Detection. Cambridge: Cambridge University Press, 1998.

[4] J.J. van de Beek et al., A Time and Frequency ynchronization Scheme for Multiuser OFDM, IEEE Jurnal Selected Areas on Communcations, VOL.17, No.11, November 1999.

[5] Z. Cao; U. Tureh; Y.D. Yao; Analysis of two receiver schemes for interleaved ofdma uplink Signals, Systems and Computers, 2002. Conference Record of the Thirty-Sixth Asilomar Conference on , Vol. 2, pp. 1818-1821, Nov. 3-6, 2002.

[6] J.Choi, C.Lee, H.W. Jung and Y. H. Lee, " Carrier frequency offset compensation for uplink OFDM-FDMA", IEEE Commun. Letters, vol. 4, no.12, pp. 414-416, Dec. 2000..

[8] D. Huang and K.B. Letaief, "An interference-cancellation scheme for carrier frequency offsets correction in OFDMA systems," IEEE Trans. Commun., vol.53, no.7, pp.1155–1165, July 2005.

[9] Manohar, Shamaiah and Sreedhar, Dheeraj and Tikiya, Vibhor and Chockalingam, "Cancellation of Multiuser Interference Due to Carrier Frequency Offsets in Uplink OFDMA", IEEE Transactions on Wireless Communications , vol. 6, No.7, pp. 2560-2571, July 2007.

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