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Novel Channel Tracking and Equalization Methods in MU-MIMO-OFDM Systems

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Abstract—The methodology undertaken, the channel model and the system model created for developing a novel adaptive equalization method and a novel channel tracking method for uplink of MU-MIMO-OFDM systems is presented in this paper. The results show that the channel tracking method works with 97% accuracy, while the training-based initial channel estimation method shows poor performance in estimating the actual channel comparatively.

Keywords—channel tracking; multiuser; MIMO; OFDM; time-varying channels; adaptive equalization; zero forcing;

I. INTRODUCTION

Multiple Input Multiple Output - Orthogonal Frequency Division Multiplexing (MIMO-OFDM) stand as promising technology to resolve bottlenecks in traffic capacity of current and future high data rate wireless systems such as LTE, Wi-Fi, and Wi-Max [1]. Recently, multiuser diversity, the extension of MIMO systems to employ multiple users, has been a major topic of interest, primarily motivated by the need for identifying the network capacity enhancements resulting from the employment of MIMO technology. Multiuser MIMO-OFDM (MU-MIMO-OFDM), enables faster wireless broadband services by using multiple antennas at an access point (AP) to serve mobile stations (MS) equipped with a single antenna. However, performance of MU-MIMO-OFDM depends greatly on the accurateness of the estimation of channel state information (CSI). In general, CSI can be estimated by transmitting known symbols. However, this results with increased overhead if the channel changes significantly over time. Therefore, the design of an efficient MU-MIMO-OFDM system still faces key challenges, particularly, the development of an efficient and accurate adaptive equalization method and channel tracking method.

This paper proposes the methodology undertaken, the channel model and the system model created to develop a novel and efficient adaptive equalization and a novel channel tracking method for MU-MIMO-OFDM systems that can recursively update the channel estimates for time-varying frequency selective channels. The rest of the paper is organized, as follows. Section II presents the methodology. Sections III and IV discuss channel model and the method for initial channel estimation. The channel tracking method is presented in section V. The simulation results are provided in section VI. Finally, section VII offers conclusions.

II. METHODOLOGY

The research for this project can be subdivided into five phases:
Phase 1: Construction of a time-varying frequency selective MU-MIMO channel model
Phase 2: Derivation of an efficient method for initial channel estimation
Phase 3: Development of a novel adaptive equalization method for MU-MIMO-OFDM systems
Phase 4: Development of a novel channel tracking algorithm for MU-MIMO-OFDM systems
Phase 5: Statistical analysis of the Error Vector Magnitude

III. CONSTRUCTION OF THE CHANNEL MODEL

Following the work [2], we use Matlab as a validation tool. First, a channel object was created to generate frequency selective fading channels that model each separate path as an independent Rayleigh/Rician fading process. In simulations number of fading paths was set to 3. Time-varying condition was created by filtering or processing the OFDM symbols through the channel object and with the maximum Doppler shift \(f_d\). Then, multiple channels were created for each channel between multiple users and multiple antennas at the AP, with 100 channel realizations. Since our focus is on the case with six users with 12 AP antennas system, as implemented in [3], the number of MSs was set to \(M = 6\) and the number of antennas at the AP was set to \(R = 12\) in the simulations. The number of OFDM symbols (time) used in the simulations was set to 96 and the number of OFDM subcarriers (frequency) was set to 128.

IV. METHOD FOR INITIAL CHANNEL ESTIMATION

The channel tracking method incorporates an initial channel estimation method and it was performed using training sequences for multiple users. Since the novel channel tracking method is a very effective method, only the first data symbol of each transmit-receiver pair is enough to be used as the known training symbol in the initial channel estimation method. The training symbol incorporates AWGN noise at each receiver antenna at the AP. For the adaptive equalization method the first 20 symbols are taken as the training sequence.
Let $Y_0$ be the training symbols recovered at the AP and $X_0$ be the training symbol. Then, the initial channel estimation is:

$$\hat{H}_0 = Y_0(X_0)^{-1} = H_0 + Z_0(X_0)^{-1} = H_0 + E \quad (1)$$

The actual channel ($H_0$) plus a noise term ($Z_0(X_0)^{-1}$) can be found by using equation 1. The noise term is the channel estimation error ($E$).

V. CHANNEL TRACKING METHOD

Adaptive equalization or Zero Forcing is performed using outputs of the Fast Fourier Transform (FFT) demodulators to detect the transmitted data for subsequent channel tracking. The initial channel estimate $H_0$ is used to perform Zero Forcing at the AP to recover data $\hat{X}$. For channel tracking, the Zero Forcing process is performed in groups of 12 symbols as $\hat{X}$ should be an invertible matrix. Next, this recovered data $\hat{X}$ is demodulated to obtain hard decision received data bits and again modulated to obtain hard decision received data symbols.

Next, in the tracking module, the channel estimates, including noise, were updated using the modulated data symbols $\hat{X}$ as follows:

$$Y = H_i \hat{X} + Z \quad (2)$$
$$Y(\hat{X})^{-1} = H_i \hat{X}(\hat{X})^{-1} + Z(\hat{X})^{-1} \quad (3)$$
$$Y(\hat{X})^{-1} = \hat{H}_i + Z(\hat{X})^{-1} \quad (4)$$

The received data ($Y \in \mathbb{C}^{R \times Q}$) with modulated data ($\hat{X} \in \mathbb{C}^{U \times Q}$), the channel ($H \in \mathbb{C}^{R \times Q}$) and the AWGN ($Z \in \mathbb{C}^{R \times 1}$) are represented in equation 2. Then, the received data are multiplied by the inverse of the modulated data symbols as expressed in equation 3. Ultimately, the tracked channel states ($\hat{H}_i$ ($i = 1, 2, \ldots, 8$)) can be found by equation 4. There were 8 groups of 12 symbols, as the simulations were conducted for 96 OFDM symbols.

Then, the updated (newly estimated) channel state $\hat{H}_i$ was used to produce a new updated channel response at the channel update module. The previously estimated channel was replaced with the tracked channel estimate at the channel update module. Noise is removed by the hard decision process. The received data symbols are spread around a constellation point, while the hard decision data symbols are exactly at the constellation points, which we select in the hard decision process. Then, perform Zero-Forcing using the updated channel response and recursively demodulate, modulate and track for all the OFDM symbols.

VI. SIMULATION RESULTS

The performance comparison of magnitude between the tracked channel estimation, the initial channel estimation and the actual channel for all the frequency selective channels with $f_d = 10$ Hz is illustrated in Figure 1. The goodness of fit values for tracked channel and the initial channel estimate are 0.9678 and 0.4158, respectively. Therefore, at $f_d = 10$ Hz, the channel tracking method works with 97% accuracy, while the training-based initial channel estimation method shows poor performance in estimating the actual channel comparatively.

VII. CONCLUSIONS

This paper discusses the methodology undertaken, the channel model and the system model created for deriving a novel adaptive equalization method and a novel channel tracking method in the uplink of MU-MIMO-OFDM systems. The results prove that the novel tracking method performs accurately and efficiently.

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