Adaptive Modulation Selection Scheme in MIMO OFDM Wireless Systems

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Abstract - Error performance and throughput in MIMO-OFDM wireless systems can be improved through the use of Adaptive Modulation. Adaptive modulation selection plays an important role in wireless communication since the wireless channel conditions vary progressively. Therefore, using one modulation type cannot be efficient for all the channel conditions. In this paper, we propose a new algorithm to utilize the BER information at the receiver based on Error Estimation Coding (EEC) to realize a simple adaptive modulation selection scheme. Compared to the adaptive modulation and coding selection schemes (AMC), which are based on SNR, our scheme needs less computational time and resources to decide which modulation type, is best suited for the current channel conditions.

Index Terms—Adaptive Modulation, Bit Error Rate (BER), Error Estimation Coding (EEC), Multiple Input Multiple Output (MIMO), Orthogonal Frequency Division Multiplexing (OFDM).

I. INTRODUCTION

Generally, the channel used in practical communication systems is either a multipath fading time-varying channel. It may depend on various factors of the channel such as the path-loss between the transmitter and receiver or channel fading due to multipath propagation. Therefore, using any one modulation technique to transmit signal in the channel would not fulfill the requirement of wireless environment. Consequently, different channel condition corresponds to different modulation type. Taking 802.11 standards [1] for example, there are four kinds of modulation type, i.e. BPSK, QPSK, 16- QAM and 64QAM. Adaptive Modulation techniques have proven to be an effective way of transmitting data efficiently through time varying channels. Also in order to counter the adverse effects of Inter-Symbol Interference (ISI), Orthogonal Frequency Division Multiplexing (OFDM) is also used in our project. In order to increase the amount of data that can be transmitted over the channel we also incorporate a Multiple Input Multiple Output (MIMO) system. For the sake of simplicity we shall consider the system to be a 2X2 MIMO OFDM system. Also we employ Spatial Multiplexing in order to transmit maximum amount of data in the least amount of time.

II. RELATED WORK

In [2], [3], the authors investigated an example of a spatial modulation technique for MIMO systems known as spatial multiplexing (SM). In SM, multiple streams are transmitted simultaneously, each using a dedicated transmit antenna and the received signal is the sum of the transmitted signals propagating the different paths. In [4], the authors propose a Spatially Adaptive Modulation and Coding (SAMC) scheme which depends on the Post Processing SNR (ppSNR) of the system. The authors have implemented the scheme on a 2X2 MIMO OFDM system. They then use the ppSNR and get the type of AMC to be used. In order to calculate the ppSNR, they require the noise present in the channel. Also they display the number of times a particular modulation scheme is used by the system. In [5] the authors propose another adaptive modulation scheme. In this paper they have introduced a new coding technique. The algorithm proposed in this paper determines the BER of only redundant bits of every training packet that is transmitted. Thus this algorithm helps to save computational time and system resources.

The EEC based AMC algorithm proposed in this paper, utilizes the Error Estimation Coding [5] during the transmission of training packets. Based on EEC Bit
Error Rate (EBER) calculation at the receiver, the modulation scheme is changed for the next training packet, while also keeping a count of the number of times each modulation technique has been selected. At the end of the training phase, the modulation scheme which has been selected the maximum number of times, is used for transmitting a fixed number of data packets. After, this retraining is carried out by sending half of the packets used in the training phase, to save time.

The paper is organized as follows: In Section II we expatiate the system model used. In Section III, we describe the Error Estimation Coding (EEC) from [5], which forms the basis of our training algorithm. In Section IV, we elaborate on the modulation selection algorithm implemented. In Section V, we present experimental results of our algorithm. In Section VI, we describe our simulation parameters, and finally in Section VII, conclusions are discussed.

III. SYSTEM MODEL

Consider a MIMO OFDM system with 2 transmit antennas and 2 receive antennas, transmitting data over 64 subcarriers. The channel is assumed to be a multipath Rayleigh slow fading channel. The channel response matrix between each transmit/receive pair is assumed to be independent and identically distributed zero-mean circularly symmetric complex Gaussian random variable with unity variance. After the modulation scheme is selected, the data is transmitted using the schematic as in Fig1.

![Fig.1 Block Diagram of MIMO OFDM System](image)

The source is a stream of random raw binary data. A convolutional coding rate of $\frac{1}{2}$ is used. An IFFT size of 64 is used. While sending the data EEC is not done and the data is coded using convolutional coding. This helps to reduce the amount of time required to transmit the data.

IV. ERROR ESTIMATION CODING

In the EEC Encoder section, we select several bits at a fixed interval from the originally generated data, then apply modulo-2 addition to groups of these bits and get the redundant EEC bits. We insert the generated EEC bits into the original data at a calculated fixed interval. At the EEC Decoder end, redundant bits are extracted from the exact same interval as used in the Encoder and also new EEC bits are calculated from the received data sequence, using the same EEC encoding algorithm. Finally, the receiver computes the Bit Error Rate (BER) based on the calculated and received EEC bits and the BER is subjected to a selection construct to decide if the BER value falls in the expected range, and if not a feedback signal is sent to the transmitter to adapt to a better modulation scheme.

Let $n$ denote the bits number of one packet and $l$ equals $\log_2 (n)$. From these $n$ bits, EEC Encoder will generate $k$ EEC bits, where $k$ equals to $l \times s$ and $s$ is the constant set in the EEC encoder. Each EEC bit is generated through the modulo-2 addition of groups of $s$ data bits which were chosen as linear groups out of the selected $s \times k$ bits. The $s \times k$ bits are taken at a fixed interval of floor ($n/(s \times k)$) denoted by ‘step’. Once the calculation is done, the Encoder will insert these ‘$k$’ EEC bits into the ‘$n$’ data bits at a calculated interval of floor ($n/k$) denoted by ‘kstep’.

At the receiver end, the EEC Decoder extracts the $k$ EEC bits out of the packet at an interval of ‘kstep’, and then regenerates new EEC bits by XOR (modulo-2) operation on group of $s$ bits taken after every ‘step’ number of bits. Comparing these $k$ new EEC bits to the received $k$ EEC bits, the receiver calculates the Bit Error Rate (BER) according to this information.

V. MODULATION SELECTION ALGORITHM

The adaptive modulation selection algorithm is as follows:

1. for $i = 1:N$
2. Transmit $i^{th}$ training packet using $cur\_mod$ modulation scheme
3. At the Receiver, obtain $p = EBER$ (i), which is the EEC based BER for the $i^{th}$ packet
4. if ($cur\_mod == mode1$)
5. $count\_mode1 = count\_mode1 + 1$
6. elseif ($cur\_mod == mode2$)
7. $count\_mode2 = count\_mode2 + 1$
8. else
9. $count\_mode3 = count\_mode3 + 1$
10. if ($p>c3$)
11. $cur\_mod = mode1$

12. elseif (p>=c2 && p<c3)
13. cur_mod=mode2
14. elseif (cur_mod>mode1 && p>=c1 && p<c2)
15. cur_mod=cur_mod - 1
16. elseif (p<c1 && cur_mod<mode3)
17. cur_mod=mode3
18. else
19. cur_mod=cur_mod
20. Send the value of cur_mod as feedback to the transmitter
21. end for
22. Calculate maximum (count_mode1, count_mode2, count_mode3) and use the mode with the maximum count_mode as the modulation scheme for transmitting M data packets.
23. Perform retraining using N/2 packets by iterating over steps 1 to 21

Where, cur_mod represents current modulation scheme, its initial value being mode1 and mode1, mode2 and mode3 denote 4-QAM, 16-QAM and 64-QAM respectively; N is the number of training packets used; count_mode (i) represents the number of times mode (i) has been used during the complete training period; c1 = 0.05, c2 = 0.25 and c3 = 0.5 are assumed constants that signify the boundary limits for the EBER (i) related to the i\textsuperscript{th} training packet.

VI. EXPERIMENTAL RESULTS

In this section we analyze the performance of our modulation selection algorithm. Fig 2 shows the Overall Bit Error Rate (BER) performance of our EEC based AMC algorithm, as compared to an algorithm not using AMC. It can be concluded, that the EEC AMC algorithm performs better especially in regions of higher SNR, as it uses 64-QAM during that interval, which sends data at a higher data rate and has less probability of error, which can be inferred from Fig 4, which shows that during the 20 dB to 25 dB SNR range, almost 65 % usage is of 64-QAM. Fig 3, shows the throughput performance of our algorithm, which also depicts a slightly higher throughput of the EEC AMC algorithm, hence better overall system performance.
VII. SIMULATION PARAMETERS

The number of subcarriers used in the OFDM scheme is 64. A transmission bandwidth of 20 MHz and a carrier frequency of 2.4GHz were used. The coherence time is equal to 650 ms on a Core 2 Duo Intel Processor at 1.66 GHz and 2 GB RAM. Here, the number of bits in a training packet, n is equal to be 256. Also s, which is a constant parameter for EEC used in training packet, is equal to 4. Therefore, $l = \log_2 (n) = 8$.

Computational Complexity ($T(K)$) of the algorithm has been derived for this specific paper.

In the given algorithm, assuming N training packets are transmitted over K subcarriers, and for each packet transmission, a selection construct to choose the appropriate modulation type executes in ‘no_of_modes’ time, hence with respect to every training packet on an average, the time complexity can be stated as:

$$T(K) = O(K \cdot \text{no_of_modes})$$  \hspace{1cm} (1)

Also, finding out the maximum out of no_of_modes takes an average time of no_of_modes/2, thus this operation is performed in serial, so the term is added to the complexity expression. Overall, the time complexity of the EEC based AMC Selection Algorithm is given by:

$$T(K) = O(K \cdot \text{no_of_modes} + \text{no_of_modes}/2)$$  \hspace{1cm} (2)

The computational complexity of [4] is given by equation (3),

$$T(K) = O(J \cdot K + \text{no_of_modes})$$  \hspace{1cm} (3)

Here J is the number of transmit antennas, K is the number of OFDM subcarriers used and number of modes is the number of modulation modes used by the system.

The proposed algorithm was simulated on MATLAB software, version of MATLAB 7.9.0.529 R2009b.

VIII. CONCLUSION

In this paper, an Adaptive Modulation algorithm was proposed and implemented based on EEC coding during training interval. It can be shown that the complexity of this algorithm is less and requires fewer resources to achieve the same error performance. Future work would be based on including an adaptive coding rate selection scheme in addition to modulation selection.

IX. REFERENCES


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