DESIGN OF PRE-PROCESSED CROSS LAYERED ADAPTIVE MODULATION FOR MIMO-OFDM RECEPTOR ARCHITECTURE

M.Bakyalakshmi, Mr. C. Susil Kumar
Department Electronics and Communication Engineering
Velammal College of Engineering and Technology, Madurai.
bakya.sharma@gmail.com, c_susil@yahoo.com

Abstract: Modern wireless communication applications are characterized by the need for advanced signal processing techniques such as Multiple-Input Multiple-Output (MIMO) technology for achieving high throughput and diversity and Orthogonal Frequency Division Multiplexing (OFDM) for achieving robustness to fading. This paper introduces techniques that increase the throughput, reduces preprocessing delay and thereby increases the overall spectral efficiency of any wireless communication system; including mobile adhoc networks and wireless sensor networks. An efficient preprocessed cross-layer adaptive modulation and coding (AMC) design for MIMO−OFDM systems, that combines the AMC at the physical layer with an automatic repeat request (ARQ) protocol at the data link layer, to maximize spectral efficiency under specified delay and packet error ratio (PER) constraints is developed and presented in this paper. We propose PLU channel decomposition replacing the widely used QR decomposition to achieve a better matching of the processing rate of MIMO−OFDM receivers to the real-time processing deadlines imposed by the structure of the incoming data packets. The modulation and encoding techniques for each subcarrier derived from the result of preprocessing is updated frame-by-frame to match the time-varying channel conditions. The proposed cross-layer AMC design is incorporated with preprocessing algorithm so as to further improve the system performance. In the event of occurrence of errors, the retransmission at the data link layer alleviates rigorous error-control requirements at the physical layer and thereby allows higher data rate transmission. This results in a desirable trade-off between spectral efficiency and delay in the MIMO−OFDM system achieved by only a smaller number of retransmissions.

I. INTRODUCTION
Orthogonal frequency division multiplexing (OFDM) has fascinated a great deal of attention due to its resilience to RF interference, high spectral efficiency[1]. The combination of MIMO and OFDM has emerged as a promising choice for future high data rate wireless communications to achieve high capacity and high robustness without excessive complexity equalization, and thus MIMO-OFDM has been proposed for Wi-Fi, WiMax and 4G communication systems[2].

The optimization of processing at the receiver is of vital importance as it can reduce the symbol processing delays and related data buffering requirements and thus reduce complexity and cost of a MIMO_OFDM receiver. Adapting SVD to this scenario is challenging since the decomposition requires multiplying by a channel-dependent matrix at the encoder which prevents from using this decomposition for MIMO-OFDM systems[3].

To augment throughput and to mitigate the channel fading in future wireless data communication systems, adaptive modulation and coding (AMC) and ARQ have been studied extensively. To minimize delays and buffer sizes in practice, ARQ protocols is used to limit the maximum number of retransmissions [4]. However, only fixed modulation and coding at the physical layer have been considered in systems with truncated ARQ protocols [14].

When the number of retransmissions increases, then the spectral efficiency decreases. Then the paper is organized as follows. Section II deals with the system description. Section III deals with the proposed pre-processing algorithm Section IV deals with the cross layer design of MIMO-OFDM. In Section V we present the simulation results.

II. SYSTEM DESCRIPTION:
We consider a MIMO-OFDM system with NTx and NRx antennas at the transmitter and receiver respectively. The total number of subcarriers is N. Per each subcarrier, we deploy the proposed cross-layer joint AMC−ARQ design.

The proposed adaptive MIMO−OFDM combining STBC is shown in Fig. 1. It consists of an AMC module at the physical layer, and an ARQ module at the data link layer. A data packet coming from data link layer, encoded by cyclic redundancy check (CRC) is sent to the Turbo encoder before feeding to the transmit buffer. Then the data is buffered. Buffered data is sent to the AMC module. Based on CSI acquired at the receiver, the AMC selector selects the modulation- coding pair (mode), which is sent back to the transmitter through a feedback channel. The AMC controller then updates the transmission mode at the transmitter. Here the channel state information is obtained from the channel estimator at the receiver. Receiver processing for MIMO_OFDM can be viewed as a sequence of computational kernels (algorithms) connected in a pipelined fashion. The channel estimation kernel involves estimation of the MIMO channel matrix per OFDM subcarrier. The pre-processing kernel is some form of matrix factorization of H(k) such as QR- or LU-decomposition[4]. In this way channel state is estimated and different modulation and coding scheme is used for different subcarriers. Then the adaptively modulated signals are then coded before transmitting from multiple antennas after modulation.
At the data link layer, the ARQ protocol is implemented. If an error occurs in a packet, a retransmission request is generated by the ARQ generator; otherwise, no request is generated. If there is no error, then an acknowledgement (ACK) message is sent back to the transmitter and the next packet is transmitted; otherwise, a no acknowledgement (NAK) message is fed back and a retransmission request is generated by the ARQ generator[5].

III. PREPROCESSING ALGORITHM

The MIMO_OFDM receiver design uses a preprocessing algorithm in the channel estimation, in order to reduce the preprocessing delay.

A. PLU Decomposition Algorithm

It presents the pseudo-code for LU decomposition based on the pivoted LU LAPACK code [11]. In PLU, row permutations are not optimized because such a task is dependent on the target platform details.

The PLU pseudo-code has been arranged so that the algorithm operates on each column of the channel transfer matrix in succession (line 2: loop j). Each iteration of j (lines 3 to 24) can be performed after the corresponding jth column is estimated by the MIMO channel estimation process (line 2). Thus PA = LU, where L is lower triangular and U is upper triangular. It is also called as PLU factorization.

We propose PLU channel decomposition replacing the widely used QR decomposition to accomplish a better matching of the processing rate of MIMO-OFDM receivers to the real-time processing deadlines imposed by the structure of the incoming data packets [11]. The PLU decomposition algorithm is an attractive algorithm for MIMO-OFDM receiver because of its lower complexity, achieving the optimal operation point and it eliminates the need for buffering even for high number of antennas.

IV. CROSS LAYER DESIGN

In this paper, we proposed the cross layer design [6] for MIMO-OFDM system which consists of joint AMC module at the physical layer and ARQ module at the data link layer.

The packets at the data link layer which comprises multiple information bits. On the other hand, the frames at the physical layer which is a collection of multiple transmitted symbols. The modulation and coding schemes for each subcarrier are chosen by the link adaptation policy. At the physical layer, we consider that multiple transmission modes are available. Each mode consists of specific modulation.

Let M denotes the total number of available transmission modes. The mode index is m and the data rate increases with the ascending mode index m. Define the maximum number of retransmissions as \( N_{\text{max}} \) [7]. Our aim is to design an optimum AMC at the physical layer with the aid of ARQ at the data link layer to match each subcarrier to time-varying channel
conditions, so as to maximize throughput under the constraints of delay and the overall system performance defined by $P_{\text{loss}}$.

Table 1 Turbo-coded modulation transmission modes

<table>
<thead>
<tr>
<th>Mode</th>
<th>Modulation</th>
<th>Coding rate</th>
<th>Data Rate (bits/sym.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BPSK</td>
<td>1/3</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>QPSK</td>
<td>1/2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>16QAM</td>
<td>1/3</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>64-QAM</td>
<td>½</td>
<td>6</td>
</tr>
</tbody>
</table>

To simplify the design of AMC, approximate PER expression is used here, as already done in [6,8,9,10]. For each subcarrier, the PER for transmitting mode $m$ is represented as

$$ \text{PER}_{m}(\gamma) = \begin{cases} 1 & 0 < \gamma < \gamma_m \\ \frac{\gamma_m - \gamma}{\gamma_m} & \gamma \geq \gamma_m \end{cases} $$

where $m$ is the index of transmission modes and $\gamma$ is the received SNR at each subcarrier. $a_m$, $g_m$ and $\varnothing_{pm}$ are mode-dependent parameters for mode $m$, given in [15].

Note that the boundary points for transmission modes are the minimum SNRs required to achieve $\text{PER} \leq P_{\text{target}}$ for transmission modes

$$ \gamma_0 = 0, $$

$$ \gamma_m = \frac{1}{g_m} \ln \left( \frac{a_m}{P_{\text{target}}} \right), \quad m = 1, 2, \ldots, M $$

$$ \gamma_{M+1} = +\infty $$

The proposed AMC will maximize the spectral efficiency, by maintaining the required performance $\text{PER} \leq P_{\text{target}}$.

After determining the SNR regions and their boundary points, AMC is operated for each mode. The cross-layer AMC algorithm for MIMO--OFDM system can be described as:

1. Determine the desirable delay, $N_{r_{\text{max}}}$.
2. Determine the packet loss probability at data link layer i.e. $P_{\text{loss}}$.
3. Determine the $P_{\text{target}}$.
4. Obtain the SNR region boundaries for transmission modes $m=0\ldots M$ using (2) for the encoded transmission or using table 2 for turbo coded transmission.
5. Select the transmission scheme for each subcarrier based on the receiver.
6. Retransmits the packets until it is received correctly.

Table 2 Switch boundaries of AMC algorithm for coded transmission.

<table>
<thead>
<tr>
<th>$N_{r_{\text{max}}}$</th>
<th>$P_{\text{target}}$</th>
<th>$\Box_1$</th>
<th>$\Box_2$</th>
<th>$\Box_3$</th>
<th>$\Box_4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.01</td>
<td>2.480</td>
<td>4.900</td>
<td>7.853</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.1</td>
<td>-0.521</td>
<td>1.746</td>
<td>4.421</td>
<td>7.300</td>
</tr>
<tr>
<td>2</td>
<td>0.215</td>
<td>-0.691</td>
<td>1.501</td>
<td>4.265</td>
<td>7.115</td>
</tr>
<tr>
<td>3</td>
<td>0.316</td>
<td>-0.778</td>
<td>1.370</td>
<td>4.180</td>
<td>7.020</td>
</tr>
</tbody>
</table>

V. SIMULATION RESULTS

This algorithm is evaluated using the Monte Carlo simulations. The bandwidth is 40Mhz. The channel is divided into 1024 subcarriers. The system requires PER less than .01 and the length of packets is 1080 bits.

The average spectral efficiency is

$$ \text{SE} = \frac{\text{total bits in transmission}}{\text{the number of subcarrier waves}} N $$

where $N$ is the average transmission number of symbols. Fig. 2 and 3 demonstrates the average spectral efficiency of the preprocessed cross layer AMC design.

![Fig. 1 PER performance for coded system.](image)

Fig. 1 depicts that PER performance of system. The PER is defined as packet error ratio in the transmission. Here the requirement on error rate performance at the physical layer is greatly reduced.

VI. CONCLUSION

In this paper, we developed the preprocessed cross layered design for MIMO-OFDM receiver, in order to increase the spectral efficiency which combines the adaptive modulation and coding module at the physical layer and automatic repeat request at the data link layer. Further the preprocessing delay is reduced by decomposition algorithm. Due to the cross layer design, rigorous error correction at the physical layer is reduced and hence it allows high data rate.
VI. REFERENCES

[13] Decomposing the MIMO Broadcast channel