Selective Retransmission Based Efficient Multiuser Detection for Overloaded MIMO OFDM System

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Summary
In wireless communication systems, multiple input multiple output (MIMO) and orthogonal frequency division multiplexing (OFDM) technologies offer reliable communication with high capacity and coverage rate. In a multiuser MIMO systems, co-channel interference increases drastically when a large number of users are added to the channel. However, it is practically not feasible to provide a separate physical receive antenna to each user, which leads the system into an overloaded condition. Although, the optimal and suboptimal multiuser detection (MUD) algorithms perform better in MIMO system but these algorithms perform poorly in an overloaded MIMO system ($\boldsymbol{N_{Rx} < N_{Tx}}$) . To overcome this problem, we proposed a receiver design that allows the application of conventional optimal and suboptimal MUD algorithms in overloaded system. In proposed receiver design, virtual receive antennas (VRA) are created using hybrid automatic repeat request (HARQ) retransmissions, and thereafter chase combining of (re)transmitted vectors is performed to convert an overloaded system into a critically ($\boldsymbol{N_{Rx} = N_{Tx}}$) or under loaded ($\boldsymbol{N_{Rx} > N_{Tx}}$) system. In addition, we introduce a selective retransmission (SR) scheme for the retransmission of erroneous OFDM subcarriers at modulation level. The SR scheme increases the throughput by reducing HARQ retransmissions. Simulation results validate the performance of our proposed scheme in terms of throughput enhancement with reduced bit error rate (BER) and packet drop rate.

Key words:
Overloaded MIMO, OFDM, HARQ, MUD, VRA, BER.

Nomenclature

p	represent bits of dth user
$\mathcal{L}$	represents the subcarrier
v_{ra}	CC-HARQ retransmission vector
v_{sr}	selective retransmitted vector
$\tilde{v}_{mod}$	modified vector
d^c	correctly decoded users
$\mathcal{S}$	selectively retransmitted subcarrier
N_{Tx}	number of transmit antennas
N_{Rx}	number of receive antennas
D	total users
n_{tx}	transmit antenna of single user
$N_{d,n}$	n^{th} transmitting antenna of d^{th} user
I	information bits vector
w	code word vector
H	channel matrix
n_{sc}	number of subcarriers for single
u_d	transmitted signal vector of d^{th}user
u	transmitted signal vector of all users
v	received signal vector
g	complex Gaussian noise
λ	LLR vector of subcarriers
$\mathbb{L}_{N_{Tx}}$	LLR values of received coded sequence
$\boldsymbol{I}$	identity matrix
$\mathcal{B}$	bits received correctly
w_p^d	received the coded sequence of p bits of d^{th}
$\mathcal{U}_p$	represent the transmitted symbol vector set with $p \in \{0, 1\}$
$\hat{u}_{mmse}$	MMSE output vector
Δ	symbol set
b_1	bit error rate of first virtual receive antenna's retransmission
b_2	bit error rate of first selective retransmission
p_c	probability of receiving correct packets
p_e	probability of receiving erroneous packets
$\mathcal{T}_{Avg}$	average number of virtual receive antennas
$\mathcal{T}_{max}$	maximum number of virtual receive antennas
$\mathcal{R}$	code rate
η_{arq}	throughput of selective ARQ receiver
η_{scc}	throughput of proposed receiver

1. Introduction

Evolution of technology brought up the scarcity of radio resources in order to meet the user's requirement. Therefore, efficient resource sharing techniques are required to enhance the coverage and reliability of wireless communication systems [1]. The techniques such as MIMO, OFDM and HARQ gained a lot of attention for proficient radio resource sharing with reliable communication even in poor channel conditions [2-5]. Both MIMO and OFDM technologies have been adopted, either combined or separately in long-term evolution (LTE), worldwide interoperability for microwave access (WiMAX) and in 5G

Manuscript received October 5, 2018
Manuscript revised October 20, 2018

communication systems to allocate communication resources efficiently [6-8].

The conventional suboptimal MUD algorithms such as Zero Forcing (ZF) and minimum mean square error (MMSE) perform efficiently either in critically or under loaded MIMO system [9]. However, performance of such algorithms degrades severely when applied for joint MUD in overloaded MIMO system [10]. This results in complicated calculations of log likelihood ratios (LLR). The optimal detection algorithm such as maximum likelihood (ML) calculates the LLR values smoothly but its complexity increases with increase in number of transmit antennas [11]. Hence, these algorithms cannot be applied directly to the overloaded MIMO system.

Main contribution of this research work is to design a receiver for an overloaded MIMO system, which performs efficiently with conventional MUD algorithms and reduce complexity. For this purpose, each HARQ re-transmission vector is combined with the previously received data vectors at the receiver to create a VRA. Chase combining of VRA results in conversion of an overloaded system into critical or under loaded system. Creating more VRAs cost more retransmissions to the system that adds an extra payload. To reduce the extra payload and performing selective retransmission of OFDM subcarriers, an additional layer is incorporated at the OFDM modulation level. The additional layer checks the subcarriers with low SNR in received OFDM frame and performs the selective retransmission of data on subcarriers with low SNR instead of full data on OFDM frame. In result of this, the throughput of system increases. The proposed receiver design is also a solution to the capacity enhancement and complexity issues of 5G systems in overloaded condition.

The manuscript is organized as follows. Literature review is described in section II. The system model and problem formulation of overloaded MIMO OFDM with selective retransmission is presented in section III. In Section IV, BICM optimal and suboptimal receivers and the throughput analysis of system is provided. We discuss our simulation results in Section V. In Section VI, conclusion of the proposed work is presented.

2. Literature Review

In recent years, researches have been proposed for joint MUD in overloaded MIMO system i.e., in [12], a genetic algorithm based detection for reduced computational complexity is proposed. This scheme exhibits significant error floors at high SNR in the performance curves. Sphere decoding, turbo codes and virtual channel based schemes is proposed in [13] and [14] respectively. However, symbol detection overloaded system is still an unresolved issue. In [10] an overloaded MIMO system transformation into critically loaded or under loaded system is done by creating VRAs through HARQ retransmission. This technique needs sophisticated implementation because unnecessary retransmission of whole data is requested, which creates an extra payload on the system. The VRA based scheme was further extended by employing network coding in [15,16], but these schemes lack in providing frequency selectivity under OFDM. In [17], adaptive extended rotation matrices selection is used in the receiver for better performance. However, system complexity makes it infeasible for practical implementations. In [18], a bandwidth efficient selective retransmission based HARQ (S-HARQ) technique for MIMO OFDM is presented to achieve high capacity and efficient MUD but this technique has not yet been investigated for overloaded scenario. In [19-22], researcher have evaluated the performance of overloaded MIMO systems, however the performance of different coding schemes were evaluated without considering the conversion of overloaded system into under loaded or critically loaded system.

To the best of our knowledge, research to date has not considered overloaded MIMO OFDM system with selective retransmission of OFDM symbols based VRA. Thus, in our receiver design we present a method based on selective retransmission of OFDM symbols that reduces the number of retransmission caused by creating VRAs. It also provides frequency selectivity with performance gains in joint MUD for overloaded MIMO OFDM system.

3. System Model and Methodology

In this section, system model is presented first and later on problem formulation is described.

3.1 System Model

An overloaded MIMO OFDM system is considered employing bit interleaved coded modulation (BICM) for uplink frequency selective channel. Multiple co-channel users are communicating with a centralized receiver equipped with N_{Rx} receive antennas. The total number of transmitting antennas is defined as:

$$N_{Tx} = \sum_{d=1}^{D} \sum_{n=1}^{n_{tx}} N_{d,n} \qquad (1)$$

Where D and n_{tx} are the total number of users and transmitted antenna on single user, and $N_{d,n}$ represents n^{th} transmitting antenna of d^{th} user. Information bits $I = [I_1, \cdots, I_{\mathscr{b}}]^T$ along with cyclic redundancy check (CRC) bits are encoded using FEC encoder and $\mathscr{b}$ represents the total number of bits, respectively. The bits are interleaved using a random bit interleaver results in code word $w = [w_1, \cdots, w_p]^T$, where p represents the code word length. These code words are circularly de-multiplexed and mapped into OFDM signal. $N_{Tx} \times N_{Rx}$, frequency selective channels are assumed between transmitters and receiver, each of them is uncorrelated in time and identically

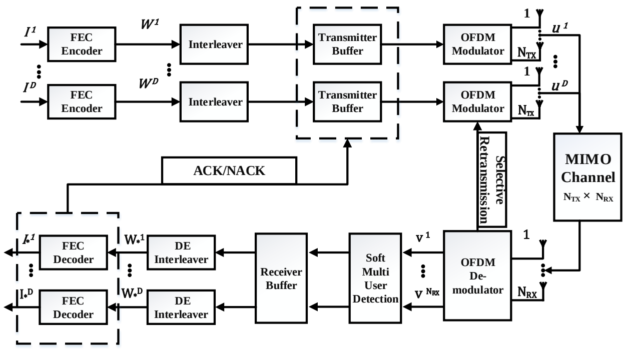

Fig. 1 Proposed beam former.

distributed as, $h \sim \mathcal{N}_{\mathbb{C}}(0, \sigma_h^2)$. The channel matrix is defined as $H = h_{N_{Tx} \times N_{Rx}}$ .Subcarriers in an OFDM signal have coherent bandwidth much less than the bandwidth of the channel which converts each frequency selective channel into n_{sc} flat fading channels. The transmitted signal can be represented as $a_n = [a_n(1), \cdots, a_n(n_{sc})]$, where n_{sc} represents the total number of subcarriers for a single transmit antenna.Let $u_d = \left[a_1, \cdots, a_{n_{tx}}\right]^T$ be the transmitted signal of d^{th} user and $u = [u_1, \cdots, u_D]^T$ represents the transmitted signals of all users.Let v be received vector and stored in receiver buffer after applying FFT transformation and eliminating cyclic prefix (CP).

$$v = Hu + g \tag{2}$$

Where g is the complex Gaussian noise with zero mean and variance $\mathcal{N}_0$.Furthermore, Perfect channel state information (CSI) is assumed at the receiver. Each element of H is the complex channel gain, corresponding to a single subcarrier between i^{th} transmit antenna and j^{th} receive antenna. The receiver employs soft output MUD which computes the log likelihood ratio (LLR) of $\mathcal{L}^{th}$ subcarrier in MIMO OFDM system.

$$\lambda(:, \mathcal{L}) = \begin{bmatrix} \mathbb{L}_1 \\ \vdots \\ \mathbb{L}_{N_{Tx}} \end{bmatrix} \tag{3}$$

Where, $\mathcal{L} = [1, \cdots, n_{sc}]$ .The LLR metric for all n_{sc} subcarriers is $\lambda = [\lambda(:,1), \cdots, \lambda(:, n_{sc})]$. These LLR values are de-interleaved and used in FEC decoder to acquire information bit vector I_* , which is an estimate of the transmitted signal I . Since, in overloaded scenario the receiver has less number of antennas than transmit antennas $(N_{Tx} < N_{Rx})$, therefore virtual antennas are created using CC-HARQ retransmissions. These (re)transmissions are separated from VRA (re)transmissions which send a NACK if the OFDM frame does not pass the CRC check. This process goes on until the data is correctly decoded or maximum virtual antennas are created.

We propose a scheme using partial retransmission of symbols corresponding to poor quality subcarrier at OFDM layer irrespective of conventional VRA (re)transmissions for the system model presented in figure 1. The proposed scheme decrease the number of virtual antennas required and enhances the throughput of the system.

3.2 Methodology

In proposed work, OFDM is used as the transmission scheme. The subcarriers in an OFDM system experience flat fading even in frequency selective environment. We exploit diversity offered by OFDM and flat fading on each subcarrier for selective retransmission of data on erroneous subcarriers in received vector. The proposed method uses channel information to send a request back to a particular user or users for a selective retransmission of data on subcarrier which have channel gain lower than a particular threshold value. After every (re)transmission of VRA the receiver sends a NACK through a partial feedback channel to a particular user or users for selective retransmission.

The proposed receiver stores the VRA transmission or the retransmission in buffer, and asks for selective retransmission of the data on low quality subcarrier. The selective retransmission triggered at OFDM layer, is independent of VRA (re)transmissions. These selective retransmissions improve the channel quality which in return enhance the throughput and decrease the overall VRA (re)transmissions and conventional HARQ retransmissions. Let v_{ra_1} be the received vector of first transmission after OFDM receiver saved in buffer.

$$v_{ra_1} = H_{ra_1} u + g_{ra_1} \tag{4}$$

Channel matrix H_{ra_1} is of the order $N_{Tx} \times N_{Rx}$ in which each element is the complex channel gain corresponding to subcarrier $\mathcal{S}$. The selective retransmission triggered at OFDM layer use partial feedback channel and NACK to request a particular user or users to retransmit the data on poor quality subcarriers. Channel information is sent back to the user by sending n_{sc} bit vector indicating which subcarriers data is to be selectively retransmitted. Let $H_{sr_1}(\mathcal{S})$ be the channel matrix for the data $u_{ra_1}(\mathcal{S})$ selectively retransmitted corresponding to the subcarrier $\mathcal{S}$. We assume that the channel matrix $H_{ra_1}(\mathcal{S})$ corresponding to first VRA of information symbol $u_{ra_1}(\mathcal{S})$ and $H_{sr_1}(\mathcal{S})$ are independent of each other. For simplicity, we use only one selective retransmission for single retransmission. The received vector $v_{sr_1}(\mathcal{S})$ after selective retransmission,

$$v_{sr_1}(\mathcal{S}) = H_{sr_1}(\mathcal{S})u_{ra_1}(\mathcal{S}) + g_{sr_1}(\mathcal{S}) \tag{5}$$

The resultant received data $\tilde{v}_{ra_1}(\mathcal{S})$ after first VRA and SR is measured as,

$$\begin{bmatrix} v_{ra_1}(\mathcal{S}) \\ v_{sr_1}(\mathcal{S}) \end{bmatrix} = \begin{bmatrix} H_{ra_1}(\mathcal{S}) \\ H_{sr_1}(\mathcal{S}) \end{bmatrix} u_{ra_1}(\mathcal{S}) + \begin{bmatrix} g_{ra_1}(\mathcal{S}) \\ g_{sr_1}(\mathcal{S}) \end{bmatrix}$$

$$\tilde{v}_{ra_1}(\mathcal{S}) = \begin{bmatrix} v_{ra_1}(\mathcal{S}) \\ v_{sr_1}(\mathcal{S}) \end{bmatrix} \tag{6}$$

$$\tilde{v}_{ra_1}(\mathcal{S}) = \mathcal{H}_{ra_1}(\mathcal{S})u_{ra_1}(\mathcal{S}) + \tilde{g}_{ra_1}(\mathcal{S}) \tag{7}$$

The users with successfully decoded data packets receive ACK and stops transmitting data. However, the data in buffer still has the previously decoded data of that particular user, which is unnecessary and removed from buffer. The data of correctly decoded user is sent back to buffer and is subtracted from the stored data. For simplicity, we assume that first d^c users are correctly decoded. The modified received vector in buffer is described as,

$$\tilde{v}_{mod_1} = \tilde{v}_{ra_1} - v^c \tag{8}$$

$$\tilde{v}_{mod_1} = \tilde{v}_{ra_1} - \sum_{d=1}^{d^c} (\mathcal{H}_{ra_1}^d u^c + g_{ra_1}^d) \tag{9}$$

The second VRA transmission only contains the data of users which are not correctly decoded in first transmission. The received vector after second VRA transmission is given below,

$$v_{vra_2} = H_{vra_2}\, u + \, g_{vra_2} \tag{10}$$

H_{vra_2}, contains the channel gains corresponding to only retransmitting users. The subcarriers with low channel gains are retransmitted for second VRA and the final received vector is given by,

$$\tilde{v}_{vra_2} = \begin{bmatrix} v_{vra_2} \\ v_{sr_2} \end{bmatrix} \tag{11}$$

The received vector $\tilde{v}_{vra_2}$ is stored with $\tilde{v}_{mod_1}$, resulting is as follows,

$$v = \begin{bmatrix} \tilde{v}_{mod_1} \\ \tilde{v}_{vra_2} \end{bmatrix} \tag{12}$$

LLRs are calculated using the stored data v and used to calculate an estimate of the transmitted signal. CRC is applied for detection of users with erroneous data and another VRA transmission is requested from users with unsuccessful CRC. However, correctly decoded users remain idle and their data is subtracted from the previous transmissions stored in buffer. This process continues until all the users are correctly decoded or maximum number of VRAs are created. As described in introduction, the complexity of ML receiver is directly proportional to transmit antennas as well as the number of VRAs. The computational complexity of full retransmission complexity is equivalent to processing two selective retransmissions [23], in result to this the computational complexity of ML reduces to some extent. However, a better performance and complexity tradeoff is offered for MMSE detector. In our work, both optimal and sub optimal receivers are considered and their performance efficiency is compared as well.

4. Joint MUD performance and Throughput

4.1 Joint MUD performance

Joint detection of multiple users is performed softly using ML and MMSE detector and (re)transmitted data is in buffer at the receiver end. As the performance of FEC decoder is highly affected by burst errors, therefore, bit interleaved coded modulation (BICM) is used in our receiver design to disperse bits randomly [24]. BICM has become a fundamental technique in new generation wireless communication systems [25]. The LLR values $\mathbb{L}$ of received coded bits from all users are calculated after BICM. Let w_p^d represents the coded sequence of p bits of d^{th} user that contains then LLR is given by,

$$\mathbb{L}(w_p^d) = \log\left(\frac{\mathbb{P}(w_p^d = 1 | v,\, H^d)}{\mathbb{P}(w_p^d = 0 | v,\, H^d)}\right), \ d = 1,2,\cdots,D \tag{13}$$

$$= \log\left(\frac{\sum_{u\epsilon\mathcal{U}_p^1}\left(-\frac{1}{\sigma_h^2}\|v-Hu\|^2\right)}{\sum_{u\epsilon\mathcal{U}_p^0}\left(-\frac{1}{\sigma_h^2}\|v-Hu\|^2\right)}\right) \tag{14}$$

Where, $\mathcal{U}_p^1$ and $\mathcal{U}_p^0$ represent the transmitted symbol vector's set with bit $p \in \{0,1\}$. After applying the maximum log-approximation, the above equation (12) turns into the following form,

$$\mathbb{L}(w_p^d) = \frac{1}{\sigma_h^2}\left(\min_{u\epsilon\mathcal{U}_p^0}\|v - Hu\|^2 - \min_{u\epsilon\mathcal{U}_p^1}\|v - Hu\|^2\right) \tag{15}$$

LLR computational complexity is strictly dependent on the number of transmit antennas and grows exponentially with the increase in transmit antennas. In overloaded case the number of transmit antenna does not vary so the complexity of ML detector remains the same as in critically loaded or under loaded environment. In case of MMSE equalizer the receiver processes received data and obtain the following received signal vector,

$$\hat{u}_{mmse} = (H^H H + \sigma_h^2 \boldsymbol{I})^{-1} H^H v \quad (16)$$

Where $\boldsymbol{I}$ represents the identity matrix and the resultant LLR of p^{th}coded data bit transmitted through i^{th} antenna of the d^{th}user is calculated using MMSE algorithm [12] as given below,

$$\mathbb{L}\left(w_{p,i}^d\right) = \frac{1}{\sigma_{i,d}^2}\left(\min_{u\epsilon\Delta_p^0}\left\|\hat{u}_i^d - u\right\|^2 - \min_{u\epsilon\Delta_p^1}\left\|\hat{u}_i^d - u\right\|^2\right) \quad (17)$$
$$i = 1,2,3,\cdots, N_{d,n} \qquad d = 1,2,3,\cdots D$$

Where, Δ_p^0 andΔ_p^1 represent the symbols and each bit $p \in \{0,1\}$, after, passing through MMSE in symbol set Δ. The received data is then passed through FEC decoder after DE interleaving. Negative acknowledgement (N-ACK) is sent using CCHARQ in case of errors in packet requesting retransmission of data and in case of no errors, a positive acknowledgement (ACK) is sent by the receiver as shown in figure 1. It is assumed that feedback channel is free from errors and without adding significant delay during transmission of ACK/N-ACK for low complexity.

4.2 Throughput Analysis

In this section, throughput analysis of selective retransmission based VRA receiver under overloaded MIMO OFDM systems is presented. For simplicity, only one selective retransmission for one VRA is considered. The throughput of the system depends upon the BER of the receiver. Let b_1 and b_2 are the BER of first VRA transmission and first selective retransmission respectively. The probability of receiving correct and erroneous Υ packets in first transmission are p_c^1, and p_e^1respectively. Likewise, the probabilities of receiving correct and erroneous Υ packets in first retransmission are p_c^2, and p_e^2 respectively.Therefore, the average number of VRAs created for all packets to be delivered correctly can be defined as [20],

$$\mathcal{T}_{Avg} = p_c^1 + 2p_e^1 p_c^2 + 3p_e^1 p_e^2 p_c^2 + 4(p_e^1)^2 p_e^2 p_c^2 + 5(p_e^1)^2 (p_e^2)^2 p_c^1 + 6(p_e^1)^3 (p_e^2)^2 p_c^2 + 7(p_e^1)^3 (p_e^2)^3 p_c^1 \cdots \quad (18)$$

$$= P_{c1}(1 + 3p_e^1 p_e^2 + 5(p_e^1 p_e^2)^2 + \cdots + (2\mathcal{T}_{max} - 1)\,(p_e^1 p_e^2)^{\mathcal{T}_{max}-1}) + 2P_{e1}P_{c2}(1 + 2p_e^1 p_e^2 + 3(p_e^1 p_e^2)^2 + \cdots + \mathcal{T}_{max}(p_e^1 p_e^2)^{\mathcal{T}_{max}-1}) \quad (19)$$

Where, $\mathcal{T}_{max}$ represents the maximum number of VRA allowed. The average number of VRA can be simplified as,

$$\mathcal{T}_{Avg} = \frac{p_c^1(1+p_e^1 p_e^2)+2(1-p_c^1)p_c^2}{(1-p_e^1 p_e^2)^2} \quad (20)$$

Note that for ARQ, the probability of receiving error free packets in any transmission is same $p_c^1 = p_c^2$, and the throughput is equal to $\eta_{arq} = 1/\mathcal{T}_{Avg} = p_c^1$.Throughput of a receiver can be defined as the ratio of number of bits received correctly $\mathcal{B}$to the total transmitted bits to deliver these bits. The selective retransmissionsfor each VRA overhead $\mathcal{O}_{sarq}$, therefore, the throughput η_{sarq} of selective retransmission enabled ARQ S-ARQ is given below,

$$\eta_{sarq} = \frac{\mathcal{B}}{\mathcal{B}(\mathcal{O}_{sarq}+1)\mathcal{T}_{Avg}} \quad (21)$$

$$\eta_{arq} = \frac{p_c^1}{(\mathcal{O}_{sarq}+1)} \quad (22)$$

The throughput $\eta_{scc}$of SCC-HARQ is calculated as,

$$\eta_{scc} = \frac{p_c^1}{(\mathcal{O}_{scc}+1)/\mathcal{R}} \quad (23)$$

Where, $\mathcal{R}$ is the code rate of FEC encoder and $\mathcal{O}_{scc}$ denotes the overhead due to CC-HARQ.

5. Simulation Results and Discussions

In this section, the performance of SR scheme is presented. The proposed scheme is evaluated upon BER, throughput and packet drop rate, outperforming standard schemes in all aspects. In simulation setup, we had four co-channel users in an overloaded MIMO OFDM system with 1024 subcarriers each. Frequency selective Rayleigh fading channel was considered with zero mean, unit variance and (i. i. d). path gains. Note that, the VRA created using HARQ is unaware of the occurrence of selective retransmissions at OFDM layer. LDPC codes are used with code rate $\mathcal{R} = 1/2$. We compare the throughput, packet drop rate and BER for selective (re)transmission enabled VRA with only HARQ enabled VRA, to analyse the performance of our proposed scheme for optimal (ML) and suboptimal (MMSE) receivers. Although the proposed scheme appears to consume additional bandwidth, but the overall number of retransmissions is reduced resulting in better throughput. We calculated the throughput of the system as [15],

$$\eta_{scc} = \frac{Error\ free\ information\ bit\ received}{total\ number\ of\ transmitted\ bits} \quad (24)$$

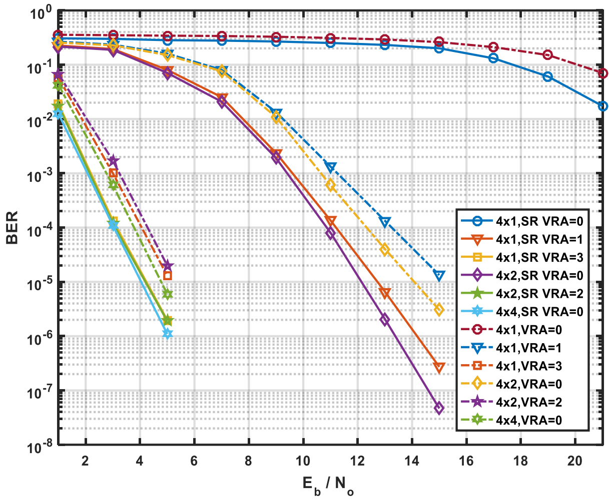

Fig. 2 BER performance of proposed scheme, $N_{Tx} = 4$ with soft output JML MUD.

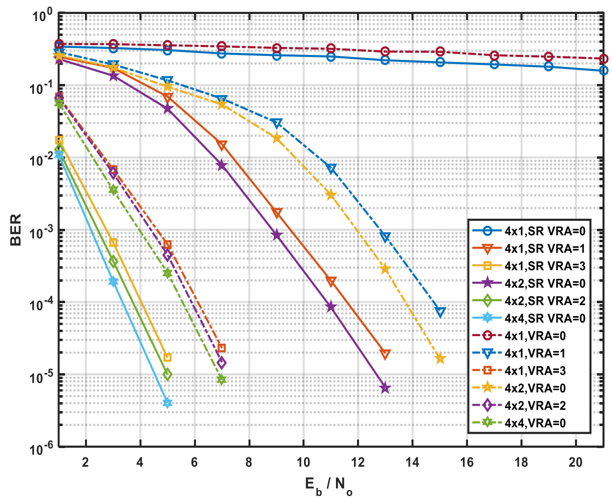

Fig. 3 BER performance of proposed scheme, $N_{Tx} = 4$ with MMSE MUD.

5.1 BER performance of ML and MMSE

First, BER comparison for selective retransmission against simple VRA based overloaded MIMO OFDM with optimal (ML) and suboptimal (MMSE) receivers is presented. This comparison shows that the addition of new VRA is not necessary to recover all the erroneous packets. The selective retransmission of subcarrier which low channel gain achieves a better BER performance than the retransmitting full data. The BER comparison of MIMO OFDM system with optimal (ML) receiver under overloaded ($N_{Rx} < N_{Tx}$) and critically loaded ($N_{Rx} = N_{Tx}$)is presented in figure 2. Clearly, it can be seen that for same number of transmissions the performance of a critically loaded system ($N_{Rx} = N_{Tx} = 4$) is better than the overloaded scenario due to its high diversity. However, for overloaded scenario ($N_{Rx} = 1, VRA = 3$ and $N_{Rx} = 2, VRA = 2$) achieves almost the similar BER performance. Enabling selective retransmission further improves the performance of the system. For overloaded case ($N_{Rx} = 1, VRA = 1$) with selective retransmission has the BER performance much better than the overloaded case ($N_{Rx} = 1, VRA = 1$) without selective retransmission.The selective retransmission can be seen as a new VRA. However, the symbols transmitted in this transmission are less than that of a full retransmission to create a VRA. Later, it is shown that we require much less number of VRAs in selective retransmission enabled system as compared to simple HARQ enabled VRA overloaded systems. Similar behavior can be seen in figure 3, where the performance comparison of overloaded MIMO OFDM system employing suboptimum receiver (MMSE) is presented.

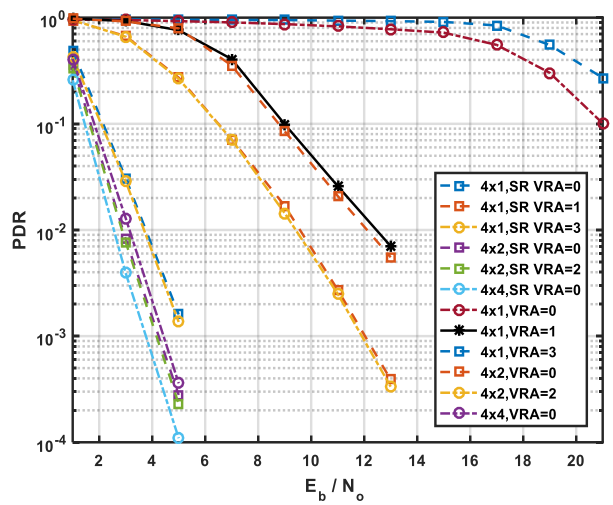

Fig. 4 PDR performance of proposed scheme, $N_{Tx} = 4$ with soft output JML MUD.

5.2 Packet Drop Rate performance

If an OFDM subcarrier is still in error even after maximum number of VRAs are created, it is declared as a dropped packet. Packet drop rate, P_{rate},is the measure of channel quality and defined as the ratio of dropped subcarrier symbols to total number of symbols transmitted. In Figure 4, comparison of the performance of our proposed system in terms of packet drop rate using optimal (ML) receiver is shown. The results shows that our proposed selective retransmission enabled VRA scheme performs better than simple VRA based schemes as compared to the joint ML techniques presented in [10], and [15]. Figure 5 shows the packet drop rate with suboptimal (MMSE) receiver and results are similar to that of optimal receiver (ML). The complexity of the receiver is reduced however, a significant amount of performance degradation is observed.

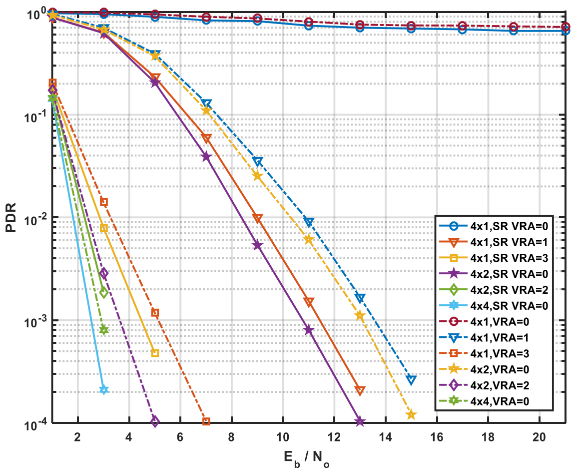

Fig. 5 PDR performance of proposed scheme, $N_{Tx} = 4$ with MMSE MUD.

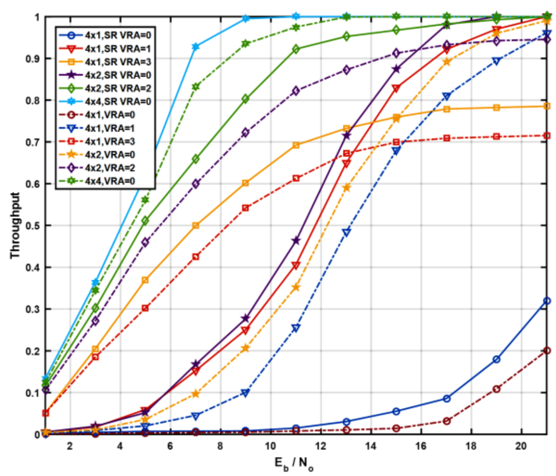

Fig 6 Throughput of proposed scheme, $N_{Tx} = 4$ with soft output JML MUD.

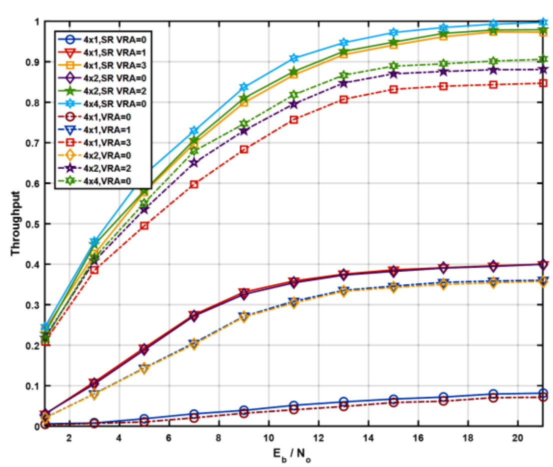

Fig 7. Throughput of proposed scheme, $N_{Tx} = 4$ with MMSE MUD.

5.3 Throughput of the proposed system

Throughput of the system is the key factor that can fully evaluate the performance of selective retransmission enabled overloaded MIMO OFDM system. Figure 6 presents the throughput analysis of the proposed selective retransmission system. It is obvious that the proposed selective retransmission enabled system provides a significant gain in throughput as compared to CC-VRA. This is because the selective retransmission enabled system improves the channel quality of a user without retransmitting the full OFDM frame that reduces the BER or throughput of the system is improved. The selective retransmission of the data can be considered as a separate VRA, however, data of OFDM subcarriers that have the channel gain lower than a particular threshold are retransmitted. The data on selective retransmission is much lower than a full retransmission. Therefore, the proposed selective retransmission method improves the throughput of the overloaded MIMO OFDM system as compared to the Selective chase combining technique presented in [17]. Figure 7 shows that throughput of the MMSE receiver is similar.

5.4 Average number of virtual receive antennas

The number of VRA created is another major factor contributing in the throughput and BER of the system. The average number of VRA created to receive an error free transmission from all users for MMSE receiver is presented in figure 8. The proposed scheme using selective retransmission requires less VRAs as compared to simple HARQ enabled VRAs. The HARQ enabled VRA use full retransmission of data to create a VRA and then estimate the transmitted data. If the CRC fails then NACK is generated to create another VRA. However, in proposed selective retransmission enabled scheme, partial retransmission of erroneous subcarriers is requested which improves the channel quality without a full data retransmission. The proposed scheme transmits less bits and create less number of VRAs to receive error free transmission that enhances the performance of the system in terms of throughput and BER.

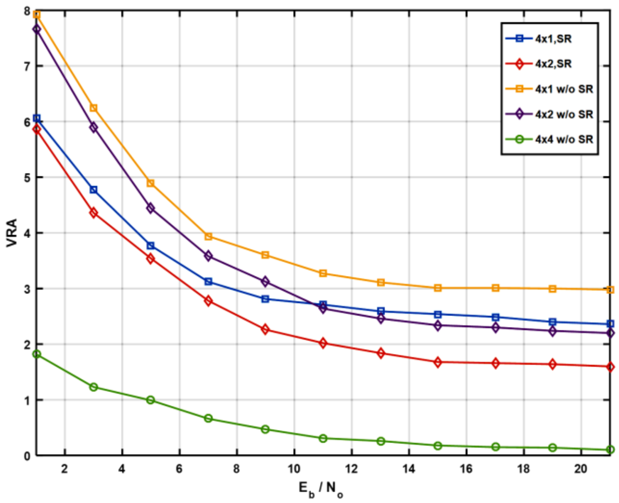

Fig. 8 Average number of VRA using proposed scheme, $N_{Tx} = 4$ with MMSE MUD.

6. Conclusion

In this work, we presented a novel low complexity and bandwidth efficient receiver design for overloaded MIMO system. The average number of retransmission is reduced by employing selective retransmission at OFDM layer therefore, increasing the average throughput of the system. The proposed scheme, being independent of conventional HARQ, can be easily incorporated in to conventional 4G and LTE environments. BER and throughput analysis of the proposed scheme show considerable improvement. The proposed scheme can be a prominent element for future wireless communication system especially for overloaded environment.

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