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Performance of WiMAX over MIMO Nakagami Fading Channels in Cross layer

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Abstract: This paper presents an optimal adaptive modulation (AM) algorithm using a cross-layer approach which combines truncated Automatic repeat request (ARQ) protocol and packet combining. Transmissions are performed on WiMAX over multiple-input multiple output (MIMO) Nakagami fading channels. Orthogonal frequency division multiplexing (OFDM) system is used. The data is transmitted in the form of packets. Here the retransmitted packets are not necessarily modulated using the same modulation format as in the initial transmission. Compared to traditional approach, cross-layer design based on the coupling across the physical and link layers has proven to yield better performance in wireless communications. However, there is lack for the performance analysis and evaluation of such design when the ARQ protocol is used in conjunction with packet combining.Indeed, previous works addressed the link layer performance of AM with truncated ARQ but without packet combining. In addition, previously proposed AM algorithms are not optimal and can provide poor performance when packet combining is implemented. Packet loss rate resulting from the combining of packets modulated with different constellations can be well approximated by an exponential function.This model is then used in the design of an optimal AM algorithm for systems employing packet combining,WiMAX and MIMO antenna configurations,considering transmissions over Nakagami fading channels.Numerical results are provided for operation with or without packet combining, and show the enhanced performance and efficiency of the proposed algorithm in comparison with existing ones.

Keywords: Cross-layer design, adaptive modulation, packet combining, truncated ARQ, packet loss rate, MIMO, OFDM.

I. INTRODUCTION

In recent years, cross-layer design approach has beenreceiving increasing attention in the wireless research community [1]. Such design consists in an optimizationbased on the interdependency between different techniques atthe different layers of the protocol stack, and is generallyimplemented by means of adaptive modulation algorithms such as in [2]–[3].

Furthermore, works in this context consider very simple schemes for the mapping of the signal-to-noise ratio (SNR) into a modulation level [1], [3], or focus on the optimization of the combining of packets at the receiver [7], [8]. The SNR-to-modulation mapping consists in selecting SNR delimiters on which the modulation level changes in order to satisfy the required quality of service (QoS). Actually, this mapping plays a major role and can significantly degrade the overall transmission performance if not selected carefully. Indeed, in [1] and [2], the mapping is based on packet loss rate (PLR) models that suppose additive white Gaussian noise (AWGN) and do not take into consideration the fading. The work in [3], on the other hand, takes into account the fading distribution and tries to achieve the maximum allowed PLR, which is not necessarily the optimal choice to maximize the average spectral efficiency (ASE) of the system.

In this paper, in stark contrast to existing works, we propose an adaptive modulation (AM) algorithm which considers a general scenario where the SNR-to-modulation mapping can be different from a transmission to another. Indeed, with the use of truncated ARQ protocols, selecting the same mapping for all transmissions of a packet is not necessarily the optimal solution for maximizing the ASE under PLR constraint. In fact, the mapping depends on the frame structure and whether packet combining is implemented in the communication sys-tem or not. Herein, we consider that retransmissions of a packet do not necessarily use the same modulation format as in the initial transmission and that packet combining is implemented at the receiver. Copies resulting from several transmission attempts of a packet are combined together at the bit level rather than at the symbol level using log-likelihood ratios (LLRs) to describe bits' correctness. The PLR for such type of packet combining is complex to formulate [9]. Hence, by means of a novel PLR modeling proposed herein, we present a new flexible and easy way to analyze the cross-layer designed algorithm, for operation with and without packet combining. Specifically, through exponential modeling of the the PLR, key performance metrics, namely, average PLR and ASE, are used in the optimization problem under study and in the performance analysis. Furthermore, performance evaluation of the proposed scheme is provided along with comparisons to two popular AM algorithms, considering 10^{-2} as the maximum value for the allowable PLR, which is suitable for multimedia traffics. In particular, it is shown that using a simple SNR-to-modulation mapping has a very negative effect on performance, whereas the scheme proposed in this paper yields enhanced performance when operating whether with or without packet combining.

II.SYSTEM AND CHANNEL MODELS

In the communication system under consideration, frame-by-frame transmission is adopted, with each frame composed of a number of packets. The packet and frame structures used are the same as in [1]. Packet and frame sizes are fixed and equal to N_b bits and N_f symbols, respectively. After each frame transmission, channel quality signaling is sent by the receiver to the transmitter in the form of an SNR value which is then mapped by the transmitter into a modulation level $n$of the Quadrature amplitude modulation ($2n$-QAM) suitable for the next frame transmission and with the aim to satisfy the required QoS (Quality of service) in terms of PLR. Further, we consider slow fading channels and assume perfect estimation of the SNR at the receiver with ideal feedback to the transmitter.Packets in the same frame can be received either correctly orwith error. In the latter case, the receiver sends the indexes ofthe erroneously received packets to the ARQ controller at thetransmitter.

The latter then determines the number of packets that can be carried out by the next frame to be transmitted: $N_{pkt} = nN_f/N_b$. In addition to the indexes of the packetsto be retransmitted, the ARQ controller sends to the packetcontroller the number of new packets that can be added andcarried on the next frame. We consider that the number ofpackets to be retransmitted is small enough so that all ofthem can be included in the next frame transmission evenif the modulation level changes. To prove the validity of this assumption, let's suppose the extreme case when the differencebetween the modulation levels used for two consecutive frametransmissions is equal to two, for instance, the initial frametransmission uses 16-QAM while the following one uses4-QAM. In such case, we are able to retransmit all the erroneously received packets, pertaining to the initial frametransmission, on the same next frame transmission even if thePLR is high, e.g., 0.25. In practice, the PLR is required tobe much less than this value, e.g., around 0.01. Therefore,the assumption is valid in realistic scenarios. A packet isretransmitted until it is correctly received or that the maximum number of transmissions N_{arq} is reached, in which case thepacket is considered lost and get purged at the receiver andthe transmitter.A frame is composed of retransmitted and new packets.Hence, if we consider different SNR-to-modulation mappingsfor the first transmission and subsequent retransmissions of apacket, i.e., different SNR delimiters on which the modulationlevel changes, we can have an SNR value for which amodulation level $n$must be used for new packets and adifferent modulation level n' must be utilized for packets to beretransmitted. This cannot be implemented because all packets.

Each frame is then forwarded to the space-time block coding (STBC) module. STBC is the most attractive MIMO technique for current and future wireless networks, such as sensor networks, because of its processing simplicity which induces very low power consumption at the transmitter and the receiver, in addition to its good performance in terms of spectral efficiency [10], [11]. In this paper, STBC with code rate $_C$ is used over MIMO configuration with $_T$ transmit antennas and $_R$ receive antennas, which can be modeled by an equivalent single-input single-output (SISO) model. We consider that each link between an antenna at the transmitter and another at the receiver is affected by slow Nakagami fading. However, the same analysis presented herein can be applied for other fading scenarios such as those presented in [12].

The SNR STBC of the equivalent SISO model follows a Gamma distribution given by [2]

$$p_{\gamma^{\mathrm{STBC}}}(\gamma) = \frac{\gamma^{m\mathcal{K}-1}}{\Gamma(m\mathcal{K})}\left(\frac{mN_{\mathrm{T}}R_{\mathrm{c}}}{\overline{\gamma}}\right)^{m\mathcal{K}} \exp\left(-\frac{mN_{\mathrm{T}}R_{\mathrm{c}}\gamma}{\overline{\gamma}}\right), \quad (1)$$

where $\mathcal{K} \triangleq N_{\mathrm{T}}N_{\mathrm{R}}$ and $\overline{\gamma}$ is the average SNR per receive antenna.

III. PACKET LOSS RATE MODELING

A. The maximum on the PLR value at the link layer isequivalent to the maximum packet error rate (PER) value atthe physical layer. The relationship

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between the PLR and thePER depends on the techniques used. Hence, by modelingthe PER for different modulation levels, we can deduce theequivalent PLR model. Instead of using exact PER formulascorresponding to transmission over AWGN channels, theanalysis can be simplified using a well-fitted approximationof the PER similar to what was done in previous works. The PER model is defined by an exponential function with two modulation-dependent coefficients, we use an exponential function with: (i) a coefficient that is modulation-dependent; (ii) another coefficient determined by the packet size only. This is well suited to our analysis which considers the combining of packets which were not necessarily transmitted using the same modulations as will be presented hereafter.

The PER model in AWGN channel is defined by

$$P_n^{\mathrm{DoI}}(\gamma) = L\exp(-a_n\gamma),$$

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Where L is a coefficient which depends on the considered packet size only, and a_n is a coefficient related to constellation where n is the modulation level. We refer to $P_n^{\mathrm{DoI}}(\cdot)$ as the degree of interest (DOI) is using modulation level n.

If we consider the use of truncated ARQ with a maximum number of transmissions N_{arq} and no packet combining, the PLR can be formulated as[1]:

$$PLR_{N_{\mathrm{arq}}} = \prod_{l=1}^{N_{\mathrm{arq}}} PER_{n(l),l},$$

where $n(l)$ and $PER_{n(l),l}$ are the modulation level and the PER at transmission index l $(l = 1, \ldots, N_{\mathrm{arq}})$.

B.WiMAX implementation:

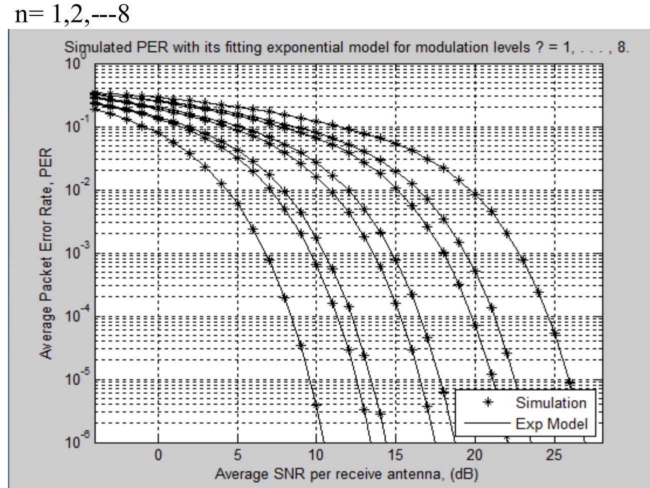
Here WiMAX is implemented on physical layer. The traffic flows in Network layer of OSI (Open System Interconnection) model. WiMAX refers Worldwide Interoperability for Microwave Access.WiMAX is related IEEE 802.11 Standards.The better Performance is observed by using WiMAX compared to MIMO.SNR to modulation level mappings can be done.Quality of service and Average Spectral Efficiency is observed over MIMO Nakagami fading channels.

APPLICATIONS

1. Used in 3G and Upper versions of 3G.
2. In Defence for the communication of airlines.

IV.SIMUL.ATION RESULTS

Below Fig.1. Represents simulated PER with exponential model for modulation levels
n= 1,2,---8



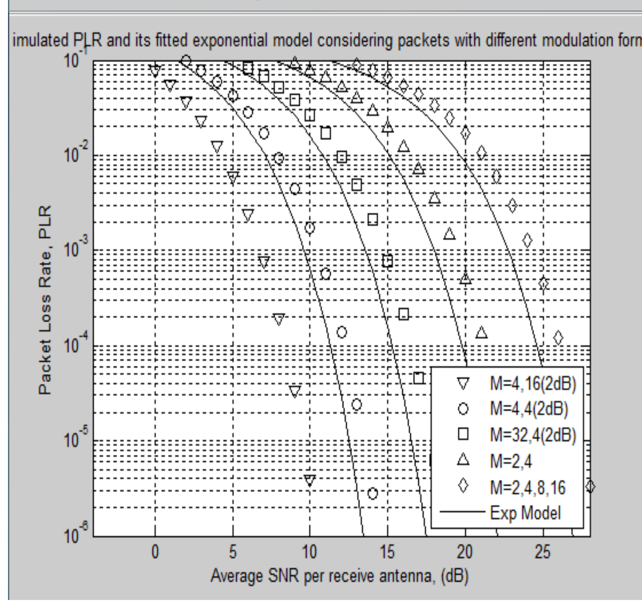


Fig. 2. Simulated PLR and its fitted exponential model considering packetswith different modulation formats and different average SNRs, where (2dB)denotes a difference of 2dB between the average SNRs of the first and secondcombined transmissions, $\gamma1$ and $\gamma2$, with Narq = 2, 4.

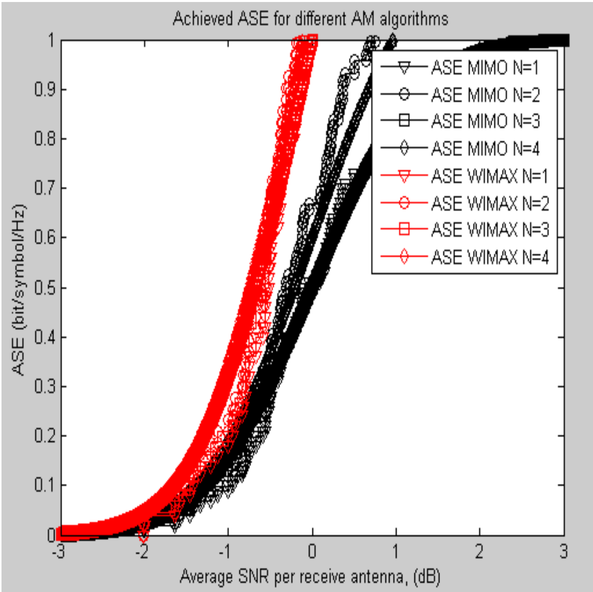


Fig. 3. Achieved ASE for different AM algorithms: optimal algorithm (black solid line), algorithm in [1] (red dotted line), and algorithm in [3] , when used without packet combining (*PLR*max = 10−2 and *N*arq =1, 2, 3, 4).

Using the exact PER formulae in a AWGN channel for these modulations and least square error (LSE) minimization, we obtain *L*0 = 132 in the case *N*0b = 1680, which can begeneralized to *L*= 0.0785*N*b for other packet size values, using the direct relationship between the PER and the biterror rate (BER), given by *PER*= 1 − (1 − *BER*) b≃*N*b*BER*when no channel coding is employed. Indeed, theBER is independent of the packet size *N*b because the bitsare uncorrelated.

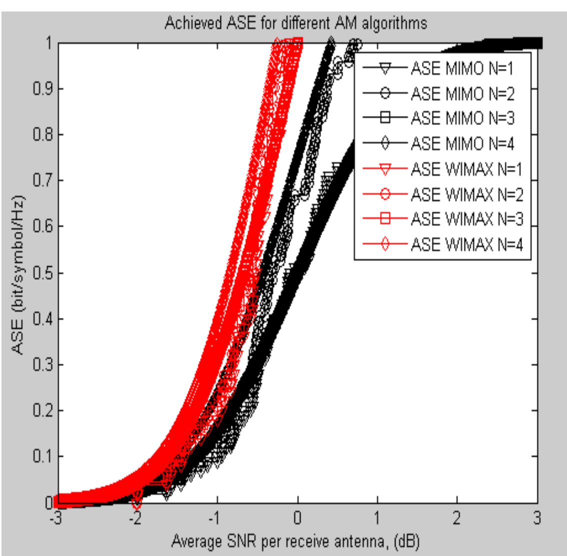


Fig. 4. Achieved ASE for different AM algorithms: optimal algorithm (blacksolid line), algorithm in [1] (red dotted line), and algorithm in [3] , when used with packet combining (*PLR*max = 10−2 and *N*arq =1, 2, 3, 4).

V.CONCLUSION

A novel packet loss rate (PLR) model was proposed for scenarios with and without packetcombining. This model was then used in the design of an optimal adaptive modulation (AM) algorithm which maximizes the average spectral efficiency (ASE) and satisfies the required quality of service (QoS). Performance evaluation and comparisons between the proposed AM algorithm and showed the enhanced performance of the proposed technique in terms of the ASE for the scenario with and without packet combining. The performance of WiMAX in physical layer achieves maximum Average Spectral Efficiency (ASE) and Quality of Service over Multiple Input Muliple Output (MIMO) Nakagami Fading channels.

VI.ACKNOWLEDGEMENTS

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