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THOUGHPUT PERFORMANCE OF ADAPTIVE MODULATION AND CODING SCHEME WITH LINK ADAPTATION FOR MIMO-WIMAX DOWNLINK TRANSMISSION

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ABSTRACT

The mobile WiMAX system is based on the IEEE 802.16m standard which is used to develop an advanced air interface (AAI) to meet the requirements for IMT-Advanced next generation networks , which are able to provide high speed access and are used to provide a rate of broadband data for low mobility scenarios up to 1 Gbit/sec. This paper investigates the application of link adaptation techniques (AM and AMC) to the downlink for the IEEE 802.16m-depending on the mobile WiMAX networks to achieve spectral efficiency gain. Also, by use of link adaptation it is possible to combine the MIMO technique with link adaptation in order to maximize the throughput. This paper considers six various MCS for link adaptation in order to find the largest throughput improvement. The working thresholds of the SNR for the various combinations of modulation, coding and MIMO will be determined through utilizing the ITU pedestrian channel model. Therefore, through employing a system level simulation, the performance evaluation results explain that the adaptive modulation and coding (AMC) system is noticeably superior compared to the systems that utilize fixed modulation (FM) or adaptive modulation (AM) schemes with regard to the spectral efficiency.

Key Words: Link adaptation, IEEE 802.16m, Spectral efficiency, Mobile WiMAX, MIMO.

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INTRODUCTION

Through utilizing the MIMO system this has demonstrated a great improvement on the systems that use a single antenna. One of promising techniques with the appearance of next generation broadband wireless communications is represented by combining the technology of MIMO wireless and the IEEE 802.16m standard (WiMAX) [1]. So, WiMAX adopts the MIMO antenna technique which represents important enhancements in terms of the spectral efficiency and link reliability. Also, the function of the modulation and coding scheme (MCS) can be executed by applying link adaptation based on the ‘got channel’ condition which represents an effective method to improve the execution of the throughput in a cellular system [2]. Hence, a large increase in throughput for the Mobile WiMAX system can be obtained by a combination of the link adaptation method with the MIMO technique. The idea of the AMC is to adapt the modulation and coding scheme (MCS) to the channel conditions to attain the highest spectral efficiency at all times. AMC is the standard approach which has lately been formulated in wireless standards, which include WiMax [3].

Another dimension for modulation and coding is the space dimension, such as multiple-antenna techniques, whereby this technique is utilized to improve the execution of the bit error rate (BER) in wireless systems, and to increase the data rate transmitted by spatial multiplexing (SM). WiMAX has two forms based on multiple antenna profiles for utilization in the downlink (DL) and uplink (UL), but the execution of these profiles is only optional for the uplink (UL). Therefore, one of them is dependent on the space time code (STC) which is suggested through the work of Alamouti for transmit diversity**,** while the other will be a 2x2 spatial multiplexing scheme (SMS) [4], [5].

This paper concentrates on the overall assessment for downlink (DL) execution for the mobile WiMAX networks utilizing AMC. In addition, this paper analyses the MIMO options included in the specifications of Mobile WiMAX (802.16m) systems.

The rest of this paper is organized as follows. Link adaptation techniques are presented in Section II. MIMO techniques definitions in WiMAX systems are studied in Section III. Performance analysis of the system is shown in Section IV, while simulation results and discussion are presented in Section IV. Finally conclusions are drawn in Section V.

LINK ADAPTATION TECHNIQUES

Link adaptation may be defined as a key solution that increases the spectral efficiency of wireless systems. It is utilized to set the modulation and the coding, in order to reflect the features for the wireless link, and to maximize the throughput. However, if the channel changes quickly such that it cannot be estimated in a reliable manner and fed back to the transmitter then the execution of the adaptive techniques will be poorer. This study uses two important mechanisms such as adaptive modulation (AM) and adaptive modulation and coding (AMC) for improving the robustness of the link in the system [3].

Adaptive Modulation

The AM allows for the mobile WiMAX system to tune the signal modulation scheme depending on the signal to noise ratio (SNR) condition of the radio link. Nevertheless for a high quality radio link condition the higher modulation scheme will be utilized which provides the highest throughput of the system or the best spectral efficiency. During a signal fade, the mobile WiMAX system may be shifted to a lower modulation scheme in order to maintain the connection quality and link stability. Nevertheless it is noteworthy that it is mandatory to have a higher SNR while utilizing a higher modulation scheme in order to overcome any interference and to maintain a certain target bit error ratio (BER). This study employs QPSK, 16-QAM and 64- QAM modulation schemes which offer 1, 2, 4 and 6 bps respectively, where the coding rate will be fixed [6, 7].

Adaptive Modulation and Coding

There is no difference when using the adaptive modulation (AM) and adaptive coding (AC) together or just the AM alone. However, under favorable channel conditions the mobile WiMAX system uses the highest levels of modulation and the highest rates of channel coding, while it utilizes lower levels of modulation and lower rates of channel coding whenever the channel condition is comparatively harsh. It is expected that the results of the performance will be enhanced when the AM and AC are combined together. Furthermore, considering the modulation schemes (QPSK, 16- QAM and 64-QAM), there are four coding rates that can be applied in this case, which are 1/2, 2/3, 3/4 and 5/6 [2].

THE DEFINITIONS FOR MIMO TECHNIQUES IN WIMAX SYSTEMS

WiMAX compliant manufacturing companies have produced a group from the naming terminology in reference to the multi-antenna techniques which interpret the MIMO term. The mobile WiMAX standard IEEE 802.16m contains two versions of the MIMO technique as Matrix A and Matrix B, where Matrix A is represented through the Space Time Block Coding (STBC) scheme and Matrix B is represented through the Spatial Multiplexing (SM-MIMO) scheme. Therefore, Matrix A and Matrix B with two receiving antennas require the Wave 2 WiMAX forum certification characteristic for WiMAX devices. The Matrix A version is used for coverage gain, which means an increase in the radius of the cell which also provides the best throughput for subscribers where access is difficult for stations that are already suffering good indication conditions. Matrix B is used to increase the capacity. A collaborative Uplink MIMO represents the other technique of MIMO that will be designed through WiMAX vendors in order to increase the capacity and spectral efficiency of the uplink communications path [6].

PERFORMANCE ANALYSISAND

The down link for the mobile WiMAX standard IEEE 802.16m that contains approximately nine cells is considered, with a square size for each cell. There is one BS located in the center of each cell and many MS that are uniformly distributed around the center of the cell , and moving with a fixed velocity in the directions that are selected randomly in the coverage area. We assume the environment used in this simulation is the suburban macro cellular environment. The median path loss for the Erceg model with the flat terrain with light tree densities (class c) is given through [8]:

$$P_i = 20\log_{10}\left(\frac{4\pi d_2}{\gamma}\right) + 10\Re\log_2\left(\frac{d_1}{d_2}\right) + Y_f + Y_k + S \tag{1}$$

Where γ is the wavelength (m), $\Re$ is the path loss exponent, Y_f and Y_k is the frequency and height correction factor respectively, and S utilized to account the effect of the shadowing, which it is modeled by using lognormal distribution. And the SINR at the MS is given by [9]:

$$SINR = \frac{P_m}{\sum_{n=1, n\neq m}^{K} S_n + P_K} \tag{2}$$

Where P_m is the received signal power from the BS m, S_n is the received strength of the interfering signal from the co-channel BS n (in the evaluation, only co-channel interference is taken into consideration), P_K is the MS receiver noise, and K is the maximum number of the interfering BSs.

There are two kinds of MIMO scheme that we consider in this simulation such as, Alamouti/MRC scheme and the spatial multiplexing (SM) scheme which are represent by matrix A and matrix B respectively.

RESULT AND DISCUSSIONS

The simulation is executed on the MIMO-WiMAX downlink transmission with different MIMO transmission modes and link adaptation. Therefore, the MIMO-WiMAX parameters selected for all simulations are explained in Table 1 [10], [11]. For fixed modulation (FM) and adaptive modulation (AM) systems, the average spectral efficiency that may be defined as a measure for the number of bits which is transferred per second for each Hz from bandwidth is plotted as a function of the SNR when the code rate using will be 1/2 is shown in the Fig. 1, where the AM will improve the throughput for the cell. Furthermore, it is clear that the execution of adaptive modulation for all values of SNR is best from the any fixed modulation schemes. The maximum spectral efficiency attained with adaptive modulation will be equal to 3 bps/Hz, while the maximum spectral efficiency attained with fixed modulation utilizing QPSK and 16-QAM is 1bps/Hz and 2bps/Hz. The throughput has improved more through utilizing 64-QAM when using the FM system to compare with the others fixed modulation schemes, while 64-QAM has executed similarly to the AM and attained a spectral efficiency of 3 bits/sec/Hz at high values from SNR. In the same situation as in Fig. 1 but with a code rate of 3/4, the spectral efficiency for adaptive modulation and fixed modulation systems are shown in the Fig. 2. It is evident that adaptive modulation system gets higher spectral efficiency than the fixed modulation system with QPSK, 16- QAM, and 64-QAM schemes with various SNR values. Moreover, the spectral efficiency will be higher based on the increase the code rate compared with the spectral efficiency obtained in Fig. 1.

Table- 1. Simulation parameters for the system

Carrier frequency (MHZ)	2500	Distance between two base stations d1 (m)	2000
Channel bandwidth (MHZ)	20	Gain of BS (dB)	15
Number of MS	100	Noise figure of BS (dB)	5
Gain of MS (dB)	0	Height of BS (m)	35
Noise figure of MS (dB)	9	Transmit power for the BS (dBm)	46
Height of MS (m)	1.5	Minimum distance from the BS to MS d2 (m)	35
Number of BS	9	Modulation scheme	QPSK, 16QAM, 64QAM
Samples_mean Samples_std_dB	0 8	Maximum number of interfering BSs	8

Fig-1. Spectral efficiency vs. SNR with code rate equal to 1/2

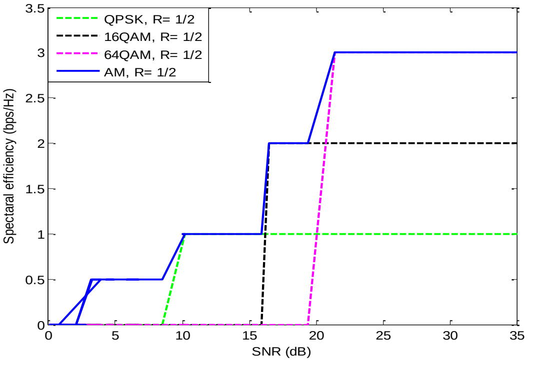
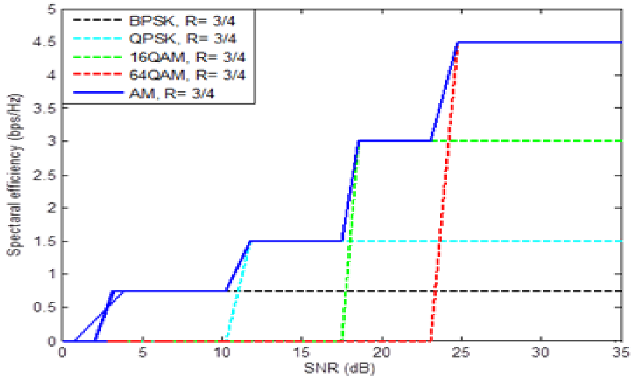


Fig-2. Spectral efficiency vs.SNR with code rate equal to 3/4



The comparison of spectral efficiency of two different code rates (such as, 2/3 and 5/6) is shown in Figure 3, from which it can seen that if the bit rate is 5/6 then spectral efficiency becomes 5 bps/Hz. However, if the bit rate is 2/3 then the spectral efficiency will be 4 bps/Hz. In the Figure 3, the spectral efficiency with the link adaptation is indicated by the blue curve and the black curve, whereas the spectral efficiency for each MCS scheme is given by the other curves. Figure 4 explains the impact of the system execution all over the cell due to the combination of the AM with AMC. From this figure, it is evident that the spectral efficiency for the adaptive modulation with any constant code rate is lower than the spectral efficiency for the adaptive modulation and coding throughout the cell. Nevertheless, the greatest spectral efficiency resulting from utilizing AMC is 6 bps/Hz, while the maximum spectral efficiency have resulted from utilizing adaptive modulation with constant code rates of 1/2, 2/3, 3/4 and 5/6 are 3.5, 4.5, 5 and 5.5 bps/Hz respectively.

Fig-3. Spectral efficiency vs. SNR with code rates equal to 2/3

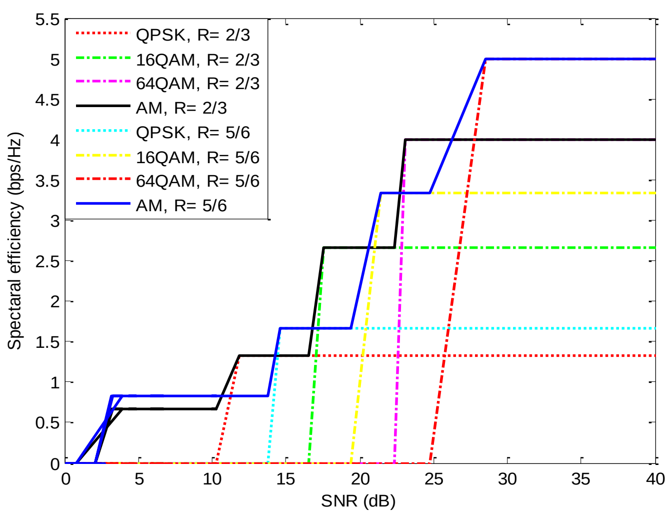
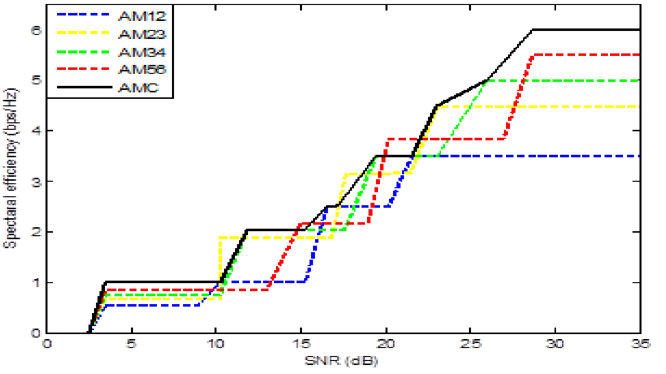


Fig-4. Spectral efficiency vs.SNR for AM and AMC 5/6.



The authors have summarized the usable schemes for modulation and coding in WiMAX systems in Table 2 (note that the table is limited to the schemes of convolution coding included in the standard). The spectral efficiency illustrated in Table 2 is for single-antenna systems, and it will be double whenever spatial multiplexing (SM) is utilized.

Table- 2. MCS schemes

MCS schemes	1	2	3	4	5	6
Modulation	QPSK	QPSK	16QAM	16QAM	64QAM	64QAM
Code rate	1/2	3/4	1/2	3/4	2/3	5/6

Figure 5 shows that the AMC concept based on the execution criterion for the forward error correction (FEC) block error rate that must be less than about 10^{-3}. This figure illustrates the link level throughput execution vs. SNR for various MCS and gives the SNR thresholds above for the various groupings for the standard modulation and coding options. The SNR thresholds are calculated by the system utilizing MIMO Matrix A at the transmit side, two antennas with Maximum Ratio Combining (MRC) at the receiver side, and the ITU Pedestrian Channel A.

Fig-5. Spectral efficiency vs. SNR for different MCS. channel A,

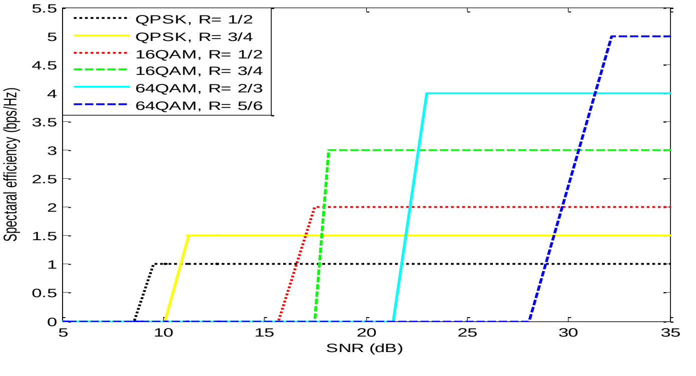
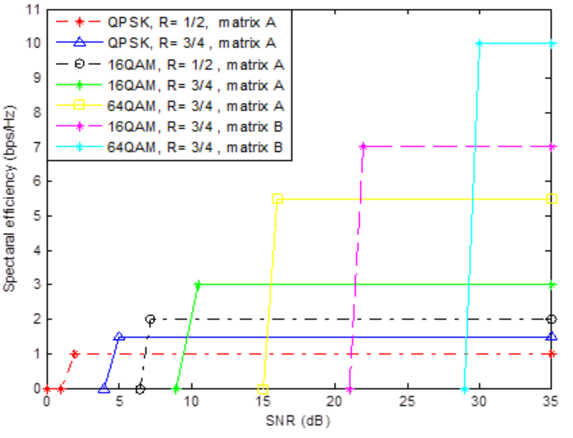


Fig-6. Operating SNR thresholds for grouping the AMC and MIMO (ITU pedestrian Speed=3km/h, BER=10^{-3}).



For example, for SNR values below 16 dB, the16QAM modulation scheme with a code rate equal to 1/2 cannot be utilized owing this resulting in an FEC block error rate larger than the 10^{-3}. Over this threshold, the modulations meet the execution criterion and also result in a spectral efficiency of 2 bps. Furthermore, Figure 5 also shows that 16QAM can be utilized with a code rate of 3/4 when the SNR values exceed 17.5dB, therefore, in this case the spectral efficiency become 3bps. Depending on the given SNR thresholds, the AMC uses the modulation and coding grouping which produces the highest value of throughput. However, Figure 5 demonstrates that some of the modulation and coding groupings are not beneficial for a specific channel based on the execution criterion utilized. For example, the 16QAM modulation scheme with a code rate of 3/4 gives the same spectral efficiency for the 64QAM as a code rate of 1/2 with a reduced SNR threshold. Therefore, it does not make sense to utilize 64QAM with a code rate of 1/2. However, the best way to handle the MIMO options is by adding the dimension of MIMO to adaptive modulation and coding (AMC), and by choosing better grouping by link adaptation. Figure 6 illustrates the SNR thresholds operating for the seven useful groups of link adaptation through the ITU pedestrian channel A model. Based on the results shown in Figure 6, the MIMO Matrix B is used with 16QAM and a code rate of 3/4 when the values of SNR are higher than 20 dB, so, this results in a spectral efficiency of 7 bps. Also, this system can utilize 64QAM with a code rate of 3/4 when the values of SNR are higher than 30 dB, which leads to a spectral efficiency of 10 bps. This represents an increase in throughput compared to the MIMO Matrix A system which has a spectral efficiency for 16QAM of 3 bps, while for 64QAM it is equal to 5.5 bps in the studied system. It is noteworthy that a small distance between the receive antennas on the mobile station can impact these results, especially in the execution of the Matrix B version. Also, interference can substantially affect the execution trade-offs between Matric A and Matric B. As a result, we can conclude that the enhancement in the cell capacity is attained with Matrix B depending on the function of the locations used and also on the matching SNR values. Moreover, Matrix B does not result in any extension to the cell range owing to the users that are near the cell edge having low SNR values and thus for high-level modulation the Matrix B version can not be utilized for these users.

CONCLUSION

Many features and the different options that can be used in order to better utilize the characteristics of the wireless channel, such as adaptive modulation and coding (AMC) have been presented. In this paper, we assessed the down link execution for the IEEE 802.16e-based mobile WiMAX networks. We showed that utilizing link adaptation techniques (such as AM and AMC) will affect the spectral efficiency in the mobile WiMAX networks. The results show that the use of these techniques will enhance the implementation of a mobile network. So, in terms of the average spectral efficiency, it was found that AMC significantly improves the system execution compared to the AM scheme. Moreover, AM improves the system execution better than FM. Also, by use of link adaptation it is possible to combine adaptive modulation and coding (AMC) with the MIMO option in order to maximize the throughput. The operating SNR thresholds for various modulation, coding and MIMO combinations will be determined by utilizing an ITU pedestrian channel model, and the regions where the Matrix B version may be utilized to increase the cell capacity. After combining the MIMO technique with link adaptation, the authors deliberate seven various MCS techniques for link adaptation in order to obtain the biggest improvement in throughput.

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