BER PERFORMANCE EVALUATION OF A MOBILE WIMAX SYSTEM OVER AN ITU-R PEDESTRIAN B MULTIPATH CHANNEL

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Abstract: A realistic modeling of the radio channel's propagation characteristics proves to be extremely important, especially when one desires to perform an accurate design of a wireless communication system. In this paper, we evaluate and optimize the performances of the ITU-R M.1225 Pedestrian B (Ped.B) channel model for a downlink (DL) mobile WiMAX system, starting from the requirements of certain multimedia services. The influence of parameters such as modulation, coding scheme and cyclic prefix (CP), was analyzed through simulations, in terms of the bit error rate (BER).

Key words: *Mobile WiMAX, Ped.B channel model, modulation, coding scheme, cyclic prefix, BER.*

I.INTRODUCTION

The increasing demand for mobile Internet and more complex multimedia applications, has determined the continuous development of broadband wireless access technologies, over the past years. Among the 4G technologies that successful managed to impose, is Mobile WiMAX, a technology developed according to the specifications of the IEEE 802.16e-2005 standard.

In a typical scenario, this technology is expected to provide a data rate of about 15 Mbps, considering a cell radius of up to 3 km, and at vehicular speeds higher than 100 km/h, without the need of a direct line-of-sight (LOS) between the transmitter and the receiver [5].

In order to accomplish these goals and to overcome the problems that might appear due to multipath propagation, phenomenon of a great importance especially in the case of mobile environments, WiMAX aggregates techniques like: OFDMA (multi-user OFDM) and adaptive modulation and coding (AMC).

Performing an accurate design of a wireless system requires a proper channel modeling. A channel model must incorporate most of the aspects present in real life, such as different variations in time, frequency or space, caused by a number of unwanted propagation mechanisms such as reflections, diffractions, etc [4].

Also, as a result of the large delay spreads induced by the channel, the ISI (Inter Symbol Interference) might appear if the channel's r.m.s. delay spread is similar or greater than the OFDM symbol duration. In order to avoid this effect, OFDM introduces a cyclic prefix (CP), a copy of the last portion of the useful symbol, which is appended at the beginning of each transmitted symbol [8]. The cyclic prefix will have a double role, both of collecting the multipath signals and maintaining the orthogonality of the OFDM subcarriers.

In this paper, we evaluate and optimize the performances of the DL channel for a WiMAX system, in terms of the modulation technique, coding scheme, as well as the guard time interval (established by the CP), for a set of multimedia applications like VoD or videoconference. The simulations are performed in terms of the bit error rate (BER); the ITU-R M.1225 Pedestrian B channel model was considered.

The rest of the paper is organized as follows: in section II, we briefly describe the ITU-R channel model used. In section III we present the main QoS parameters used for describing the requirements of a service. Section IV is dedicated to the system's description, and section V evaluates the results obtained. Section VI contains our conclusions.

II. ITU-R CHANNEL MODEL

The channel models can be classified into two main categories: statistical and empirical models. Empirical models are based on measurements performed in real environments, while the statistical models estimate the channel's characteristics through mathematical relations.

Two empirical models are generally used for describing a WiMAX system: the SUI (Stanford University Interim) channel model, which is used for simulating an IEEE 802.16-2004 system (a fixed WiMAX system), and the ITU-R channel model, which was developed according to the ITU-R M.1225 Recommendation. This type of model is used for the simulation of an IEEE 80216e-2005 system (a mobile WiMAX system).

Initially developed for the IMT-2000 technologies, the ITU-R channel model is used for modeling a mobile WiMAX system, since mobile WiMAX was adopted by ITU as one of the IMT-2000 technologies in November 2007 [10]. The ITU wideband channel, is described based on a *tapped delay line model*, with a maximum number of 6 taps,

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similar to the one presented in figure 1, where only 4 taps are presented. Each tap is characterized by a delay, τ_i and an amplitude coefficient, c_i. The selection of the N taps and delay values depend upon what is considered to be a significant level.

The output signal can be expressed as a linear combination of attenuated and shifted copies of the original signal. The first tap corresponds to the LOS component, having the highest amplitude and the smallest delay; the other taps are due to the various obstacles.

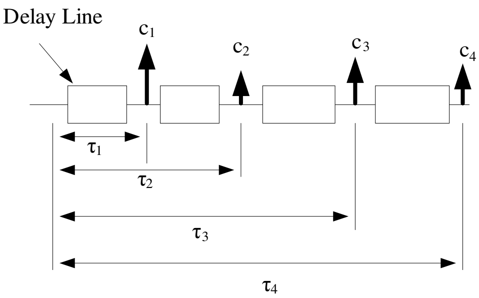

Figure 1.Tapped Delay Line Model [4]

In [6], three different test environments are specified: indoor office, pedestrian and vehicular. To account for the large variability of the wireless channel, two different delay spread profiles are specified for each of the test environments, a *low delay spread* profile (denoted with *A*) – for r.m.s. delay spreads of up to a hundred nano-seconds, and a *medium delay spread* profile (denoted with *B*) – for r.m.s. delay spreads of a few hundreds nano-seconds.

Based on the expected percentage of occurrence of each of these models, the WiMAX Forum recommends using just two out of the six models, which are Pedestrian B (Ped.B) and Vehicular A (Veh.A) [4].

ITU recommends that the pedestrian models, which are designed to model either indoor or outdoor pedestrian environments, to be used to represent multipath conditions in micro-cells. These environments are characterized by low transmission powers, low antenna heights and low mobility (3-4 km/h).

The Ped.B channel model, whose parameters are presented in table 1, will be used for our further simulations. The model is specified based on the number of taps that reach the receiver, the time delay relative to the first tap (LOS tap), the average power relative to the strongest tap (which is usually the LOS tap) and the Doppler spectrum of each tap.

Tap No.	**Channel B**		
	Relative Delay (ns)	**Average Power (dB)**	**Doppler Spectrum**
1	0	0.0	Classic
2	200	-0.9	Classic
3	800	-4.9	Classic
4	1 200	-8.0	Classic
5	2 300	-7.8	Classic
6	3 700	-23.9	Classic

Table 1.Pedestrian B Channel Parameters [6]

III. MULTIMEDIA SERVICE REQUIREMENTS

The QoS (Quality of Service) requirements that must be fulfilled by a certain application are usually described in terms of four parameters [7]:

- *Capacity of the link (throughput)* – expressed in kb/s;
- *End-to-end delay* – refers to the average time a packet needs to travel from one end point of the network to the other;
- *Jitter* **-** the variation in the end-to-end delay of sequential packets;
- *Bit Error Rate (BER)* – refers to the amount of bits that are in error, from the total number of transmitted bits.

In table 2, the QoS requirements for a DL channel are specified, for different types of services.

Service	**Capacity (kb/s)**	**Delay**	**Jitter (ms)**	**BER**	**Packet Size**
VoD	$1\text{-}10^4$	< 2s	< 500	$< 10^{-7}$	large
VoIP	10-50	< 50ms	< 10	$< 10^{-6}$	small
Video conf.	$100\text{-}2\cdot10^3$	<150ms	< 50	$< 10^{-7}$	med./ small
Online gaming	10-200	< 50ms	< 10	$< 10^{-6}$	small

Table 2.QoS Requirements for different services [7]

IV. SYSTEM DESIGN

The Ped.B channel's performances are analyzed, for a mobile WiMAX system, having the parameters presented in table 3. The analysis is performed for a DL channel, so for a channel from the base station (BS) transmitter to the mobile station (MS) receiver.

In what concerns the design of the system, it was done based on the WMAN_16e_OFDMA_Rx_prj example, following the ADS 2008 (Advanced Design System) simulator provided by Agilent Technologies. The schematic used incorporates the following blocks: transmitter, channel, receiver, delay line, add noise and BER computation block. The parameters of all these blocks were modified according to table 3.

Parameter	***Value***
Carrier frequency	2.3 GHz
System channel bandwidth	10 MHz
Transmitter power	20 dBm
Number of transmitted bursts	1
FFT size	1024
Cyclic prefix	Variable (1/4, 1/8, 1/16,1/32)
Modulation Scheme	QPSK, 16 QAM, 64 QAM
Coding Rate	1/2, 3/4
Frame Duration	2 ms
Subcarrier Allocation Mode	DL PUSC
Duplexing Mode	TDD
MAC PDU payload length	100 bytes
Doppler spread	6.38 Hz
Distance between BS and MS	100 m
Velocity of the MS	3 km/h

Table 3.System Parameters

The simulation parameters are selected according to [1] and [4]. The operating frequency is 2.3 GHz. The nominal bandwidth is set to 10 MHz, and the transmitter power for this type of environment is set to 20 dBm, according to [6]. For the DL subframe, a PUSC (Partially Used Subchannelization) zone is defined, with two symbols per slot, as this is the compulsory allocation mode that must be implemented for every mobile WiMAX system, no matter of the frequency profile.

Regarding the modulation and coding scheme, the QPSK, 16 QAM and 64 QAM modulations are considered, both in conjunction with *convolutional coding (CC)* and *convolutional turbo coding (CTC).* The required ratio of bit energy to noise power spectral density (Eb/No) is set to a minimum of 10 dB. For a correct estimation of the bit error rate (BER), 1000 frames are taken into account.

V. EXPERIMENTAL RESULTS

First of all, we analyze the behavior of the Ped.B multipath channel model, in terms of different modulation schemes, and at different coding rates. For the first case, we consider a cyclic prefix of 1/8 and convolutional coding.

The results obtained in this case, are presented in figure 2, and are expressed in terms of BER vs. Eb/No. Eb/No is an important parameter for digital communications and can be considered as a normalized "SNR per bit". It is extremely useful, when comparing the BER performance of different modulation schemes, in noise-limited rather than interference-limited communications. Eb/No is inversely related to the BER.

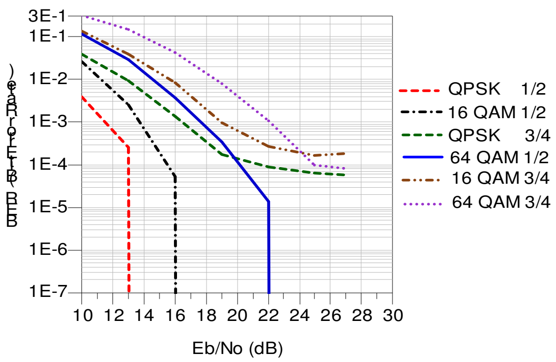

Figure 2.BER vs. Eb/No representation, for a Ped.B channel- convolutional coding

As one can observe, as the Eb/No ratio increases, we can use a higher modulation (such as 64 QAM). The use of a higher order modulation allows us to transmit more bits per symbol (ex: 6 bits per symbol for 64 QAM), which results in a higher data rate, but this kind of modulation is more susceptible to interference. 64 QAM is generally used by the users that are in the close vicinity of the BS.

On the other hand, the QPSK modulation allows lower data rates, having only 2 bits per symbol, but is more robust to interference. It needs only an Eb/No of about 13 dB, to reach a BER of 10^{-7}, value needed for most multimedia applications.

Another interesting element that can be extracted, regards the coding rate. The best results are obtained for the coding rates of ½, where one redundant bit, for error protection, is introduced after each useful bit. For the ¾ coding rates, where one redundant bit is introduced after three useful bits, the results are very poor, as confirmed in [11]. This is due to the very large delays that characterize this type of channel, which can reach up to a value of 3.7 µs, and to the high puncture pattern.

Next, we optimize our system, by computing the receiver sensitivity needed for the proper transmission of multimedia services, such as VoD and videoconference.

From the data presented in table 2, one can see that the throughput should be around 1 Mbps, in order to satisfy the requirements of both services. Still, a higher data rate is needed in order to accommodate for the framing, overhead and checksum. Typically, the throughput desired is about 70 % to 75 % of the peak data rate [9], which will be, in our case, of about 1.5 Mbps.

Based on the results obtained in figure 2, we establish a correspondence between Eb/No and the SNR (Signal-to-Noise Ratio), necessary for a receiver to achieve a specified level of reliability in terms of BER, for QPSK ½, 16 QAM ½ and 64 QAM ½. We use the bellow formula [9]:

$$SNR = (Eb / No) \cdot (R / B_T) \qquad (1)$$

In (1), *Eb/No* represents the energy to noise power spectral density and is read from the graph, *R* represents the requested system data rate of 1.5 Mbps, and B_T represents the system bandwidth of 10 MHz. After the SNR computation, we determine the channel noise power, according to the formula presented in (2) [9]:

$$N = k \cdot T \cdot B \qquad (2)$$

With *N* we have denoted the noise power (in W), *k* represents the Boltzman's constant ($1.38 \cdot 10^{-23}$ J/K), *T* represents the system temperature (usually assumed to be 290 K), and *B* represents the channel bandwidth (Hz).

The noise power computed according to (2) corresponds to a theoretical noise power for an ideal receiver. A real receiver noise floor will be always higher, due to the noise and the losses induced by the receiver itself. The noise figure at the MS receiver is considered to be 7 dB [2].

The last step implies the computation of the receiver sensitivity (P_{rx}), so of the required signal strength needed at the receiver input, according to the formula presented in (3):

$$P_{rx} = \mathrm{Re}ceiver\_Noise\_Floor + SNR \qquad (3)$$

The results obtained for different modulation schemes, concerning the required SNR and receiver sensitivity (P_{rx}) needed for a target BER of 10^{-7}, are displayed in table 4.

Modulation Scheme	Eb/No (dB)	SNR (dB)	P_{rx} (dBm)
QPSK 1/2	13	4.7	-91.3
16 QAM 1/2	16	7.7	-88.3
64 QAM 1/2	22	13.7	-82.3

Table 4.SNR and the required P_{rx} for different modulation schemes

These results are compliant with the specifications of a typical IEEE 802.16e receiver. For example we can compare these results with the specifications of an Accton™

PCMCIA card [12], designed to work with Windows XP laptops, to see that they are almost the same.

In the next simulation we determine the influence of the coding scheme, for the case of the QPSK ½ and 16 QAM ½ modulations. The results obtained are presented in figure 3, both for the convolutional coding (CC) and convolutional turbo coding (CTC).

As expected, the CTC perform better, as they allow an increase of the throughput, obtained by using a more complex modulation scheme, without requiring a higher Eb/No ratio. For example, from the figure bellow one can notice that if we have an Eb/No of 13 dB, in the case of CC, only QPSK ½ can be used. If we change the coding scheme and we use CTC, then, for the same Eb/No, we can use 16 QAM ½.

So, as it can be noticed from figure 3, for a Pedestrian B multipath fading channel, the CTC leads to better results than CC. Still, as a disadvantage associated with the use of these codes, is the high receiver decoding complexity.

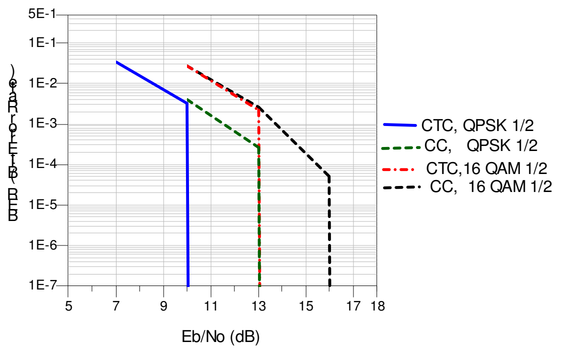

Figure 3.BER vs. Eb/No representation, for a Ped.B channel –CC and CTC

In the last simulation performed, we evaluate the influence of the cyclic prefix (CP) upon the transmission link quality. The obtained results, for the 16 QAM ½ CC, modulation and coding scheme, are presented in figure 4.

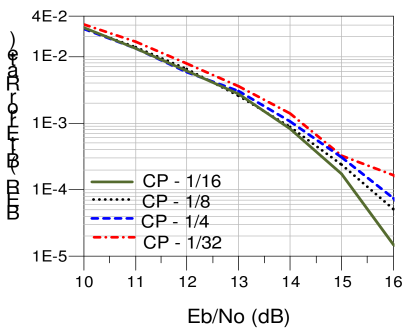

Figure 4.BER vs. Eb/No representation, for a Ped.B channel - different cyclic prefix (CP) values

In a typical mobile environment the channel delay spread is not constant, so assigning a fixed value to the CP may force devices that encounter a smaller delay spread, to use an unnecessarily large CP, which will result in both a loss in the spectral efficiency, and a waste of the transmitter energy [8].

Based on the results presented in figure 4, and on [8] where a similar analysis was performed for CTC coding, we can conclude that a CP of 1/16 of the useful symbol duration (= 91.43 µs) slightly outperforms the other lengths in terms of BER reduction. So, an optimal duration for the guard time interval would be 5.71 µs, which is a value seven times higher than the r.m.s. delay spread of the Ped.B channel, which is of 0.75 µs. As it was proved, such a value is more than sufficient for counteracting the ISI that might appear.

VI. CONCLUSIONS

In this paper, several parameters, such as the modulation, coding scheme and the optimal value of the CP, were investigated for the case of a DL mobile WiMAX system modeled by a Ped.B ITU-R channel model. The purpose of this analysis was to analyze and determine the optimal combination of parameters that leads to the system's best performance in terms of BER. Also, the receiver sensitivity needed for the proper transmission of certain multimedia services was computed.

The results showed that optimum performances are achieved in the case of a CTC coding scheme, based on a low coding rate (1/2) modulation scheme. Regarding the CP, a value of 1/16 of the useful OFDM symbol time offers good results, especially for BER values of up to 10^{-5}.

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REFERENCES

[1] IEEE Std. 802.16e-2005, *IEEE Standard for Local and Metropolitan Area Networks. Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems. Amendment 2: Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands*, December 7, 2005.

[2] WiMAX Forum, *Mobile WiMAX - Part 1: A Technical Overview and Performance Evaluation*, August 2006.

[3] WiMAX Forum, *WiMAX Forum® Mobile System Profile Specification: Release 1.5 Common Part (Revision 0.2.1: 2009).*

[4] WiMAX Forum, *WiMAX System Evaluation Methodology*, Version 2.1, July 2008.

[5] J. G. Andrews, A. Ghosh, R. Muhamed, *Fundamentals of WiMAX. Understanding Broadband Wireless Networking*, Prentice Hall Press, 2007.

[6] ITU Document, *Rec.ITU-R M.1225 - Guidelines for Evaluation of Radio Transmission Technologies for IMT-2000*, ITU-R, 1997.

[7] European Commission Sixth Framework Integrated Project BROADWAN - Broadband services for everyone over fixed wireless access networks, Deliverable D21, *Planning Guidelines for Broadband Access Networks with Case Studies*, May 2006.

[8] W.E.Osman, T.Abd.Rahman, "Optimization of Guard Time Length for Mobile WiMAX System over Multipath Channel", *Proceedings of IMECS 2008*, vol. 2, 19-21 March, Hong Kong.

[9] J. Zyren, Al. Petrick, *Tutorial on Basic Link Budget Analysis*, Intersil Application Note, June 1998.

[10] F. Wang, A. Ghosh, "Mobile WiMAX Systems: Performance and Evolution", *IEEE Communications Magazine*, vol. 46, no.10, pp.41-49, October 2008.

[11] M.Tran, G. Zaggoulos, *Mobile WiMAX: Performance Analysis and Comparison with Experimental Results*, IEEE, 2008.

[12] A.Kumar, *Mobile Broadcasting with WiMAX: Principles, Technology, and Applications*, Focal Press, 2008.