Analysis of WiMAX data rate performance

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***Abstract*— In recent months, Mobile WiMAX has gained momentum as a top candidate to deliver the dream of full mobile wireless internet. In spite of this, the available data regarding the performance of Mobile WiMAX in real world scenarios is still scarce. In this paper, the available downlink (DL) throughput as a function of distance to the Base Station (BS) is estimated for a number of propagation scenarios.**

I. INTRODUCTION

Pushed by the increasing market demand for wireless wideband services, strong industry support and a competitive edge over deployed 3.5G systems Orthogonal Frequency Division Multiple Access (OFDMA) based Mobile WiMAX is on the verge of becoming a reality all over the globe [1]. However, in spite of all the hype, public results concerning the performance of IEEE 802.16e based systems in real world scenarios are still scarce, more so if the focus is on the 3.5 GHz band, which will be the licensed band for operation of WiMAX in most European countries.

As the auctioning and licensing of spectrum takes way all over the world, and particularly in many European countries, it becomes of capital importance for telecommunications operators to gain some grasp on the real performance scenarios they can count on to develop their business cases.

In this paper, a preliminary analysis of the available data rate as a function of the distance of the subscriber station (SS) to the BS is developed, considering different propagation environments and operation in the 3.5 GHz band.

II. SYSTEM PARAMETERS

A. Frequency Bands

Considering the 3.3-3.8 GHz spectrum, the WiMAX Forum™ Mobile System Profile [2] specifies the channel bandwidth combinations, Fast Fourier Transform (FFT) sizes and duplexing modes shown in Table 1, for the possible frequency range configurations.

Frequency Range (GHz)	Channel Bandwidth(s) (MHz)	FFT Size	Duplexing Mode
3.3-3.4	5	512	TDD
	7	1024	TDD
	10	1024	TDD
3.4-3.8	5	512	TDD
	7	1024	TDD
	10	1024	TDD
3.4-3.6	5	512	TDD
	7	1024	TDD
	10	1024	TDD
3.6-3.8	5	512	TDD
	7	1024	TDD
	10	1024	TDD

Table 1 – Possible WiMAX configurations for the 3.3-3.8 GHz band.

Although IEEE 802.16e also specifies FDD modes [3], one should note that the first system profiles released by the WiMAX Forum only contemplate time division duplexing (TDD) modes, due to a number of advantages over frequency division duplexing (FDD). TDD offers the ability to adjust the downlink (DL)/ uplink (UL) ratio while frequency division duplexing (FDD) usually has fixed (and most times equal) downlink and uplink bandwidths.

Moreover, TDD assures channel reciprocity because the DL and UL frames are sent in the same band, providing easier support for link adaptation and advanced antenna techniques (AAS). Finally, TDD requires a single channel for UL/DL while FDD requires a pair of channels and also TDD eases the burden on transceiver design [4].

B. OFDMA Parameters

For the possible system channel bandwidths allowed, Table 2 summarizes the IEEE 802.16e OFDMA parameters.

Parameters	Values		
Channel Bandwidth	5 MHz	10 MHz	7 MHz
Sample Frequency	5.6 MHz	11.2 MHz	8 MHz
FFT Size	512	1024	1024
Subcarrier Spacing	10.94 kHz		7.81 kHz
Useful Symbol Time	91.4 μs		128 μs
Guard Time	11.4 μs		16 μs
Symbol Duration	102.9 μs		144 μs
Nb. OFDMA Symbols/Frame	48	48	34

Table 2 – OFDMA Parameters

All through this work a frame duration of 5 ms has been assumed, since, at least initially all WiMAX equipments will only support this duration.

C. Frame and Subchannel Structure

In Figure 1 the general TDD frame structure for WiMAX is shown.

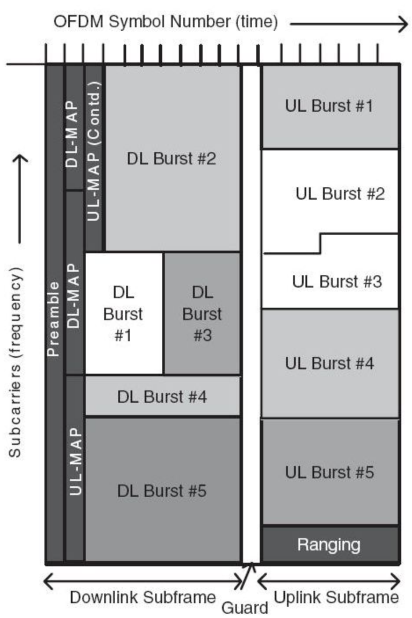


Figure 1 – WiMAX OFDMA TDD Frame. (extracted from [4]).

The overheads in Figure 1 have variable size depending on the type of traffic carried. In this analysis Full Buffer FTP traffic will be assumed, and a corresponding typical distribution of OFDMA symbols in the frame is shown in Table 3.

This option is somehow conservative, since most applications have a traffic which is bursty in nature and can operate efficiently with less overhead.

Also, as previously referred, TDD allows for flexible DL/UL ratios to cope with different traffic profiles. In this study a 3:1 DL:UL ratio will be analyzed, the respective data symbols distribution is also shown in Table 3.

Parameters		Values		
Channel Bandwidth		5 MHz	10 MHz	7 MHz
Nb. OFDMA Symbols/ Frame		48	48	34
Total Nb. of OFDMA Overhead Symbols		10	10	7
Nb. of OFDMA symbols for TTG (guard)		1	1	1
Total Nb. of OFDMA Data Symbols		37	37	26
DL:UL 3:1	*DL OFDMA Data Symbols*	28	28	19
	UL OFDMA Data Symbols	9	9	7

Table 3 – TDD Frame configurations used.

IEEE 802.16e also allows different subcarrier permutations schemes, although the initial WiMAX system profile [3] only includes for the DL, Downlink Partial Usage of Subcarriers (DL PUSC) and Band Adaptive Modulation and Coding (Band AMC), with only the first being mandatory. Therefore, we will consider DL PUSC as the subchannel permutation scheme used. Table 4 shows the distribution of subcarriers for this mode.

DL PUSC Parameters		
Channel Bandwidth	5 MHz	7 MHz 10 MHz
Null Sub-carriers	92	184
Pilot Sub-carriers	60	120
Data Sub-carriers	360	720
Sub-channels	15	30

Table 4 – PUSC Parameters.

D. Modulation and Coding Modes (Burst Profile)

From the several burst profiles allowed by IEEE 802.16e, the six listed in Table 5, along with the minimum required SNR, have been considered.

Burst Profile	SNR Required (dB)
QPSK CTC ½	3.5
QPSK CTC ¾	6.5
16 –QAM CTC ½	9.0
16–QAM CTC ¾	12.5
64–QAM CTC 2/3	16.5
64–QAM CTC ¾	18.5

Table 5 – SNR required for considered burst profiles. (CTC – Convolutional Turbo Codes)

E. Propagation Environments

a) Propagation Model

For the propagation model COST 231 Hata [5] has been adopted. Although this model is based on empirical data obtained at 2 GHz, [6] considers that it is a valid model at 3.5 GHz.

b) Penetration Loss

Penetration will be modeled as an excess loss introduced by the penetrated walls, using the model suggested in [7]:

$$L_{ex}(k) = L_{wi} k^{\left(\frac{k+1.5}{k+1} - b\right)} \text{ [dB]} \qquad (1a)$$

$$b = -0.064 + 0.0705 L_{wi} - 0.0018 L_{wi}^2, \qquad (1b)$$

where L_{wi} is the average excess attenuation per wall and k is the number of penetrated walls.

Table 6 shows the penetration loss (L_{wi}) as a function of frequency for thin board dividing between rooms and thick walls made of reinforced concrete.

Frequency [GHz]	Loss for thin walls [dB]	Loss for thick walls [dB]
2	3.3	10.9
3.5	3.4	11.4
5	3.4	11.8

Table 6 – Penetration loss as a function of frequency for two types of walls [8].

Three indoor scenarios have then been considered, listed in Table 7 along with the respective attenuations calculated through equations (1a) and (1b) for a 3.5 GHz frequency.

Parameter	Indoor 1 Thick Wall	Indoor 2 Thick Wall + Thin Wall	Indoor 3 2 Thick Walls
Total Penetration Loss [dB]	11.4	12.9	18.0

Table 7 – Penetration Loss Parameters.

The chosen Indoor scenarios try to represent possible limiting situations on propagation. The analysis was limited to two walls, since when the number of walls increases, other propagation mechanisms become dominant.

c) Fading

The diverse fading components due to the propagation environment will be taken into account in the form of propagation margins.

Table 8 resumes the adopted margins and the total margin for the different considered scenarios. WiMAX Forum™ reference studies have provided the guideline for this parameterization [9].

Margin	
Log Normal Fade Margin	5.56 dB
Fast Fading Margin	2.0 dB
Interference Margin	2.0 dB

Table 8 – Fading Margins Adopted.

The value of 5.56 dB for the shadow fade margin is based on a log-normal shadowing standard deviation of 8 dB assuring a 75% coverage probability at the cell edge and 90% coverage probability over the entire area.

The interference margin assumes a cellular reuse pattern of 1 with 3 sectors per site.

F. Station Parameters

Tables 9 resumes the parameters used for the link budget calculations for the BS and SS, again based on WiMAX Forum™ analysis [9].

III. RESULTS & CONCLUSIONS

Taking into account the data in Tables 2-4, the maximum DL data rate has been computed for the different system profiles and results are shown in Table 10.

Base Station Parameters			Subscriber Station Parameters		
BS Height	h_b	32 m	*Subscriber Station Height*	h_m	1.5 m
Tx Power per Antenna Element	P_E	10 W	*Number of Rx Antenna Elements*		2
Number of Tx Antenna Elements		2	*Antenna Diversity Gain*	G_{DIV}	3 dB
Cyclic Combining Gain	G_{CYC}	3 dB	*Rx Antenna Gain (Handheld Outdoor)*	G_R	-1 dBi
Tx Antenna Gain	G_E	15 dBi	*Rx Antenna Gain (Fixed in Indoor)*	G_R	6 dBi
Pilot Power Boosting Attenuation	A_{PILOT}	-0.7 dB	*Noise Figure*		7 dB

Table 9 – BS and SS Parameters

	Modulation	Data Rate [Mbps]
5 MHz	QPSK ½	2.016
	QPSK ¾	3.024
	16 –QAM ½	4.032
	16–QAM ¾	6.048
	64–QAM 2/3	8.064
	64–QAM ¾	9.072
10 MHz	QPSK ½	4.032
	QPSK ¾	6.048
	16 –QAM ½	8.064
	16–QAM ¾	12.096
	64–QAM 2/3	16.128
	64–QAM ¾	18.144
7 MHz	QPSK ½	2.736
	QPSK ¾	4.104
	16 –QAM ½	5.472
	16–QAM ¾	8.208
	64–QAM 2/3	10.994
	64–QAM ¾	12.312

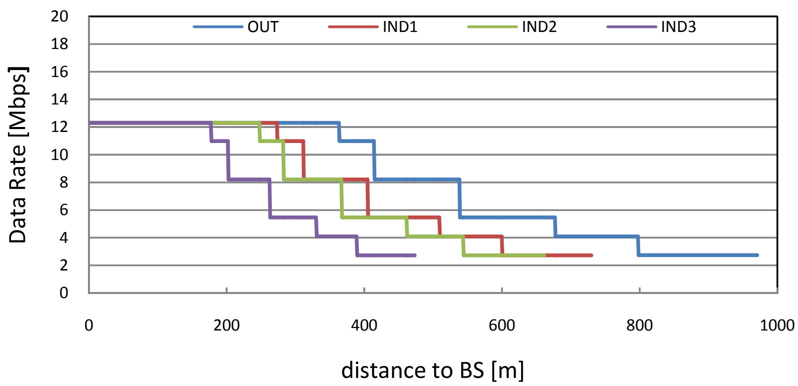
Table 10 – Useful Maximum DL Data Rates for chosen modes.

For the system specified in section II and considering the four stated scenarios (OUTDOOR; INDOOR 1, INDOOR 2 and INDOOR 3), the variation of the DL data rate with the distance to the BS has been computed for the 10 MHz and 7 MHz cases, with the results being presented in Figure 3 a) – d).

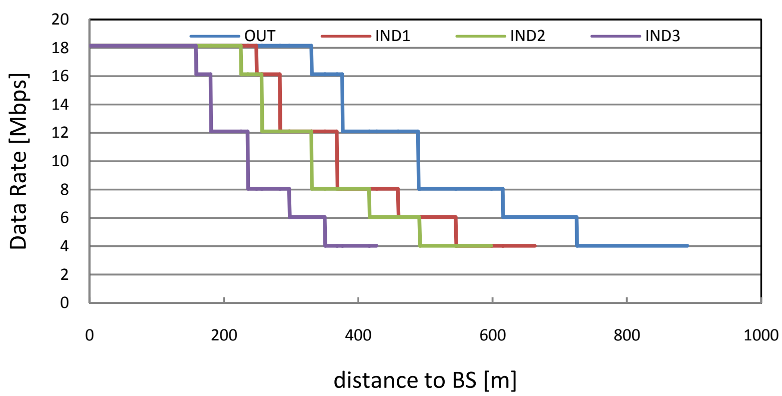
From Figure 3 it is evident the serious challenge penetration is to the deployment of a WiMAX network.

Iin the suburban case at 10 MHz bandwidth one can observe a reduction in the maximum cell radius ranging from 25% in the least penalizing indoor scenario up to 51% in the more hostile one.

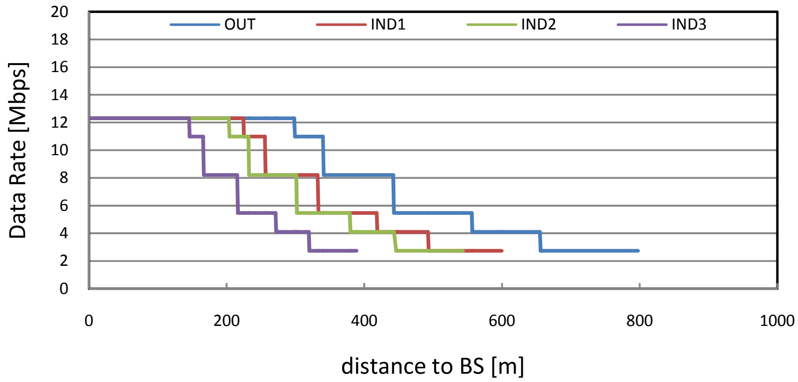
As expected, as one decreases the system bandwidth the data rates offered are lower, and the cell radius is slightly increased..



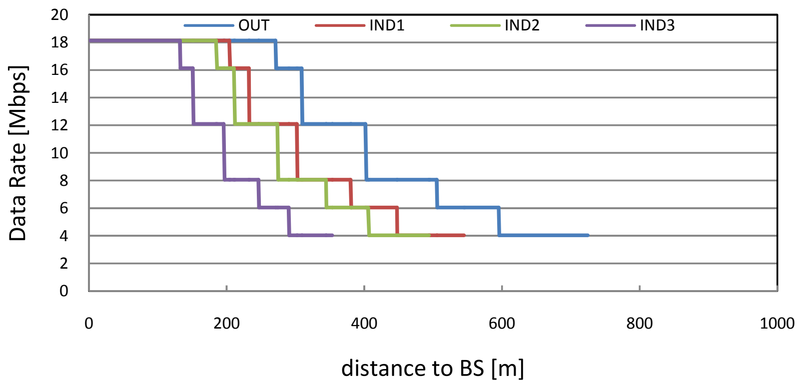
(a) SUBURBAN environment; 7 MHz Bandwidth



(b) SUBURBAN environment; 10 MHz Bandwidth



(c) URBAN environment; 7 MHz Bandwidth



(d) URBAN environment; 10 MHz Bandwidth

Figure 3 – DL useful data rate versus distance for four considered scenarios.

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