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SIMPLE CAPACITY ESTIMATIONS IN WIMAX/802.16 SYSTEM

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ABSTRACT

In this paper, we propose some simple capacity estimations for WiMAX/ IEEE 802.16 system. The OFDM Physical layer of 802.16 is considered. We compare between the now-classical data rates values based on OFDM considerations and data rates obtained in simulation taking into account inter-cell interference. Figures are given for various scenarios of frequency reuse (1x1 and 1x3) and services (real-time and FTP) allowing interesting observations about WiMAX radio efficiency. These results can be used as an order of magnitude of more realistic WiMAX performance results.

I. Introduction

WiMAX Technology promoted by the WiMAX Forum and based on IEEE 802.16-2004 standard [1] and its amendment 802.16e [1a] is a very promising BWA, Broadband Wireless Access, Technology. Some studies have been published about the throughput of WiMAX [3], [4]. These papers consider a complex system simulator. In this paper we try to estimate the capacity of WiMAX system with simple Matlab programs. We consider a simple simulation model in order to have some results that can be considered as an order of magnitude for the more realistic results. The figures obtained give way to some interesting comments.

The system model is described in the following Section. In Section 3, we propose data rates values based on OFDM and WiMAX system considerations. In Section 4, we estimate the effect of interference which cannot be avoided in wireless systems on data rate and system performance. The figures obtained in Sections 3 and 4 are commented in the last section which contains also the conclusion.

II. Simulation model

In order to study the capacity of WiMAX system, we consider a dense urban interference-limited network deployment with uniformly distributed subscriber stations (SS) in many cells. We consider the OFDM-256 PHYSICAL Layer of IEEE 802.16, the only one included in the first WiMAX Forum system profiles. During data transfer, the subscribers stay at the same position (stationary) and are always connected to their initial best serving base station (BS). The considered model has 36 sites in a wrapped-around (torus-like) zone with 3 sectors per site, and 900 m site-to-site distance, leading to 108 sectors (300m cells).

Simulations have been performed in 1x1 and 1x3 frequency reuse schemes. 3.5 MHz (1x1 model) and 10.5 MHz (1x3 model) bandwidth availability scenarios in the 3.5 GHz

frequency band have been assumed. These 2 models lead to 1 cell per site with 3.5 MHz bandwidth frequency for each cell.

The base stations (BS) operate in FDD (Frequency-Division Duplexing) mode, with 10 ms frame duration (see [1] for all possible frame durations of a 802.16 system). The OFDM symbol duration is $T_s = T_b + T_g$ where T_b is the useful symbol time, given by:

$$T_b = \text{floor}\left(\frac{BW * n}{8000}\right) * 8000 * N_{FFT}$$

where BW is the frequency bandwidth ($BW=3.5$ MHz in our case), n is the sampling factor ($n=8/7$) and N_{FFT} is the length of Fast Fourier Transformation ($N_{FFT} = 256$). This equation leads to a T_b equal to $64\mu s$. The guard time is noted T_g , and corresponds to the CP (Cyclic Prefix). The value of T_g is given by [1]:

$$T_g = G * T_b$$

where G is the ratio of CP time to useful time. We choose $G = 1/16$ which leads to $T_g = 4 \mu s$ and $T_s = 68\mu s$. The number of OFDM symbols in the frame can then be computed. It is equal to 147 symbols per frame (see Figure 1). We study the capacity of WiMAX system in the downlink. In this case, 3 OFDM symbols are dedicated to the preamble at the beginning of the frame (2 OFDM symbols) and to the FCH, Frame Control Header, a subheader in the downlink frame (1 OFDM symbol).

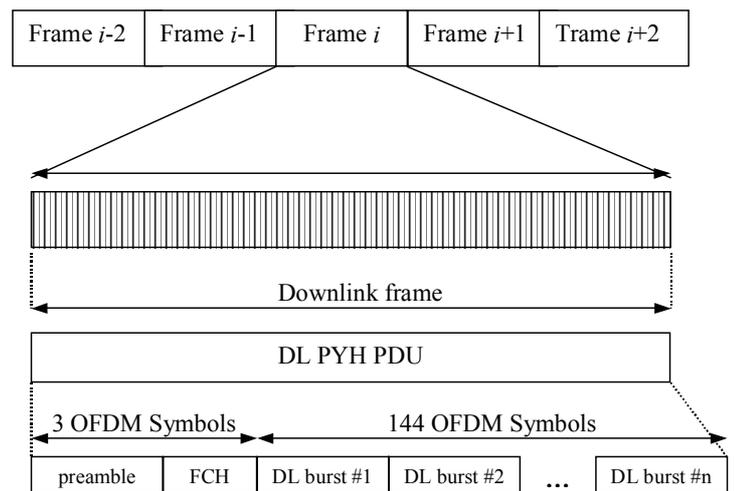


Figure 1: FDD Downlink Frame

We do not consider the MAP messages (DL-MAP and UL-MAP) which sizes from 2 and up to 15 OFDM Symbols depending of the number of users of the frame. As a result, we have 144 OFDM symbols as payload symbol.

An Erceg propagation model [2] and a slow fading (standard deviation equal to 8 dB) have been considered. The radio interface supports full automatic Link Adaptation functionality with maximum throughput optimization. The BS transmitted power is fixed and equal to 2 Watts, i.e., downlink power control is switched off. The BS antenna is considered to be 35 m above the ground, with 17 dBi gain. The SS antennas heights are fixed equal to 1.5 m above the ground, 0 dBi gain. Table 1 gives an overview on the main parameter settings used in our simulation model.

Table 1. The simulation model main parameters

Parameter	value
Number of sites	36
Number of cells	108
Frequency reuse pattern values	1x1 1x3
Available bandwidth	3.5 MHz (in 1x1 scheme) 10.5 MHz (in 1x3 scheme)
Frequency band	3.5 GHz
MSS distribution	Random uniform
Propagation model	Erceg A [2]
BS RF TX power	2 watts (33 dBm)
BS antenna	17 dBi, 35 m above ground
MSS antenna	Omni, 0 dBi, 1.5 m above ground
Power control (PC)	Downlink PC switched off
Slow fading std. deviation	8 dB
Modulation and coding rate	BPSK $\frac{1}{2}$, QPSK $\frac{1}{2}, \dots$, 64QAM $\frac{3}{4}$ (all WiMAX Modes)
Link adaptation	Enabled, best throughput criterion
OFDM symbol duration	68 μ s, 4 μ s CP (Cyclic Prefix)
Duplexing	FDD
Frame duration	10 ms (147 OFDM symbols, 3 symbols MAP + 144 symbols payload)
Scheduler	Cyclic Round Robin

III. Data rates calculation interference not considered

The WiMAX throughput is given by the equation:

$$\text{throughput} = \text{floor}\left(\frac{BW \cdot n}{8000}\right) \cdot 8000 \cdot \frac{N_{used} \cdot 1}{N_{FFT} \cdot 1+G} \cdot \text{coderate} \cdot E$$

where N_{used} is the number of used subcarriers (data subcarriers), $N_{used} = 192$, coderate is the rate of channel coding and E is the modulation efficiency (the number of bits per subcarrier). Coderate and E are function of the modulation and coding scheme (MCS), e.g. coderate = $\frac{1}{2}$ and $E = 4$ when the 16-QAM, $\frac{1}{2}$ MCS is considered.

According to this equation, the throughput of a WiMAX cell for the different WiMAX MCSs is given in Table 2 (Bandwidth = 3.5 MHz).

Table 2. throughput of WiMAX cell, in Mbit/s, for 3.5 MHz bandwidth

G	BPSK $\frac{1}{2}$	QPSK $\frac{1}{2}$	QPSK $\frac{3}{4}$	16-QAM $\frac{1}{2}$	16-QAM $\frac{3}{4}$	64-QAM $\frac{2}{3}$	64-QAM $\frac{3}{4}$
1/32	1.46	2.92	4.36	5.82	8.73	11.64	13.09
1/16	1.41	2.82	4.23	5.65	8.47	11.29	12.70
1/8	1.33	2.67	4.00	5.33	8.00	10.67	12.00
1/4	1.20	2.40	3.60	4.80	7.20	9.60	10.80

The equation above considers all the frame (including synchronization and control messages) as useful throughput. Hence the effective throughput is smaller if the following overheads are considered: the preamble length (2 OFDM symbols in the beginning of downlink frame), FCH message length (1 OFDM symbol), and broadcast messages (DL-MAP, UL-MAP, UCD, DCD...) which length is variable according to the number of served users in the cell, as well as to the length of control message specified to each user.

For BW = 3.5 MHz, FDD duplexing, frame duration equal to 10 ms, 10 active users in the cell, normal transmission (AAS, STC, subchannelization, etc. not used), the MAP messages not containing an Extended IE (Extended Information Element), the effective WiMAX throughput is given in Table 3.

Table 3: effective WiMAX throughput, in Mbit/s (BW= 3.5 MHz, frame duration = 10ms, 10 users)

G	BPSK $\frac{1}{2}$	QPSK $\frac{1}{2}$	QPSK $\frac{3}{4}$	16-QAM $\frac{1}{2}$	16-QAM $\frac{3}{4}$	64-QAM $\frac{2}{3}$	64-QAM $\frac{3}{4}$
1/32	1.33	2.67	3.99	5.33	8.00	10.67	12.00
1/16	1.29	2.58	3.88	5.18	7.77	10.35	11.65
1/8	1.20	2.42	3.63	4.84	7.27	9.70	10.91
1/4	1.07	2.15	3.23	4.31	6.47	8.63	9.71

The spectrum efficiency is given by the equation below:

$$\text{Spectrum efficiency} = \frac{\text{effective throughput}}{BW}$$

According to this equation, the Spectrum efficiency may reach $\frac{12}{3.5} = 3.4 \text{ bit/s/Hz}$ (in 64-QAM $\frac{3}{4}$ case), which is a relatively high efficiency compared to other known wireless and cellular systems.

IV. Effect of interference on data rates

In this section we try to estimate the WiMAX performance taking into account inter-cell interference. Simulations are executed with Matlab programs based on the system model described in section 2. The modulation/coding thresholds are taken from papers [3], [4]. Two types of service are considered: either a real time service with 200 Kbits/s as fixed throughput, or 500 Kbytes download file as FTP service.

All the users that have a real time service try to access to the system for one time. The users that have a sufficient modulation/coding scheme ($>QPSK \frac{1}{2}$) are accepted by the system. The others, which have a BPSK $\frac{1}{2}$ or QPSK $\frac{1}{2}$ modulation/coding scheme are considered as blocked (to avoid charging system for long time with modulation/coding schemes having a poor spectrum efficiency). For these users, we calculate their percentage according to the total number of real time users. Once the user is connected to the system, he remains served until the end of simulation. We calculate, for active users (not blocked), the percentage of ‘outage’ time where the received signal strength of some active user is below the corresponding threshold of their modulation/coding schemes.

Table 4: percentage of blocked users (real time service) according to frequency reuse pattern

Frequency reuse pattern	Percentage of blocked users
1x1	37%
1x3	7%

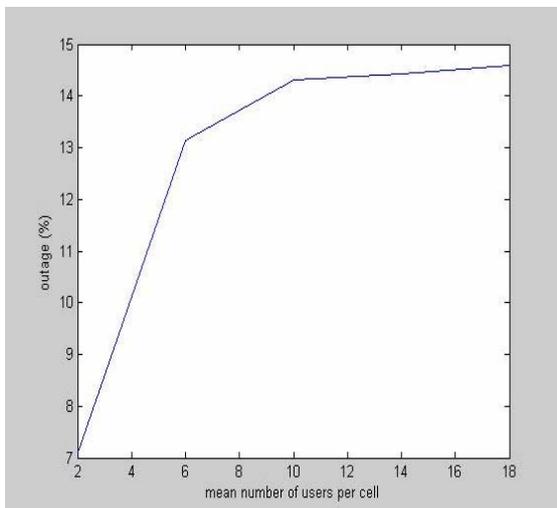


Figure 2: percentage of ‘outage’ time as function of users’ number per cell in two frequency reuse patterns (1x1 reuse pattern)

The users that have a FTP service try to connect to the system during at least in one minute. If the connection is blocked (received strength signal is not sufficient, even for QPSK $\frac{1}{2}$), the user try to connect to the system at another

time. A user that have a successful download try to connect to the system again for a new service. For these users we calculate the mean download delay of a 500 Kbytes file. The BS serves the real time connections first and then divides the remaining bandwidth between the FTP connections in an equal manner (cyclic round robin scheduler). Finally we calculate the mean cell throughput and spectrum efficiency of the system.

Two simulations are performed where the two types of service are considered. In the first simulation the 1x1 frequency reuse pattern is used. The 1x3 pattern is used in the second simulation. Each user has one type of service, 40% of users have a real time service and 60% have a FTP service. The percentage of blocked users (real time service) is given in Table 4. The percentage of ‘outage’ time is given by figure 2. The mean download delay (for FTP service) is given by figures 3 and 3a. The mean cell capacity is given by figures 4 and 4a. As result, the spectral efficiency goes from 1.6 to 0.55 bit/s/Hz (1x1 model) and from 1.7 to 0.94 bit/s/Hz (1x3 model).

A third simulation has been performed in 1x1 frequency reuse pattern, where only the FTP service is considered, i.e., all users have the same service. The results are given in figures 5 and 6. The spectrum efficiency goes from 3 to 0.7 bit/s/Hz.

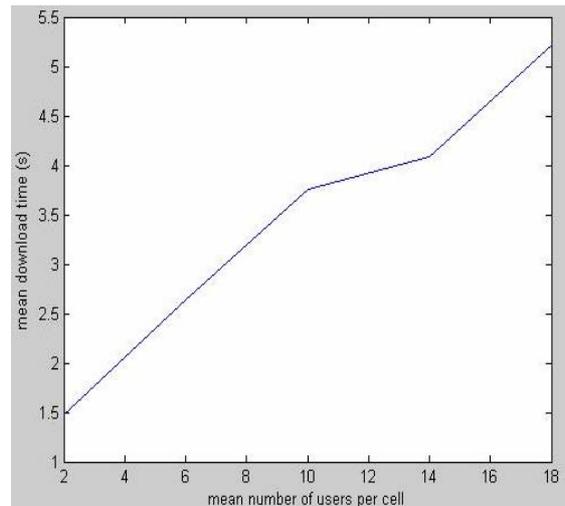


Figure 3: mean download time (in seconds) as function of mean number users per cell in a 1x1 frequency reuse pattern

A fourth simulation is performed in 1x1 frequency reuse pattern, where only the real time service is considered, the simulation is performed as ‘snap shot’. The bandwidth is divided in an equal manner between the users. The percentage of blocked users is 20%. The cell capacity is shown in figure 7. The spectrum efficiency varies between 2 and 1.6 bit/s/Hz. The reason for this big efficiency is the snap shot simulation where the variation of received signal strength is not considered.

V. Analysis of results and conclusion

In this paper we propose estimations of the capacity of WiMAX system. Considering a simple simulation model we propose some results that can be used as an order of magnitude for the more realistic results.

Using 1x3 frequency reuse pattern, the interference is reduced in the system. This interference reduction allows users trying the access to system to have a good carrier-to-noise ratio. This explains the difference between the two percentages of blocked users in table 4. As a counterpart, the data rate efficiency in bits/s/Hz/Cell is smaller.

In figure 4 we notice the difference of system capacity between the 2 reuse patterns, where this capacity decreases from 3.2 Mbit/s in 1x3 model to less than 2 Mbit/s in 1x1 model, in case of a loaded system. Hence, the spectral efficiency decreases from 0.94 bit/s/Hz in 1x3 model to 0.55 bits/s/Hz. This interesting efficiency, even in a 1x1 reuse pattern, shows the advantage of WiMAX technology in comparison to other technologies.

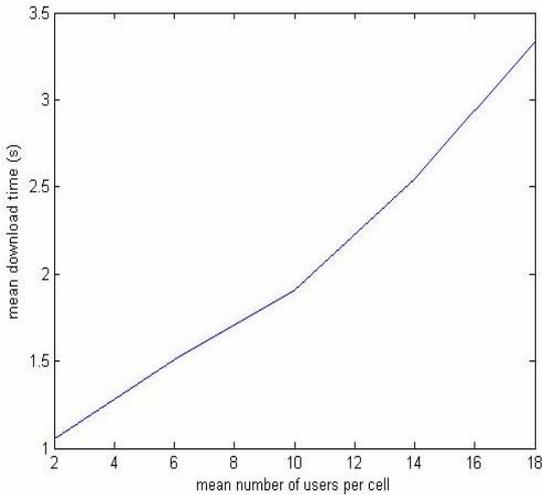


Figure 3a: mean download time (in seconds) as function of mean number users per cell in a 1x3 frequency reuse pattern

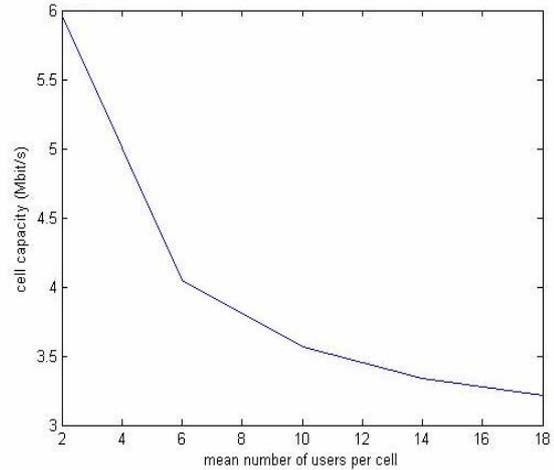


Figure 4a: cell capacity (in Mbits/s) as function of users' number per cell in a 1x3 frequency reuse pattern

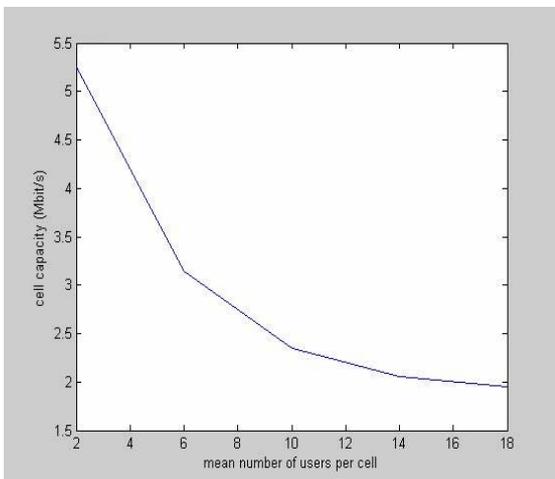


Figure 4: cell capacity (in Mbits/s) as function of users' number per cell in a 1x1 frequency reuse pattern

In figures 2, 3 and 4, it is clear that the system performances depend strongly on the users' number. The system in the 2 frequency reuse patterns have approximately the same results in case of little number of active users. Then, these results differ greatly when the number of active users per cell increases, i.e., where the interference level increases. In figure 3, the mean download time of 500 Kbytes' file becomes smaller in 1x3 reuse pattern than 1x1.

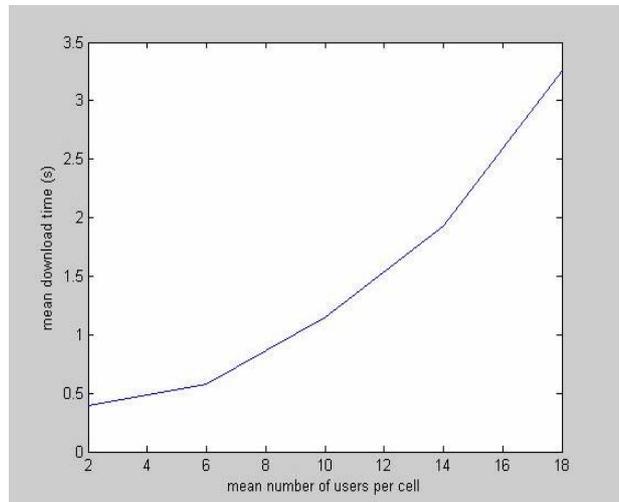


Figure 5: mean download time (in seconds) as function of users' number per cell

Figure 5 represents the mean download time of 500 Kbytes file where all users have the same service. Evidently, this time increases when the active users' number increases. We notice that the system is more efficient than before (when we considered two services in the system). This is because in this case the system has one service which can be achieved quickly and the resources become quickly free again instead of serving a user that have a long time service (real time service as video conference). This explains the higher system

capacity especially in case of small number of active users in the system (11 Mbit/s), where the BS achieves the service quickly (less than 1 second) and becomes free again, listening if there is some user asking for a new service. So the interference duration created by this BS is very small, hence the interference level in the system is very small.

can be more efficient if some advanced techniques like AAS (advanced antenna systems) and MIMO (Multiple-Input Multiple-Output) are considered. Efficient radio resource management procedures such as power control allow the use of 1x1 pattern with a small outage probability. This is then a guaranty to have a high spectral efficiency. A Future topic of research would be the study of power control of WiMAX: what can be proposed in the framework of WiMAX and what are the corresponding performances.

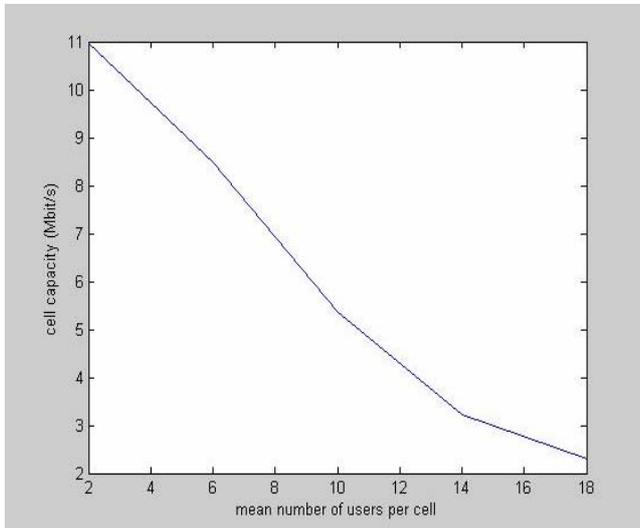


Figure 6: cell capacity (in Mbits/s) as function of users' number per cell

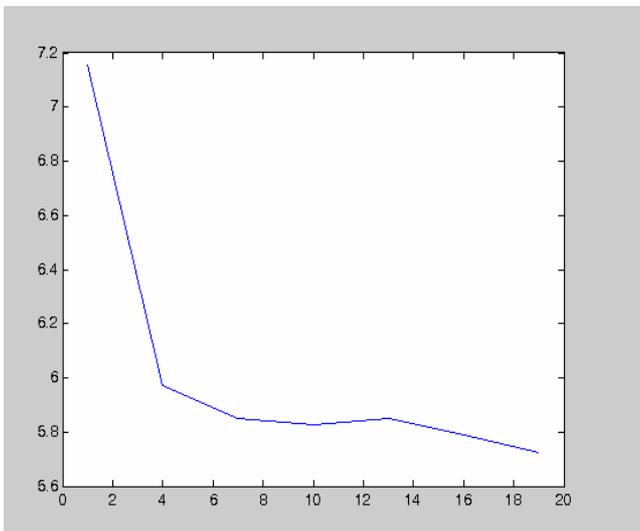


Figure 7: cell capacity (in Mbits/s) as function of users' number per cell

As a conclusion we can say that capacity is highly correlated to the number of active users in the system, the services types and the frequency reuse pattern. WiMAX system presents an interesting spectrum efficiency in comparison to other wireless technologies (0.55 bit/s/Hz in 1x1 frequency reuse pattern and 0.94 bit/s/Hz in 1x3 pattern) while supporting many types of service such as real time service, FTP service and others. The WiMAX performances

REFERENCES

[1] IEEE 802.16-2004, IEEE Standard for local and metropolitan area networks, Air Interface for Fixed Broadband Wireless Access Systems, Oct. 2004.

[1a] IEEE 802.16e, IEEE Standard for local and metropolitan area networks, Air Interface for Fixed Broadband Wireless Access Systems, Amendment 2: Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands and Corrigendum 1, Feb. 2006 (Approved: 7 dec 2005).

[2] V. Eceg, K.V.S Hari, M.S. Smith, D.S. BAUM, "Channel Models for Fixed Wireless Applicatons", IEEE 802.16.3c-01/29r4, Jul. 2001.

[3] C.F. Ball, E. Humburg, K. Ivanov, F. Treml, "Performance Analysis of IEEE 802.16 Based Cellular MAN with OFDM-256 in Mobile Scenarios", IEEE VTC 2005 Spring, May. 2005.

[4] C.F. Ball, F. Treml, X. Gaube, A. Klein, « Performance Analysis of Temporary Removal Scheduling applied to mobile WiMAX Scenarios in Tight Frequency Reuse », IEEE PIMRC 2005, Sep. 2005.