Comparison between UMTS/HSPA+ and WiMAX/IEEE 802.16e in Mobility Scenarios

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***Abstract* - The main purpose of this paper is to compare the performance of UMTS/HSPA+ and mWiMAX. Two scenarios were considered: single and multiple users. The single user model estimates the cell radius for a certain application throughput. Afterwards, the model was adapted to a multiple users and services scenario. The results for single user scenario show that UMTS/HSPA+ can serve users placed further away, for a certain throughput, compared to mWiMAX. Considering the multiple users scenario, UMTS/HSPA+ presents also better results than mWiMAX, both for down- and uplink, regarding average network throughput and average network radius.**

I. INTRODUCTION

Currently, third generation (3G) systems, e.g., the Universal Mobile Telecommunications System (UMTS), are designed for multimedia communication. In the standardisation fora, Wideband Code Division Multiple Access (WCDMA) technology has emerged as the most widely adopted 3G air interface and important evolution steps occurred on top of it: High Speed Packet Access (HSPA) for downlink (DL) in Release 5 and uplink (UL) in Release 6. Furthermore, Release 7, also known as HSPA Evolution or HSPA+, has its commercial deployment foreseen for 2009 and has been standardised by 3GPP in Release 8, [1] and [2].

HSPA+ offers a number of enhancements, providing major improvements to end-user performance and network efficiency. Multiple Input Multiple Output (MIMO) and Higher Order Modulation (HOM) extend the peak data rate to 43.2 Mbps in DL and 11.5 Mbps in UL [3].

Worldwide Interoperability for Microwave Access (WiMAX) is an emerging wireless communication system that can provide Wireless Metropolitan Area Networks (WMANs). IEEE 802.16.e, also known as mWiMAX, designed to support portability and mobility, consists of an amendment to the standard, and offers improved support for MIMO and Adaptive Antenna Systems (AASs) [4].

The Mobile WiMAX, mWiMAX, Air Interface adopts Scalable Orthogonal Frequency Division Multiple Access (SOFDMA) to support channel bandwidths from 1.25 to 20 MHz. The use of Adaptive Modulation and Coding (AMC) allows WiMAX to, adaptively, exploit the highest available data rate based on link quality. The system offers scalability in radio access technology and network architecture, supporting peak DL user data rates up to 63.4 Mbps, and UL ones up to 14.1 Mbps, in a 10 MHz channel.

Both UMTS/HSPA+ and mWiMAX technologies are being developed simultaneously, which makes possible that mWiMAX services will complement existing and future broadband technologies to best assure the coverage and capacity requirement of consumers [5].

The main purpose of this work is to compare UMTS/HSPA+ and mWiMAX performances at the cellular level, both for DL and UL, in a multiple users and services scenario, giving special emphasis to coverage and capacity aspects. In order to accomplish this goal, a default scenario and algorithms to compute the throughput achieved for a certain distance were created and developed.

In Section II, the models necessary for the theoretical calculations are described. The default scenario parameters and the main results are presented and analysed in Section III. In Section IV, the main conclusions are drawn.

II. MODELS

In order to access UMTS/HSPA+ and mWiMAX capacity and coverage, two models were developed: single and multiple users. The former has the objective of estimating the maximum cell radius in a single user scenario, taking an important role in the first phase of radio network planning. The latter is intended to study the performance of both systems in a comparative term, analysing a more realistic traffic scenario with multiple users performing different services, being randomly non-uniformly spread over the coverage area.

A. Single User

The UMTS/HSPA+ single user model is used to calculate the maximum cell radius according to several system parameters, as the desired application throughput, antenna configuration, modulation scheme, environment and overheads, among others. For mWiMAX, the same approach was followed, but some additional parameters such as Time Division Duplex (TDD) Split DL:UL and channel bandwidth were added.

For UMTS/HSPA+, the available throughput is calculated, for DL and UL respectively, based on the Signal-to-Noise Ratio (SNR) and on the energy per chip to noise spectral density ratio, E_c/N_0, [3].

For mWiMAX, the available throughput is calculated based on the tables of physical throughputs for different code rates, modulations, TDD Split DL:UL and SNR values [4].

The path loss is calculated using the link budget derived from the COST-231 Walfisch-Ikegami propagation model [6]. This model is also used to obtain the cell radius dependence on the Equivalent Isotropic Radiated Power (EIRP) and on the received power, among other parameters.

B. Multiple Users Simulator

The multiple users simulator was adapted from the one developed in [7] and [8]. New UMTS/HSPA+ and mWiMAX modules were added, for both DL and UL, while the main structure was left unchanged. A more detailed description of the simulator and respective files can be found in [9].

The UMTS/HSPA+ and mWiMAX modules' main objective is the analysis of the network capacity and coverage, through a snapshot approach, where the users are connected to the closest Base Station (BS). An extrapolation to obtain busy hour results is also done. When the offered traffic exceeds the BS's capacity, three reduction strategies, adapted from [7] and [8], with different Quality of Service (QoS) requirements, are applied.

The interference margin is introduced in the multiple users model, and its calculation is described in detail in [9]. The distributions assumed for the slow and fast fading margins are the Log-Normal and the Rayleigh ones.

For UMTS/HSPA+, the Signal-to-Interference-plus-Noise-Ratio (SINR) value is calculated for the distance between BS and the user, taking the link budget parameters into account, such as path loss and processing gain, among others. Afterwards, the SINR value is mapped onto the throughput with the use of the curves presented in [3].

The throughput calculation process presents some differences when mWiMAX is considered. In this case, the received power is compared with different receiver sensitivities, for different SNR and channel bandwidth values. The objective is to obtain the better approximation of the SNR value to be used in the computation of the throughput achieved corresponding to the distance between the user and the closest BS. The number of data sub-carriers available, N_{DSC}, depends on the sampling frequency, implementation margin, noise figure, total number of sub-carriers, SNR value and received power at receiver input [9].

Afterwards, the user physical throughput, R_b^{PHY}, due to the distance to BS is given by [10]:

$$R_{b\ [\text{bps}]}^{PHY} = \frac{N_{DSC} \cdot N_{SB} \cdot \beta \cdot N_{DS}}{T_{F[\text{s}]}} \quad (1)$$

where:

- β: effective code rate;
- N_{DS}: number of OFDM data symbols for a TDD Split;
- N_{SB}: number of symbol bits;
- T_F: frame duration.

For the radio network, the most important parameters are the average radius, the average satisfaction grade (ratio between the served and the requested throughput) and the average network throughput. For the busy hour, the most demanding period, it is important to obtain the number of users and the total traffic. The expressions used in the calculation of all these parameters are listed in [9].

In UMTS/HSPA+, the operators have two carriers: one for Release 99 and the other dedicated to HSPA+. Services like voice and video-telephony (VT) are served by the Release 99 carrier since dedicated channels are needed, while data services are transported by the HSPA+ carrier. In order to reach to a coherent comparison, the calculated parameters take only the data services into account. Nevertheless, voice and video-telephony users reduce the available bandwidth for data services in mWiMAX.

III. RESULTS ANALYSIS

A. Single User Results

The environments considered are: pedestrian, vehicular and indoor. They differ on the slow and fast fading constant margins and on indoor attenuations. In terms of spectrum allocation, the UMTS/HSPA+ frequencies are 1922.5 and 2112.5 MHz for UL and DL respectively. The frequency band adopted for mWiMAX is the 2.5 GHz one. With respect to transmission power, the default scenario considers 44.7 and 24 dBm for UMTS/HSPA+, DL and UL, and 43 and 23 dBm for mWiMAX, DL and UL. The differentiation of the system overheads is also referred in [9].

The modulation scheme and the antenna configuration, such as Single Input Single Output (SISO), Single Input Multiple Output (SIMO) 1×2 or MIMO 2×2 are variable parameters for both systems. In what concerns the TDD Split DL:UL and channel bandwidth, these parameters are exclusively of mWiMAX. All these parameters were chosen with the purpose of obtain a common interval of application throughputs for both systems. Therefore, the cell radii achieved for the range of application throughputs are calculated by applying the developed single user model.

Figure 1 presents the results for a pedestrian environment. Regarding DL, with UMTS/HSPA+ the maximum cell radius is 1.34 km, while for mWiMAX it is 0.27 km, both for 6.0 Mbps. The ratio between the UMTS/HSPA+ and the mWiMAX radii decreases from 5.0 to 4.6, which indicates that the existing differences are slightly minimised for higher throughputs.

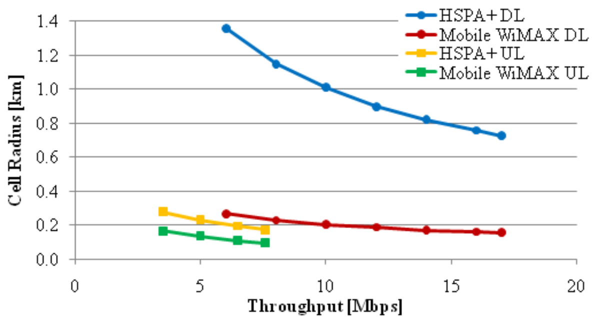

Fig. 1. UMTS/HSPA+ and mWiMAX maximum cell radii for different throughputs and the pedestrian environment.

Concerning UL, the interval of throughput values analysed is between 3.5 and 7.6 Mbps. In UMTS/HSPA+, the radius for 3.5 Mbps is 0.28 km, corresponding to the highest value in the analysed domain, whereas for mWiMAX the maximum radius assumes the value of 0.17 km, also for 3.5 Mbps. Contrary to DL, the ratio between the radii for two systems is not so notorious in UL: 1.7 for 3.5 Mbps and 1.8 for the upper limit of the interval.

For both systems, UMTS/HSPA+ presents higher cell radii, which constitutes a key advantage regarding coverage requirements. Additional results are presented in [9].

B. Multiple Users Default Scenario

A default scenario was created to study both systems and compare their performances. Several parameters were changed in order to study the impact of those variations. The results for all scenarios conceived can be found in [9]. In the default scenario, the largest percentage of users corresponds to indoor environments, since data services are almost entirely performed in laptops in offices or houses.

Seven services with different QoS classes were considered. The penetration percentage, the QoS priority list, according to the services are reduced, as well as the maximum throughput allowed to services, are presented in Table I. The higher throughputs reflect the strong trend of users requesting more demanding services in terms of data rate and bandwidth.

Table I
Penetration, QoS priority and throughput.

Service	Penetration Percentage [%]	QoS	Maximum Throughput [Mbps]	
			DL	UL
Voice	48.6	1	0.0122	
VT	0.2	2	0.064	
Streaming	7.1	4	3.6	0.512
FTP	16.9	7	10.0	3.6
Web	11.8	3	7.2	3.6
E-mail	10.5	5	3.6	
MMS	4.9	6	0.512	

The default parameters for the link budget evaluation and other default values are listed in [9]. Transmission powers are similar to the single user scenario ones. For DL, the MIMO configuration was chosen and a service throughput reference of 7.2 Mbps was used to deploy the network. Regarding UL, the SIMO configuration was adopted and the service throughput reference is 3.6 Mbps, assuming a typical asymmetry of services. In mWiMAX, the channel bandwidth is 10 MHz and the TDD Split is 3:1 for DL and 1:1 for UL. For UMTS/HSPA+, the modulations are 64 Quadrature Amplitude Modulation (QAM) for DL and 16 QAM for UL whereas, in mWiMAX, all modulations are considered with the exception of 64QAM in UL. It is important to point out that DL and UL are analysed independently, and that, due to the absence of MIMO curves for mWiMAX DL, the Relative MIMO Gain (RMG) model was applied [11].

A common traffic model was defined for both systems, based on volume, session duration, number of messages exchanged and average reading time, among other parameters. The traffic model takes the services asymmetries into account and is presented in [9].

In these simulations, the city of Lisbon is the coverage area considering 194 BSs and 1 600 users, performing both data and real time services, spread over the service area.

C. Multiple Users Coverage Results

The cell radius is defined as the distance of the user served further away from the BS. As expected, due to the single user results, UMTS/HSPA+ can serve users placed farther away and, consequently, covers a large area compared to mWiMAX. Both for DL and UL, there are users covered that are not served. The data rate reduction strategies have not a key role in this analysis, since the maximum throughput supported by BSs is enough to support the taken number of users, due to the use of MIMO, among other technology features. So, the reason for the existence of non served users is that, because of slow and fast fading margins and indoor attenuations, there are users associated to receive power and SNR values under the threshold to achieve the minimum throughput for a service, being, as a consequence, delayed.

Therefore, the average DL cell radius for UMTS/HSPA+ is, approximately, 0.29 km and near to 0.12 km for mWiMAX. For UL, due to the mobile terminal limitations concerning the transmission power, the values are lower: 0.10 km for UMTS/HSPA+ and 0.06 km for mWiMAX, Figure 2. These values are very low, and deserve a deeper analysis. These values for the cell radius are not advantageous for the operators. This means that the services throughput references are too optimistic for the present technology and capabilities of the systems.

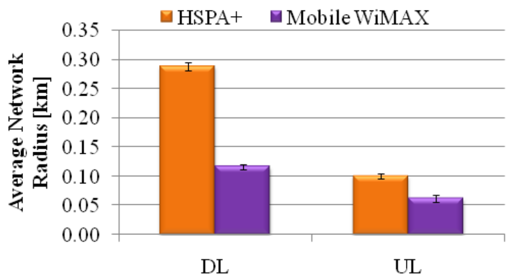

Fig. 2. UMTS/HSPA+ and mWiMAX Average Cell Radius.

D. Multiple Users Capacity Results

In terms of average network throughput, UMTS/HSPA+ presents higher values compared to mWiMAX, for both DL and UL, Figure 3. This throughput is 8.9 and 1.9 Mbps for UMTS/HSPA+ DL and UL, while for mWiMAX it takes the values of 3.3 and 1.1 Mbps.

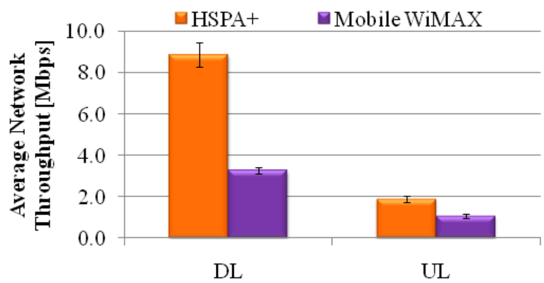

Fig. 3. UMTS/HSPA+ and mWiMAX Average Network Throughput.

This fact can be explained by several reasons. First of all, the average number of users per BS is higher in UMTS/HSPA+, existing in UL a large number of inactive BSs in both systems, with emphasis on mWiMAX. Another reason is that, instantaneously, users served by

UMTS/HSPA+ are also associated to higher throughputs, which is explained by the more significant correlation, verified in UMTS/HSPA+, between the served traffic and the one requested by users. This means that there are more users requesting more demanding services, such Web and File Transfer Protocol (FTP), not being delayed. Finally, the average satisfaction grade of UMTS/HSPA+ contributes to better average network results. In UMTS/HSPA+, the average satisfaction grade is 0.95, both for DL and UL, while for mWiMAX it is near 0.81 in DL and 0.89 in UL, where the requested throughputs are not so demanding. From a service viewpoint, the most demanding ones are associated to lower satisfaction grades.

The number of users in the busy hour context depends on the available throughput necessary to perform the services requested, and especially on the number of covered users. Bearing this in mind, one should notice that UMTS/HSPA+ presents a larger number of users per hour. The differences are more noticeable in DL with 260 000 users for UMTS/HSPA+ and only 120 000 users for mWiMAX. In UL, the ratio between served users per hour, by UMTS/HSPA+ and mWiMAX, is 1.4 with 45 800 users for the former. The large number of users per hour in UMTS/HSPA+, especially those that are responsible for performing services with higher volume sessions, is responsible for the higher network traffic generated obtained for UMTS/HSPA+, Figure 4.

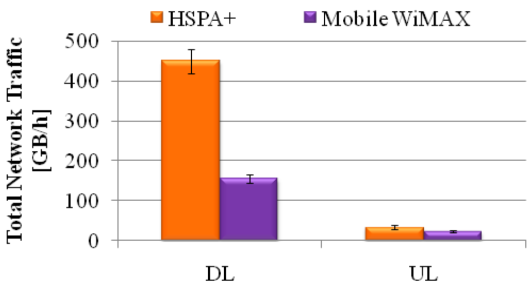

Fig. 4. UMTS/HSPA+ and mWiMAX Total Network Traffic.

In fact, for DL, the network traffic in UMTS/HSPA+ is 450 GB/h, the triple of the one verified in mWiMAX. In UL, not only the number of covered users is lower, but also the volume of Streaming and Web sessions is almost due to signalling and control processes; FTP files are also smaller in UL. Together, these facts contribute to lower network traffic compared to DL, but, one more time, with better results are obtained for UMTS/HSPA+, with 34 GB/h compared to 23 GB/h for mWiMAX.

IV. CONCLUSIONS

This paper deals with the comparison between UMTS/HSPA+ and mWiMAX when deployed in the same conditions, focusing on capacity and coverage aspects. A simple theoretical approach is taken, enabling the calculation of the maximum cell radius in a single user scenario.

Comparing UMTS/HSPA+ with mWiMAX for the single user model, one can conclude that the cell radius decreases with the increase of the throughput, because higher throughputs require higher SNR values, which leads to a decrease of the path loss and, as a consequence, of the cell radius. For the range of application throughputs and environments considered, UMTS/HSPA+ presents always better results. In a pedestrian environment, the ratio between UMTS/HSPA+ and mWiMAX radii decreases from 5.0 to 4.6 in DL, and presents a slightly increase from 1.7 to 1.8 in UL.

In what regards the multiple users scenario, one can conclude that UMTS/HSPA+ covers a larger number of users, including those placed further away from BSs, presenting average cell radii of 0.29 and 0.10 km, for DL and UL. These values are small, and present a problem concerning radio network deployment, for high data rates.

In terms of average network throughput, due to its higher coverage and satisfaction grade values, UMTS/HSPA+ has a better performance than mWiMAX with 8.9 and 1.9 Mbps, for DL and UL respectively, compared with 3.3 and 1.1 Mbps in mWiMAX.

In what concerns the number of users, UMTS/HSPA+ also serves more users per hour than mWiMAX. When the total network traffic is evaluated, one verifies that, for DL, one gets 450 GB/h for UMTS/HSPA+ and 150 GB/h for mWiMAX. For UL, the values are lower due to the traffic profile scheme and the lower coverage of the systems: 34 GB/h in UMTS/HSPA+ and 23 GB/h in mWiMAX.

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