Handover Performance Evaluation in WiMAX Mobility Scenarios

Mihai Constantinescu and Eugen Borcoci

University Politehnica of Bucharest, Romania
{mihai.constantinescu,eugen.borcoci}@elcom.pub.ro

Abstract. In the context of mobility management and cross-layer design and optimization for multimode wireless access networks, the paper presents the simulation campaign done to construct a multidimensional decision space for WiMAX parameters, in order to identify the sets of configuration parameters with major impact into the handover process for the IEEE 802.16e mobile station. Simulation results could then be used by cross-layer optimization algorithms to increase the handover performance, from the application point of view.

Keywords: WiMAX, hard handover, mobility management, cross-layer optimization.

1 Introduction

The globalization of culture and economy are mixing and opening new standpoints emphasizing that knowledge is a real strength in the competitive world. Concepts such as connectivity, mobility and Quality of service have now rooted in the routine. Mobility expands connectivity and allows service continuity. The process of handover, commonly described as transfer of a data session or an ongoing call from one network channel to another, is essential to mobility and started as a way to overcome the cell range limitations and balance the number of users inside the same area.

IEEE 802.16/WiMAX family of standards and specifications introduces the mobility as an important feature to increase the usability of the WiMAX technology in the context of Broadband Wireless Access (BWA). The IEEE 802.16d [1] is defined for fixed terminals, while IEEE 802.16e [2] adds the mobility and power management support. Additionally, the WiMAX Forum [3] [4] extends the framework, by defining the reference models and procedures, including the IEEE 802.16 technology in a complete end to end architectures. WiMAX Forum reference model defines three tiers: the first is the wireless interface – IEEE 802.16 between the Subscriber fixed or Mobile Stations SS/MS and Base Station (BS); the second is the Access Services Network (wireline or wireless - implemented) linking several Base Stations (BS) to one or several ASN Gateways (ASN-GW) – the latter having a double functional role both in the data and control plane; the third part is Connectivity Services Network (Home or visited one). On this architecture, several types of mobility can been encountered: micro-mobility (solved at Layer two - L2) ,

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intra or inter BS, but preserving the same anchor (in ASN-GW) and macro-mobility (inter-ASN or Inter-CSN). The latter is solved by cooperation between L2 mobility and Mobile IPv4/v6 [3] [4]. The basic scope of the IEEE 802.16 is the L2 mobility.

The standard IEEE 802.16e [2] defines three L2 HO types: Hard Handover (HHO), Fast Base Station Switching (FBSS) and Macro Diversity handover (MDHO). The basic (mandatory) one is the HHO, where the MS is logically linked to a single (serving) BS at each time instance. When the MS is moving it can switch to another BS by performing a „break before make" sequence of actions, i.e., it breaks the connection with the serving BS and then reconnects to a new (target) BS by performing all phases necessary phases for a network entry. While HHO involves a gap in the connection (and this will be reflected in a decrease of the corresponding throughput at application level), this is the most simple in terms and implementation and largely used in practice. The HO is decided at MS or network level and is performed following scanning actions [2]; it is executed after the signal strength from neighbor's cell exceeds with a given amount the signal level from the current cell.

While FBSS and MDHO are more performant (especially for seamless HO needs) they are more complex and costly. However, optimizing the HHO performance raises difficult problems of very complex interactions of a large set of parameters for 802.16e entities (at L1, L2 layers). Therefore analytical model cannot be defined and solved, but only very simplified ones. On the other side, the intelligence of the lower PHY and MAC layer of 802.16 creates the possibility of cross-layer optimization, usable to enhance HHO performance. Simulations based on realistic complex models can help.

SMART-Net Project. The work on mobility presented in this paper has been perform within a European research project SMART-Net (SMART-antenna multimode wireless mesh Network) having among its objectives studies and experimentations on hybrid mesh networks, including mobility issues. SMART-Net project is developing a heterogeneous access network solution incorporating multi-radio access technologies (RAT) and smart antennas to offer advanced wireless broadband solutions, [5] and [6]. This paper is focused on defining a a multidimensional decision space based on major WiMAX HHO parameters and their effects on HHO performance. A complex HHO-oriented simulation models are defined, with parameters modified step by step, in order to capture the exact behavior of the system and to define and to quantify the effect of each parameter modification to the overall performance. Analyzed parameters are related to PHY and MAC, together with environment parameters (distance, mobile speed, network topology). The effects on HHO performance are measured both at L2 level and at application level (throughput, delay, etc.). Simulation results could then be used to construct a database to guide some cross-layer optimization algorithms deciding upon HO trigger.

The paper is organized as follows: the Section 1 presents some related work. The Section 2 defines the HHO mobility issues to be studied in the paper. The Section 3 describes the simulation models, with comparative results of simulation analyzed on Section 4. Section 5 outlines the utilization of the simulation results toward mobility management and cross-layer optimization. Conclusion, open issues and future work are shortly outlined in the Section 6.

2 Related Work

Zhong et al. proposed a scheme for reducing unnecessary association procedure by evaluating mobile locations. That scheme offers application QoS requirements and can reduce the total handover latency [8].

A new downlink handover priority scheduling algorithm for different scheduling services is proposed in [8], aiming to provide lossless handovers and QoS.

A pre-coordination mechanism (PCM) for supporting fast handover in WiMAX networks is presented in [9]. This goal is achieved by measuring the distance between the BS and the MSS and predicting the time of handover occurs, and thus pre-allocating available resources for handover usages.

A MAC Layer solution to guarantee the demanded bandwidth and supporting a higher possible throughput between two WiMAX end points during the handover is described in [10], along with a PHY and MAC layers scheme to maintain the required communication channel quality for video streams during handover.

Barolli et al. presented a new handover system based on fuzzy logic [11]. That system uses 3 parameters for handoff decision: the change of signal strength of the present Base Station (BS), signal strength from the neighbor BS, and the distance between Mobile Station (MS) and BS.

3 IEEE 802.16 Handover Mobility Issues in Smart-Net and Cross-Layer Optimization

The simulations goal was to study in a large set of simulations the influence of different PHY and MAC parameters together with external parameters (distance, mobile speed) on application throughput, HO delay, and serving BS. The HO studied is HHO MS initiated. This is the simplest one, in terms of implementation, and actually is the only one defined in the IEEE 802.16 standard as mandatory for equipments. Two types of mobility: micro/macro, horizontal/vertical were considered, with HHO using MIPv4 and ASN-Anchored Mobility, in order to fulfill the SMART-Net project objectives related to WiMAX mobility.

A moving MSs may get current knowledge about its environment, by its scanning activity and through dialogue with the serving BS. If the MS “sees” in its geographical neighborhood several other BSs (apart from the serving BS) then it should take the decision if, when and to which new BS to perform the HO. The most simple decision is to perform HO whenever the SNR seen from other BSs is better than that of the serving BS. However each HHO action can determine a relative longer - in time - loss of connectivity (seconds), during HHO. A cross-layer optimization approach may improve the performance related to HO actions.

The results obtained after running simulations with a large combination of parameters can be organized in a database and then used in a cross-layer optimization (PHY-MAC) approach, to offer guiding data to algorithms/policies for MS to decide when to perform or not. This is applicable when the MS is currently located in an environment where based on scanning activity it “sees”, several BSs (different from the serving BS) as possible targets for HO, but it still has enough SNR seen from the serving BS, in order to sustain the current service flows. Then the MS can apply one of the following policies:

- Delay the HHO decision until the SNR seen from the serving BS is too low for sustaining its throughput of current flows, despite that some other BSs offer better SNR in comparison with the serving BS. Such actions can reduce the number of unnecessary HOs and have two benefices: first, avoid real-time flows interruptions (provoked by HHO) and increase the mean throughput.
- Apply a hysteresis threshold. This is used to select BSs as that are suitable candidates for the target BS in a HO. When finding the candidate BSs, the MS may compute the difference between the CINR(or SNR) of the serving BS and the CINR (or SNR) of the potential target BS .The value of this attribute (Multitarget Hysteresis threshold) specifies the minimum amount by which the CINR/SNR of potential target BS must exceed that of the serving BS. The value of this attribute must be less than the value of the Handover Threshold Hysteresis that triggers the HO.
- Use a SMART-Net antenna in directional mode instead of omnidirectional mode. Replacing an Omni-directional antenna by a smart one is impacting on many network mechanisms. The antenna systems need to be appropriately controlled by the MAC layer based on requests issued from higher layers of the stack. Such control is required for pointing in the right direction at the right time according to scheduling, routing and other mechanisms. However, such mechanisms should use optimal sets of WiMAX parameters, as determined from the multidimensional decision space, previous created using complex simulations. These mechanisms are not treated in the paper, being the scope of the next phases of SMART-Net project [5][6].

4 Simulation Models

The simulation was performed with OPNET v14.5 and v.16 [12]. Multiple network topologies were used: linear and random round trajectory, omnidirectional and 3 sectors BS antennas.

Basic Scenario Description (Linear Topology and Linear Trajectory, Macro-Mobility). The basic configuration contains a network composed of six BSs. The scenario uses MIPv4 as method to solve inter-BS mobility (Fig.1). The BS0 plays additionally the role of Home Agent (HA) and the other BSs the roles of Foreign Agents.

The MS has a linear trajectory along the above 6 BSs, moving from BS0 towards BS5, with constant but different speeds (5, 10, 15, 20, 25 m/s). The six BSs use the same frequency resource, thus some overlapping of cells and interference exists. The application flow is supposed to a 64kb/s UGS like flow – generated by an application server and flowing in download direction, from the server to a subscriber MS.

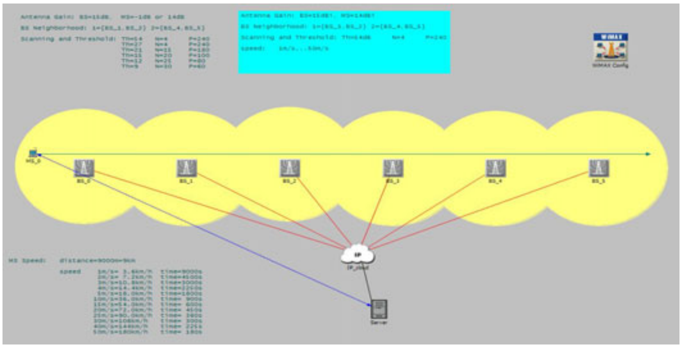

Fig. 1. Basic linear topology in IEEE 802.16 simulation scenarios

While moving the MS performs (depending on conditions and preconfigured settings) multiple HOs among BSs. The main parameter of interest for the application is the throughput variation (gaps in the real time flow) and mean values. These should be optimized by proper configuration of the MS behavior.

Heterogeneous Topology and Random Trajectory. In this scenario, the MS has a pseudo round random trajectory along 6 BSs located in a heterogeneous way. (Fig.2).

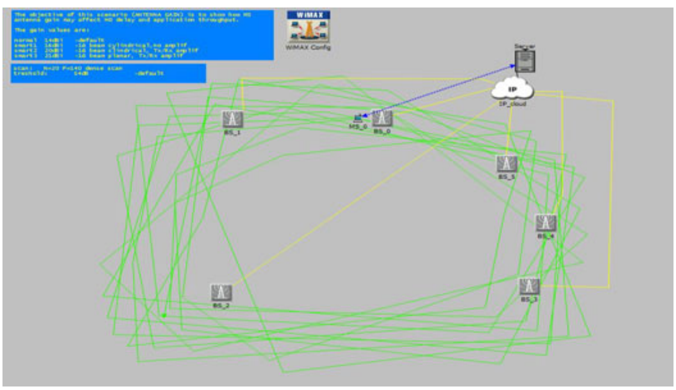

Fig. 2. Random topology in IEEE 802.16 simulation scenarios

The application flow is still a 64kb streaming download from an application server. The MS has two different speed sets: low speed - 1, 2, 3, 4, 5m/s (3.6, 7.2, 10.8, 14.4, 18km/h) and high speed - 10, 20, 30, 40 50m/s (36, 72, 108, 144, 180km/h). The MS antenna gain value has been selected as 14dBi, and for the BS antenna gain was 15dBi.

MIP Mobility with 3 Sectors BS. A set of simulations with sectored antenna on BS was performed, in order to study the combined effects of different parameters, (antenna gain, channel type, hysteresis threshold, multi-target hysteresis threshold, Tx power for BS and MS, etc.) on mobility performance, in comparison with the results from heterogeneous topology and random walk scenarios.

Network topology and configuration shown in Fig. 3, consists from: 3 BS with 3 sectors antenna ; 1 MS with omni-directional antenna; MS antenna gain: -1dBi (isotropic) – scenarios 01,02, 03 and 04; 16dBi (omni-directional) – scenarios 05, 06, 07 and 08. MIP Home Agent configured on BS_A; 128Kbps bidirectional voice flux configured between MS and Voice server; Multipath –vehicular; Pathloss: vehicular type A; Scanning threshold = 1dB; HO threshold hysteresis/Multi-target HO threshold range: 0dB/0dB – scenario 01 and 05; 5dB/0dB – scenario 02 and 06; 10dB/5dB – scenario 03 and 07; 15dB/5dB – scenario 04 and 08.

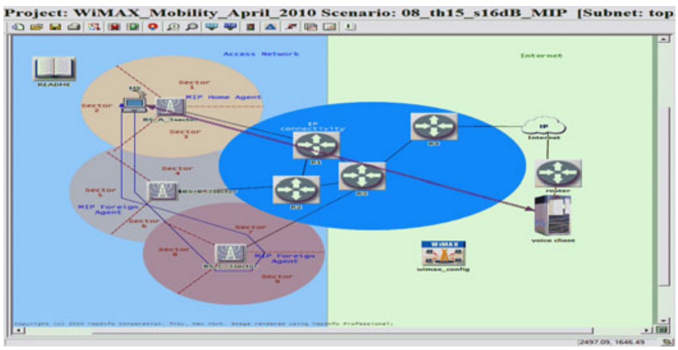

Fig. 3. MIP Mobility_BS 3 sectors topology in IEEE 802.16 simulation scenarios

ASN Anchored Mobility Scenarios-3 Sectors BS. The simulation scenario has the same network topology as MIP- 3 sectors BS scenario, the difference consists in the replacement of MIP with an ASN Gateway and in the configuration of 3 bidirectional tunnels, each of them connected one BS to the ASN-GW (Fig. 4).

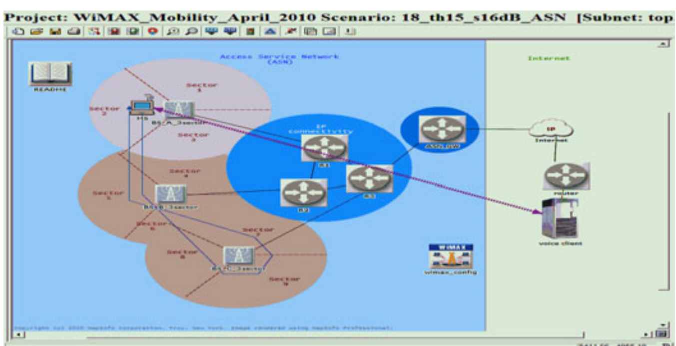

Fig. 4. ASN Anchored Mobility_BS 3 sectors topology in IEEE 802.16 simulation scenarios

The main configuration parameters are: 3 BS with 3 sectors antenna ; 1 MS with omni-directional antenna; MS antenna gain: -1 dBi (isotropic) – scenarios 11,12, 13 and 14; 16 dBi (smart antenna, unidirectional) – scenarios 15, 16, 17 and 18; ASN_GW tunnel configured on BS_A, BS_B and BS_C; 128 Kbps bidirectional voice flux configured between MS and Voice server; Multipath –vehicular; Pathloss: vehicular type A; Scanning threshold = 1dB; HO threshold hysteresis/Multi-target HO threshold range: 0dB/0dB – scenario 11 and 15; 5dB/0dB – scenario 12 and 16; 10dB/5dB – scenario 13 and 17; 15dB/5dB – scenario 14 and 18.

5 Comparative Simulation Results

This section presents samples of a large set of simulation sessions where several parameters are varied (MS speed, scanning threshold, neighborhood components, BS or MS antenna gain, scanning interleaving parameters, type of modulation/coding, etc. The purpose is as declared to observe what parameters and how much can influence the performance in HHO cases.

Mobile IP and ASN anchored mobility effects on Application Throughput, MS antenna gain -1 dB and 16 dB are presented in comparative mode (Fig. 5).

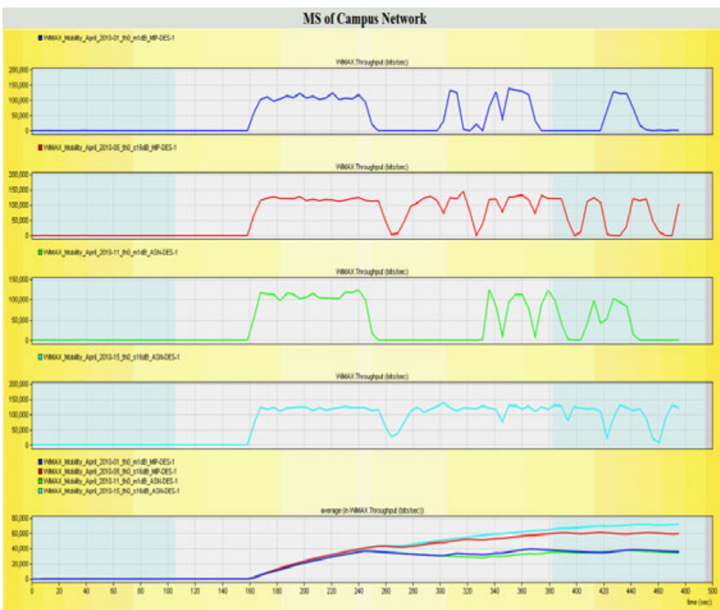

Fig. 5. Comparative average throughputs, scenarios 01-05-11-15, ASN/MIP

As expected, ASN anchored mobility provide a better throughput and lesser gaps with respect to Mobile IP. Clearly better results are obtained for antenna gain 16 dB toward -1 dB.

Fig. 6 and Fig. 7 show the effects of BS power threshold on throughput, for ASN, respectively MIP scenarios.

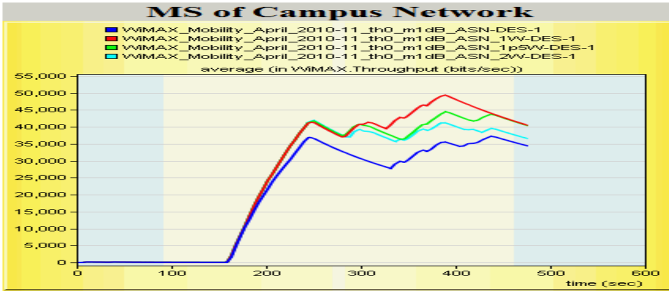

Fig. 6. Effects of BS power threshold (0.5-2W) on throughput, ASN_BS 3sectors

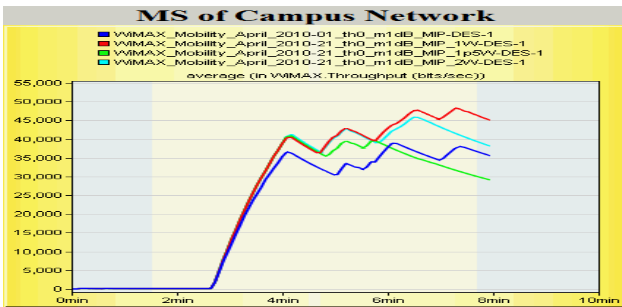

Fig. 7. Effects of BS power threshold (0.5-2W) on throughput, MIP_BS 3sectors

The power increase produces a non-monotonic effect on the HO performance and consequently on averaged throughput measured at application level. It is seen that there is an optimum of power at BS which is P= 1W, while for 0.5, 1.5, 2W the results are worse. The decrease in throughput at higher TX power is due to higher interference produced in the regions crossed by the MS (see the trajectory). An important conclusion is that one should correlate the TX power with the antenna gain and geographical positions in order to get good results. Another important result is that the effect is the same (qualitatively) for ASN mobility case and for MIP mobility case.

A comparison between ASN and MIP related to combined BS power and MS antenna gain effects is presented in Fig. 8.

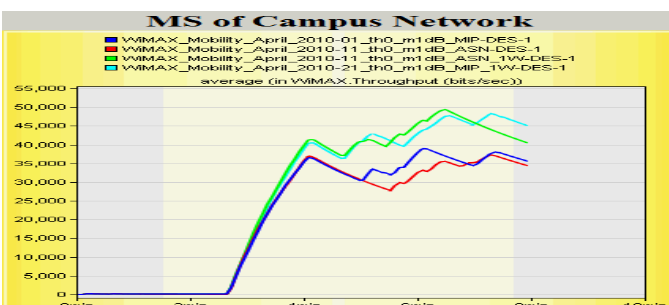

Fig. 8. Comparison ASN_MIP 0.5-1W, MS antenna gain -1dB_16dB - _BS 3sectors

The graphics clearly show that the TX appropriate power value adjustment is important (the average throughput for Ptx=0.5 W is only 60% of that obtained with Ptx= 1W).

An important result is that the MS antenna gain has a more dominant influence than BS power, so optimal results could be achieved using a smart antenna on MS, instead of increasing the BS power.

The temporal throughput and average throughput diagrams show a significant improvement both for MIP and ASN mobility cases while is a second order factor. Also, the ASN anchored mobility has a better result than MIP, as expected, due faster HO.

6 Conclusions on WiMAX Mobility Simulations

The extensive experiments described above and performed on various configurations for studying the mobility in IEEE 802.16/WiMAX mobility can be summarized in some conclusions as below:

- Micro-mobility (ASN-GW anchored) is clearly to be preferred versus micro plus macro-mobility (MIP) in terms of handover performance ; much faster handover can be obtained in the first case;
- A large set of parameters can influence the HO performance (topology, relative geographical distances Tx Power of BS and MS, MS trajectory, MS speed, interference, types of antennas (omni-directional, sectored, directional) antenna gain, scanning threshold, hysteresis threshold, etc. These makes the problem of optimizing the HO a multi-criteria problem and it is non-convex one; therefore local and context dependent can be only done;
- Antenna gain is a primary factor to influence the HO performance;
- Tx Power is a secondary factor influencing the HO performance;
- Adjusting the scanning threshold by cross layer optimization can reduce the HO delays;
- Combined adjustment of hysteresis threshold and scanning threshold can produce a better performance.

7 Conclusion and Future Work

This paper presents the simulation campaign done to identify the sets of configuration parameters in the IEEE 802.16e mobile station, in order to help the cross-layer optimization decision-taking algorithms, applied during scanning and hard handover activities. Given the limited space of the paper, we present only a few simulation result examples (taken out from a large set of simulations performed), in order to highlight the cases when the related parameters have a major influence to the HO performance. Future work will be done to study how these parameters could be used by cross-layer mechanisms to allow a coordination of smart antenna beam selection with the network topology [13], which, together with some signaling protocols on applications layers, will provide a seamless HO from the application point of view. A cross-layer mechanism for seamless HO for multimedia applications was proposed in [14], and further study for network topology awareness on MS level is under progress.

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