Performance Evaluation of Real-Time Services in Mobile WIMAX

Aleksandar Bozinovski, Zdravko Naumoski, and Toni Janevski, *Senior Member, IEEE*

***Abstract* — In this paper we provide a performance analysis for real-time services with a limited bandwidth in a single-cell Mobile WiMAX network. We analyze the most critical performance parameters for real-time services, such as voice over IP. Since the throughput is a given constraint for a real-time service, the focus is on delay and jitter introduced by the Mobile WiMAX technology. We have used different user velocities, including nomadic users as well as mobile users. The main contribution of this paper is that we have shown that Mobile WiMAX can be efficiently used for real-time services with applied admission control and priority over non-real-time traffic, because it is adding a very small portion to the delay budget for the real-time service, as well as it keeps the jitter far below the end-to-end jitter threshold for telephony in a Mobile WiMAX network.**

***Keywords* — Analysis, Mobile, Performance, WIMAX.**

I. INTRODUCTION

WIRELESS world became more diverse with the introduciton of IEEE 802.16 (known as WiMAX) technologies several years ago, targeted to cover the gap in the metropolitan areas, which was left between Wireless Local Area Networks (such as IEEE 802.11) as well as mobile cellular networks (such as 3G and beyond). This was a revolution in the wireless world in the first decade of the 21st century [1]-[4].

Wireless broadband access is a technology that enables wireless access to data networks with high data speeds, enabling competition in the broadband services market and offering an alternative to cable access networks, such as optical links, coaxial systems and Digital Subscriber Lines - DSL. Because wireless systems have the property to cover a large geographic area without costly infrastructure development in setting the cable links to individual sites, they can provide cheaper development and broadband access everywhere present as shown in Fig. 1. There are several advantages of the systems with wireless broadband access such as fast start-up implementation of the system, dynamic allocation of radio resources, lower costs (when compared to 3G mobile networks), efficient use of radio spectrum, large throughput in uplink and downlink directions, wide range of QoS, etc.

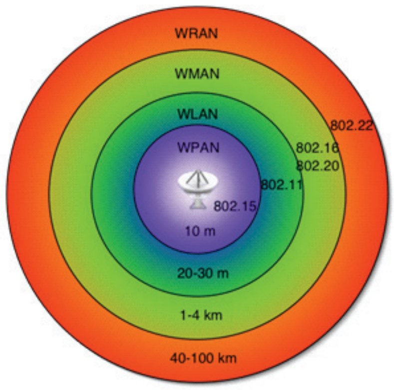

Fig. 1. Global Wireless Standards.

This broadband access is standardized by the IEEE 802.16 Working Group and the WiMAX Forum. However, the IEEE 802.16 Working Group developed the standards for the physical and MAC level [5]-[6].

The mobile WiMAX standard, IEEE 802.16e [5], was released several years ago and it is still in its "baby" years. However, it is certain that it will have a place on the technology scene in near future [6]. However, there are challenges regarding the capabilities of the Mobile WiMAX for the well known services in the mobile world such as telephony. Because WiMAX is IP native (as all other standards from IEEE), the telephony is represented by Voice over IP (VoIP). However, if one wants to provide real-time services over Mobile WiMAX, such as VoIP, then we need to provide whether the QoS requirements for these services are met or not. For that purpose in this paper we perform performance analysis of Mobile WiMAX regarding the VoIP service by using simulation technologies [7]-[8]. Some obtained results are presented already in the literature regarding mainly the physical layer analysis [9]-[10].

This paper is organized as follows. Section 2 describes important aspects of the physical layer regarding our analysis. Simulation scenario and results are given in Section 3 and 4, respectively. Finally, Section 5 concludes the paper.

II. DESCRIPTION OF PHYSICAL AND MAC LAYERS

Modulation of the physical level is based on OFDMA, in combination with the central MAC optimal level of resource provisioning and QoS support for different types of services (VoIP, real-time and non-real-time services,

Aleksandar Bozinovski is a postgraduate student at the Ss. Cyril and Methodius University, Faculty of Electrical Engineering and Information Technologies, Karpos 2 bb, 1000 Skopje, R. Macedonia (e-mail: bozinovskial@yahoo.com).

Zdravko Naumoski is a postgraduate student at the Ss. Cyril and Methodius University, Faculty of Electrical Engineering and Information Technologies, Karpos 2 bb, 1000 Skopje, R. Macedonia (e-mail: zdravko_n@hotmail.com).

Dr. Toni Janevski is Associate Professor at the Ss. Cyril and Methodius University, Faculty of Electrical Engineering and Information Technologies, Karpos 2 bb, 1000 Skopje, R. Macedonia (e-mail: tonij@feit.ukim.edu.mk).

and best effort). OFDMA physical level is adjusted to the middle of the Non Line of Site (NLOS) propagation in the frequency range of 2-11 GHz [3]. Together with adaptive modulation, which applies to each subscriber individually according to the power of radio channels, OFDMA can provide high spectral efficiency of 3-4 bits/s/Hz. On the other hand, the physical level cannot meet only by itself the requirements for quality of service (QoS) for mixed traffic (e.g. real-time and non-real-time) and does not know the type of application which is using the resources, such as VoIP, HTTP, or FTP (just one example of many).

Further, Media Access Control (MAC) level is responsible for monitoring and multiplexing a large number of links used in the same physical medium. The MAC level of WiMAX, is divided into three components: convergence sublayer – (CS), common-part sublayer and security sublayer. CS is the interface between the MAC level and level 3 (i.e. IP). It receives packets from higher levels. Data packets that are coming from the higher level are in fact the MAC Service Data Unit (SDU). CS is responsible for the execution of all operations that depend on the protocols of higher levels, such as header compression and mapping of addresses. CS can be seen as an adaptive level to map the protocols of higher levels and MAC and physical levels of the WiMAX network. The common-part sublayer of the MAC performs all the operations that are independent of higher levels, such as fragmentation and concatenation of the SDUs in MAC Protocol Data Units (PDUs), the transmission of MAC PDU, control of QoS, and ARQ. Furthermore, the security sublayer is responsible for encryption, authorization, and proper exchange of encrypted keys between the base station (BS) and the mobile station (MS).

A. *WIMAX network architecture*

Standard IEEE 802.16e-2005 defines the air interface for WiMAX but it is not fully defined for WiMAX network end-to-end. Network Working Group (NWG) of the WiMAX Forum [11] is responsible for developing the network architecture from end to end, and defining protocols in WiMAX, using it in IEEE 802.16e-2005 standard. WiMAX NWG defines a reference model of the network to serve as a basic architecture for WiMAX, and to ensure interoperability among various WiMAX operators and manufacturers. The reference model of network architecture is defined to support fixed, nomadic and mobile models, which are based on IP service model. The network may logically be divided into three parts: mobile stations that are used by end users to access the network; Access Service Network (ASN) as access network, which consists of one or more base stations and one or more ASN gateways, which form the radio access network; and Connectivity Service Network (CSN) which provides IP connectivity [5].

The WiMAX architecture also defines other entities, such as Network Access Provider (NAP) which owns and operates the ASN, Service Provider Network which provides IP connectivity and WiMAX services to consumers via the ASN infrastructure through one or more NAPs, Application Service Provider (ASP) which provides additional services such as multimedia services by using IMS (IP Multimedia Subsystem) and VPN (Virtual Private Networks) [6].

III. WIMAX SIMULATION SCENARIO IN NS-2

In this section we describe simulation scenarios which were used in our analysis. The simulations are performed using the network simulator ns-2 [7]. The purpose of the simulation is to show the results of testing the impact of the number of mobile stations that appear random in the surroundings of the base station and that are moving with different speeds. The performances are analyzed by using several QOS parameters such as: delay, jitter, and throughput. Fig. 2 shows the basic concept of the simulation scenario. It consists of a Mobile WiMAX base station, which serves a given number of users (e.g. 5, 10, 15, and 20 mobile users) and it is connected with the router which further is connected to a server that generates traffic for real-time services such as voice and video.

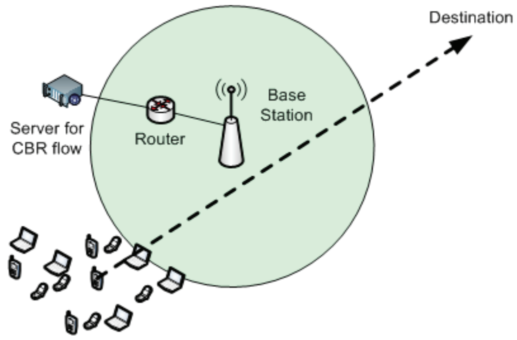

Fig. 2. Simulation scenario for Mobile WiMAX.

For real-time service, as usual, UDP is used as a communication protocol for data traffic.

We have used several scenarios with different numbers of active mobile-nodes. The position of the nodes in the cell is random as well as their velocity. The duration of the simulation is 110 sec, while the duration of a broadcast traffic from the server is 80 sec, starting at 20 sec and ending at 100 sec of shown simulation time.

The throughput between the base station and the router is 100 Mbit/s which results in introduced transmission delay of 1 msec. CBR (Constant Bit Rate) traffic is delivered to all mobile stations which are within the scope of coverage of the WiMAX base station.

In our analysis we assume that admission control is applied for real-time services and real-time traffic is served with priority over non-real-time traffic.

IV. RESULTS

The Mobile stations are generated at random positions and they are moving linearly to a certain point of simulation area. If mobile units are located outside the coverage area of the base station, packets from the flow are not reaching the mobile node and vice versa. We have analyzed delay and delay variation (i.e. jitter) as two most sensitive performance parameters for real-time services, for different numbers of mobiles and different velocities in Mobile WiMAX network.

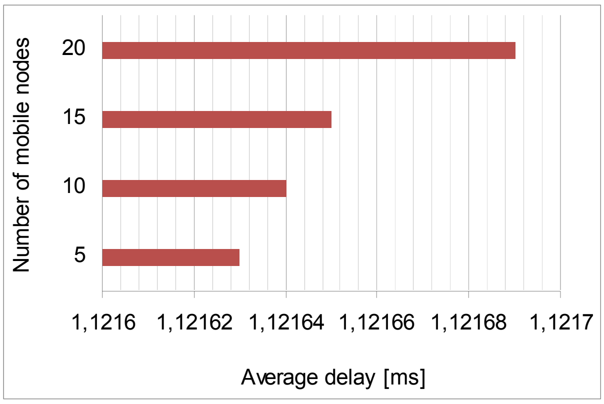

Fig. 3. Average delay depending on the number of mobile nodes.

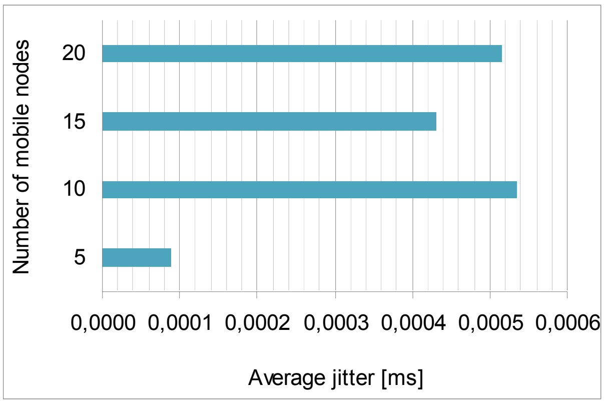

Fig. 4. Average jitter depending on the number of mobile nodes.

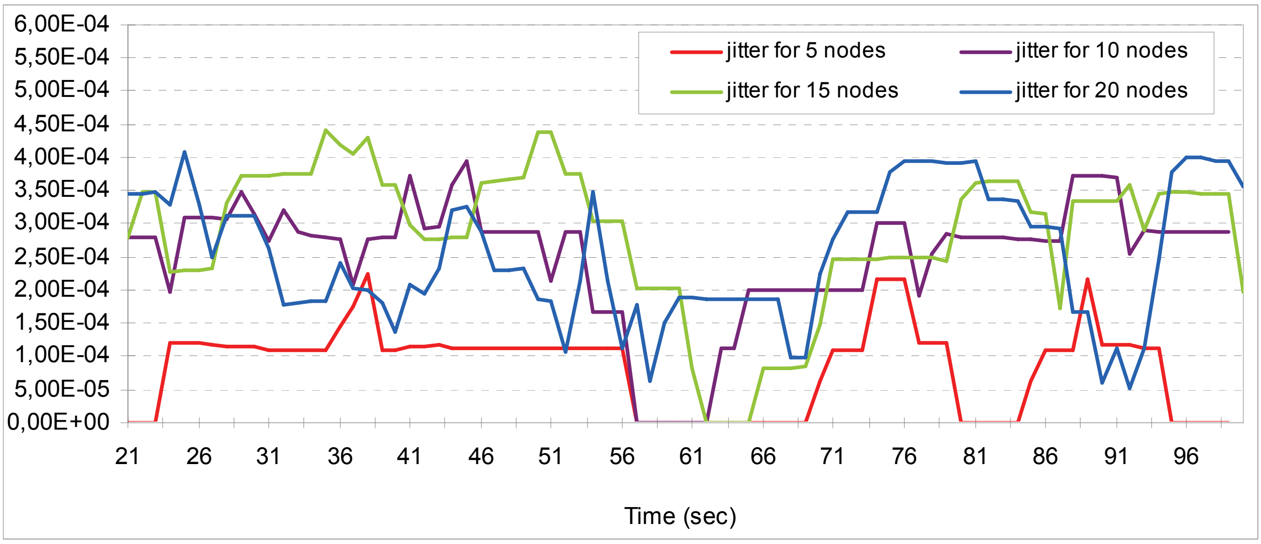

Fig. 5. Comparing jitter for different numbers of mobile nodes.

Fig. 3 shows the average delay, which is slightly dependent on the number of mobile nodes, which will not affect the performance of real-time services, even for voice, since voice budget is maximally 150 msec end-to-end, but for packet networks also 200-300 msec are acceptable (but not more than 400 msec end-to-end). Video traffic is more tolerant to delay since it is unidirectional (usually in the downlink, although the uplink will become more popular within next years for web cameras, social networking, home and office surveillance, various sensors, etc.).

In Fig. 4 we show that the lowest jitter is obtained for the lowest number of nodes, and by increasing the nodes the jitter is increased. However, jitter increment is negligible in the case when the mobile WiMAX network is not overloaded and when real-time services (which are analyzed in this case) are served with priority in the wireless access channel as well as in the core network (as in this case).

Fig. 5 show results of the analysis for the jitter for different numbers of mobile nodes. The results showed that Mobile WiMAX base station is not affected by the number of active mobile users using real-time services with a limited bandwidth with applied admission control (in the same fashion as it is for telephony in mobile cellular networks today). This leads to a conclusion that Mobile WiMAX can be used for VoIP service with all given delay and jitter constraints. However, the maximum jitter which can be afforded for telephony is 1 msec, but the budget for jitter introduced by the Mobile WiMAX access link seems to be much lower than the maximum acceptable value, which is an excellent result for Mobile WiMAX targeting towards mobile telephony with VoIP as a service.

Further, we have analyzed the throughput and jitter of the VoIP in a Mobile WiMAX network for different mobility of users, i.e. for nomadic users with velocity of 1 m/s and for mobile users (in a city area) with velocity of 10 m/s. The results are given in Fig. 6 and Fig.7 as a time trace for the throughput and jitter, respectively, for these two mobility scenarios. One can easily note that there are no notable differences in the throughput for the VoIP flows at different user velocities, i.e. they are almost the same for the nomadic and for mobile WiMAX users. However, we have to admit that this will not be possible if we do not apply admission control to voice traffic and if we do not differentiate voice traffic from the rest of the traffic in the wireless network as well as in the core IP network.

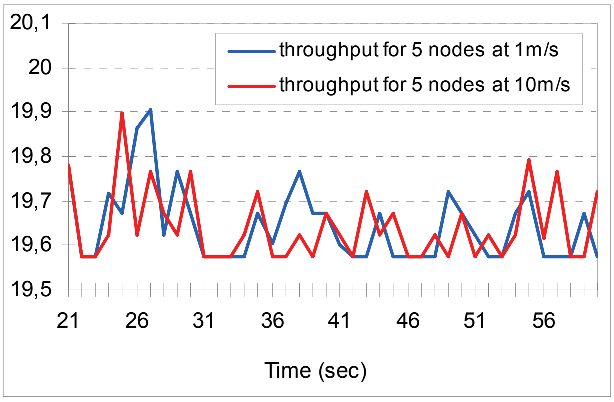

Fig. 6. Comparing throughputs at different velocities.

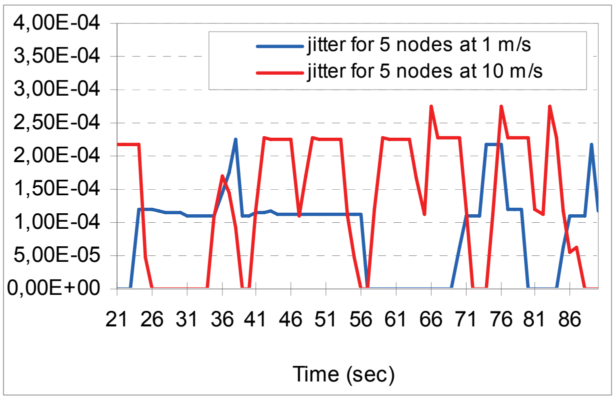

Fig. 7. Comparing jitter at different velocities.

I. CONCLUSION

In this paper we have provided a performance analysis for real-time services with a limited bandwidth (bits per second) in a Mobile WiMAX network. The aim was to analyze the most critical parameters for real-time services, such as voice over IP, and they are delay, jitter and throughput. Since the throughput was limited as a constraint for a real-time service in our analysis, the focus was on delay and jitter introduced by the Mobile WiMAX technology. We have used different user velocities, including nomadic users as well as mobile users in a city. The assumption was that there is applied admission control for the real-time services and real-time flows are served with priority over the non-real-time services in the wireless access network and in the packet core network. The main contribution of this paper is that we have shown that Mobile WiMAX can be efficiently used for such services, adding a very small portion to the delay budget for the real-time service, as well as keeping far below 1 msec threshold for end-to-end jitter for telephony i.e. voice over IP service in Mobile WiMAX case.

However, we may say that there are many more scenarios that can be investigated and many more situations that can be analyzed. Also, these analyses were limited to a single cell scenario. However, a multi-cell mobile WiMAX scenario will result in the fluctuation in some boundaries for the available capacity in a cell, which will then be used mainly for the admission control, and thus, should not have much influence on the obtained results from the single cell scenario.

For our future work, we intend to perform analysis for complex Mobile WiMAX environments with the aim to introduce the effect of handovers and at the same time to focus on the usage of mobile WiMAX for road-to-vehicle and vehicle-to-vehicle communications.

REFERENCES

[1] R. Krishna R. Radhamani, *WiMAX A Wireless Technology Revolution*. New York, USA 2008.
[2] J. Andrews, A. Ghosh, and R. Muhamed, *Fundamentals of WIMAX: Understanding Broadband Wireless Networking*. Prentic Hall Communication Engineering and Emerging Series, February 2007.
[3] R. Nee, and R. Prasad, *OFDM for Wireless Multimedia Communications*. *Artech House Publishers*, Norwood, MA, 2000.
[4] M. A. Hasanm, “Performance Evaluation of WiMAX/IEEE 802.16 OFDM Physical Layer”, *Espoo*, June 2007.
[5] *IEEE802.16e*: IEEE Standard for Local and metropolitan area networks Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems, 2005.
[6] *WIMAX Forum,* “Fixed, nomadic, portable and mobile applications for 802.16-2004 and 802.16e WiMAX networks” November 2005.
[7] http://www.isi.edu/nsnam/ns/
[8] http://www.lrc.ic.unicamp.br/wimax_ns2/
[9] G. Zaggoulos, A. Nix and A. Doufexi, “WiMAX System Performance in Highly Mobile Scenarios with Directional Antennas”, *Proceedings of IEEE PIMRC 2007*, Athens, Greece, Sept. 3-7, 2007.
[10] Q. Zhang and H. Dam, “WiMAX network performance monitoring &optimization”, *Proceeding of IEEE NOMS*, 2008, Bahia, Salvador, April 7-11, 2008.
[11] The WiMAX Forum, “Mobile WiMAX – Part I: *A Technical Overview and Performance Evaluation*,” 2006.
[12] D.T. Chen, N. Natarajan, and Y. Sun “On the Simulation, Modeling, and Performance Analysis of an 802.16E Mobile Broadband Wireless Access System”, *Proceeding of CCN*, Marina del Rey, USA, October 24 – 26, 2005.