SIMULATION OF RADIO-VISIBILITY IMPACT ON THE PROVIDED QUALITY OF SERVICE WITHIN THE WIMAX NETWORK

Saša Klampfer[1], Jože Mohorko[2], Žarko Čučej[2], Amor Chowdhury[1]

[1]Margento R&D d.o.o., Maribor, Slovenia
[2]Univerza v Mariboru, Fakulteta za elektrotehniko, računalništvo in informatiko, Maribor, Slovenia

Key words: signal attenuation, radiation, base station, WiMax, intermediate barriers, simulation, OPNET Modeler, model, elevation mapping, DTED, visibility, end user, signal strength, cross section, equipment allocation.

Abstract: This paper presents the latest generation of wireless networks, which includes WiMax networks. WiMax allows wireless broadband internet access in areas where a physical connection (optical connection, wired connection) is not possible or available. Because of many benefits, and good user properties of the WiMax network (a relatively large amount of available channel bandwidth (up to 70 Mbit/s) and a comprehensive range (up to 50 km)) such networks have in the last year become popular all around the world, especially in Africa. The abovementioned benefits are also the main reason for an increasing popularity of WiMax technology in Slovenia which also has high terrain roughness and large dispersion of the population in rural areas. Since the beginning many questions about WiMax are being posed on various internet forums: how far away from the main base station can a potential user be to receive a good quality of service, how many potential users can one base station cover, how do intermediate barriers (houses, hills, woods etc.) influence the WiMax signal strength, should a potential user of the WiMax technology have direct radio-visibility to the base station in order to receive a good quality of service, etc. The main aim of this paper is to answer some of the mentioned questions by using a WiMax simulation model in the OPNET Modeler simulation tool. Simulation results must be precise, and that preciseness depends on model accuracy, which is why we have also included DTED elevation mapping covering a wide range of Pohorje area beside a precise WiMax network model. With such elevation mapping we imitate intermediate barriers, and the effect of the terrain on dissemination and diffusion of radio signal emitted into the landscape. Elevation mapping allows us to observe a cross-section of the terrain between a potential user and a WiMax base station. It is also possible to observe the influence of the distance of the WiMax user from the base station, the changes of the signal strength due to terrain barriers etc. Each included scenario has a different geographical placement of the end-user unit in relation to the base station. In each simulation scenario we have observed the signal strength level, signal to noise ratio, ratio between all sent and all received packets between the base station and the end-user unit, etc. With all the obtained results and the observed parameters we try to provide answers to some of the abovementioned questions. Simulation and the simulation model are our starting points for the research presented in this paper.

Simulacija vpliva vidnosti na sprejem radio signala in kvalitete storitve znotraj omrežja WiMax

Kjučne besede: slabljenje signala, radiacija, bazna postaja, WiMax, vmesne ovire, simulacija, OPNET Modeler, model, višinska kartografija, DTED, vidljivost, končni uporabnik, jakost signala, prečni preprez, pozicioniranje opreme

Izvleček: V članku predstavljamo simulacijo WiMax brezžičnega omrežja. Ker takšno omrežje omogoča brezžičen širokopasovni dostop do sodobnih aplikacij na večje razdalje (do 70 km), je slednji še kako dobrodošel na neurbanih področjih, kjer je poseljenost redka, dostop preko fizičnega medija pa ni dostopen. Takšnih področij je še dandanes kar nekaj tudi v Sloveniji, zato postaja zanimanje za takšne storitve še kako zanimivo. V ta namen smo izvedli raziskavo v simulacijskem orodju OPNET Modeler, s katero smo želileli odgovoriti na vprašanja, ki jih vsakodnevno srečujemo na številnih spletnih portalih. Med takšna vprašanja sodijo npr.; ali vmesne ovire vplivajo na sprejem signala?, kako se vmesna ovira (npr. hrib) odraža na kvaliteti storitev?, kolikšen je domet? ipd. V ta namen smo v simulacijski model vključili višinsko kartografijo DTED, ki pokriva predel Pohorja in bližnjo okolico, prilagodili oddajno/sprejemno WiMax anteno, ustvarili odjemalca WiMax storitev, kateremu smo v različnih scenarijih spreminjali lokacijo postavitve (oddaljenost, vmesne ovire, ipd.), prilagodili frekvenčni pas, ter nenazadnje uporabili TIREM4 propagacijski model razširjanja radijskega valovanja, ki upošteva tudi faktorje prenosnega medija (zrak), kot so; vlažnost, nasičenost, refleksija ipd. Z upoštevanimi faktorji smo v simulaciji ustvarili, kar se da natančni približek dogajanja v realnem okolju.

1 Introduction

Use of mobile wireless communications, applications and mobile data transfer is nowadays rapidly increasing. Standardization of GSM-based systems has begun in the 1980s, when the development of a unique radio-communications system for Europe at 900MHz started. Since then many modifications have been made in order to fulfill increasing demands from the operators as well as cellular users.

This paper describes a Worldwide Interoperability for Microwave Access (WiMax) network and the influence of intermediate barriers on service reception (for example; data reception, when a VoIP application is in use). WiMax represents the next generation of long-range wireless networks, which allows broadband packet-based transmission of text, video, digitized voice and multimedia at data rates up to 70 megabits per second (Mbps) /1/. WiMax is intended for a consistent set of services provided to users, who do not have the option to connect to any other communication media, such ADSL, FTTH, and VDSL.

Because WiMax is today fully available, internet service providers can also provide WiMax networks; mostly in rural areas where population dispersion is relatively high, and an ISP can for example cover such users with only one transmitting/receiving base station without using any optical or other cables to end-users. WiMax clients will have exactly the same set of possibilities and applications as users using wired broadband connections (xDSL, FTTH, etc.). WiMax offers many different applications, such as: light and heavy web browsing, reading web mail, VoIP quality speech, video conferencing, base access, telnet session, file transfer, file copy, e-mail, and so on. For simulation purposes, described further on, we have chosen only one application, i.e. VoIP, which is today widely used among most of the world's population, because it allows the user to communicate with the world at any place and time. WiMax networks are a part of making such communication available. This research work is mostly concentrated on the radio-visibility impact on service quality (VoIP), and the influence of distance on service quality. These are two major problems which are going to be exposed in the paper. With the obtained simulation results we are going to see how intermediate barriers between the base station and the WiMax end-user influence service quality, how distance affects the same provided service (VoIP), etc. The paper is organized into seven sections. The second section is devoted to the presentation of a WiMax network, its main constitutive parts and their properties and descriptions. The third section shortly presents the main problem, which is explained and argued with different simulation scenarios described in further sections. The fourth section presents the OPNET Modeler simulation tool as an essential part of a precise simulation procedure /5, 6, 9/. Within this section a description of the elevation maps (DTED) is also given, together with their impact on the simulation model and their presentation in a geographical form. Under the fifth section the TIREM4 signal propagation model, used in our case, is presented. The sixth section presents three simulation scenarios used for testing different impacts on the service quality provided by the WiMax network (first scenario – without barriers and at a short distance, second scenario – without barriers and at a large distance, and third scenario – with barriers between the base station and the end user). The first two scenarios are intended for testing the influence of distance on the services provided by WiMax. A modeled WiMax network corresponding to the abovementioned testing scenarios is also presented and explained in this section, together with the simulation results, which give us answers to questions posed on many different forums. The seventh section concludes the paper.

2 WiMax network and main parts presentation

Worldwide Interoperability for Microwave Access or shortly WiMax is at the moment one of the most popular wireless technologies in the world. The IEEE organization (Institute of Electrical and Electronics Engineers) in 2004 issued the IEEE standard 802.16 known as Revision D. It was published for the needs of WiMax and fixed applications. One year latter the same organization published Revision E of the 802.16 standard, which includes also the mobility options. WiMax typically operates in the 2.5GHz, 3.5GHz and 5.8GHz frequency bands licensed by many government authorities. It uses RF technology and OFDM (Orthogonal Frequency Division Multiplexing) multiplexing technology. OFDM is very effective in cases when carriers have a bandwidth equal to 5MHz or grater. WiMax can be used for many applications, including the so-called 'last mile' broadband connections, where the WiMax base station spreads the wireless link around.

The WiMax system consists of two main parts /4/:

- a WiMax base station, and
- a WiMax receiver station

The WiMax base station consists of interior electronics and a WiMax antenna. Such base station can usually cover a radius up to 10km, in theory even up to 50km. Any receivers node placed within the mentioned radius can receive the WiMax RF signal. These specifications will be tested in the OPNET Modeler simulation tool, as the original contribution of this paper. Nowadays, all WiMax networks are cellular, which means that the WiMax network is constructed by using many base stations. Several base stations can be interconnected using the so-called 'backhaul' microwave links. According to Revision E, this allows a WiMax subscriber to roam from one base station area to another base station area. The roaming procedure is quite similar to that known in the GSM/UMTS networks /3/.

The WiMax receiver station could be a stand-alone set-top-box or a PC, PCI or PCIe card, or simply a USB receiver dongle. The base station acts as an access point, so the access is similar as in case of WiFi.

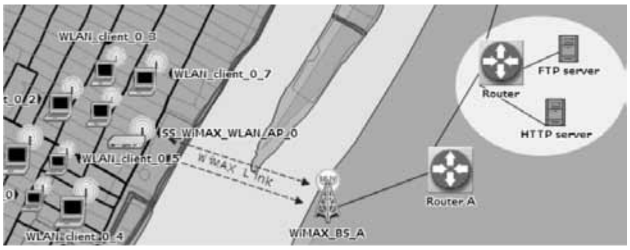

Fig. 1. A WiMax network example with a base station, a core network, and WiMax receivers.

In such a network it is necessary to provide logical separation between IP addressing, routing and connectivity management procedures and protocols to enable the primitives and interworking deployment.

The network reference model developed by the WiMax Forum NWG defines a number of functional entities and interfaces between them. Figure 2 below shows some of the more important functional entities. The WiMax network core consists of the following elements:

A base station (BS) which is responsible for providing an air interface to the MS (Main Station). Additional functions that may be a part of the BS are micro mobility management functions, such as handoff triggering and tunnel establishment, radio resource management, QoS policy enforcement, traffic classification, DHCP (Dynamic Host Control Protocol) proxy, key management, session management, multicast group management etc.

Access service network gateway (ASN-GW) which typically acts as a layer 2 traffic aggregation point within the ASN. Additional functions that may be a part of the ASN gateway include intra-ASN location management and paging, radio resource management and admission control, caching of subscriber profiles and encryption keys, AAA (Authorization And Accounting platform) client functionality, establishment and management of a mobility tunnel with base stations, QoS and policy enforcement, foreign agent functionality for mobile IP, and routing to the selected CSN (see below).

Connectivity service network (CSN) which provides connectivity to the Internet, ASP, other public networks, and corporate networks. CSN is owned by the NSP (Network Service Provider) and includes AAA servers that support authentication for the devices, users, and specific services. CSN also provides per-user policy management of QoS and security. CSN is also responsible for IP address management, support for roaming between different NSPs, location management between ASNs, and mobility and roaming between ASNs.

The WiMax architecture framework allows for a flexible decomposition and/or combination of functional entities when building the physical entities. For example: ASN may be decomposed into base station transceivers (BST), base station controllers (BSC), and an ASN-GW analogous to the GSM model of BTS, BSC, and Serving GPRS Support Node (SGSN) /2, 3 and 4/.

3 Research area and limitations

Our aim at this research work is to answer some questions which can be found on many internet forums. With a WiMax simulation model and the OPNET simulation tool we will demonstrate how distance affects WiMax applications such is VoIP etc., how intermediate barriers affect service availability, if direct radio visibility is necessary or not, etc. In order to obtain relevant results and to prevent other traffic from affecting our simulation results we have used use the same traffic generators (same traffic amount) and the same number of clients in all simulation scenarios. We were thus able to compare delays at short and large distances as well as see what happens with end-to-end delay in case when an obstacle is placed between the transmitter and the receiver.

4 OPNET Modeler simulation tool

OPNET Modeler is one of the most useful simulation tools in the area of communication industry. The tool enables designing and studying telecommunication infrastructures, individual devices, protocols, applications, etc. It is based on object-oriented modeling. Individual modules included in specific libraries are representative of real building blocks used in real communication infrastructure. The created simulation models thus present a good approach compared to equivalent real networks. Support for modeling of all types of communication networks, included in advanced technologies such as Wi-Fi, UMTS, GSM, Fast Ethernet, etc. is also available. The tool allows modeling of PSTN, ISDN, xDSL, as well as optical networks. The user interface is based on a series of hierarchical graphic interfaces, which enable editing at every stage, as well as illustrate the structure of protocols, devices and networks. The tool also supports animations, which can provide a better understanding of the simulation results and events appearing in the simulated networks. The user can observe how individual packets travel during the execution of the simulation (slow motion support). OPNET Modeler offers a rich existing model library of standard equipment and protocols, including the possibility of modeling new or upgrading existing ones, which can be done by using code level in C/C++ programming languages /9/.

5 The used radio-signal propagation model (TIREM4)

TIREM is an abbreviation for the English phrase Terrain Integrated Rough Earth Model, which means an integrated land undulating terrain. TIREM includes two models, TIREM4 and TIREM3 which are often used when we model wireless links. TIREM3 has been developed by the Department of Defense (United States of America). In recent years it has been replaced with a more detailed model of radio-wave propagation: TIREM4, which offers a faster path-loss calculation, especially in cases when we have to deal with sophisticated 3D terrain landscape cartography. TIREM has the ability to anticipate loss-distribution of radio waves (RF) for the frequency bands between 1MHz and 40 GHz for land and open sea areas. The signal propagation model allows us to change the soil conductivity (ground conductivity) parameters, relative permeability, humidity, wave reflection and dispersion surface refractivity as well

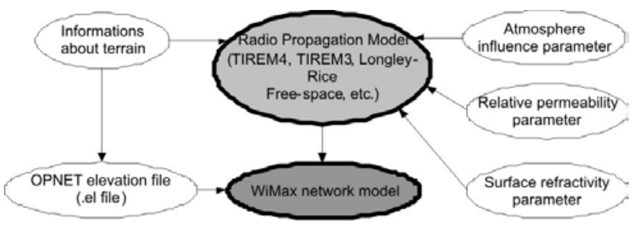

Fig. 2. The correlation between a radio propagation model and its parameters and a WiMax network model.

as resolution defined by the distance between isohypses on the elevation map /7, 8, 9/.

6 Simulated network presentation, simulation scenarios and simulation results

We have conducted the tests in the experimental part with the OPNET Modeler simulation tool where we have modeled the WiMax network structure serving as an example for the testing scenarios which will be described later. This is the simplest example with only one WiMax base station and two WiMax clients. We were focused on observing how the distance affects the VoIP application (a representative of time-sensitive applications) provided by the WiMax network, how intermediate barriers influence the WiMax RF-signal reception etc. Other WiMax users were not included, because we did not want to observe their impact on voice delay. Figure 3 presents a fictitious network. Our main goal in these simulations was to show the reader how the distance-parameter and intermediate barriers affect network's performance regarding the VoIP end-to-end delay, received power level, SNR etc.

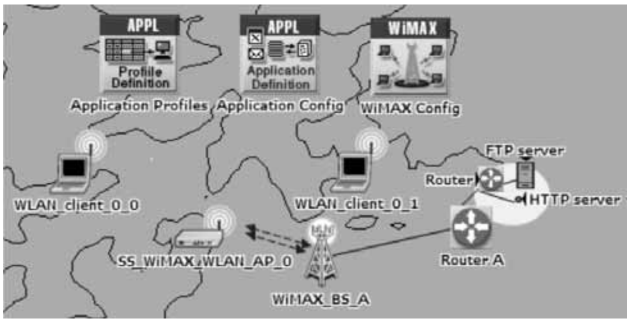

Fig. 3. Simulated WiMax network structure.

The whole network is constructed of two main parts:

- a wired network,
- the WiMax network.

The wired network structure consists of servers, such as Web Server, FTP server, etc, which are connected through a 100BaseT connection through an 8-port router. From this router, the 100BaseT connection is connected to Router A, which is intended to have WiMax base stations (in our case only one) connected to it. A WiMax base station with an Omni transmitting/receiving antenna produces a WiMax RF signal in the 3.5GHz frequency band /1/, which is then redistributed through a WiMax wireless access point.

Two WiMax clients establish a VoIP session through the WiMax wireless access point. Such VoIP application is defined by the 'Applications' node shown on the top-left side in Figure 3. With the 'Profiles' node (beside the 'Applications' node) client profiles are defined, i.e. what should the User Equipment (UE) do, or in other words, which application is such UE capable of using (in our case VoIP).

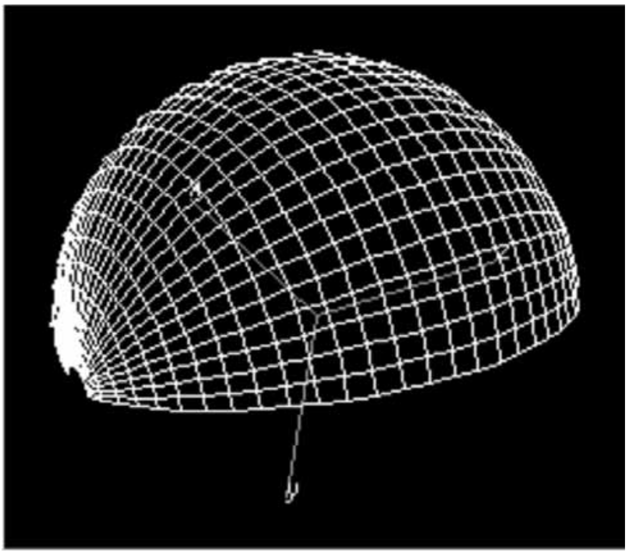

Fig. 4. WiMax Omni antenna radiation pattern.

Scenario 1: A short distance without barriers

In this scenario, the end-user equipment was placed near the WiMax access point. The distance between them was 820m and there was free space between them, so no obstacle (hill, building etc.) was presented. The transmitter power was in this case set to 0.05W. Figure 5 presents the described scenario.

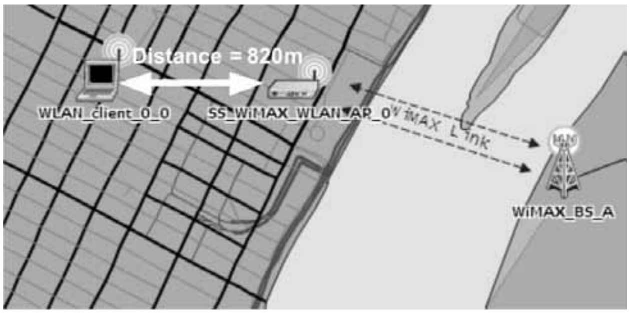

Fig. 5. A short distance (820m) between the WiMax access point and the WiMax client.

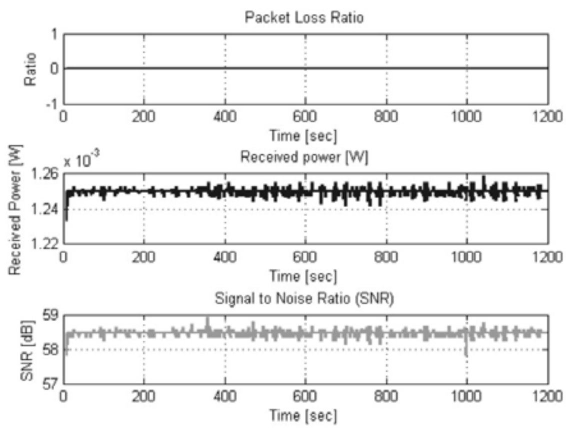

Fig. 6. Packet Loss ratio, received power and SNR for a WiMax client at a short distance (820m) and with a transmitting power 0.05W.

During the simulation process we have obtained the results presented in Figure 6. Data transfer was clear, so no data was lost. The received power was within acceptable borders and was fairly constant during the whole VoIP transfer process. The same can be said for signal-to-noise ratio (SNR).

The VoIP delay and the delay in the wireless network were minimal and also within the expected borders /10/. This is shown in the figure below (Figure 7).

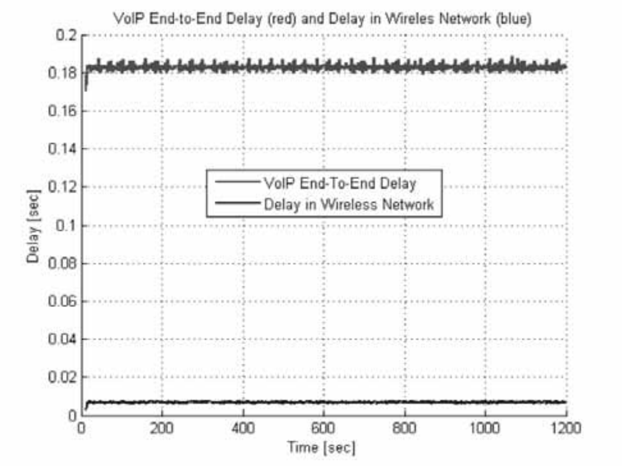

Fig. 7. VoIP end-to-end delay (red) and the delay in the WiMax wireless network for a WiMax client at a short distance (820m) and with a transmitting power 0.05W.

This scenario shows that at a short distance without intermediate barriers between the WiMax client and the base station there are no problems in the communication process.

Scenario 2: Large distance without barriers

In the second scenario we have moved the client node to a different position, which was 9.7km away from the WiMax access point.

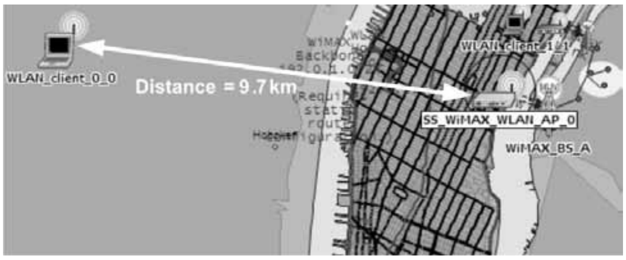

Fig. 8. A long distance (9.7km) between the WiMax access point and the WiMax client.

Like above there were no intermediate barriers between the client and the base station, and other settings and the traffic amount were also the same as in the first simulation scenario. This simulation scenario is presented in Figure 8.

With this simulation scenario we have obtained similar results as in the first scenario. They are presented in Figure 9. Also in this case data transfer was clear, and no data was lost. The received power was within acceptable limits and was also in this case fairly constant (1.6mW) during the whole VoIP transfer process. The same applies for signal-to-noise ratio (SNR). From this we can conclude that distance has a minimal influence on the power of the received signal. The difference between the first and the second scenario was in the base station transmitting power, which was in first scenario set to 0.05W, and in t

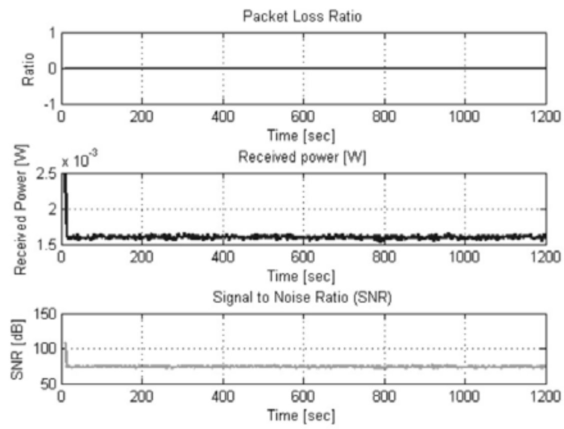

Fig. 9. Packet Loss ratio, received power and SNR for a WiMax client at a long distance (9.7km) with a transmitting power 1W.

However a completely different story appears when we observe the VoIP delay and the delay in the wireless network. Those delays have rapidly increased, but this was the consequence of a larger SNR factor in the first few seconds of the simulation. Such a case is presented in Figure 10. When we repeat the same scenario and ensure a constant SNR and received power, we obtain pretty similar results

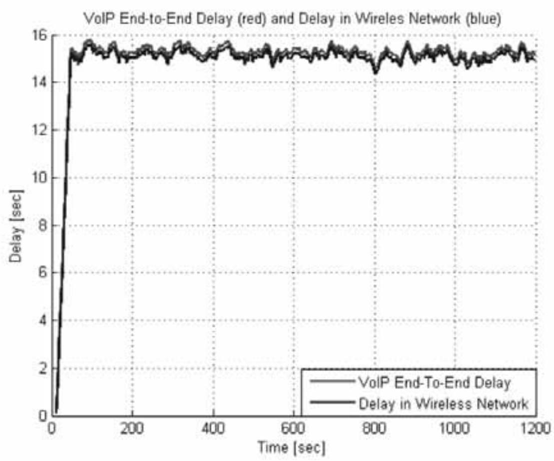

Fig. 10. VoIP end-to-end delay (red) and the delay in the WiMax wireless network for the WiMax client at a long distance (9.7km) with a transmitting power 1W (the receiver operates in the saturation area).

as those presented in Figure 7 (first scenario). Figures 9 and 10 show only a worst-case example, which happens when the SNR is increased and when the receiver operates in the saturation area. Under normal circumstances the differences in the delay between the first and the second scenario are minor and negligible. According to the obtained results we can confirm that the delay only minimally depends on the distance, but we have to be very careful with the transmitting power and the receiver density so that it does not pass into the saturated area.

A higher delay in Figure 10 is a consequence of the receiver saturation where the SNR also exceeds all allowed limits.

Scenario 3: Intermediate barriers between the WiMax client and the WiMax access point

The distance between the WiMax client and the WiMax access point was 5.26km in this simulation case. Between both units there were many intermediate barriers (hills) as shown in Figure 11 where the cross-section of the terrain between both units is presented. Traffic generator parameters were the same in this scenario as in both previous cases, so the traffic amount was equal in all three scenarios. Because of the nature of the frequencies that the WiMax uses, intermediate barriers should not have a noticeable influence on the service quality, which our last scenario has confirmed. In this scenario we have used the DTED cartography which simulates the geographical properties around the Pohorje area. Because of the DTED cartography and the used TIREM4 RF signal-propagation model, the terrain influence on signal dispersion is included.

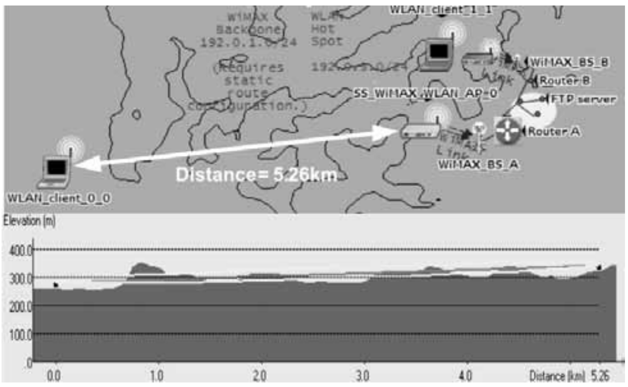

Fig. 11. Intermediate barriers between the WiMax access point and the WiMax client.

As shown in Figure 12, the abovementioned thesis on the WiMax frequency operation band is confirmed; meaning that intermediate barriers do not have a significant influence on the quality of the provided application.

Like in previous scenarios data transfer was clear, and no data was lost. The received power was within acceptable limits and was also in this case fairly constant. Compared to previous scenarios the received power was only slightly lower than in cases where there were no obstacles between the client and the base station.

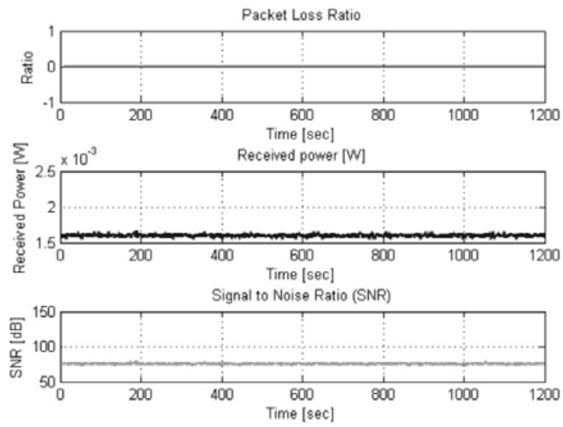

Fig. 12. Packet Loss ratio, received power and SNR for a WiMax client at a 5.26km distance with intermediate obstacles (hills). Transmitting power = 1W.

7 Conclusion

According to the obtained simulation results we can confirm that the WiMax network is very robust in terms of its frequency band operation. Intermediate obstacles, such as woods and hills, do not affect the quality of the provided service significantly. Distance also does not present a problem in the communication process, when it is within the specified borders. But as we have already mentioned, properly set transmitting power and configuration are very important for an undisturbed service delivery to the end-user. To conclude, we can say, that intermediate barriers and large distances which are within specified areas have only a small influence on the provided WiMax service.

Literatura

/1/ Frank Ohrtman, WiMax Handbook – Building 802.16 Wireless Networks, McGraw-Hill, June 2004

/2/ Kalai Kalaichelvan, Lawrence Harte, WiMax Explained (System Fundamentals), 2007

/3/ Jeffrey G. Andrews, Fundamentals of WiMax: Understanding Broadband Wireless Networking, Department of Electrical and Computer Engineering, The University of Texas at Austin, February 2007

/4/ G.S.V. Radha, K. Rao, G. Radhamani, WiMax: A Wireless Technology Revolution, Auerbach Publications, October 2007

/5/ Mohorko Jože, Matjaž Fras, Žarko Čučej, Modeling of IRIS Replication Mechanism in Tactical Communication Network with OPNET

/6/ J. Mohorko, M. Fras, Ž. Čučej, Modeling methods in OPNET simulations of Tactical Command and Control Information Systems

/7/ M. Fras, J. Mohorko, Ž. Čučej, A new approach to the modeling of network traffic in simulations, Informacije MIDEM 2008 (Junij)

/8/ M. Fras, J. Mohorko, Simulacija komunikacijskih sistemov v realnem času z realno komunikacijsko opremo v simulacijski zanki, Informacije MIDEM 2008 (Junij)

/9/ Opnet Documentation. http://www.opnet.com/

/10/ Jeffrey E. Wieselthier, Craig M. Barnhart and Anthony Ephremides, Data-delay evaluation in integrated wireless networks based on local product-form solutions for voice occupancy, Volume 2, Number 4, 297-314, DOI: 10.1007/BF01262049, March 29, 2005

Authors' presentation

Saša Klampfer graduated in 2007 from the Faculty of Electrical Engineering and Computer Science in Maribor, with a thesis title: "Networks simulation in OPNET Modeler". At the same faculty he defended his Master thesis: "Expert system for automatic analysis of tactical radio network properties" in 2009. His research work is focused on simulations and planning of telecommunication (UMTS) and computer networks (Fast Ethernet, Wi-Fi), and the influence of individual applications on individual networks in terms of delays, utilization of transfer channels, packet losses, etc.

Jože Mohorko received his B.Sc., M.Sc., and Ph.D. degrees in electrical engineering from the University of Maribor, Slovenia, in 1990, 1994 and 2002, respectively. He is a docent and researcher at the Faculty of Electrical Engineering and Computer Science in Maribor, University of Maribor. His research interests include image processing, modeling, simulating and evaluating telecommunication infrastructures.

Žarko Čučej is a full professor for automatic control and robotics, and telecommunications at the Faculty of Electrical Engineering and Computer Science of the University of Maribor. His recent research interests include signal processing and industrial data networks. He is a member of the IEEE.

Amor Chowdhury graduated in 1994 from the Faculty of Electrical Engineering and Computer Science in Maribor, with a thesis title: "Design of discrete regulation systems on a personal computer" In 1997 he defended his Master thesis: "The theory of robust synthesis" at the same Faculty. Four years later (2001) he finished his postgraduate studies with a doctoral dissertation: "Robust synthesis of control systems with consideration of performance criteria". He is an excellent innovator and researcher, which is proved by the number of granted patents and patent applications which are currently in the registration procedure, such as for example patent 11643 Terminal Device for Monitoring, Maintenance and Service Data.

Saša Klampfer[1], Jože Mohorko[2],
Žarko Čučej[2], Amor Chowdhury[1]

[1]Margento R&D d.o.o., Gosposvetska cesta 84,
2000 Maribor, Slovenia
[2]Univerza v Mariboru, Fakulteta za elektrotehniko,
računalništvo in informatiko, Smetanova 17,
2000 Maribor, Slovenia
E-pošta: sasa.klampfer@margento.com

Prispelo: 31.01.2011 *Sprejeto: 23.08.2011*