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Audio Streaming Over WiMAX Technology

FINAL REPORT

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1 Abstract

The aim of this project is to simulate bandwidth intensive, delay sensitive audio traffic representation of audio streaming by using WiMAX, also known as WirelessMAN and more formally IEEE 802.16. WiMAX is a set of wireless standards designed to provide high-speed Internet access to a wide range of devices such as laptops, cell phones, cameras and music players used by clients over the 'last mile'. It has become a lone frontrunner in broadband access compared to other technologies such as Asymmetric Digital Subscriber Lines (ADSL) and T1 lines in terms of cost and complexity. We hope to examine specific results such as throughput, traffic received, traffic dropped, queue size and Signal-to-Noise Ratio (SNR) of a subscriber station over a WiMAX access network.
As Opnet is an industry adopted commercial-based network modeling tool with support for WiMAX, we will use Opnet in this project for simulation purposes.

2 Introduction

2.1 WiMAX overview

Worldwide Inter-operability for Microwave Access, largely known as WiMAX is a telecommunication technology designed to provide effective transmission of data using transmission modes "from point-multipoint links to portable and fully mobile Internet access" [4]. The technology is so advanced that it can provide up to 72 Mbps symmetric broadband speed without cables [4]. The traditional cable-based access networks can deliver content only to subscribers at fixed points. This technology appears to be outdated for the modern world where an alarming rate of people use cell phones and other portable electronic devices such as laptops to do their daily work at mobile locations. Therefore, there is an increasing demand for a new technology that can deliver information to mobile users [6]. WiMAX is intended to surpass the current, expensive network transmission technologies such as ADSL and T1 line and provide fast and cheap broadband access especially to rural areas lacking the necessary infrastructure such as optical fiber and copper wires. WiMAX operates in the frequency range of 10GHz - 66GHz as it has less interference and more bandwidth. A lower range of frequency band was later introduced which operates between 2GHz and 11GHz [1]. There are two main types of WiMAX services: mobile and fixed. Mobile WiMAX enables users access Internet while traveling whereas fixed WiMAX stations provide wireless Internet access to clients within a fixed radius. Moreover, WiMAX is capable of delivering high speed wireless services up to a range of approximately 50km which is far longer than that of DSL, cable modem, etc. which has a span of approximately 5.5km [2].

WiMAX is an evolving set of the commercialization of IEEE 802.16 standard which was initiated at the National Institute of Standards and Technologies in 1998. In June 2004, it was transferred to the IEEE for the purpose of forming a working group 802.16. The WiMAX forum, which was established in 2001comprises of a group of industry leaders such as Intel, AT&T, Samsung, Motorola, Cisco etc who are entitled to support as well as promote the technology by certifying products that conform to the WiMAX standards [1].

In order to provide effective transmission of data with minimum delay, it is necessary for the WiMAX base station and the subscribers to obtain a clear line-of-sight. Large objects such as buildings and trees can interfere with the signals which would result in packet loss and delay. In order to avoid this unfortunate scenario WiMAX uses mesh mode topology that allows subscriber stations to communicate directly with each other while communicating with the base station. This way, if the line-of-sight between one client and the base station is interfered, the base station can route the information to that client via another client that has a clear line-of-sight. Furthermore, WiMAX uses a scheduling algorithm for exchange of data meaning the subscriber stations transmit data in their scheduled slots which helps minimize interference within networks [1].

2.1.1 WiMAX physical layer

The IEEE 802.16 standard defines one air interface for the bands in the 10GHz - 66GHz range with a single carrier modulation called WirelessMAN-SC (Wireless Metropolitan Area Network - Single Carrier). The bands in the 2GHz - 11GHz range experience higher interference and are therefore more complex to implement. Hence, three air interfaces are defined for the lower frequency bands:

-WirelessMAN-SCa (uses Single Carrier modulation)

-WirelessMAN-OFDM (uses Orthogonal Frequency Division Multiplexing)

-WirelessMAN-OFDMA (uses Orthogonal Frequency Division Multiple Access) [1].

Additionally, the physical layer supports varying frame sizes and scalable bandwidth for multimedia traffic which is ideal for applications such as Internet Protocol TV (IPTV), Voice over IP (VoIP), etc [6].

2.1.2 WiMAX Medium Access Control (MAC) layer

The WiMAX base station in advance schedules transmission through a flexible frame structure. As a result, the client stations only need to content to when they access the base station for the first time unlike Wi-Fi which has to content every time before transmitting which in turn reduces efficiency.

The MAC layer of 802.16 standards support different transport technologies such as Internet Protocol (IP version 4 and 6), Ethernet, and Asynchronous Transfer Mode (ATM). This allows service providers use WiMAX regardless of the transport technology they use. The MAC layer also supports Quality of Service (QoS) for base and subscriber stations "through adaptive allocation of uplink and downlink traffic" [1].

The main aim of WiMAX is to replace the wired access networks at the 'last mile' and provide its customers with an easy and efficient broadband experience. In addition, WiMAX is often used in disaster recovery scenes or as a backup where existing network carrier cables have broken down [1]. For example, WiMAX was used to communicate with the victims and support missions in New Orleans during hurricane Katrina and in Indonesia after the recent tsunami.

Another intriguing function of WiMAX is providing secure delivery of content to mobile users at vehicular speeds; i.e., a client can access Internet while traveling [6]. This feature only comes with mobile WiMAX. In this project, we would focus our attention on a single fixed WiMAX station proving broadband access to several fixed clients at different distances.

2.2 Audio streaming overview

Audio content are the information provided by various audio applications such as newscasts, sports programs, Voice over IP (VOIP) and music files that can be stored and heard later on or live. Since transmitting audio content takes a lot of bits, they are compressed using 'lossy' or 'lossless' compression algorithms. The audio files streamed at the server can be compressed and sent to subscribers which can be decompressed and listened to.

Due to compression and decompression methods, data loss up to a certain extent can go unnoticed to the human ear. However, delays or variations in the playback can greatly decrease the quality of the audio file which leaves the client unhappy. Therefore, audio streaming can be considered as a loss-tolerant, delay-sensitive mechanism which has to be carefully balanced to produce quality audio at high SNR.

Lossless audio compression preserves the exact copy of the audio file which achieves high SNR, but at the same time uses many bytes of memory. On the other hand, lossy audio compression such as MP3 can compress original audio files anywhere between 5%-20% depending on the quality the client prefers as the higher the compression rate the lower the audio quality [8].

Audio streaming experiences many types of delays while being transmitted from the sender to the receiver. End-to-end delays, propagation delays, processing and queuing delays are the most common types of delays present in audio streaming. In this project, we hope to gather statistics of audio streaming using the Opnet modeler.

3 Opnet Simulation

As an initial step, two fixed subnets were included called client and server. The client is located in Montana and the server is in Minnesota, approximately 788 miles away from the client. The two subnets are connected using a Point-to-Point Protocol (PPP) Digital Signal 3 (DS3) link and a 100 BaseT link via a Cisco 7200 router. The global view of the network is shown in Figure 1 below:

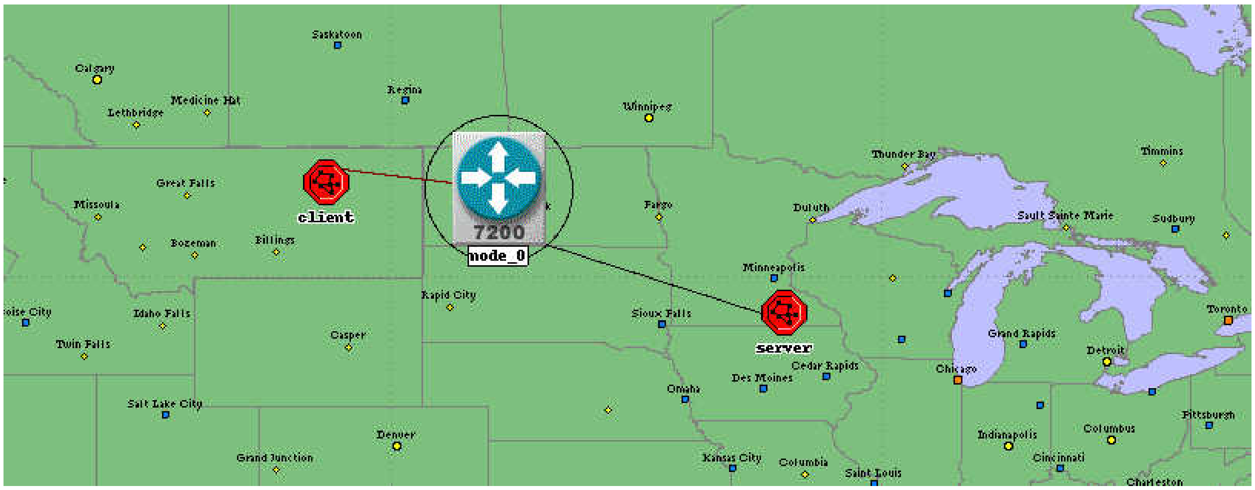

Figure 1: The overall network

The server subnet contains an audio server that support Pulse Code Modulation (PCM) voice conferencing, a switch and a router all connected with 100 BaseT links. The purpose of the server subnet is to generate audio traffic that will be sent over to the client. Figure 2 below shows the body of the server subnet:

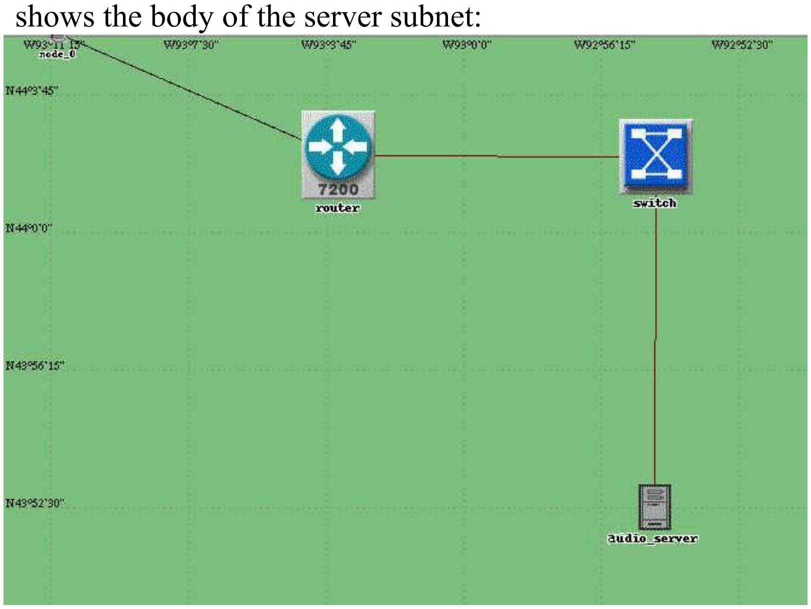

Figure 2: The server subnet

The client subnet contains a WiMAX base station and two fixed WiMAX subscriber stations called home1 and home2. Home1 and home2 are located at different distances away from the base station in which home2 is closer to the base station than home1. The purpose of the variation of distance is to analyze signal quality measures of WiMAX subscribers as the network is easily affected by interference and distance. Since WiMAX uses microwaves as the interface communication, the base station and the subscribers are not connected with any physical links.

In order to configure the WiMAX base station, Will Hrudey's Opnet model was used as a reference and the attributes were edited accordingly. In order for the subscriber stations to support and receive audio data, a voice application was added in the Application definition tool and a voice profile in the Profile definition tool. The overall client subnet model is shown in Figure 3 below:

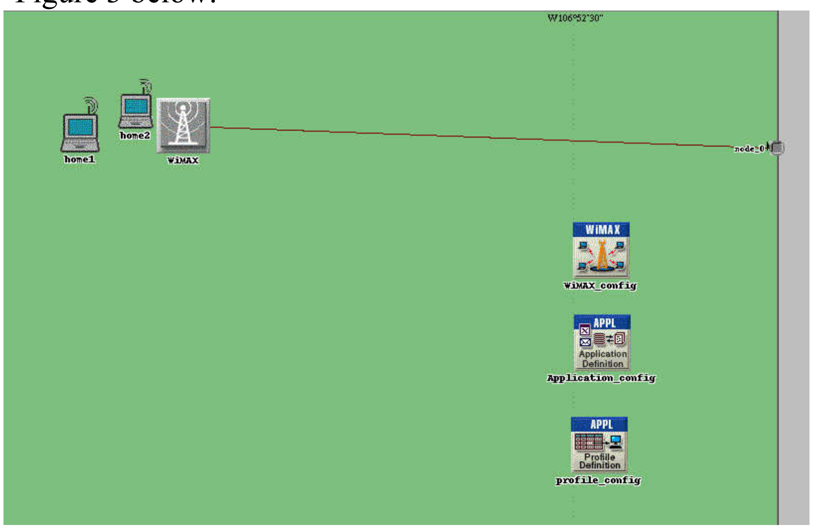

Figure 3: The client subnet

Moreover, OFDM was used as the air interface of the WiMAX base station which supports a gain of 15dB and uses a maximum power of 3.8W. The subscriber stations support a gain of 13dB and use a maximum power of 2W.

Node and link statistics were gathered to support the purpose of this project. Under node statistics, we gathered queue size, downlink packets dropped, downlink SNR and traffic received and under link statistics we gathered point-to-point throughput. The simulation was run for a ten minute simulation period which took approximately five minutes to finish.

Figure 4 (Left) below shows the average voice traffic in bytes/second received at home1 subscriber and Figure 4 (Right) shows the same for home2 subscriber. The two graphs show that both subscribers are receiving traffic directed from the WiMAX base station.

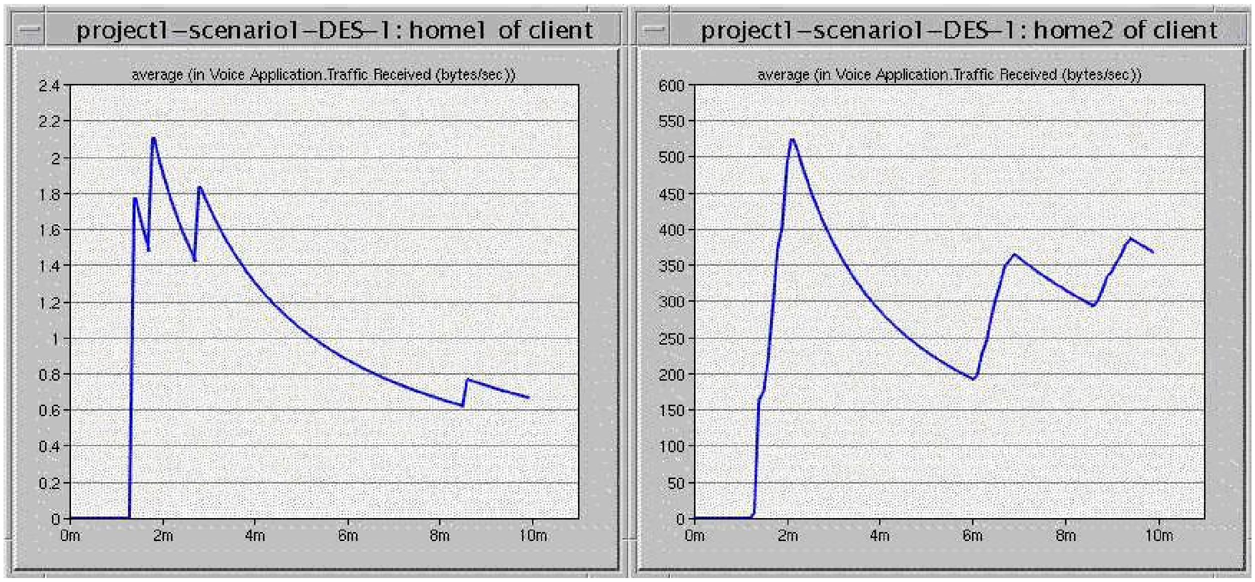

Figure 4 (Left): Average voice traffic received at home1
Figure 4 (Right): Average voice traffic received at home2

From the two graphs in Figure 4 we can see that the traffic received at each subscriber station is different in time and value. Figure 5 below shows a clear picture on how much traffic each subscriber station receives:

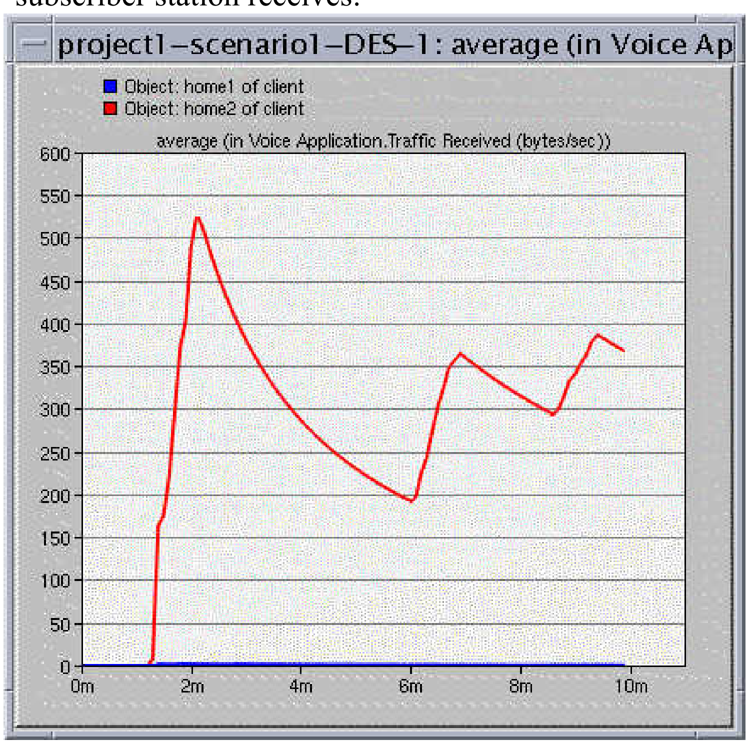

Figure 5: Average voice traffic received at home1 and home2

From Figure 5 we can clearly see that home2 which is closer to the WiMAX base station receives a higher volume of traffic than home1 which is farther apart. This is acceptable since the signal degrades as the transmission distance increases and hence a large amount of packet loss and delay is present. Moreover, one can observe that both subscriber stations start to receive data about 1.5 minutes after the transmission. This is considered the transmission delay. We then looked at the data traffic successfully received by WiMAX MAC from the physical layer in bits/second which also includes the physical layer and MAC headers. This is shown in Figure 6 (Left and Right) below:

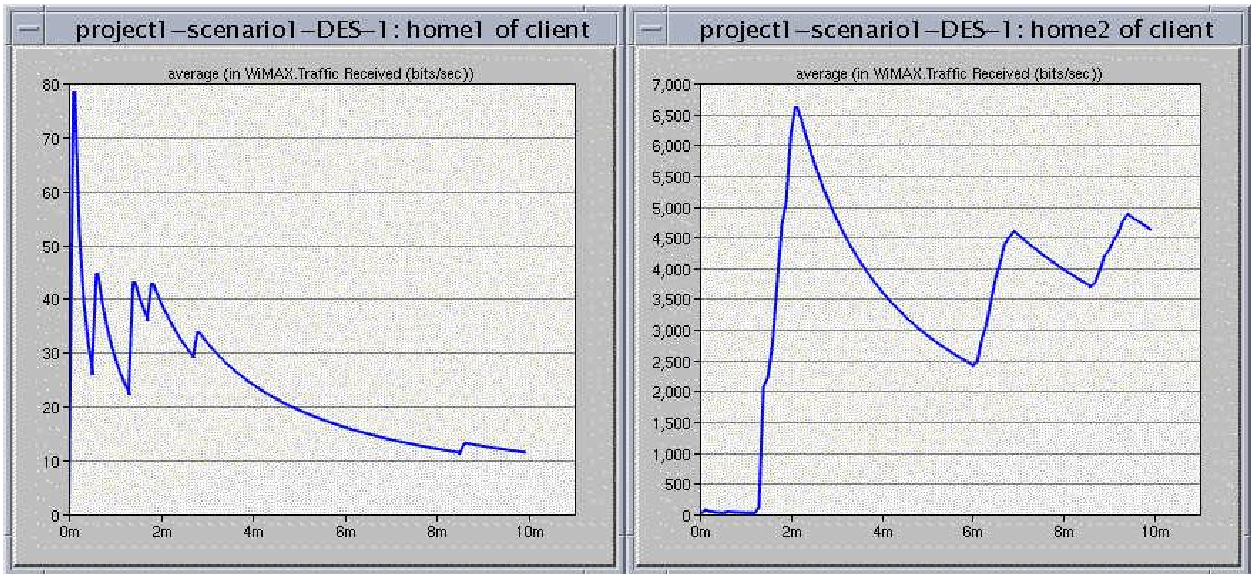

Figure 6 (Left): Average data received by WiMAX MAC of home1 from the physical layer
Figure 6 (Right): Average data received by WiMAX MAC of home2 from the physical layer

Furthermore, Figure 7 below can be used to compare the relative amount of traffic received at the two subscribers:

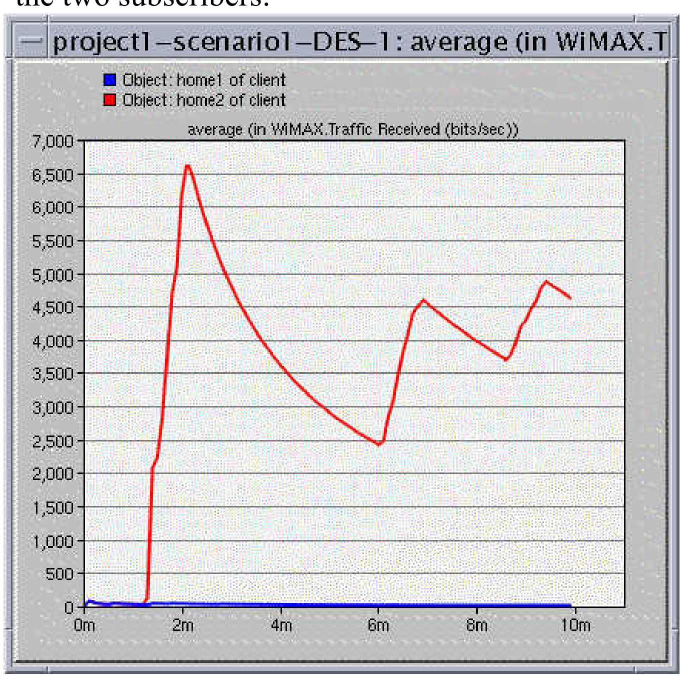

Figure 7: Average data received by WiMAX MAC from the physical layer for both subscribers

From the above figure, we again see that the data received at home2 subscriber is clearly larger than home1 which explains signal degradation due to increase in distance.

Next, the queue size which is the size of the queue that holds the data packets received from the higher layer of the WiMAX base station until they are transmitted to each subscriber station was analyzed. We expect to see a higher queue size for home1 as it is farther apart from the base station and hence it takes longer to transmit data. This increases the amount of data being queued at the base station until they are streamed to the subscribers. Figure 8 below shows the queue size of home1 and home2 subscribers, it reveals that the queue size is indeed higher for home1 than home2.

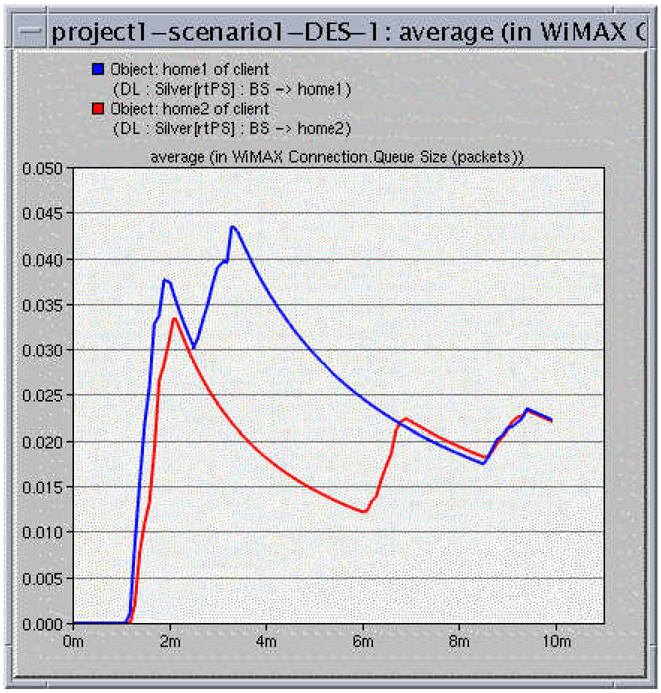

Figure 8: Queue size of traffic flowing from base station to subscribers

No network is considered perfect. Every network suffers delay and packet loss to some extent. In a WiMAX network, packets are dropped due to reasons such as physical layer impairments. Again, increase in distance between the WiMAX base station and subscriber stations can cause a large amount of packet drop. We gathered packet loss statistics while simulating our WiMAX model in Opnet and gained the graph shown in Figure 9 below. As expected, home1 experienced a higher packet loss than home2 as it is at a larger distance from the base station.

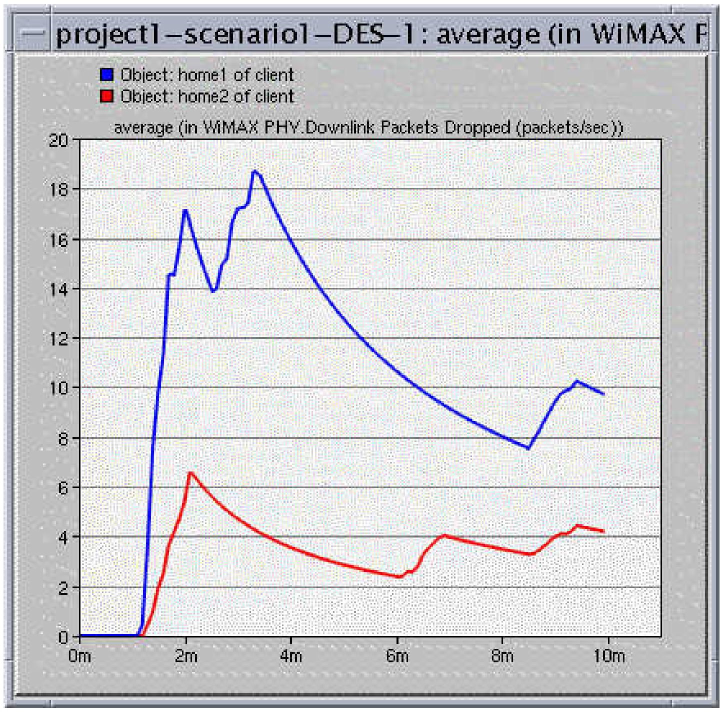

Figure 9: Subscriber station average packets dropped

As an added measure, the downlink SNR for packets transmitted through the physical layer of the WiMAX base station to the subscribers were analyzed. We expect the SNR of home2 to be higher than home1 again considering distance and the associated degradation of signal quality. The results that were obtained are shown in Figure 10 below:

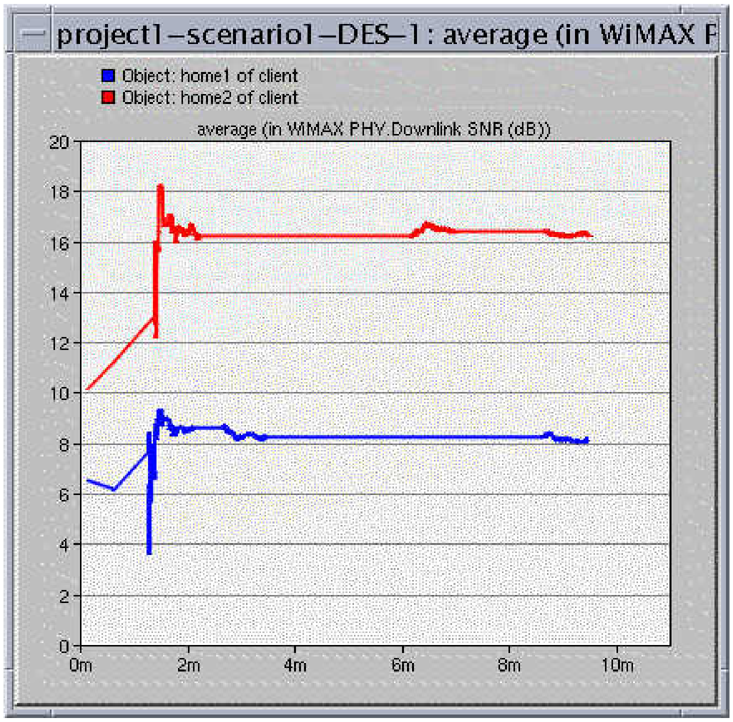

Figure 10: Downlink SNR of home1 and home2 subscribers

Figure 10 shows that at approximately 1.5 minutes, the SNR decreases significantly at both subscriber stations. This is because the subscribers start to receive data at approximately the same time and the sudden volume of data received decreases its quality. The SNR then settles to a fairly constant value as time advances. It can also be seen that the SNR of home2 subscriber is higher than that of home1 as expected.

Lastly, we were interested in analyzing the average number of packets successfully transmitted by the transmitter channel per second. Thus, the results for the link between the audio server and the switch as well as the link between the switch and the router in the server subnet were viewed and analyzed. The throughput graphs are shown in Figure 11 (Left and Right) below:

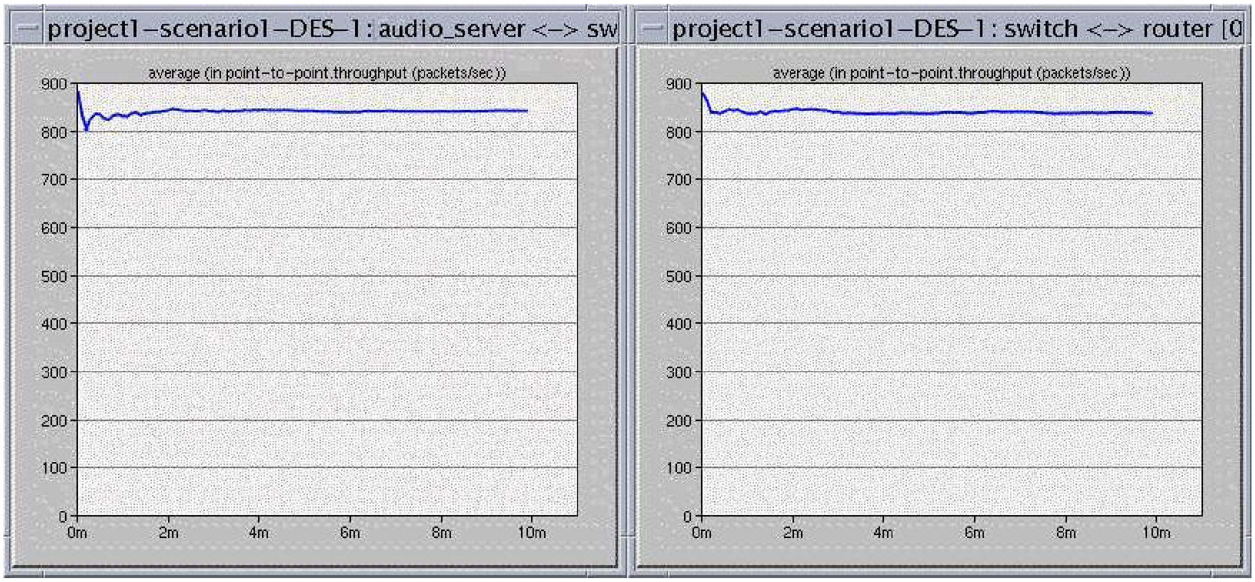

Figure 11 (Left): Point-to-point throughput from audio server to switch
Figure 11 (Right): Point-to-point throughput from switch to router

Figure 11 shows that the server subnet is transmitting data at a rate of approximately 850 packets/second.

From the statistics collected and the simulation results achieved, our Opnet model for audio streaming over WiMAX seems to give reasonable results.

4 Discussion and Conclusion

Initially, we faced some difficulties in our project such as being unable to run the simulation at first. The server was very slow and it was taking a long time to run the simulation. Also, our attempt was to simulate video streaming using WiMAX and we were unable to achieve reasonable results, this was due to the fact that the video file we were streaming was not big enough to achieve proper results. Therefore, we simulated audio streaming rather then video in Opnet and we were able to achieve desired results.

WiMAX technology has a very broad future as Wi-Fi and WiMAX are the two technologies that are currently on demand and this project could be broadened in many ways such as simulate audio as well as video streaming over Wi-Fi and WiMAX networks and compare the results. Also the number of WiMAX base stations could be increased to widen the region of coverage. Furthermore, mobile subscribers could be added to the existing project in order to have a network of fixed and mobile WiMAX.

In a nutshell, the goal of this project is to simulate the audio traffic representation of audio streaming using WiMAX technology. The bandwidth and range of WiMAX make it suitable for many potential applications such as Connecting Wi-Fi hot spots to the Internet, providing data and telecommunications services, providing a source of Internet connectivity as part of a business continuity plan. That is, if a business has a fixed and a wireless Internet connection, especially from unrelated providers, they are unlikely to be affected by the same service outage, providing portable connectivity. Companies are closely examining WiMAX for 'last mile' connectivity. The resulting competition may bring lower pricing for both home and business customers or bring broadband access to places where it has been economically unavailable.

5 References

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