Simon Fraser University

ENSC 427 Communication Networks
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Final Project
Voice over Internet Protocol (VoIP) over Worldwide Interoperability for Microwave Access (WiMAX)

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List of Acronyms

VoIP	Voice over Internet Protocol
IP	Internet Protocol
WiMAX	Worldwide Interoperability for Microwave Access
QoS	Quality of Service
PSTN	Public Switched Telephone Network
UMTS	Universal Mobile Telecommunications System
CDMA	Code Division Multiple Access
Wi-Fi	Wireless Fidelity
IEEE	Institute of Electrical and Electronics Engineers
QPSK	Quadrature Phase-Shift Keying
MOS	Mean Opinion Score

Abstract

Voice over Internet Protocol (VoIP) is a communication technology for voice and multimedia transmission over Internet Protocol (IP) while Worldwide Interoperability for Microwave Access (WiMAX) is a wireless telecommunications protocol. With the increasing popularity of information transfer, VoIP will be widely in use. As customers' desire nowadays for mobility and flexibility, long distance data transfer with the use of smart phones with WiMAX are highly desirable. Analysis of Quality of Service (QoS) on long distance data transfer between two locations with VoIP over WiMAX will be performed. Performance on selected parameters will be discussed using the network simulator, OPNET Modeler 14.0.

1.0 Introduction

1.1 VoIP

Voice over Internet Protocol (VoIP) is an internet technology for the transmission of voice and multimedia over the Internet Protocol (IP) based network, especially the Internet. It has been widely in use as a communication protocol to replace traditional telephone technology, Public Switched Telephone Network (PSTN).

Over the past few years, VoIP has greatly increased its popularity due to substantial cost savings over traditional long distance telephone calls. Telephone calls can be made over computer network, such as the Internet, with VoIP-to-VoIP at no additional cost other than the monthly fee the user is paying for Internet access. VoIP converts analog voice signal into digital data packets from an end-user, and the converted data packets will be transmitted to another end-user via a computer network. The digital data packets will undergo conversion again and will end up being the original analog voice signal. This technology provides service for real-time transmission of conversations with cost-effectiveness and flexibility. VoIP-to-PSTN services are also available at a fixed monthly payment; however, the performance of this type of services is beyond the scope of this project and will not be discussed or analyzed.

There are also some downsides for the VoIP technology. It has an average drop calls at 3% and it could go up to 5% while regular phone services has an average drop calls at less than 0.1%. In case of power outage or lost access to the Internet, VoIP calls would not be able to make. Furthermore, there are no available VoIP-to-VoIP calls for emergency services, such as 911.

1.2 WiMAX

Worldwide Interoperability for Microwave Access (WiMAX) is a telecommunications protocol which provides wireless Internet access for fixed and mobile nodes, and it is known as the IEEE 802.16 wireless-networks standard. It has been widely deployed in many countries due to its wide coverage range and its high data transfer rate.

WiMAX is often compared with Wi-Fi and existing 3G technologies, such as UMTS and CDMA2000. With Wi-Fi’s advantage in speed and 3G’s advantage in mobility, WiMAX sits between the two in data transfer rate and coverage range. It is currently the IEEE 802.16e standard which provides up to 75 Mbit/s in data transfer rate with support for mobility of up to 50 km in coverage rage [10]. In the underdeveloped IEEE 802.16m standard, the data transfer rate could go up to 1 Gbit/s for fixed users and 100 Mbit/s for mobile users. With such specifications, WiMAX is definitely a competitor to existing 3G technologies, and it is also aiming to fulfill the requirements for the next generation mobile telecommunication standard, 4G.

Like other wireless technologies, WiMAX can provide either fast data rate or wide coverage range but not both. With a node at 50 km in maximum range away from the base station, the bit error rate would go up which results in a lower data rate. Likewise, to improve the data rate to its maximum of 75 Mbit/s, the range away from the base station would go down which means the distance available is reduced. There are variety of modulation and coding schemes available which are supported by WiMAX. A lower modulation scheme, such as QPSK, will be deployed for long range transmission since it provides better performance under noisy conditions. And a higher modulation scheme, such as 64-QAM, will be deployed for short range transmission since it provides far better transfer rates but suffers from high bit error rate under noisy conditions [8].

1.3 Overview

In the past years, VoIP was mainly in use over the Internet by wireless connection such as Wi-Fi. Therefore, VoIP users were used to stay at a fixed location to enjoy the service provided by VoIP; however, customers' desire for mobility and flexibility has greatly increased nowadays. The service provided by VoIP without having to stay at a fixed location for Internet access via Wi-Fi is highly desirable. As a result, VoIP service over mobile wireless technologies using smart phones is in demand. However, the main disadvantage of VoIP is that it has a great potential for dropped calls and a not-as-good voice quality.

In this project, Quality of Service (QoS) on long distance data transfer between two locations with VoIP over WiMAX will be analyzed and discussed. The effects on end-to-end delay, packet loss probability, packets received or sent for calling pairs using VoIP over WiMAX will be analyzed. Beside these parameters, environmental factors, such as distances between base stations and mobile workstations and mobile users' moving speed, are also important and are concerned to affect QoS. Therefore, scenarios comparing fixed and mobile calling pairs will be also discussed.

2.0 Implementation

OPNET Modeler 14.0 was used to simulate the two-way VoIP calls made by users on WiMAX network. Four scenarios were implemented, and their simulated results were compared to analyze the effect on overall performance due to environmental factors. Each scenario has a conversation pair, one workstation being the caller and the other one being the callee. The caller starts sending data packets to the callee through the WiMAX base station at 100 seconds after the simulation has started, and the callee replies to the caller through the WiMAX base station to form a two-way communication. All nodes used in simulations can be found in built-in OPNET library - WiMAX.

2.1 General Configuration

All four scenarios shared the same set of configurations as specified below.

2.1.1 Application

To support the VoIP application, the application definition has to be configured. It was defined to be “VoIP Application” and was implemented to simulate IP Telephony. Also, the voice encoder scheme was defined to be G.729 A. G.729 is a voice compression algorithm which compresses digital audio in packets, sends the packets, and decompresses the packets at the other end. The reason of choosing G.729 A is its low usage of bandwidth, and it transmits a 10 byte packet every 10 milliseconds which means a transfer rate of 100 packets/sec [11]. The changed attributes mentioned in the application definition are explained in Figure 1 while the other attributes were remained to be default.

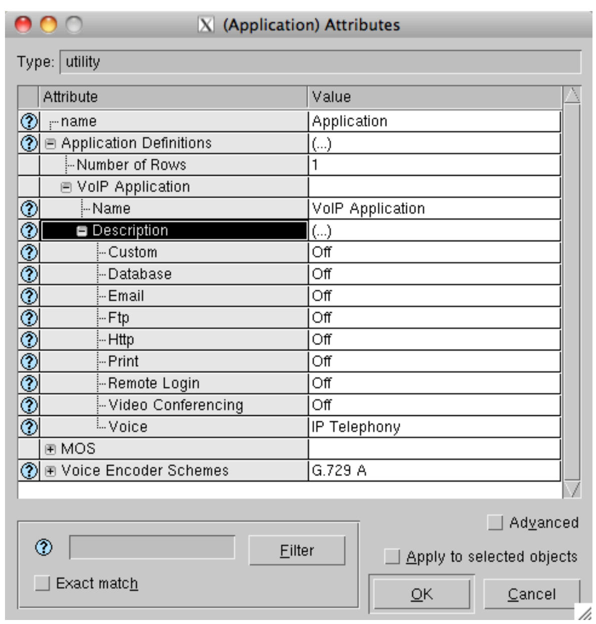

Figure 1. Application Configuration

2.1.2 Profile

Once the application configuration has been set, the profile would be ready to be configured since the profile definition was built upon the VoIP application. The profile was specified to support the VoIP application with the traffic set to be started at 100 seconds after the simulation has started, and the traffic last constantly until the end of simulation. The start time of the VoIP application was set to be no offset to the start time of the profile configured while the other attributes were remained to be their default values. The profile definition is clarified in Figure 2.

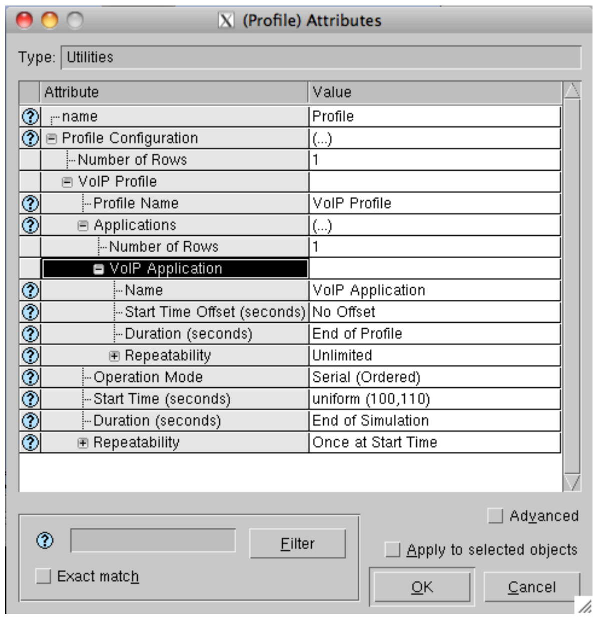

Figure 2. Profile Configuration

2.1.3 WiMAX

To operate WiMAX, some WiMAX parameters have to be specified for simulations in OPNET. There were two important attributes to be set: efficiency mode and MAC service class definitions.

The efficiency mode was set to be Efficiency Enabled as default, and it causes some confusion since there was no packet loss at all although the workstations were placed outside range of the WiMAX base station. As such, the efficiency mode has to be set as Physical Layer Enabled in order to observe any effects when varying the distances between the base station and the workstations.

The MAC service class definitions allow the priority of the packets transmitted to be set based on the class of the packets, and this permits the simulator to configure the quality of service (QoS) of WiMAX. QoS is important to the simulations as this is the main goal of this project; however, only one type of traffic was simulated in this project, so priority control would not affect the performance of the network [7]. The MAC service class definitions was defined to be Gold/Silver/Bronze, and this model was used for the entire simulations.

The other attributes were remained to their pre-defined values, and the WiMAX attributes are shown in Figure 3.

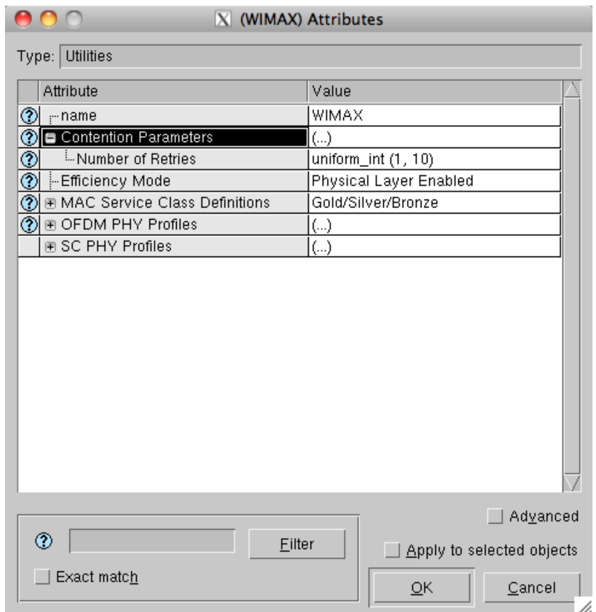

Figure 3. WiMAX Configuration

2.2 Nodes Configuration

As for the general configuration, all four scenarios had the same configuration for both of the WiMAX base station and the WiMAX subscriber stations. The configuration for each of them are listed below.

2.2.1 WiMAX Base Station

Few key attributes were required to change in the WiMAX base station for the simulations in OPNET to run. These parameters were antenna gain (dBi), maximum transmission power (W), and the service class name under the classifier definitions. For the base station, the antenna gain was set to be 15 dBi, and the maximum transmission power was set to be 10 W. Since there was only one type of traffic, the service class name could be any one of the three values: gold, silver, or bronze. In this project, silver was chosen for the service class name. All other attributes were set as default and they are demonstrated in Figure 4.

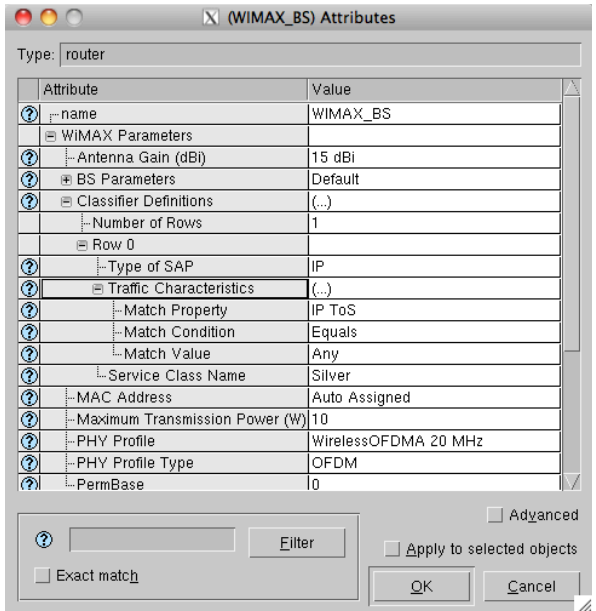

FIgure 4. WiMAX Base Station Configuration

2.2.2 WiMAX Subscriber Stations

Same attributes were modified for both of the WiMAX subscriber stations (Caller and Callee) as they were changed for the base station. The maximum transmission power was initially set to be 0.5 W; however, during the initial simulation, the throughput was not close to 100% even when the subscriber stations were relatively close to the base station (100 m). As such, the maximum transmission power was modified to be 2 W while the antenna gain was set to be 14 dBi. Silver was chosen for the service class name as it was chosen for the base station. Figure 5 and Figure 6 show the configuration for the caller and the callee respectively.

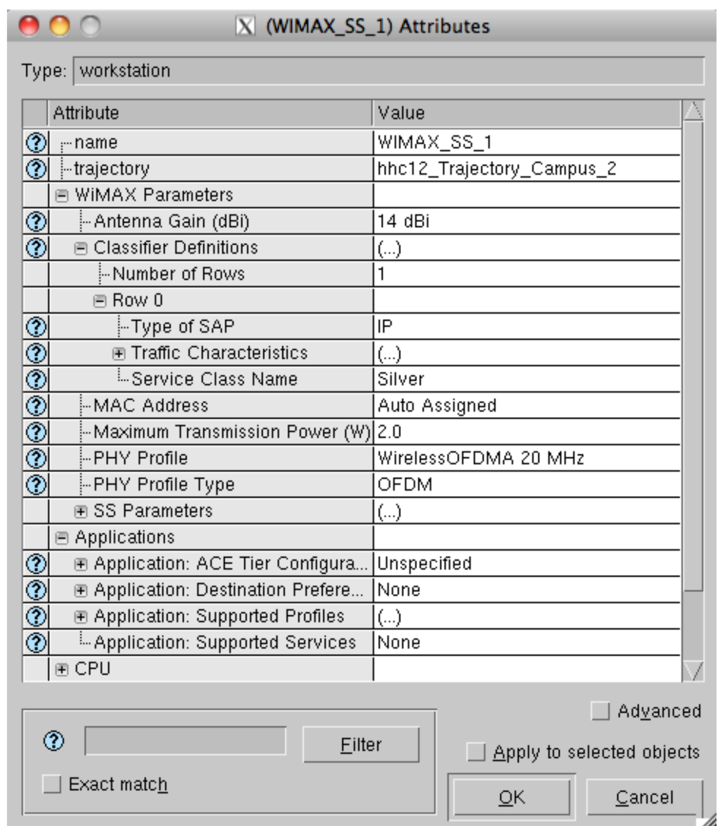

Figure 5. WiMAX Subscriber Station (Caller) Configuration

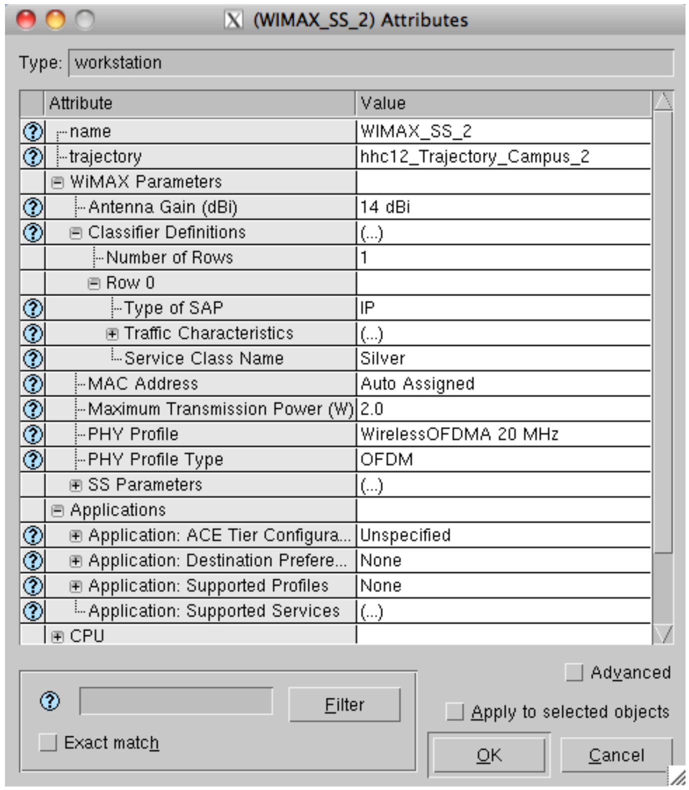

Figure 6. WiMAX Subscriber Station (Callee) Configuration

Beside the above parameters, the caller was set to support the profile for VoIP which was defined in section 2.1.2 while the callee was specified to support the service provided by the profile of VoIP. The corresponding attributes are clarified in Figure 7 and Figure 8 respectively.

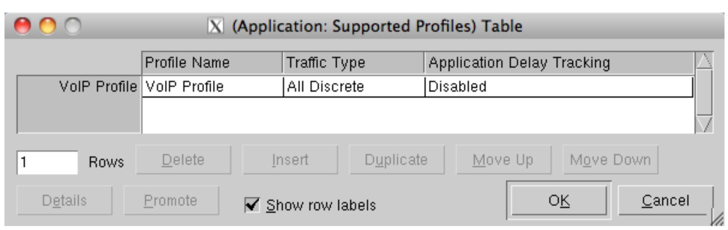

Figure 7. WiMAX Subscriber Station (Caller) Supported Profile

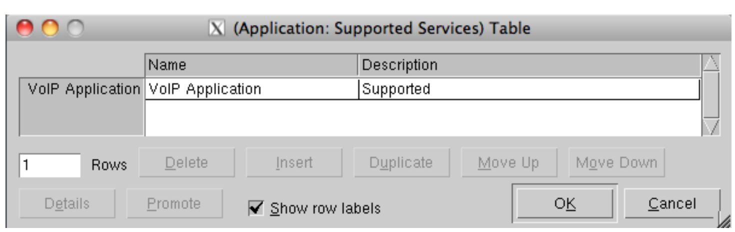

Figure 8. WiMAX Subscriber Station (Callee) Supported Service

Downlink service (from base station to subscriber) and uplink service (from subscriber to base stations) can be set with different modulation schemes in WiMAX. Since the distances between the base station and the subscriber stations were relatively long, a lower modulation scheme could be deployed for better performance under noisy conditions [10]. The modulation scheme QPSK was chosen for both downlink service and uplink service for both subscribers. Figure 9 and Figure 10 explain the attributes set for downlink service and uplink service respectively.

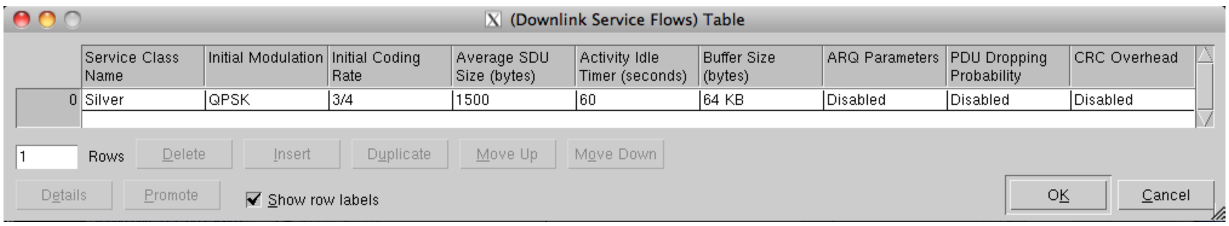

Figure 9. WiMAX Subscriber Stations Downlink Service

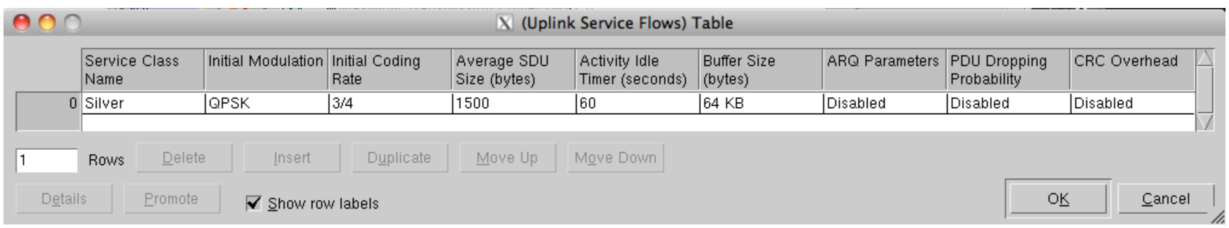

Figure 10. WiMAX Subscriber Stations Uplink Service

The attributes that have been modified for the base station and the subscriber stations are listed as below in Table 1.

Table 1. WiMAX Base Station and WiMAX Subscriber Stations Attributes

	WiMAX Base Station	WiMAX Subscriber Stations
Antenna Gain (dBi)	15 dBi	14 dBi
Maximum Transmission Power (W)	10 W	2 W
Service Class Name	Silver	Silver
Modulation Scheme (Downlink)	QPSK	QPSK
Modulation Scheme (Uplink)	QPSK	QPSK

2.3 Network Topology

The network topology consists of a WiMAX Base Station and two WiMAX Subscriber Stations, one being the caller and the other one being the callee. In each of the four scenarios, a slightly different topology was used in order to observe the effect of varying the distances and speeds of the subscriber stations on the network.

2.3.1 Scenario 1 (Fixed Nodes, Within Range)

In the first scenario, both of the subscriber stations (caller and callee) were being held fixed at 17.68 km (x = 12.5 km, y = 12.5 km) away from the base station. The nodes were held fixed throughout the simulation, and they were within the maximum range of the base station's coverage range of 50 km. The network topology for scenario 1 is illustrated in Figure 11.

2.3.2 Scenario 2 (Fixed Nodes, Outside Range)

In the second scenario, the same two subscriber stations were used as in the first scenario; however, they were brought further away from the base station. The two nodes were held fixed at 63.74 km (x = 62.5 km, y = 12.5 km) away from the base station. They were outside the maximum range of the base station's coverage range of 50 km for the entire simulation. Figure 12 demonstrates the network topology for scenario 2.

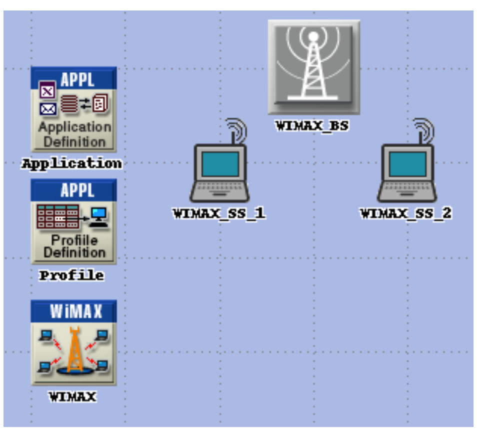

Figure 11. Scenario 1 (Fixed Nodes, Within Range)

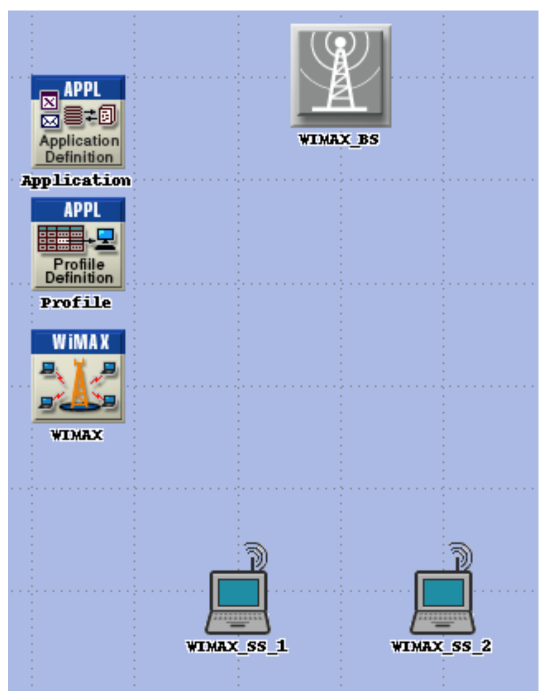

Figure 12. Scenario 2 (Fixed Nodes, Outside Range)

2.3.3 Scenario 3 (Mobile Nodes, Within Range)

The initial positions of the two subscriber stations were the same as the first scenario (17.68 km away from the base station). However, in stead of holding them fixed at a location, they were traveling away from the base station at the speed of 100 km/h. The final positions of the two subscriber stations would be 31.76 km (x = 12.5 km, y = 29.2 km) away from the base station. Although they were moving away from the base station, the two nodes were still inside the maximum coverage range of the base station. The network topology for scenario 3 is shown in Figure 13.

2.3.4 Scenario 4 (Mobile Nodes, Outside Range)

In this case, the initial positions of the two subscriber stations were the same as the second scenario (63.74 km away from the base station). Mobility of the nodes was added in to this scenario as the third scenario; however, instead of moving away from the base station, they were traveling towards the base station at the speed of 100 km/h. The final positions of the two nodes were 47.47 km (x = 12.5 km, y = 45.8 km) away from the base station. This implied that the two subscriber stations could just make it to be within the maximum coverage range of the base station at the end of the simulation. Figure 14 demonstrates the network topology for scenario 4.

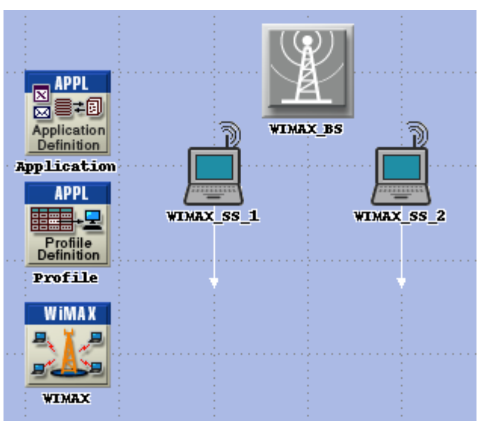

Figure 13. Scenario 3 (Mobile Nodes, Within Range)

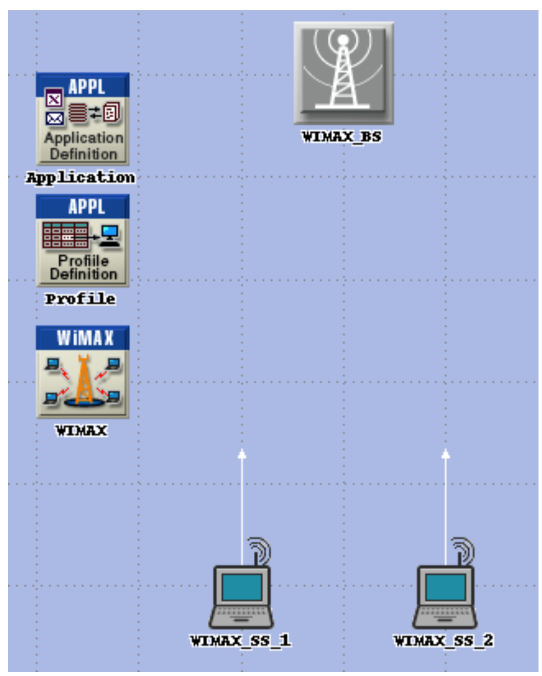

Figure 14. Scenario 4 (Mobile Nodes, Outside Range)

3.0 Discussion

The duration of the simulation for all four scenarios was 15 minutes. For the mobile nodes (scenario 3 and scenario 4,) the subscriber stations would complete their pre-defined trajectory at the speed of 100 km/h in 10 minutes, then the nodes would stay at their final positions onward until the simulations have completed. The caller and callee started to transmit and receive signals 100 seconds after the simulation has started; therefore, simulated results would have a 100 seconds grace period at the beginning of the simulation. The parameters that are most interesting in this project are throughput, end-to-end delay, and MOS value. In all simulated results, dark blue line indicates the first scenario, red line represents the second scenario, green line indicates the third scenario, and light blue line represents the fourth scenario.

3.1 Throughput

Figure 15 illustrates the throughput of the packets in all four scenarios.

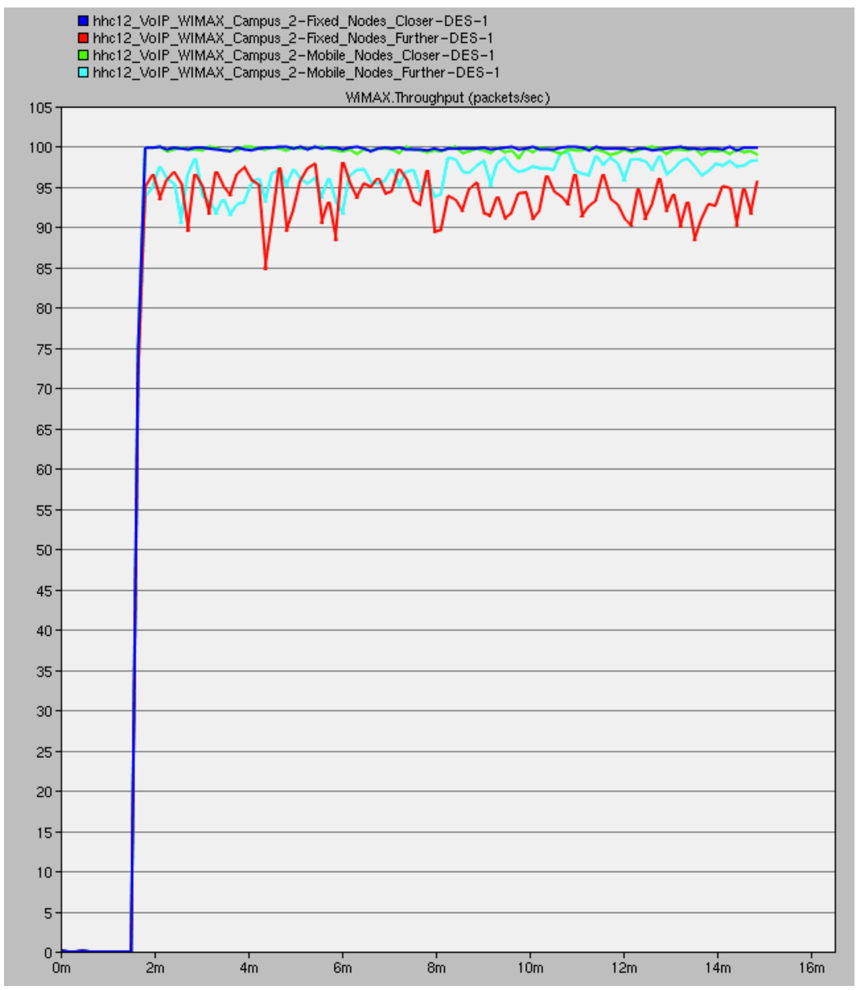

Figure 15. Throughput

As expected, the fixed and within range subscriber stations in the first scenario (dark blue) gave 100 packets/sec steadily throughout the simulation while the fixed and outside range nodes in the second scenario (red) gave relatively bad throughput as seen in Figure 15. One important thing to note is that the mobile and within range nodes in scenario 3 (green, which is underneath the dark blue) gave a nearly 100% throughput as in scenario 1. And the mobile and outside range nodes in scenario 4 (light blue) had a throughput as bad as the second scenario at the beginning, but as it approaches the base station, the throughput improved.

3.2 End-to-End Delay

The end-to-end delay for all four scenarios is demonstrated in Figure 16 while the color indications stay the same.

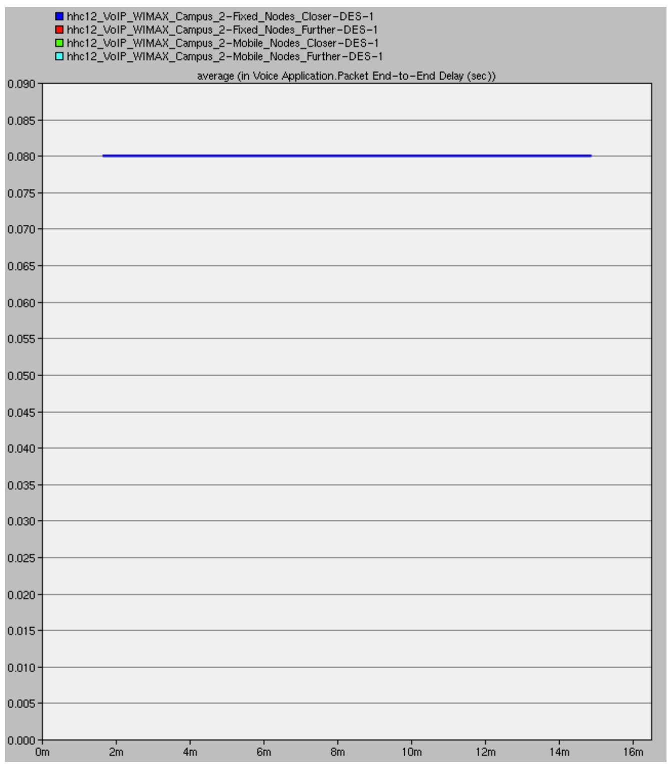

Figure 16. End-to-End Delay

As seen in Figure 16, all four scenarios had an end-to-end delay of 0.080 seconds throughout the simulation, and that is why only the dark blue line is showing while the other lines are underneath the dark blue line. This result was not what I have expected since the further the nodes are, the longer the end-to-end delay would be in theory. However, they were all having the same end-to-end delay which suggested that the distances between the base station and the subscriber stations do not affect the time of the packets being transmitted.

3.3 Mean Opinion Score

Mean Opinion Score (MOS) indicates the quality of received audio after transmission in a numerical measurement. The MOS value is expressed in a scale from the worst (1) to the best (5) which is clarified in Table 2.

Table 2. MOS Indication

MOS	Quality	Impairment
5	Excellent	Imperceptible
4	Good	Perceptible but not annoying
3	Fair	Slightly annoying
2	Poor	Annoying
1	Bad	Very Annoying

Figure 17 illustrates the MOS value on all four scenarios while the color indications stay the same.

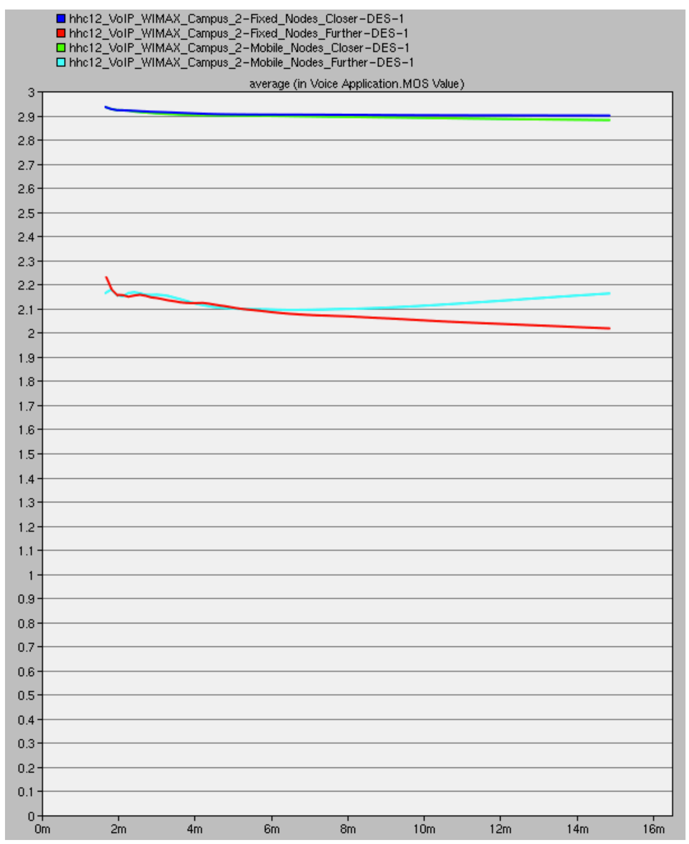

Figure 17. Mean Opinion Score

As expected, the first scenario and third scenario have better MOS values of close to 3. The reason of the third scenario has a nearly identical MOS value as the first scenario is because it has a really close throughput as the first scenario. The MOS value of scenario 2 was the worst at about 2 as anticipated because of its distance away from the base station. The last scenario experienced a MOS value as bad as the second scenario; however, it got better towards the end of simulation as the nodes were moving towards the base station, and it has a MOS value of close to 2.2 at the end of simulation.

3.4 Difficulties

The original project idea was motivated by the current cellular data network, 3G network, and one of the 3G technologies widely in use nowadays is Universal Mobile Telecommunications System (UMTS.) However, with the absence of the corresponding license, simulations were not permitted to run on OPNET. This issue stalled the progress of the project, and finally, the decision was made to change the project's scope to WiMAX.

The other difficulty the project has faced was the lack of information on the transmission powers for the base station and subscriber stations. The transmission powers had to be set in order to be realistic, and the values were obtained from previous projects done for ENSC 427 in Simon Fraser University.

Also, the time needed for the simulations to be completed was one of the challenges. For each scenario, it took around 18 minutes to complete running the simulation in average. And it took even longer when OPNET was running remotely on payette, one of the servers at Simon Fraser University.

3.5 Future Work

With the simulated results, re-defining some of the parameters is some potential future work due to the unrealistic finding on the end-to-end delay. Furthermore, to make the project even more practical, more background traffics have to be added, namely adding more conversation pairs to the network. In order to explore more on the effect caused by the environmental factors, more variations can be made on parameters, such as transmission powers, distances and speeds of the mobiles subscriber stations.

4.0 Conclusion

In this project, the QoS of VoIP over WiMAX was analyzed based on the variations of distances and speeds of the conversation pair. Using OPNET, the statistics for throughput, end-to-end delay, and MOS value were collected and discussed.

The simulation results have demonstrated that the speed of the mobile subscriber stations would not affect the overall performance as suggested by the statistics. Also, as long as the nodes are in the maximum coverage range of the base station, the overall performance would not be affected too much by the distances between the base station and the subscriber stations.

However, there was one unrealistic finding from the OPNET simulation which was the end-to-end delay. The data implied that the subscriber stations' distance away from the base station do not affect the time needed for the packets to be transmitted. This might be happened due to some wrongly defined attributes.

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