Performance Evaluation of WiMAX Networks with Mobility in Metropolitan Area Network

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Abstract

WiMAX is a wireless standard developed to provide last mile connectivity to devices in metropolitan area while supporting data rates of around 75Mbps. WiMAX uses a combination of contention and scheduling techniques to manage access to the air interface. In our project, we plan to use OPNET Modeller to simulate a WiMAX (802.16) Metropolitan Area Network and compare fixed nodes with mobile ones for two cases i.e. when the distance from the base station is increasing (linear path) and when the distance from the base station is kept constant (circular topology). Doing so, we evaluate performance metrics like but not limited to Delay, Throughput and Jitter to support our results.

Keywords: WiMAX; Mobility; Video Streaming

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List of Acronyms

WiMAX	World wide Interoperability for Microwave Access
IEEE	Institute for Electrical and Electronics Engineers
AAA	Authorization, Authentication and Accounting
DSL	Digital Subscriber Line
Mb	Megabits
MB	Megabytes
4G	4th Generation
W-MAN	Wireless Metropolitan Area Network
fps	Frames per second
Kbps	Kilobits per second
CPE	Customer Premise Equipment
LOS	Line of Sight
NLOS	Non-line of Sight
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
MHz	Megahertz
GHz	Gigahertz
MAC	Medium Access Control
QPSK	Quadrature Phase Shift Keying
QAM	Quadrature Amplitude Modulation
TDM	Time Division Multiplexing
TDMA	Time Division Multiple Access
TDD	Time Division Duplexing
FDD	Frequency Division Duplexing
SC	Single Carrier
Mbps	Megabits per second
BPSK	Binary Phase Shift Keying
QoS	Quality of Service
RTP	Real time Transport Protocol
TCP	Transmission Control Protocol

UDP	User Datagram Protocol
IP	Internet Protocol
DS3	Digital Signal 3
WAN	Wide Area Network
SS	Sub-station
BS	Base station
Km/hr	Kilometers per hour
UGS	Unsolicited grant service
rtPS	Real time polling service
nrtPS	Non-real time polling service
BE	Best effort
PHY	Physical
dBi	Decibels
SNR	Signal-to-noise ratio

Chapter 1.

Introduction

WiMAX (World wide Interoperability for Microwave Access) technology is based on the IEEE 802.16 standards family which supports high data rates, high sector throughput, multiple handoff mechanisms, power-saving mechanisms for mobile devices, advanced QoS and low latency for improved support of real-time applications, advanced authorization, authentication and accounting (AAA) functionality [1]. Over the years, it has evolved from just a last mile broadband access solution being deployed as an alternative to DSL, to a complete 4^{th} Generation technology. WiMAX technology brought wireless broadband to not just developed countries but also developing countries. In fact, number of WiMAX subscribers in Asia-Pacific outnumbers the WiMAX subscribers in North America. WiMAX has been deployed in around 150 countries around the world [2]. Amidst rapid growth in the data rates provided by technologies such as WiMAX, multimedia rich applications such as video-on demand and real time video streaming are gaining popularity. Moreover, subscribers of wireless connection inevitably demand mobility. Therefore, WiMAX has to provide not just high data rates, but high data rates with mobility. In this project, our aim is to evaluate that whether WiMAX technology would be able to support multimedia rich applications such as video-on demand when mobility is accounted.

Chapter 2.

Motivation

There has been a steady increase in the usage of mobile networks. Mean monthly usage in North America in year 2013 was 443.5 MB [3]. Moreover, there has been a steady shift in composition of traffic of these networks supporting mobility. Real-time traffic consisting of applications involving video and audio streaming is the most dominant traffic. In fact, 29.5% of upstream traffic, 39.91% of downstream traffic and 37.53% of aggregate traffic during peak periods actually comes from real-time streaming applications [3]. Furthermore, this trend is on the rise. Therefore, we can expect the traffic from real time streaming application to increase further in coming years.

WiMAX on the other hand is a wireless broadband standard that has over the years evolved into a complete 4G technology. Mobility is an inherent feature of wireless communication. Therefore, our aim in this project is to evaluate the performance of WiMAX Networks when streaming video traffic, taking mobility into consideration.

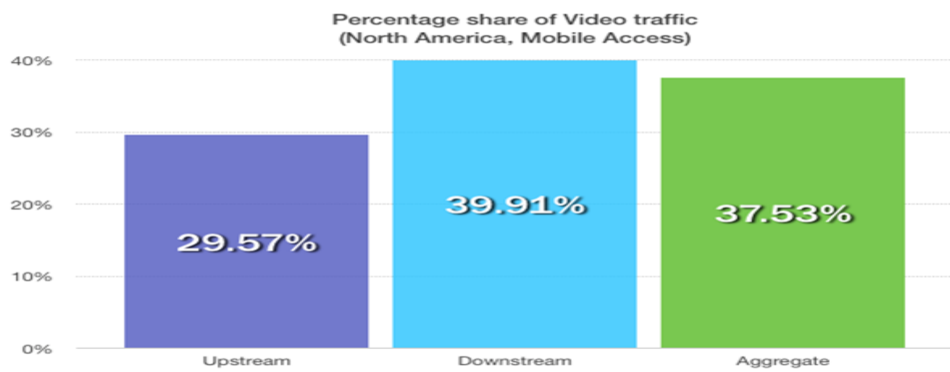

Figure 2.1 : Percentage share of Video Traffic in Mobile Traffic in North America [3]

Chapter 3.

Background Technologies

3.1 WiMAX Technology

WiMAX or IEEE 802.16 is a standard that describes the air interface for wireless broadband access. It is the foremost important W-MAN (Wireless Metropolitan Area Network) standard. It is used widely to provide Internet access to fixed and mobile users and advertised as a cheap alternative to wire-line broadband access. A WiMAX system consists mainly of two parts: base station and subscribers.

The typical size of a WiMAX base station is usually between 7 and 10 kilometres. However, radii can extend up to 50 kilometers with favourable conditions and can be further extended with the help of Backhauls. Backhauls are simply WiMAX towers that act as repeaters for WIMAX base stations thus helping to extend the range. A WiMAX base station is usually connected to the Internet using a high-bandwidth wired connection (for example, a T3 line). Customer uses Customer Premise Equipment (CPE) to connect to base station. CPE is simply a receiver antenna that is oriented towards the WIMAX base station to get optimum signal. Alternatively the receiver antenna could be built into laptops or other mobile devices [4].

Development of WIMAX started in 1998 with establishment of 802.16 working group with a mandate to develop Wireless Metropolitan Area Network Standard. Initially, 802.16a standard was developed to provide Line of Sight (LOS) communication, without any support for mobility. It operated in the frequency range of 10-66 GHz using a single carrier. In year 2003, 802.16d standard was released which provided improved data rates and started supporting Non-Line of Sight (NLOS) communication. It operated in 2-11 GHz range, had 256 sub-carriers and used OFDM encoding.

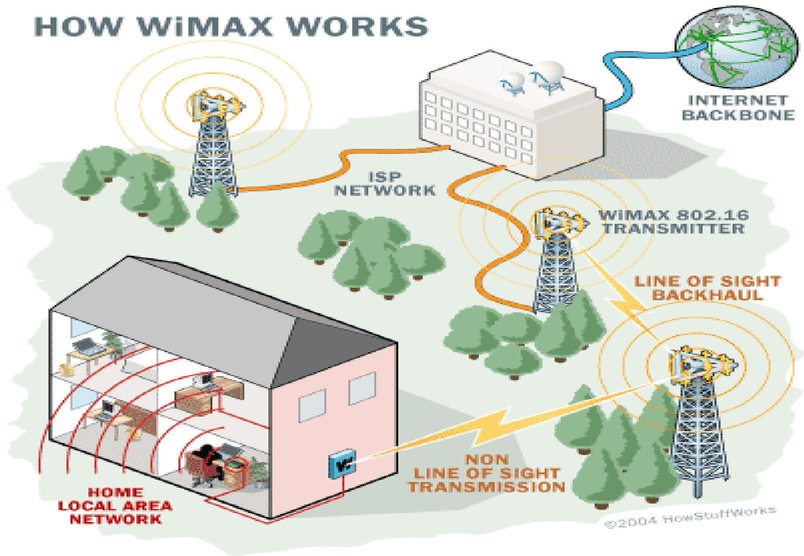

Figure 3.1 : WiMAX Base Station-Client Connection [4]

WIMAX gained popularity in 2005 when 802.5e standard was released which used OFDMA encoding, 2048 sub-carriers, provided data rates of around 75 Mbps and most importantly supported mobility. ODFM and OFDMA are methods of encoding in which subcarriers are placed orthogonal to each other, thus achieving higher efficiency without interference. Data capacity is increased as a result of this. Bandwidth of the channel in WiMAX can be in multiples of 1.25 MHz, starting from 1.25MHz to 20 MHz's.

Features	802.16	802.16-2004	802.16e-2005
Frequency band	10–66 GHz	2–11 GHz for fixed	2–11 GHz for fixed 2–6 GHz for mobile applications
MAC architecture	Point-to-multipoint mesh	Point-to-multipoint mesh	Point-to-multipoint mesh
Transmission scheme	Single carrier only	Single carrier, 256 OFDM or 2,048 OFDM	Single carrier, 256 OFDM or scalable OFDM with 128, 512, 1,024, or 2,048 Subcarriers
Modulation	QPSK, 16 QAM, 64 QAM	QPSK, 16 QAM, 64 QAM	QPSK, 16 QAM, 64 QAM
Multiplexing	Burst TDM/TDMA	Burst TDM/TDMA/OFDMA	Burst TDM/TDMA/OFDMA
Duplexing	TDD and FDD	TDD and FDD	TDD and FDD
Channel bandwidths	20, 25, 28 MHz	1.75, 3.5, 7, 14, 1.25, 5, 10, 15, 8.75 MHz	1.75, 3.5, 7, 14, 1.25, 5, 10, 15, 8.75 MHz
Gross data rate	32–134.4 Mbps	1–75 Mbps	1–75 Mbps
Air-interface designation	WirelessMAN-SC	WirelessMAN-SCa WirelessMAN-OFDM WirelessMAN-OFDMA	WirelessMAN-SCa WirelessMAN-OFDM WirelessMAN-OFDMA
Application	Fixed LOS	Fixed NLoS	Fixed and Mobile NLoS
Time of completion	December 2001	June 2004	December 2005

Table 3.1 : Salient Features of IEEE 802.16 standards family [5]

Frequency spectrum is divided into four types of carriers: guard subcarriers, data subcarriers that are used to carry data, pilot subcarriers and DC subcarrier, which is used as a reference point. Data and Pilot sub carriers in WIMAX are not fixed but keep rotating. Sub - carriers may be modulated using different digital modulation techniques to carry data. These modulation schemes can be Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), Quadrature Amplitude Modulation (16-QAM and 64 QAM). Figure 3.2 shows the different type of carriers used in OFDM.

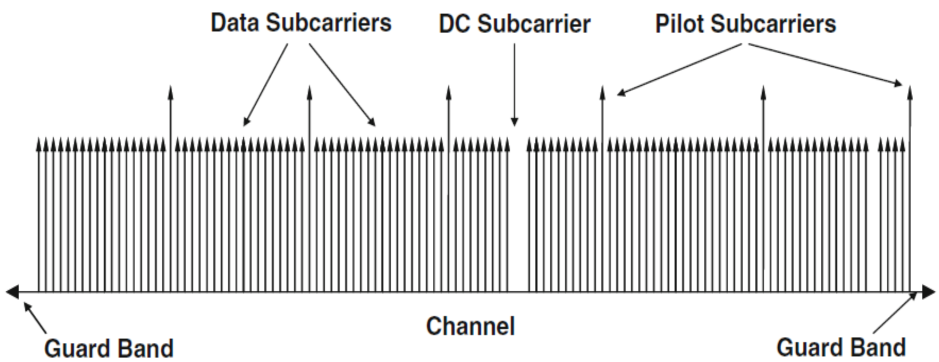

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Figure 3.2 : OFDM Frequency Description [6]

WiMAX subscribers that want to join the network have to request bandwidth from the base station. Subscriber station is assigned a time slot by the base station, which can be enlarged or restricted. This time slot remains allotted to the subscriber for its exclusive use. This 'request and grant' scheme prevents the base station from oversubscribing. This not only leads to efficient bandwidth utilization but it also allows the base station to implement Quality of Service (QoS) by enabling it to carefully manage its resources. [7]

3.2 Video Content Overview

In online video streaming process, client request to view pre-recorded view from the server. Server responds to this request and related data is sent over the network. Client on its end plays the video with the help of media player that is installed at the client's machine.

One of the salient features of video streaming is high bit rate. It can vary from about 100kbps for low quality video to 3Mbps for high definition movies. Video is typically displayed as a sequence of images played at constant rate of 24 to 30 frames per second. However, another feature of videos is redundancy. There are two types of redundancy in videos - special redundancy and temporal redundancy. Spatial redundancy refers to redundancy within the image and temporal redundancy refers to redundancy between images. Encoding techniques can take advantage of this redundancy to execute compression algorithms [8].

Video streaming applications put high throughput requirements on the network. In order to have a smooth streaming experience, instantaneous throughput must be greater than video bit rate.

However, inter arrival rate of the frames is not constant as it keeps on changing depending upon the network conditions. Moreover, packets may not follow the same paths, resulting in different end-to end delay. This results in jitter (variation in end to end delay) and overall video playback experience is degraded. However, use of the buffers enables us to do continuous video playback, if the average throughput (over 5 to 10 seconds) is more than the bit rate of the video [8]. Figure 3.3 illustrates the need for client video system to play frames at a constant rate. .

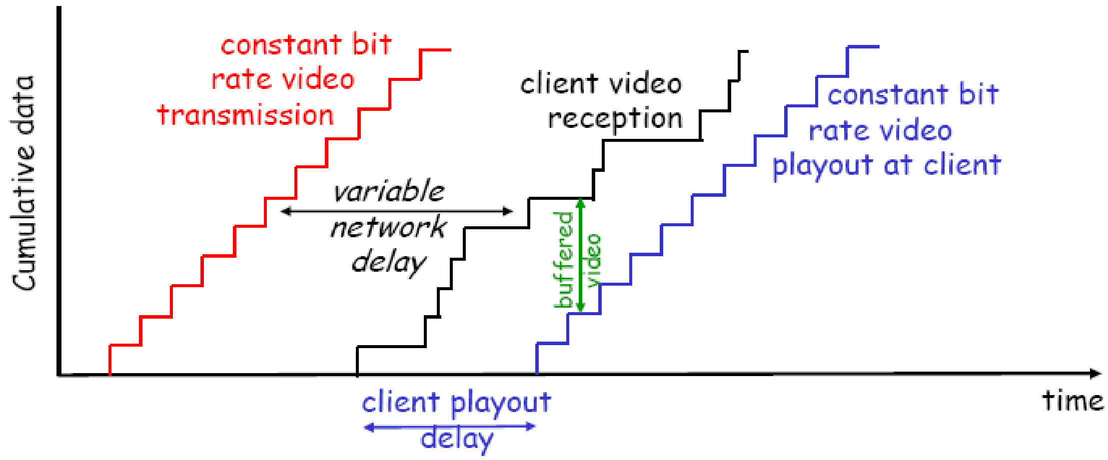

Figure 3.3 : Buffering required at Video Client [10]

Figure 3.4 shows the process of video streaming. The raw video and audio are compressed using compression algorithms and then saved in a server for transmission later on. When a client requests the data, server starts sending the data and employs the application layer based QoS mechanism that adjusts the bit stream according to the network conditions. Transport layer protocol stack add the necessary information such as time-stamps, sequence numbers and other important fields to the data. Corresponding layers at the client process packets that successfully reach the destination. The data is decoded and played by the video/audio media player, which is installed at the client workstation [10].

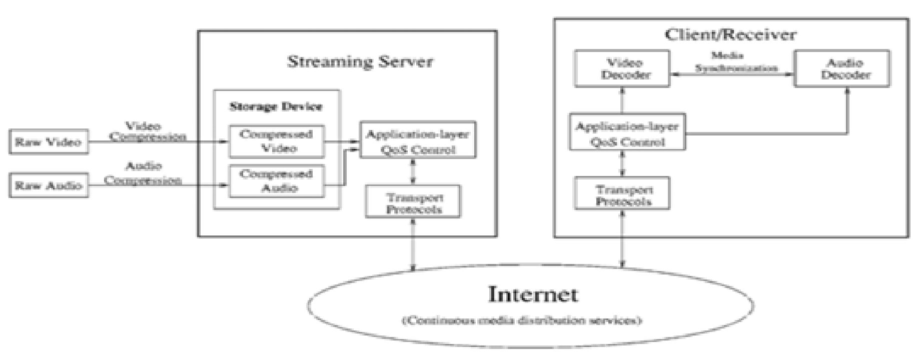

Figure 3.4 : Architecture of Video Streaming [10]

The Real Time Transport Protocol (RTP) is a protocol that provides standardised packet structure that incorporates video and audio data, encoding scheme, time stamps, sequence numbers and other useful fields. It is an end-to-end protocol that operates on top of the Transmission Control Protocol (TCP) or User Datagram Protocol (UDP). RTP provides best effort service without any guarantee of loss or delays. The sending side encapsulates the data to be sent (video and/or audio data in this case) into RTP packets, which is further encapsulated into UDP packet and is then handed over to the network layer. IP layer passes these packets to MAC and Physical layer, from where they enter the network. The receiving side extracts the RTP packet from the received UDP packet and extracts the media chunk from it. This is passed to the media player that decodes and plays it at a constant rate for the viewer [11].

In this project, to evaluate the video/audio streaming performance, four metrics are measured and analysed. Corresponding average and ideal values of these metrics for good video streaming experience is also listed [11].

- Packet loss: number of packets dropped
    - Definition : 1 - (# of received packets) / (# of expected packets)
    - Average value : $< 10^{-3}$
    - Ideal Value : $< 10^{-5}$
- Delay: average time of transit
    - Definition : Processing delay + propagation delay + queuing delay
    - Average value : < 300 ms
    - Ideal value : < 10 ms [9]
- Jitter: variation in packet arrival time
    - Definition : Actual reception time – expected reception time
    - Average value : < 60 ms
    - Ideal value : < 20 ms
- Throughput: minimum end-to-end transmission rate
    - Definition : Measured in bytes/sec (or bps)
    - 10 kbps – 5 Mbps

Chapter 4.

Model Development and Validation

We have made modifications and included new nodes into a previously developed model [11]. We have used OPNET 16.0 to run this model. At first, the reference model caused several issues to work. After fixing the issues related to the reference model, we duplicated the scenario to create two scenarios, one for implementing linear trajectory and the other one for implementing circular trajectory as discussed later in the report. The reference model consists of 3 fixed WiMAX nodes located at 2km, 4km and 6km from the base station and an ADSL subscriber. In our model, in both scenarios, we have removed the 4km fixed node and the ADSL subscriber. We then added a mobile node in the current subnet and assigned trajectories to it with respect to the scenario and motive we were working on. Hence, after implementing the nodes and making related edits and modifications, we needed to validate our model against the reference model before we could start our simulation. Therefore, to do this, we ran the reference model scenario along with the two scenarios we created for a simulation time of 48 minutes and compared the global statistics for both models.

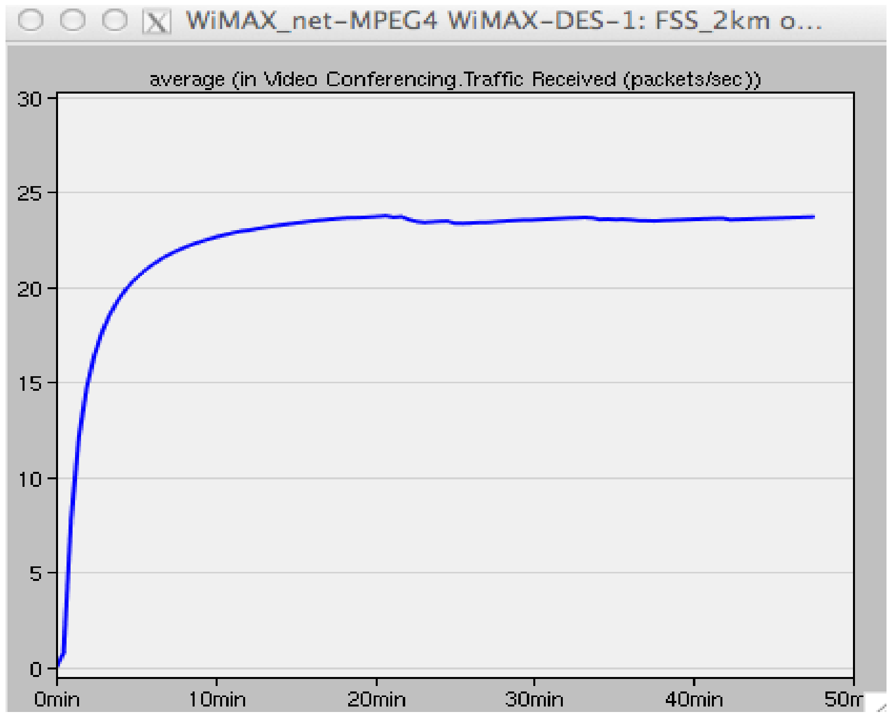

Figure 4.1 : Average Network Traffic Received in Reference Model

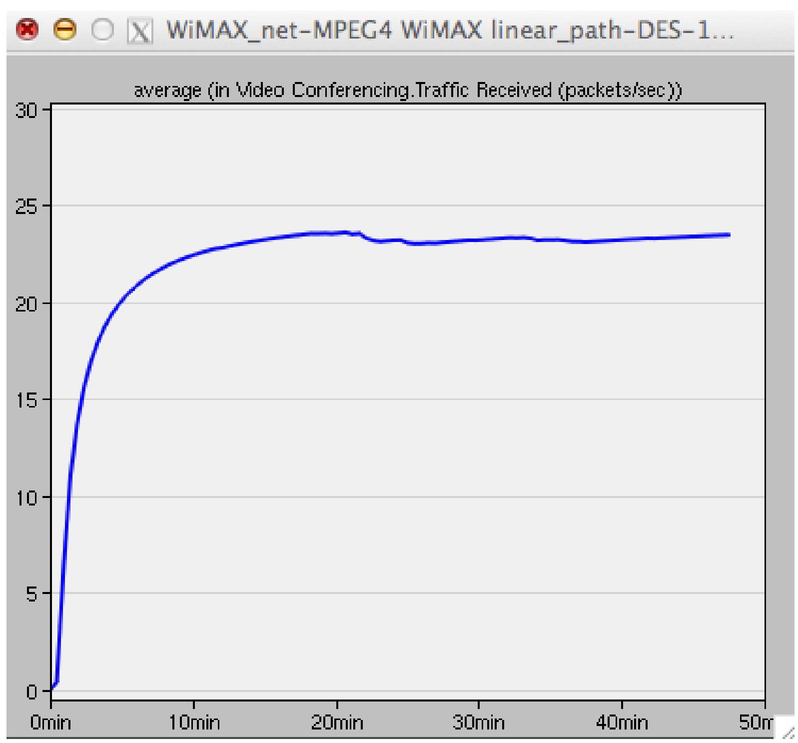

Figure 4.2 : Average Network Traffic Received for Linear Trajectory (Scenario 1)

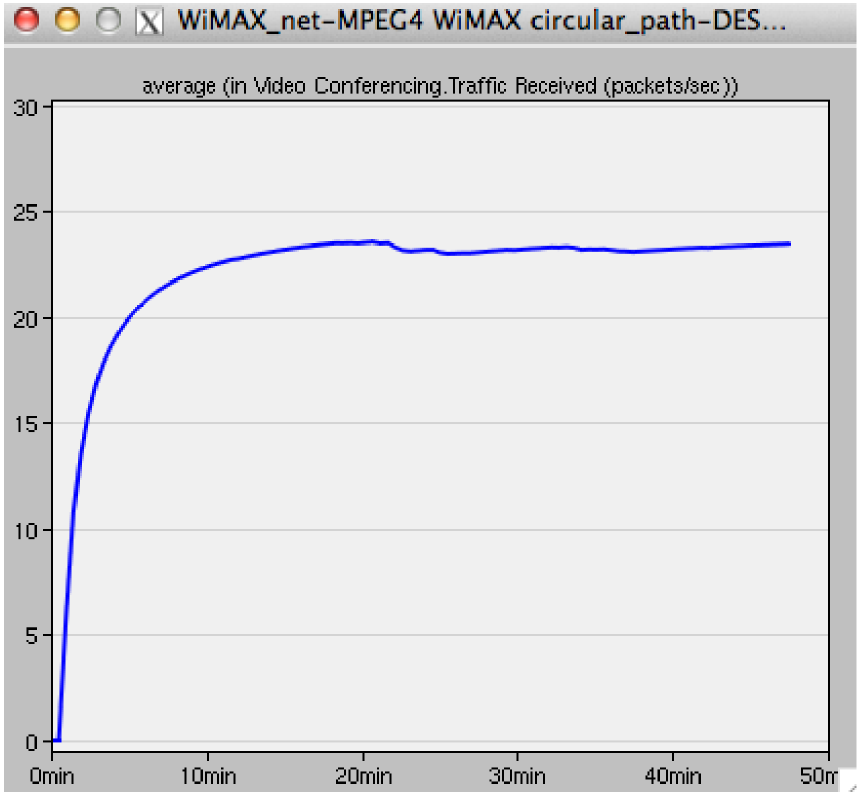

Figure 4.3 : Average Network Traffic Received for Circular Trajectory (Scenario 2)

As we can see in Figure 4.1, the average network traffic received in the reference model is around 24 packets per second. We validated this with our two scenarios (Figure 4.2 and Figure 4.3) where we noticed that the average network traffic received in both these cases is also around 24 packets per second and obtained a similar shaped graph as that of the reference model. We can also verify our model by comparing the packet delay variation and end-to-end packet delay to observe similar exhibits from both models i.e., the reference model and our model. Packet delay variation for the reference model is about 35ms and for both the scenarios in our model, this variation is about 25ms. Packet Delay Variation or Jitter for all three cases are shown in Figure 4.4.

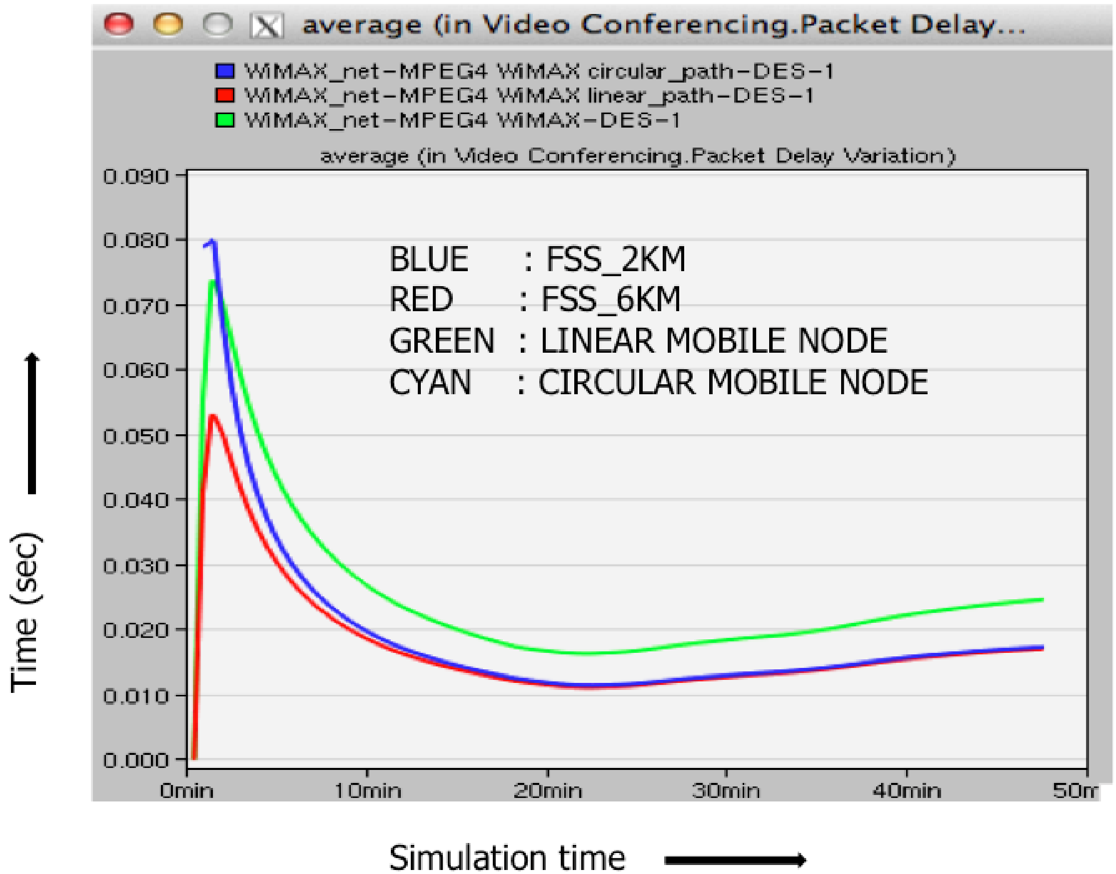

Figure 4.4 : Packet Delay Variation for all three cases (i.e., Reference Model, Scenario 1 and Scenario 2)

Chapter 5.

Simulation Design

In this project, we have used OPNET Modeler version 16.0 to create the simulation models. We stream a trace of 48 minutes interval of the Matrix 3 movie, which is streamed from server subnet that is set up in Toronto, Canada. The client subnet is in Vancouver, Canada. Therefore the server subnet and the client subnet are geographically separated. Topology used in the simulation is shown in Figure 5.1. Distance between the two subnets is 3,342 kilometers.

Topology of server subnet is shown in Figure 5.2. Server subnet represents the basic corporate architecture in which video server has been set up to stream video in a 100Mbps Ethernet network. This network is protected by firewall. The firewall's outer interface connects to an access router, thus connecting server network to the Internet via 45 Mbps Digital Signal 3 (DS3) Wide Area Network (WAN) link.

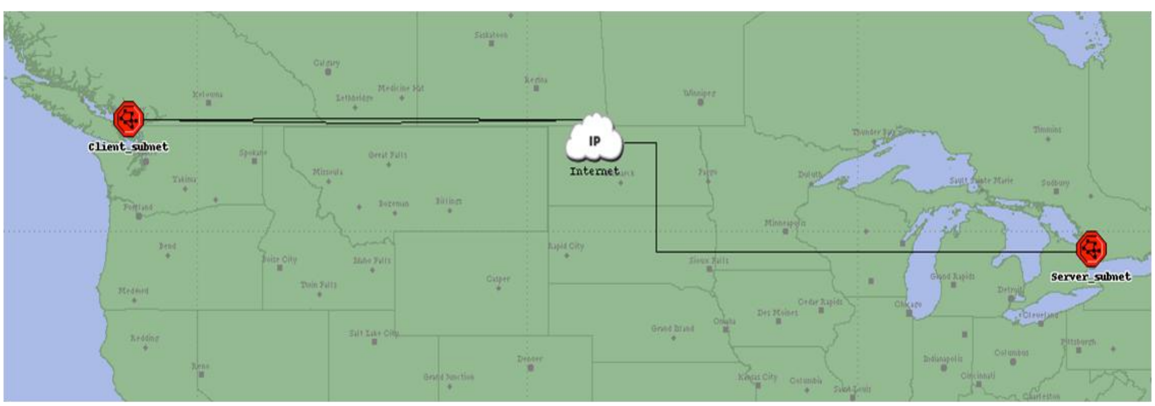

Figure 5.1 : Network topology used in simulation showing geographically separated server subnets and client subnets

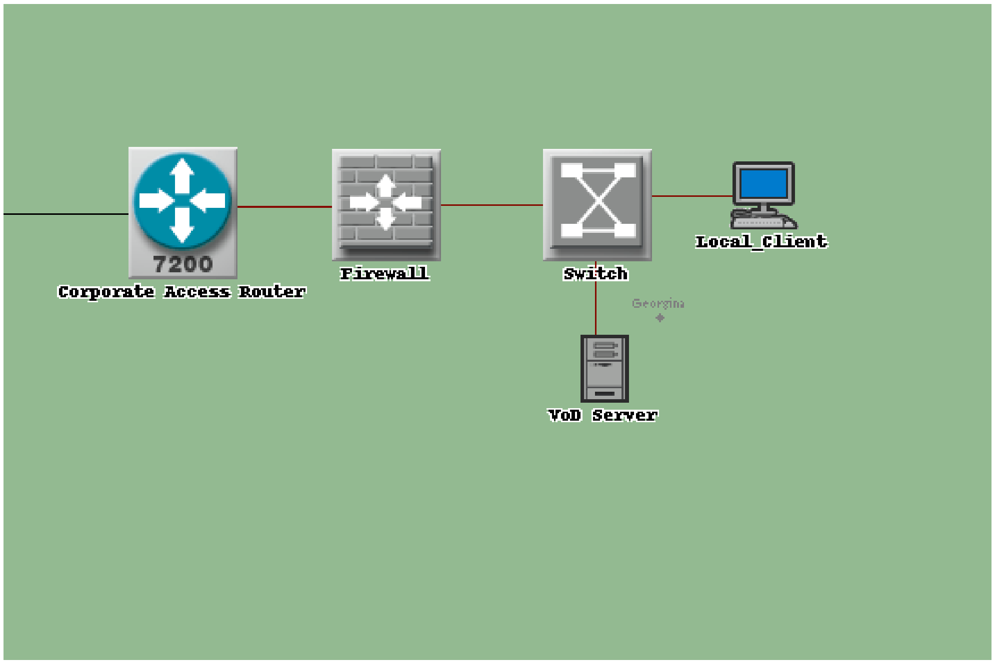

Figure 5.2 : Video Server subnet

Two distinct simulation models have been simulated. The first scenario has two fixed SS (sub-station) or receiver nodes at a distance of 2 kilometers and 6 kilometers respectively from the base station (BS) and a mobile SS that is moving at a constant speed of 5km/hr, following a linear trajectory from distance of 2 kilometers towards 6 kilometers from the base station (BS). The second scenario has linear SS node replaced with a mobile SS that is moving in a circular trajectory with a constant speed of 5km/hr at a distance of 2 kilometers from the base station. Base station is connected to the Internet via DS3 WAN link. The two scenarios are shown in Figure 5.3 and 5.4 respectively.

Now, performance parameters that will be used to evaluate the performance at mobile WiMAX receiver nodes are a function of both distance and speed. For example, performance at mobile receiver moving away from BS at constant speed of 5 km/hr will be different from the performance at the mobile receiver that is moving towards the BS, even if the speed of the two clients is the same. Idea behind using circular trajectory is make the distance constant, thus enabling the study of the effect of pure speed on performance.

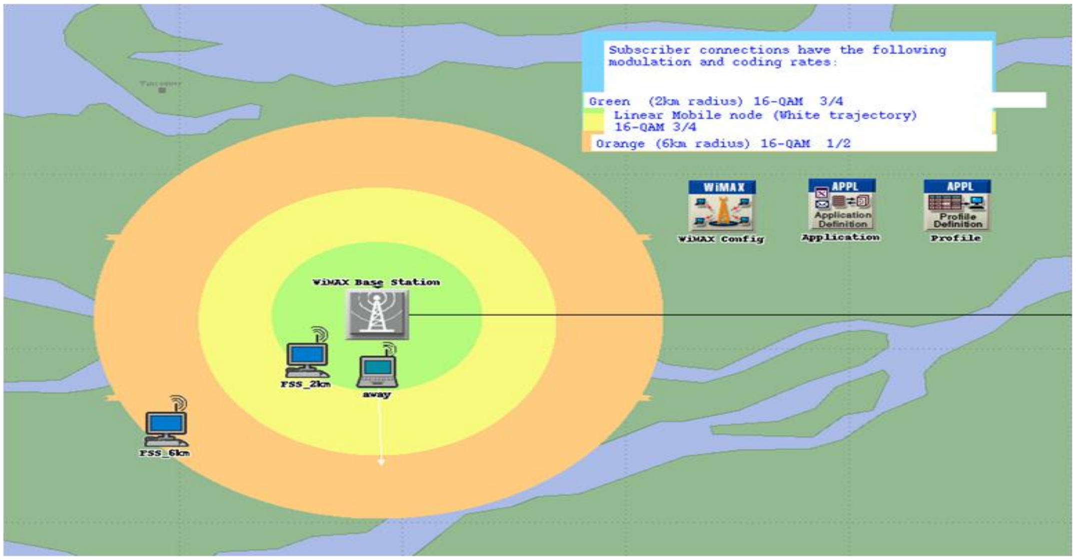

Figure 5.3 : Scenario 1 – Two fixed clients at 2km & 6kms, and a mobile client following a linear trajectory (moving away from the BS at a constant speed of 5km/hr).

Points in the map in the OPNET Modeler are defined by co-ordinate systems. We have used the tools that are readily available online to find the distance between the various co-ordinates.

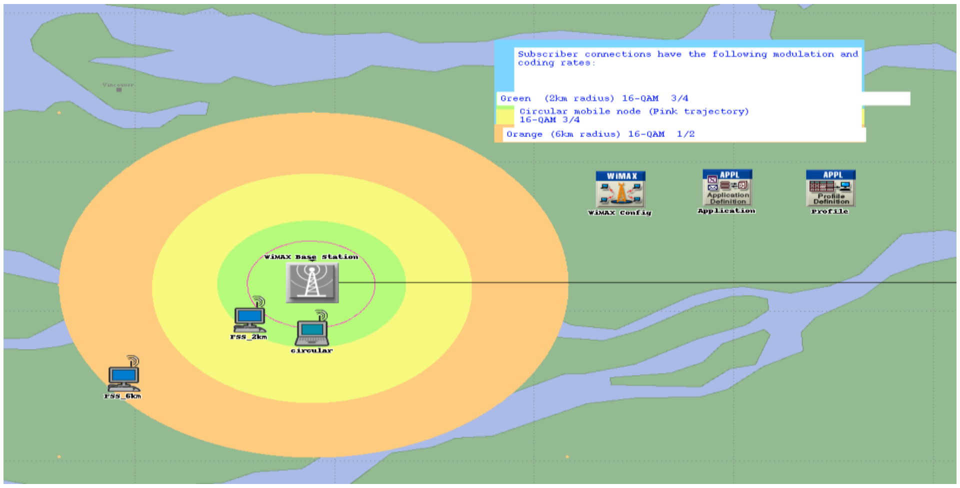

Figure 5.4 : Scenario 2 involves a mobile WIMAX client moving in a circular trajectory at distance of 2 km from the BS at a constant speed of 5km/hr.

Chapter 6.

Simulation Parameters

Various WiMAX parameters deployed at the base station and the sub-Station (Client station) in the simulations are the following :

- Media Access Control (MAC) scheduler
- Burst Profile/ Coding Rates
- Air Interface
- Operating Frequency
- Channel Bandwidth and Subcarriers
- Transmit Power and Antenna Gain
- Path Loss Model

QoS is an important aspect in WiMAX deployment. One of the key parameters that describe QoS is the MAC Scheduler. Scheduler helps in supporting QoS by providing support for delay sensitive traffic (such as video streaming traffic). Typically, there are four types of schedulers used. These are UGS (unsolicited grant service), rtPS (real time polling service), nrtPS (non-real time polling service) and BE (best effort). Available bandwidth is first given to UGS users, than to rtPS and nrtPS respectively. At last, the available bandwidth is allocated to BE (best effort) users [9]. In our simulation, we have used BE for all users which means that no bandwidth is reserved for any user.

In real world WiMAX deployment, there is use of adaptive modulation, which means coding rate changes automatically according to signal-to-noise ratio (SNR) received by the client. However, OPNET modeler does not support adaptive modulation. Therefore, client stations have been manually configured to use the coding rate of 16-QAM (Coding -3/4). This coding rate represents the best fit in our model as it represents the best trade off between the transmission efficiency and accuracy, as higher coding rates require certain minimum SNR. Modulation/coding rates employed at corresponding minimum SNR are given in Table 6.1.

Modulation	Coding	Information Bits/symbol/Hz	Required SNR (dB)
QPSK	1/2	1	9.4
	3/4	1.5	11.2
16-QAM	1/2	2	16.4
	3/4	3	18.2
64-QAM	2/3	4	22.7
	3/4	4.5	24.4

Table 6.1 : Modulation / Coding Rates employed at corresponding SNR [10]

Air Interface has been configured to utilize the ODFM on 2.5 GHz operating frequency with 5 MHz channel bandwidth. 5 MHz channel bandwidth is equivalent to 512 sub-carriers that are spilt as shown in Table 6.2.

Frequency Division		
	DL Zone	UL Zone
Number of Null Subcarriers - Lower Edge	46	52
Number of Null Subcarriers - Upper Edge	45	51
Number of Data Subcarriers	360	272
Number of Subchannels	15	17

Table 6.2 : PHY layer frame Division Pattern [10]

Base station has been configured to transmit power of 3.8 watt with antenna gain of 15 dbi antenna gain. Client station on the other hand, have been configured to operate on transmit power of 2 watt with 14 dbi antenna gain. Figure 6.1 shows the various attributes we have used in setting up of video client stations.

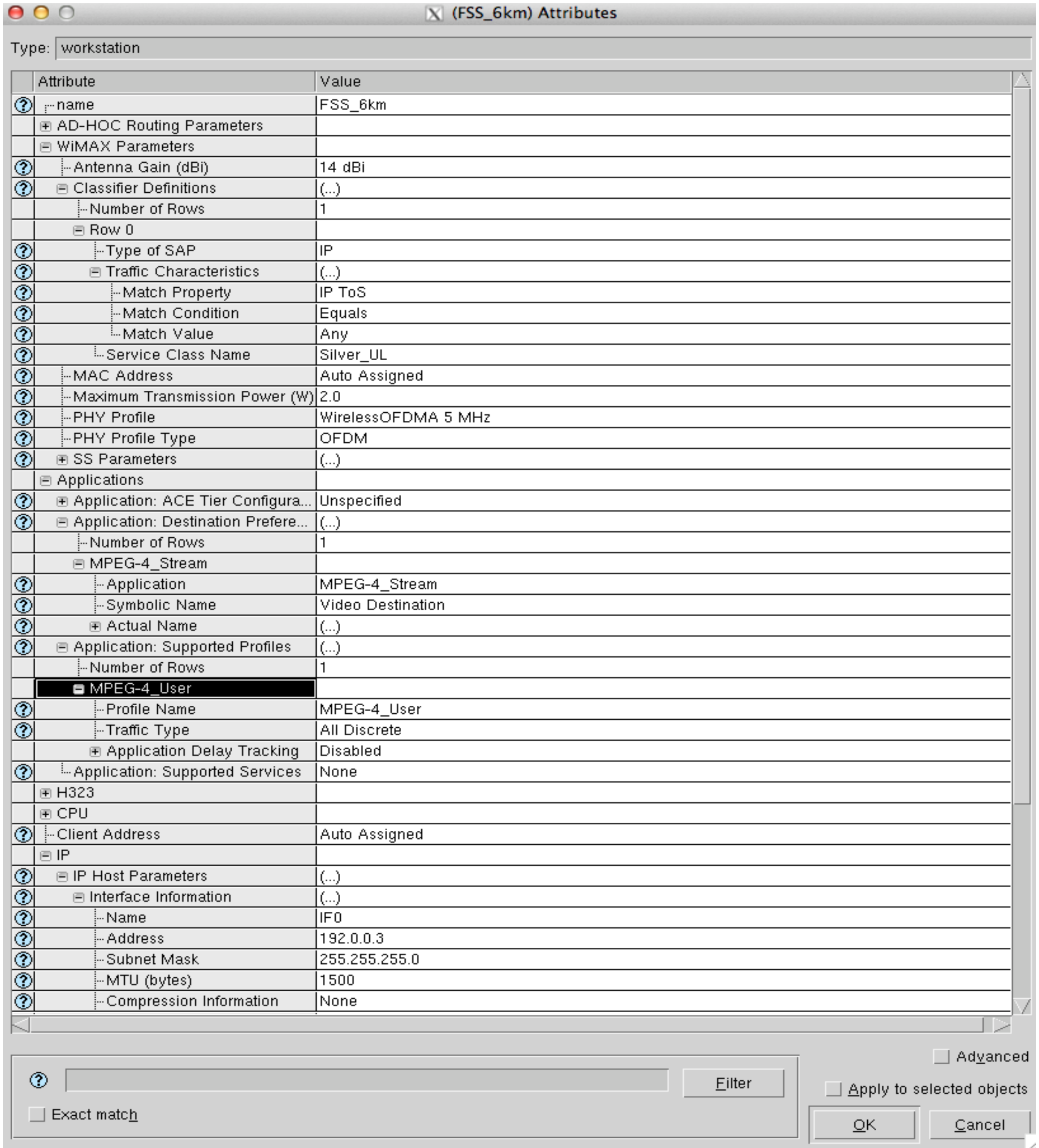

Figure 6.1 : Attributes used in configuring Video Clients

Path loss model used is fixed suburban (Erceg) path loss model with conservative terrain model that represents flat terrain with light tree densities (typical suburban environment).

Chapter 7.

Simulation Results

Simulation results reflect the streaming of 48 minutes of MPEG-4 video content to the client subscribers. The total simulation time is 96 minutes as it is run for 48 minutes each for two scenarios. The actual run time for a single scenario is 15 minutes and therefore total actual run time for two scenarios is 30 minutes.

Performance was evaluated taking four parameters into consideration: packet loss, delay, delay jitter and throughput.

Physical link statistics provide valuable information about the performance of the WiMAX networks. Figure 7.1 show the Physical Downlink Packets Dropped (packets/second) for the four WiMAX clients. Clients fixed at 2 km from the BS(blue) and the client moving in the circular trajectory (cyan) have least number of packets dropped. However, the client following the linear trajectory (green), moving away from the BS has a steady increase of packets dropped after 15 minutes of simulation time. Video client fixed at 6km (red) has the highest packet loss rate.

This can be explained with the help of Figure 7.2 that shows corresponding signal-to-noise ratio (SNR) of the WiMAX clients. Clients located at 2 km from the BS(blue) and the one moving in circular trajectory(cyan) show fewer packet drops as they have a healthy SNR (around 30 to 35 dB). This SNR is almost double of the minimum SNR required to have 16—QAM ¾ coding. Therefore, these two clients show almost no packet dropped throughout the simulation.

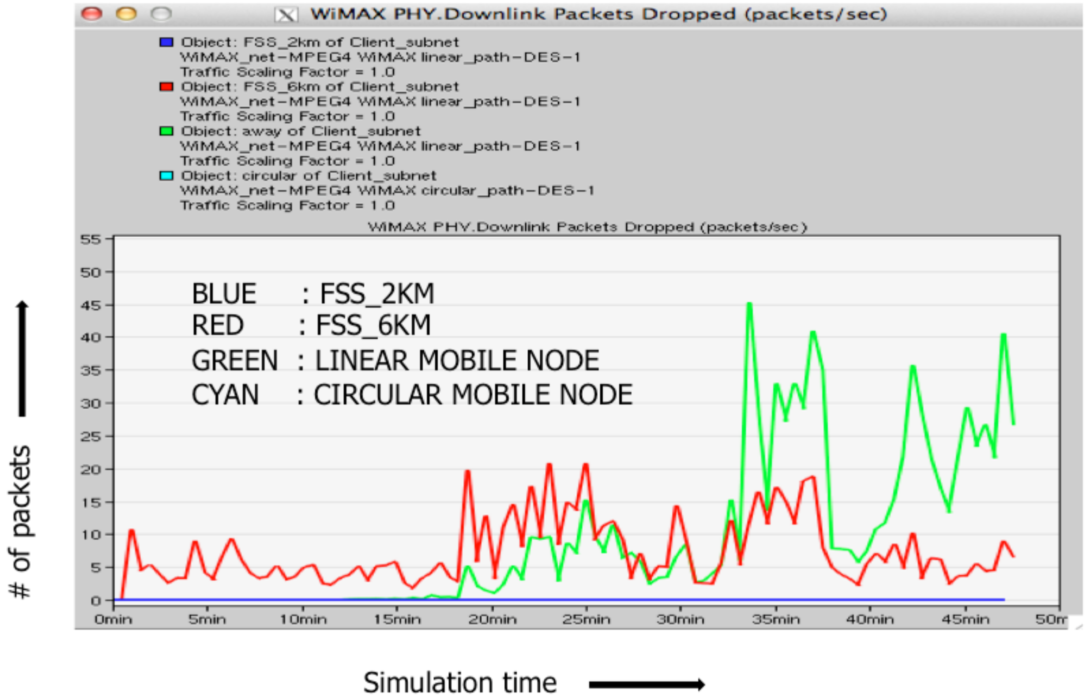

Figure 7.1 : Packets Dropped (packets/sec)

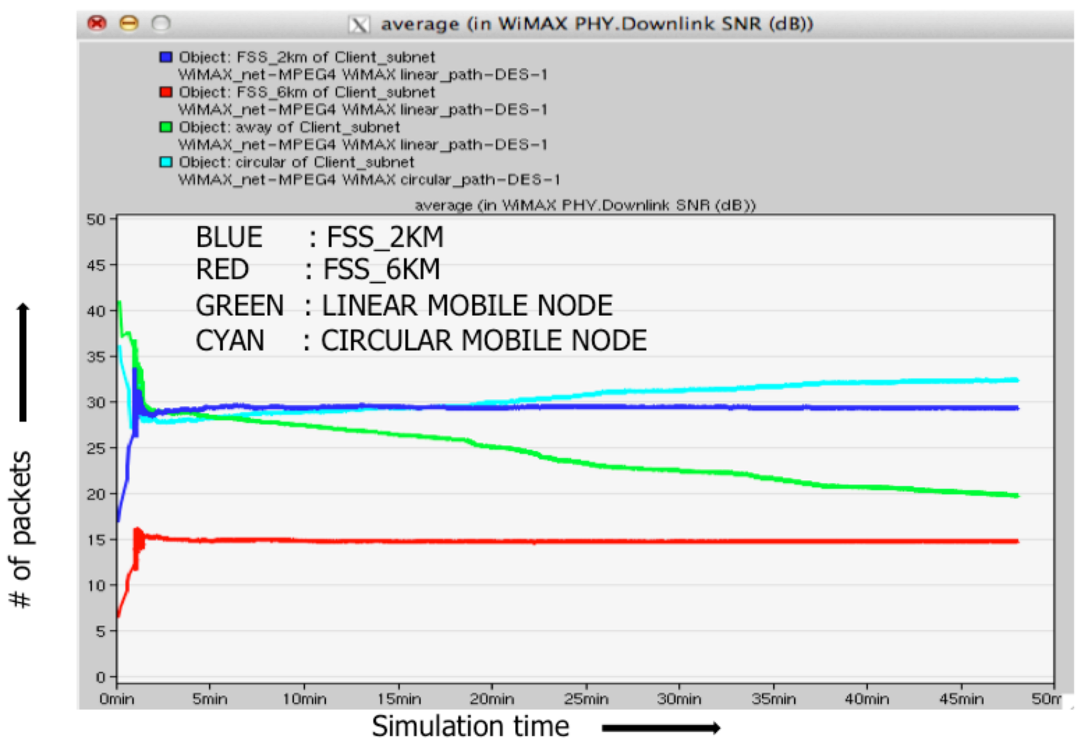

Figure 7.2 : Signal to Noise Ratio for four WiMAX clients

Client that is moving in linear trajectory (green) has very few packets dropped until 15 minutes of simulation time as the SNR is healthy (about 40 dB), however, as the simulation time and its distance from BS increases, its SNR starts decreasing till it reaches 19 dB. As a result of this steady decrease in SNR, there is an increase in the number of packets dropped.

Client that is fixed at the distance of 6 km from the BS (red) consistently drops comparatively more packets from the start till the end of the simulation. SNR for this client is about 15 dB, which is less than minimum SNR required to sustain 16-QAM 3/4 coding efficiently (18.2 dB). Therefore, we see consistent dropped packets for this client.

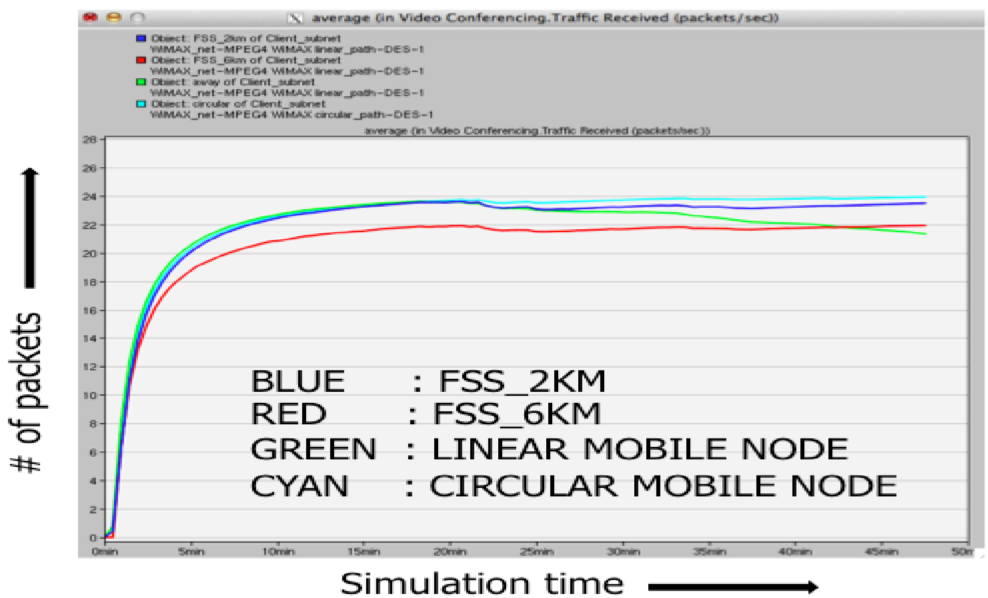

Figure 7.3 : Number of Packets Received (Packets/ Seconds)

Corresponding curves of number of packets received for the four WiMAX clients is shown in Figure 7.3. Since the number of packets received is inversely proportional to number of packets dropped, the curves for number of packets received show a trend that is reverse to the curves for number of packets dropped.

End-to-end delay is shown in the Figure 7.4. The end-to-end delay of the four video clients is averaged for 48 minutes MPEG-4 movie. End-to-end delay curves of the four video clients are closely stacked with each other. The average end-to end delay for four video clients is on the higher side in the start (but well within average acceptable value), dampens over the time and settles within the range between 0.06 seconds (60ms) to 0.08 seconds (80ms) towards the end. In order to get a smooth video streaming experience, the end-to-end delay should be ideally 10ms and average acceptable end-to-end delay should be less than 300ms. It can be seen from the Figure 7.4 that end-to-end delays for all four video clients are well within the acceptable range that are required to have smooth video streaming experience**.**

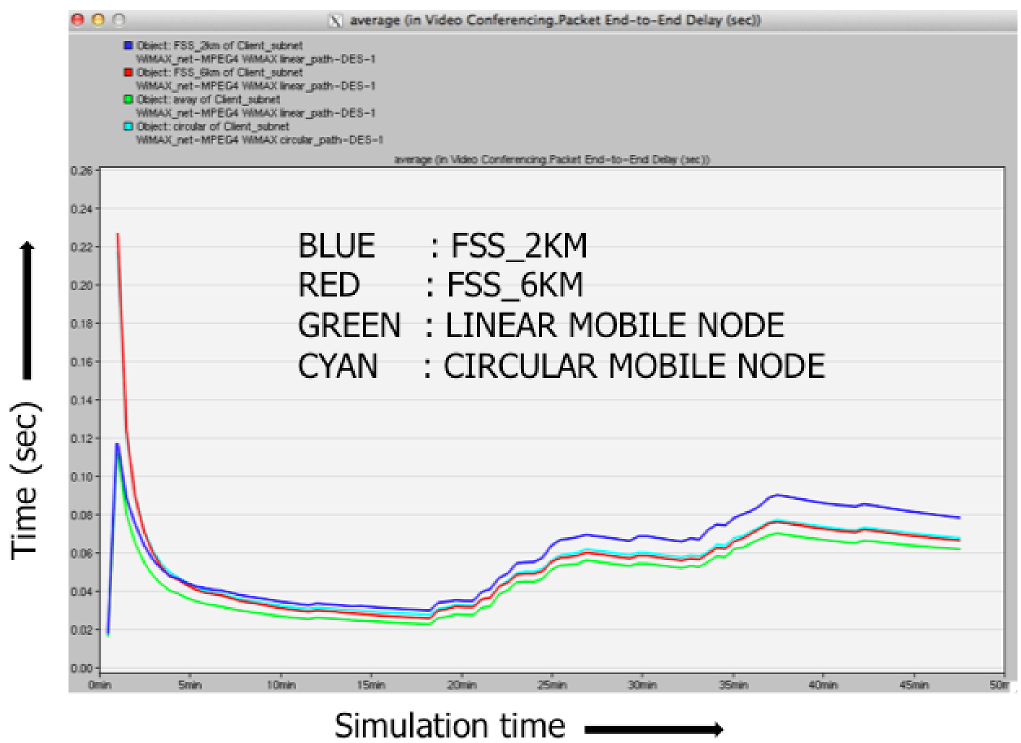

Figure 7.4 : End-to-End Delay (Average)

Average value of **Delay Jitter** for four WiMAX video clients, averaged for 48-minutes is shown in Figure 7.5. Curves of delay jitter for all four video clients are closely grouped together showing similar jitter characteristics. Results indicate that the average delay jitter statistics for all four video almost always remain in the range between 10ms to 15 ms, which is well below the ideal delay jitter value for video streaming (20ms) and average delay jitter value (< 60ms). Therefore, all WiMAX video clients (fixed and mobile), showed better than ideal behaviour required for video streaming services in this 48-minute video stream.

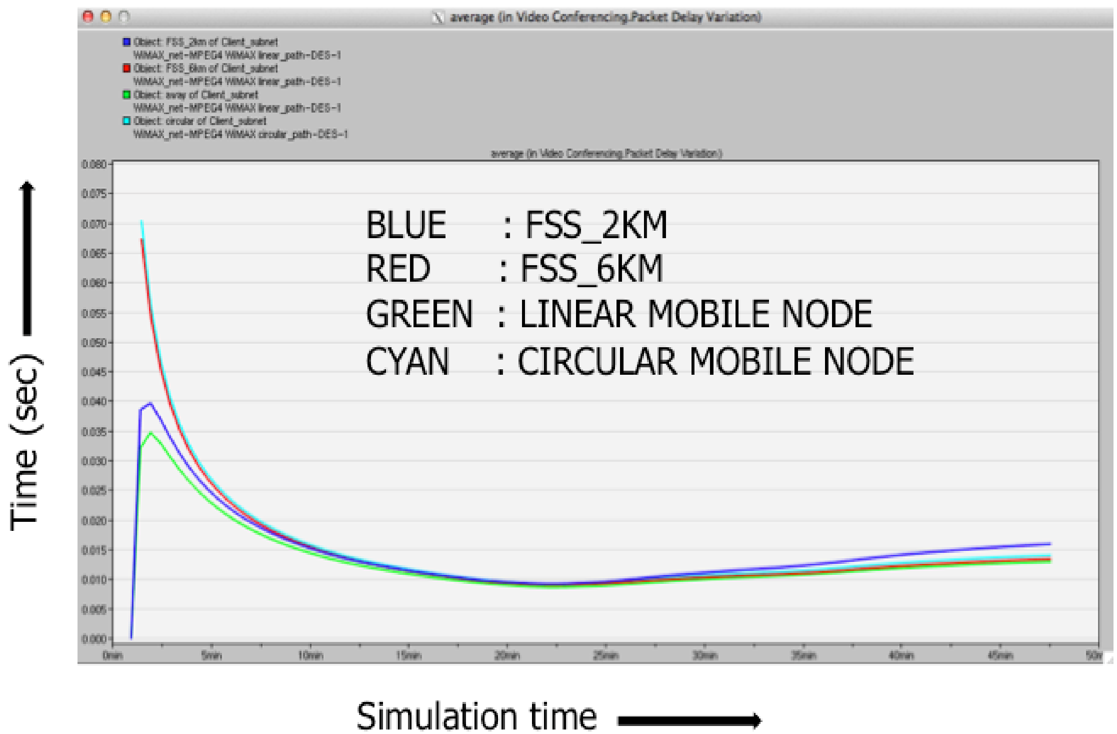

Figure 7.5 : Delay Jitter (Average)

Average **Throughput** curves for all four video clients measured in bytes/second are shown in Figure 7.6. Fixed WiMAX client at 2kms (blue) shows the highest average throughput. Mobile WiMAX client following circular trajectory (cyan), displays second highest average throughput. By comparing this curve (cyan) with the throughput curve of the fixed client at 2 kilometers (blue), we conclude that the decrease in throughput in the former is due to addition of mobility, since distance from the base station (BS) for both these curves is the same (that is, there are both at a distance of 2 kilometers from the BS). Average throughputs of the client fixed at 6 kilometers (red) and the client moving in linear trajectory (green) are closely stacked and are at around 45000 bytes/second at the end of the simulation.

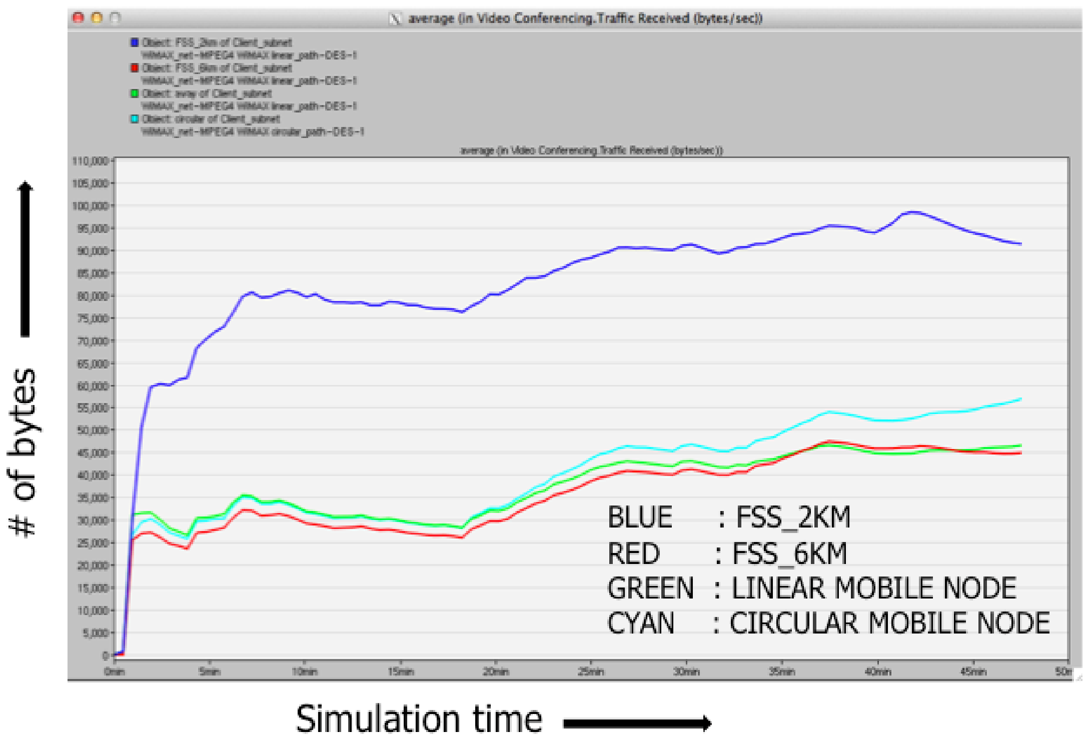

Figure 7.6 : Throughput (Average)

Although, both mobile clients (circular as well as linear) are moving at the same constant speed of 5km/hr, throughput of the client following linear trajectory is less than that of the one following circular trajectory. This is because, for the client following linear trajectory (green), distance from the base station goes on increasing with time (since it is moving away from the BS). Whereas, circular client moving in circular trajectory (cyan), distance from the BS with time remains constant. This verifies the fact that throughput for WiMAX decreases with increase in distance from the base station.

Clearly, we can see that WiMAX client at the fixed client at 2 kilometers (blue) from the base station has maximum throughput. Using this node/client as a reference client/node and comparing other curves with it, we can conclude that both: increase in distance and mobility have negative effects on the throughput. Also, it can be observed from Figure 7.6 that throughout for all the WiMAX client stations are in the acceptable throughput range (10kbps to 5Mbps) required for the video streaming applications.

Chapter 8.

Future Work

In this project, we analysed the performance of WiMAX networks in terms of a bandwidth intensive, delay sensitive video streaming load, taking mobility into consideration. In this simulation, we made some assumptions that can be revisited in the future work. These include:

- In this project, study was mainly concentrated on circular and linear trajectory for mobility. However in real life, users will rarely use either circular or pure linear trajectory. Thus, future work can include work on trajectories that are closer to real life movement of users.

- This project simulated the slow moving clients (5km/hr). In the future, work can be done on studying the effects of different (higher) speeds on performance.

- Effect on performance can be studied for other applications such as HTTP, FTP, e-mail, etc.

- Effect on performance by using various buffer sizes can also be studied.

- Performance can be evaluated at different operating frequencies (other than 2.5 GHz) and bandwidths other than 5 MHz

- Performance can be evaluated for better MAC Scheduler (Best Effort Scheduling is least intelligent scheduling)

Chapter 9.

Conclusion

In this project, extensive simulations of WiMAX wireless networks under different scenarios were conducted and finally scenarios discussed were reached. The aim of this study was to explore whether WiMAX technology could provide acceptable network performance for video streaming applications to nomadic (slow moving) WiMAX clients. OPNET modeler 16.0 was used to design two scenarios involving fixed clients and mobile clients (client moving in linear and circular trajectory). Performance was characterized using four metrics (packet loss, delay, delay jitter and throughput), which are critical when analyzing any video streaming services.

In conclusion, mobile WiMAX clients pass the minimum acceptable ranges for all four metrics used for evaluation. Another observation is, with increase in distance of the client from the base station (BS) or with introduction of mobility, there is relative decline in performance output. Thus, both distance from the base station and mobility play an important role in performance of WiMAX networks.

Another point worth mentioning is that these performance results are understated as we have used bandwidth of just 5MHz, whereas WiMAX system can provide bandwidth of upto 20MHz. Moreover, we have used Best Effort Scheduling for the clients. Performance can be much better if better scheduling mechanism such as UGS or rtPS is employed.

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Appendix A. Various Trajectories

Linear Path Test

While testing our scenario with the mobile node containing the linear path motion, we were wondering if the same scenario would give us the same results if we place the mobile node 2km from the base station but at a different position. The below figure explains what we intended to do. We found out that the results of this and our scenario are similar and hence this also led to re-verifying our model.

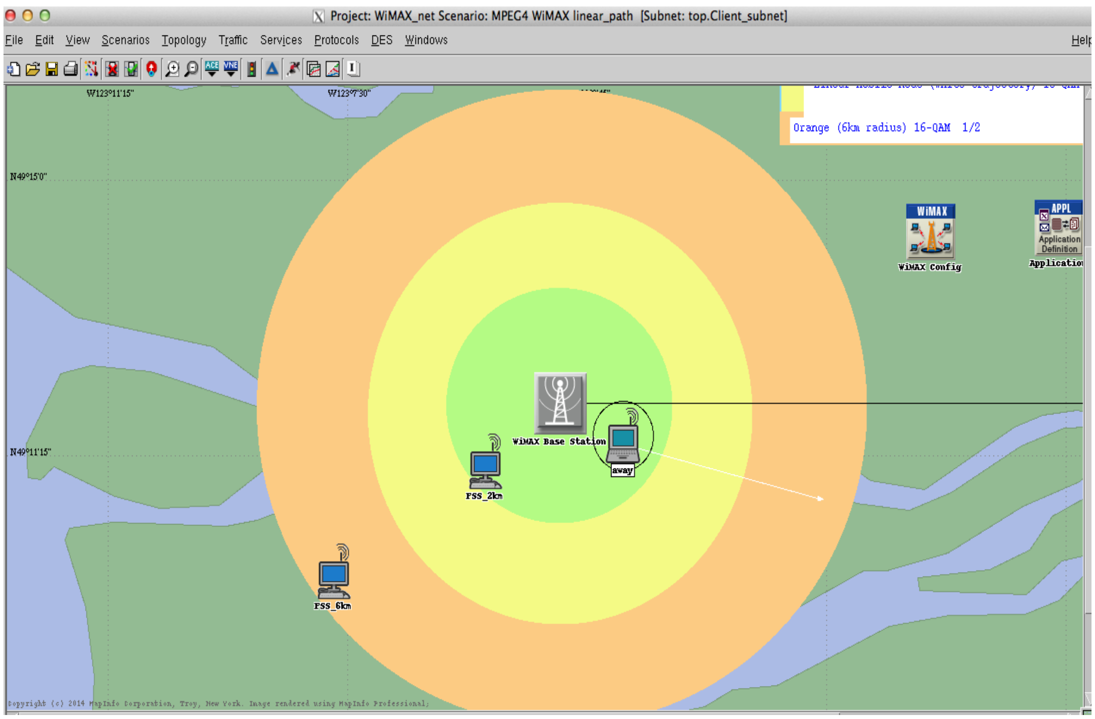

Figure A.1: Linear path alternative test

Incorrect Positioning

When we first decided to test our model using a mobile node moving in a linear trajectory, we initially thought that the circumference of the green circle is distanced at 2km and so on. However, after setting up the parameters and running the simulations, we observed very funny results and later with the help of online GPS tools, realized that the circumference of the green circle is not 2km away from the base station. It is in fact more than that. Hence, we used the online GPS tools to correctly position our new mobile node.

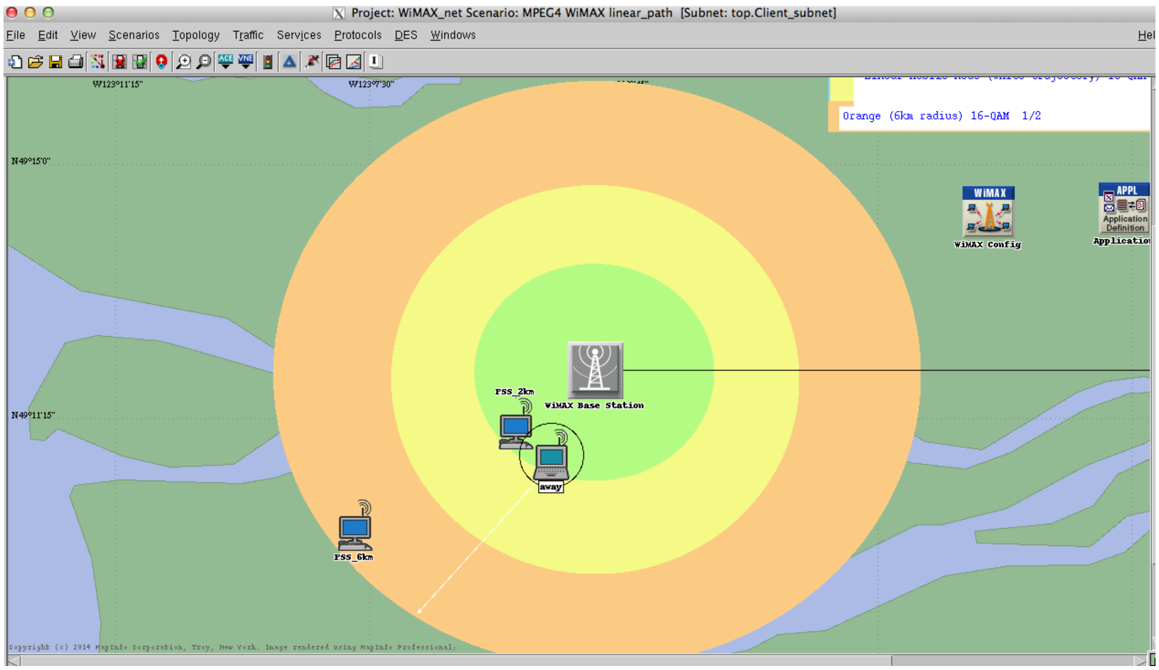

Figure A.2: Incorrect positioning of the mobile node

Creating a ‘towards’ trajectory than an ‘away’ trajectory

While thinking about which trajectories to implement, we also thought that what if we implement another trajectory that would make the mobile node move towards the base station and start from 6km. However, this scenario did not help us in our project goal and we had to ignore this scenario. This is because we wanted to compare the effect of speed and distance on a mobile node and since our circular trajectory was at 2km, it only made more logical sense to have the ‘away’ trajectory than the ‘towards’ one however, both of them would give just inversed results.

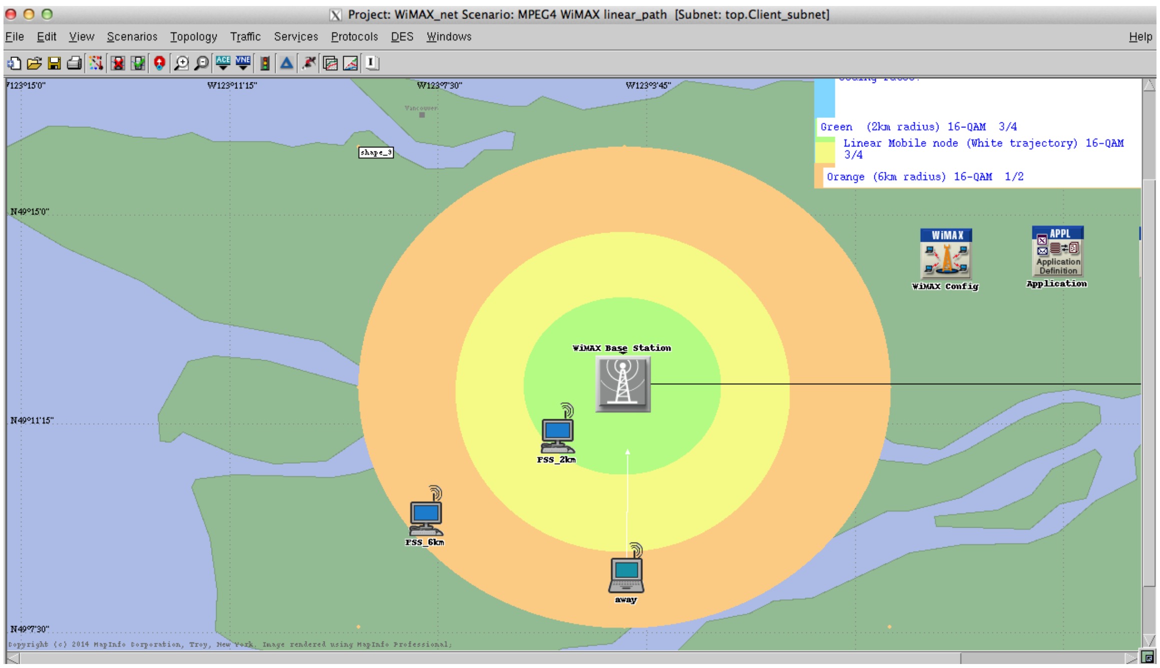

Figure A.3: ‘Towards’ trajectory

Note: We haven’t been able to display the simulation results for these trajectories even though we have run it is because we did not intend to use these trajectories and since our project was still under developing stage, we did not take screenshots unless we were sure of which trajectory we would be using. Also, due to the limited disk space, we were not able to save these results and had to immediately delete them to be able to run the next trajectory/simulation.

Random Trajectories

Initially, we were planning to deploy trajectories as realistic as possible and hence random trajectories were very essential. However, later in the project, we realised that random trajectories are not giving us a lot of meaningful information and we had to eradicate this, as this cannot be related to the effect of speed and distance i.e., the main goal of the project. We implemented randomization using the built-in tools available in OPNET under the menu Topology and also by creating our own randomization.

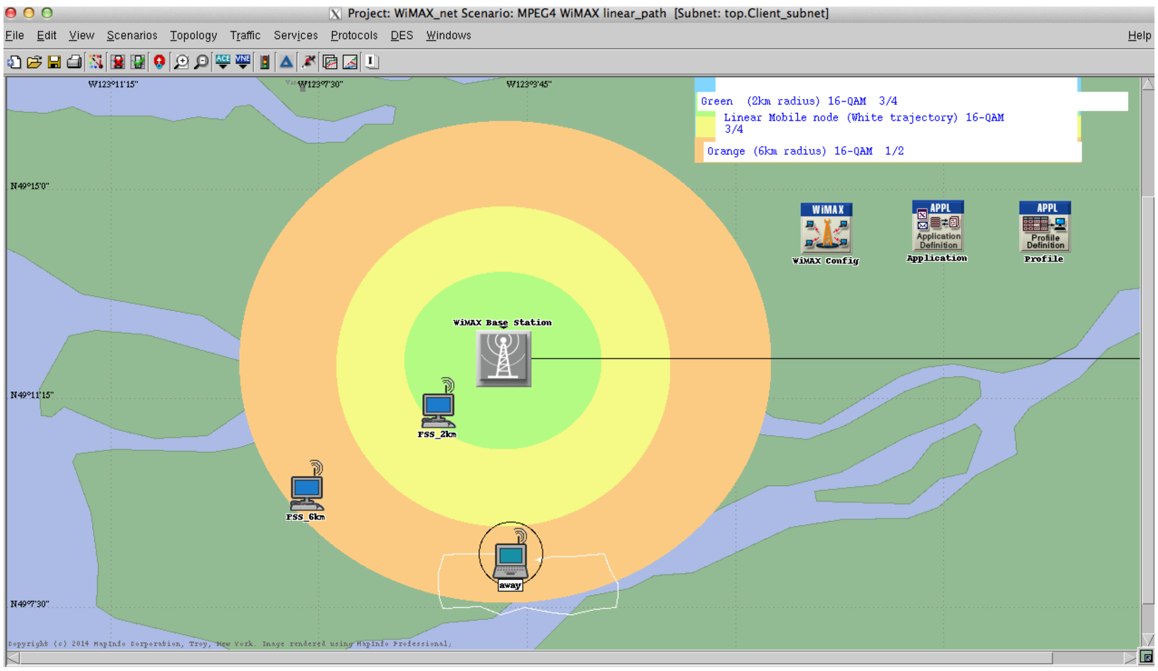

Figure A.4: Random trajectory using built-in tools on a node at 6km from base station

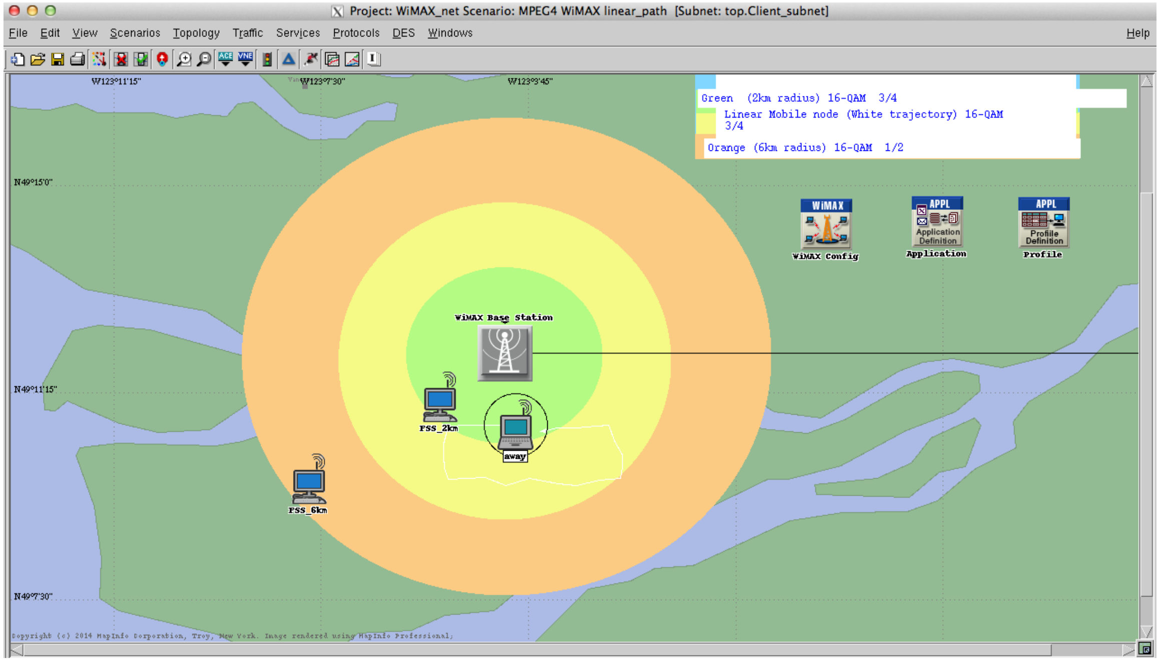

Figure A.5: Random trajectory using built-in tools on a node at 2km from base station

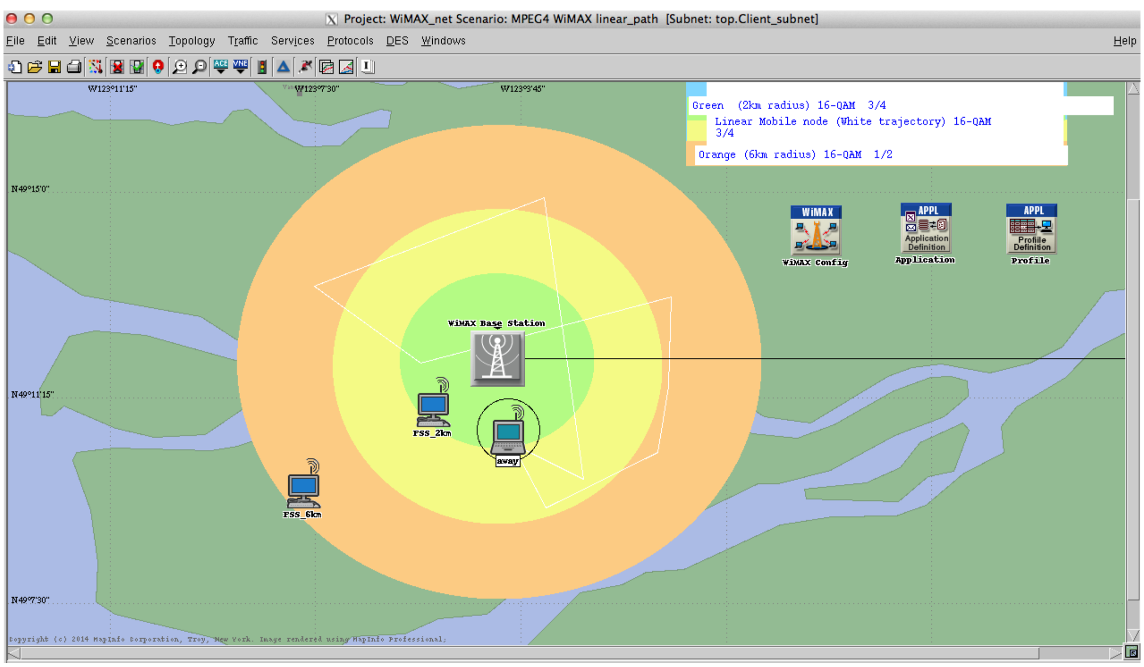

Figure A.6: Custom random trajectory on node at 2km from base station.

Appendix B.

Original Reference Model

We have used the below scenario from the reference model to work on our project. As we can see the below model has a base station and three fixed mobile nodes placed at 2km, 4km and 6km. There is also an ADSL network setup in the model. However, for our purpose, we did not need the fixed mobile node at 4km and the complete ADSL network as this was not giving any logical meaning to our project goal. Hence, we used a modified version of the reference model.

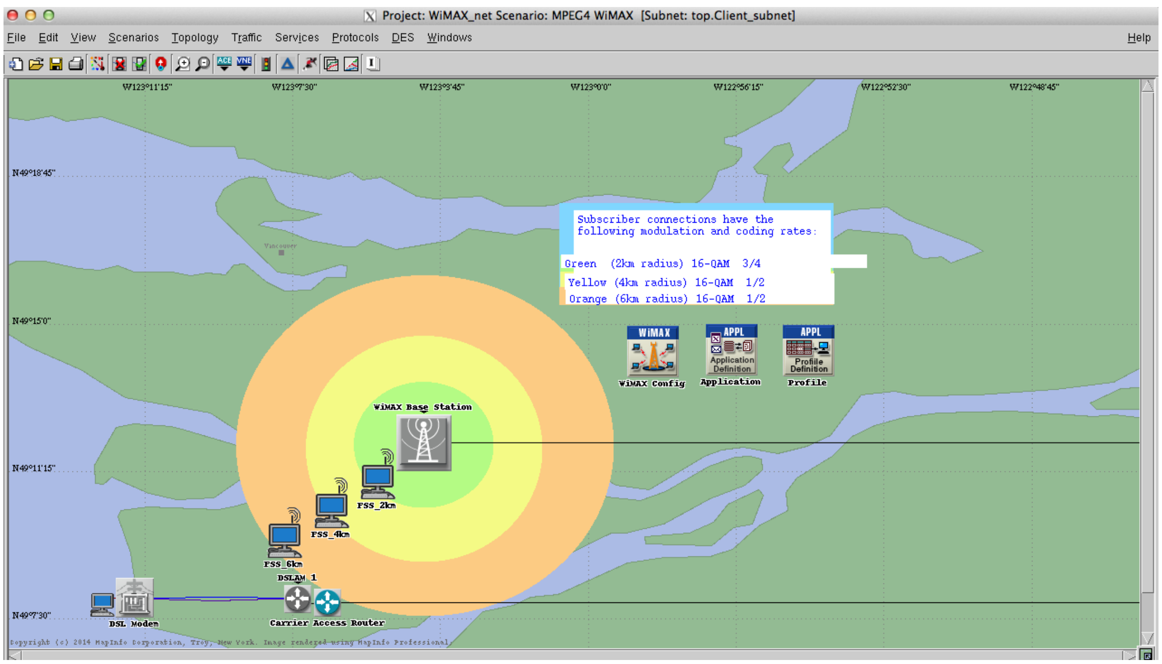

Figure B.1: Original Reference model – Client Subnet

Appendix C

Working issue of Reference Model

In order to start our project, we downloaded the reference model from https://enterprise1.opnet.com/tsts/4dcgi/MODELS_FullDescription?ModelID=978 which has been developed under OPNET 16.0.A and has the model ID 978. When we tried to open the model in OPNET 16.0.A, the below mentioned error was received.

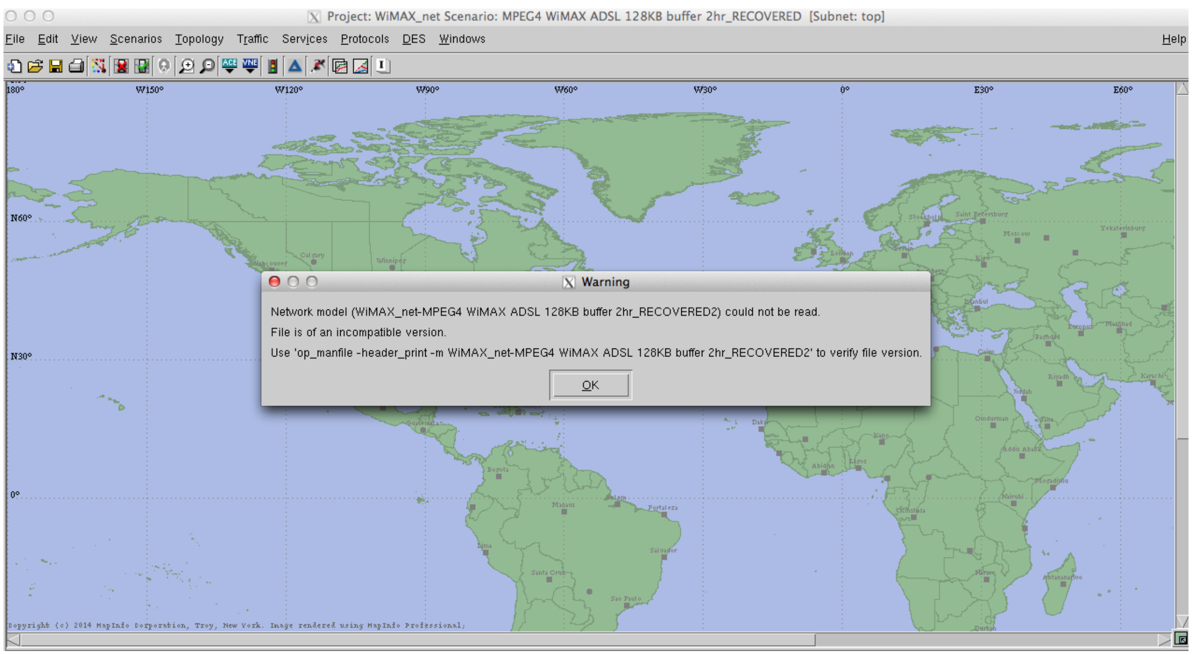

Figure C.1: Reference model error

After clicking on “OK”, it shows an empty map. In this state, we cannot run any simulations, as according to the error, the scenario in the model cannot be recovered. Hence, to solve this issue, we had to go deeper and identify the root of the problem. When we explored the folder containing the project, we noticed that there are a couple of scenarios within the project file. Hence, we opened the model in OPNET again and went to Scenarios → Switch to Scenario. Here we tried all the scenarios and found out that the only two working scenarios are MPEG4_WiMAX and MPEG4_ADSL. All the other scenarios give an unrecoverable error. Since, the goal of our project was to perform tests on mobility in the WiMAX network, the scenario MPEG4_WiMAX was sufficient.

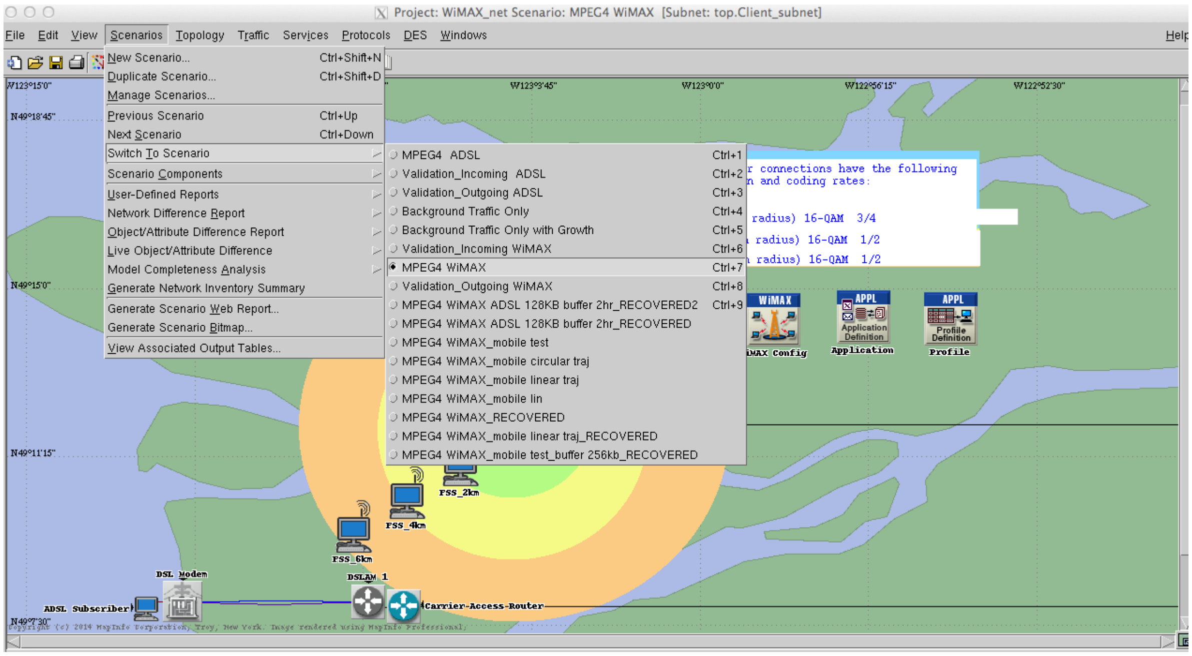

Figure C.2: List of scenarios available

We tried to understand why the above error was displaying but since the model has been developed in OPNET 16.0.A and we were trying to run it on OPNET 16.0.A, the message “File is of an incompatible version” makes no sense.