ENSC 833: NETWORK PROTOCOLS AND PERFORMANCE

SIMULATION AND PERFORMANCE ANALYSIS OF WIMAX AND WI-FI WHILE STREAMING AUDIO & VIDEO CONTENT

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FINAL PROJECT

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ABSTRACT

WiMAX (Worldwide Interoperatability for Microwave Access) is an IEEE 802.16 standard wireless technology used to provide very high data rate over large areas to a large number of users where broadband is unavailable. Wi-Fi (Wireless Fidelity) is based on the IEEE 802.11 standard used for data transmission in small areas. WiMAX and Wi-Fi are quite similar to each other on infrastructure level but speed and distance are main differentiating factors. WiMAX provides a faster and longer distance network to users than Wi-Fi. The speed of WiMAX may reach up to 70 Mbps compared to Wi-Fi that can only achieve 50 Mbps. As the radio technology develops, the speed of Wi-Fi continues to increase. The fastest speed of Wi-Fi is when using IEEE 802.11n standard, because it has doubled spectrum and bandwidth. The speed may be up to 300 Mbps. However, setup for WiMAX is more expensive than for Wi-Fi, because WiMAX needs outdoor facilities such as base stations for its implementation. The main difference between these two systems is their range. There is no doubt that WiMAX coverage is larger than Wi-Fi. WiMAX may cover up to 50 kilometers while Wi-Fi only covers 30 to 100 meters.

In order to compare the two technologies fairly, the same conditions should be applied. In this project an attempt has been made to compare the WiMAX and Wi-Fi capabilities over the same distance, which eliminates their differences and analyze their features which cause them to have different applications draws our interest. We plan to analyze the quality of service such as throughput, jitter and delay of the two networks by having the same conditions. The comparison will be implemented by streaming a high resolution video and audio content using video conferencing application.

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ACKNOWLEDGEMENT

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ACRONYMS

WiMAX	Worldwide Interoperability for Microwave Access
Wi-Fi	Wireless Fidelity
IEEE	Institute for Electrical and Electronics Engineers
QoS	Quality of Service
VoD	Video on Demand
MPEG	Moving Pictures Expert Group
fps	frames per second
RTP	Real-time Transport Protocol
UDP	User Datagram Protocol
IP	Internet Protocol
MAC	Medium Access Control
PHY	Physical Layer
GHz	Gigahertz
Mbps	megabits per second
Km	Kilometer
4G	Fourth Generation
WLAN	Wireless Local Area Network
U-NII	Unlicensed National Information Infrastructure
ISM	Industrial, Scientific, and Medical radio
bps	bits per second
MHz	Megahertz
HSPA	High Speed Packet Access
UMTS	Universal Mobile Telecommunications System
GSM	Global System for Mobile Communications
OFDM	Orthogonal frequency-division Multiplexing
BPSK	Binary Phase Shift Keying
QPSK	Quadrature Phase Shift Keying
QAM	Quadrature Amplitude Modulation
DES	Data Encryption Standard

AES	Advanced Encryption Standard
CSMA/CA	Carrier Sense Multiple Access/Collision Avoidance
AP	Access Point
W	Watt
ToS	Type of Service
OFDMA	Orthogonal Frequency-Division Multiple Access
dBi	decibels-isotropic
dBm	decibels per milliwatt
msec	milliseconds
Mbps	Megabits per second

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1. INTRODUCTION

WiMAX (Worldwide Interoperability for Microwave Access) and Wi-Fi (Wireless Fidelity) are two wireless network technologies that are well known and widely used in normal life. However, there are some notable differences between these two technologies. First of all, WiMAX covers a large area where as Wi-Fi is commonly used for smaller area within homes or business location. The range of Wi-Fi is about 30 to 100 meters while WiMAX is 50 Kilometers. The frequencies used and the power of the transmitter are the key reasons for this huge difference. Secondly, WiMAX has a faster speed than Wi-Fi. The most popular and common Wi-Fi standard is 802.11g. It offers a speed up to 50 Mbps. WiMAX on the other hand provides 70 Mbps data rates. Next, Wi-Fi could not guarantee the Quality of services (QoS) while WiMAX provide several levels of QoS. QoS is the overall performance of network which includes some common aspects such as throughput, jitter, delay and load.

Video/audio streaming is gaining wider adoption in the Internet community. Unmanaged services refer to Internet services that have little control over the end-to-end performance between the subscribers and corresponding services. This project is designed around streaming services using an Internet topology on expected video/audio performance. In this project, we will initially test and analyze the behavior of WiMAX and Wi-Fi in similar environment where some typical test scenarios will be set for data gathering. With desire data gathered, we will compare the critical properties of these two technologies such as throughput, delay, load, traffic received/sent and analyze the performance of WiMAX and Wi-Fi communication networks.

The last part is our main focus in this project. Test scenarios will be slightly adjusted for both Wi-Fi and WiMAX in order to eliminate their differences such as the scale of network. We would like to implement our performance test by streaming a high resolution video. The test will be simulated on Riverbed Modeler 18.0 which is a network simulation software tool. Some statistics and graphs will be presented in simulation section to provide a better picture of the comparison result.

2. BACKGROUND KNOWLEDGE

2.1. Streaming Video Content

Video content consists of both the audio and the visual information. This information is available in media service providers; like sporting events, movies in real time and video on demand (VoD) formats. This is known as real-time multimedia services over the Internet. Real-time transport of live video or stored video is the significant part of real-time multimedia. This project focuses on video streaming, which refers to real-time transmission of stored video.

There are two modes for transmission of stored video over the Internet: the download mode and the streaming mode (video streaming). In the video streaming mode, it is not essential to download the full video content, but it is being played-out while parts of the content are being received and decoded. As it is real-time, video streaming has bandwidth, delay and loss requirements [2].

For video streaming the video content is organized as a sequence of frames or images that are sent to the subscriber and displayed at a constant frame rate. The video component is coupled with a multi-channel audio component that is also structured as a series of audio frames which is included in the video content. The video content may be characterized by several parameters including video format, pixel color depth, coding scheme and frame inter arrival rate.

Due to these characters the raw video size becomes very large, which affects transmission and buffering requirements from the network. To reduce their traffic load requirements, streaming services encode uncompressed content using MPEG-x and H.26x codecs. While these encoded streams are marginally loss-tolerant, their performance is inherently a function of available link bandwidth and delay characteristics.

Video frame inter-arrival rates can range from 10 frames per second (fps) to 30 fps. This parameter can be especially critical as network conditions can influence the frame inter-arrival rates and which if left uncompensated, significantly degrades the video playback quality. Figure 1 illustrates the necessity of the client video system to playback frames at a constant rate amidst variable delays in video frame packet arrivals [1].

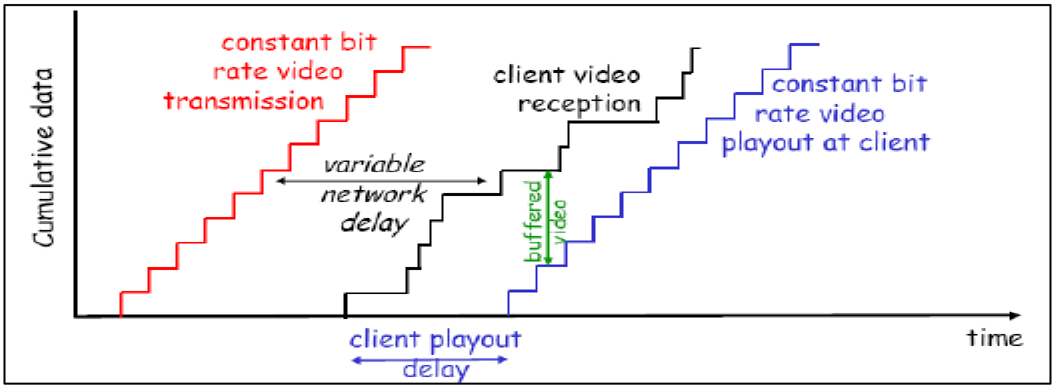

Figure 1: Video client buffering [2]

Figure 2 illustrates architecture for video streaming. The raw video and audio data are pre-compressed by compression algorithms and then saved in storage devices. Upon client's request, a streaming server retrieves compressed data from storage devices and then the application-layer quality of service (QoS) control module adapts the video/audio bit-streams according to the network status and QoS requirements. The transport protocols packetize the compressed bit-streams and send the packets to the Internet. Packets may be dropped or experience excessive delay inside the Internet due to congestion. For packets that are successfully delivered to the receiver, they first pass through the transport layers and are then processed by the application layer before being decoded at the video/audio decoder. [1].

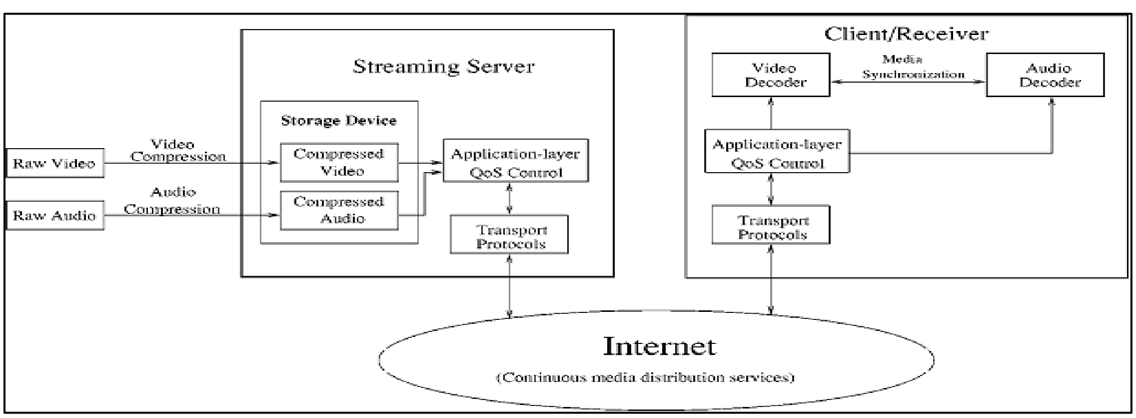

Figure 2: Architecture of video streaming [4]

Figure 3 shows the protocol stack for streaming video services includes the Real Time Protocol (RTP) that provisions a packet structure for video/audio data above the transport layer protocol. RTP specifies a twelve-byte header with protocol fields to describe the type of content being carried (MPEG-4), packet sequencing, and time stamping. Since RTP resides on top of the transport protocol, it is deployed in the end-systems rather than in the network core. RTP does not provide mechanisms to guarantee bandwidth or packet delays [1]. But it provides services like time-stamping, sequence numbering, payload type identification, source identification [1].

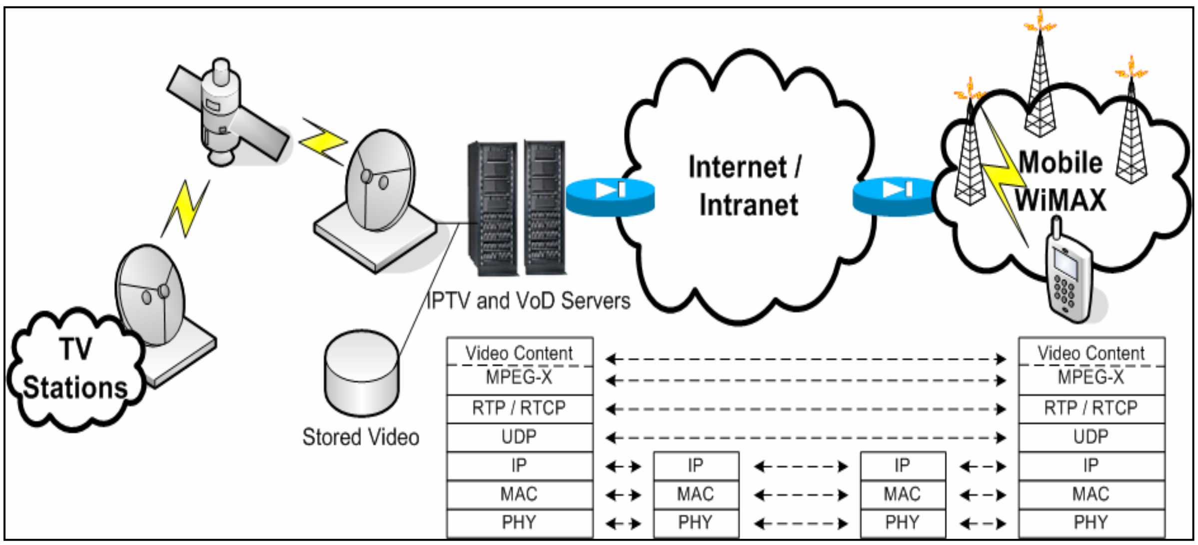

Figure 3: Video streaming network topology [1]

Below the RTP layer, usual streaming services utilize the User Datagram Protocol (UDP) because it provides best effort service without delay, loss, or bandwidth guarantees. UDP is connectionless, unreliable and it does not provide flow control or congestion control. The lack of reliability and congestion control mechanisms are desirable properties in media content streaming because video servers can stream their content at the native video/audio source encoding rates without being constrained by congestion control when packet loss occurs. UDP segments are then encapsulated into unicast (or multicast) IP packets for proper addressing and routing to the video client stations.

IP packets can be lost due to router buffer overflows or delayed due to router congestion, which impacts the client station playback rate as outlined earlier. IP packets pass through appropriate media access control (MAC) and physical (PHY) layers and then propagate through the Internet and access networks, which can be wired or wireless, to the client subscribers. Subscriber stations buffer, decompress and playback the video/audio frames at a constant rate [1].

By observing communication performance between the server and the client, four performance metrics with appropriate thresholds may be used to measure streaming performance. Furthermore, these metrics enable comparisons between WiMAX and Wi-Fi connected clients because they access the same VoD services over the same wired network infrastructure. The performance metrics are:

- Throughput
- Jitter
- Delay
- Packet loss

2.2. WiMAX (802.16a)

WiMAX (worldwide Interoperability for Microwave Access) is a wireless communication technology which first proposed at 2001 intended to replace Wi-Fi as a wireless transmission method. However the performance of WiMAX is closer to 3.5G (High Speed Downlink Packet Access) which focused on long distance transformation yet having lower transformation speed comparing with Wi-Fi. The original WiMAX version, 802.16a, occupies range of 10 to 66 GHz, and added specifications for 2 to 11 GHz range in 2004 with the updated 802.16-2004 standard.

In 2005, WiMAX based on IEEE 802.16e was approved as a new wireless communication standard. It is theoretically capable of providing a maximum speed up to 75 Mbps and can cover a maximum distance of 50Km. As a competitive wireless communication standard, WiMAX is used in 178 countries, with 1.7 million customers in Asia and 1.4 million in the USA and Canada, amongst over 10 million users around the world [7]. As competing advantages, it has more signal coverage, better frequency utilization and bandwidth efficiency, cheaper equipment and lower energy usage than other pre 4G (the fourth generation of mobile phone mobile communication technology standards) standards. The WiMAX does also support mobile product. In fact, the ungraded version of WiMAX, the WiMAX - Advanced, which is based on standard IEEE 802.16m was intended to satisfy the needs for the 4G standard and is now one of the two 4G standards wildly used around the world. In this report, however, we will focus on the behavior of WiMAX based on standard 802.16a. The WiMAX network configuration is shown in Figure 4.

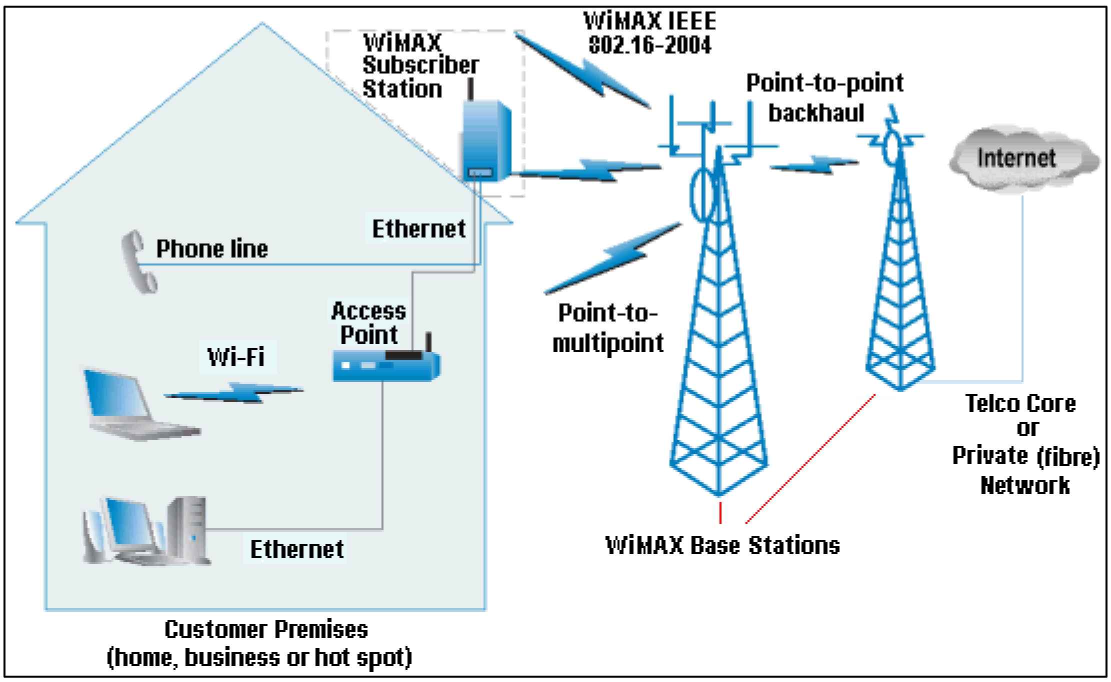

Figure 4: WiMAX Network configuration [3]

2.3. Wi-Fi (802.11a)

Wireless network is a kind of ability to connected personal computer and handheld devices as terminal wirelessly. Wi-Fi as a trademark of the Wi-Fi alliance is one type of a wireless network communication technology. Wi-Fi as one important part of WLAN is based on the IEEE 802.11family of standards. There are various types of 802.11 and majority of the wireless router is based on IEEE 802.11a and 802.11g that support a peak physical-layer data rate of 54Mbps and typically provide indoor coverage over a distance of 100 feet [6]. Comparing with the wide coverage of radio waves, the radio coverage based on Bluetooth technology is small that near 30 feet. Therefore, one significant benefit of Wi-Fi over Bluetooth is the wide scope of coverage. Wi-Fi can meet the needs of individual and social information as the transmission speed can deliver 11 mbps. The IEEE 802.11a was published in 1999. It provides data rates to 54 Mbps in the 5 GHz U-NII bands by using the Orthogonal Frequency Division Multiplexing. Comparing to 802.11 that just three in the 2.4 GHz ISM bands, more spectrums in U-NII bands allows room for 12 non-overlapping channels. In addition, it has development to allow the seamless handoff of communication between the overlapping. The user can use laptop or smart phone to connect to Internet by connecting to wireless router for Wi-Fi services [6].

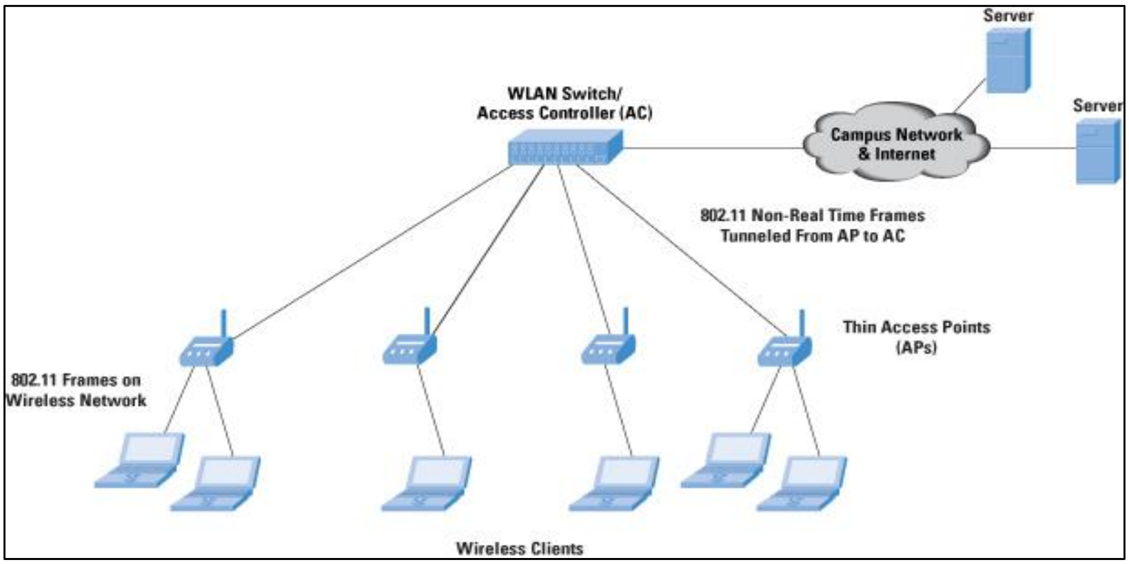

Figure 5: Wi-Fi Network configuration [5]

2.4. Comparison between WiMAX and Wi-Fi

Since WiMAX and Wi-Fi both are based on IEEE standards, however, Wi-Fi is based on IEEE 802.11 standard and WIMAX is based on IEEE 802.16. For bit rate between Wi-Fi and WiMAX, the range of operating in 20 MHz channel is between 2.7bps/Hz and 54Mbps, nevertheless, the range of WiMAX works between 5bps/Hz and 100Mbps in 20 MHz channel. Although, WiMAX and Wi-Fi are both belongs to wireless local area network, however, Wi-Fi works faster but in shorter range, mostly used in in-house applications. Whereas, WiMAX operates slower but works over much longer ranges. The speed Vs mobility graph is shown in Figure 6.

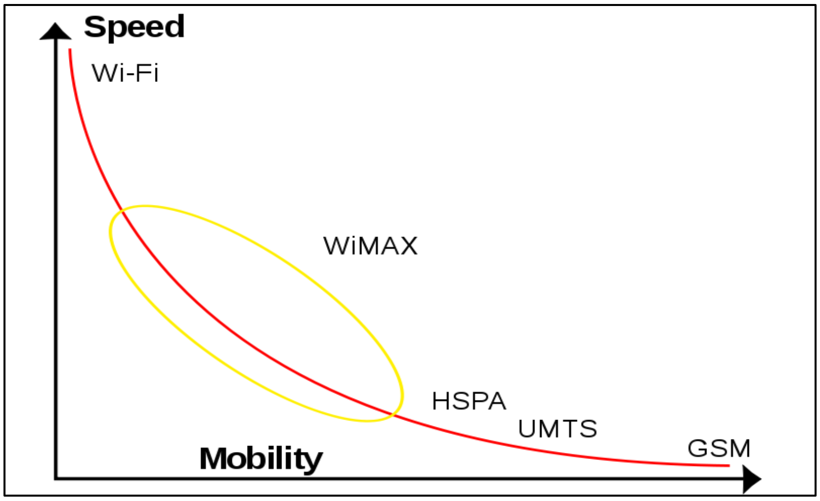

Figure 6: Speed Vs Mobility on Wi-Fi and WiMAX [6]

Wi-Fi provides peer-to-peer connections between users and creates a mesh network. To the contrary, WiMAX provides high-speed mobile data and telecommunication services. The characteristics comparison between Wi-Fi and WiMAX are shown in Table 1.

Feature	**WiMAX(802.16a)**	**Wi-Fi(802.11a)**
Primary Application	Broadband Wireless Access	Wireless LAN
Frequency Band	Licensed/Unlicensed 2G to 11GHz	5GHz U-NII
Channel Bandwidth	1.25M to 20MHz	20MHz
Half/Full Duplex	Full	Half
Radio Technology	OFDM (256-channels)	OFDM (64-channels)
Bandwidth Efficiency	<=5 bps/Hz	<=2.7 bps/Hz
Modulation	BPSK, QPSK, 16-, 64-, 256-QAM	BPSK, QPSK,16-, 64-QAM
Forward error correction	Convolution Code Reed-Solomon	Convolution Code
Encryption	Mandatory-3DES Optional-AES	Optional-RC4 (AES in 802.11i)
Mobility	Mobile WiMAX (802.16e)	In development
Mesh	Yes	Vendor Proprietary
Access Protocol	Request/Grant	CSMA/CA

Table 1: Comparison between WiMAX and Wi-Fi [3]

2.5. Riverbed Modeler

Riverbed Modeler is one tool to simulate the behavior of the oriented network. The simulator makes possible modeling and simulating the wired and wireless network in the comprehensive development environment. It allows users to create customized models and simulate different types of network scenarios. Riverbed Modeler is used to create models and simulate the wireless scenarios. The Modeler is object-oriented and employs the communication network using the hierarchical method. It allows graphical user to capture the technical data of deployed networks and protocols. The three-tiered Riverbed Modeler hierarchy consists of three domains including network, node that specifies object in network domain and process that specifies object in node domain. Simulating WiMAX and Wi-Fi by using Riverbed Modeler 18.0 provides us high-fidelity modeling, protocol stack such as routing, layer protocols and application, and analysis of deployed network such as throughput, delay, jitter, traffic received and sent. It also can show us three kinds of output including vectors, scalars and animations.

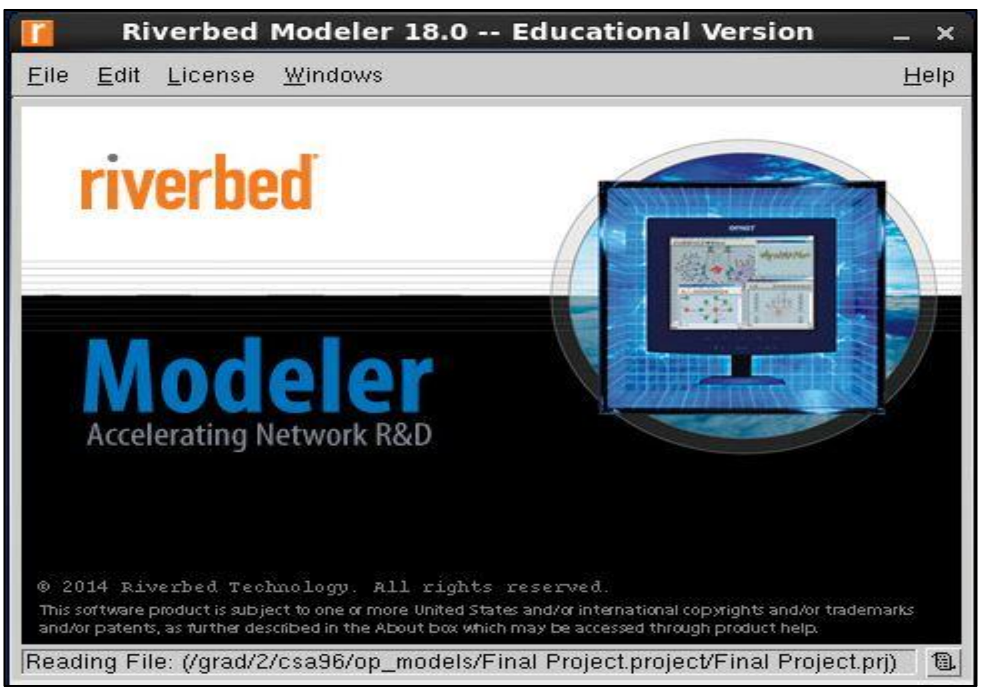

Figure 7: Start View of Riverbed Modeler 18.0

3. SIMULATION DESIGN & RESULTS

3.1. Simulation Design

We plan to perform two test scenarios in this project for streaming high resolution video by using video conferencing application in both WiMAX and Wi-Fi networks together in a small area network. Riverbed Modeler test scenarios developed for WiMAX and Wi-Fi network for fixed and mobile stations in a small-scale network of 1 Km × 1 Km are shown in Figures 8 and 9, respectively.

3.1.1. Scenario 1

Figure 8 captures the network topology consisting of WiMAX and Wi-Fi networks with fixed mobile station. In this scenario, a fixed station each in the range of WiMAX and Wi-Fi network is located which will access the video streaming from the same server located on a remote location. Server is configured for video conferencing application. Video conferencing is an interactive telecommunication technology that allows two or more locations to simultaneously interact via two-way video and audio transmissions.

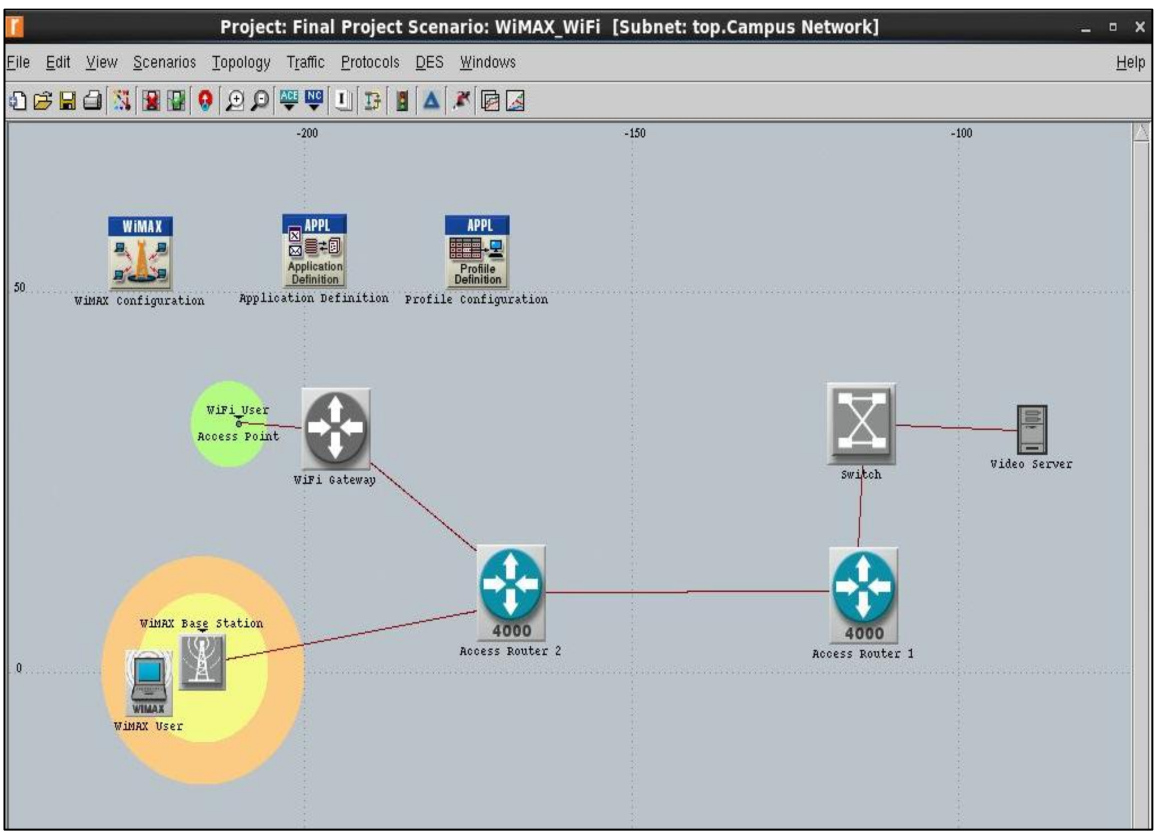

Figure 8: WiMAX and Wi-Fi Network Scenario with Fixed Nodes

3.1.2. Scenario 2

Figure 9 captures the network topology consisting of WiMAX and Wi-Fi networks with moving mobile station. In this scenario, a mobile station each in the range of WiMAX and Wi-Fi network is located accessing the video streaming from the same server located on a remote location while roaming. The trajectory of mobile stations is depicted with red line. Figure 10 and Figure 11 shows the extended zoom view of Wi-Fi and WiMAX mobile station trajectories, respectively.

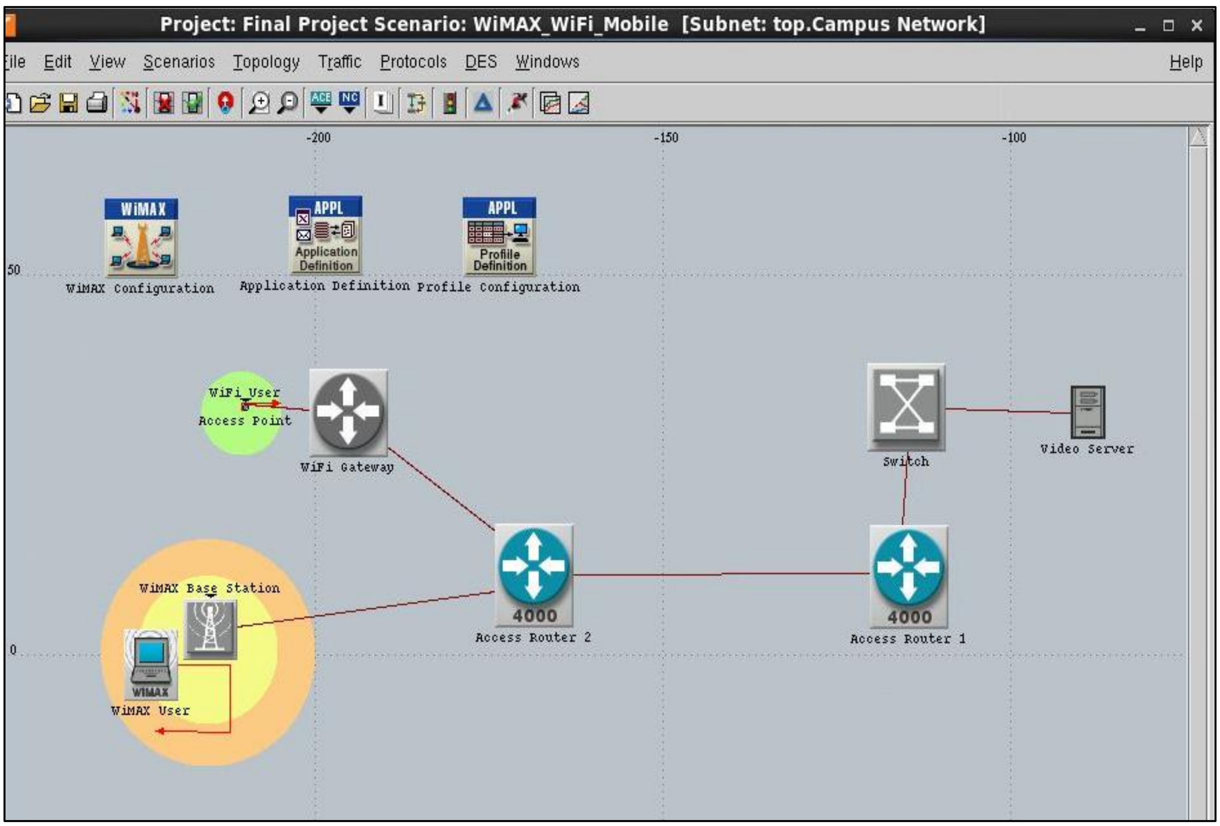

Figure 9: WiMAX and Wi-Fi Network Scenario with Moving Nodes

In both networks, the trajectories have been defined in such a manner that the mobile stations first roam within the very close range of Wi-Fi access point and WiMAX base station while later moves away from their range to see the variation in simulation results as the distance between the client and Wi-Fi access point or WiMAX base station increases.

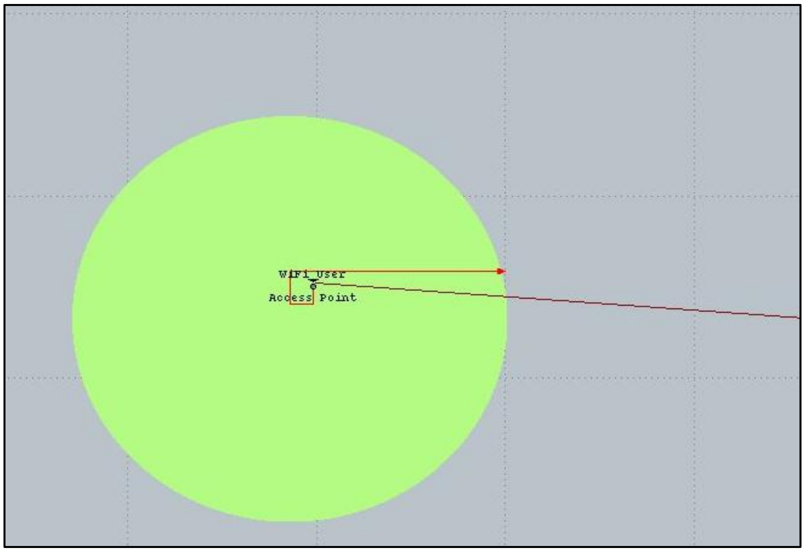

Figure 10: Trajectory of Wi-Fi User in Network Scenario with Moving Nodes

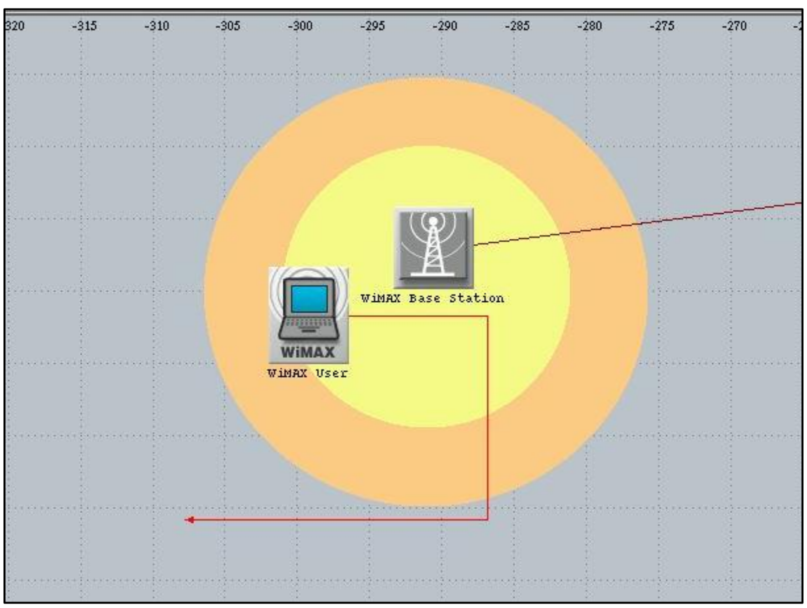

Figure 11: Trajectory of WiMAX User in Network Scenario with Moving Nodes

The WLAN parameters for Wi-Fi network used in the model are presented in Tables 2 and Table 3. The parameters used for mobile and wireless stations are shown in Table 2. We applied the extended rate physical (PHY) layer (802.11g) standard for Wi-Fi network with 54 Mbps date rate for both Wi-Fi mobile workstation and the AP.

BSS identifier	Auto assigned
Access point functionality	Enabled
Physical characteristics	Extended rate PHY (802.11g)
Data rate (bps)	54 Mbps
Transmit power (W)	2.0
Packet reception-power threshold	-95
Short retry limit	7
Long retry limit	4
Buffer size (bits)	256,000

Table 2: Wireless LAN parameters for Wi-Fi Network

Traffic characteristics are shown in Table 3.

Match property	IP To S
Match condition	Equals
Match value	Excellent effort

Table 3: Traffic characteristics

The WiMAX parameters are shown in Table 4. Antenna gain of 15 dBi, maximum transmission power of 3.8W, PHY profile wireless OFDMA with 5MHz, and receiver sensitivity of -200 dBm are used in WiMAX network for both scenarios.

Antenna gain (dBi)	15 dBi
MAC address	1
Maximum transmission power (W)	3.8
PHY profile	Wireless OFDMA 5 MHz
PermBase	1
Receiver sensitivity	-200 dBm

Table 4: WiMAX Base station parameters

3.2. Simulation Results

We would like to demonstrate the graphic results and make comparison between WiMAX and Wi-Fi networks on their data transmission performance in this section.

3.2.1. Traffic Received/Sent

Figure 12 shows the traffic received (bytes/sec) of WiMAX and Wi-Fi network in case of fixed node scenario where the red line representing WiMAX and the blue line represents Wi-Fi. It is clear that the traffic received by WiMAX is much higher than the Wi-Fi network.

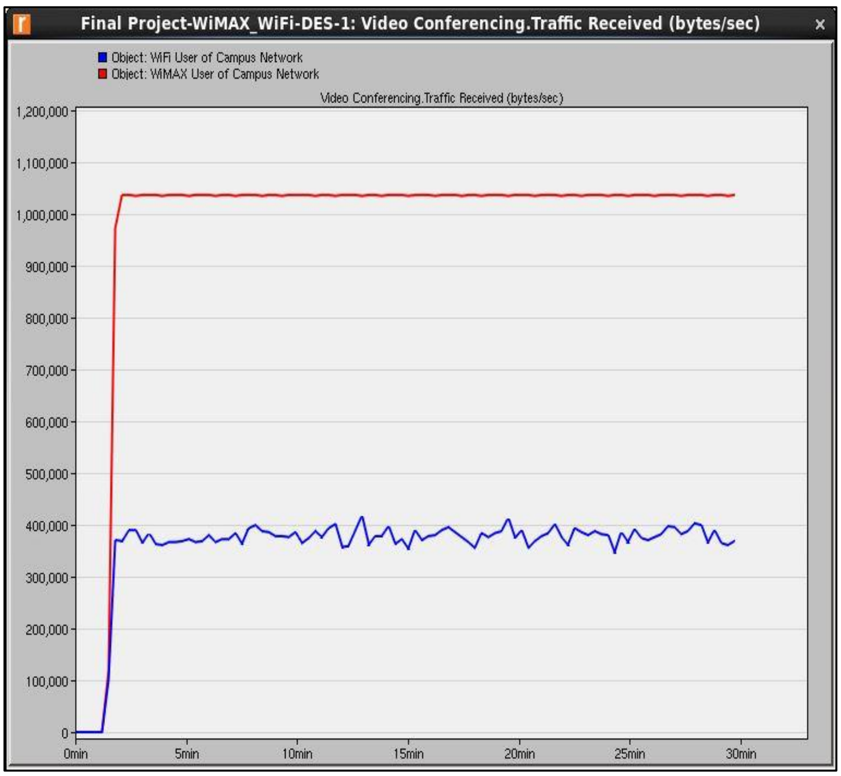

Figure 12: Traffic Received of Network Scenario with Fixed Nodes

Figure 13 shows the traffic received (bytes/sec) of WiMAX and Wi-Fi network in case of mobile node scenario with same color representation. In this case, it is interesting to find that as the Wi-Fi user is in very near range (within 10 m) of access point, it receives higher traffic than WiMAX which indicates that Wi-Fi transmission is nearly perfect for small area network. However, as the distance between the Wi-Fi user and access point increased, the traffic received suddenly decrease abruptly. On the other hand, the traffic received by the WiMAX user is mostly stable throughout the simulation period.

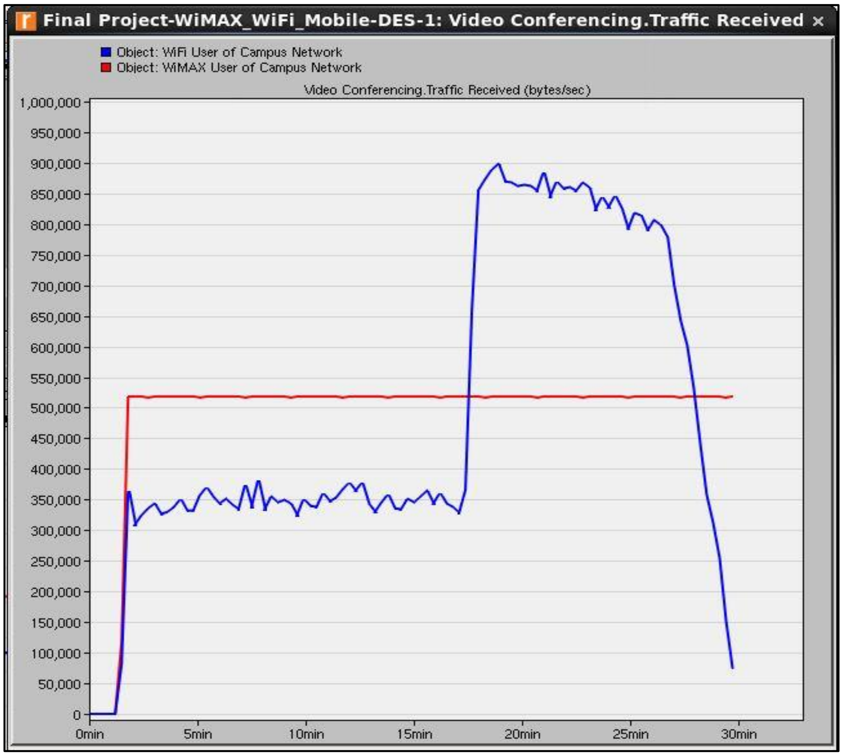

Figure 13: Traffic Received of Network Scenario with Mobile Nodes

The above results show that Wi-Fi is best suited for small area networks whereas WiMAX gives better performance for large area networks. The WiMAX coverage is larger than Wi-Fi. WiMAX may cover up to 50 kilometers while Wi-Fi only covers 30 to 100 meters.

Figure 14 and Figure 15 shows the traffic sent (bytes/sec) of WiMAX and Wi-Fi network in case of both fixed and mobile station scenarios respectively. In both scenarios, the results show that the traffic sent by WiMAX user is almost double the traffic sent by Wi-Fi user to the server. Since Wi-Fi does not provide the broadband Internet services, WiMAX provides broadband service to carry additional load in the network.

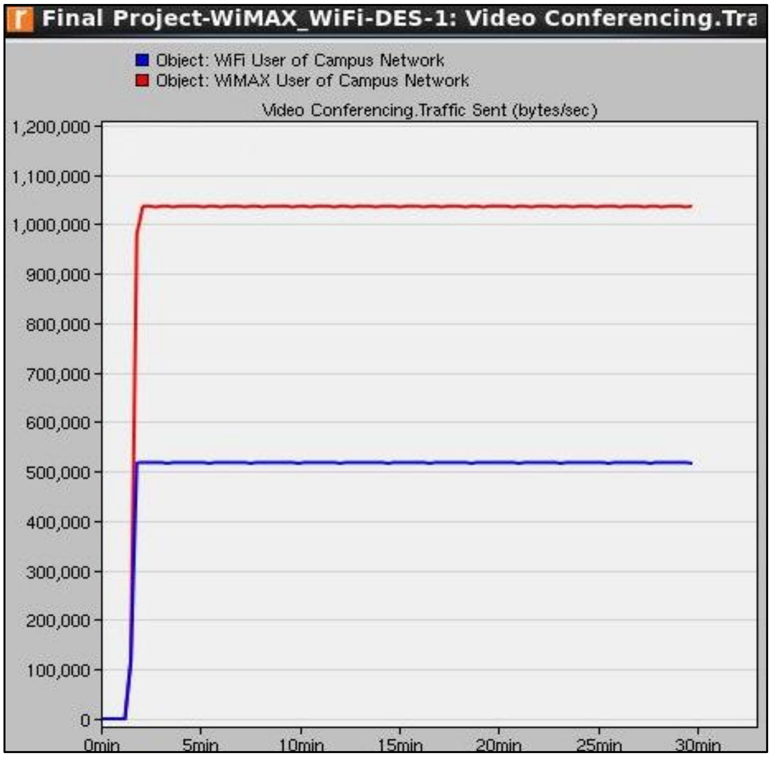

Figure 14: Traffic Sent of Network Scenario with Fixed Nodes

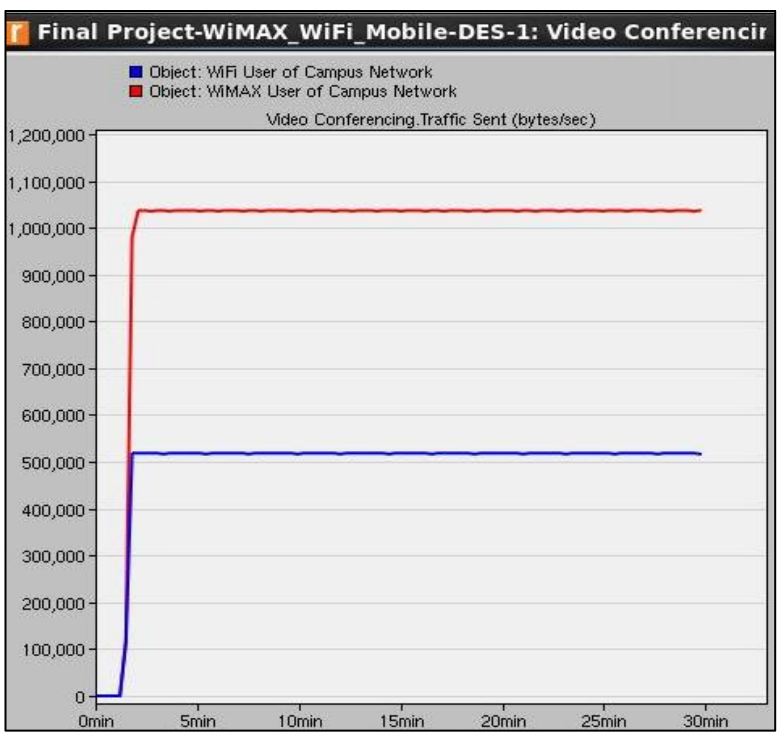

Figure 15: Traffic Sent of Network Scenario with Mobile Nodes

3.2.2. Throughput

The average rate of successful packet delivery through the channel is showing visually as the throughput in the following figures. In case of fixed mobile station scenario the throughput for WiMAX is higher than Wi-Fi as shown in Figure 16. The throughput is almost doubled in WiMAX network than Wi-Fi.

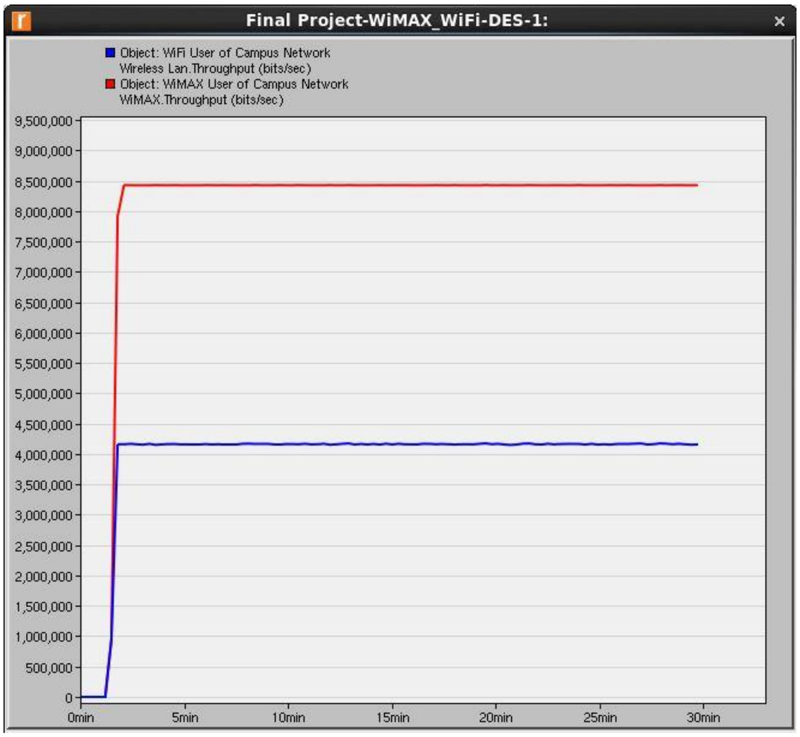

Figure 16: Throughput of WiMAX and Wi-Fi Network with Fixed Node

However in case of roaming station it is interesting to note that as the Wi-Fi user is within 10m range of access point, it gives better throughput than WiMAX. However, as this Wi-Fi user moves away from the Wi-Fi access point, its throughput decreases gradually and becomes zero as it moves out of the range of the Wi-Fi coverage. While the throughput WiMAX is stable as the mobile station moves away from the WiMAX base station suggesting that WiMAX gives better performance for long area coverage.

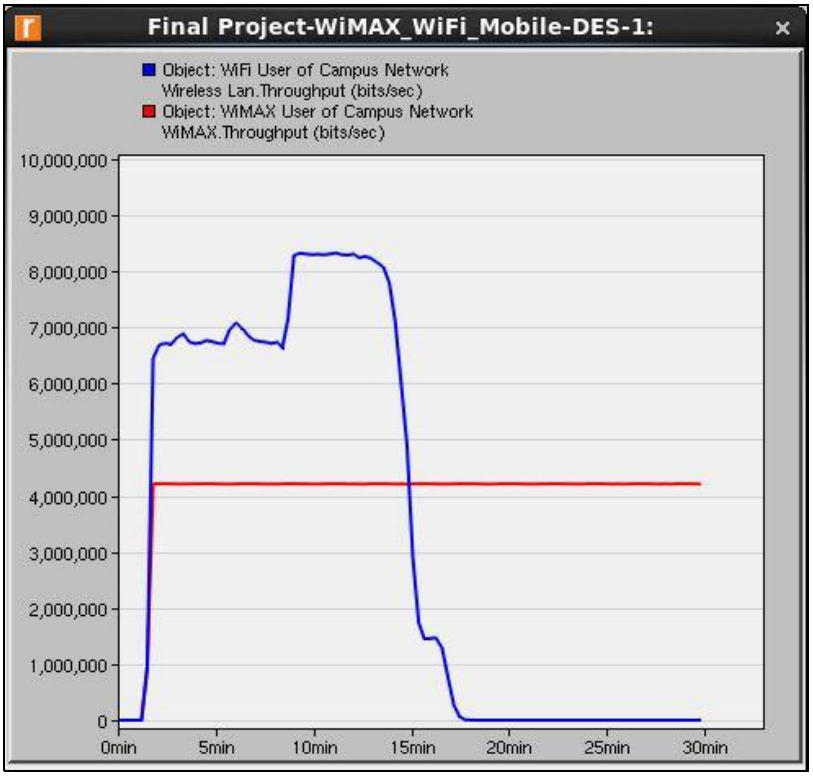

Figure 17: Throughput of WiMAX and Wi-Fi Network with Mobile Node

This suggests that the WiMAX is overall a better communication network by only looking at the aspect of throughput.

3.2.3. Jitter

Figure 18 shows the average packet delay variation (jitter) of WiMAX and Wi-Fi network in case of fixed mobile station scenario where the red line representing WiMAX and the blue line represents Wi-Fi. Jitter is an interval between subsequent packets. It is caused by network congestion, route alteration etc. Video Conferencing applications are highly sensitive to the factors of Jitter and packet loss. Hence these factors need to be kept at minimum values in order for the QoS to be as high as possible in transmitting or streaming a video application. Jitter should be kept under 30 msec. The simulation result shows that in both networks jitter is below 30msec which is good for a video conference application to generate a good picture quality.

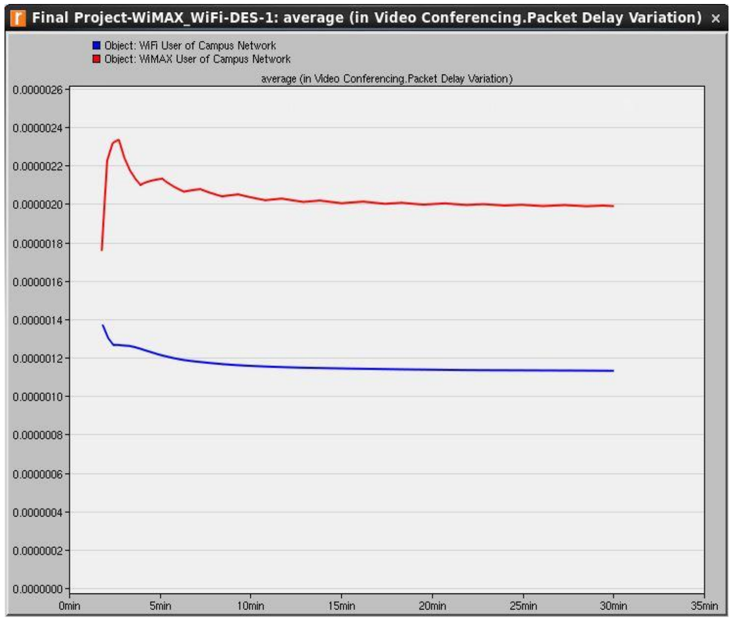

Figure 18: Jitter of WiMAX and Wi-Fi Network with Fixed Node

However in case of mobile station scenario, as the Wi-Fi user moving away from the access point, the jitter value for Wi-Fi network dramatically increased depicting WiMAX became the superior network for video conferencing applications which has lower delay variation. This shows the sensitivity of Wi-Fi and the stability of WiMAX.

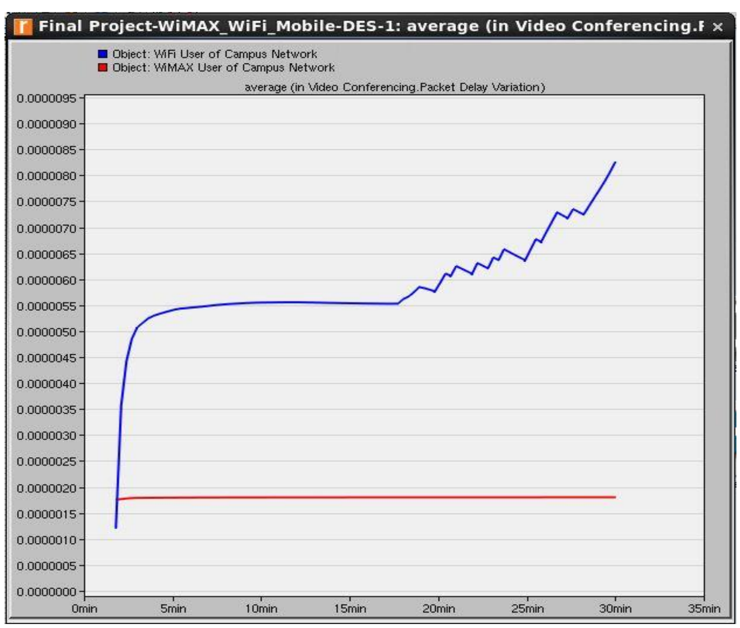

Figure 19: Jitter of WiMAX and Wi-Fi Network with Mobile Node

3.2.4. Delay

Another aspect we compared is the delay. Delay has major impact on users experience accessing internet which is expected to be smooth by any user. The delay provides a more intuitive feel for the performance of the corresponding communication network where a better network would have a lower delay. Figure 20 shows the delay of WiMAX and Wi-Fi network in case of fixed station scenario where the red line representing the delay of WiMAX and the blue line represents the delay of Wi-Fi. The delay of Wi-Fi is almost one-third of the delay of WiMAX. This means the transmission of Wi-Fi is faster and smoother in a small area network as compared to WiMAX.

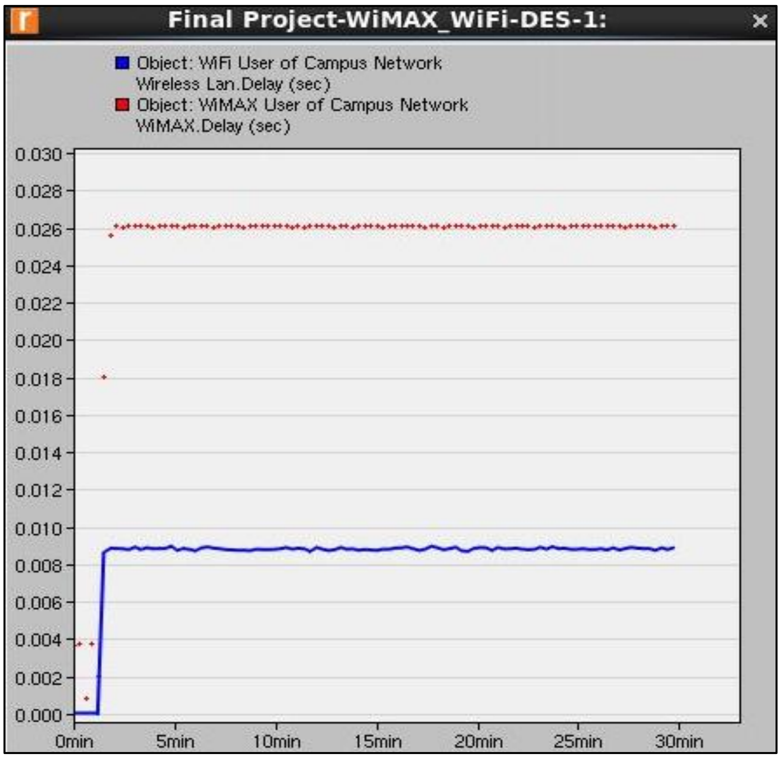

Figure 20: Delay of WiMAX and Wi-Fi Network with Fixed Node

Figure 21 shows the delay of WiMAX and Wi-Fi network in case of moving mobile station scenario with same color representation as in case of fixed node scenario. In this case also, the delay of Wi-Fi is less than the delay of WiMAX as long as Wi-Fi user remains in the specified range of Wi-Fi network. However as soon as the Wi-Fi user is roaming outside the range of Wi-Fi network, its delay is significantly increased and causing WiMAX became the superior network which has lower delay. This graph also shows the sensitivity of Wi-Fi and the stability of WiMAX network.

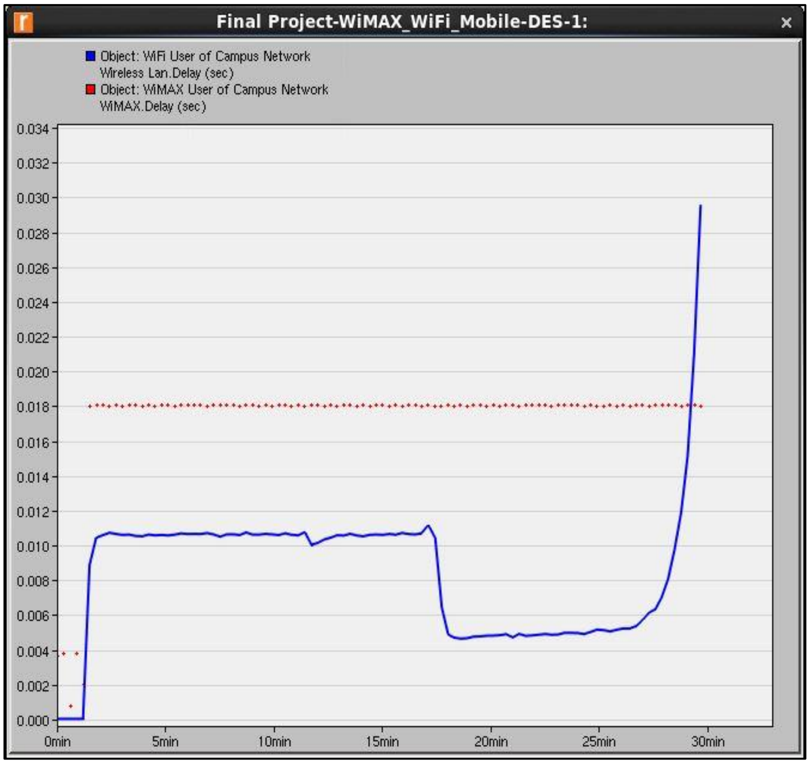

Figure 21: Delay of WiMAX and Wi-Fi Network with Mobile Node

3.2.5. Load

Figure 22 and Figure 23 shows the simulation results of load (bits/sec) for WiMAX and Wi-Fi networks in both fixed and mobile node scenarios where the red line representing WiMAX load and blue line represents load of Wi-Fi network load. It is clear from the graphs that WiMAX networks can sustain higher load than Wi-Fi network. Wi-Fi carries 4000,000 bits over the network while WiMAX can carry 85,000,000 bits in both cases.

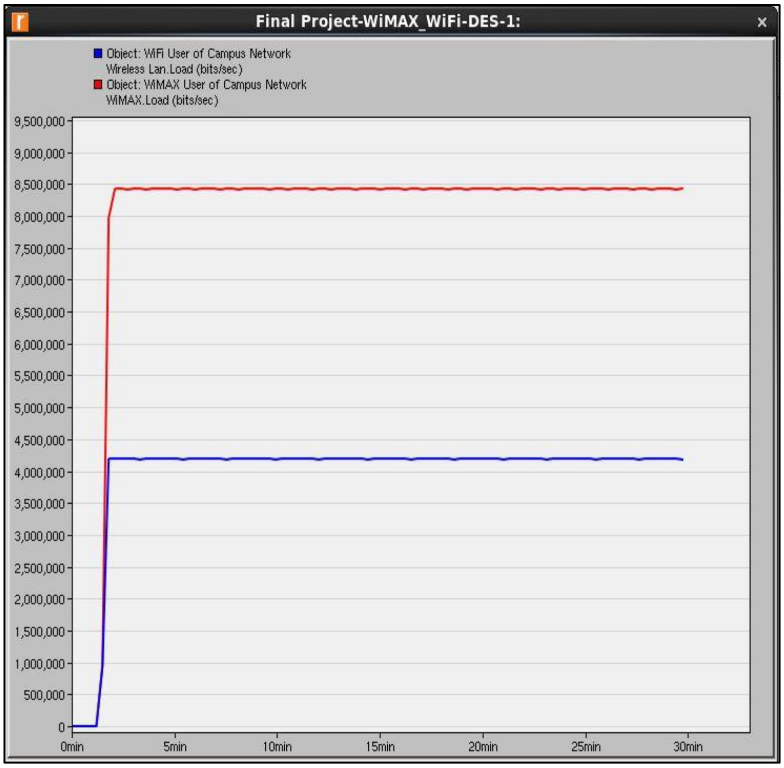

Figure 22: Load of WiMAX and Wi-Fi Network with Fixed Node

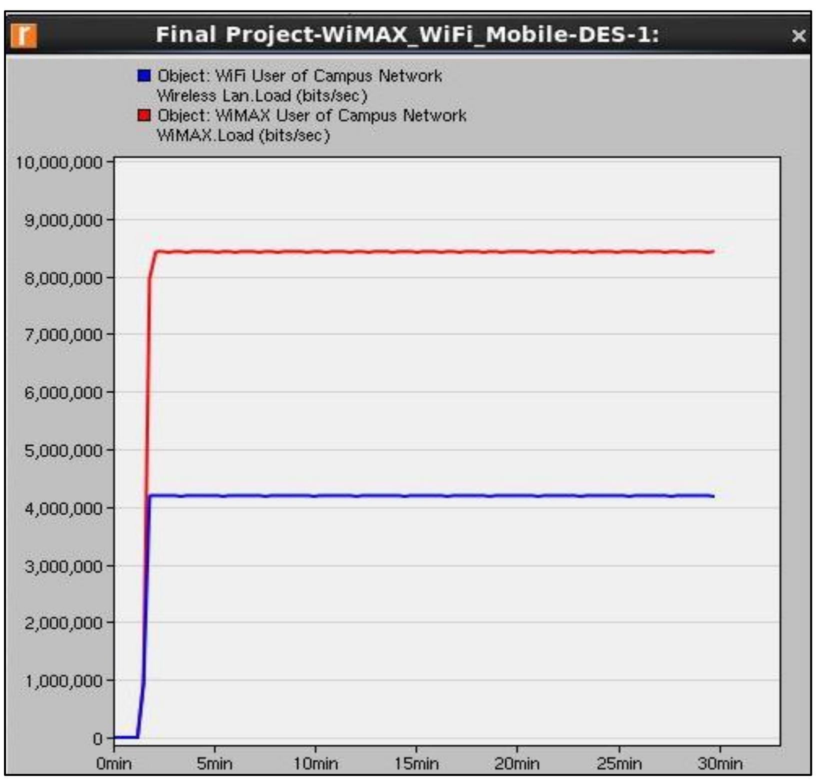

Figure 23: Load of WiMAX and Wi-Fi Network with Mobile Node

4. CONCLUSION AND FUTURE WORK

4.1. Discussion

Although these wireless devices are very close to access point or WiMAX base station, we can still see some differences or outstanding results on each graph especially on throughput result. That is because of multipath effects. Multipath effects will make radio signals reach mobile station by different paths due to refraction and reflection of the atmosphere [8]. From the graphs in the simulation results section, we believe that WiMAX has an overall better performance than Wi-Fi mainly because of Quality of Service (QoS). The goal of QoS is to ensure high data transmission performance such as throughput, jitter and delay [7]. We have proved this result in our simulations for by streaming high resolution video.

4.2. Conclusion

From the analyses of our data, we can conclude that at smaller range of typically 10 to 20 meters, Wi-Fi has better performance with higher band width efficiency and lower delay. However this advantage decays and eventually is exceeded by WiMAX as the distance between wireless devices and access point or base station increased. At larger range of few kilometers WiMAX have better performance and is the better network having higher throughput and lower delay. This result did meet our expectation, and does explain why these two communication networks have their different applications whereas WiMAX is more regional oriented, and Wi-Fi is used for a much smaller area.

The fast transmission speed of Wi-Fi makes it a perfect communication network for close range information transmission. However, it is dramatically affected by the distance between the access point and the client. As a result, Wi-Fi is rarely used for long distance information transmission. Meanwhile, the superiority of WiMAX where it is much less sensitive to distance increases and is capable to remain relatively stable with greatly increased distance makes is a great choice for long distance information transmission.

4.3. Challenges

Numerous challenges were experienced throughout this project. Initially, environment problem was faced due to which simulation and log in (license expiration) were big issues.

Additionally, the major challenge was disk quota. Linux operating system has limited disk quota and it did not support simulation for 2 hours (which was reference model run time). So, the simulation was run for only 30 minutes and analysis of the results of those 30 minutes was done.

Finally, learning WiMAX and Wi-Fi fundamentals within the duration of this project to drive the design of this simulation model proved to be challenging given the breadth and depth of the technologies.

4.4. Future Work

After comparing the above key data transmission parameters, we conclude that WiMAX outperforms Wi-Fi. However, we can still see some shortage on WiMAX compared to Wi-Fi nowadays. Most of our current mobile devices do not have WiMAX capability. Therefore, wireless users are not able to enjoy the advantages of using WiMAX network technologies. The solution of this problem is to integrate Wi-Fi and WiMAX technologies together in order to maximize their performance. This can be done by connecting a WiMAX WLAN router to a WiMAX base station. That is also what we want to implement in our future simulations. Moreover, we would like to see the data transmission performance on Wi-Fi and WiMAX when a large number of users are using network at a same time.

5. REFERENCES

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APPENDICES

Appendix A. Parameters Setup in Riverbed Modeler Scenarios

The following Riverbed Modeler simulation parameters were used in the simulation runs for WiMAX and Wi-Fi network for this project:

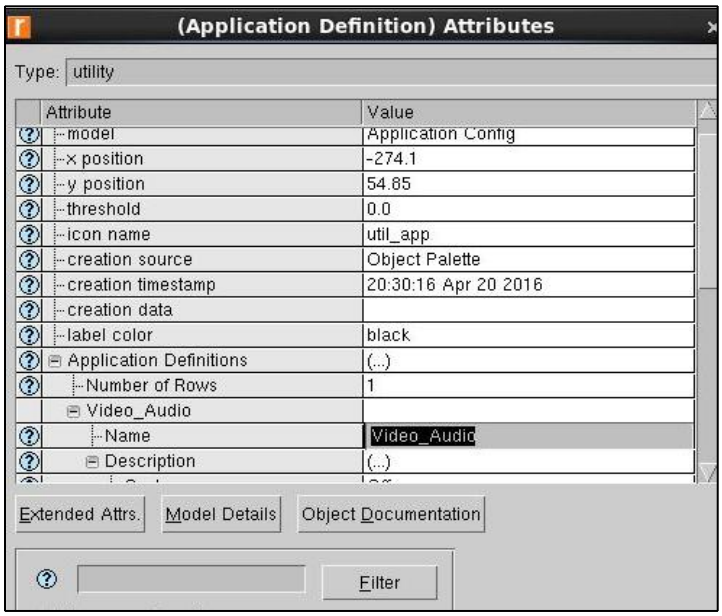

Figure 24: Application Definition Attributes

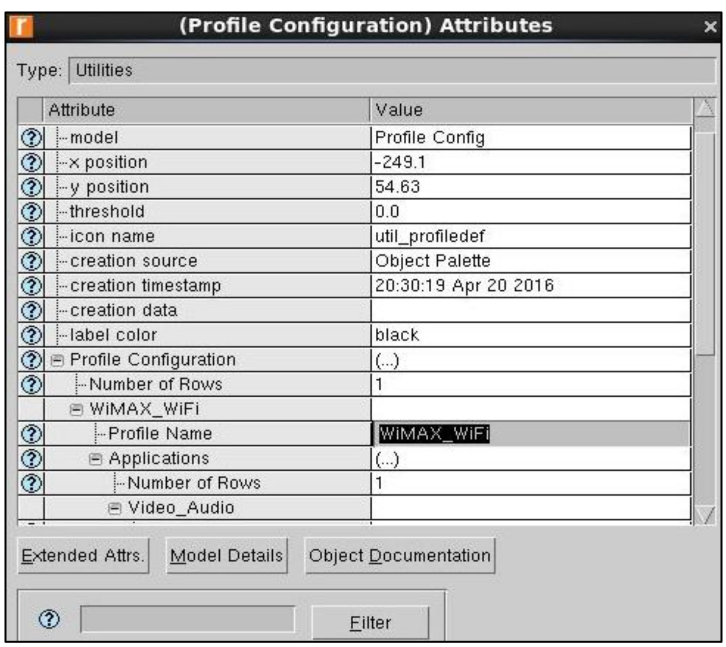

Figure 25: Profile Configuration Attributes

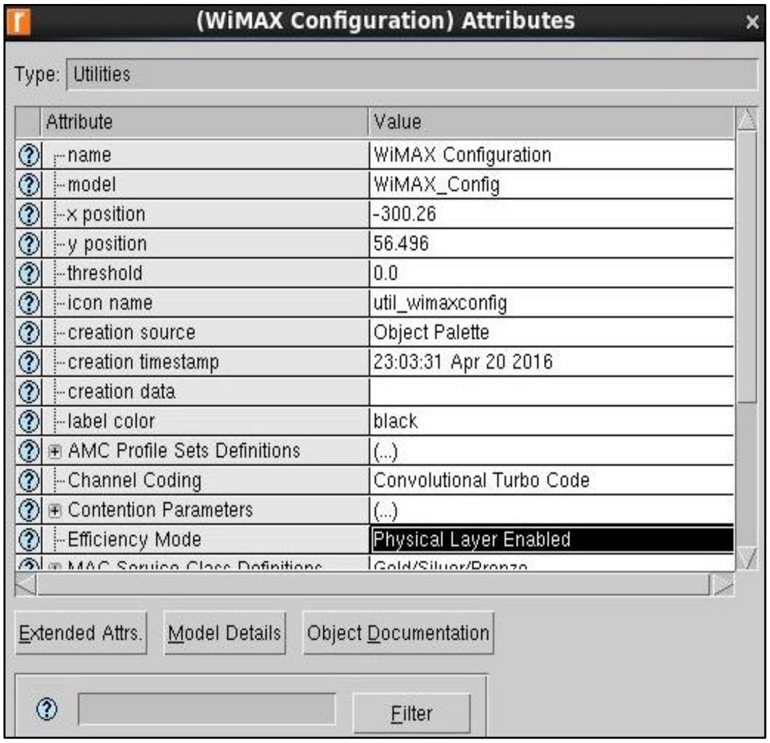

Figure 26: WiMAX Configuration Attributes

Appendix B. Simulation Environment

The following development environment was used during the execution of this project:

- Dell Vostro 2520 D830
  - Intel® Core™ i3-3110, 2.40 GHz
  - 4GB DDR3 PC3L-12800S SDRAM
  - 500 GB, 7200 RPM HD
- Microsoft Windows 10 Home Single Language (64-bit)
- Riverbed Modeler 18.0.1 (Build 18041 64-bit)
- MobaXterm Personal 8.5 (For Remote Login to Linux Machines on watt.ensc.sfu.ca)