ENSC 427 COMMUNICATION NETWORKS

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Final Project Report

Comparison of QoS between WiFi, WiMAX, and Ethernet LAN for Online Gaming Traffic

Group #9

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1. Abstract

As online video gaming becomes more common as a form of entertainment, Quality of Service (QoS) factors such as throughput and delay are important considerations for the users. Over the recent years, the development of Worldwide Interoperability for Microwave Access (WiMAX) with superior data rate and wireless range allowed it to gain much ground in the wireless technology sector over the current Wireless Fidelity (WiFi) technology. Ethernet Local Area Connection (LAN) currently assumes one of the fastest data transfer rates in computer technology. By using LAN as a baseline, we will be able to accurately gauge all these technologies. In this project, we will use OPNET's simulation tool to compare the QoS factors mentioned. We will make comparisons between WiFi, WiMAX, and LAN.

Table of Contents

List of Figures

List of Tables

2. Introduction
2.1 Motivation

As technology continues to improve with faster speed and higher complexity, gaming is slowly adopting on many different Internet provider services. In this project, the three main technologies simulated are Wireless Fidelity (WiFi), Worldwide Interoperability for Microwave Access (WiMAX) and Ethernet Local Area Network (LAN). The motivation for this project is to get a better understanding on the different technologies that affect gaming and to compare the performances between these technologies.

2.2 Scope

The scope for this project is to use Quality of Service (QoS) factors to analyse the measure performance between WiFi and WiMAX, while Ethernet LAN acts as a baseline for the most optimal result. The network topologies are implemented in OPNET 16.0 with a custom gaming traffic application.

2.3 General Background

The rapid development and growth of the Internet in recent decades has allowed the technology to be much more accessible. The Internet has become a major component of people's daily lives. This technology is becoming an integral part of people's daily activities such as email, work, and entertainment. Online entertainment especially online video gaming has become much more popular in recent years. Gaming exposure through the use of applications such as Facebook has changed the perception of video games, 24 hours non-stop of constant clicking. Now, many people are becoming casual gamers. This growing demand and popularity for video games means the same for online video gaming traffic networks performances. According to [1], video gaming traffic on a major network is at least 4% of the total and growing. This traffic demand has to be met through the development of newer and better technologies. Comparisons will be made between some current wireless technologies to determine their feasibility and performance capabilities in Quality of Service (QoS) factors such as network delay, and network throughput when paired up versus the superior standard wired local area network (LAN) Ethernet technology.

2.4 Wireless Fidelity (WiFi)

WiFi is a wireless local area network (WLAN) technology that belongs to the Institute of Electrical and Electronics Engineers (IEEE) 802.11 standards. This family of standards contains many different protocols with different specifications and performance standards that are coded as 802.11a, b, g, n, ac as shown below in Table 1. Devices with WiFi technology allows them to connect to the Internet wirelessly when it is within coverage range of a "WiFi hotspot", this coverage range depends on factors such as indoor/outdoor and frequency. WiFi networks have limited range, typically between 30 meters indoors to 100 meters outdoors, but this range may also vary due to frequency. Normally, WiFi in the 2.4GHz frequency band has better coverage range compared to the 5GHz frequency band. Through recent years from the 21st century, WiFi has gained much popularity among the general public. WiFi's capabilities allow cheaply deployed wireless local area networks to be in places that have difficulties with wired connections, such as the outdoors. The increasing popularity of wireless networks and WiFi hotspots have been regarded with such importance some cities around the world that they have successfully achieved full city-wide WiFi coverage. The success of WiFi has also been shown through the ongoing research of this technology, as the newest WiFi protocol 802.11ac has been drafted and is currently under development.

Table 1: 802.11 Network standard protocol definitions [3].

802.11 Network Protocol	Frequency (GHz)	Bandwidth (MHz)	Data rate per stream (Mbps)	Modulation method	Approx. Indoor range (m)	Approx. Outdoor range (m)
a	5, 3.7	20	6, 9, 12, 18, 24, 36, 48, 54	OFDM (Orthogonal frequency-division multiplexing)	35	120
b	2.4	20	5.5, 11	DSSS (Direct-sequence spread spectrum)	35	140
g	2.4	20	6, 9, 12, 18, 24, 36, 48, 54	OFDM, DSSS	38	140
n	2.4, 5	20/40	7.2, 14.4, 21.7, 28.9, 43.3, 57.8, 65, 72.2 for 20 MHz 15, 30, 45, 60, 90, 120, 135, 150 for 40 MHz	OFDM	70	250
ac (Draft)	5	80/160	433, 867 for 80 MHz 867, 1.73 Gbps, 3.47 Gbps, 6.93 Gbps for 160 MHz	OFDM		

2.5 Worldwide Interoperability for Microwave Access (WiMAX)

WiMAX is a wireless broadband established by the IEEE as a 802.16 standard for the Wireless Metropolitan Area Network (WirelessMAN). WiMAX is defined as part of the 4th generation wireless communication technology. WiMAX coverage surpasses the conventional limits of WLAN with signal in the kilometres (km) range. It provides portable mobile broadband connectivity for many devices. Additionally, it also provides remote location with Internet access where certain areas WiFi cannot reach [2]. The limitation WiMAX faces is that it can only serve one of two purposes: either delivering signal to far places or providing high speed Internet connection, but it cannot do both. At long distances, the error bit rate also increases. WiMAX is also efficient as it provides subscribers fix time slot and that each subscriber can only use their time slot. WiMAX operates in the frequency range of 10 to 66 GHz with a bandwidth of 20 MHz.

2.6 Ethernet Local Area Network (LAN)

Ethernet LAN or Ethernet is the standard wired networking technology introduced in 1980’s. Ethernet was standardized by the IEEE 802.3 network protocol definition. Since its introduction Ethernet has gained the wired LAN technology sector, “because Ethernet was able to adapt to market realities and shift to inexpensive and ubiquitous twisted pair wiring, these proprietary protocols soon found themselves competing in a market inundated by Ethernet products and by the end of the 1980s, Ethernet was clearly the dominant network technology.” [3]. Ethernet technology allows for immense speeds starting from 10 Mbps all the way up to 100 Gbps. In current Ethernet protocol standards, there are two different communication modes for Ethernet LAN: half-duplex and full-duplex. Half-duplex allows two-way communication over one channel, but only one-way communication occurs at a time. Full-duplex, on the other hand, allows for simultaneous two-way communication over two channels. Table 2 below shows a general comparison in the technology between WiFi, WiMAX, and Ethernet LAN.

Table 2: Comparison between WiFi, WiMAX, Ethernet LAN.

	WiFi (Wireless Fidelity)	WiMAX (Worldwide interoperability for microwave access)	Ethernet (Local Area Network)
IEEE Standard	IEEE 802.11g	IEEE 802.16e	IEEE 802.3
Bandwidth	20MHz	20MHz	
Data Rate	54 Mbps	Up to 75Mbps	100Mbps
Indoor Range	38m	Varies depending on equipment	Limited by wire length
Outdoor Range	140m	About 50km	Limited by wire length

3. Gaming Traffic Overview

There are many different genres of games when it comes to online gaming. Each genre of game has their own merits and different technicalities with respect to the traffic and requirements. There is massively multiplayer online role playing games (MMORPG) which deals with many users around the world connecting to a specific server location simultaneously. There is real time strategy games (RTS) which involves usually 2 up to 8 players connected simultaneously. Finally, there is a first-person shooter (FPS) genre that typically deals with 8 to 32 players. This genre of games will be the main focus for this study due to the nature of the traffic it provides. J. Farber's “Network game traffic modeling” [1] suggests a few features that are important within this genre. The game is modeled by a server to client relationship, average packet sizes are small, and the transmission rate of packets are described as many together with gaps in between segments.

A study done by S.Chiu, “Evaluation of Interactive Gaming Traffic over 802.11 Network”, modeled the FPS gaming traffic based on the work of J.Farber. Table 3 shows the nature of packet arrival time and typical packet size of the server and clients parameters used by S.Chiu. Similarly, we used the same parameters in this study.

Table 3: First person shooter traffic modeled by S.Chiu [4].

	Packet Interarrival Time Approximation	Packet Size Approximation
Server	Extreme (55,6)	Extreme (120, 36)
Client	Constant(0.04)	Extreme (80,5.7)

4. Simulation Overview

In this study, OPNET 16.0 was used to create the simulation models. The same scenario setup was used for the 3 different technologies. The same traffic model was used for the technologies as well. However, due to complication with creating a custom traffic application, profile, and task to model our gaming traffic in OPNET 16.0. We had to change our methodology and instead modified the traffic for video conferencing into the parameters used for FPS gaming traffic. All scenarios were simulated at 15 minutes with 128 as the seed number.

4.1 WiFi Network Topology

The WiFi network topology is shown below in Figure 1. The Ethernet server is connected to the WiFi access point (AP) using a 100Base-T Ethernet connection. 3 WiFi users are placed at the specific coordinates shown; these coordinates remain consistent between all 3 different network topologies. These coordinates determine the distances of the user away from the server/AP/base station (BS), which is shown in Table 4. The different distances of each client offer diversity to the performances and results. The WiFi profile was configured to the 802.11g protocol with a transmission rate of 54.0mbps. An additional application and profile options were added to create our gaming traffic. As mentioned earlier, video conferencing was selected as the application, however we manually modified the type of traffic into our approximation of a FPS gaming traffic.

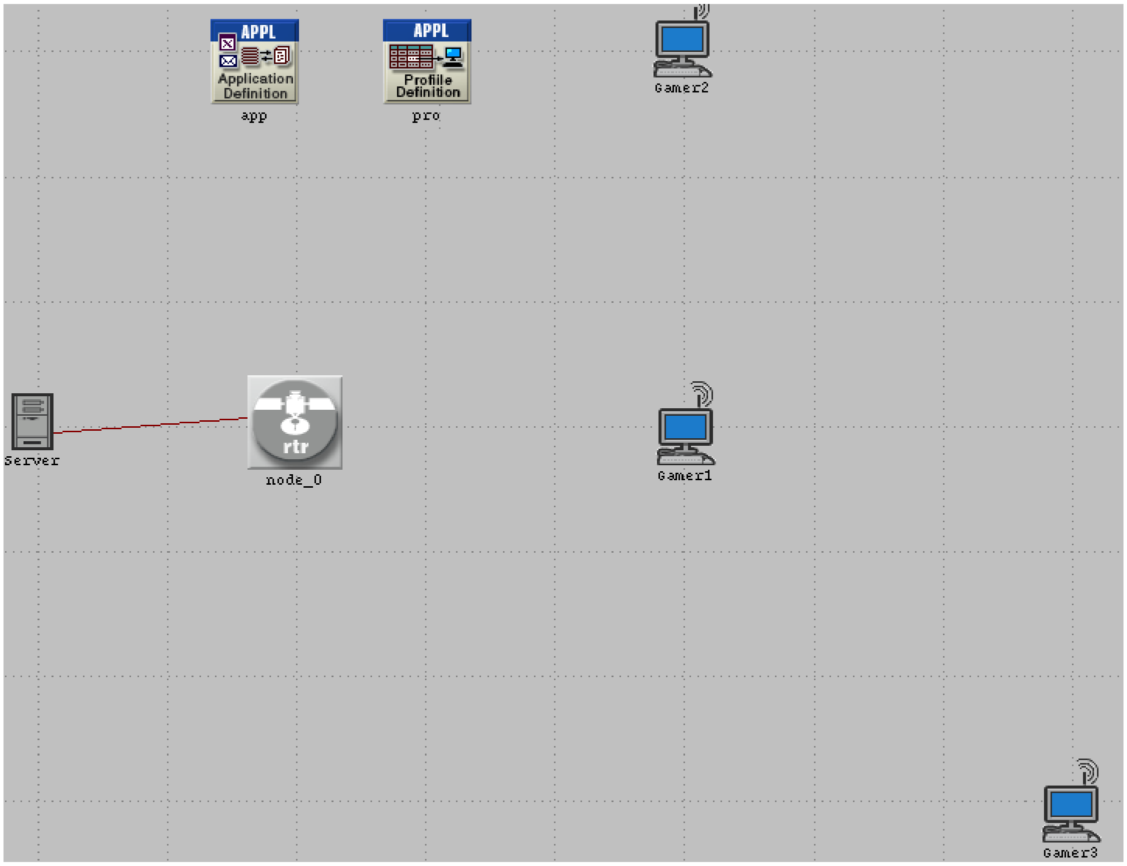

Figure 1: WiFi network topology.

Table 4: Distances of each client with respect to the server/AP/BS.

	Client1	Client2	Client3
Distance to Server/AP/BS	30m	42m	98m

4.2 WiMAX

4.2.1 WiMAX Network Topology

The WiMAX network topology is similar to the WiFi topology. A PPP server is connected to a WiMAX BS using a through a 45 Mbps Digital Signal (DS3) link. 3 WiMAX wireless clients are placed at a distance same as the WiFi topology, the distance is shown previously in table 4. WiMAX 802.16d protocol was used. Similarly, an additional application and profile options were added to the topology to create the gaming traffic. The WiMAX configuration tab for the topology is explained below. Figure 2 illustrates the WiMAX network topology.

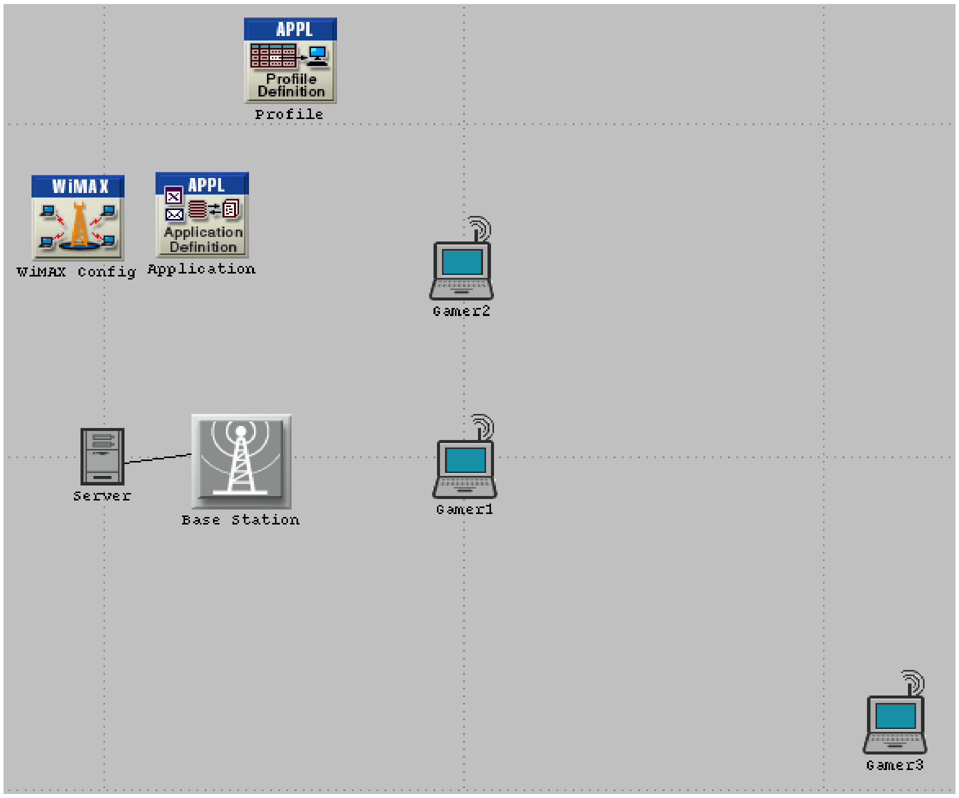

Figure 2: WiMAX network topology.

4.2.2 WiMAX configuration

The WiMAX configuration in the topology model consists of:
- service class/service flows
- media access control (MAC) scheduler
- burst profiles
- air Interface
- operating frequency
- channel bandwidth and subcarrier allocation
- transmit power
- path loss model.

The key parameter is the MAC scheduler. It controls the WiMAX QoS and support for video and audio traffics. The different options are UGS (Unsolicited Grant Service), rtPS (Real-Time Polling Service), nrtPS (Non-Real-Time Polling Service) and BE (best effort). The WiMAX configuration parameters contain the best effort scheme. There are also other options for the type of service provided; for which we have chosen the gold service class.

WiMAX client stations support many different methods of modulation schemes. Our WiMAX clients are configured to support 16-Quadrature Amplitude Modulation (QAM) modulation method for both uplink and downlink service flows.

Next, the WiMAX base station and client antenna gains were set to 15 dB. The BS transmission power was set to 10W, while the client uses 0.5W.

4.3 Ethernet LAN Network Topology

Again, the Ethernet LAN network topology is similar to the previous topologies. An Ethernet server is connected to the Cisco 7200 router using the 802.3u 100Base-T Ethernet link. Three fixed users are connected to the router using the 802.3u 100Base-T Ethernet links as well, resulting in the fixed distances. Similarly, an additional application and profile options were added to the topology to create the gaming traffic. Figure 3 shows the Ethernet topology.

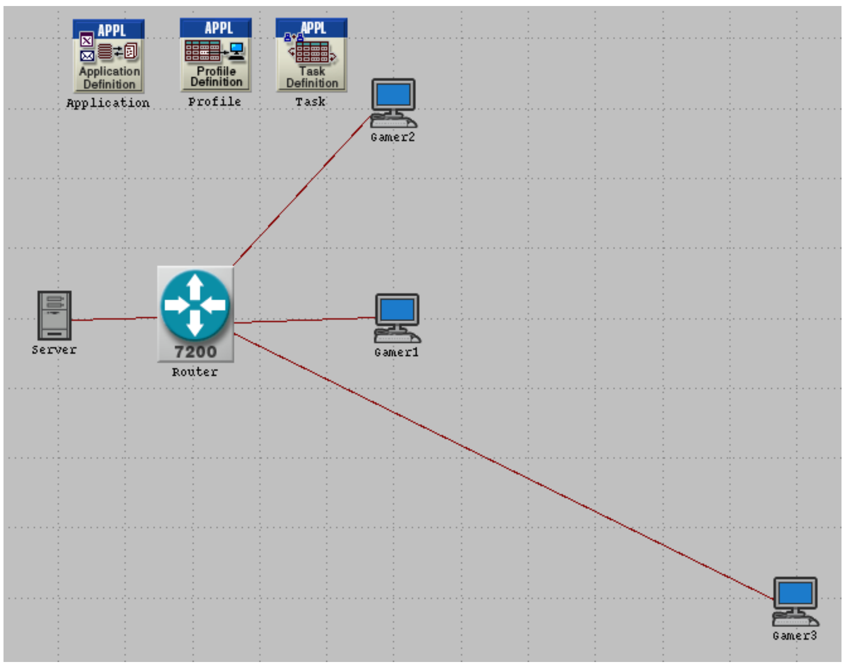

Figure 3: The Ethernet LAN network topology.

5. Simulation Results

5.1 Channel Efficiency

In a communication network, channel efficiency, also known as channel utilization or normalized throughput, is the ratio between the rate of successful packet delivery and the rate of total packet delivery. Throughput is the average rate of successful packet delivery through the channel, whereas the load is the rate of total packet deliveries. They are usually measured in bits per second (bps) or packets per second (p/s).

5.1.1 WiFi Channel Efficiency

Figure 4 depicts the WiFi average throughput in bps for all three gaming clients. We can see that all three gaming clients nearly saturate at 22.36 kbps. Evidently, Gamer1 still has a slightly higher average throughput than Gamer2, who in turn has a higher average throughput than Gamer3. The results correspond to the differing distances between the gaming clients. The longer the distances from the client to the AP results in lower throughput.

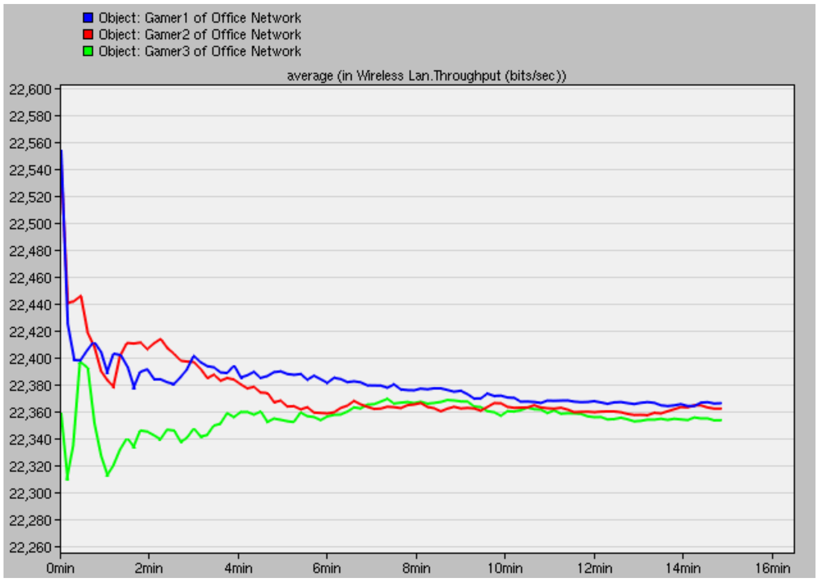

Figure 4: WiFi Average Throughput (bits/sec)

Figure 5 reports the average load transferred from the server to the three gaming clients. The distribution of packets is roughly the same between the clients. Because each client uses the same gaming traffic, they roughly saturate at 23.2 kbps. As a result, longer distances from the client to server should result in higher load because of packet loss.

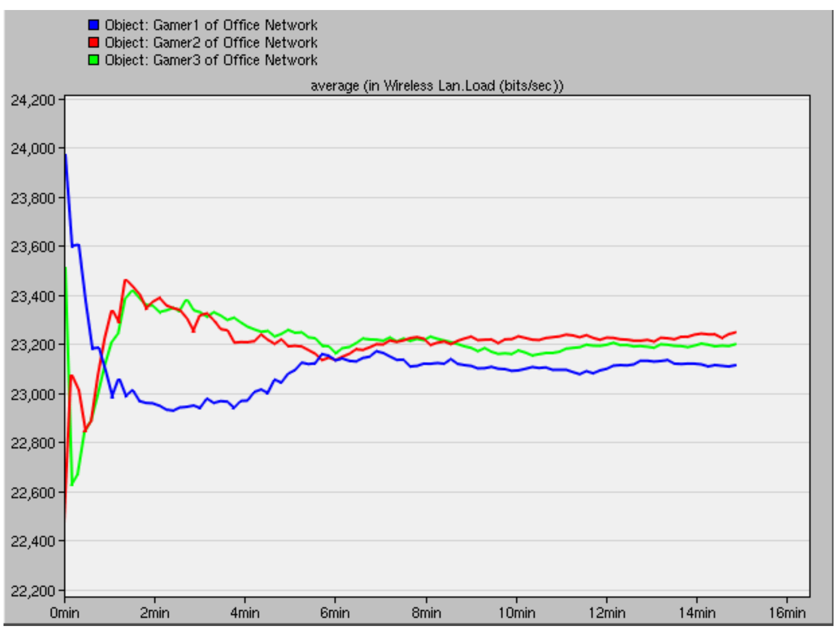

Figure 5: WiFi Average Load (bits/sec)

The channel efficiency of this WiFi simulation can be approximated by taking the ratio between the average throughput and the average load. Since the average throughput occurs around 22.36 kbps and the average load is estimated at 23.3 kbps, we see the channel efficiency of this WiFi network simulation to be at 96.38%. Therefore, the packet loss can be attributed to be 3.62% in this topology.

5.1.2 WiMAX Channel Efficiency

The WiMAX global average throughput is shown below in Figure 6. The simulation utilizes the global spectrum of the average throughput, which is the average of all three throughputs from the server to the client. In this case, the simulation reports the throughput and load in p/s. We see that the WiMAX global average throughput saturates at 126.31 p/s.

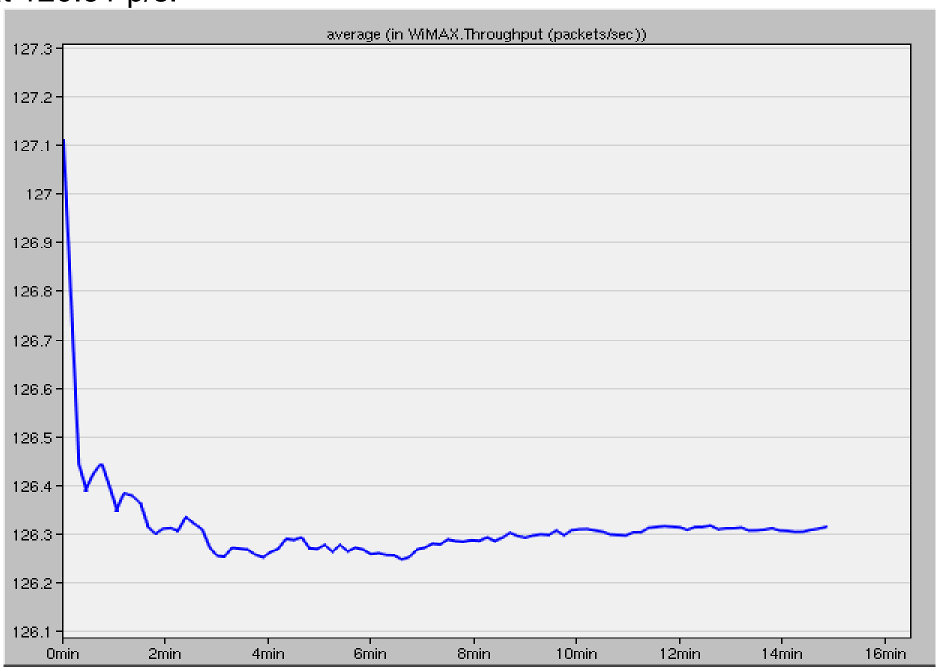

Figure 6: WiMAX Global Average Throughput (packets/sec)

In order to accurately compare with the WiMAX global average throughput, we chose the simulation of the WiMAX global average load. The simulated graph in Figure 7 provides a saturated value of 126.32 p/s.

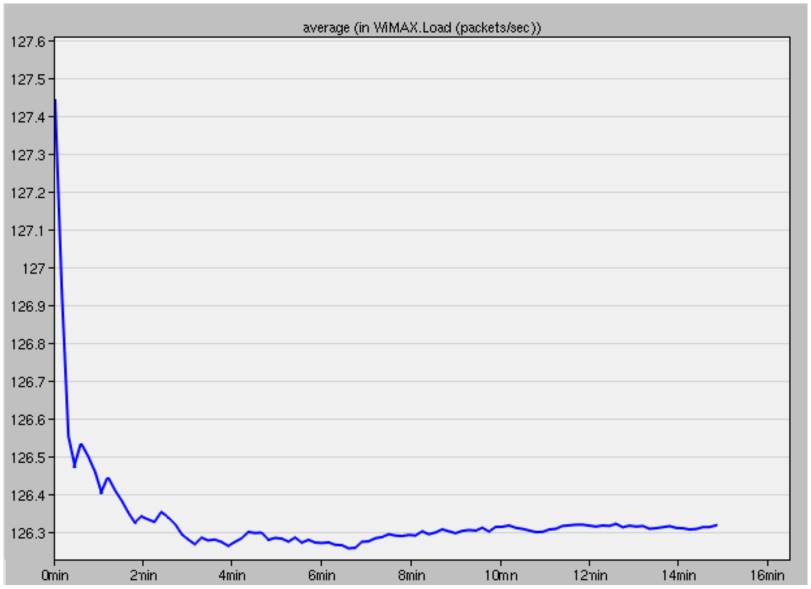

Figure 7: WiMAX Global Average Load (packets/sec)

The channel efficiency for this WiMAX network topology is calculated in the same way as the WiFi network topology, the average rate of successfully delivered packets divided by the average rate of total delivered packets. Thus, we attribute the channel efficiency to be 99.99%, whereas the packet loss to be 0.01%.

5.1.3 Ethernet LAN Channel Efficiency

The Ethernet average load simulated results is shown below in Figure 8, but OPNET 16 did not provide any results for Ethernet throughput. We attribute this factor to zero packet loss of this network. Therefore, the average load is equal to the average throughput and has 100% channel efficiency.

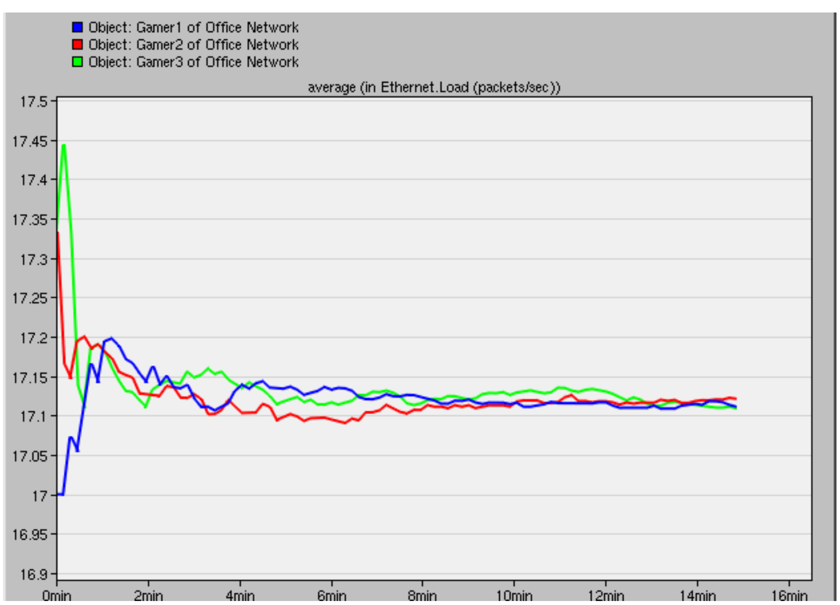

Figure 8: Ethernet Load (packets/sec)

5.2 Delay

In communication networks end-to-end delay is the time it takes for a packet to transfer from the source to the destination. It is measured in sec (seconds) over a duration of 15 minutes for gaming simulation.

5.2.1 WiFi Delay

Figure 9 shows the measure WiFi delay between the three gaming clients. We can see the delay for all three gaming clients are roughly between 50-127 μs. Gamer1 has the highest delay at 127 μs and Gamer3 has the lowest delay of 50 μs. All three gaming clients have a fairly constant steady state. We see that in longer distance, it results in smaller delay.

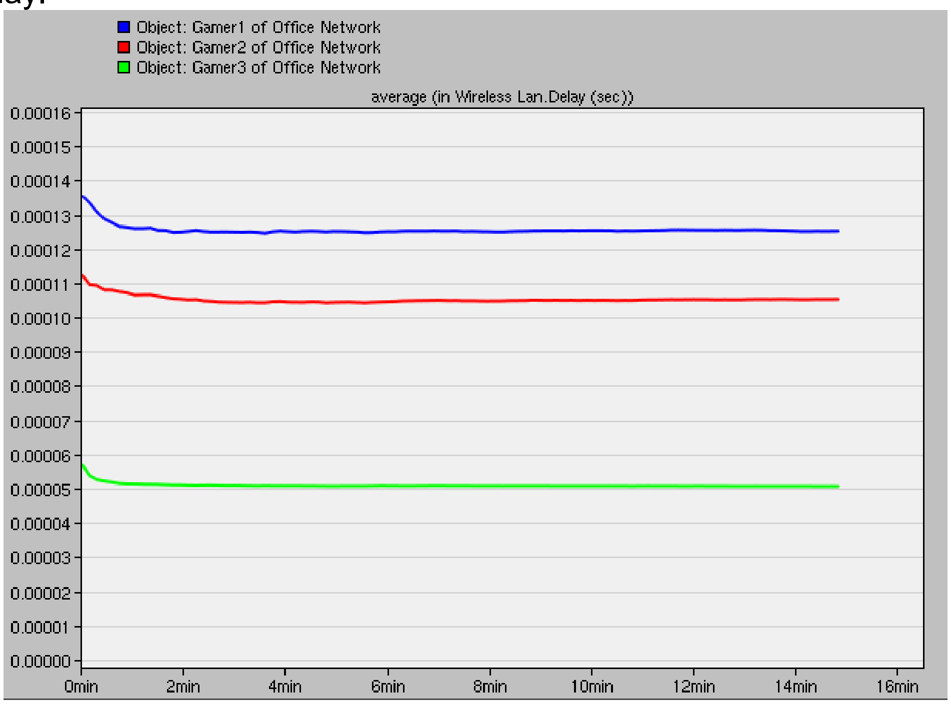

Figure 9: WiFi Delay (sec)

5.2.2 WiMAX Delay

Figure 10 displays the measure WiMAX delay result of all three gaming clients. We can see that all three gaming clients converge to approximately 53 μs. The delay is roughly even for the different distances. The gaming clients all have a fairly constant steady state. As WiMAX has a big broadband range, the delay is not affected by the distances in metres.

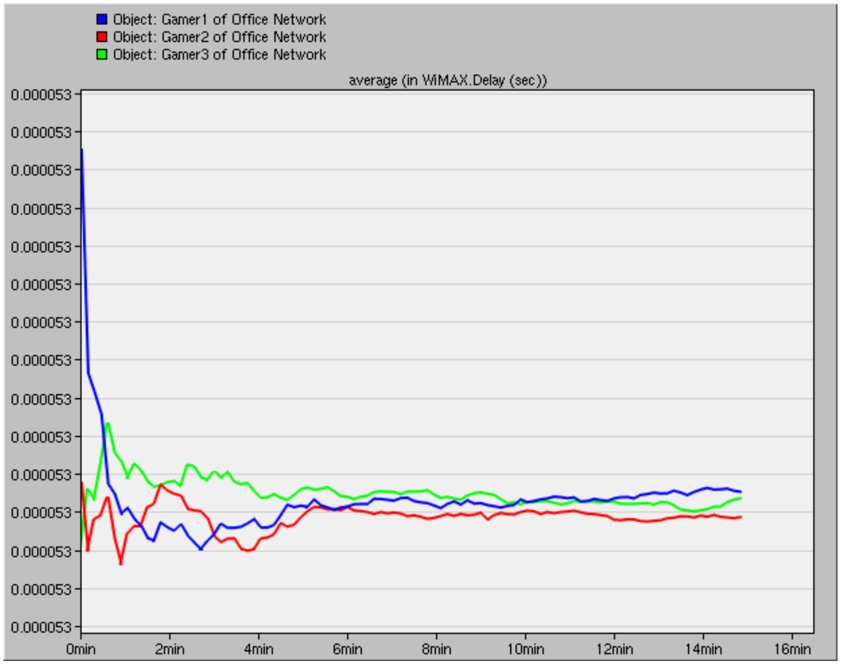

Figure 10: WiMAX Delay (sec)

5.2.3 Ethernet LAN Delay

In Figure 11, the Ethernet delay for all three gaming clients is roughly between 11-12μs. Gamer1 is the shortest distance to the router and has about 11.3 μs delay. Gamer2 has a delay around 11.44 μs. Gamer3 has the longest distance and has around 12.07 μs. All three gaming clients have a fairly constant steady state. The longer the distance from the router will result in a higher delay.

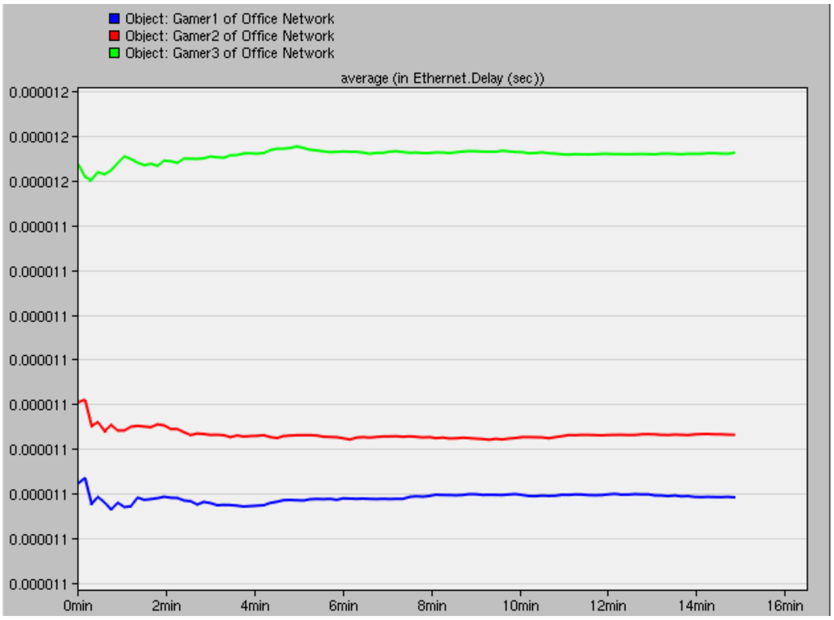

Figure 11: Ethernet Delay (sec)

5.2.4 Comparison of Delays between Gaming Clients

Figure 12 shows the delay of all three technologies for Gamer1. We can see the Ethernet delay for Gamer1 is around 11.3 μs. Roughly 53.4 μs WiMAX delay and 126 μs WiFi delay for Gamer1. All three technologies have a constant delay. Out of the three technologies, WiFi has the highest delay when the distance is shorter while Ethernet has the lowest delay with the shorter distance.

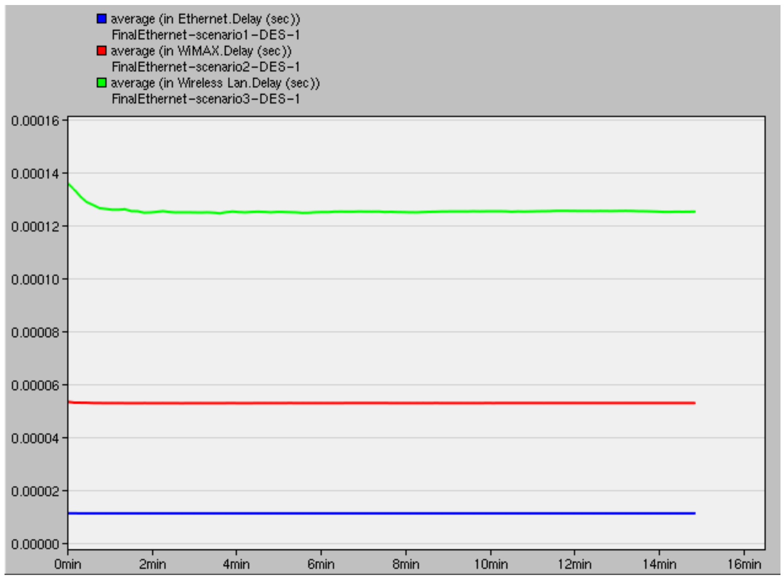

Figure 12: Gamer1 Delay (sec)

Figure 13 is the measure delay between all three technologies for Gamer2. As we can see, the result is similar to Gamer1. WiFi has the highest delay at roughly 106 μs. Ethernet has the lowest delay around 11.4 μs. The simulation result is similar to Gamer1 where higher delay occurs at longer distances.

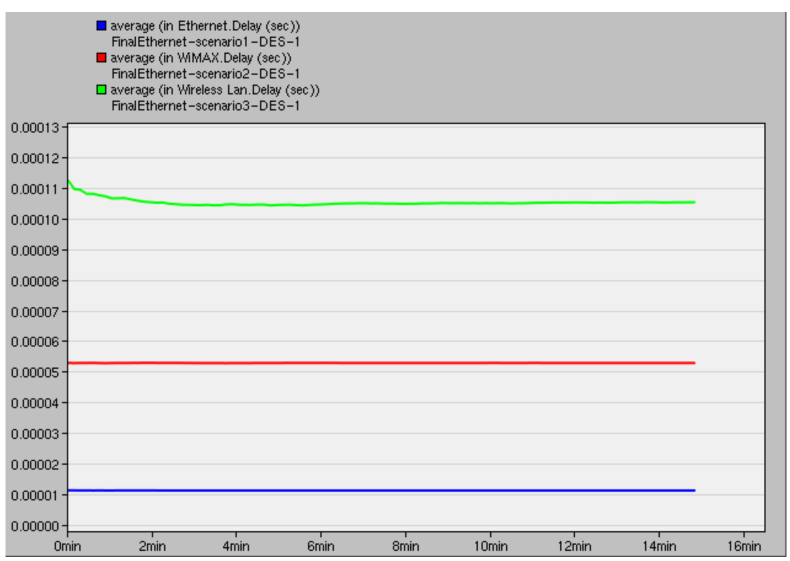

Figure 13: Gamer2 Delay (sec)

Figure 14 refers to the simulation result delay for Gamer3. We see that Ethernet still has the lowest delay at roughly 12.0 μs. WiMAX has the highest delay around 53.3 μs. For WiMAX, it has been fairly constant around 53.3 μs over the three gaming clients. All three technologies have a constant steady state. The result is different for WiFi as the delay decreases when the distance gets longer.

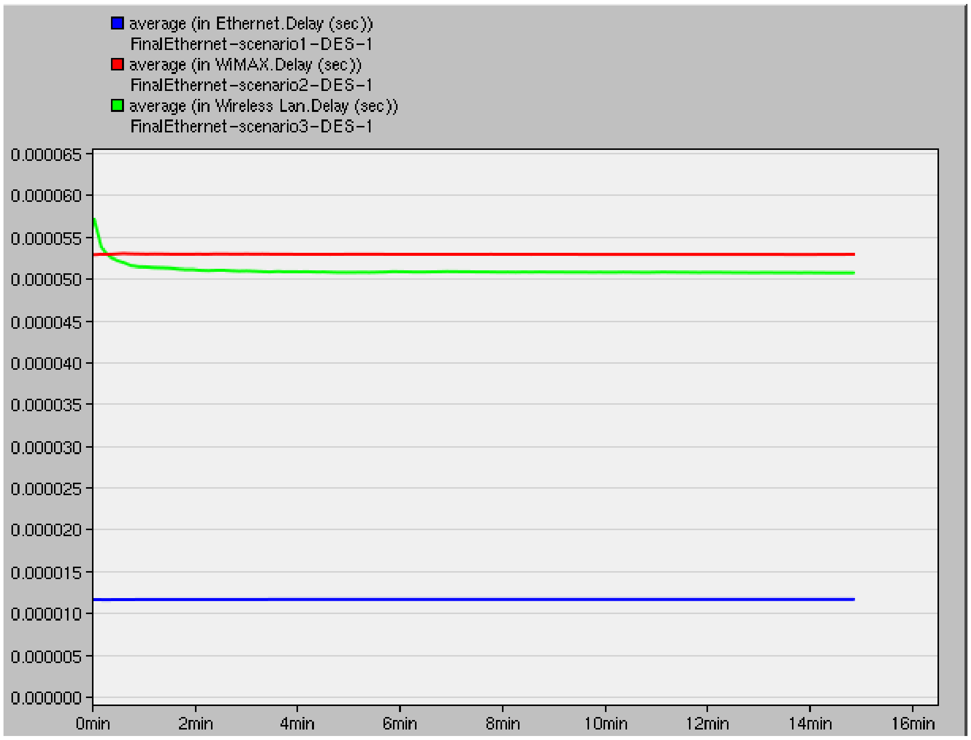

Figure 14: Gamer3 Delay (sec)

In Table 5, the comparison for delay of each gamer show that the Ethernet delay and WiMAX delay are relatively constant. The WiFi delay varies depending on the distance. As the distance increases, the delay decreases.

Table 5. Comparing delay between the 3 topologies for each gamer

	WiFi Delay	WiMAX Delay	Ethernet Delay
Gamer1	126μs	53.4μs	11.3μs
Gamer2	105μs	53.2μs	11.4μs
Gamer3	50μs	53.3μs	12.0μs

6. Conclusion

The purpose of this report is to provide a better understanding of the vastly growing communication network systems of the world, particularly wired and wireless networks. A moderate study of Ethernet, WiFi, and WiMAX allowed us to provide a general topology of each network. Thus, QoS factors and performance can be analysed using OPNET 16’s modeler.

As a result, the simulation results provided us with a deeper knowledge. From that, we confirmed that channel efficiency ranks the network topologies as Ethernet LAN being the most efficient at 100%, WiMAX second at 99.99%, whereas WiFi has the lowest channel efficiency percentage out of all three network topologies. Our presumption for this topology was that longer distances will result in higher load and lower throughput. However, in the WiFi topology, Gamer2 exhibited a higher average load than Gamer3. We conclude that this has to do with the packet distribution of the WiFi network topology. A more extensive study into 802.11d’s packet distribution processes may reveal more substantial information.

The average delays of these three network topologies were also explored. Similar to our previous assumption, we believed that longer distances will result in higher delays. The Ethernet network did behave as we suspected. However, WiMAX average delays were relatively constant throughout the entire simulation. We believe this to be the affect of WiMAX’s broad coverage. Since its natural coverage is large, our network topology was not large enough to show the drop in delay. Another anomaly occurs in the WiFi network topology. Simulation results showed that as the distance increases, the delay of the WiFi starts to decrease. We attribute this to the limited range of WiFi. The WiFi connection will begin to deteriorate as it reaches a certain threshold. Further research into the WiFi network topology on client-to-AP connection may reveal further information.

In conclusion, this study accomplished its goal in providing a brief understanding on these network topologies. Although we realize this comparison is a bit unrealistic when exacting these topologies in real life, we believe our study will further extend into a better and more realistic comparison. Overall, OPNET provided a decent environment to simulate our different scenarios. It was versatile enough to handle our different parameters and applications.

7. Related Work

We built our project on several past projects. S. Chiu's "Evaluation of Interactive Gaming Traffic over 802.11 Network" provided us the idea of using online gaming traffic over WiFi [4], while T. Cheung and his group's "Evaluation of online gaming traffic over WiMAX" [5] inspired us to compare the effects of online gaming traffic between different network topologies. We also used J. Farber's "Network game traffic modeling" [1] to create our model for gaming traffic. The idea is to create a first person shooter gaming traffic as a model over our three different technologies and analyse its effects.

8. Future Work

In this project, we have analyzed the performance of WiFi, WiMAX, and Ethernet LAN over online gaming traffic models. This allows for a more accurate analysis on the quality of service factors between these three different network topologies. The aforementioned QoS factors include network delay and network throughput.

Future work could modify our network specifications and improve upon them to reflect the rapid growth of the current technology. Our WiFi network protocol standard corresponds to IEEE 802.11g; however, newer standard such as IEEE 802.11n is already implemented, while IEEE 802.11ac is under development. Similarly, WiMAX's IEEE 802.16e standard has already been superseded, with newer protocol standards such IEEE 802.16m being implemented and IEEE 802.16p being developed. The Ethernet LAN protocol encounters the same problem as well. In our simulation, we used IEEE 802.3 10Base-T Ethernet. Future models may contemplate simulating with the faster IEEE 802.3z Gigabit Ethernet or even the IEEE 802.3ae 10 Gbps Ethernet. Implementing newer standards, relative to the ones we've used, allows for greater advances in modern-day technology and a larger baseline for comparisons.

We understand that different communication networks cannot be compared directly, as WiFi promotes wireless access through a short distance, whereas WiMAX provides wireless access through large geographical areas. However, with the implementation of 100 Gigabit Ethernet, the Ethernet cables are able to reach upwards to 40 km. With this, we can use Ethernet as a baseline. Networks with shorter distances, like WiFi, can be compared to Fast Ethernet's 100BaseT, whereas networks with larger distances, such as WiMAX, can be compared to the 100 Gigabit Ethernet networks.

9. References

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10. Appendix
10.1 Acronyms

WiFi - Wireless Fidelity
WiMAX - Worldwide Interoperability for Microwave Access
LAN - Local Area Network
FPS - First Person Shooter
RTS - Real Time Strategy
MMORPG - Massively Multiplayer Online Role Playing Game
QoS - Quality of Service
QoE - Quality of Experience
ADSL - Asymmetric Digital Subscriber Line
Kbps - Kilobits per second
Mbps – Megabits per second
Gbps – Gigabits per second
AP - Access Point
PPP - Point to Point Protocol
DS - Digital Signal
WAN - Wide Area Network
MAC - Media Access Control
UGS - Unsolicited Grant Service
rtPS – Real-Time Polling Service
nrtPS – Non-Real-Time Polling Service
BE - Best Effort
QAM – Quadrature Amplitude Modulation
bps – Bits per second
p/s – Packets per second

10.2 Challenges

There were numerous challenges we encounter during the whole project. Firstly, we encounter a problem when we were creating a WiFi and WiMAX topology with an IP cloud. The actual time for the simulation time didn't seem to be correct as it was too fast to simulate the gaming traffic.

We also encountered difficulties in creating a custom gaming traffic application using the Task Application in OPNET. We seek for the TA's help, but they could not find a solution. As a result, we had to emulate the custom gaming traffic as a part of the video traffic task.

In addition, we wanted to utilise actual traceroute packets in our OPNET simulation. Since we had a lot of trouble creating the custom gaming traffic at first, we scrapped the idea of analysing traceroute packets of three different types of games through an actual router. The three different types of games would have consisted of a FPS, MMORPG, and RTS game.

Furthermore, we had to learn three different technologies WiFi, WiMAX and Ethernet to compare which technology currently provides the best services. The depth of each technology is very challenging with many different options to choose from. In turn, we were not able to create such in-depth scenarios for analysis.

Lastly, we could not improve our OPNET models we created with the licensing issues. This was a major challenge we encountered since there were things we want to fix to make the project better, such as adding an extra Ethernet scenario using the 10GBase Ethernet. This Ethernet link, which can extend up to long scenarios, was going to be a major comparison with WiMAX since we understood that WiMAX cannot compare with WiFi directly. However, without this extra scenario, our report would seem unrealistic and may be under looked. We believe that this was the biggest detriment to our project as it would have provided ourselves with a way to improve our project since the presentation.