ENSC 427: COMMUNICATION NETWORKS

EVALUATION OF GAMING TRAFFIC OVER WiMAX

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FINAL PROJECT

Group #3

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List of Acronyms

dBi – Decibel Isotropic

DSL – Digital Subscriber Loop

FPS – First Person Shooter

Kbps – Kilobits per second

MAC – Machine Address Code

QAM – Quadrature amplitude modulation

QoE – Quality of Experience

QoS – Quality of Service

RPG – Role Playing Game

RTS – Real Time Strategy

SAP – Service Access Point

SNR – Signal-to-Noise Ratio

WiFi – Wireless Fidelity

WiMAX – Worldwide Interoperability for Microwave Access

1. ABSTRACT

The goal of this project is to simulate online gaming traffic over a Worldwide Interoperability for Microwave Access (WiMAX) network. Over the past couple of years, WiMAX has been gaining popularity as an IP-based wireless access network due to its suitability for mobile users compared to Wireless Local Area Network (WLAN) technology. Since then, a high quality of service for both the video and audio signals is essential for online gaming, the project will focus on measuring quantities such as delay and jitter, latency and bandwidth consumption for various online gaming traffic loads. We will use OPNET Modeler 14.0 as the simulation tool for this project.

2. INTRODUCTION

2.1 Background and Motivation

The internet is becoming more ubiquitous and more available to people and the demand and usage for entertainment is constantly increasing as well. According to [1], gaming traffic on any major traffic backbone consist of 4%-5%. According to Cisco's Virtual Networking Index, gaming traffic is expected to continue growing at an average rate of 39% over the next 3 years as shown in Appendix A [2]. As per Cisco's definition, gaming includes casual online gaming, networked console gaming, and multiplayer virtual world gaming.

Older forms of connectivity to the internet required a physical connection – whether it be a cable or a digital subscriber loop (DSL). Unfortunately, this meant that many remote locations or inaccessible locations will not be able to have connectivity to the internet. Technology, however, has bridged the gap and now a solution exists for providing internet to these locations – Worldwide Interoperability for Microwave Access (WiMAX) is one of the suitable wireless solutions.

WiMAX is continuously being deployed in many areas – Figure 1 below provides a map of all the deployed and future deployments of WiMAX. While WiMAX is relatively new, a few concerns arise with the Quality of Experience (QoE). A lot research has been completed on various applications, such as Voice-over-IP, Multimedia streaming, and regular browsing, but little to no research has been completed on gaming applications over WiMAX.

Figure 1 – Worldwide Deployment of WiMAX

2.1   PROJECT GOALS

The main goal of this project is to determine if WiMAX will be able to provide a high quality of experience for a generic, yet popular gaming application using a client-to-server model. Shown in the table below briefly illustrates the requirements for a quality user experience:

Table 1 - WiMAX Application Classes [3] Error! Reference source not found.

Class	Application	Bandwidth Guideline		Latency Guideline		Jitter Guideline	
1	Multiplayer Interactive Gaming	Low	50 kbps	Low	< 25 msec	N/A	
2	VoIP & Video Conference	Low	32-64 kbps	Low	< 160 msec	Low	<50 msec
3	Streaming Media	Low to High	5 kbps to 2 Mbps	N/A		Low	<100 msec
4	Web Browsing & Instant Messaging	Moderate	10 kbps to 2 Mbps	N/A		N/A	
5	Media Content Downloads	High	> 2 Mbps	N/A		N/A	

According to DSL Forum's technical report on *Triple-play Services: Quality of Experience Requirements* [4], there are three critical aspects of playability in networked games:

- Responsiveness: The delay it takes for an update event to be registered by affected players. With a networked game, the responsiveness will depend on the network delay experienced.
- Smooth responsiveness: Delays can be variable and responsiveness can vary as well. Players can adapt to a slow "game pace" but a jerky responsiveness renders networked games impossible to play.
- Information consistency: Consistency refers to the similarity of the view of the game status by other players. The data must be well synchronized so that fairness is achieved between players.

There are three important variables that will be monitored in our simulations: delay, jitter, packet loss that will determine WiMAX will support the playability of multiplayer games. In addition, we will vary other variables, such as distance and connected clients to determine their impact on the three main variables.

In order to achieve our results, we will simulate gaming traffic between clients connected by WiMAX and varied the number of clients, the distance of clients, and the overall background load in our simulation. Our collection results will be compared to acceptable values and this will determine if WiMAX will be able to support gaming applications.

3. GAMING TRAFFIC DESIGN

In order to determine if WiMAX would be able to support interactive multiplayer games, we used a genre of games that would require the highest requirements according to DSL Forum [4]. As shown in the table below, First Person Shooter (FPS) games have one of the highest demands:

Table 2 - One way game delay requirements

Game Category	Responsiveness	Consistency	Delay(ms)
First Person Shooter	Highest	Lowest	25-75
Role Playing Game	Medium	Highest	50-150
Real Time Strategy	Lowest	Medium	100-500

One popular game that will satisfy this game category would be Counter-Strike, a first person shooter based on terrorists and counter-terrorists. Since we decided to model multiple scenarios, using a statistical model for our simulations is the more flexible solution.

A study done by Johannes Färber, *Network Game Traffic Modelling* [1], describes the statistics involved in a 36 hour capture with 50 participants.   From his study, there are several important points that must be mirrored in our OPNET simulation:

- Server – Client relationship (as opposed to peer-to-peer)
    - Server sends game state information to every client.
    - Clients synchronize game state with their local information and returns update packets with player movement and status information.
    - Clients constantly updates server
- Packet sizes are small.
- "Bursty" nature of packets sent.

Based on Färber's study, we will model our traffic similarly to Chiu's implementation of gaming traffic over Wi-Fi [6]. The statistical graphs are included in Appendix A and illustrate the packet size and interarrival times of both the server and the client. Based on these graphs, Färber states the Counter Strike traffic characteristics and approximations for both the server and the client:

Table 3- Counter Strike traffic characteristics and approximations

	Server (per client)		Client	
	Characteristic	Approximation	Characteristic	Approximation
(burst) Interarrival time	Peak = 55 ms mean = 62ms coeff. Of variation = 0.5	Extreme (a=55, b=6)	Mean = 41.7 ms Coeff. Of variation = 0.24	Deterministic (40 ms)
Packet size	Mean = 127 Bytes Coeff. Of variation = 0.74	Extreme (a=120, b=36)	Mean = 82 Bytes Coeff. Of variation = 0.123	Extreme (a=80, b=5.7)

Färber also noted that most games under the genre of "First Person Shooter" can be characterized with a similar model. Other FPS game traffic analysis of "Unreal Tournament" and "Quake 2" has yielded results that were close to Färber's research.

4. SIMULATION DESIGN

In our project, we used OPNET Modeler 14.0 to simulate 4 different network topologies, as categorized in the following section. We used the WiMAX model and the corresponding object palette that is provided with OPNET. As mentioned above, all scenarios use an approximated statistical model for the game traffic for Counter Strike.

4.1 NETWORK TOPOLOGIES

In each of the three scenarios, we use a slightly different topology in order to test the capability of WiMAX and gaming traffic. In the first scenario, we placed 1 client at approximately 1km away from the Base Station (BS). In the second scenario, we placed 3 clients, each increasing 1km away from the BS. In the third scenario, we placed 5 clients away from the BS at 1km intervals. With these three scenarios, we can monitor the traffic and the network as the number of users increases. Lastly, we tested the distance limitations of WiMAX and the way it will affect our gaming traffic and the quality of experience. We placed one client 1km and another 25km away from the BS.
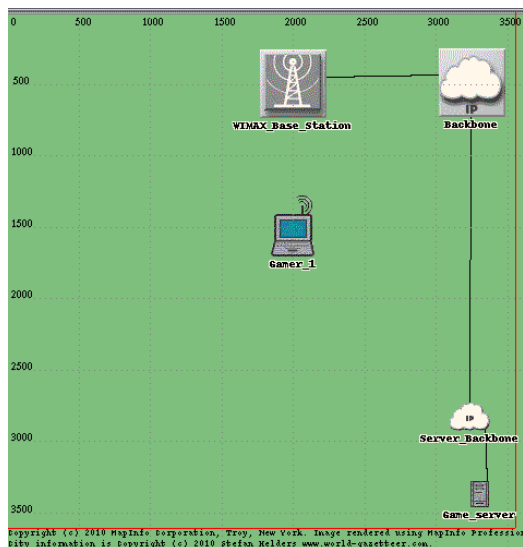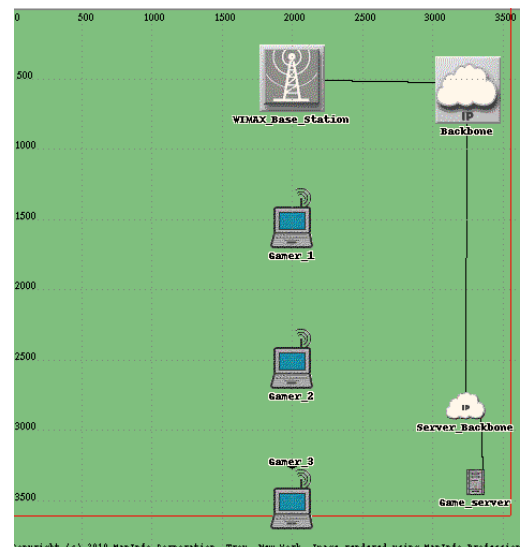

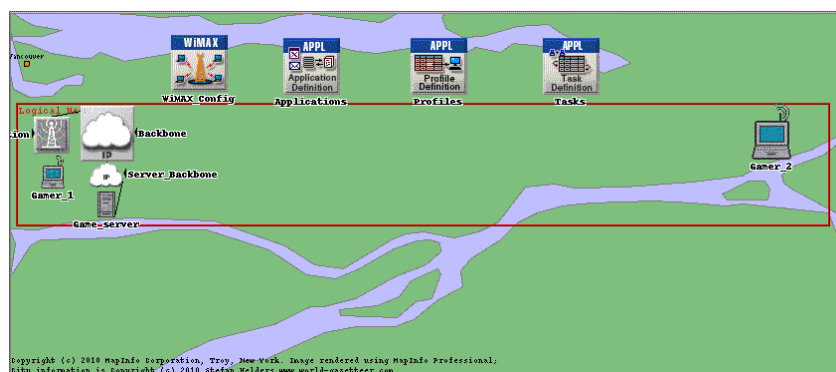**Figure 2 – 1 Client setup to verify gaming traffic**

Figure 3 – 3 Client setup
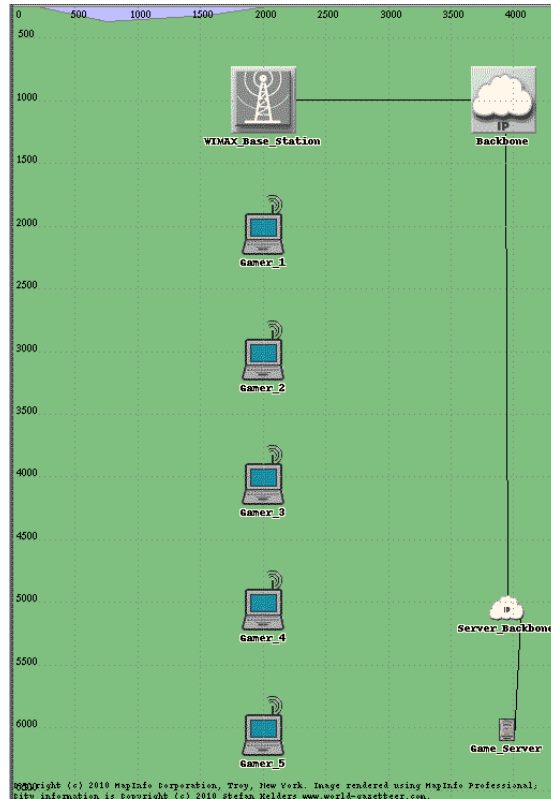

Figure 4 – 2 Client setup.

Figure 5 – 5 Client setup

4.2 WiMAX Configuration

In order to be able to setup a WiMAX wireless connection, we have to configure the WiMAX parameters node provided in OPNET. The parameters that need to be modified are the MAC Service Class Definitions and the Efficiency Mode.

The MAC Service Class Definitions allows us to configure parameters with the same Quality of Service (QoS) requirements. As we are only modeling one type of traffic, we only need to use one service class. For this project, we used the Gold service class with the scheduling type set to Best Effort, with all other parameters kept as default.

The Efficiency Mode was set to Physical Layer Enabled in order to take into account the effects of distance on the Signal-to-Noise Ratio (SNR) and packet loss [8]. The configuration can be seen in the following figure.
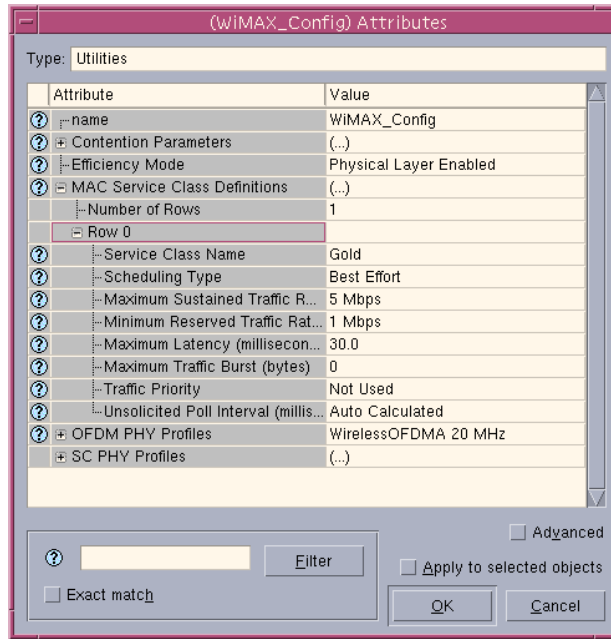
Figure 6 – WiMAX Configuration

Next, the WiMAX Base Station and the user nodes have to be configured. The key parameters that were modified are the antenna gain, the maximum transmission power as well as the classifier definitions. For the base station, the antenna gain was set to 15 dBi and the transmission power was set to 10 W [9]. For the fixed user nodes, the antenna gain was changed to 14 dBi and the transmission power was changed to 0.5 W [10]. These are typical values that are commonly used in real life situations. As for the classifier definitions, the Service Access Point (SAP) type for both the base station and the user nodes was set to IP. The Gold service class was used in both cases. The base station and user node configuration can be seen in the following figure.
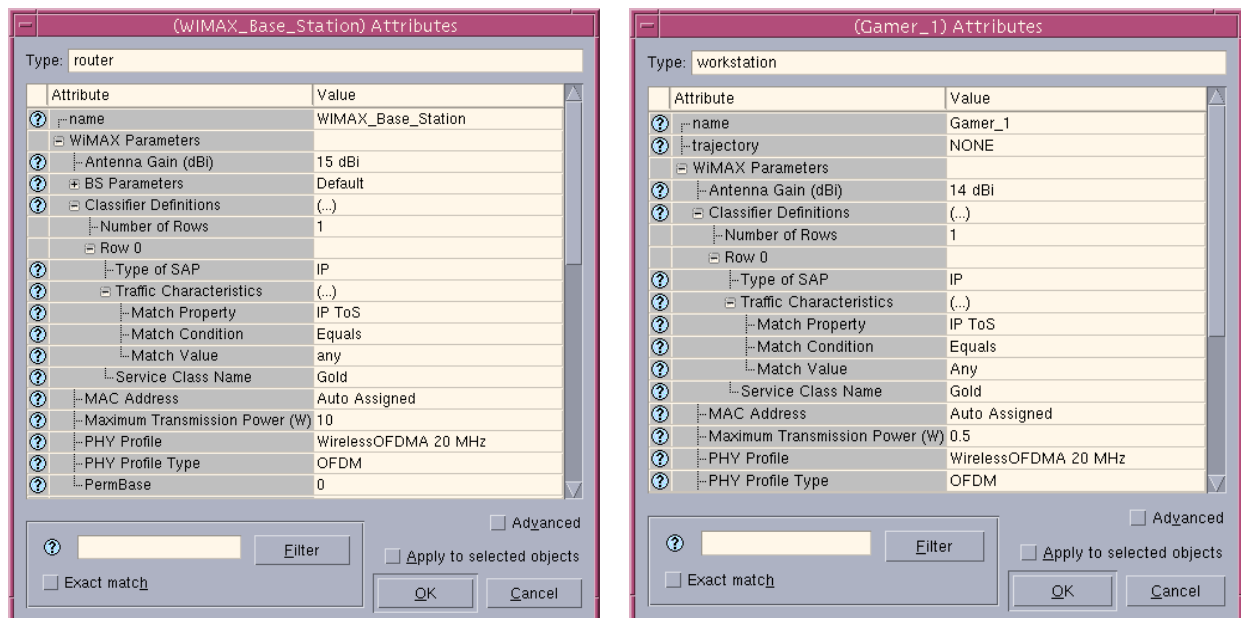

Figure 7 – Base Station and User Node Configuration

Following that, the downlink and uplink service flows have to be configured for each user node. The downlink signals move from the base station to the user node and the uplink signals are directed from the user node to the base station. WiMAX supports adaptive modulation, in which the modulation scheme is adjusted depending on the distance from the base station. Since all of the user nodes in our model are relatively close to the base station, we will use the 16-QAM modulation with 3/4 coding rate for both the downlink and the uplink [11]. These settings are shown in the following figure.
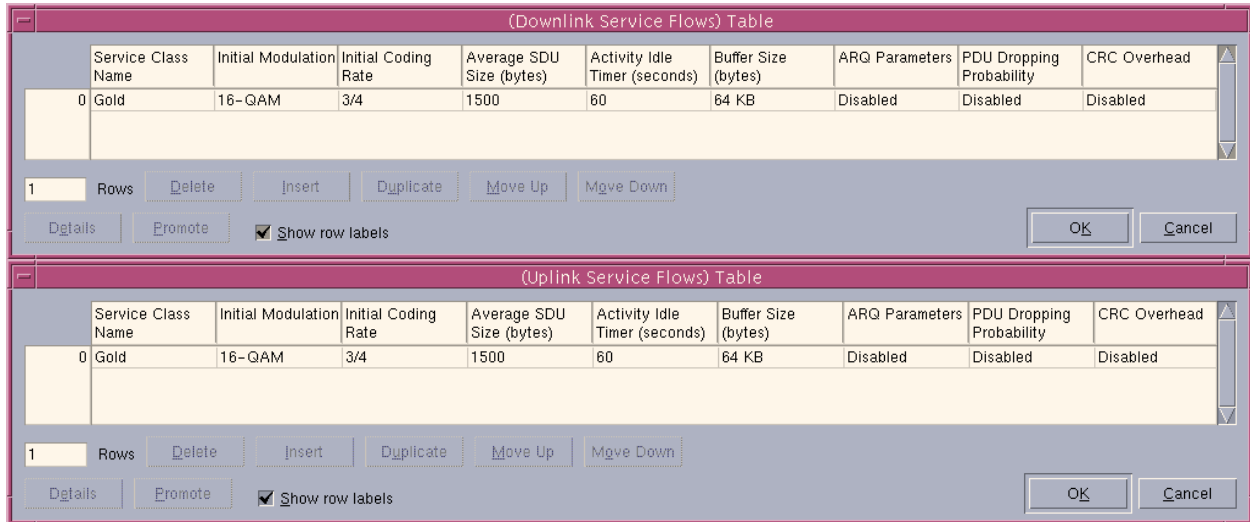

Figure 8 – Downlink and Uplink Service Flows

4.3   GAMING TRAFFIC MODEL

For all of the gaming scenarios, a custom traffic model had to be created, since OPNET did not have a default gaming application. In order to create a custom traffic model, the Application, Profile and Tasks nodes had to be configured.

First, a custom application named *game* was created in the Applications node. It was defined to have serial (ordered) task ordering, use TCP as the transport protocol and utilize best effort service type. These settings are shown in the following figure.
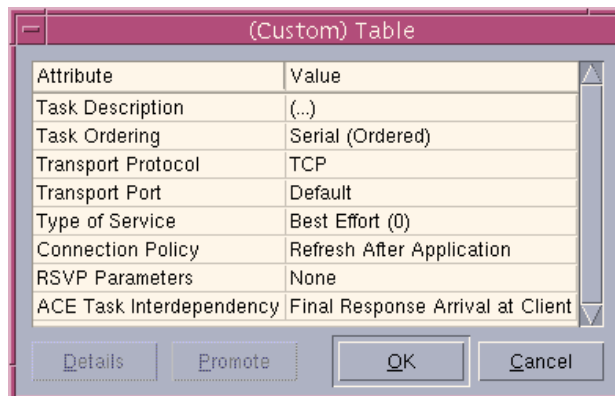

Figure 9 – Custom Application Parameters

The task description field specifies the task that the custom application will be performing. For the case of the *game* application, the task will be defined later. However, in order for the task to be automatically associated with the application, we specified a task called *game_traffic* in the task description field. This can be seen in the following figure.

Figure 10 – Task Description

Second, a profile called *game_profile* was created in the Profiles node. This profile is used by the user nodes in order to generate traffic. The profile was defined to use the *game* application and it was set to begin at the start of the simulation and continue until the simulation is completed. The figure below shows the profile configuration menu.
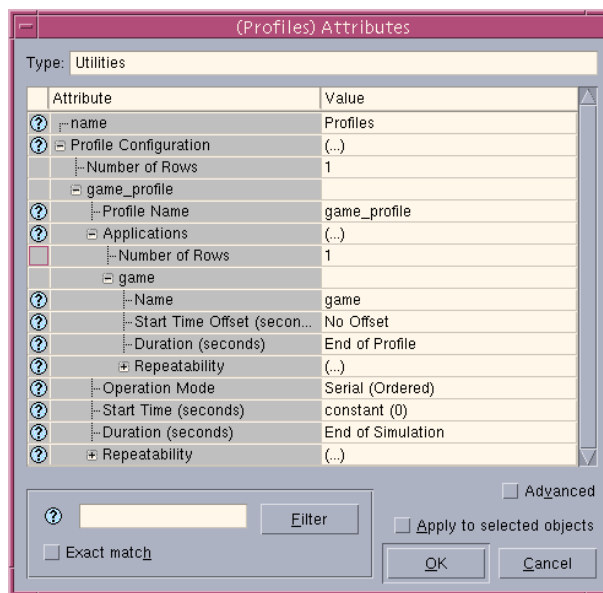

Figure 11 – Profile Attributes

Lastly, the Task node was configured. As mentioned earlier, to associate the task with the *game* application, the created task was named *game_traffic*. It was configured manually in order to correctly define the client-server relationship of the First Person Shooter (FPS) gaming traffic [1]. The task was defined to execute at the start of the application with the Source being the user nodes and the Destination being the game server. These settings are outlined in the following figure.
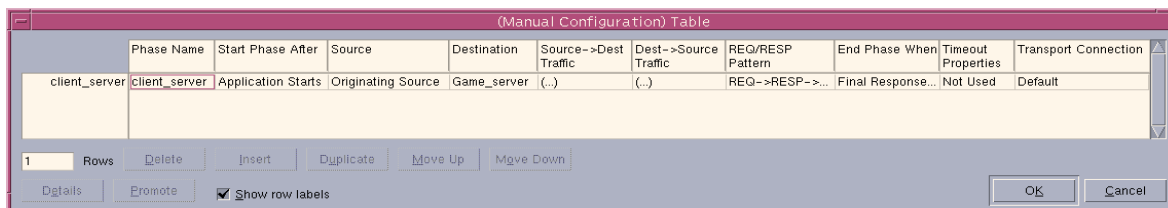

Figure 12 – Task Manual Configuration

The source to destination (client to server) traffic and the destination to source (server to client) traffic are modeled by the probability density function of the packet size and packet interarrival rate graphs in Appendix A [1]. These two parameters can be approximated with the help of the Extreme Value distribution by specifying the peak value a and the scale factor b [6]. The specific peak and scale factor values can be found in Table 3 of the Gaming Traffic Design section. The figure below illustrates traffic settings for the client-server interaction.
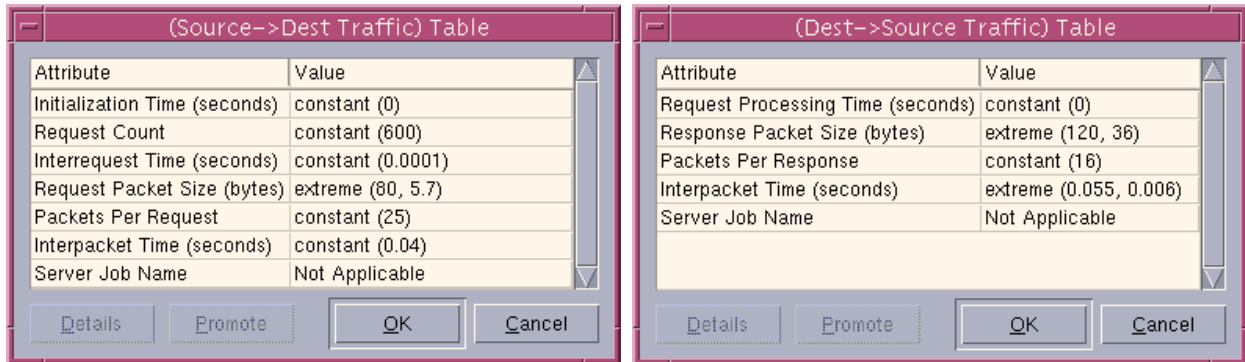
(Source−>Dest Traffic) Table	
Attribute	Value
Initialization Time (seconds)	constant (0)
Request Count	constant (600)
Interrequest Time (seconds)	constant (0.0001)
Request Packet Size (bytes)	extreme (80, 5.7)
Packets Per Request	constant (25)
Interpacket Time (seconds)	constant (0.04)
Server Job Name	Not Applicable

Details   Promote   OK   Cancel

(Dest−>Source Traffic) Table	
Attribute	Value
Request Processing Time (seconds)	constant (0)
Response Packet Size (bytes)	extreme (120, 36)
Packets Per Response	constant (16)
Interpacket Time (seconds)	extreme (0.055, 0.006)
Server Job Name	Not Applicable

Details   Promote   OK   Cancel

Figure 13 – Client-Server Traffic Settings

 Next, the fully-functional *game_profile* was added to the supported profiles section of each user node. Moreover, the preferred destination was set to point to the location of the game server. The following figure outlines these additions.
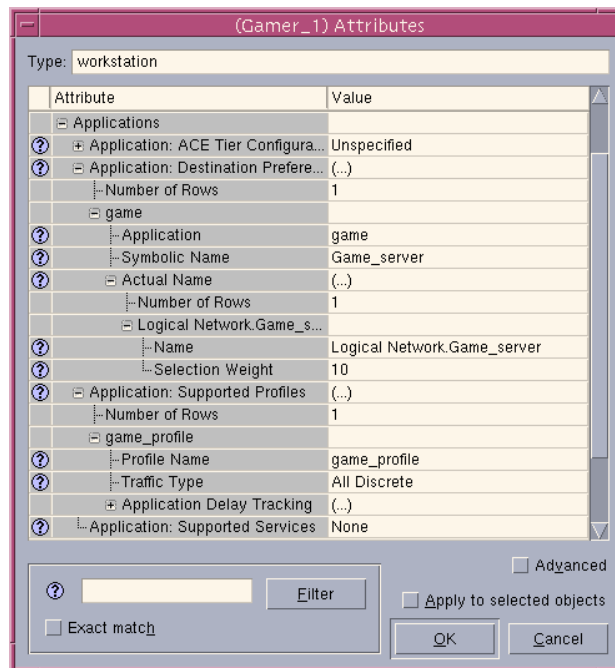
(Gamer_1) Attributes	
Type: workstation	
Attribute	Value
⊟ Applications	
⊕ Application: ACE Tier Configura...	Unspecified
⊟ Application: Destination Prefere...	(...)
⌐Number of Rows	1
⊟ game	
⌐Application	game
⌐Symbolic Name	Game_server
⊟ Actual Name	(...)
⌐Number of Rows	1
⊟ Logical Network.Game_s...	
⌐Name	Logical Network.Game_server
⌐Selection Weight	10
⊟ Application: Supported Profiles	(...)
⌐Number of Rows	1
⊟ game_profile	
⌐Profile Name	game_profile
⌐Traffic Type	All Discrete
⊕ Application Delay Tracking	(...)
⌐Application: Supported Services	None

☐ Advanced

⑦ [   ] Filter   ☐ Apply to selected objects
☐ Exact match   OK   Cancel

Figure 14 – User Supported Profiles

Finally, the *game* application was added to the supported services section of the game server. This is shown in the figure below.

Figure 15 – Game Server Supported Services

5. EXPECTED RESULTS

Prior to running the 4 simulations, we expect certain results based on theories and provided technical specifications. By comparing our simulated results to our expected results, we should be able to explain any unexpected results.

As the theoretical maximum range of a WiMAX system is 50km, we expect that the client in the first scenario should have a relatively low delay, low packet loss, and low jitter. The result of only one client and its proximity to the BS should indicate that a gaming application should have a high quality of experience.

As the clients increase and the distances increase, we expect the delay, packet loss, and jitter to increase to a point where the gaming application will not be playable. In theory, according to Table 1, we expect the throughput to be low, perhaps even lower than 50 kbps. In addition, the delay will be greater than 25 ms, creating a "slow paced" gaming environment that reduces the quality of experience. Although the quality may be low, the gaming application will still function albeit a poor experience for the user.

For the last scenario with one client 25km away, we expect delay, packet loss and jitter all to be unacceptable for a quality experience for gaming applications.

6. SIMULATION RESULTS

With the above scenarios described, we have obtained the following simulation results:

6.1 THROUGHPUT

The screenshots in this section illustrate the throughput in the 4 scenarios. One important observation is that the throughput is fairly constant even up to 5km away from the BS, but when the client is moved to a further distance of 25km, we noticed a severe drop in throughput – up to 50% reduction in comparison to the client 1km away.
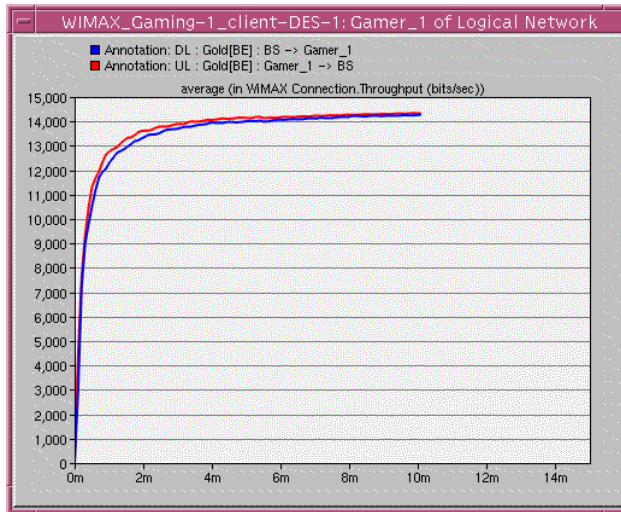
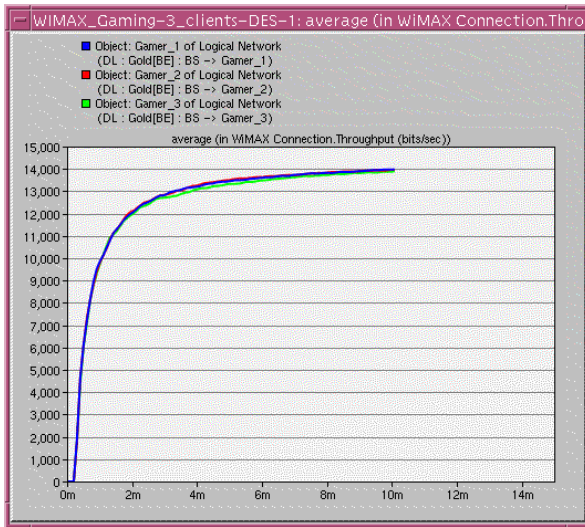**Figure 16 – 1 Client scenario: Throughput (Uplink and Downlink)**
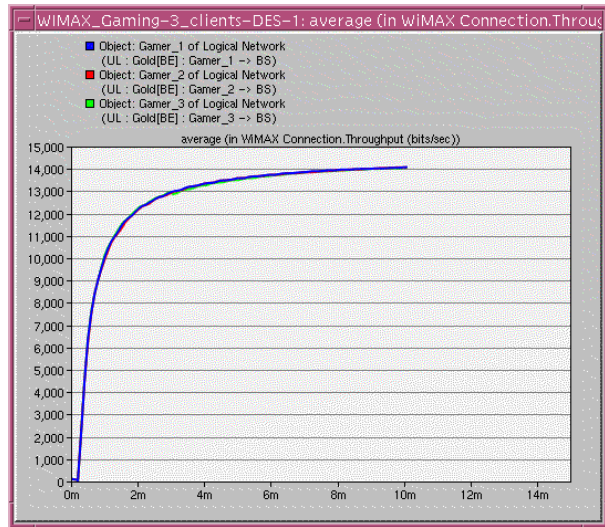

Figure 17 – 3 Client scenario: Throughput (Downlink)

Figure 18 – Client scenario: Throughput (Uplink)
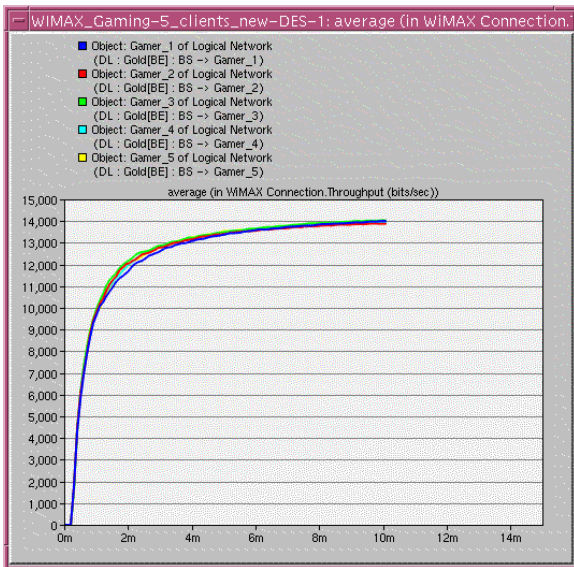

Figure 19 – 5 Client scenario: Throughput (Downlink)
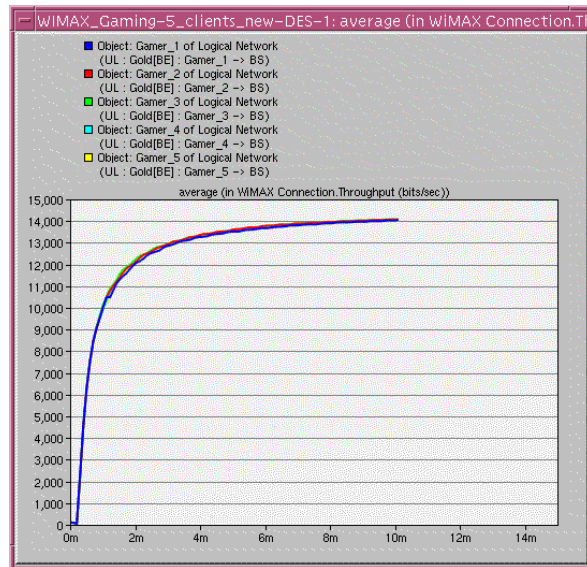

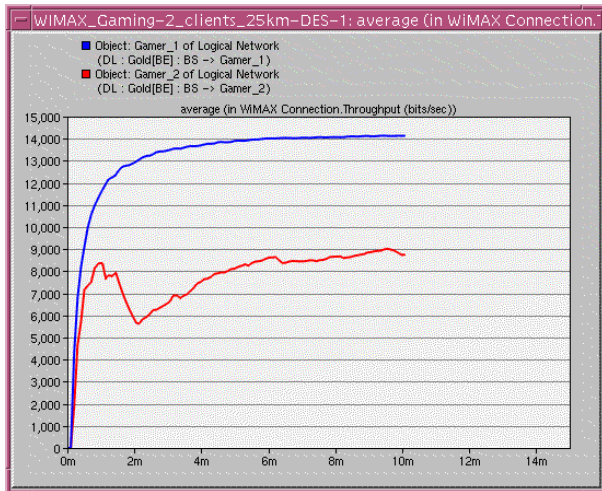**Figure 20 – 5 Client scenario: Throughput (Uplink)**

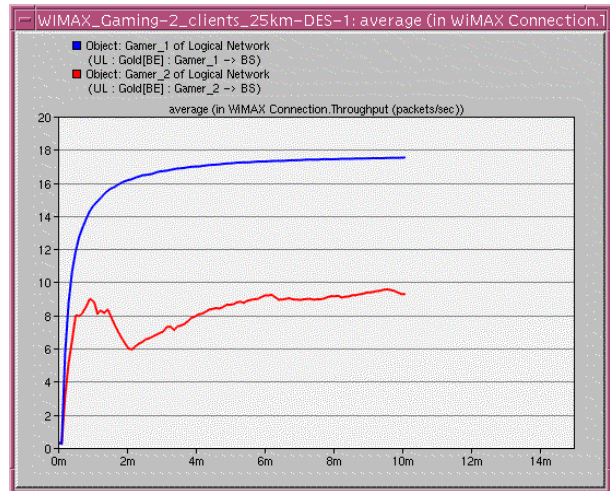**Figure 21 – 2 Client scenario: Throughput (Downlink)**

Figure 22 – 2 Client scenario: Throughput (Uplink)

Moreover, it seems that the addition of extra computers does not affect the throughput of the other computers. Distance is the major variable contributing to the throughput difference in the clients.

6.2 END TO END DELAY (UPLINK AND DOWNLINK)

The screenshots below describe the end to end delay in the four scenarios. Surprisingly, there are no major differences in all scenarios. Even though the throughput had dropped drastically for the client 25km away from the base station, we see that the delay is constant in all four scenarios.
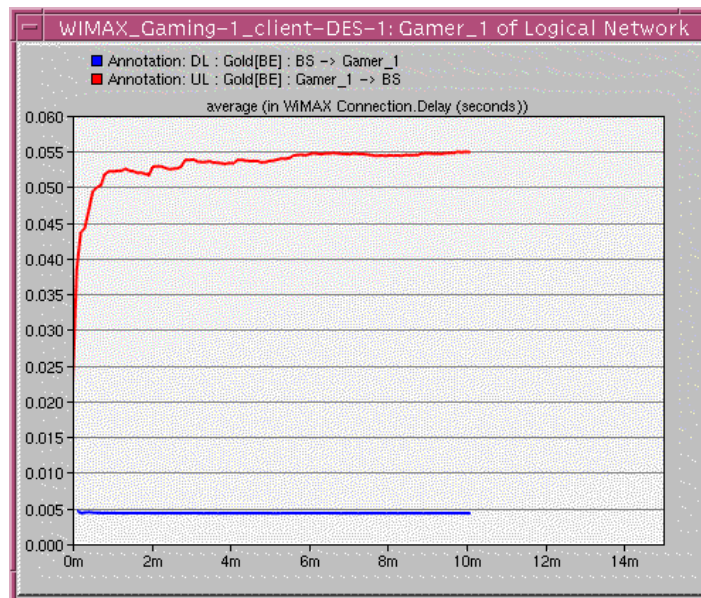

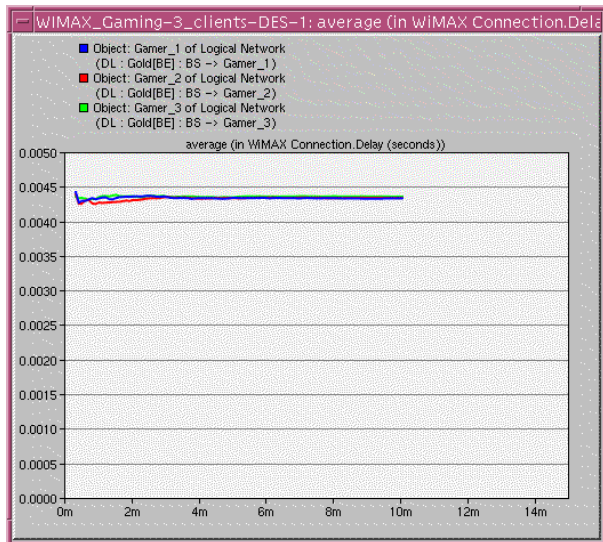**Figure 23 – 1 Client scenario: Delay (Uplink and Downlink)**

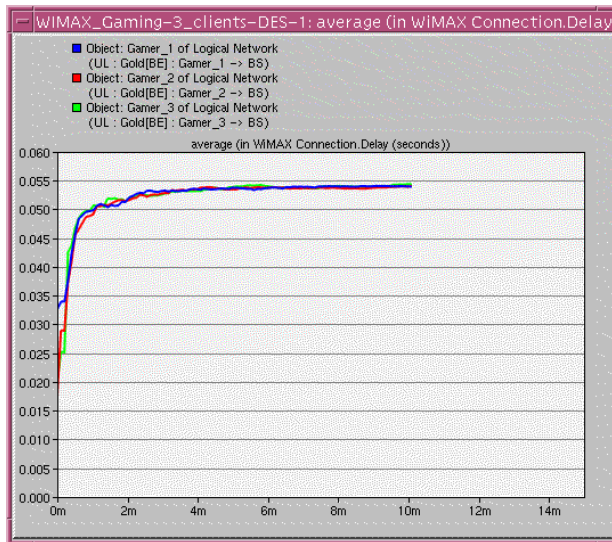Figure 24 – 3 Client scenario: Delay (Downlink)
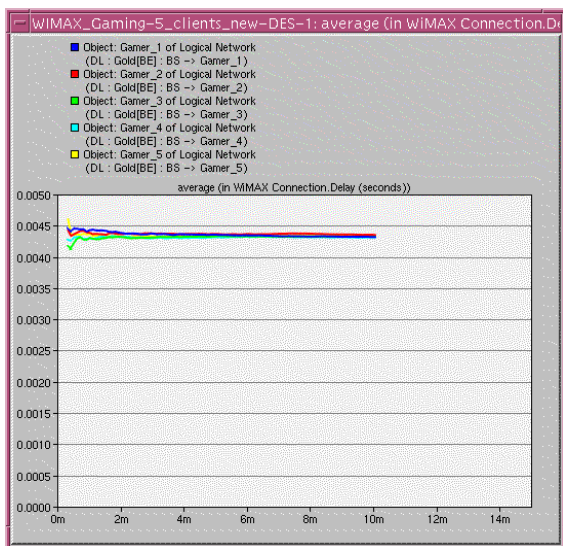

Figure 25 – 3 Client scenario: Delay (Uplink)

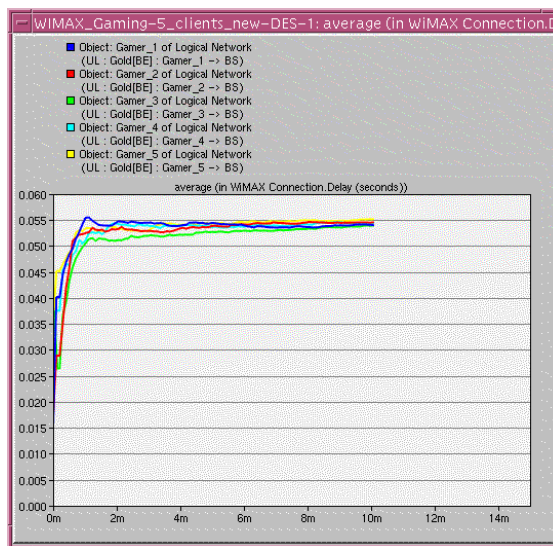Figure 26 – 5 Client scenario: Delay (Downlink)
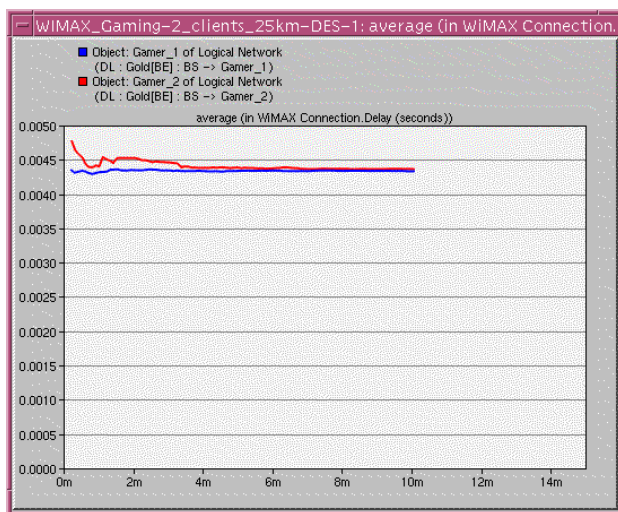

Figure 27 – 5 Client scenario: Delay (Uplink)
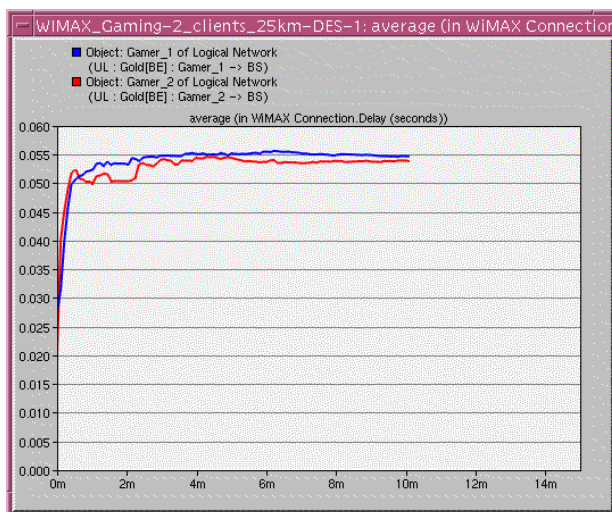

Figure 28 – 2 Client scenario: Delay (Downlink)

Figure 29 – 2 Client scenario: Delay (Uplink)

6.3 PACKET LOSS

In this section, we analyze the packet loss with the given game traffic. The most important thing observed in the packet loss analysis is how the uplink connection has more packets loss compared to the downlink. The reason behind is could be the result of the power of a customer antenna – the power from the base station is significantly stronger than the power from the customer's antenna. For this reason, we will analyze the uplink packet loss as it will determine the quality of experience for gaming traffic on a WiMAX network.
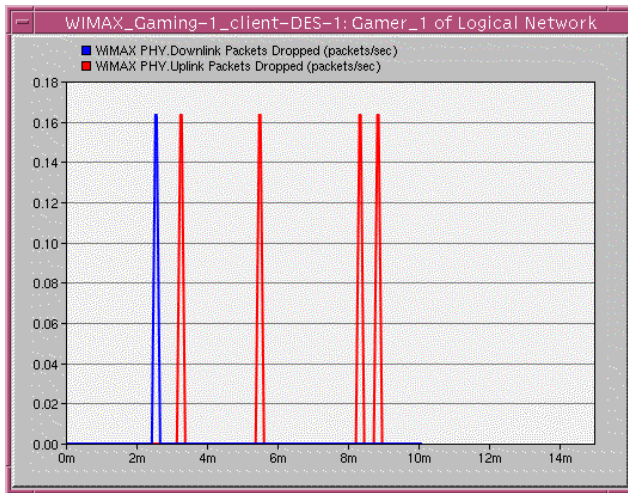

Figure 30 – 1 Client Scenario: Packet Loss
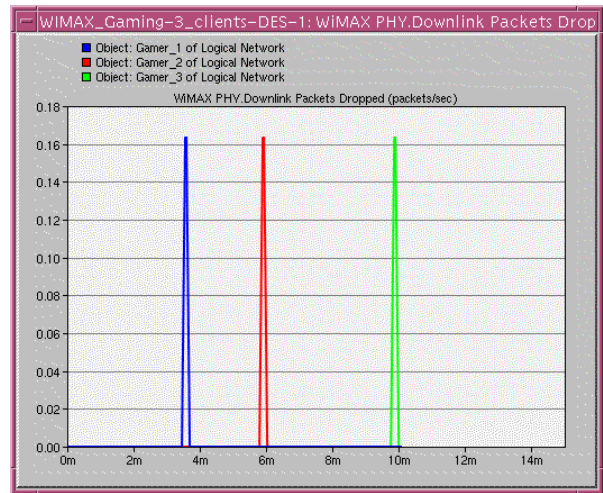

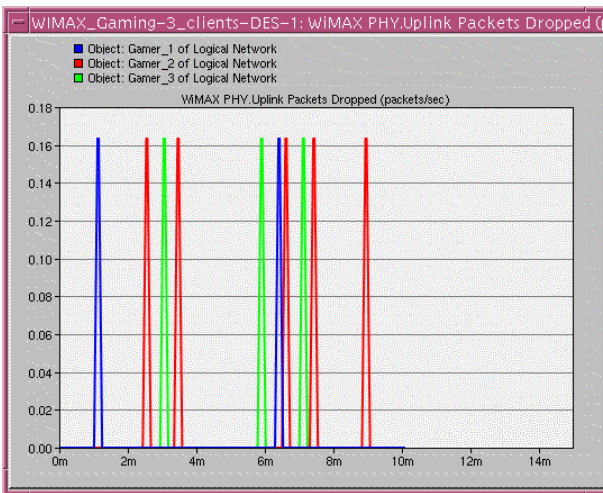Figure 31 – 3 Client Scenario: Packet Loss (Downlink)
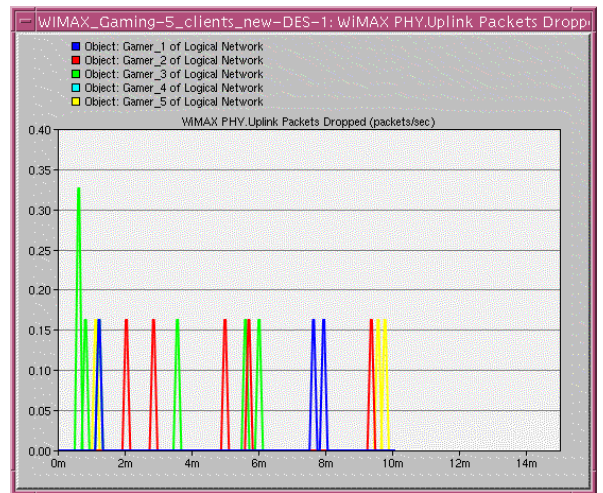

Figure 32 – 3 Client Scenario: Packet Loss (Uplink)

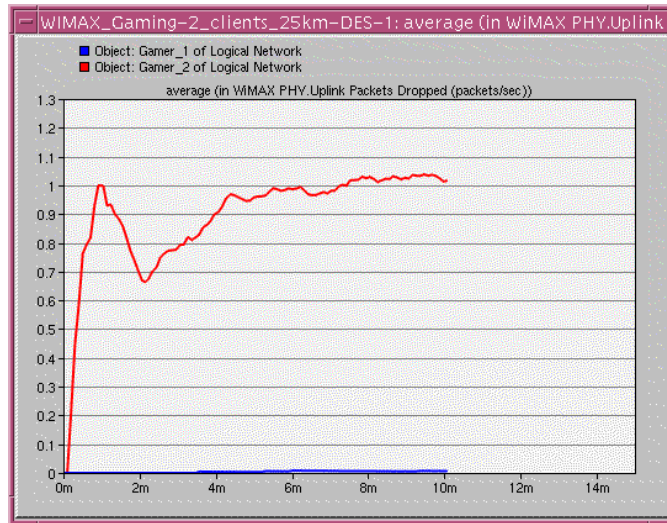Figure 33 – 5 Client Scenario: Packet Loss (Uplink)

Figure 34 – 2 Client Scenario: Packet Loss (Uplink)

6.4 JITTER

Although OPNET has jitter statistics for predefined applications, it does not support jitter statistics for a custom application. Thus, we were unable to collect any simulated data for network jitter.

6.5 SIMULATION SUMMARY

In analyzing the three different statistics, we noticed several things:

For throughput, we notice that regardless of the numbers of clients, we do not see a reduction. It remains quite constant up to 5km, at an approximate of 13-14Kbps for downlink. At 25km, the throughput drastically drops to half that amount, to approximately 7Kbps.

For end to end delay, we don't observe anything drastic – the delay is quite consistent between all four scenarios, even with the client at 25km away from the base station. For most of the scenarios, the downlink delay is approximately 43ms and the uplink delay is approximately 54ms. There is one anomaly, however, for the first scenario of only 1 client at 1km away. The uplink delay is consistent with the other scenarios, but the downlink delay is a lot lower – 5ms. This could be the result of only one station connected at a very close proximity.

For the packet loss, we notice that all uplink packet loss statistics are greater than downlink packet losses. This is expected, as the power from a base station is much greater than the receiving station at the customer's end. As a result, the uplink should be weaker and more packet losses should occur. Since packets are approximately 160 bytes and the throughput is 14KBps, that translates roughly to 90 packets per second. In all scenarios except the last one, we notice instances of packet loss up to 0.18 packets per second. In the last scenario, however, we notice a constant packet loss of 1 packet per second for the uplink. Again, this is expected as the distance is quite far for WiMAX standards.

7. CONCLUSION AND FUTURE WORK

7.1 CONCLUSION

Our project explored the possibility and feasibility of interactive multiplayer game traffic on WiMAX wireless networks as a solution to traditional landline methods. By using OPNET, we simulated 4 scenarios to test for throughput, delay, jitter, and packet in regards with game traffic. In addition, we have also gathered WiMAX results to determine the physical capabilities, independent of game traffic.

By creating custom task, application, and profile definitions we modeled the gaming traffic from Counter Strike and integrated it with our WiMAX network. The results were achieved all indicated that WiMAX will be able to support this genre of multiplayer games. Unfortunately, without jitter results, we cannot reach a conclusive answer that WiMAX will be able to support a high quality of experience. Jitter results aside, the other results meet the demands for interactive multiplayer gaming traffic:

- The throughput was sufficient at 14Kbps as Counter Strike and similar games have a low bandwidth requirement. At 25km away, throughput reduced drastically and may not be able to provide a seamless experience.
- The end to end delay was fairly consistent in all scenarios at approximately 43ms for downlink and 54ms for uplink, even with the client at 25km away.
- The uplink packet loss was fairly low – approximately 0.19 packets per second for the first three scenarios, and 1 packet per second for the last scenario.

With these results, we can conclude that WiMAX will be able to support the genre of interactive multiplayer FPS games. With jitter information, our results will be more accurate and a quantitative measure of the quality of experience can be obtained.

7.2 FUTURE WORK

Although our approximated statistics is a good estimate of the gaming traffic, we could increase our accuracy by incorporating game traffic traces available at Worchester Polytechnic Institute [7]. Unfortunately, the game traces are done in specific configurations and each scenario would requir a precise layout.

In addition, while Counter Strike is still a popular game, there are newer games that have been gaining a significant amount of market share. Moreover, Counter Strike only fulfills one type of genre – there are other genres such as Real Time Strategy and Role Playing Game, both having different demands in a network. Further research and simulation can confirm WiMAX's capability of supporting this class of applications. Lastly, although most users who are using game applications are fixed, there is the possibility of mobile users. Simulating a mobile client with game traffic could also determine if WiMAX can provide something unique; the ability for users to be mobile.

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9. APPENDIX A

Consumer Gaming, 2008-2013 [PB per month]							
	2008	2009	2010	2011	2012	2013	CAGR
Web/Email	1,239	1,595	2,040	2,610	3,377	3,965	**26%**
File Sharing	3,345	4,083	5,022	6,248	7,722	9,629	**24%**
Internet Gaming	47	87	135	166	217	239	**39%**
Internet Voice	103	129	152	174	183	190	**13%**
Internet Video Communications	36	57	94	160	239	354	**58%**
Internet Video to PC	1,112	2,431	4,268	6,906	9,630	12,442	**62%**
Internet Video to TV	29	149	381	1,004	1,711	2,594	**146%**
Ambient Video	110	224	634	1,332	2,089	2,715	**90%**

Server and Client Traffic for Counter Strike
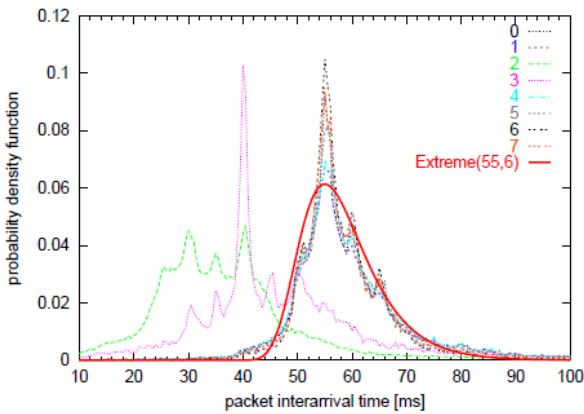
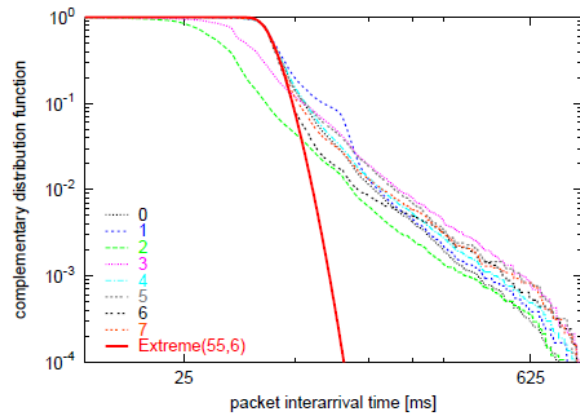Figure 35 - PDF of server packet interarrival time per client

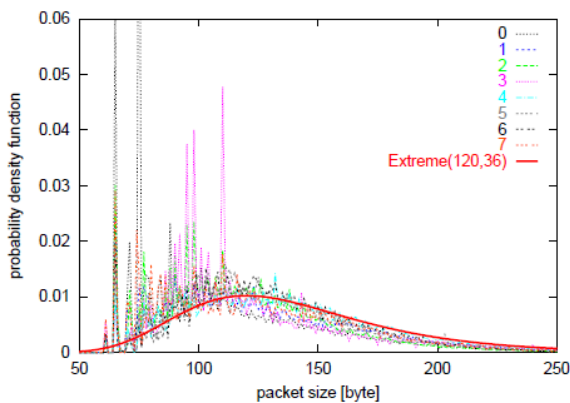Figure 36 – Complementary CDF of server packet interarrival time per client

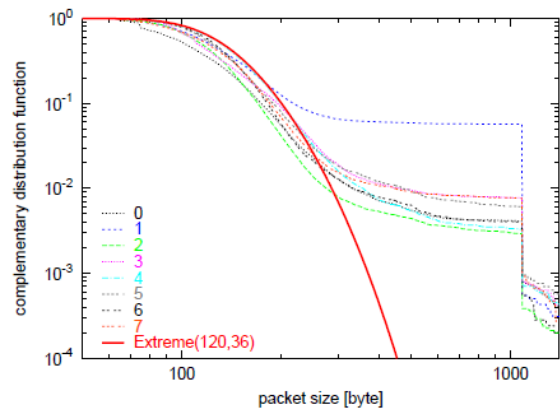Figure 37 – PDF of server packet size per client

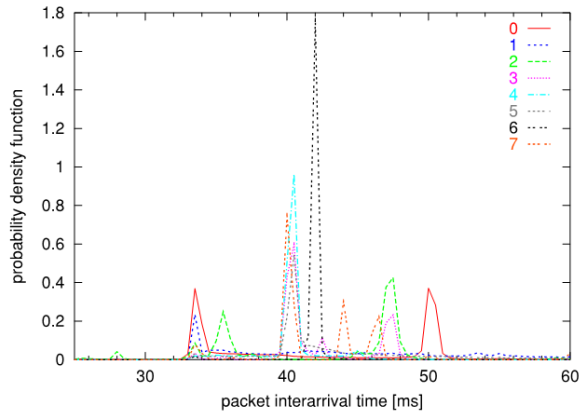Figure 38 – Complementary CDF of server packet size per client

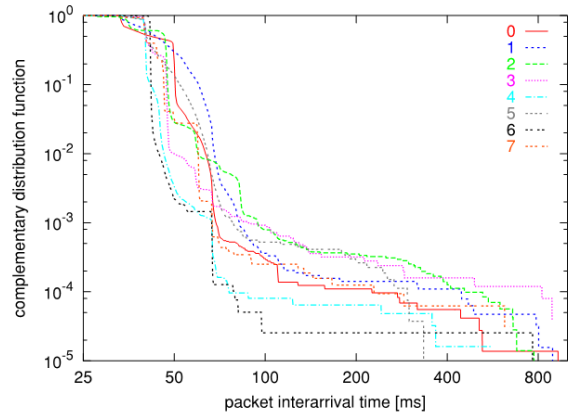**Figure 39 – PDF of client packet interarrival time per client [1]**

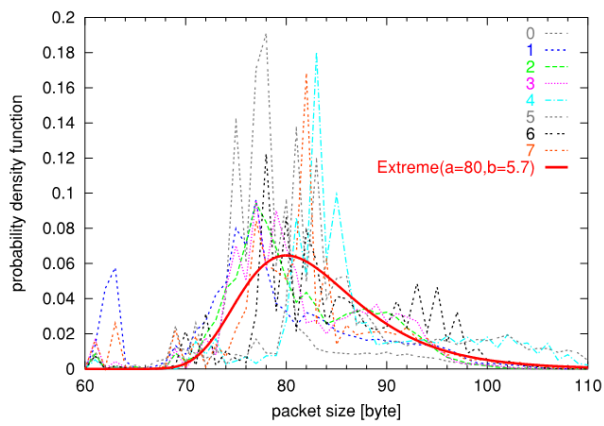**Figure 40 – Complementary CDF of client packet interarrival time per client [1]**

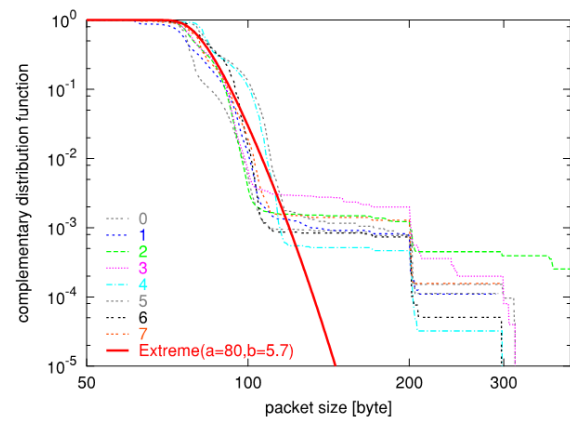**Figure 41 – PDF of client packet size per client [1]**

Figure 42 – Complementary CDF of client packet size of client [1]