ENSC 427: Communication Networks
Spring 2016
Final Project Report

Video Streaming over WiFi using Riverbed Modeler
http://www.sfu.ca/~chweng/ENSC427HP.html

Group #1

Michael Ng – 301136816 – mzng@sfu.ca
Ching Ho Weng – 301139567 – chweng@sfu.ca

Table of Content

List of Figures

1. Abstract

Streaming videos has become extremely popular, whether it is for business, education, or entertainment. Applications such as Netflix, Twitch, and YouTube are all video streaming services that are very widely used. For entertainment purposes, a large majority of audiences stream media using their WiFi network. In our project, we simulated the performance of a multi-user network during video streaming, and tested how connecting to a particular server will affect the performance of the network. In addition, we compared and contrasted streaming 2 different movies, and the effects of changing the server on the results. In our conclusion, we discuss how changing some attributes affects various network statistics and some theories as to explain why. For our simulations, we used Riverbed Modeler 18.0.

2. Introduction

In this project, we simulated a home environment, with various profiles representing users with different amounts of activity. Such profiles include Heavy and Light Browsing, as well as Video Streaming. We will then compare and contrast the 3 profiles and the effects of the network on the throughput and the delay. Next, we simulated a scenario where a user was streaming 2 different movies. We simulated the effects on throughput, delay, jitter, and packets received by comparing and contrasting the 2 different movies, after changing attributes to the server, such as data rate. In these simulations, we observe how various metrics affect a user in a home network and how they impact the video streaming experience.

3. Network Topology

We consider a network topology where a router is connected to different WLAN devices that represent different Internet usage. The router is connected to the server, which provides service to all the devices. The server and router are connected using a 1000BaseX Ethernet link. The devices are WLAN compatible workstations, which we chose due to their higher functionality and flexibility. The average household has many workstations that use WiFi; the workstations can also be modeled as cellphones or tablets. However, the WLAN workstations were chosen for the simulation over the various tablet and cellphone modules, due to their simplicity.
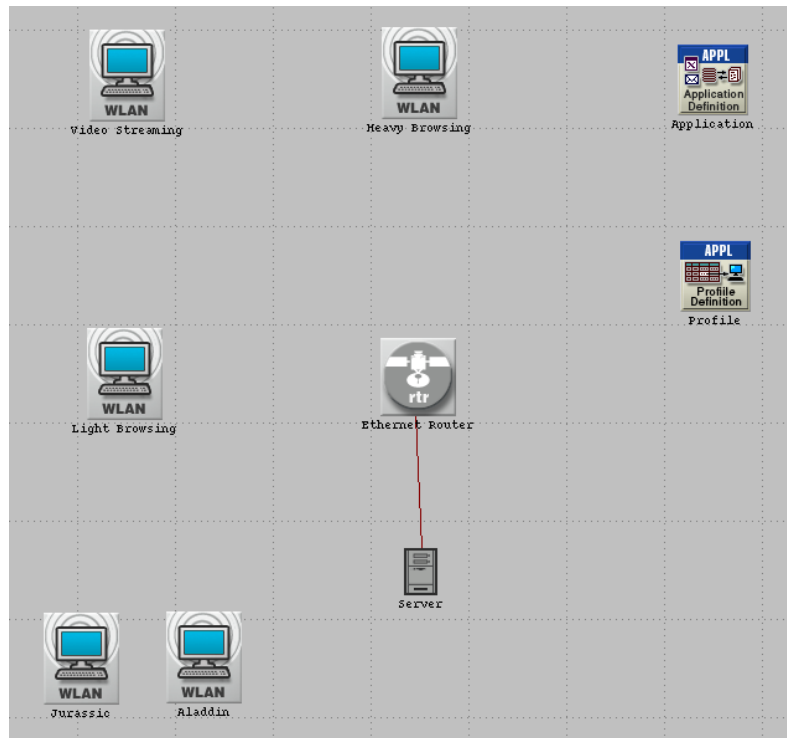
Figure 1: Wireless-LAN Topology.

4. Simulated Applications

In our simulation of the WiFi usage in a typical home network, our scenario includes 3 users browsing the Internet on the same home network. The 3 different applications are: Heavy Browsing, Light Browsing and Video Streaming. The selection of these profiles were chosen because they most accurately describe the general activity of 3 different types of users: average user, casual user and the very heavy user. It's not uncommon for a household to have all 3 of these users on the same network at the same time. The 3 applications were all chosen from the Object Palette provided in Riverbed Modeler [3][5].

4.1. Heavy Browsing

The heavy browsing application is designed to simulate a user that is browsing many websites at the same time, or a website that has high data usage, such as PDF's. Other usage patterns for heavy browsing include websites that have many high-resolution images to load or large bodies of text. In order to simulate a heavy browsing application, some values had to be changed from the default module. The exact profile configuration can be seen below in Figure 2. The most notable change was increasing the Object Size. This size represents how much data a heavy browsing application would use.

Figure 2: Profile Configuration (top) and Heavy Browsing Attributes (bottom).

4.2. Light Browsing

On the other end of the data usage spectrum, the light browsing application is designed to simulate a user that is browsing websites that have very little text. Examples of this are the Google homepage, or the ENSC 427 website. Similarly to the heavy browsing application, some changes had to be made to the default profile for an accurate simulation. The exact profile configuration can be seen in Figure 3 below. Again, we note that the Object Size was increased from the default values. However, for light browsing they are much smaller in size compared to the heavy browsing application, to accurately simulate this type of user.
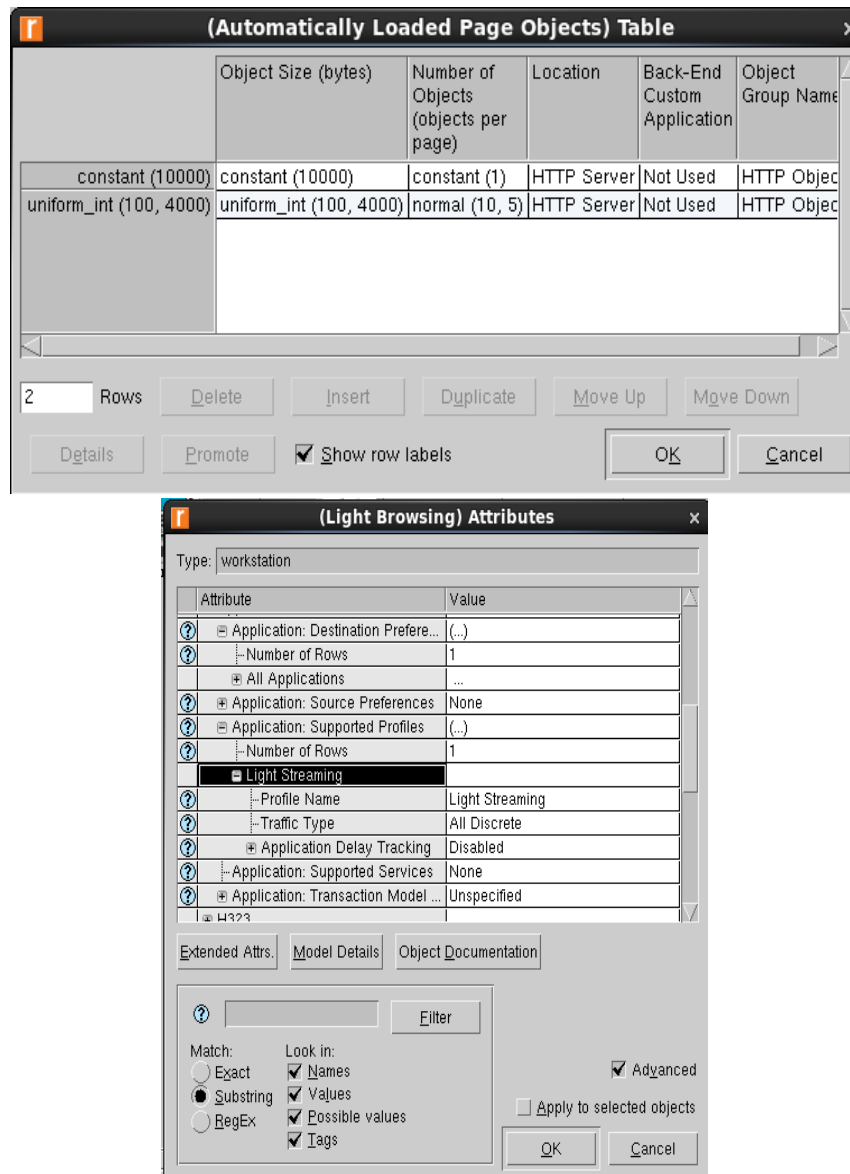
Figure 3: Profile Configuration (top) and Light Browsing Attributes (bottom).

4.3. Video Streaming

The video streaming application was designed to simulate a user that is streaming media that is being delivered by a user. The most popular examples of this are Netflix and Twitch. The exact profile configuration can be seen in Figure 4 below. A hypothesis before doing any simulations is that video streaming will have much higher data usage, as live streaming media is dependent on the delivery method of the medium, rather than simply just downloading the media.

Figure 4: Video Streaming Attributes (top) and Application Attributes (bottom).

4.4. Simulation Scenario and Results
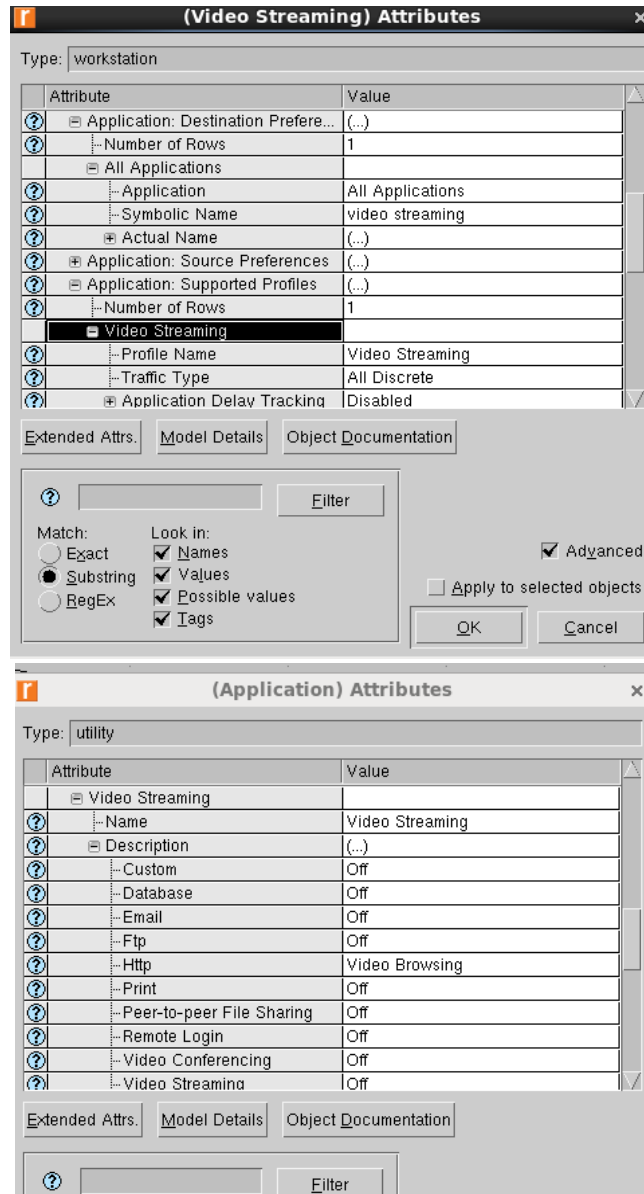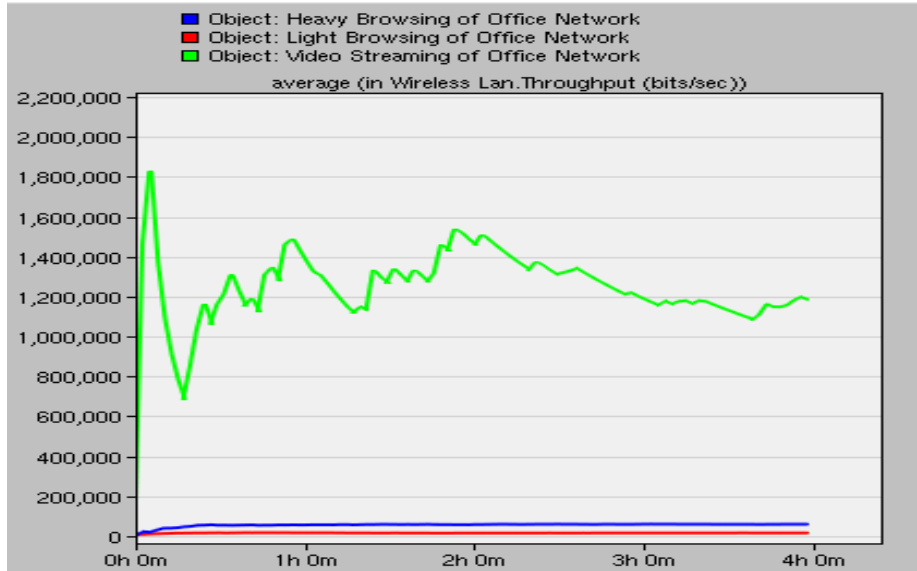
We simulated the light, heavy browsing, and video streaming application, and compared the throughput and delay of each. For our first simulation, we overlaid the throughput graphs for light and heavy browsing as seen in Figure 5 below. Notice that the throughput of the heavy browsing application (blue graph) is much higher than that of the light browsing application (red graph). This matches our hypothesis, as the heavy browsing application has much more content than its light counterpart, thus the throughput would be much higher.
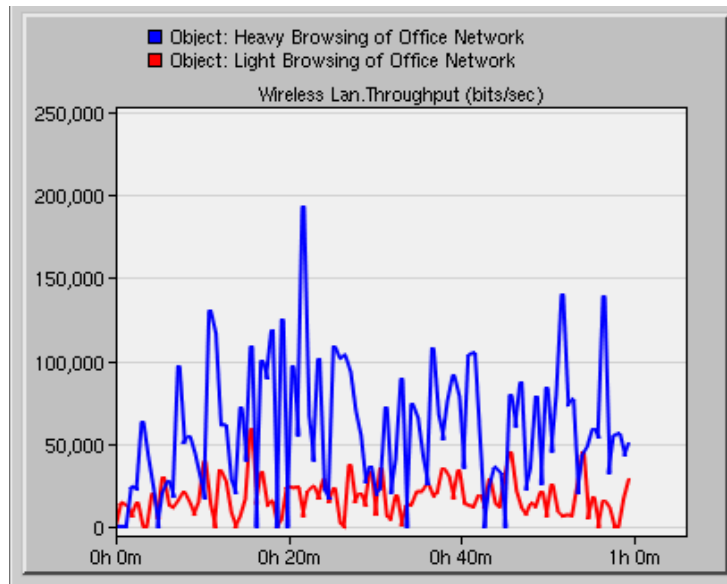
Figure 5: Overlaid Throughput of Light and Heavy Browsing.

In the next simulation, we compare the average throughput of all 3 applications. The overlaid average graph can be seen in Figure 6. At first glance, it is very apparent that the throughput of video streaming (green graph) is extremely high compared to either of the web browsing profiles. This matches our hypothesis, as video streaming has high data usage, which results in a high throughput.

Figure 6: Average Throughput of Light Browsing, Heavy Browsing and Video Streaming.

Next, the delay was compared for each of the applications in Figure 7. Video streaming has the highest delay, while light browsing has the lowest delay. Given a fixed bandwidth, like in our simulation, a high throughput is directly related to a high delay. Thus, the relatively high delay for video streaming and low delay for light browsing is expected.
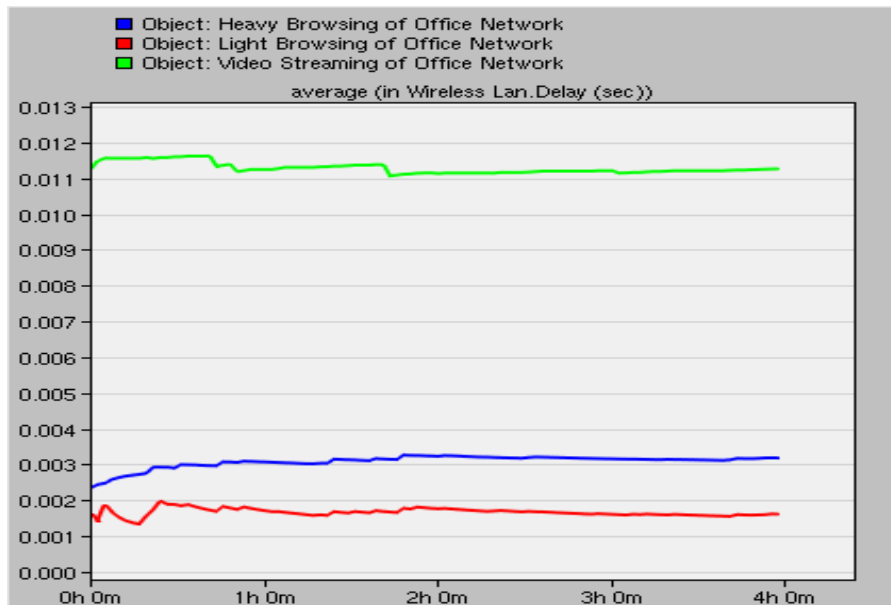
Figure 7: Average Delay of Light Browsing, Heavy Browsing and Video Streaming.

5. Streaming a Movie

The next part of our simulation of WiFi usage in a home network is simulating a user streaming movies from a home media server. This is used in households where the user is located in a different room than the media server. We will simulate a user streaming an MPEG-4 movie by including the trace file of the movie into Riverbed [7][8]. The purpose of this simulation is to determine which attributes of the movie affects the user's Quality of Service (QoS), such as frame rate, data rate, and the type of movie.

5.1. Effect of Frame Rate

Frame rate is the rate at which still images of a movie are projected onto the screen. The rate at which the frames are shown is called Frames Per Second (FPS). We simulated a user streaming the movie "Aladdin" from their home network; running at 10 FPS and 30 FPS. The average movie frame rate is 24 FPS, so we chose 10 and 30 FPS to see the results more clearly. Then we compared and contrasted various network statistics such as throughput, jitter, and end-to-end delay.

Throughput is the "rate of successful message delivery over a communication channel" [10]. With a higher data rate, it is able to transfer more data in a fixed amount of time. Below in Figure 8, we can see that the movie run at 30 FPS has a higher throughput. This is expected, as with a higher FPS, the movie is showing more frames, thus, will have higher amounts content.
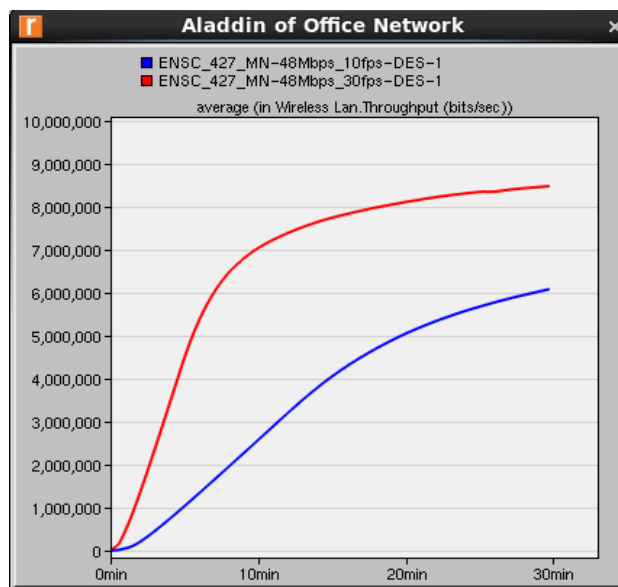
Figure 8: Throughput of Aladdin at 10 FPS (Blue) and 30 FPS (Red).

Another consequence of higher FPS movies having more content, is that they will also have an increased rate of which traffic is received. The user receives more traffic from the server, as the server simply has more information to send. This increase in received traffic is shown in Figure 9.
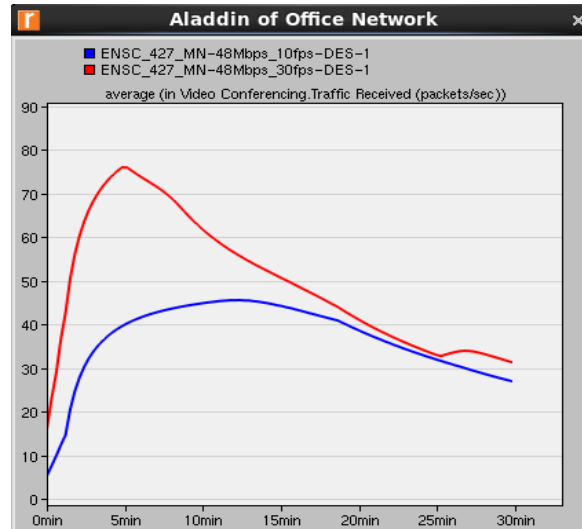
Figure 9: Traffic Received of Aladdin at 10 FPS (Blue) and 30 FPS (Red).

Next, we look at how packet delay variation, also known as jitter, is affected by the FPS. Jitter is defined as the variation in packet delay. High jitter is bad for the QoS, as it can cause undesired effects in the audio, or perhaps cause the frames of the movie to flicker. This is due to the fact that the amount of time it takes for data to travel between the user and the device has suddenly shifted.
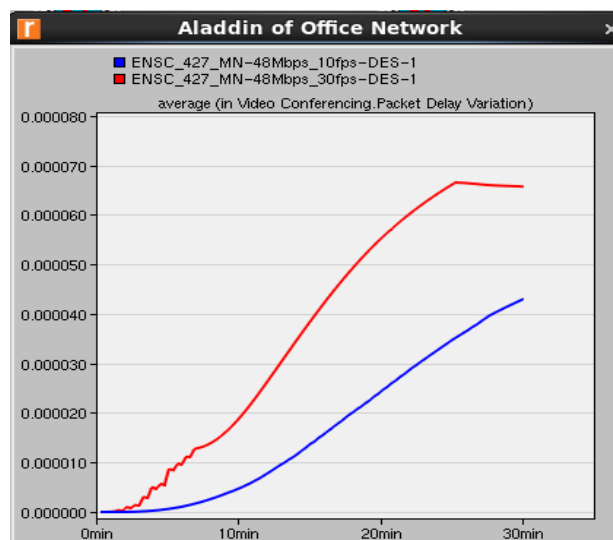
Figure 10: Packet Delay Variation of Aladdin at 10 FPS (Blue) and 30 FPS (Red).

In Figure 10 above, we see that at 30 FPS, Aladdin has a slightly higher jitter compared to its 10 FPS counterpart. Given a fixed bandwidth, the network of the 30 FPS case is more likely to be congested, due to a higher content count. As a result, the jitter is increased, due to the contention in the network.

Next, we look at the End-to-End delay, which is defined as the time it takes for a packet to be transmitted across the network from the source to the destination. In our simulation, this refers to the movie being transmitted from the home server to the user. The End-to-End delay of the 30 FPS movie is higher, as the transmission delay of a network is higher, given an increased number of bits to transmit. This can be seen in Figure 11.
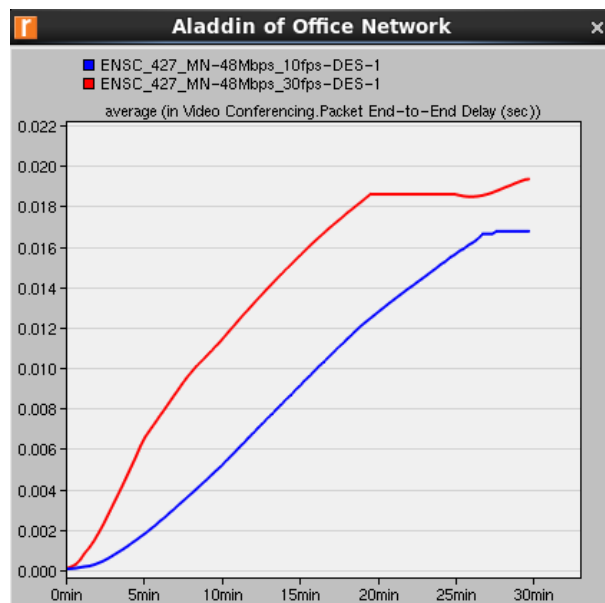
Figure 11: End-to-End Delay of Aladdin at 10 FPS (Blue) and 30 FPS (Red).

Based on the above characteristics between the 10 FPS case and the 30 FPS case, by increasing the FPS, the throughput is increased by a significant amount; over 2 million bits/sec at 30 minutes! However, the tradeoff is that the jitter and End-to-End delay is increased as well for an increased frame rate. However, the jitter and End-to-End delay is increased by a much smaller amount than the throughput. Generally speaking, it is desirable to have an increased frame rate, but this will vary, depending on the preference of the user.

5.2. Effect of Data Rate

In this section we compare how the data rate of the router will affect the QoS in movie streaming. Our first simulation had the two movies streamed at 12Mbps, and the next simulation, they were both streamed at 48Mbps. From the figure below, it shows that by increasing the data rate by 300%, the Wireless LAN delay drops about 50%. With the graph on the right, the End-to-End Delay drops at about 50% as well. This simulation shows that the higher the data rate is, the less time it takes for a block of information to travel across a network.
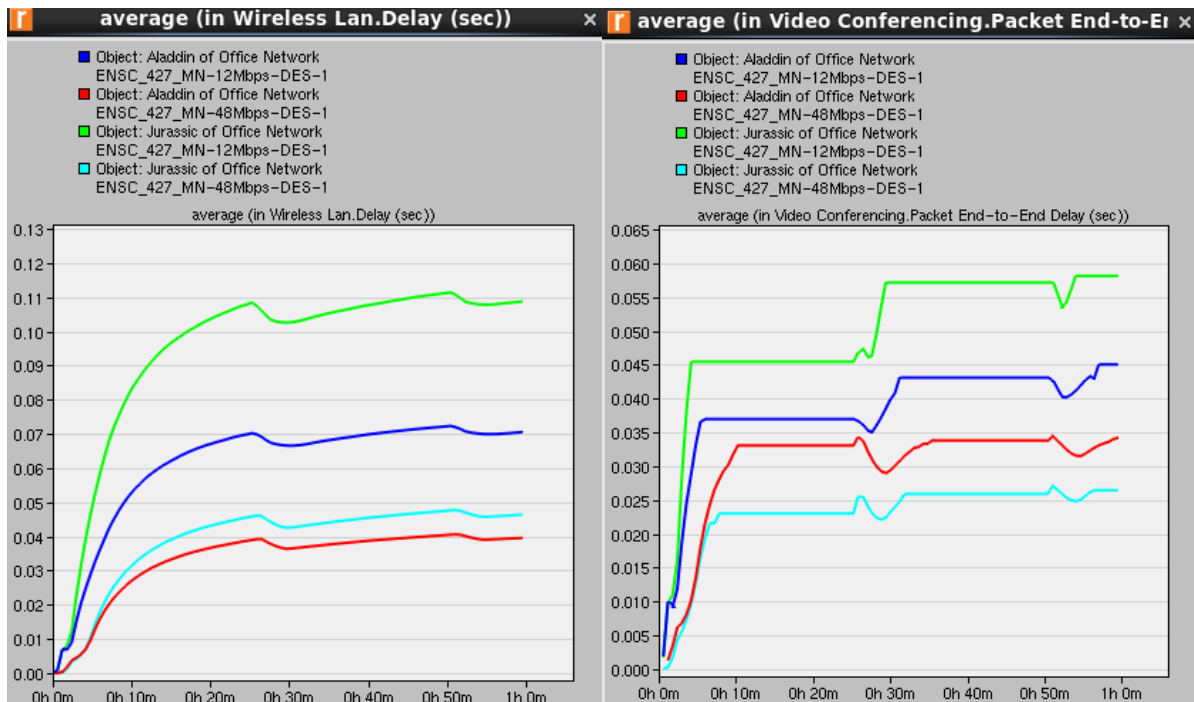

Figure 12: Delay (Left) and End-to-End Delay (Right) between Two Different Movies and Data Rates.

From Figure 13, we can see that at 48Mbps, the jitter is much lower, compared to the 12Mbps data rate. This is expected as the router is less likely to backup at a higher data rate.
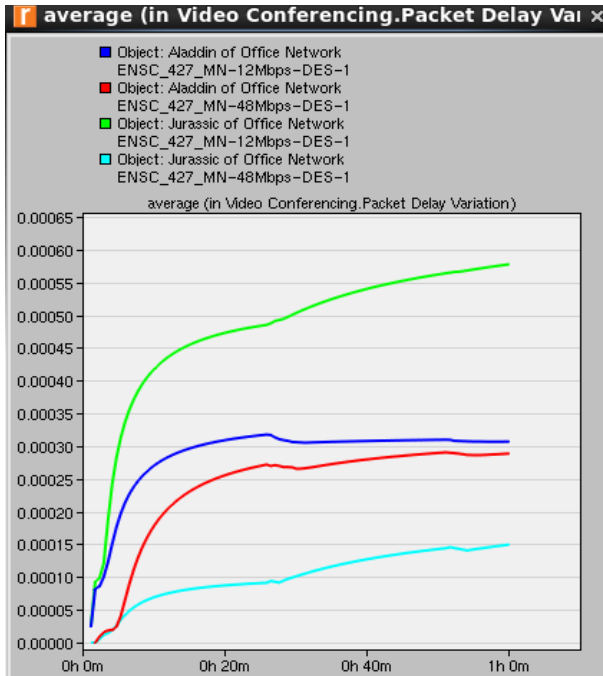
Figure 13: Packet Delay Variation between Two Different Movies and Data Rates.

With our previous definition of throughput, the higher data rate channel is expected to have a higher chance of successful message delivery, as it can transfer more data within the same time frame. This is shown below in Figure 14 with Jurassic Park (teal and green graphs). Aladdin, on the other hand, has a higher throughput with the lower data rate (red and blue graphs).
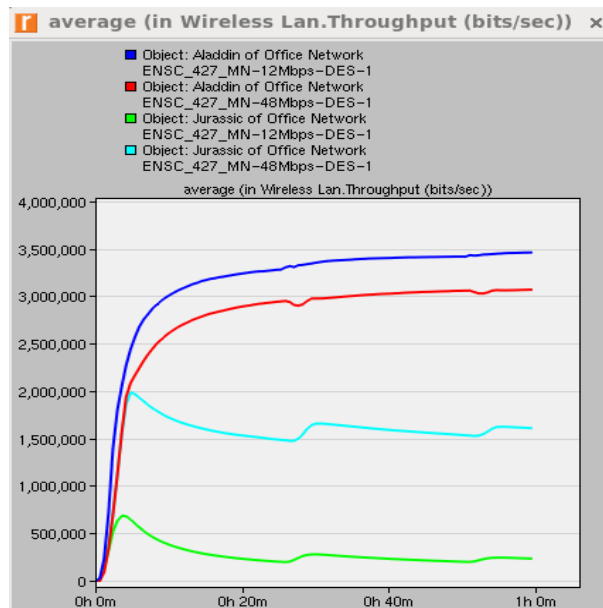
Figure 14: Throughput between Two Different Movies and Data Rates.

An explanation for the conflict between the simulation and theory is that streaming Aladdin is not as dependent on the data rate. As seen below in Figure 15, Aladdin at both the 12Mbps and 48Mbps data rates is receiving roughly the same amount of traffic. The large spike corresponding to Aladdin ran at 12Mbps (blue graph) can be attributed to a buffer. The buffer is pre-loading the movie beforehand, so the rest of the movie can be run smoothly. As a result of similar amounts of traffic received, the throughput of the two different data rates are also similar.
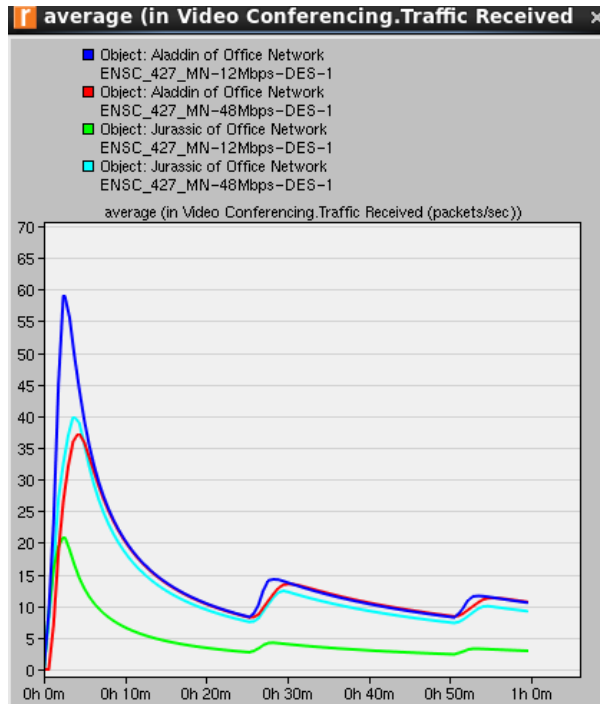
**Figure 15:** Packet Received between Two Different Movies and Data Rate.

Based on our simulations, the delay, End-to-End delay, and jitter are all decreased when the data rate is increased from 12Mbps up to 48Mbps. At the same time, the throughput of the router is increased. Thus, we can conclude that having an increased data rate vastly improves the QoS of the user.

5.3. Movie Content

In this section, we compare how much content of the movie will affect the quality of movie streaming. In theory, the movie Aladdin is a movie with less content, since it's is a movie where all the frames are hand drawn. Jurassic Park on the other hand, which is a movie containing lots of computer-generated imagery, has much more content.

From Figure 16, movie Aladdin has a lower delay and End-to-End delay than Jurassic Park. This result is expected, since Aladdin has less content, there will be less congestion in the network.
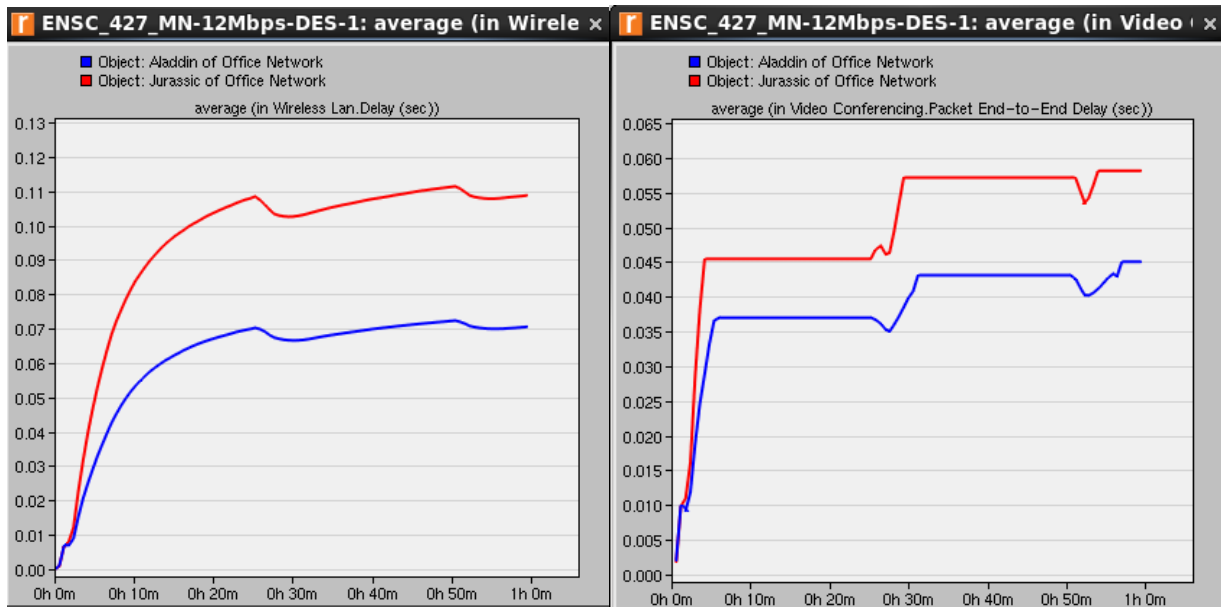
Figure 16: Delay (Left) and End-to-End Delay (Right) between Two Different Movies.

In Figure 17, the graph on the left shows that the movie Aladdin has less jitter than the movie Jurassic Park. Since the movie Aladdin is a less intense movie, it's more likely going to be less affected by delay.

The right graph of Figure 17 shows that the movie Aladdin actually has much higher throughput than the movie Jurassic Park. One reason for this can be that since the movie Jurassic Park is the first movie that contains a large amount of computer-generated imagery, the compression algorithms aren't as efficient at compressing the movie. Therefore, the amount of packets dropped is increased during the data transfer. We compared the compression ratio of the trace files of Aladdin and Jurassic Park. We found that this ratio for Jurassic Park (9.92) was much smaller than that of Aladdin (17.46) [9], which supports our theory.
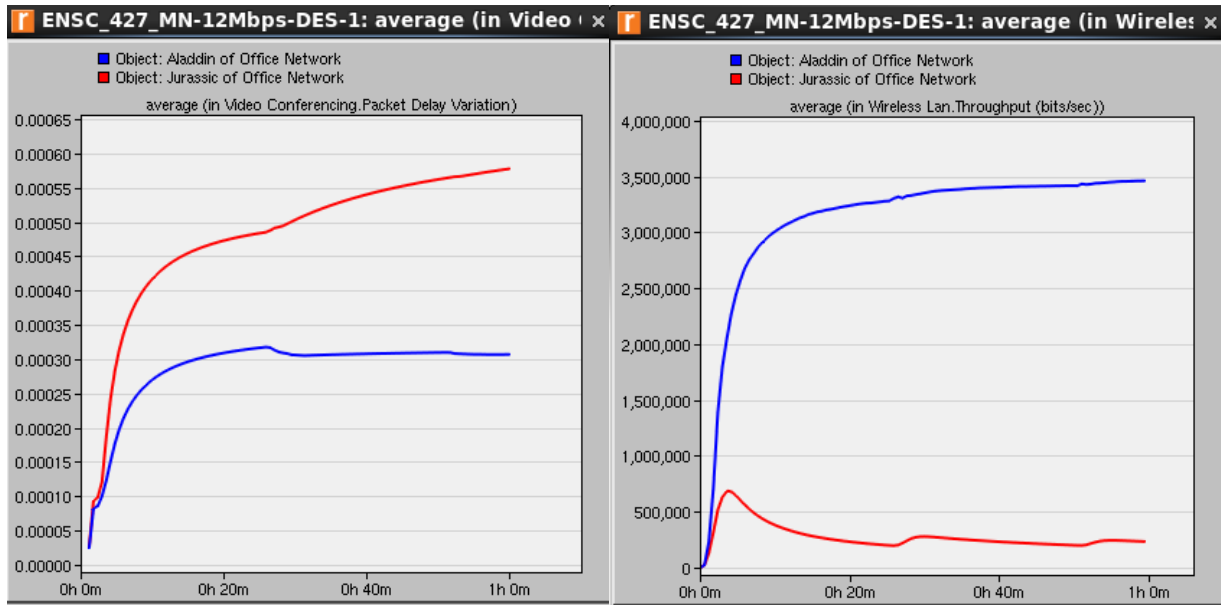
Figure 17: Jitter (Left) and Throughput (Right) between Two Different Movies.

Since the packet are more likely to dropped during data transmission it is reasonable to assume that the movie Jurassic Park is receiving less packets than the movie Aladdin. This result can be seen below in Figure 18.
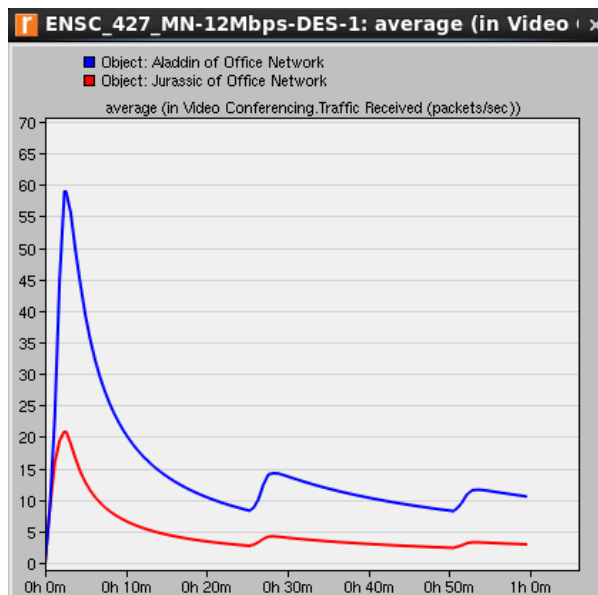
Figure 18: Traffic Received between Two Different Movies.

In conclusion, streaming movies with less content, such as Aladdin, yield better results in terms of the QoS, compared to high-content movies, like Jurassic Park. Our simulation shows that Aladdin has higher throughput, while minimizing negative characteristics.

6. Discussion and Conclusion

In the simulation of multiple users browsing the Internet on the same network, we saw that the Heavy Browsing user browsed higher content websites or media, compared to the Light Browsing user. This resulted in the Heavy Browsing user to have the higher throughput value. This is especially evident when Video Streaming is introduced, which has the highest data usage of the 3 applications, and thus has the highest throughput. In the case of home browsing, the data usage is also directly related to the amount of delay. As a result, Video Streaming has the highest delay, while Light Browsing has the lowest. This concept is intuitive, as the more packets there are required to be transmitted in the network, the longer it takes for them all to be transmitted.

In the simulation of streaming a movie in a home network, we compared and contrasted a variety of attributes, such as changing the frame rate, data rate, as well as the contents of the movie. We then measured the effects of each on network parameters such as throughput, delay, and jitter.

With frame rate, the higher frame rate has a significant advantage in the throughput rate. However, this has a tradeoff with an increase in jitter and End-to-End delay. It can be noted that the throughput is heavily increased while the jitter and End-to-End delay is only slightly or moderately increased. Therefore, it is desirable to have a moderately high frame rate to have an increased throughput, but not high enough that the jitter and End-to-End delay decreases the Quality of Experience (QoE) for the user.

In our simulation of increasing the data rate, we saw an increase in the throughput rate of the router when we increased the rate from 12Mbps to 48Mbps. In addition, we saw a decrease in the delay, End-to-End delay, and the jitter. From these results, we can conclude that increasing the data rate significantly improves the QoS for the user.

When simulating two movies with differing amounts of content, the lower content movie, Aladdin, has yields better statistics regarding the QoS. Streaming Aladdin had increased throughput rates, while having lower delay, End-to-End delay, and jitter, compared to Jurassic Park. One possible explanation for the higher content movie having lower throughput is that the algorithm that compresses the high content movie may be inefficient, resulting in packet loss. Jurassic Park has a lower compression ratio than that of Aladdin, which supports our hypothesis. However, this lossy compression method may not alter the movie greatly compared to the uncompressed file. Many minor inconsistencies caused by the compression algorithm are imperceptible to the human eye.

7. References

[1] I. Gupta and P. Kaur, "Comparative Throughput of WiFi and Ethernet LANs using OPNET MODELER," *International Journal of Computer Applications*, vol. 1, no. 2, Dec. 2010. [Online]. Available: http://www.ijcaonline.org/volume8/number6/pxc3871753.pdf.

[2] "Wireless LAN (Wifi) Tutorial." *Tutorial-Reports.com*. Feb. 2013 [Online]. Available: http://www.tutorial-reports.com/wireless/wlanwifi/index.php.

[3] R. Paul, S. Lally, and Lj. Trajkovic, "Simulation and performance evaluation of WiFi and WiMAX using OPNET," *OPNETWORK 2011*, Washington, DC, Aug. 2011. [Online]. Available: http://www2.ensc.sfu.ca/~ljilja/papers/Opnetwork2011_paul_lally_final.pdf.

[4] "How Wi-Fi Works", retrieved Feb 2016. [Online]. Availible: http://nostarch.com/download/wifi_01.pdf.

[5] W. Hrudey and Lj. Trajkovic, "Streaming Video Content Over IEEE 802.16/WiMAX Broadband Access," *OPNETWORK 2008*, Washington, DC, Aug. 2008. [Online]. Available: http://www2.ensc.sfu.ca/~ljilja/papers/hrudey_trajkovic_opnetwork2008_final_revised_again.pdf.

[6]J. Kim, J. Zheng and P. Bertsch, Video Streaming over WiFi, 1st ed. 2015. [Online]. Available: http://www2.ensc.sfu.ca/~ljilja/ENSC427/Spring15/Projects/team2/ENSC427_team2_report.pdf.

[7]"Directory listing for Jurassic", *Www-tkn.ee.tu-berlin.de*, 2016. [Online]. Available: http://www-tkn.ee.tu-berlin.de/research/trace/pics/FrameTrace/mp4/indexaa60.html.

[8]"Directory listing for Aladdin", *Www-tkn.ee.tu-berlin.de*, 2016. [Online]. Available: http://www-tkn.ee.tu-berlin.de/research/trace/pics/FrameTrace/mp4/indexa4f6.html.

[9]"Trace Statistics", *Www-tkn.ee.tu-berlin.de*, 2016. [Online]. Available: http://www-tkn.ee.tu-berlin.de/research/trace/stat.html. [Accessed: 01- Apr- 2016].

[10]"Throughput", *Wikipedia*, 2016. [Online]. Available: https://en.wikipedia.org/wiki/Throughput.