ENSC 427: COMMUNICATION NETWORKS
SPRING 2015

FINAL PROJECT
Video Streaming over WiFi
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1) Abstract

Wireless Fidelity (WiFi) is a wireless local area network (WLAN) technology that allows multiple users to connect to a network through radio waves. WiFi was introduced as the 802.11 standard by the Institute of Electrical and Electronics Engineers (IEEE). Nowadays, many devices such as smartphones, laptops, and tablets can connect to a network environment through access points. With video streaming applications becoming more widely used than ever, we will attempt to simulate streaming performance in a home environment using various 802.11 specifications. This simulation will cover metrics such as packets received, jitter, and end-to-end delay with Riverbed Modeler.

2) Introduction

We will attempt to simulate a home environment with clients utilizing video streaming, web browsing, and VoIP. The first case involves creating a multiuser scenario where the network is incapable of handling the overall throughput requirements at a given data rate. In an attempt to correct this, the data rate of the router and workstations will be increased. Next, we would like to compare the performance of the 802.11a/g/n standards, and observe which performs the best for a given topology. Lastly, the effects of distance on the aforementioned standards will be tested using a mobile node trajectory. This will also try to show if there are any tradeoffs between data rate and range. The main focus of these simulations will be to observe performance metrics of a mobile user utilizing a video stream, and what kind of scenarios can affect the Quality of Service (QoS).

3) Background

Wireless network is a type of computer network that removes the requirement for physical cables, and has become widely used over the last 15 years. WiFi is capable of transferring data through radio frequencies between 2.4 GHz to 5 GHz [1]. Due to the advantage of reducing the amount of wiring and cables, the spread of WiFi has reached homes, offices, hotels, and other public environments. Now, for the average user, WiFi has reached an acceptable speed which has led to many devices supporting the WiFi technology. Along the way, several classes of the 802.11 standard has been developed, each with their own advantages and disadvantages that stem from the various modulation schemes and protocols used [1].

IEEE 802.11a operates with a data rate of up to 54 Mbps, and at a frequency of 5 GHz [2]. It uses Orthogonal Frequency Division Multiplexing (OFDM), which allows a spread spectrum of channel availability and variable data rate [2]. An advantage of operating in the 5 GHz frequency band is that interferences from other devices are a less common issue, as opposed to operating in the heavily used 2.4 GHz range [2]. On the other hand, there is the drawback of incompatibility with devices equipped only for the 2.4 GHz band.

IEEE 802.11g allows up to 54 Mbps and utilizes the 2.4 GHz band. It uses two modulation schemes: Complementary Code Keying (CCK) and OFDM. It is compatible with hardware that supports 802.11b, but suffers interference from other devices using the same frequency band. Lastly, 802.11n was developed to improve the preceding standards by implementing multiple-input multiple-output (MIMO) support. Using MIMO allows the standard to use space-division multiplexing to handle the problem of multipath, which occurs when signals reflect off of objects and arrive at the antennas at different times and locations [2]. The major result of this is a potential data rate of up to 140 Mbps (or higher, depending on access point configuration) [2].

4) Applications

To simulate WiFi usage of a typical home network, there were 4 different applications implemented: heavy browsing, light browsing, VoIP, and video conferencing. The definitions of each application were derived from the default configurations that Riverbed provides. These 4 applications were chosen because of their usage and popularity in today's home environments. There are frequent scenarios where 1 or 2 users are browsing for different purposes while additional users may be utilizing the same access point through video streaming (e.g. Netflix) or VoIP (e.g. Skype).

a) Heavy/light browsing

As mentioned, the browsing applications were slightly modified from the default configurations in order to model more realistic throughput requirements. In this case, we attempted to model "Heavy Browsing" to someone browsing a website with relatively large amounts of text and images (e.g. imgur, reddit) at a decent pace. The exact specifications of the application are shown below in Figure 1. The loaded objects represents the size of a typical webpage with numerous images and heavy text.

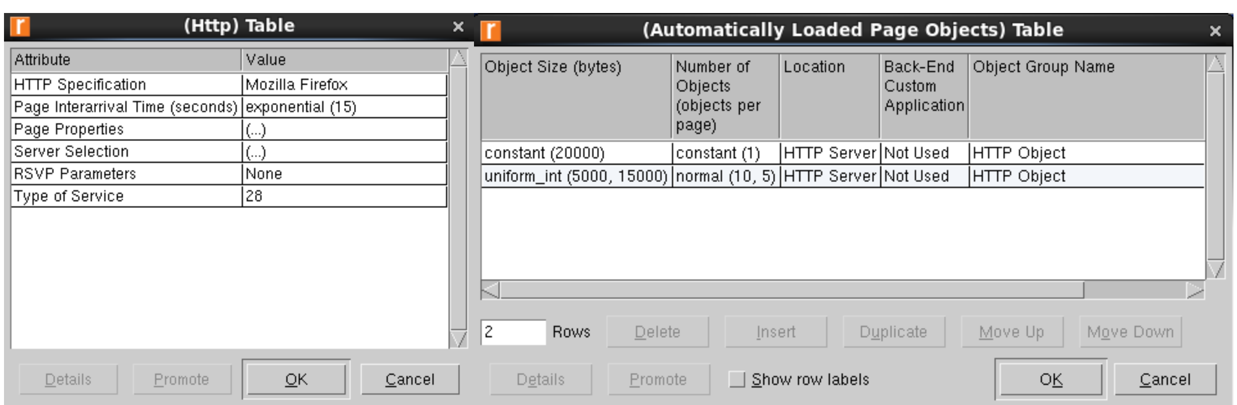


Figure 1: Heavy browsing settings

On the other hand, “Light Browsing” is reflective of someone using a search engine or loading relatively bare pages as their form of browsing. The application was setup similarly to “Heavy Browsing” except with lower object sizes and higher Page Interarrival Time. The Page Interarrival Time allows us to control how often the application requests an HTTP page i.e. the rate of browsing done by a user.

The throughput of heavy and light browsing is shown below in Figure 2. As expected, the clients request pages sporadically as a user might click a page and take time scrolling through it before requesting another page.

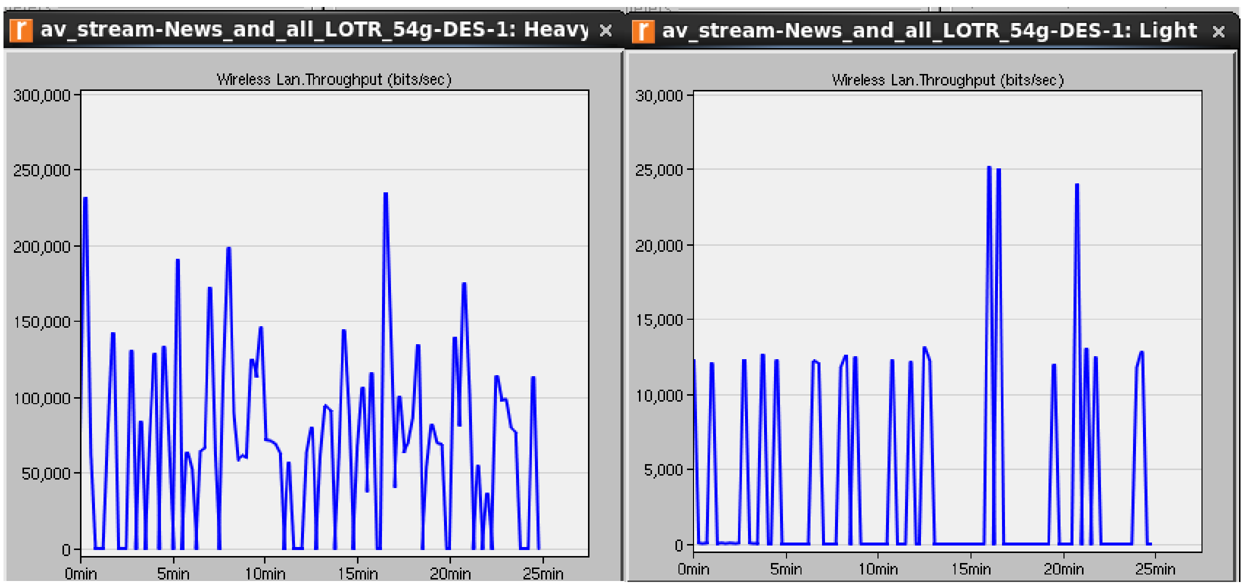


Figure 2: Throughput of heavy (left) and light (right) browsing

b) VoIP

In this case, there were no modifications to the predefined application setting; the configuration and throughput are shown below in Figure 3.

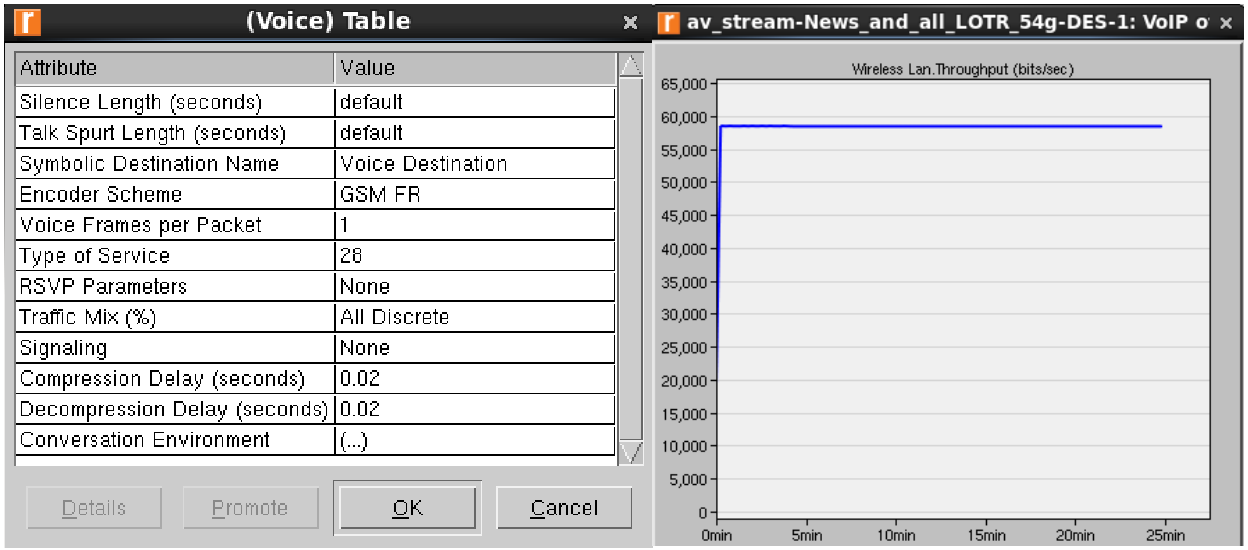


Figure 3: VoIP settings and throughput

c) Video conferencing

Instead of using predefined PDFs (such as exponential or uniform) to model the video traffic, Riverbed provides the option of using video trace files in order to improve the realism of the simulations. Since the size of each frame can vary wildly (depending on the information shown on screen), it is not viable to model the frames with numerical distributions. In these simulations, the 3 video traces used were Star Wars (24 fps, 480x504, MPEG), Lord of the Rings (25 fps, 352x288, MPEG-4), and a news broadcast (30 fps, 352x288, MPEG-4) [3] [4]. Since we do not want the video clients transmitting any frames (in order to emulate video streaming), the outgoing frame rate was set to 0 (as was done in [5] and [6]). Furthermore, in the case of the news broadcast, the incoming stream interarrival time was set to 0.0333 seconds/frame to reflect the 30 FPS frame rate of the video. As shown below in Figure 4, the name of the trace file was provided to Modeler.

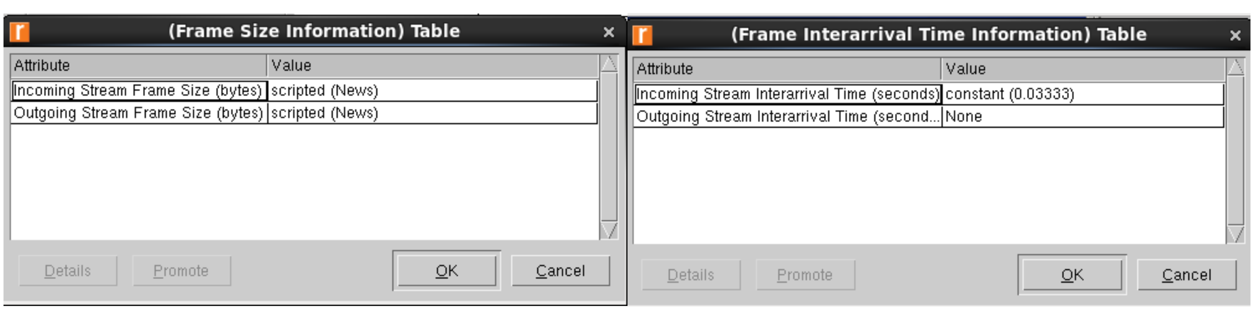


Figure 4: Video streaming settings

Modeler reads each cell in the .csv trace file as they contain the sizes of each frame. Separate applications were defined for the remaining video traces with similar adjustments. Lastly, the rest of the video conferencing settings were left as default values.

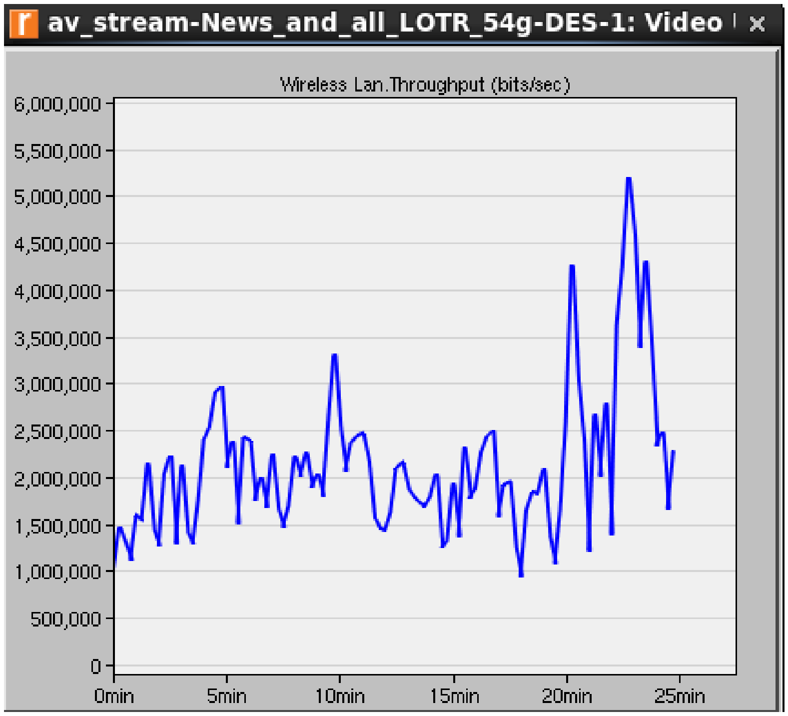


Figure 5: Throughput of news broadcast

The throughput of the news broadcast is shown above in Figure 5. As expected, the throughput varies depending on the size of a particular scene (or frames). To get a sense of each video's traffic demand, a comparison of each application's throughput is shown below in Figure 6 (pink is Lord of the Rings).

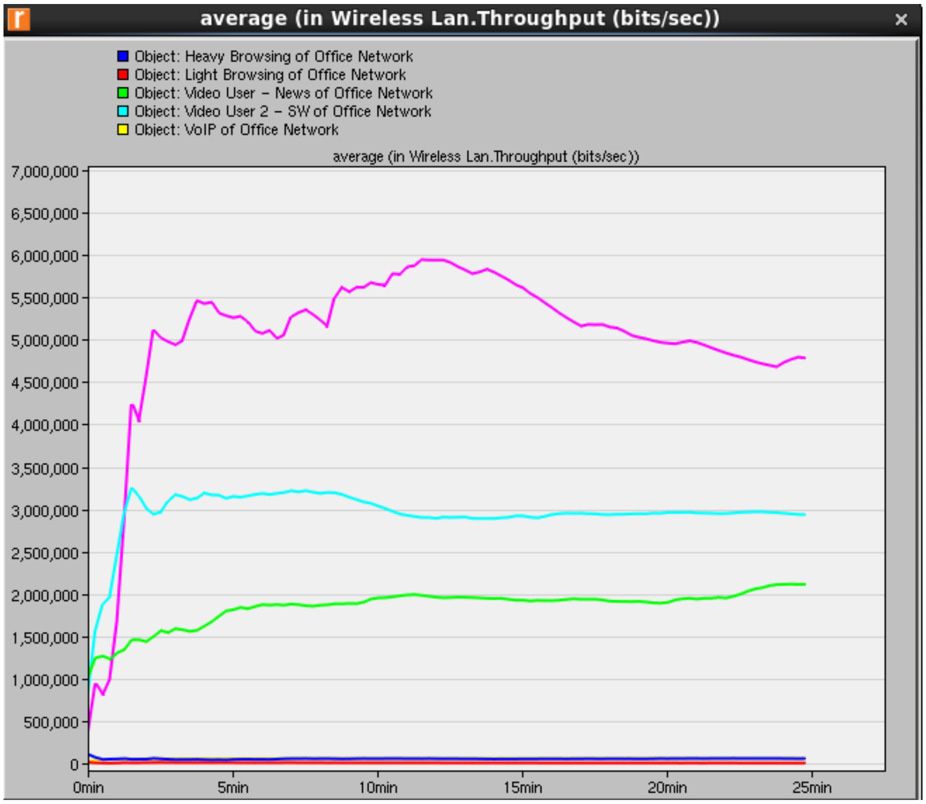


Figure 6: Throughput of videos relative to each other

5) Topology and simulation setup

The topology of the network used was based on a typical network one might find at home, and is shown below in Figure 7. The access point which is connected to the server by a 100BaseT Ethernet link, is shared by multiple users. Mobile workstations were placed in appropriate distances away from the router (around 10-15 meters). The distance between the server and router was not chosen as a factor to be tested during these simulations. In other words, the propagation delay between server and router was determined to be negligible. Lastly, the models used in this topology were ethernet_server, wlan_wkstn, and wlan_ethernet_router, which can be found in the Ethernet and Wireless LAN libraries of Riverbed.

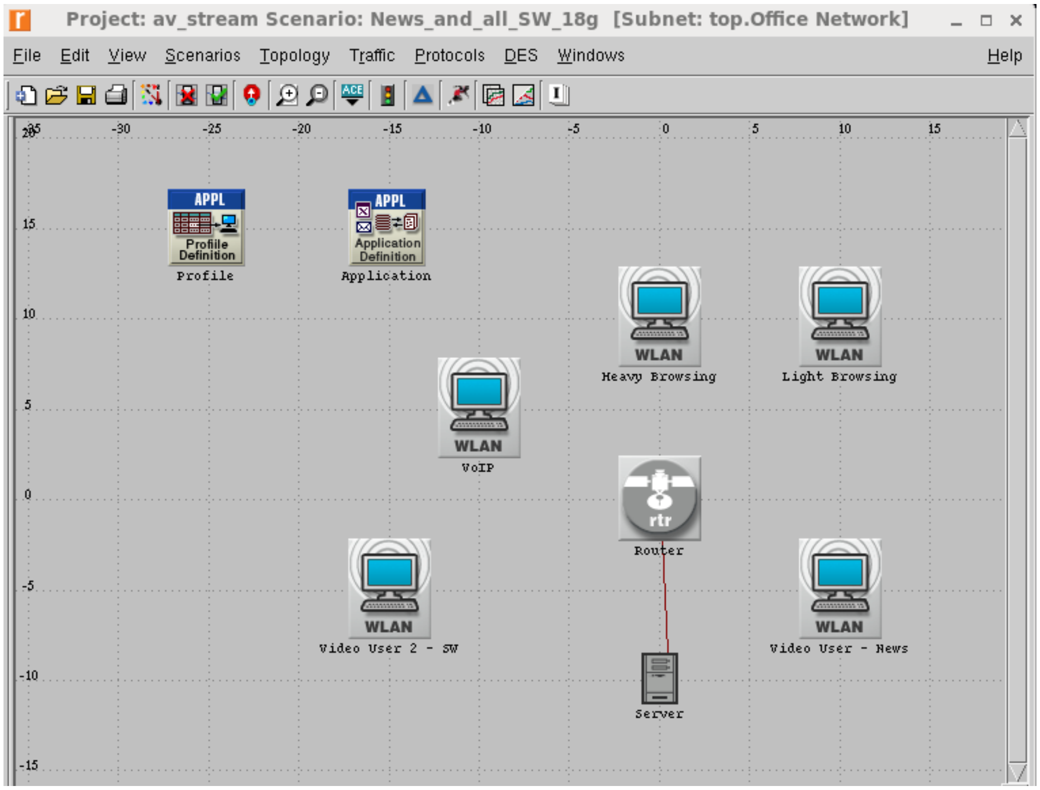
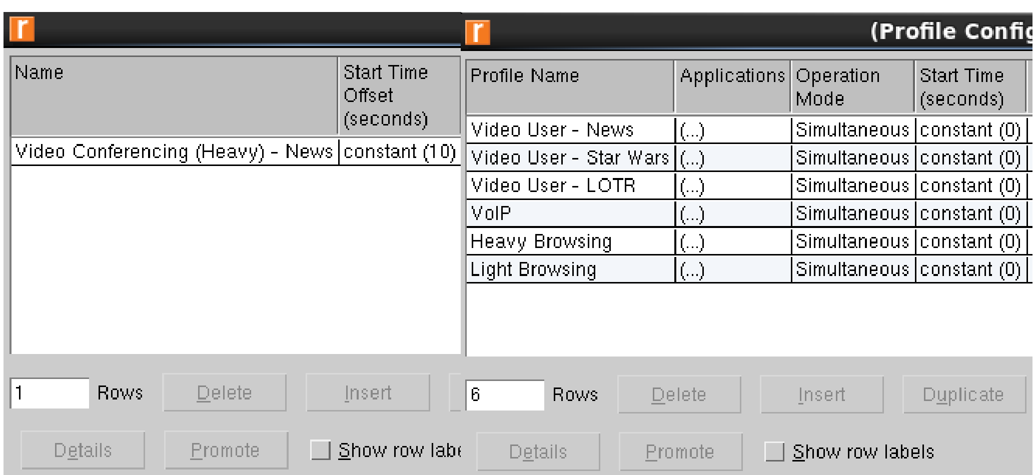


Figure 7: Main topology

Next, each application was added to its own profile and each profile was configured similarly. This was required in order for each client to use only one application. The profiles were set to start at the beginning of the simulation while each application was configured for a 10 second offset (shown below in Figure 8). This may not be the most appropriate scenario (where everyone starts browsing and streaming at the exact same time), but was decided upon for simplicity.



Name	Start Time Offset (seconds)
Video Conferencing (Heavy) - News	constant (10)

Profile Name	Applications	Operation Mode	Start Time (seconds)
Video User - News	(...)	Simultaneous	constant (0)
Video User - Star Wars	(...)	Simultaneous	constant (0)
Video User - LOTR	(...)	Simultaneous	constant (0)
VoIP	(...)	Simultaneous	constant (0)
Heavy Browsing	(...)	Simultaneous	constant (0)
Light Browsing	(...)	Simultaneous	constant (0)

Figure 8: Profile settings

In continuing with the setup, each client was adjusted to support the corresponding profile with the desired application. Additionally, the server was setup to support every profile *and* service that has been configured thus far. Finally, the remaining setup requirements involves the Wireless LAN parameters of the router and workstations. The base station subsystem (BSS) ID were set to ‘1’ for all workstations and access point, along with the desired 802.11 specification (a/g/n) and data rates. These Wireless LAN settings must be identical across all workstations and router for desired results (as advised in [5]).

6) Results and discussion

Two things to note during these cases: the length of the News trace provided in [4] allowed simulations up to 25 minutes, and the results will mainly be focused on what happens to the News client.

a) Case 1 – Increasing data rate

Initially, these simulations were run using the 802.11g specification with a data rate of 18 Mbps. A base topology that consisted of only the News user was created. Afterwards, each application was added on separately to see what the effect of each application would be on the News user. From the figure below, we can conclude that only applications requiring relatively high amounts of throughput (user watching Star Wars, in this case) have discernible effects on network performance. With this data rate, the network is capable of handling the client demand without any loss in throughput for the News workstation. There is an increase in delay, but it is still low enough that there is no effect on throughput.

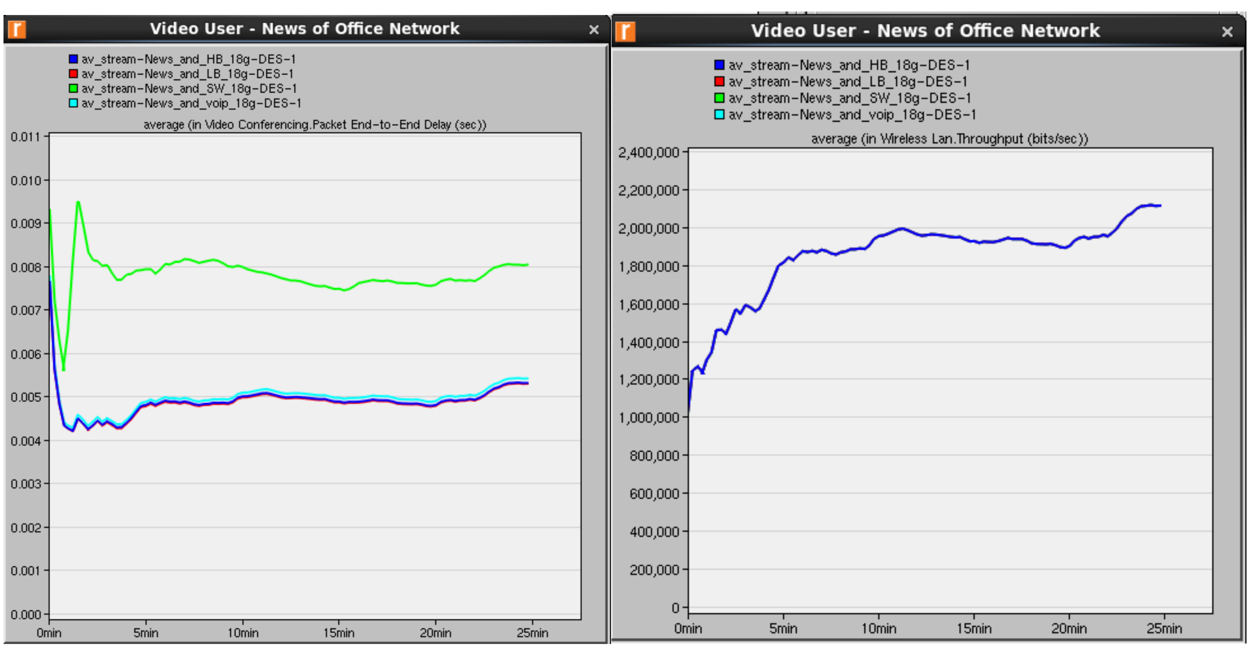


Figure 9: Effect of adding different applications to network

Next, the topology in Figure 7 was made and we switched out the Star Wars user for the Lord of the Rings (LOTR) user to see what would happen if the overall throughput demand was almost doubled. The figures below indicate that at 18 Mbps, the QoS has worsened for the News client when the LOTR user was added; there are packet drops that occur for extended periods of time, which can translate to freezing or stuttering when watching a live video without buffering.

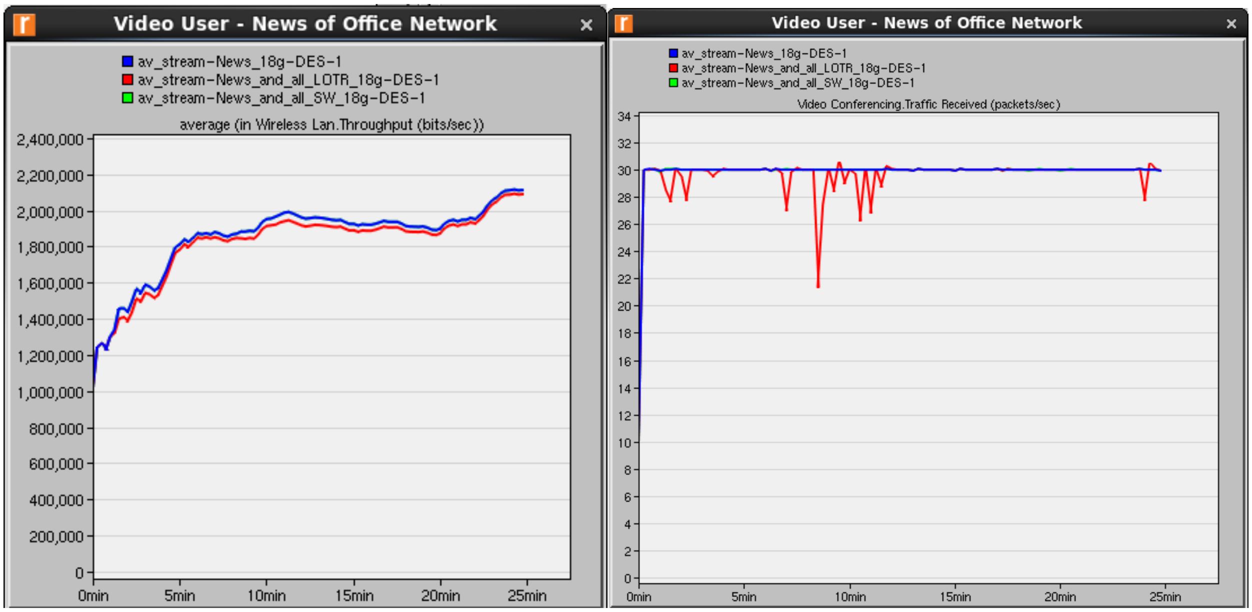


Figure 10: Drop in throughput and packets received

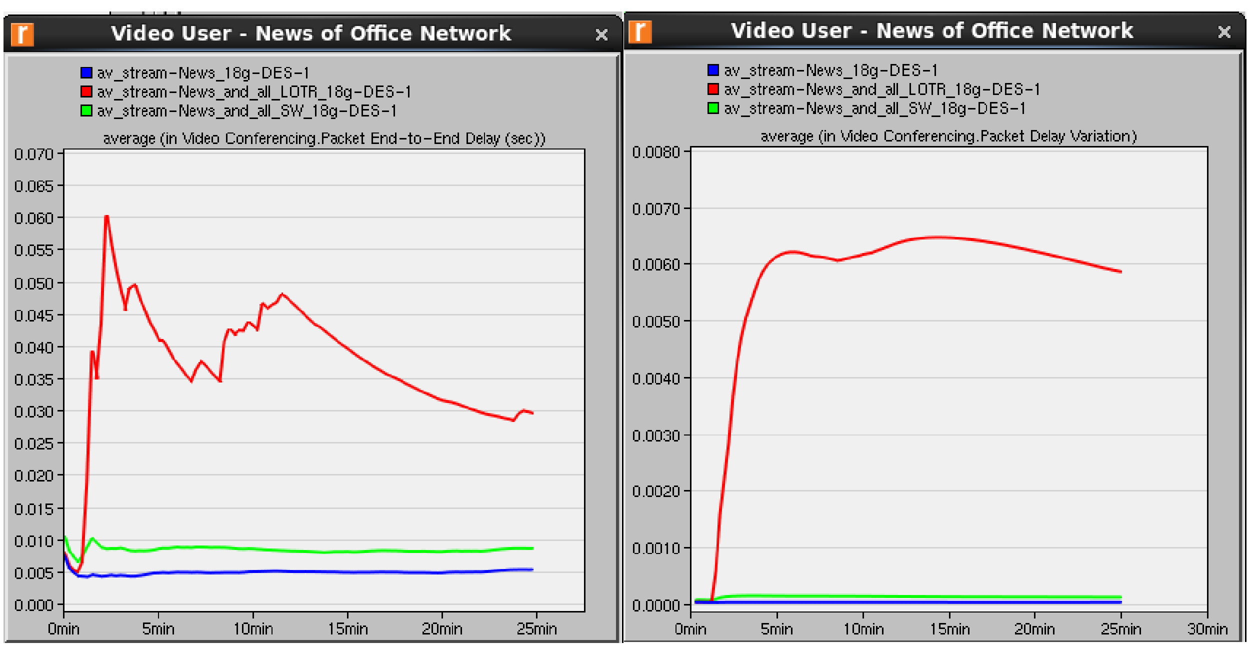


Figure 11: Increase in end-to-end delay and jitter

To remedy this, we tried increasing the data rate (while staying with the 802.11g specification) of the router and workstations. Given a throughput requirement, an increasing data rate allows the router to process and transmit a higher number of packets from the server to the workstations in the same amount of time. As expected, there are less packet drops and lower delay/jitter as the data rate increases (shown in Figures 12 and 13). For a situation like this, we can conclude that a data rate of at least 48 Mbps is recommended for smooth video streaming.

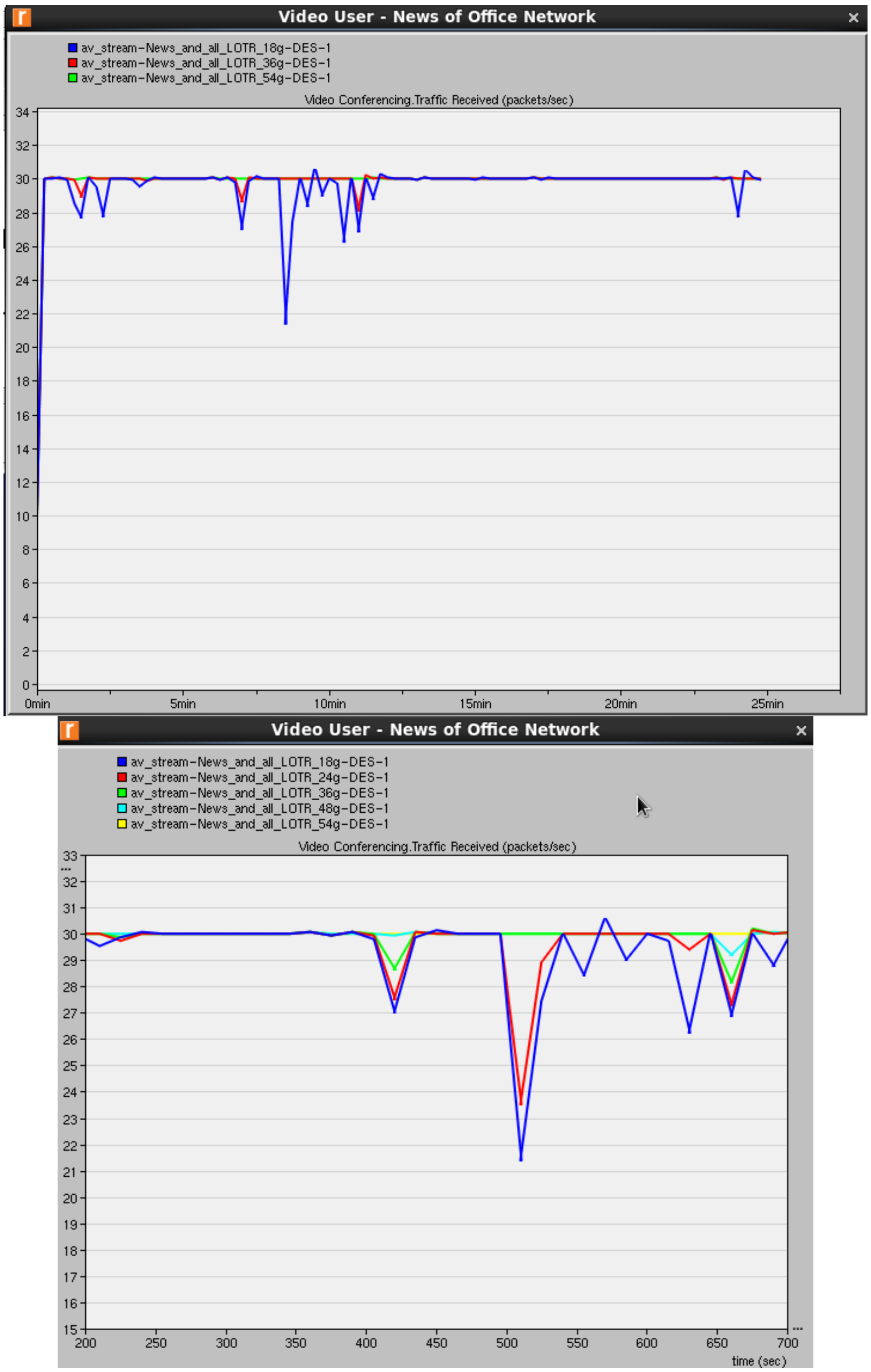


Figure 12: Improvements in packets received

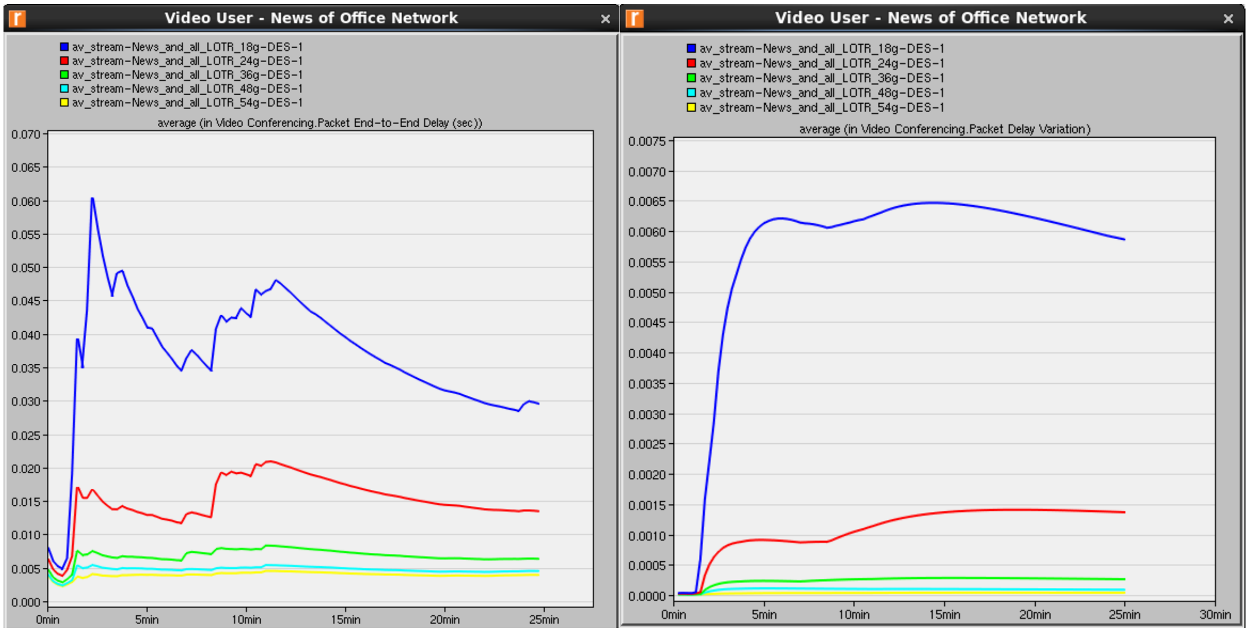


Figure 13: Improvements in delay/jitter

b) Case 2 – Comparison of a vs. g vs. n

In this simulation, we would like to compare the performances of the different 802.11 specifications. The topology in Figure 7 will be used, except with the LOTR user instead of the Star Wars client. The comparisons are made with the following speeds:

Specification	Data rate
802.11a	54 Mbps
802.11g	54 Mbps
802.11n (5 GHz band)	39, 58.5 Mbps

Table 1: Case 2 comparisons

There were some issues running the simulations for 802.11n that were unable to be debugged, but the general idea is still captured. The results of throughput and end-to-end delay are displayed in Figures 14 and 15. It is apparent that each standard is capable of handling the throughput requirement of the main topology. The end-to-end delays of 2 to 4.5 ms have practically no effect on video playback, but the results were saved for the sake of comparison. The performance of the ‘a’ and ‘g’ specifications are similar while the ‘n’ standard performs better in comparison. The network using a data rate of 39 Mbps on the ‘n’ standard still performed better than ‘a’ and ‘g’, despite the lower data rate. This may be attributed to the ability of the 802.11n specification to resolve multipath interference due to its MIMO feature.

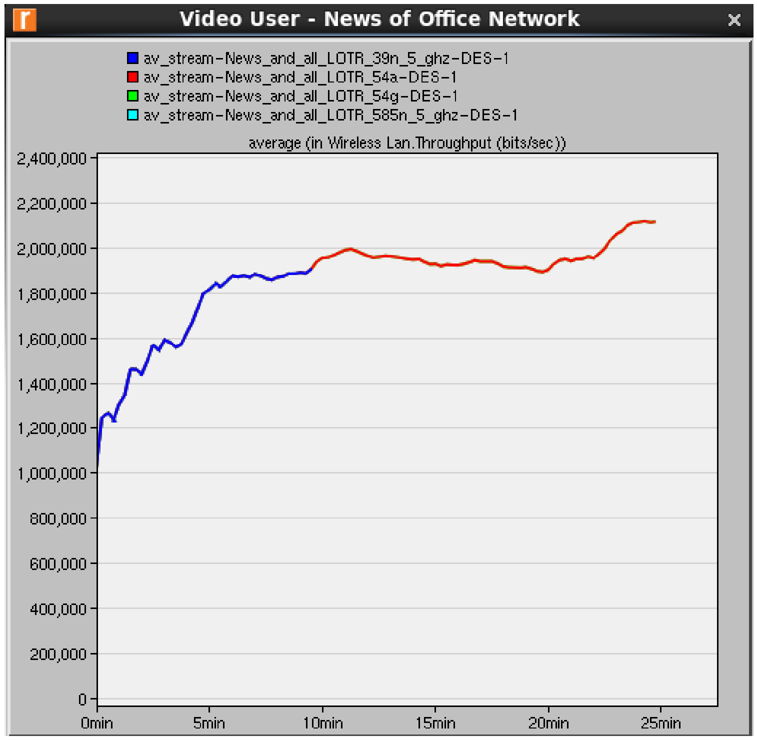


Figure 14: Throughput comparison between specifications

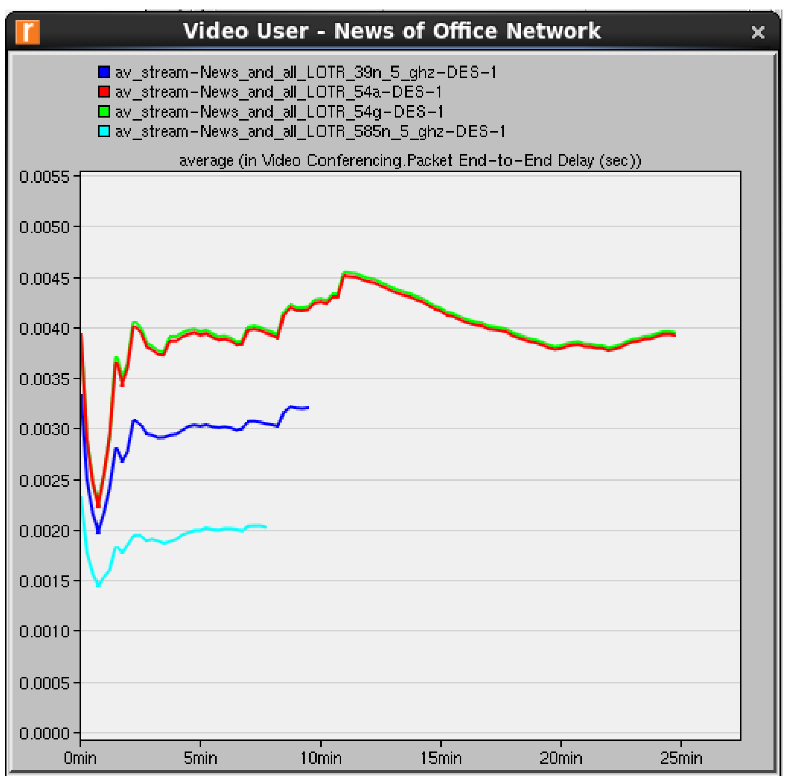


Figure 15: End-to-end delay comparison between specifications

c) Case 3 – Effect of distance

In this scenario, the effect of distance on the various specifications are of interest. To test this, the topology in Figure 16 was used. A trajectory was defined for the News workstation where it moves 190m to the right, 95m downwards, and then back to its original location. The actual distances are not of concern as we are not sure how Modeler incorporates the effect of distance. Therefore, this scenario is mainly used to see which specification (and data rate) has the best/worst range.

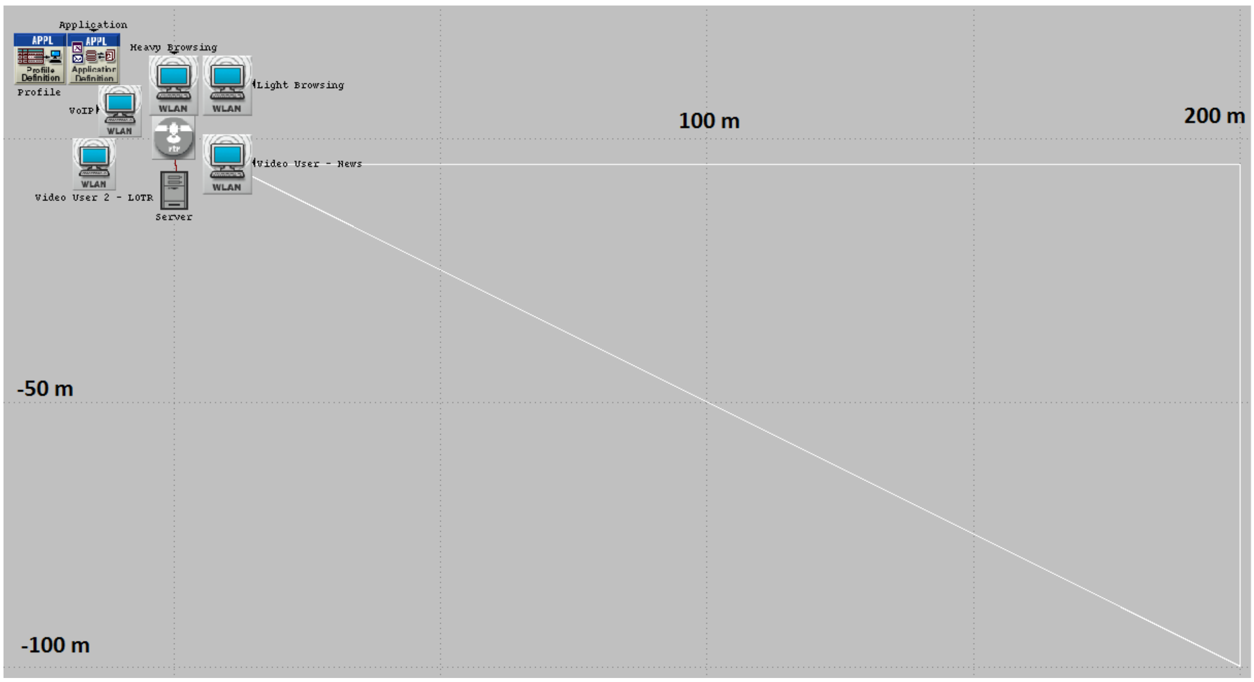


Figure 16: Case 3 topology – mobile trajectory

Figure 17: Effect of distance on packets received

The effects of increasing distance between access point and workstation are shown above in Figure 17. We can see that the specifications that operate in the 5 GHz band perform the worst when it comes to range. In real life, because the 5 GHz signal has a shorter wavelength compared to the 2.4 GHz signal, it is more susceptible to being absorbed by objects [7]. This results in the 802.11a/n standards to be unable to travel as far as 802.11g. One thing to note in Figure 17 is that despite operating in the 5 GHz range, the scenario running the 'n' standard with 39 Mbps (blue line) performed comparably to the 'g' standard. This tells us that there is a tradeoff between data rate and range, which we see with the 58.5 and 52 Mbps cases as well (yellow and red lines). Lastly, 802.11g is the most resilient to the effects of distance because of the signal's relatively long wavelength.

7) Conclusion

In this project, various scenarios involving a typical WiFi network in a home environment was simulated and analyzed. These simulations focused in on the QoS provided to the workstation watching a news broadcast. The remaining applications were added in separately and we found that only applications with relatively high throughput would make any noticeable effects on the News workstation. Once the throughput requirement became too large for the network to handle, packets ended up being dropped. To correct this, the data rate of the access point and workstations were increased. We found that a higher data rate decreases delay and increases throughput. If the router was capable of handling more data per second, then it would be expected that a higher throughput can be handled and QoS would improve. Next, a comparison between 802.11a/g/n were made. For similar data rates, we concluded that 'a' and 'g' perform similarly while 'n' outperforms them both. Lastly, the ranges of each specification were tested using a trajectory on the mobile workstation. From this test case, we can conclude two things: specifications running in the 5 GHz band have worse range than ones operating in the 2.4 GHz band, and there is a tradeoff of higher data rate vs. lower range.

8) Future work

As many devices today are supporting 802.11ac, it would be of interest to compare the performance between 'ac', 'n', and 'g' to get a quantitative observation of the differences. Furthermore, we would like to get a sense of the performance of WiFi's competitors. First, we would like to test the European version of the 802.11 standard, HiperLAN, and see if there any differences in performance with WiFi. WiFi is considered to be simpler to implement and was faster in reaching the market than HiperLAN, but the advantages of HiperLAN (if any) would be interesting to observe. Next, we would like to run the same topology using Ethernet to see if the tradeoff between mobility and data rate is worth it. Nowadays, the general trend for laptop manufacturers is to drop hardware support for Ethernet, and we would like to see if WiFi's performance is comparable enough to warrant this decision. Lastly, more throughput intensive applications could be modeled (such as P2P) to see their effect on a home network.

9) References

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