ENSC 427: Communication Networks

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Final Project Report:

802.11n and 802.11g Performance Comparison in Office Size for FTP Transmission

Group 6

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Glossary

AP – Access Point

CSMA/CA – Carrier Sense Multiple Access with Collision Avoidance

MIMO - Multiple In Multiple Out

OFDM - Orthogonal Frequency-Division Multiplexing

WLAN – Wireless Local Area Network

Abstract

The rapid growth in wireless LAN hardware and the network infrastructure in the last two decades make Wi-Fi technology so necessary that people cannot live conveniently without it. Different IEEE 802.11 standards have been invented to meet expected QOS (quality of service) of the wireless network. In order to design a qualified wireless LAN under specific environment and satisfy the application requirement, the limitation of data rate and coverage from the access point must be first predicted and considered before actual designing, which makes the understanding of IEEE 802.11 standards critical.

This report will provide a performance comparison between 802.11n and 802.11g standards by first introducing the background of Wi-Fi and its history followed by a brief introduction of IEEE 802.11 standards. Then four simulation cases based on the office environment using Riverbed Modeler software will be presented. Lastly, a complete analysis will be provided to demonstrate advantages and improvements for 802.11n compared to 802.11g.

1. Introduction

1.1 Motivation

Wi-Fi is being an important role in people's daily life. Almost every activity nowadays such as reading, gaming and communication involve Wi-Fi transmission. Due to the rapid development of the network infrastructure, different standards have been invented to meet higher performance requirements in the past two decades. Among of all Wi-Fi standards, 802.11n and 802.11g are most common used today. To understand the distinction between 802.11n and 802.11g not only acquaints people with Wi-Fi development history, but also presents people the Wi-Fi development trend in the future.

1.2 Project Description and Scope

Wi-Fi is commonly implemented under small size area environment such as home, office and school. The goal of this project is to simulate the Wi-Fi performance of FTP application upon 802.11n and 802.11g standards in office size by using Reverbed Modeler. The scope of the project includes simulations for

- Single AP Single Client with Fixed Distance
- Single AP Single Client in Varying Distance
- Single AP Multi-Client
- Multi-AP Signal Interference

Simulation of single AP connected to a single client under a fixed distance will demonstrate the difference in the data rate between the two standards. Measurement of the maximum reachable distance is used to detect the signal coverage. The multi-client simulation can find out the user capability. At the end, the signal interference will be investigated between 802.11n and 802.11g.

2. General Background

2.1 WLAN and Wi-Fi

Currently, the wireless access technology mainly bases on 802.11, 802.15, 802.16 and 802.20 which provides standards for WLAN, WPAN, Bluetooth and WMAN. People also refer 802.11 based WLAN as Wi-Fi (Wireless Fidelity). After 1999 when Wi-Fi was first invented, generalizing the use of Wi-Fi was difficult due to high cost, privacy concern, bandwidth limitation and lack of application. The turning point was occurred in 2004 when network infrastructure started to boom and more applications were developed. The demand for Wi-Fi appeared almost anywhere including home, schools, airports and shopping malls.

Compared to a traditional wired network, Wi-Fi possesses advantages including wireless Ethernet, extended access, cost reduction, high mobility and flexibility [4]. Wi-Fi provides the same functionality as Ethernet and some core elements can be shared which makes Ethernet replaceable under certain situations. Without the physical restriction of wires, more clients are able to join the network anywhere within the signal coverage. Omitting the cable interface in the access point also reduces the manufacture cost by removing trenching and drilling process. All factors mentioned above result in the popularization of Wi-Fi.

A wireless network consists of different types of stations (STAs) including PCs, phones or laptops. There are two operating modes for the wireless network: infrastructure mode and ad hoc mode. A STA communicates with other STAs through an access point (AP) in infrastructure mode and communicate directly with each other in ad hoc mode. The configuration of these two mode are demonstrated in the diagram below. An office network normally operates under infrastructure mode thus the simulated environment for this project will be set up with such configuration.

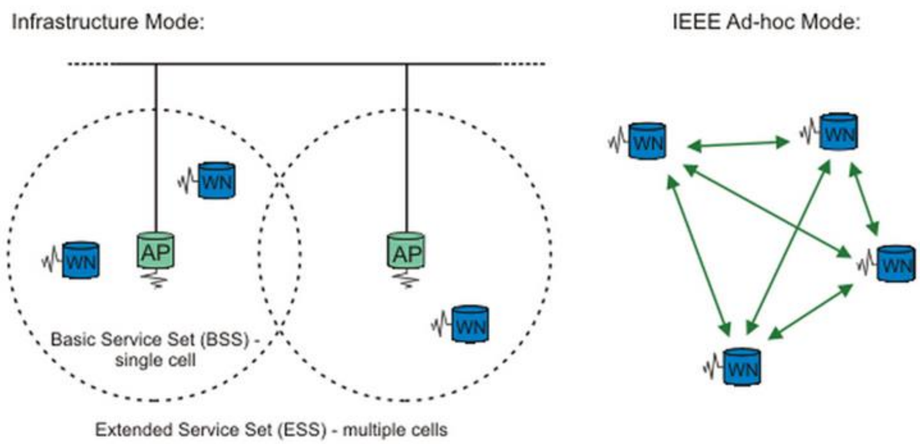

Figure 1: Infrastructure Mode and Ad hoc Mode [6]

2.2 IEEE 802.11 Standards

802.11 standards define the MAC sub-layers and the physical layer for the wireless network as illustrated in the figure below. An important protocol in MAC layer is CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance) which is used to deal with transmission before the data collision happens. Due to this reason, data can be transferred successfully even when the interference occurs.

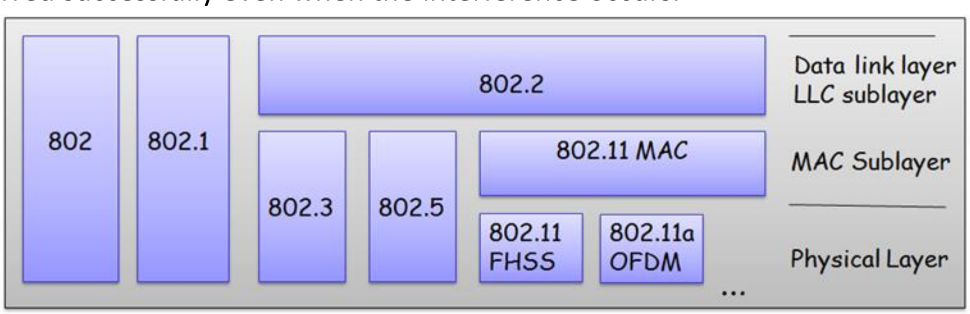

Figure 2: 802.11 in OSI Model [5]

Electronic hardware develops so rapidly that the original 802.11 standards soon later could not satisfy user's expectations. Six versions of 802.11 have been invented and released since 1999 by modification and optimization in the physical layer. Among all these standards, 802.11n as an improved version of 802.11g becomes the most widely-used standard in Wi-Fi network today.

Compared to early standards, both 802.11n and 802.11g utilize orthogonal frequency-division multiplexing (OFDM) for the modulation which allows channels to be packed closer so that more data can be transferred within the same bandwidth. Another significant improvement in 802.11n is the usage of multiple in multiple out (MIMO) technology for radio transmission. Traditional transferred data distorts each other due to uncontrolled multipath, by splitting data stream into parts and transmit them using maximum four separate antennas will dramatically increase raw data rate and efficiency. Other improvements in 802.11n include high diversity, MIMO power save mode and reduced inter-frame spacing

All improvements in 802.11n mentioned above increase the maximum data rate from 54 Mb/s to 600 Mb/s theoretically. Table below summarizes the characteristics and resultant performance among all 802.11 standards.

Standard	Frequency band	Bandwidth	Modulation	Maximum data rate
802.11	2.4 GHz	20 MHz	DSSS, FHSS	2 Mb/s
802.11b	2.4 GHz	20 MHz	DSSS	11 Mb/s
802.11a	5 GHz	20 MHz	OFDM	54 Mb/s
802.11g	**2.4 GHz**	**20 MHz**	**DSSS, OFDM**	**54 Mb/s**
802.11n	**2.4 GHz/5GHz**	**20 MHz, 40 MHz**	**OFDM**	**600 Mb/s**
802.11ac	5 GHz	20, 40, 80, 160MHz	OFDM	6.93 Mb/s
802.11ad	60 GHz	2.16 Ghz	SC, OFDM	6.76 Mb/s

Table 1: IEEE 802.11 Standards [3]

3. Simulation and Results

In this project the simulation was done by using Riverbed Modeler 18.0 to simulate the 802.11n and 802.11g performance by transferring files using FTP protocol. The data were being monitored and collected are:

- Wireless throughput (transfer rate)
- Delay,
- Distance between server and client,
- Number of clients.

In this simulation our data will look like the figure below. The left curve has a lot of ripples and the value is not constant. It is due to the TCP congestion control. Therefore for easier analysis, we will be using the average of the data to plot the graph which is similar to the right.

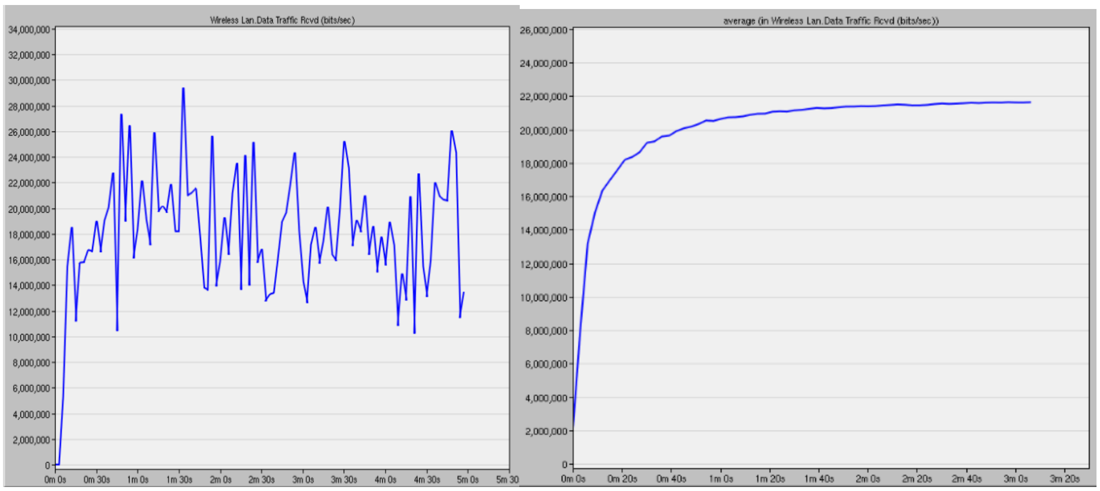

Figure 3: Sample Data (Left: without Averaging; Right: Averaging)

3.1 Case 1 – Single AP Single Client with Fixed Distance

Firstly, we need to set up the fundamental scenario for the entire project.

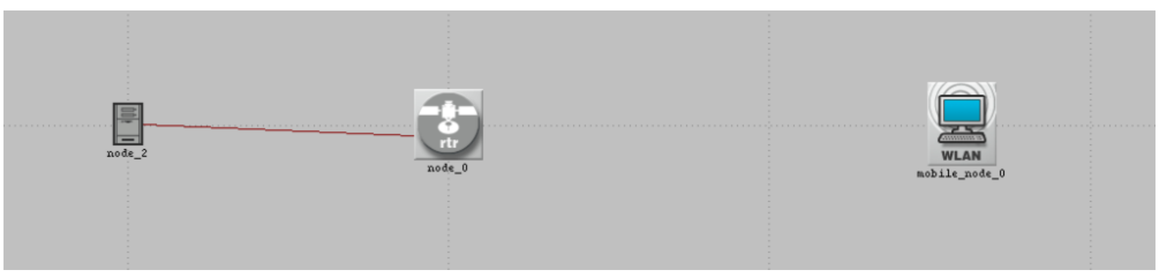

Figure 4: Setup for Basic Connection

The figure above shows the connection, on the left is the server (node_2), the middle is AP (node_0) and on the right is the client (mobile_node_0).

In order to achieve the maximum bandwidth of wireless to monitor the throughput, we decided to use FTP protocol to transfer the 5MB file from server to client simultaneously.

(Ftp) Table

Attribute	Value
Command Mix (Get/Total)	100%
Inter-Request Time (seconds)	constant (1)
File Size (bytes)	constant (5000000)
Symbolic Server Name	FTP Server
Type of Service	Best Effort (0)
RSVP Parameters	None
Back-End Custom Application	Not Used

Figure 5: Application Definition

File Transfer (Heavy)	
Name	File Transfer (Heavy)
Start Time Offset (seconds)	constant (1)
Duration (seconds)	End of Profile
Repeatability	Unlimited
Operation Mode	Simultaneous
Start Time (seconds)	constant (1)
Duration (seconds)	End of Simulation
Repeatability	Unlimited

Figure 6: Profile Configuration

3.2 Case 2 – Single AP Single Client in Varying Distance

Based on the scenario in the previous case, now we can start adjusting the distance between the access point and client to find out the relationship between distance, delay and throughput.

Next page is the plotted results of delay and throughput vs distance, in 802.11n (2.4GHz) and 802.11g.

3.2.1 802.11n (2.4GHz) Result

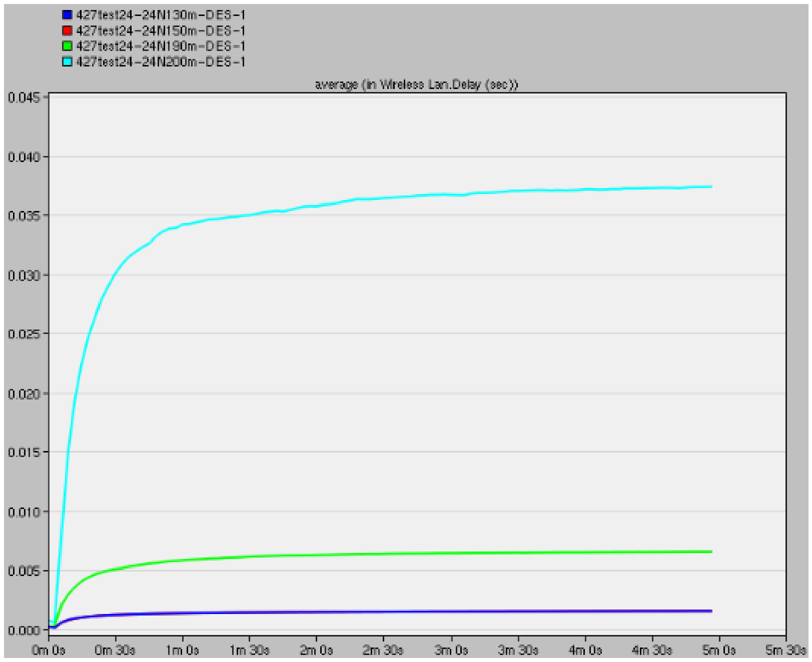

Figure 7: Delay vs Distance of 802.11n (2.4GHz)

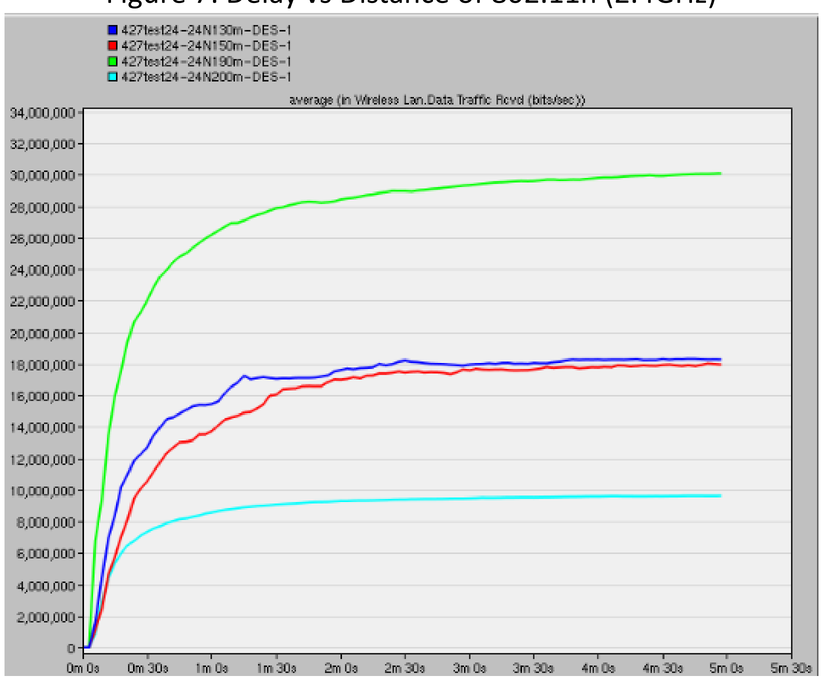

Figure 8: Throughput vs Distance of 802.11n (2.4GHz)

When the distance is above 190m, the delay is over 10ms and the throughput is approaching 0. So we determined the maximum range of 802.11n (2.4GHz) is 190m with delay of 5ms and the maximum throughput is 24.8Mbps.

3.2.2 802.11g Result

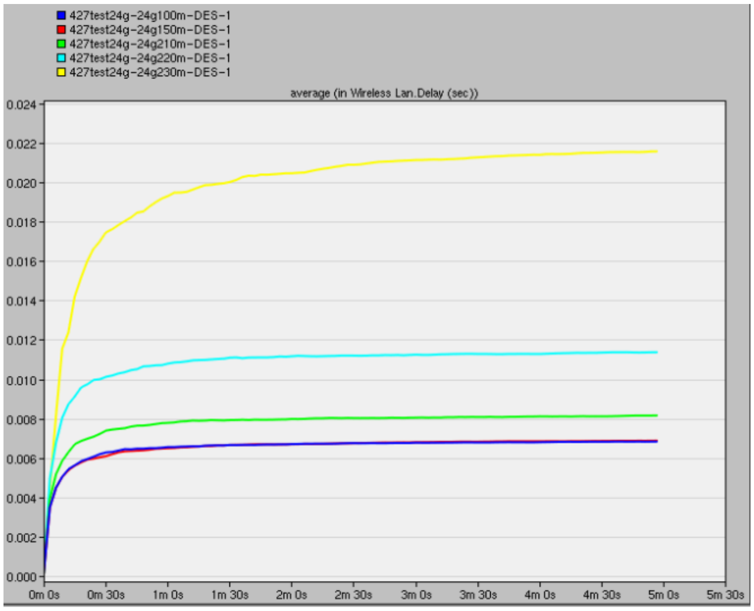

Figure 9: Delay vs Distance of 802.11g

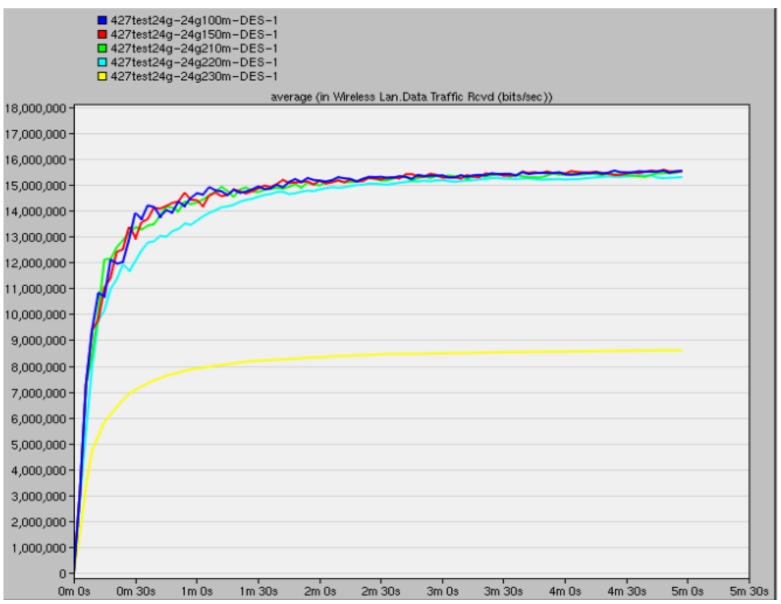

Figure 10: Throughput vs Distance of 802.11g

From the figures above, when the distance increases to 230m, the delay is far above the normal delay which is 7ms, and the throughput is less than 7Mbps. Therefore, the maximum range of 802.11g is 220m with delay of 7ms and the maximum throughput is 14Mbps.

3.3 Case 3 – Single AP Multi-Client

Now we will be testing the performance when multiple clients connect to only one access point. In this case we will expand the network to 100 clients as figure shown below and reduce the FTP transfer file to 0.5MB for every client.

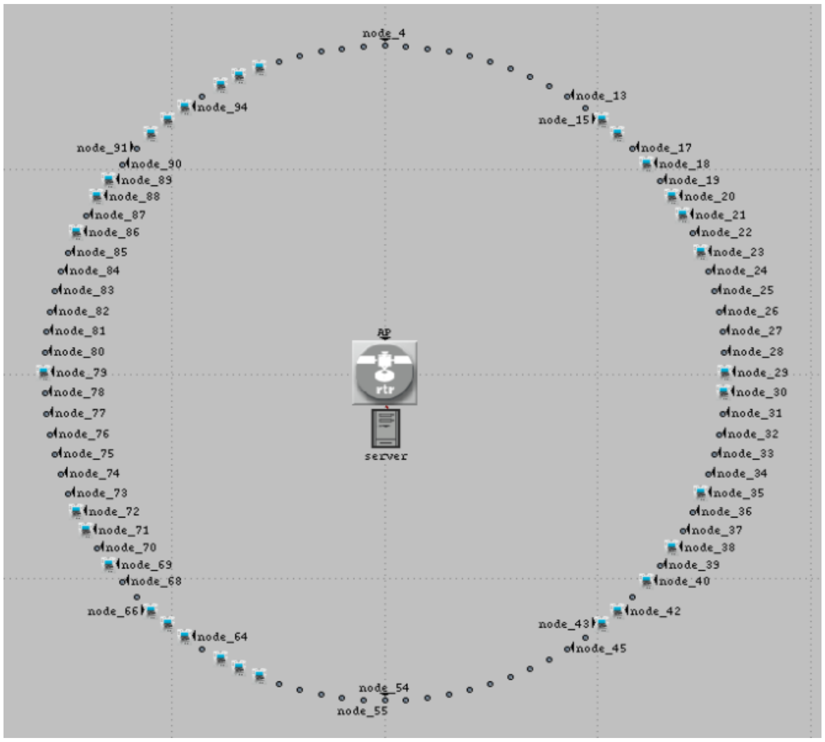

Figure 11: Setup for Single AP Multiple Clients (100 clients in figure)

From the case 2 we found out for when the distance is below 180m, both 802.11n and 802.11g are able to maintain high throughput with low delay. Therefore we choose 80m as our simulation testing distance in case 3 for each client to the access point.

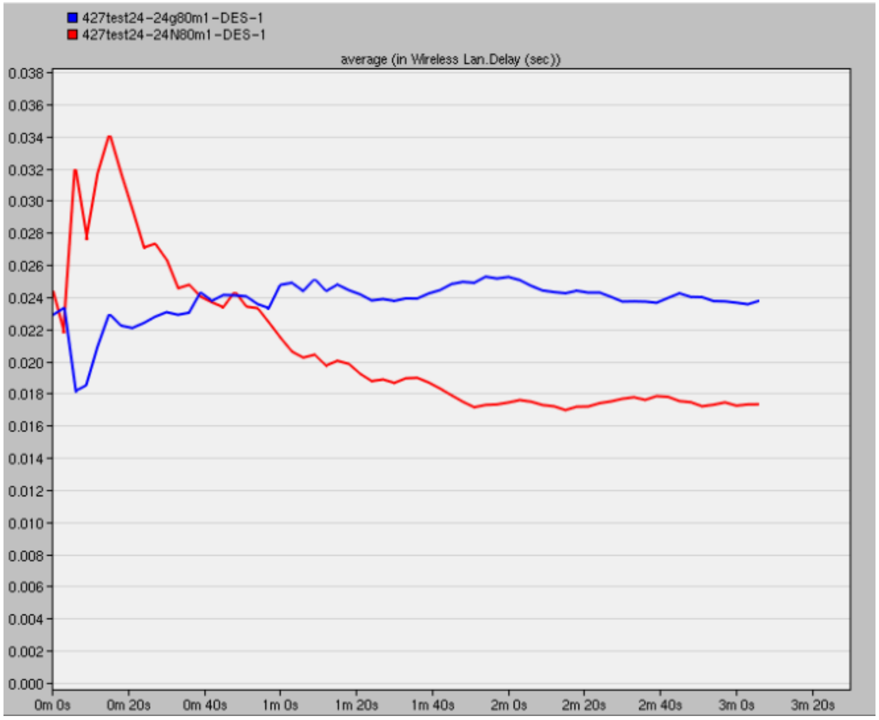

Figure 12: Delay with 1 AP 100 Clients

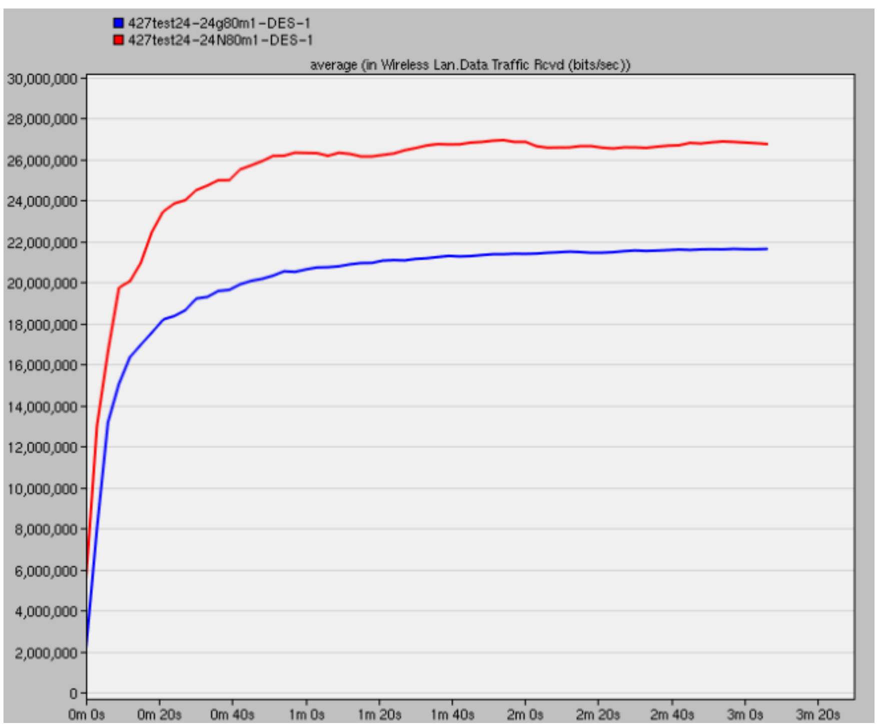

Figure 13: Throughput with 1 AP 100 clients

The red line in the above 2 figures is 802.11n and blue line is 802.11g. It is clearly that once the 100 connections are established, 802.11n has 25% lower delay than the 802.11g and 23% higher throughput.

3.4 Case 4 – Multi-AP Signal Interference

In case 4 we will try to find out whether signal interfere with each other or not. Since 802.11n and 802.11g are using the CSMA/CA[1] in MAC layer[2], they should have the same data collision algorithm. Therefore we will only demonstrate the interference under 802.11n environment.

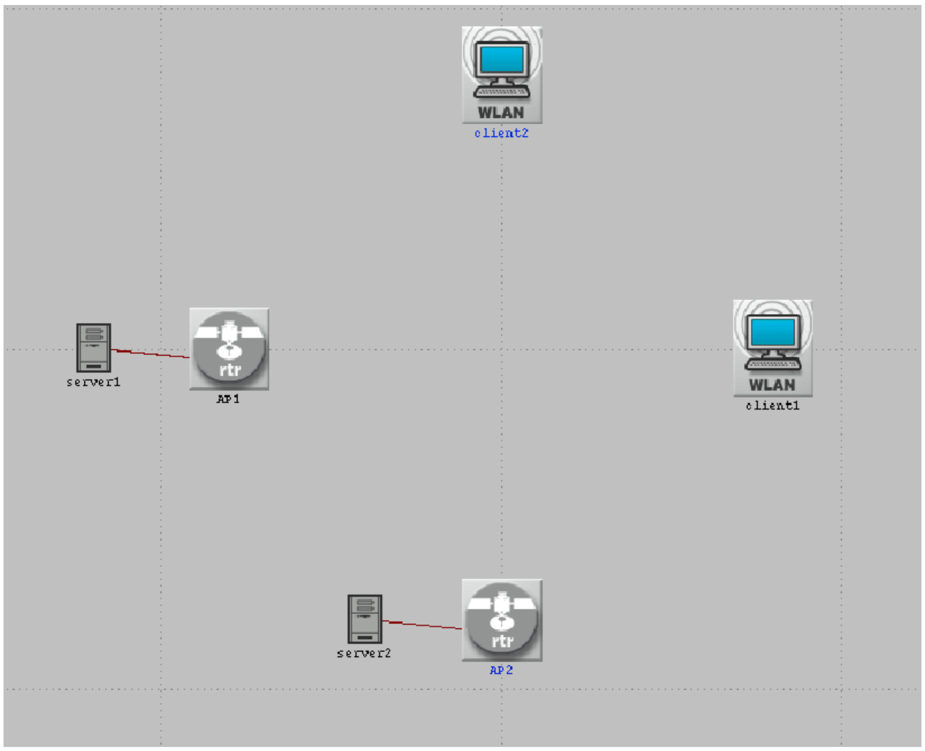

Figure 14: Setup for Multi-AP Signal Interference

In the figure above, we will reuse the application definition in case 1 and 2. The AP1 on left will transfer 5MB file simultaneously to the client1 on right with 80m distance, and AP2 on bottom will transfer to the client2 on top with 80m distance.

3.4.1 Two 802.11n 2.4GHz APs Result

In this scenario we set both connection pairs using 2.4GHz to communicate.

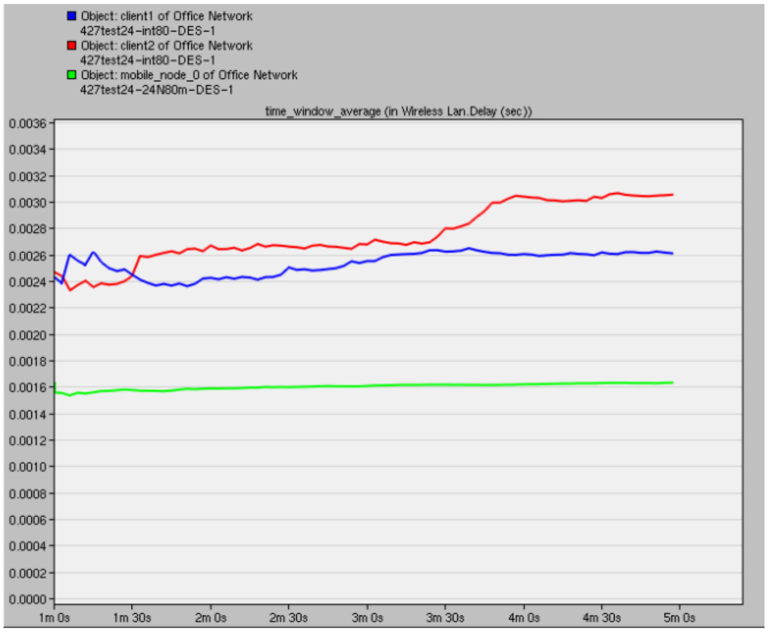

Figure 15: Delay with Two 802.11n 2.4GHz APs Interference

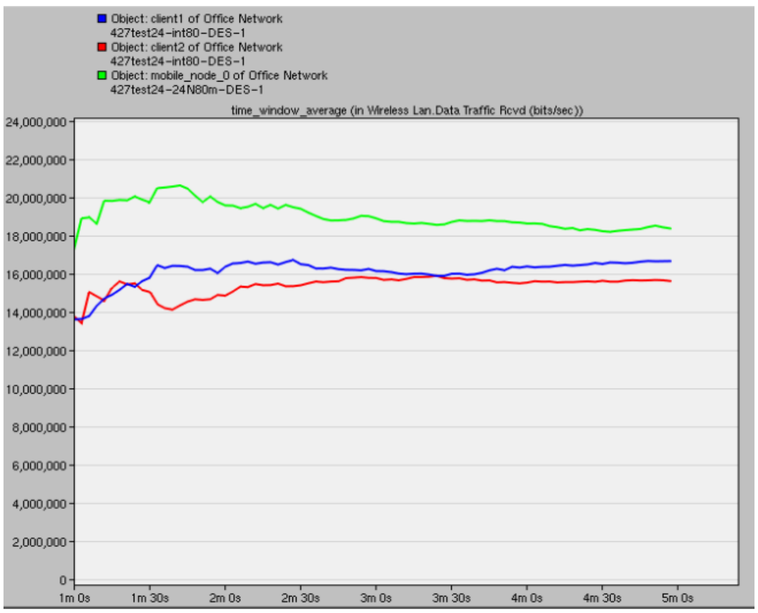

Figure 16: Throughput with Two 802.11n 2.4GHz APs Interference

The red and the blue lines are the connection for each pair, and we added the data from case 2 with single AP at 80m as reference. The delay and throughput for both connections are very similar, however when comparing to single AP, the delay is 50% higher and throughput is 25% less. So there is signal interference between each connection.

3.4.2 One 802.11n 2.4GHz AP and One 802.11n 5GHz AP Result

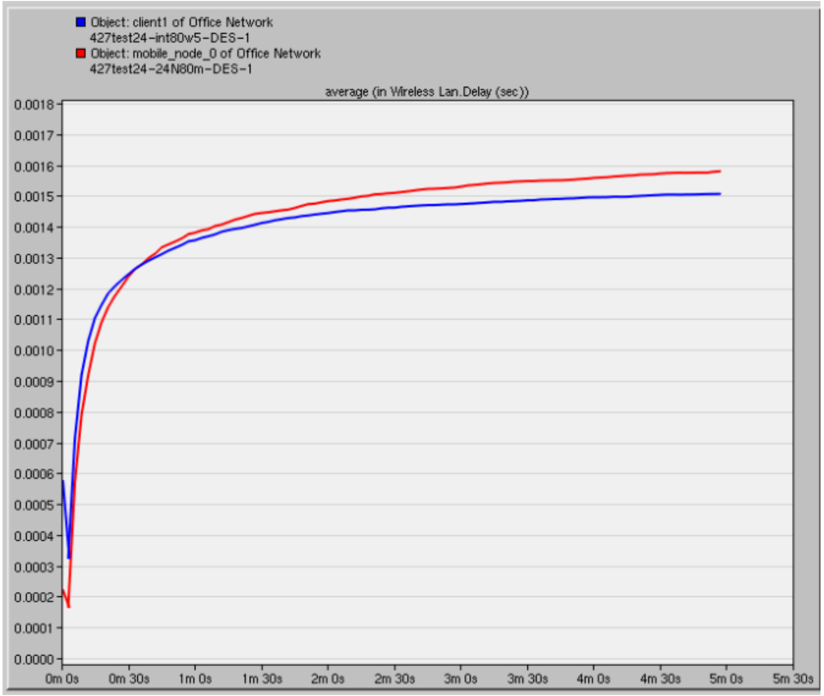

Figure 17: Delay with One 802.11n 2.4GHz AP and One 802.11n 5GHz AP Interference

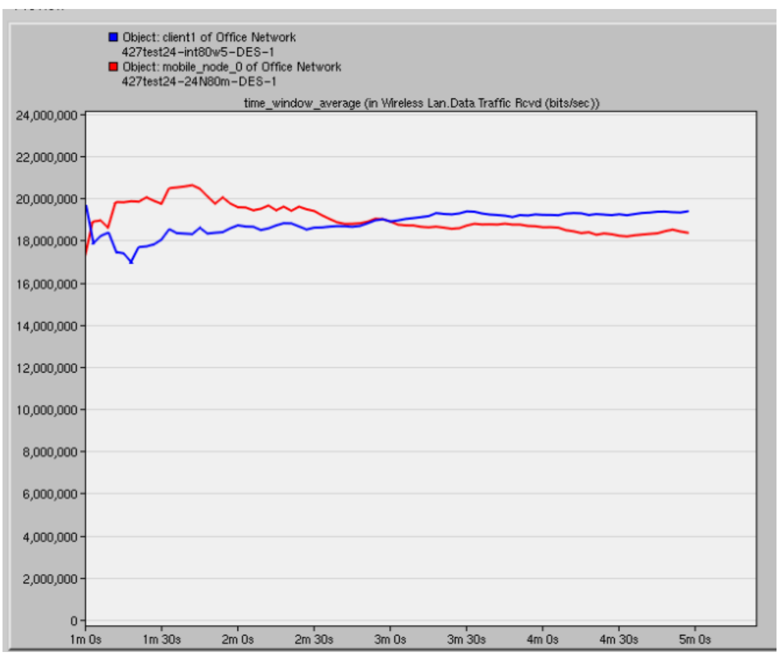

Figure 18: Throughput with One 802.11n 2.4GHz AP and One 802.11n 5GHz AP

Similar to previous scenario, this time one connection is using 5GHz and the other is 2.4GHz. The delay and throughput of each connections are very close, and almost identical when comparing to single AP scenario.

4. Summary and Discussion

For easier analyzing, we have summarized all the results above.

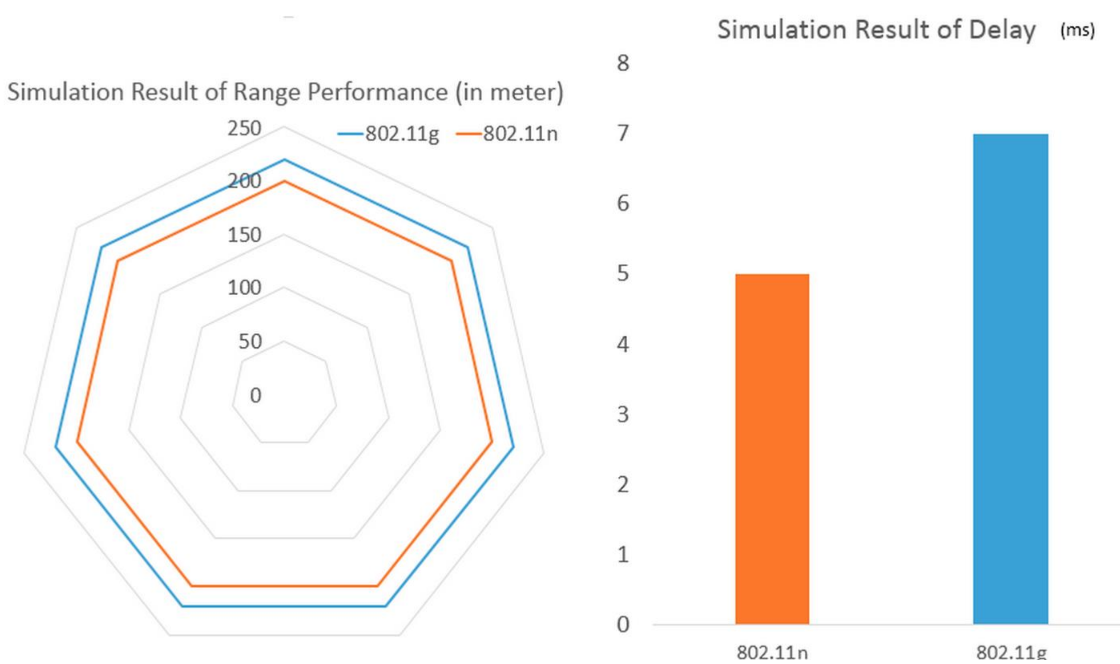

Figure 19: Maximum Range with delay of 802.11n and 802.11g

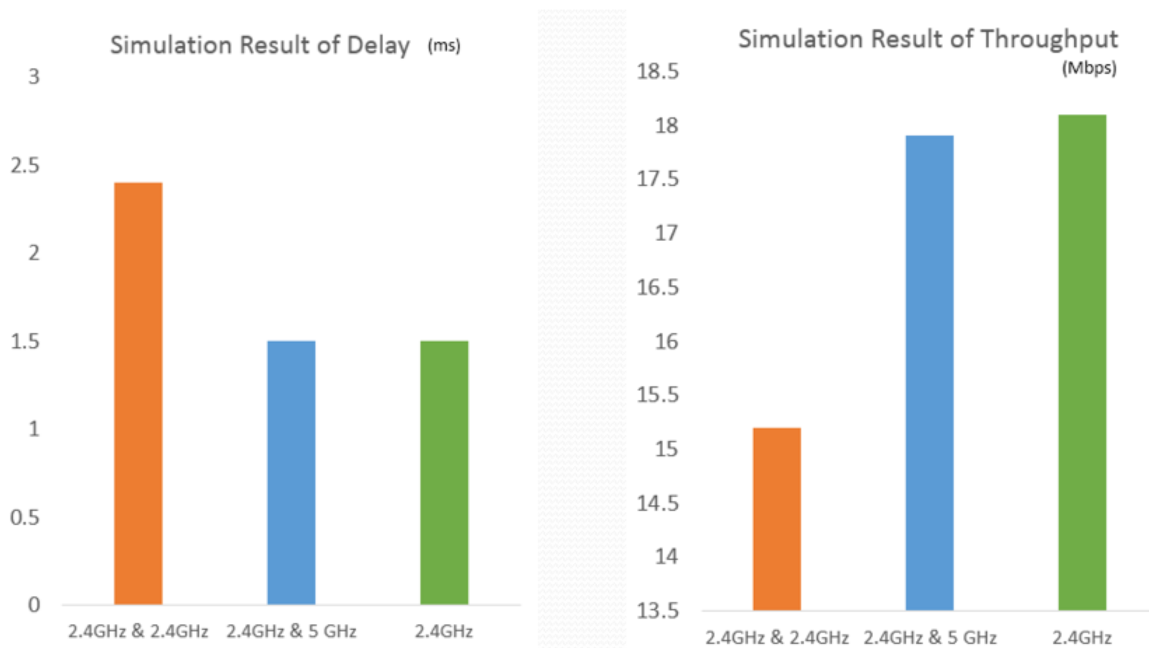

Figure 20: Network Interference Comparison

To conclude, 802.11n has better throughput and significantly less delay with almost same range as 802.11g. Besides that, 802.11n is more capable to handle multiple clients than 802.11g. Regarding the signal interference, if both AP are using the same radio band, the signal interference exists; if both AP are using different radio bands, they will not interfere each other.

Apply the results to the real world office environment, due to the significantly advantages in terms of throughput, delay and the number of clients, we recommend to use 802.11n instead of 802.11g. If more performance is required, 5GHz is preferred in 802.11n due to less overlapping channels compare to 2.4GHz band from other wireless devices.

5. Difficulties and Desired Improvements

5.1 Difficulties

For this project we have encountered many difficulties in the beginning of the Riverbed simulation. At first our topic was about 802.11ac and we had spent lots of time by researching and adjusting the configuration to implement the 802.11 topology. However we realized the work it involves is huge and it is very difficult for us to finish the project before the deadline. Therefore we switched to the current standards which are 802.11g and 802.11n.

In order to compare the performance, we have to know what aspect we should be looking at. Therefore, clear understanding of 802.11 standards and topologies is required. Especially, we need to know why and how the performance is different.

During the simulation, it also took time to figure out the parameter of router, application and profile. Once we have the result, we have to identify which data is required and its correctness compare to the standard. If the value is not expected, future debugging and adjusting are required.

5.2 Desired Improvement

Although we have simulated the performance of 802.11g and 802.11n, there are still some things can be improved for the project.

For example, in the case 3 we can try to simulate the performance with variable distance instead of fixed distance for every client. In this way we can obtain a more realistic result for the office environment.

Moreover, according to the specification, 802.11g should have less range than 802.11n. But our result is the other way around, 802.11n has slightly less distance than 802.11g, even by increasing the delay to match 802.11g's delay. We should have investigate this problem further to know the causes.

Lastly, we could have use other application instead of FTP to simulate the performance, such as HTTP which is more commonly used in the office. Our goal is to maximize the bandwidth and test the performance, and FTP allows us to set up the transfer file size easily, that is the reason why we choose FTP application. However nowadays people rarely use FTP, we could have implemented HTTP application which is closer to real office environment.

6. Future Work

Based on our results and recommendation, the additional simulation could be tested to implement into the project.

- Dual-band Radio Router Simulation

  In our recommendation 5GHz is preferred, however there are a lot of devices which have not supported this radio band yet. Therefore in the current market, manufactures have proposed the dual-band radio router. We could implement this router in the Riverbed as a model to simulate in the future work.

- Throughput and distance in the real office environment

  In the real world situation, the office is not in the open space and the office size should be taken into consideration, such as concrete walls which will reduce the signal significantly. We could try to simulate that in the Riverbed as well.

There are other things we could also implemented into our design, and our goal is to find the best way and place to install the AP to result the better wireless coverage and performance in the real world office environment.

7. Conclusion

For our project we want to compare the performance of two most widely used 802.11 standards, 802.11g and 802.11n, in Riverbed by transferring the file using FTP protocol. Using the Riverbed we have simulated and collected the data to find the relationships between throughput, delay, distance and number of clients. As a result, we conclude that 802.11n has significantly advantage compares to 802.11g and 5GHz is preferred in Office environment.

8. Reference

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