ENSC 427 COMMUNICATION NETWORKS

Wi-Fi NETWORK SIMULATION OPNET

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FINAL REPORT

Group 8

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1   Abstract

We are going to use OPNET to simulate the office wireless network by using Wi-Fi technology. From the simulation model, we want find out network delay and throughput by various numbers of user and data traffic. We also simulate by setting different parameters to optimize the performance of Wi-Fi network.

2   Introduction

2.1   Overview of Wi-Fi Technology

Wi-Fi (Wireless Fidelity) as a trademark of the Wi-Fi alliance becomes the most common used wireless technology today. Technically Wi-Fi is referred as the 802.11 communications standard for WLAN (Wireless Local Area Networks). IEEE 802.11b, IEEE 802.11a, IEEE 802.11g and IEEE 802.11n are the most common used protocol in today's environment. We are going to use 802.11g in our simulation.

Table 2.1 comparison between each protocol

	802.11a	802.11b	802.11g
Frequency	5GH	Both at 2.4GH	
Channel	19 channels	11 22MHz channels	
Bandwidth	54Mbit/s	11Mbit/s	52Mbit/s
Realistic Max throughput	25Mbit/s	6Mbits/s	25Mbits/s
Compatibility	Not compatible	Not compatible	Compatible with b
Range	Up to 50M	Up to 100M	

2.2   Project Idea and Scope

Our targeted network is the SFU Burnaby campus wireless network. However, this wireless network involves too many number of clients, would up to few thousands probably, that OPNET is not capable to simulate, we will limit the network to only clients in the engineering building, and the clients we simulating are from one to over twenty.
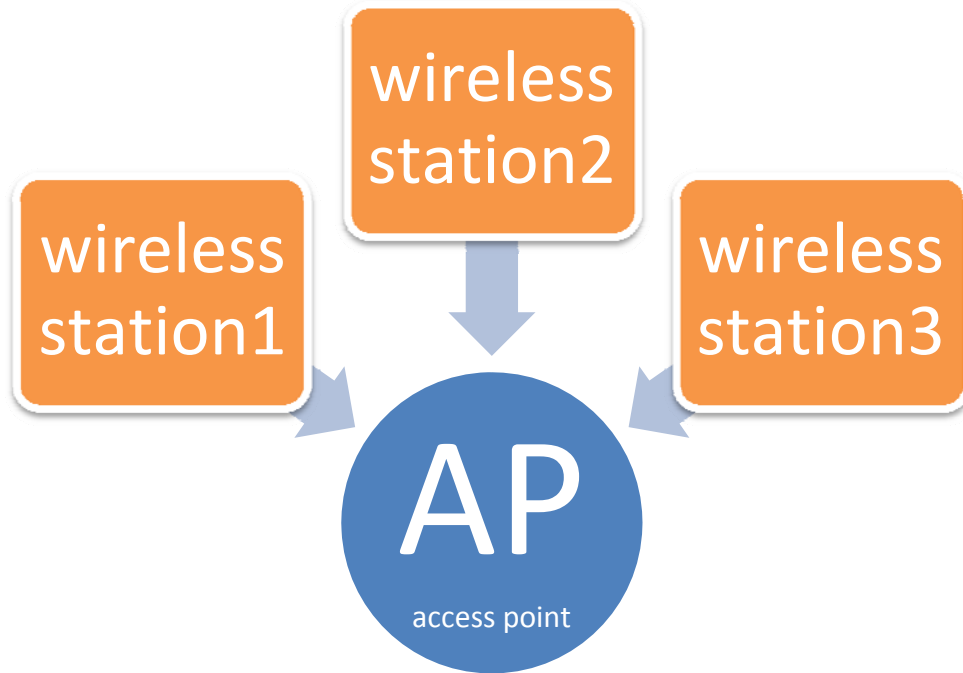
Data for delays, traffic load to the server, and throughput will be collected for comparing different network setting, and the optimal setting will then be found.

3   Main Section

3.1   Description of Overall Design

There are two operation modes defined in IEEE 802.11

3.1.1   Infrastructure Mode

In the infrastructure mode above, the wireless network consists of at least one AP (access point) connected to the wired infrastructure. All the wireless stations are connected to the AP. An AP controls encryption on the network and also can router the wireless traffic to a wired network (same as a router). We can think an AP as the base station used in cellular networks.   This is the mode we are using for this project.

3.1.2   Ad-Hoc Mode
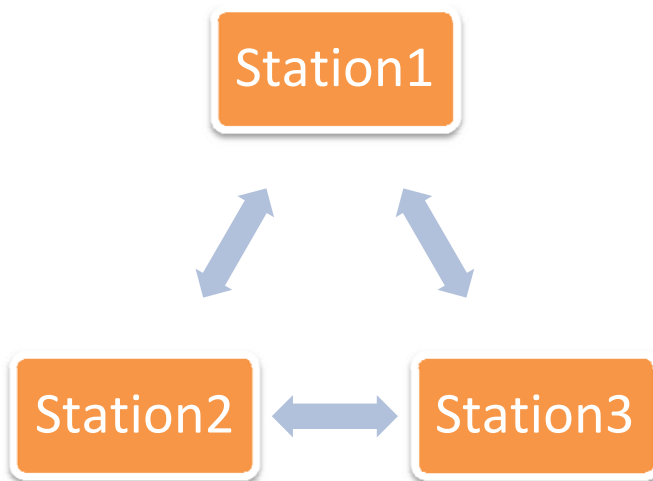
AP is not requiring in Ad-Hoc mode, the wireless station is connecting to each other directly without using an AP or any other connection. The topology is very useful to set up a wireless networks quickly and easily. Ad-Hoc mode is also called peer to peer mode or (IBSS) Independent Basic Service Set.

3.1.3   Wi-Fi Layer

Datalink layer

An 802.11 datalink layer is divided in two sublayers: (LLC) Logical Link Control and (MAC) Media Access Control.

LLC is the same as in 802 LANs allowing for very simple bridging from wireless to wire networks.

MAC is different to WLANs. The first method in MAC is CSMA (Carrier Sense Medium Access) with collision avoidance protocol. This protocol is to ask each station to listen before action. If the channel is idle, the station is allowed to transmit. If the channel is busy, the station has to wait until channel is free.

Another method in MAC is called RTS/CTS to solve Hidden-Node problem.
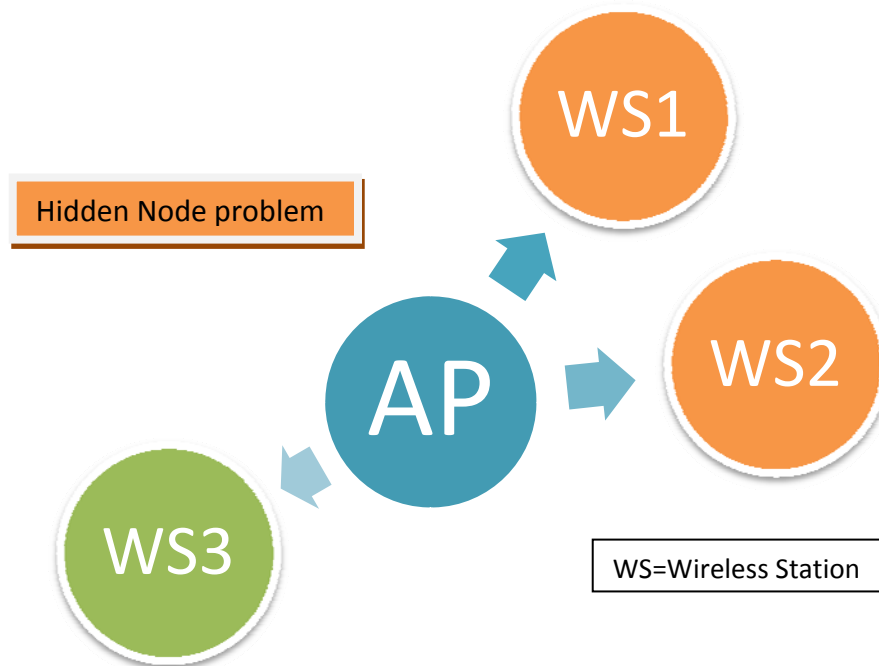
The wireless station 1 and 2 cannot receive signals from wireless station 3; in this case a transmitter may sense the medium as being idle even if the other one is transmitting. This result in a collision at the receiving station

Table 3.1 RTS/CTS table to solve hidden node problem

Time	Period1	Period2	Period3	Period4	Period5
Station	RTS(to AP)	Waiting for AP response	Sending Data	Finish sending	Free
Access Point	Free	CTS (back to station)	Receiving Data	Acknowledgement back to Station	Free

3.2 OPNET Implementation

The simulation tool we are using is OPNET (Optimized Network Engineering Tool) which is runs under Linux environment. This tool is a set of decision support tools, providing a comprehensive development environment for specification, simulation and performance analysis of communication networks, computer systems and applications. It allows us to create models in great, execute simulations, and analyze the output data.

OPNET provides four hierarchical editors to develop a modeled system, Network Editor, Node Editor, Process Editor, and Parameter Editor. The basic building block is a node, which is an underlying model. Nodes are corresponding to communication devices such as PC, file server, printer, and router.

We start building the Wi-Fi networking model with creating a project with Model Family "wireless_lan" included, and work on the model at the network layer. A subnet is created to represent the office wireless network. Within the subnet, we put one or two Access Point (AP) as a wireless router to transmit wireless signals, and various numbers of workstations according to different scenarios. The AP is connected to a switch and then connected to a server which provides applications used for the workstations. We also need to define applications and profiles by adding a node for each, and we can associate the work station with the profiles in order to use the applications.

Important Attributes Changed for each Node

Access Point
Node Model: wlan_ethernet_slip4_adv
Wireless LAN Parameters:
BSS Identifier: same level number as the associated Workstations
Access Point Functionality: Enabled
Operation Mode: 802.11g,
Data Rate: 54Mbps
Transmission Power: 0.005W
Dimensions of WLAN network: 100m x 100m,

Workstation
Node Model: wlan_station_adv
BSS Identifier: same level number as the associated AP
Supported Application: varies correspond to different scenarios
 Access Point Functionality: Disabled
Operation Mode: 802.11g,

Data Rate: 54Mbps
Transmission Power: 0.005W

Switch
Node Model: Bay Networks Accelar1050

Server: supported services
Node Model: ethernet_server
Application Supported Services: All

Application
Node Model: Application Config
Application Definitions: Default (It includes 8 applications with high load and low load for each.
Email, File Transfer, Web Browsing, File Print with high load are used for this project)

Profile
Node Model: Profile Config
Profile Configuration: choose the applications using for correspond to different scenarios

Table 3.2 Summarization of Nodes used

Node	AP	Workstation	Application	Profile	Switch	Server
Node Icon						

3.3   Case 1: Single AP and Single Workstation

3.3.1   Throughput Monitoring

This scenario is to monitor the performance for a simple structure with only one AP and one workstation. Throughputs are analyzed for four applications applied to the workstation gradually.

Configurations are as following:

Applications: Email, FTP, and Web Browsing, Print (all with high load)
          Applications applied gradually with 30mins interval
   Each application runs for two hours of duration
Simulation Duration: 3.5 hours
Simulation Running Time: ~1min
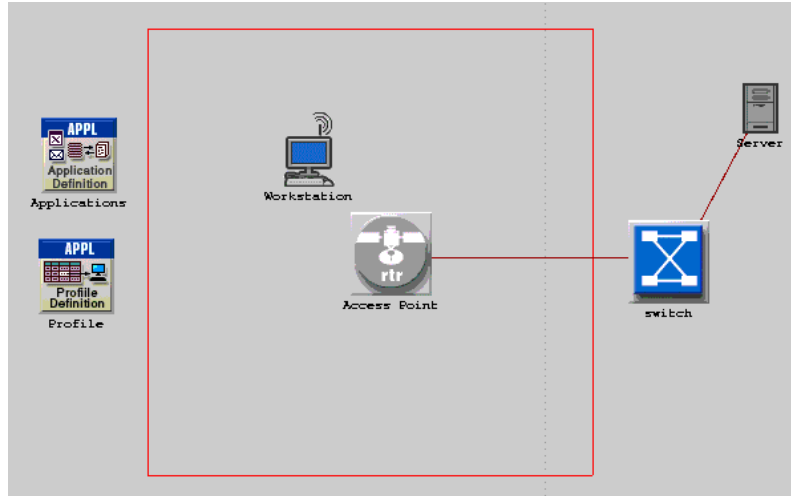
Figure 3.4.1: Structure of 1 AP and 1 Workstation Networking

From the following simulation result graph, we can see the email throughput starts at initial, FTP starts after half an hour, web browsing starts at time one hour, and finally file print starts at time one and half hour. Each throughput lasts for two hours of duration.
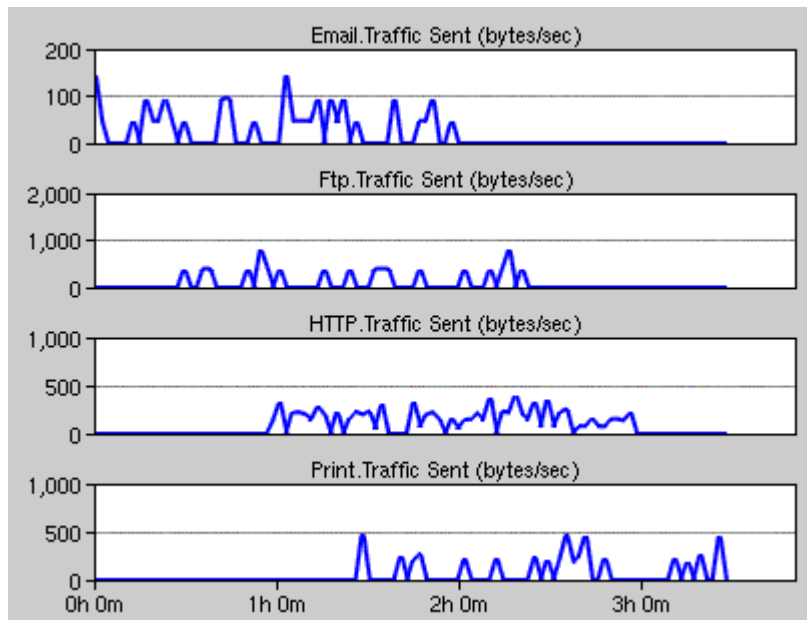
**Figure 3.4.2: Throughput for Each Application**

3.3.2   Power of Moving Workstation

In this section, we are simulating a workstation moving from out of AP range towards AP and continuing moving away from the AP. The following figure show the structure of this configure, and the path of the moving workstation. Workstation moves at the speed of 0.5 meter per second for a total distance of 100 meters.

Applications: FTP (high load)
Simulation Duration: 1 hour
Simulation Running Time: ~1min
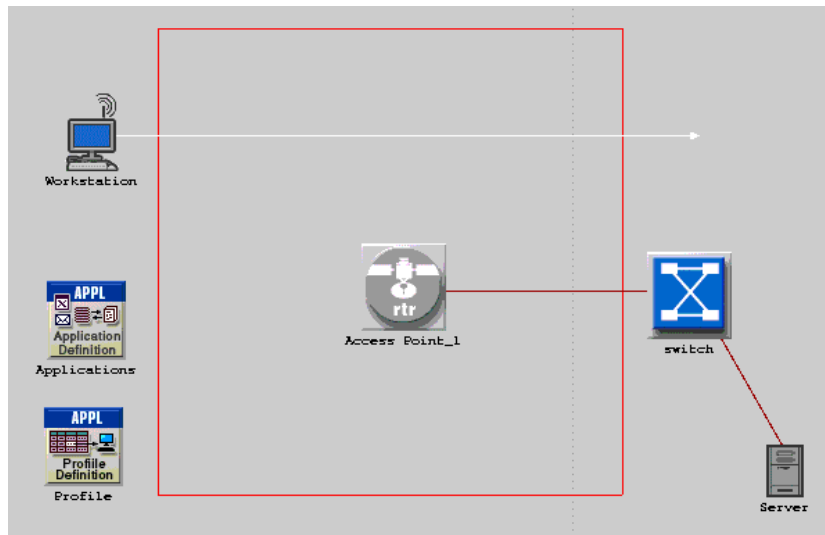
Figure 3.4.3: Workstation Moving Path

The power of the workstation received is showing in the following graph. It is as expected that the power is very the lowest at the beginning and end of the duration time because the workstation is at very far from the AP, so it receives very little power. As the workstation moves close to the AP, the highest power received is when the workstation is closest to the AP, so we can sees a peak on the graph.
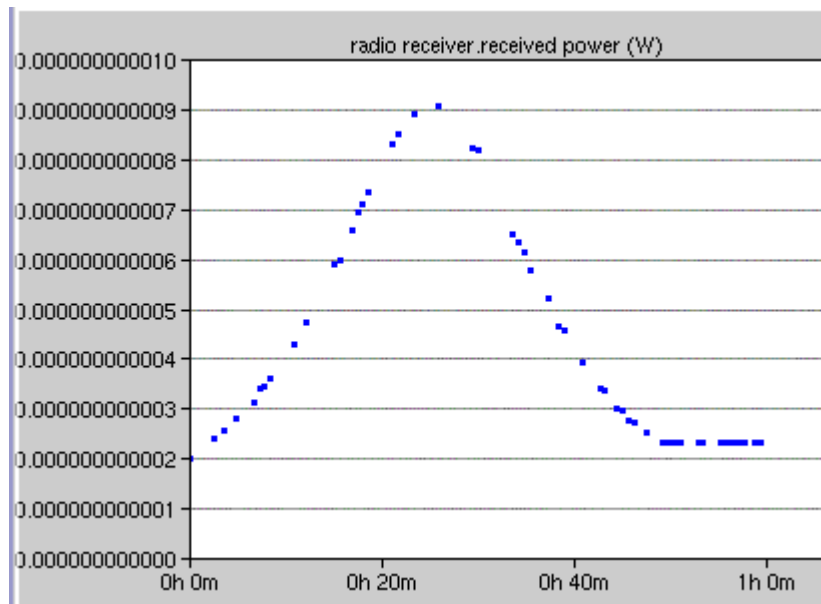
Figure 3.4.4: Power(W) Received of Workstation vs. Time(hour)

3.4 Case 2: Single AP and Multi-Workstations

In case 2, we break into several sub-cases, and each sub-case has few scenarios, so we can investigate the AP delay time due to different situation with multiple workstations. We also want to know the main determine limit the AP performance in order to improve the AP delay time.

We defined several our application before we explore the different scenarios. In case 2, for simplicity we only use File Transfer application. In figure 3.4.1 it showed comparison of FT heavy load 1 with constant 10s required time, the other with exponential 360s required time.
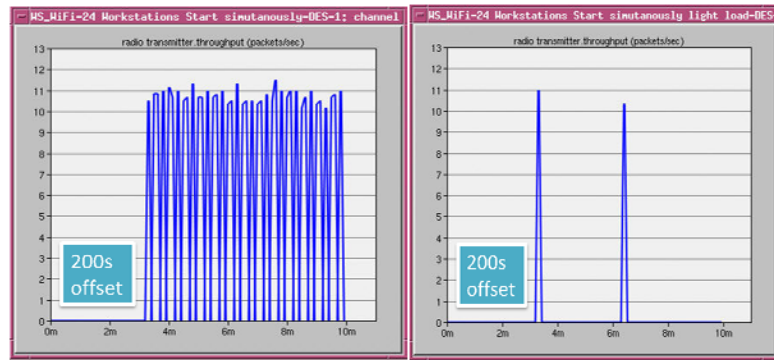

Figure 3.4.1: File transfer heavy transfer High intensity VS Low intensity

3.4.1 2, 10, 50 workstations with same application

In this sub-case, we are running 3 scenarios by increasing the number of the workstations from 2 to 50, Figure 3.4.2 clearly showed the AP delay time due to different scenarios.

Simulation Duration: 10mins for 2workstation, 1hr for 10workstations, 6hr for 50 workstation.
Simulation Running Time: ~10min
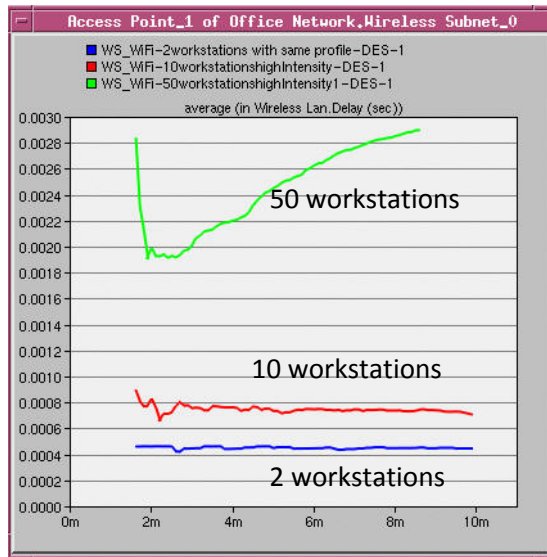
Figure 3.4.2: AP delay time comparison for 2, 5 and 10 workstation

Obviously 50 workstation network have the longest delay as we expected. At the beginning of 50 workstation scenario, the decrease of delay time is because the AP don't know how much data that 50 workstation is going to transfer, AP limit the workstation throughput and slowly increased to reach the maximum bandwidth where AP has the maximum delay.
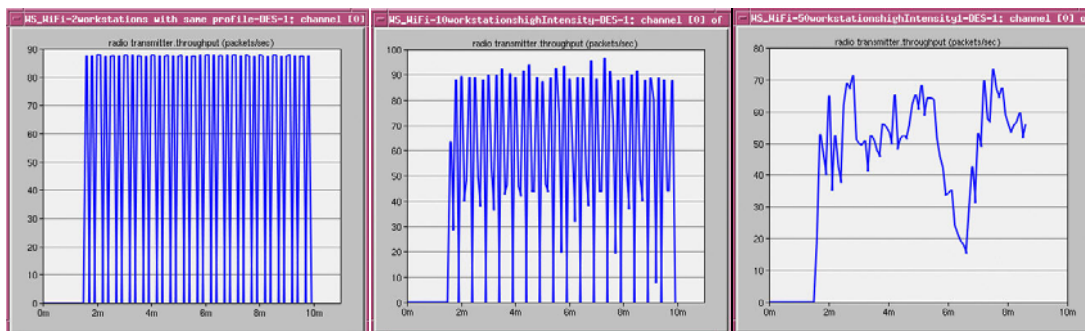
Figure 3.4.3: Radio Transmitter throughput for single workstation in each scenario

In this case, all workstations are running FT (heavy load) high intensity; however, not all workstations are transmitted ideally as we expected. The radio transmitter throughput is not only limit on what application we are running; it is also limited by the AP bandwidth and delay time. More workstation joined into network will use more bandwidth; therefore single station throughput is dropping by increase the total number of workstations in the network.

3.4.2 24 workstations joined 1 by 1 compare joined simultaneously

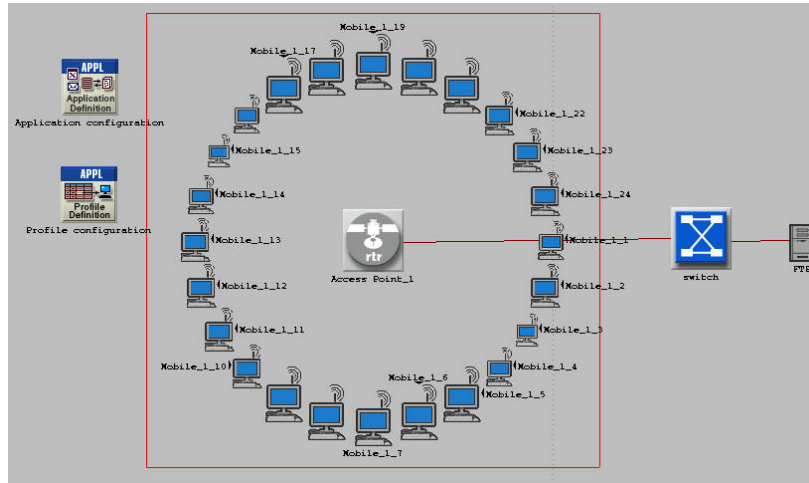Simulation Duration: 1 hr
Simulation Running Time: 2hrs

Figure 3.4.4: setup for 24 workstations with a single AP and FTP server

In this sub-case, we are using File Transfer heavy load low intensity application.

For 24 workstations joined 1 by 1, a new station joined the network every 200s.

Figure 3.4.5: 24 workstations joined 1 by 1 VS joined simultaneously

As expected, when 24 workstations joined 1 by 1, the AP delay is slowly getting higher to reach a stable time at 0.00045s. For 24 workstation joined simultaneously scenario, all workstations ask for service at the same time at beginning result a high AP delay time, but eventually reach the stable delay at 0.00045s too. This is perfect matched with 24 workstation joined 1 by 1

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scenario. Because in a long run, 24 workstations in a single AP network running the same application should result a same AP delay time.

From the 2 sub-cases 3.4.1 and 3.4.2 above, we found the single load is not only can effect on the AP, it is also can indirect effect on other workstation in the same networks. With this question, we build the next scenario below.

3.4.3 Performance Optimization

As the number of workstations and the size of packets increase, the performance will be reduced. In this section, we monitor the improvement in performance by first applying a RTS (Request-to-Send) threshold, then applying a fragmentation threshold, and final applying both RTS and fragmentation. We will also look at any downside of applying these thresholds.

Configurations as following:

Number of AP: 1
Number of Workstation: 20
Applications: Email, FTP, and Web Browsing, Print (all with high load)
    Applications applied gradually with 5mins interval
    Applications run until the end of simulation
Simulation Duration: 1 hour - 2 hours
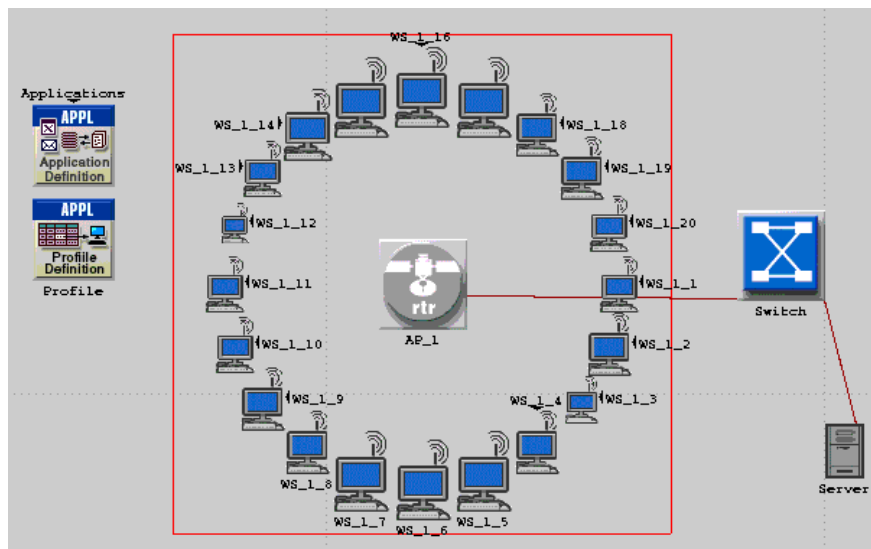Simulation Running Time: 10min - 30min

Figure 3.4.6: Structure of 1 AP and 20 Workstations Networking

RTS (Request-to-Send)

AP Attribute changed:
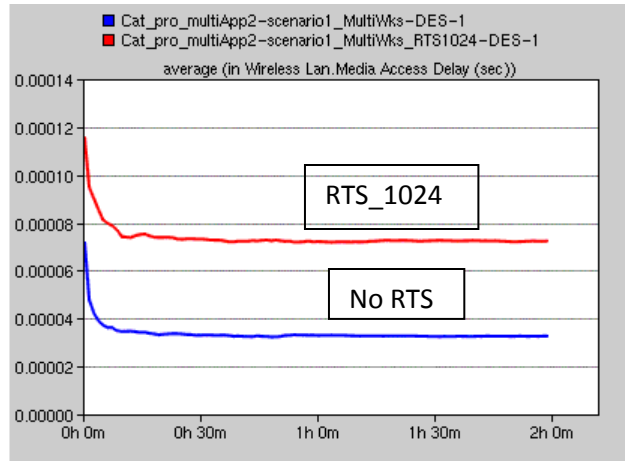RTS Threshold: 1024
Fragmentation: None

The request-to-send mechanism is a handshaking procedure used by the IEEE 802.11 wireless network to reduce the possibility of collision.   RTS threshold specifies a threshold to determine whether RTS frames is required for a particular data frame. If the MAC Service Data Unit (MSDU) received from higher layer has a size greater than the RTS threshold then the RTS frame is needed for media reservation.

As the number of workstations in the network increases, the wireless LAN throughput will reduce. This problem can be solved by applying the RTS mechanism. The default value for wireless LAN parameter RTS of the AP is none, change the RTS Threshold to 1024bytes. Since the time for running simulation is long due to the busyness of server which runs OPNET, we limit our workstation to 20, which can only see a slight improvement in throughput as showing in the following graph. However, with up to hundreds of workstations, we will be able to see obvious improvement.
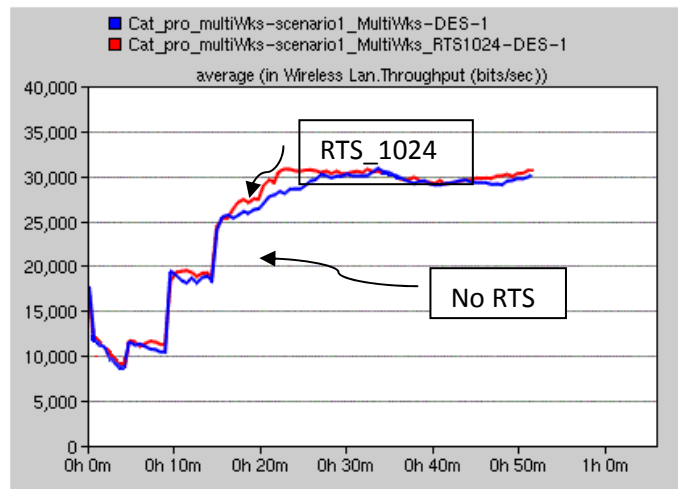
Figure 3.4.7: Throughput with no RTS and RTS_1024

This mechanism is a four-way handshaking technique instead of the basic two-way handshaking technique for packet transmission. The trade of using RTS is the increasing of Media Access Delay (as shown in the following graph). Since RTS frames waiting to receive CTS (Clear-to-Send) frame will take a certain period of time while data are waiting in the transmission buffer, while without using RTS, data are send immediately once it is ready to send.

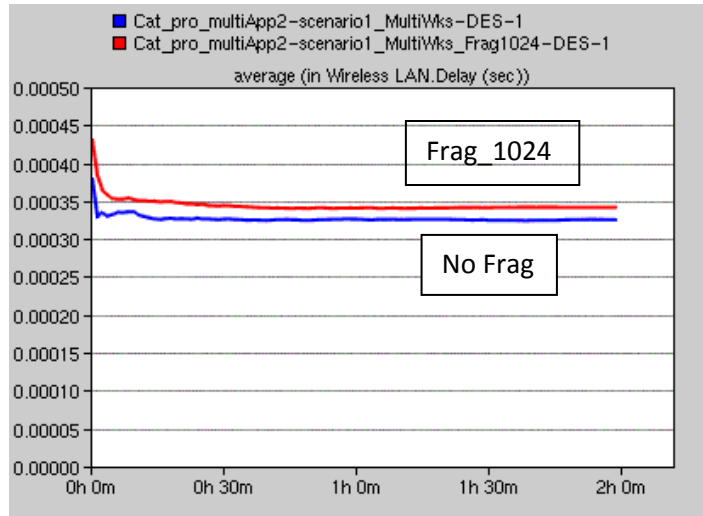**Figure 3.4.8: Media Access Delay for no RTS and RTS_1024**

Fragmentation

AP Attribute changed:
RTS Threshold: None
Fragmentation: 1024

Using fragmentation for packets with larger sizes can improve the reliability of data exchange between stations. The fragmentation threshold specifies the value to decide whether MSDU received need to be fragmented before transmission. The default threshold is none. We apply the fragmentation by setting the AP wireless LAN Fragmentation Threshold attribute to 1024bytes.

Sending packets as multiple fragments, it will reassemble at the destination after a period of time, therefore the trade off is the increasing of the overall WLAN delay (shown in following graph). The smaller the fragmentation threshold means more packets will be fragmented and will result higher WLAN delay.

Figure 3.4.9: Overall Delay for no Frag. And Frag_1024

When a packet is fragmented in a node, other packets have to wait until sending all the fragments of the previous packet, so the fragmentation process also increases the Media Access Delay in the node.
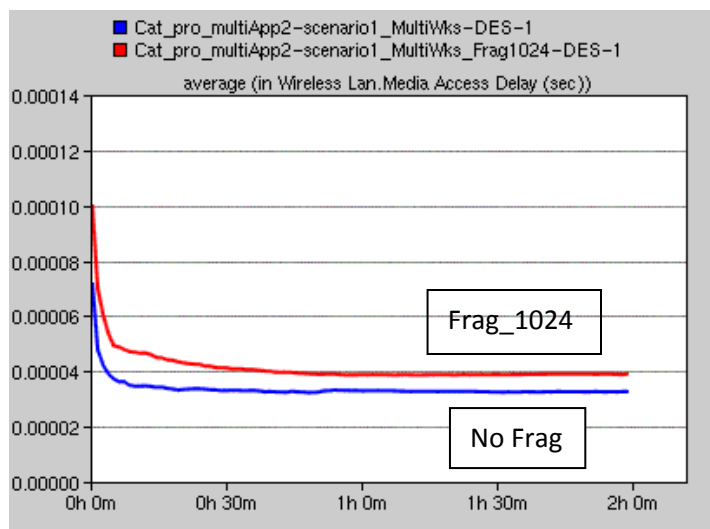
Figure 3.4.10: Media Access Delay for no Frag. And Frag_1024

In addition, larger fragments results a decrease in performance as shown in the following graph. However this problem can be solved by applying both fragmentation and RTS.

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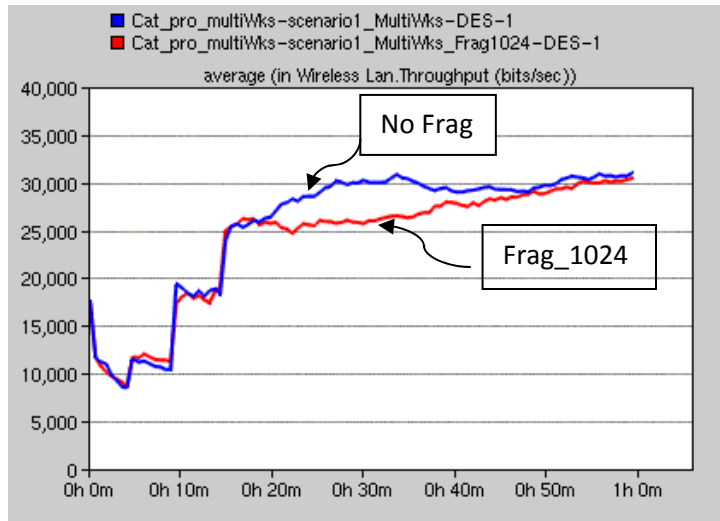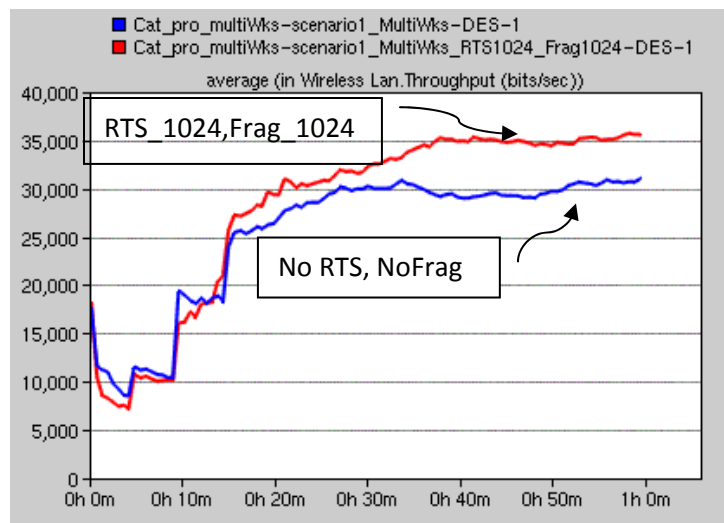
Figure 3.4.11: Throughput for no Frag. And Frag_1024

RTS and Fragmentation

AP Attribute changed:
RTS Threshold: 1024
Fragmentation: 1024

The result from the previous section shows if we want improve the reliability when transmitting large size of packet by applying fragmentation, the throughput is reduce. However if we also apply RTS in addition to fragmentation, it will totally change the result, the throughput is also improved compare to without applying RTS and fragmentation.

Figure 3.4.12: Throughput for no RTS and Frag, and RTS_1024 and Frag_1024

However the trade off is longer media access delay:
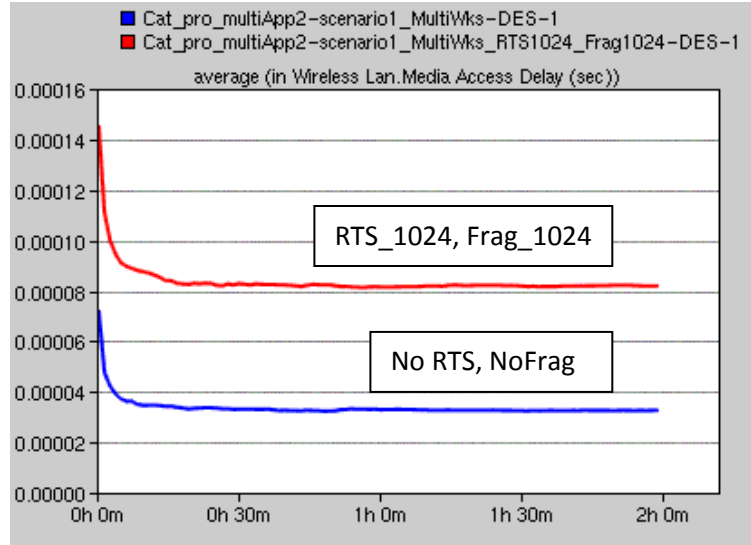
Figure 3.4.13: Media Access Delay for no RTS and Frag, and RTS_1024 and Frag_1024

3.4.4   2 workstations 1 with extreme load 1 with normal heavy load

This is an easy set up only have 2 workstations and they all inside the range of AP. The difference of these two workstations is one is running a normal File Transfer heavy load (0.5MB) every 10s and the other one is running a File Transfer extreme load (50MB) every 10s.

Simulation Duration: 1 hr
Simulation Running Time: 5mins
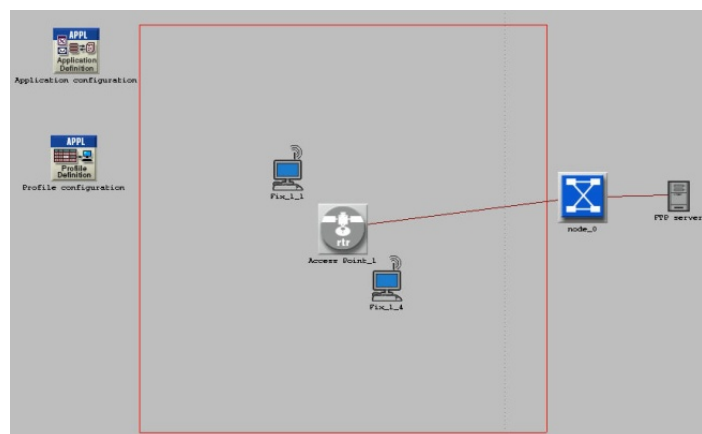
Figure 3.4.14: setup for workstation with extreme load VS normal load

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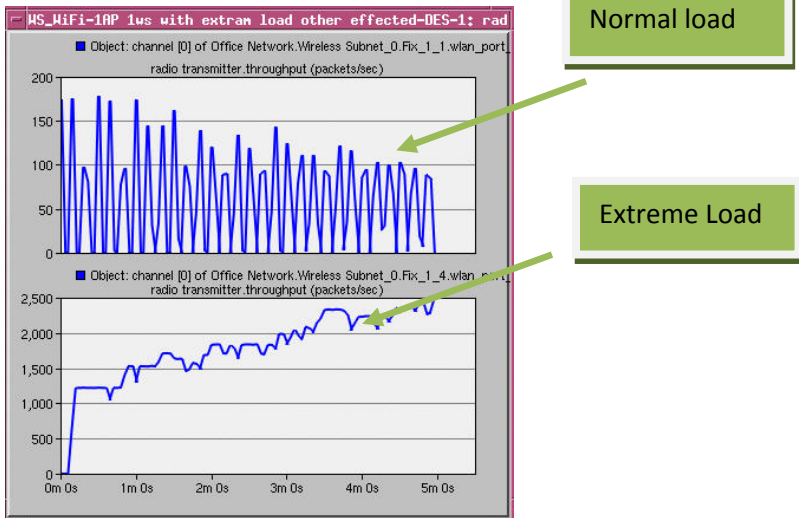
Figure 3.4.15: throughput for workstation with extreme load VS normal load

From the Figure 3.4.7, we found that increase the load on 1 workstation of the networks will decrease other workstations throughput bandwidth.
We also found that extreme load throughput graph shape is not a wave shape as normal load. First we explain why the normal load has a wave shape.

The application we are running here is File Transfer heavy load (0.5MB) every 10s. Because the normal load station finished transfer less than 10s, the throughput has nothing to transfer until next request. Therefore the throughput has wave shape output. For the extreme load file transfer workstation, it cannot finish transfer 50MB in 10s before next request, therefore the throughput cannon take a break and also have to increase the throughput bandwidth to finish the job.

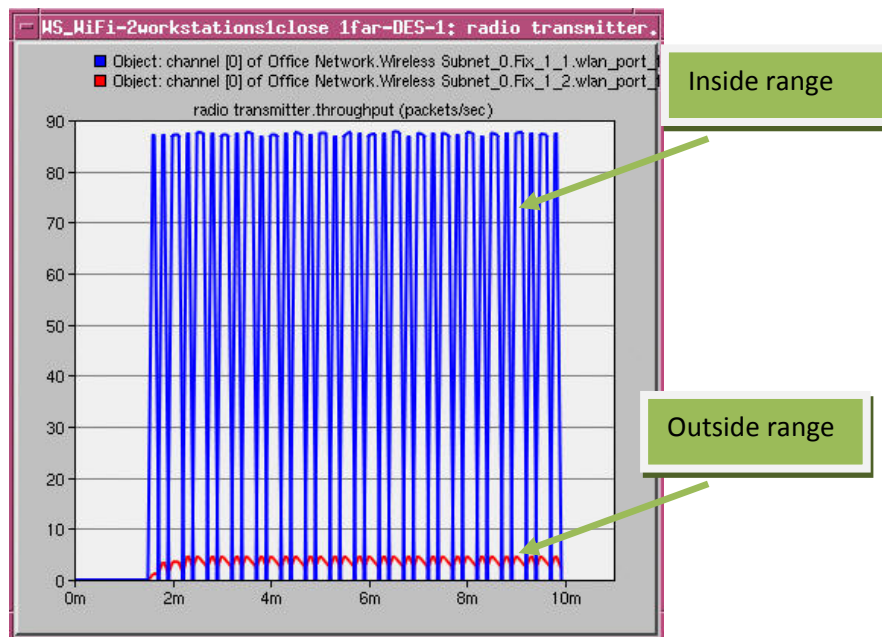### 3.4.5   2 workstations 1 inside range VS 1 outside range

After we have a basic understand of the relationship between workload on workstation and AP causing the delay time. Now we are going to investigate the relationship between the transmitting distance and throughput on each workstation.

Simulation Duration: 40mins
Simulation Running Time: 10mins
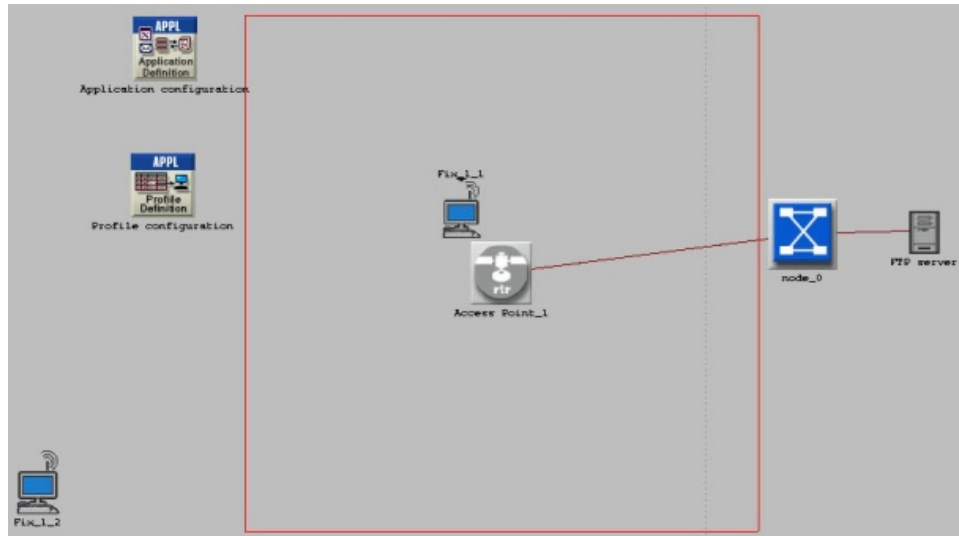
Figure 3.4.16: setup for 2 workstations 1 inside range VS 1 outside range

Figure 3.4.17: workstation throughput inside range VS outside range

Clearly we can see that workstation inside the range works full load as expected. The workstation outside the range cannot transmit as much as request by application. This is due to the signal strength is weaker by increase the distance between workstation and AP,

One more interesting thing we found that, for workstation inside the range, the throughput is a wave shape graph; but for workstation outside the range, the throughput is approximates a straight line. The application we are running here is File Transfer heavy load (0.5MB) with a constant 10s request. Therefore every 10s, the workstation will ask to transfer 0.5MB, because the station inside the range finished transfer less than 10s, so the throughput will back to 0 for a

while and start transmitting until next request. For workstation outside the range, it cannot finish transfer 0.5MB in 10s before next request, therefore the throughput cannon take a break will result a line shape as shown above.

In this scenario we found that distance between workstation and AP is a factor that significant effect on workstation's throughput. To investigate more detail about this relationship, we build next scenario: a moving workstation analysis.

3.4.6   1 moving workstation analysis

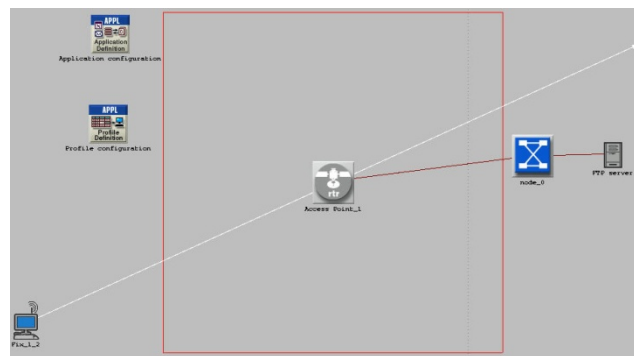Simulation Duration: 30mins
Simulation Running Time: 15mins

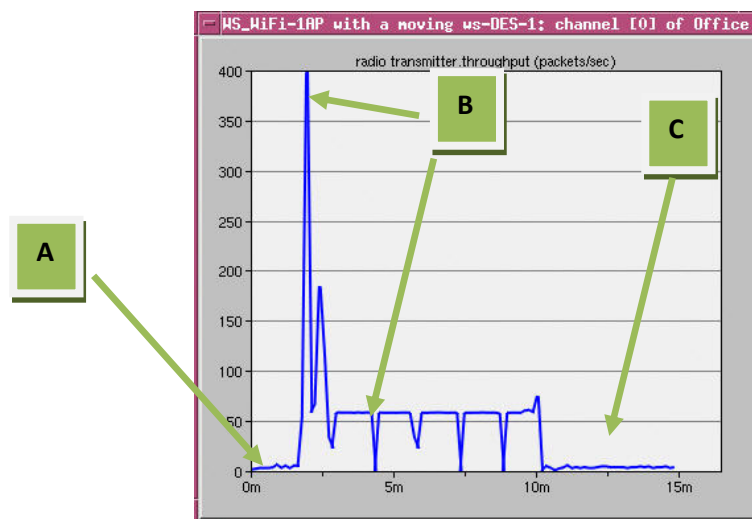**Figure 3.4.18: setup for 1 moving workstation**

Figure 3.4.19: Throughput for 1 moving workstation

From the figure 3.4.11, I divide into 3 areas. Area A is from the start point to before enter the effective range of the AP. Area B is inside the range of AP. Area C is from just leaving the range of AP to the final destination position. During the Area A and C, workstation has the same throughput as we expected. We are more interesting on Area B.

Before just entering the area B, the workstation have a lot of data need to be send by using FTP, but due to the signal strength, it cannot be done as required time. Once the station move into the area B which is inside the affective range of AP, workstation send all the data in the buffer which suppose to be send in the earlier time. That's why we saw a very sharp pulse at the beginning. Then everything back to schedule throughput back to normal, when workstation out the range, throughput fade out.

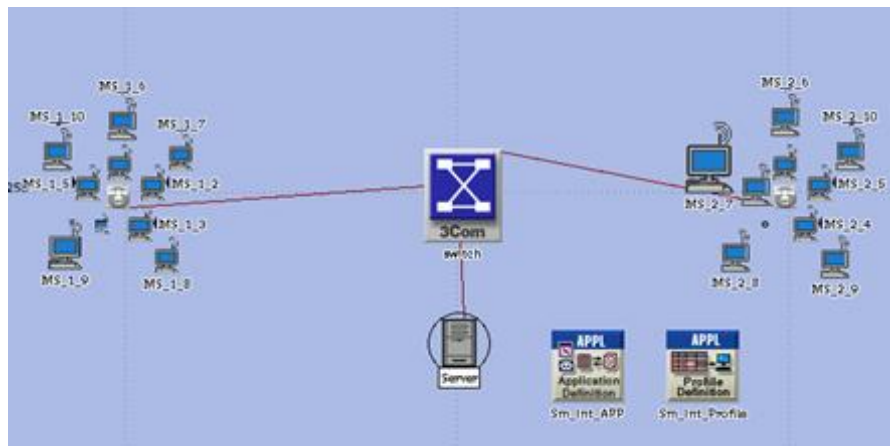## 3.5   Case 3: Two APs and Multi-Workstations

3.5.1   Delay Improvement

Figure 3.5.1: Case 3 Network setup

In the third scenario, we have a server connected to a switch and the switch split into 2 links and connected to 2 access points. For each access point, 10 stations are connected to its closet access point by assigning the correct BSSID. Each of these stations runs the FTP heavy application which will be requesting a burst of 50000 bytes of data for a mean period of 360 seconds from the server. The network setup is shown in Figure 3.5.1.

Configurations are as following:

Applications: FTP (heavy loaded)
Simulation Duration: 2 hours
Simulation Running Time: ~5 mins
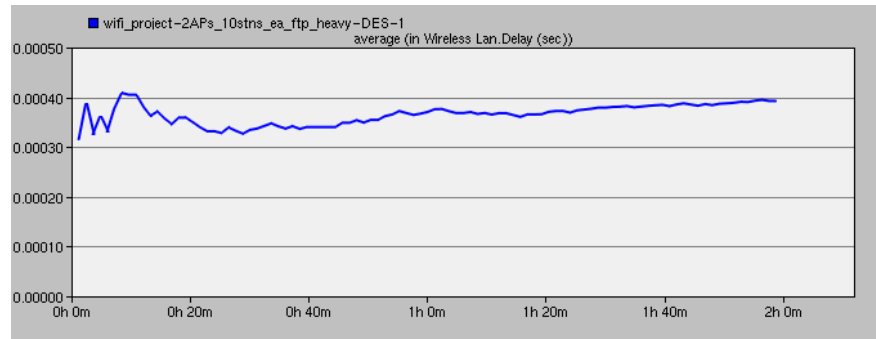
Figure 3.5.2: Simulation result for AP delay

From the simulation result, the delay for one of the AP is about roughly 0.0004 second. This delay time is lower than the second scenario in case 2 where 20 work stations are connected to 1 single AP. The delay time of the second scenario in case 2 is roughly about 0.00045 second. This delay improvement can be explained by the lowered load to the access point. As work stations number decrease, load to the access point decrease, hence improves the delay time performance.

4 Conclusion

In this project, we have greatly experienced the use of a network simulation software – OPNET. We now understand a scenario, how to set different parameters for a model and how to model the behaviors of different network components.

We project deal with WiFi network. We have simulated many different scenarios in infrastructure mode – 1 AP and 1 work station; 1 AP and multiple work stations; 2 APs and multiple work stations; mobility of WiFi work station; etc.

One conclusion from these scenarios we can draw is that, the delay time of an access point dependent on the amount of traffic load it has. The higher the load, the greater the delay time. Therefore, an access point should always keep a limited number of work stations connect to it if budget available in order to maintain a good quality of service for the network.

5 Reference

1. Explained Wi-Fi http://en.wikipedia.org/wiki/Wifi

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9. Wireless Network Performance Optimization Using Opnet Modeler http://www.scialert.net/qredirect.php?doi=itj.2006.18.24&linkid=pdf

6 Appendix

A.   List of Abbreviations

AP   Access Point

BSS   Base Station System

FTP   File Transfer Protocol

LLC   Logical Link Control

MAC   Media Access Control

MSDU   MAC Service Data Unit

OPNET   Optimized Network Engineering Tool

PC   Personal Computer

RTS   Request-to-Send

Wi-Fi   Wireless Fidelity

WLAN   wireless Local Area Network