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ANALYSIS OF WIRELESS NETWORK PERFORMANCES IN WLAN TOPOLOGIES

School of Technology

2015

ACKNOWLEDGEMENTS

I would like to thank God who has given me the grace and opportunity throughout my study.

I would like to thank my my mother, Mrs Oluwakemi Adesokan, who has supported me both financially and mentally.

My supervisor, Antti Virtanen for his advice and leadership which has guided me through the final project work.

Special thank to all my family members that supported me.

And to all my friends and colleagues that we started together both at School of Technology and Business.

Adesokan Adeyemi Oyemade

Vaasa, 9th of June, 2015.

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ABSTRACT

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Title	Analysis of Wireless Network Performances in WLAN Topologies.
Year	2015
Language	English
Pages	42
Name of Supervisor	Antti Virtanen

Expanding wireless networks can be accomplished by adding Access Points (APs) which is known as infrastructure mode or without an Access Point (AP) which is known as Ad-hoc mode. Both bring about several issues, the design must be carefully considered before it is deployed. There are many factors that are affecting the performances of Wireless Local Area Networks (WLAN) topologies designed for our network.

This thesis work is about investigating and analysing the performances of two types of WLAN topologies namely; Basic Service Sets (BSSs) and Extended Service Sets (ESSs). Both Basic Service Set (BSS) and Extended Service Set (ESS) are categorised as Infrastructure mode i.e. they require AP or APs before they can function.

The two types of WLAN topologies were modelled with an Optimized Network Engineering Tool (OPNET) into scenarios. There are connections between APs, switch and application server which host application of high priority.
The simulation was performed with real-time video conferencing with variations in numbers of users, and data rate in megabit per seconds (Mbps). Performance metrics such as throughput, and delay were measured and closely analysed to see which connection maintain its Quality of Service (QoS).

Keywords WLAN Topologies, QoS, Throughput

CONTENTS

LIST OF ABBREVIATIONS

AP	Access Point
BPSK	Binary Phase Shift Keying
BSS	Basic Service Set
CA	Collision Avoidance
CDMA	Code Division Multiple Access
CSMA	Carrier Sense Multiple Access
DES	Discrete Event Simulation
ESS	Extended Service Set
ETE V	End to End Delay Variation
GSM	Global System for Mobile Communication
IBSS	Independent Basic Service Set
IEEE	Institute of Electrical and Electronic Engineers
RF	Radio Frequency
MAC	Medium Access Control
MANET	Mobile Ad-hoc Network
OPNET	Optimized Network Engineering Tool
OFDM	Orthogonal Frequency-Division Multiplexing
PHY	Physical Layer
QoS	Quality of Service
SSID	Service Set Identifier
WLAN	Wireless Local Area Network

LIST OF FIGURES

1 INTRODUCTION

Wireless networks have been a very important part of communication these days as everybody want to have access to information at anytime and anywhere. There has been a rapid growth of usage of wireless devices which has made it possible for users to have connections anywhere hence, the need to continue study the performances and limitations of wireless networks. A wireless LAN (WLAN) provides network connectivity between devices, also known as stations, by using radio as the communication medium. /5/

All devices that communicate over WLAN conform to the interfaces and procedures defined by the IEEE 802.11 standards. /5/

There are four types of wireless networks namely: Wireless Local Area Network, Wireless Personal Area Networks, Wireless Metropolitan Network and Wireless Wide Area Networks.

In this thesis, we shall be analysing the performances of two types of Wireless Local Area Network (WLAN) topologies using Optimized Network Engineering Tool (OPNET) Guru Academic Edition. Two types of WLAN topologies will be modelled, namely; BSS and ESS, into scenario one and two respectively, each modelled scenario will have the number of users changing in their respective networks. There will be an application of high priority traffic, a high priority in an attempt to place high demand on the modelled network resources. It is because its load should have an impact on the QoS of the two designed networks.

An important network parameter data rate in Mbps will be made constant at first on all the networks as the application is being passed through. The data rate will now be varied with constant users so as to analyse effectively how they perform and investigate which of the connections maintains its QoS. The aim is to measure the performance metrics such as throughput and delay that determine the QoS of a network.

2 BACKGROUND AND AIM OF THE PROJECT

The capability of a wireless network to provide good QoS is very important in today's world, so therefore it has to be given maximum priority. Since it defines a system with good transmission quality, service availability and minimum delay. It is mandatory for us to test the reliability performance of our WLAN topologies network applications due to growing numbers of audio and video being sent over a packet-switched network.

Er. Ishu Gupta and Er Perminder Kaul work on comparative throughput of Wi-Fi and Ethernet LANs, where they compare the performance of both wired and wireless networks based on various performance parameters with variation in number of users. /1/

Providing QoS in WLAN networks has been a great challenge in the past and continues to be. The challenges associated with providing QoS are numerous, but the biggest challenge for traditional networks has been congestion. However, many more challenges exist for wireless and mobile networks. /9/

Therefore, a completely different set of QoS techniques are required for wireless networks than for wired networks. In 1G networks and 2G networks such as Global System for Mobile Communication GSM and CDMA, there was only one aspect of QoS, and it is voice, i.e., providing quality speech was a major concern. /2/

The main purpose of this thesis is to investigate how the two types of WLAN topologies respond when their networks are subject to an application that requires high bandwidth such a video conferencing. In this work, we shall be using OPNET Guru to implement BSS and ESS with IEEE 802.11n standard.

3 IEEE 802.11 STANDARDS

IEEE Std 802.11^{TM}-2012 also known as Wi-Fi is a specification developed for WLAN technology by Institute of Electrical and Electronics Engineers (IEEE). The specification was accepted and the first standard was published in 1997 and reaffirmed. The current revision, IEEE Std 802.11-2012, incorporates subsequent amendments into 2007 revision. /3/

The first standard that was accepted is 802.11-1997. It defines the protocol and compatible interconnection of data communication equipment by the “air,” radio or infrared, in an LAN with the use of collision avoidance (CSMA/CA) medium sharing mechanism. It medium access control (MAC) supports operation that is under the control of an AP and independent stations. It has an infrared implementation of the PHY which supports 1 Mbps data rate with an optional 2 Mbps. /4/

3.1 802.11n Standards

802.11n expands the main concepts of 802.11 with additional new options to improve quality of wireless link with the aim of increasing data rate and range. It coding scheme is far better than the earlier standards, which ensures more data bits being transferred with the same channel size. It contains (multiple in, multiple out) MIMO, which enables the transmission of multiple streams of data on separate antennas but the same channel. It also has the ability for channel bonding that increases the data rate. /7/

The first generation of it is known as Draft N, it supports two spatial streams, with expectation of 144 Mbps as higher data rate in one 20 MHz. Its own physical layer (PHY) is based on the OFDM PHY as defined in clause 18 with room for up to four spatial streams i.e. four spatial streams at 40 MHz bandwidth. These features can support data rates up to 600 Mbps. It PHY data subcarriers are modulated with Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), 16-Quadrature Amplitude Modulation (16-QAM) and 64-QAM. It also uses Forward Error Correction (FEC) coding with rate at 1/2, 2/3, 3/4 and 5/6. /3/

3.2 802.11 Networks

There are two types of WLAN networks that can be formed: Ad-hoc networks; and Infrastructure networks.

The Ad-hoc mode can also be called “peer-to-peer” mode or IBSS, it network connection does not require an AP. Devices of this type of wireless network connection must be equipped with a wireless adapter and connects directly to each other e.g. Setting up two computers in wireless mode without a centralized AP.

Infrastructure mode is when computers and devices do not communicate directly, rather, equipped computers and devices with a Wireless Adapter communicate with each other as well as a wired network through a wireless AP. The AP negotiates all traffic between both wired and wireless network. It can also be called BSS while a set of two or more BSS is called ESS.

3.3 WLAN Topologies

Provision of network access by broadcasting a signal across a wireless radio frequency (RF) carrier is accomplished by a WLAN. A receiving station can be within the range of a number of transmitters, the transmitter showcase its communication with a Service Set Identifier (SSID). /13/

There are three basic types of WLAN topologies supported by IEEE 802.11 and they are IBSS, BSS and ESS. /12/

3.4 IBSS

These are sets of wireless stations that communicate directly with each other in the absence of an AP or wired network as shown in figure 1 below. It is also known as an ad-hoc network due to its peer-to-peer basis. It is very useful in case of an emergency where a network connection or setup is quickly required. /l2/

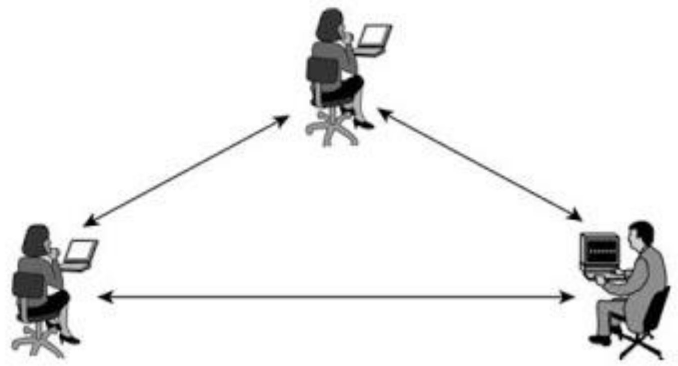

Figure 1. An IBSS WLAN. /14/

3.5 BSS

This type of WLAN topologies uses one AP which is connected to infrastructure wired network as shown in figure 2 below. Wireless stations on this type of network communicate through the AP which serves as a logical server. /12/

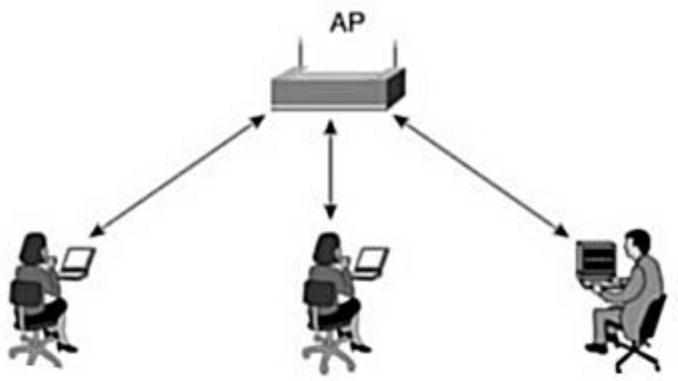

Figure 2. A BSS WLAN. /14/

3.6 ESS

This is when multiple infrastructure BSSs, each with an AP, are connected together by means of the Distribution System (DS) which is mostly and Ethernet LAN. Figure 3 below shows an ESS with two APs. /12/

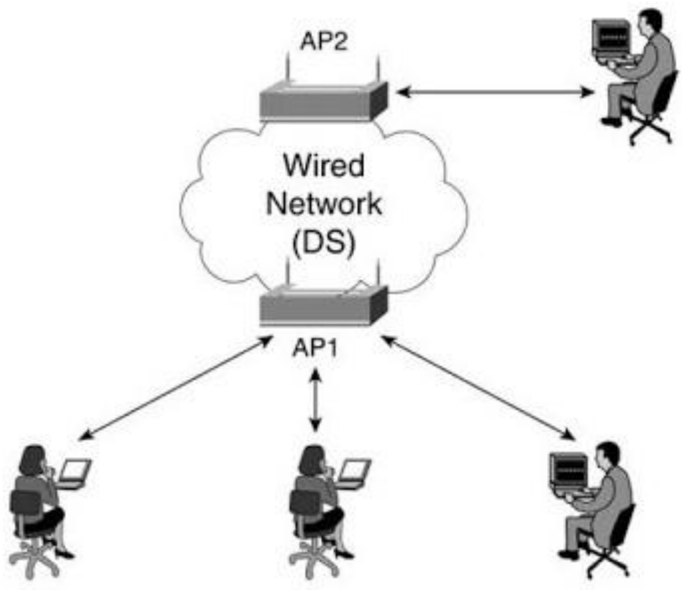

Figure 3. An ESS WLAN. /14/

3.7 Quality of Service

A communications network is the backbone of any successful organization, and these networks carry several applications and data such as high-quality video and delay-sensitive data such as real-time voice. The high priority traffic or bandwidth-intensive applications stretch network resources but also ensure the smooth business process. Networks must, therefore, provide secure, predictable, durable, measurable and guaranteed services. This is to achieve the required QoS by managing delay, delay variation (jitter), bandwidth and packet loss parameters on a network. Therefore, QoS is a set of techniques to ensure successful management of network recourses. /10/

3.7.1 Throughput

Throughput is one of the best indicators of performance of a WLAN due to its provision of actual time it takes to send information. It is the flow of information over time through a communication channel. We can therefore conclude that throughput is a measure of how much data can be transferred from the originating source to the destination in a given amount of time; its unit is Mbps. /13/

3.7.2 Delay

Delay is an important performance metric that can be used to determine the QoS.of a wireless network mostly, real-time multimedia applications. It is the time taken by the network data to reach its destination from its source. Delay of any network can be measured at three different layers and they are: wireless LAN delay, end-to-end delay and media access control delay. /8/

3.7.3 Jitter

This is also known as variation in the End-to-End delay (ETE), as packets are put into queues, the ETE delay in the transmission of packets from one source to destination will vary depending on the packets' position in the queue and also the different queue sizes. It is therefore very important to minimize jitter so as to improve the quality of transmitted information, especially in applications requiring real-time data transmission. /8/

3.8 Data Rates and Buffer Sizes

Data rates are the speed of the nodes or workstation connected to a network. It is the speed of transmitters and receivers connected to a WLAN Media Access Control (MAC), each associated with a separate channel stream. /13/

The Buffer size is the specified maximum length of higher layer data arrival. For an example, if the buffer limit is reached, the data received from higher layer are removed until many packets are removed from the buffer so as to create space for new packets. /11/

3.9 Why Simulation in OPNET

Due to the high cost of setting up laboratory equipment for real-time networking measurements, the use of a network simulator such as OPNET has become effective and realistic. OPNET is one of the leading network development software introduced in 1986 with the aim of simulating networking and telecommunication environment by modeling system behavior by the user. It is a high-level event-based network level simulator that operates at packet-level, it contains a huge library of accurate models, accurate network behavior and commercially available fixed network hardware and protocols. /6/

Its high-level user interface is developed from C and C++ source code and modeling is divided into three main domains: network domain, node domain ad process domain. /6/

3.10 The main components in OPNET Guru (Academic Edition).

The main components and features used for this thesis are application definition (figure 4), profile definition (figure 4), project menu, and scenario menu and object palette tree.

The application describes the parameters for any chosen application to be used. The profile definition is used to select the activity pattern of the user in regard to the chosen application while the object palette tree gives access to all the models available in OPNET such as network devices and also helps in modeling network topologies.

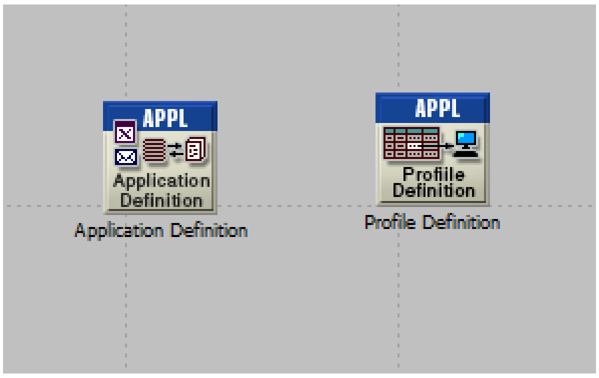

Figure 4. Application and Profile Definition

3.11 Object Palette Tree

Object palette tree is very important in OPNET as it contain the entire network devices required to model a network, it can also be used to create a custom model. It is a window that opens automatically as the new project is created. It can also be launched from project editor by clicking on its icon on the toolbar or selecting topology.

In figure 5 (below), we can see the wireless servers, workstations, Ethernet server and WLAN routers which are used to model both BSS and ESS network.

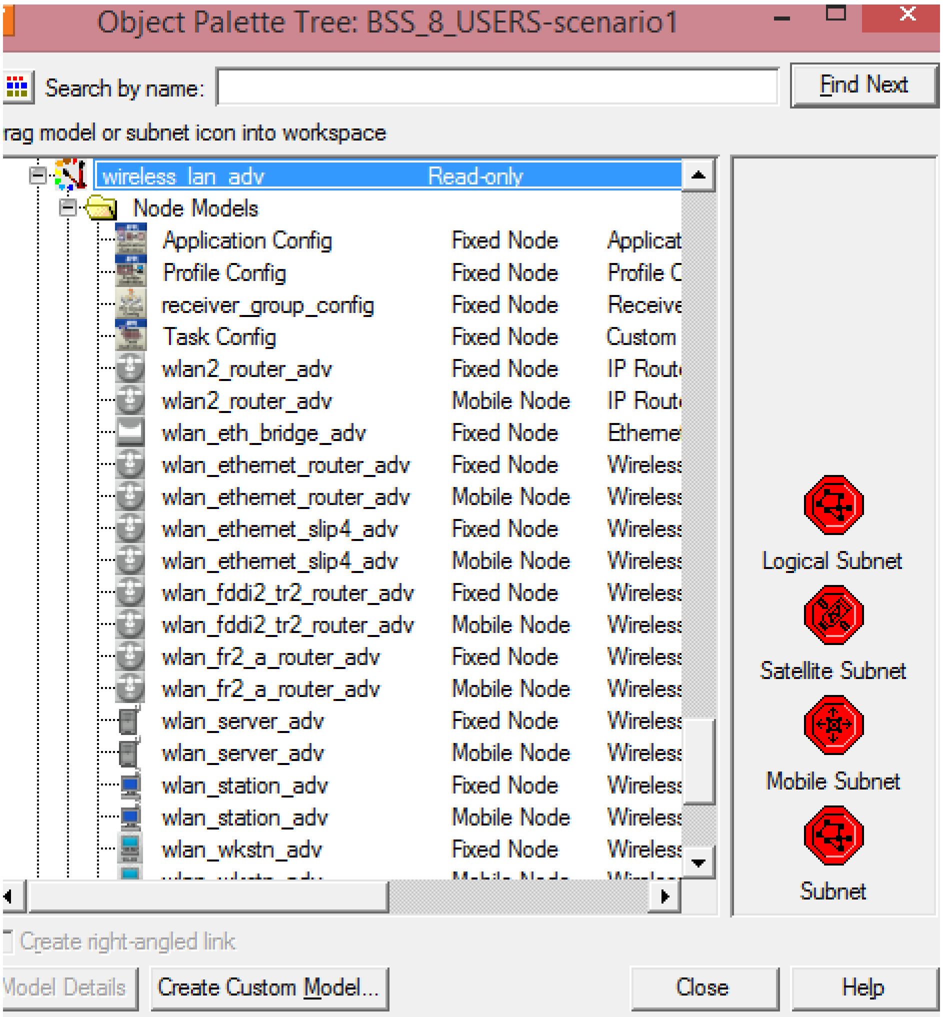

Figure 5. Object palette tree

4 IMPLEMENTATION AND DESIGN IN OPNET GURU

The simulation of the designed network was carried out using the OPNET IT Guru simulator (Academic Edition). The two WLAN topologies were modelled, into two main scenarios, scenario 1 is for infrastructure mode BSS and scenario 2 is for infrastructure mode ESS. Each of the scenarios will have their data rates and number of users varied, and the results measured and recorded, but the applied application remains constant for all scenarios and in this case, video conferencing is applied.

4.1 Scenario 1, Infrastructure mode (BSS)

In this scenario, the network was modelled with one AP, an Ethernet server which hosts the application. Figure 6 below shows a modeled BSS with eight users.

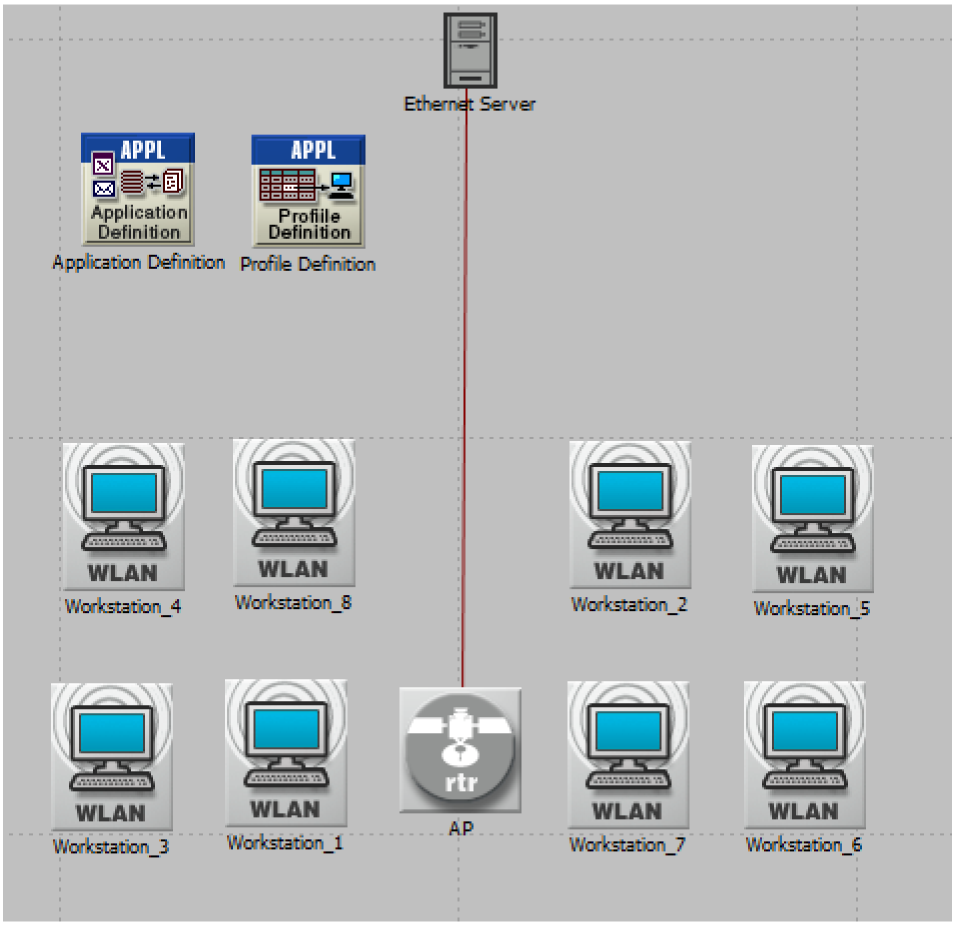

Figure 6. Infrastructure mode BSS with 8 users

After modelling BSS, both profile definition and application definition need to be configured. The application definition is used to define or specify the type of application to be used, while the profile definition profiled the defined application for it to be hosted by the Ethernet server. The configuration of both can be shown below in figure 7 and figure 8.

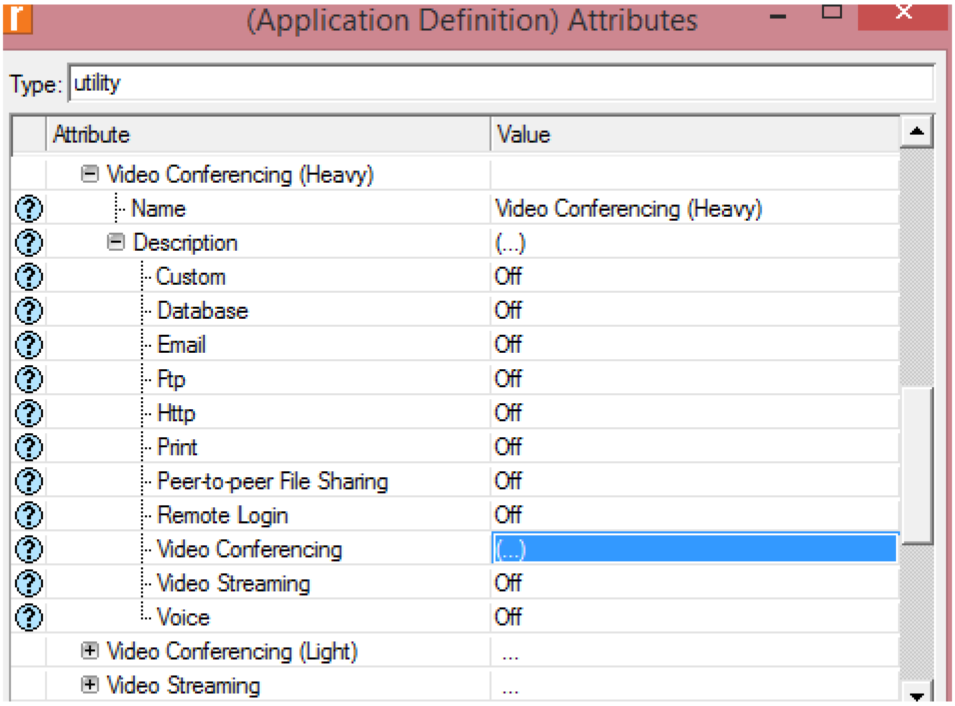

Figure 7. Application Definition Configuration

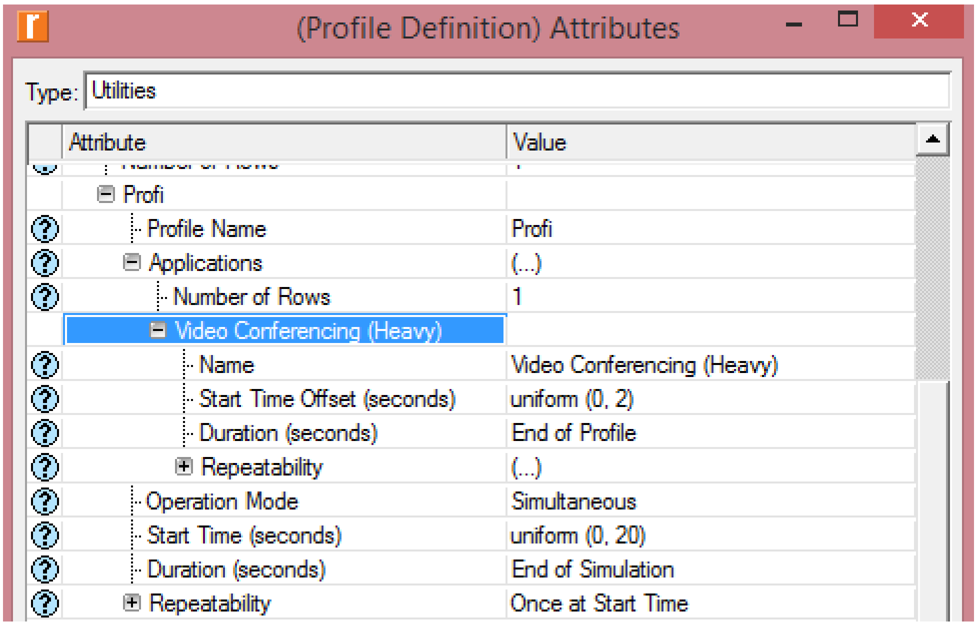

Figure 8. Profile Definition Configuration.

The Ethernet server hosts the application; it has to be configured with the same application as specified in application definition so as to be able to deplore the application. Figure 9 below shows configuration of application server.

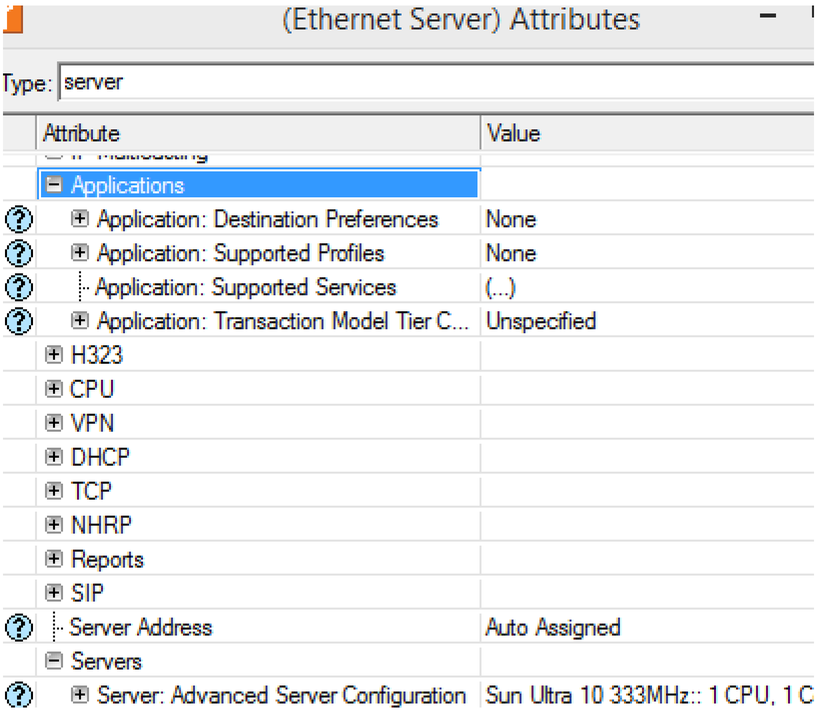

Figure 9. The Ethernet server configuration.

The AP and the workstation also have to be configured by setting both to the same BSS Identifier, which enables the AP connection to the workstation wirelessly. Data rates are also configured and can be changed from workstation attributes. Figure 10 and figure 11 below show the configuration of AP, workstation and data rates.

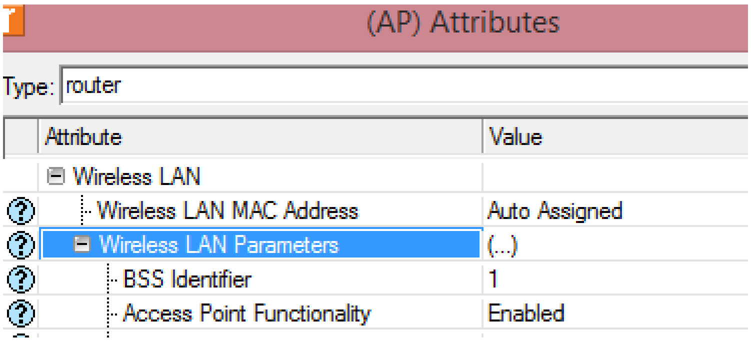

Figure 10. AP Configuration.

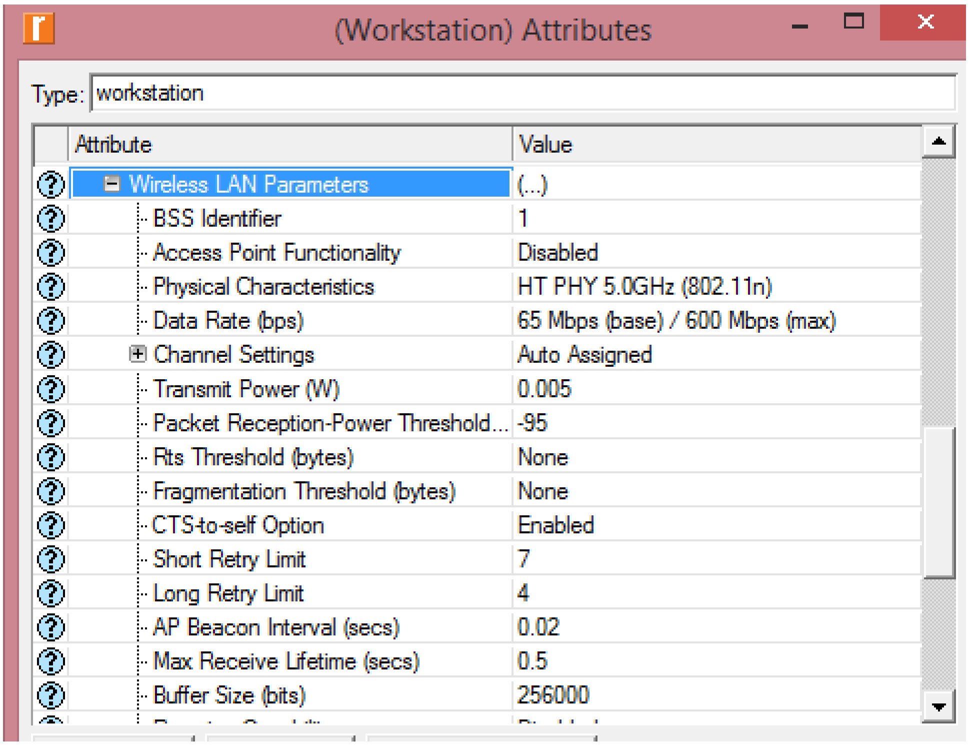

Figure 11. Workstation and Data Rates Configurations.

4.2 Collecting Statistics and Setting Simulation Time

After configuring the network models, the next thing is to specify the statistics to be collected which can either be Global or Object statistics. The Global statistics are the measurements for the entire network while Object statistics are for nodes. This can be done by right clicking in the project editor and click on choose individual DES statistic, desired parameters for measurement can now be selected as shown in figure 12 below.

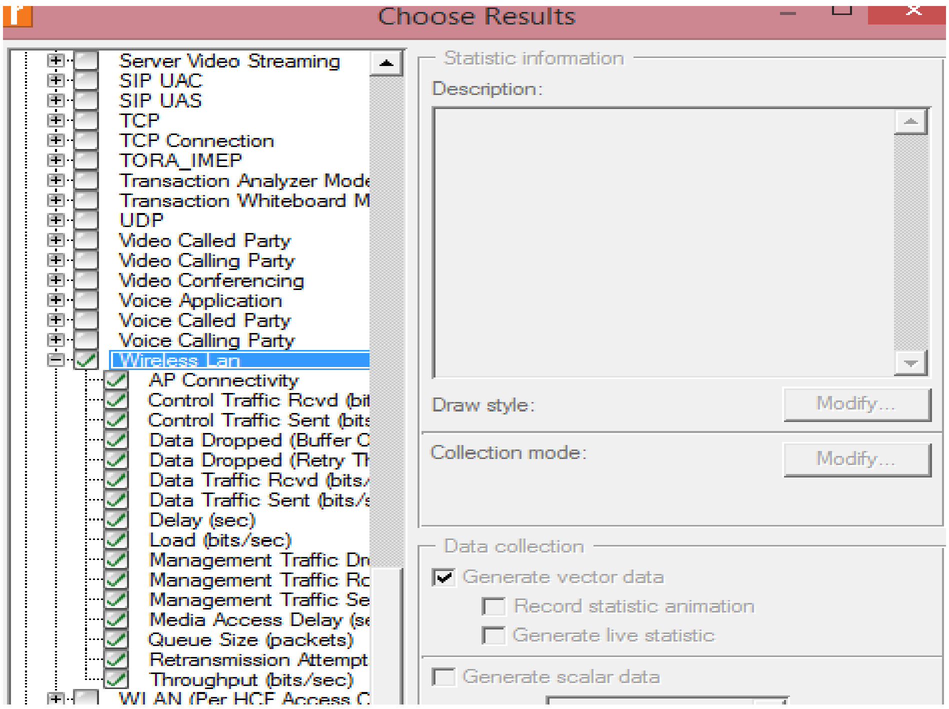

Figure 12. Selecting Parameters for Statistics

The next thing is setting the simulation time, it is very important to set the right simulation time as it will affect the result that will be generated. Figure 13 below shows simulation time preview.

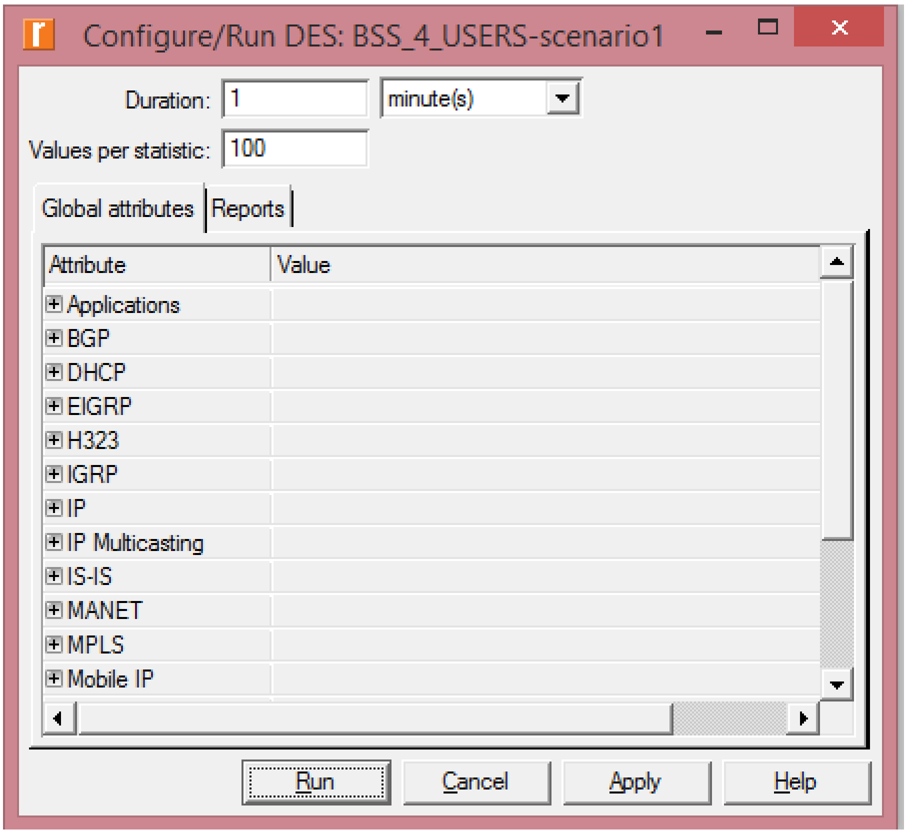

Figure 13. Simulation Time Menu

4.3 Scenario 1 case 1

In this case the number of users is varied while the data rates are kept constant as shown in Table 1 below

Table 1. Parameters for case 1

Parameters	Scenario1_Case 1	Scenario1_Case 1
No of Users	4 users	8 users
Data Rates (Mbps)	65	65

4.4 Scenario 1 case 2

In this case the users are kept constant while the data rates varies as shown in the Table 2.

Table 2. Parameters for case2

Parameters	Scenario1_Case 2	Scenario1_Case 2
No of Users	4 users	4 users
Data Rates (Mbps)	13	65

4.5 Scenario 2, Infrastructure mode (ESS)

In this scenario there are two APs in the network, with their BSS Identifier set to 1 and 2 respectively. The AP and the workstation are configured as shown in the case of BSS with four workstations set with BSS Id 1 and the other with BSS Id 2. Each AP now has four users each. An Ethernet switch is then used to connect the two APs together with an Ethernet server. Figure 14 below shows a modelled ESS network with eight users.

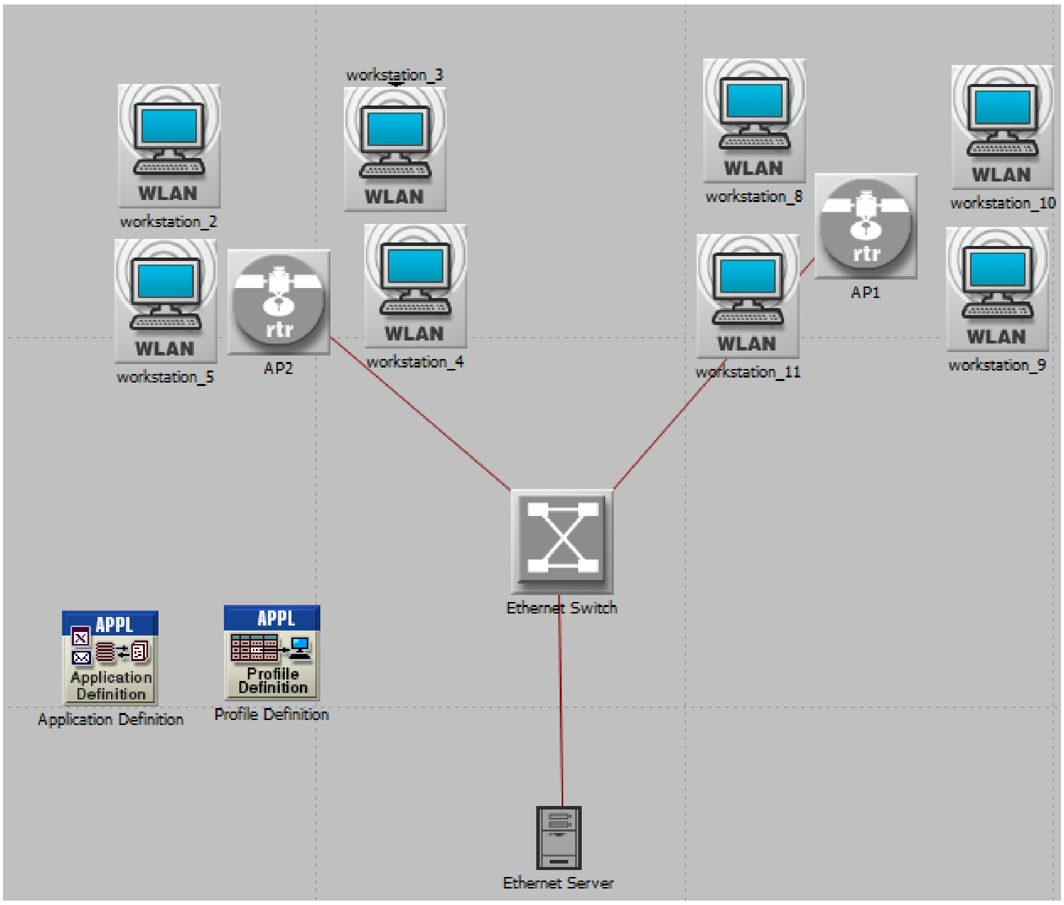

Figure 14. Infrastructure mode (ESS) with 8 Workstations

4.6 Scenario 2 case 1

In this case the number of users is varied for the ESS while data rates are kept constant. Table 3 (below) shows the parameter changes.

Table3. Parameters for case1

Parameters	Scenario2_Case 1	Scenario2_Case 1
No of Users	4	8
Data Rates (Mbps)	65	65

4.7 Scenario 2 case 2

In this case the users are kept constant while the data rate is varied as shown in Table 4.

Table 4. Parameters for case2

Parameters	Scenario2_Case 2	Scenario2_Case 2
No of Users	4 users	4 users
Data Rates (Mbps)	13	65

5 SIMULATION RESULTS AND ANALYSIS

5.1 Results and Analysis for Scenario 1 Infrastructure Mode (BSS)

After the simulation, the graphs in figure 15 and figure 16 below were obtained for throughput and delay for variations in number of users, i.e. case 1 scenario 1.

5.1.1 Analysis of Scenario 1 Case 1(WLAN Throughput)

In this case the numbers of users keeps on changing while both the data rate and buffer sizes remain constant for four and eight users. As figure 15 below shows, the blue graph represents the four users, while the red graph represents the eight users. Both graphs rise sharply before they become stable, but that of four users rises above that of eight users. If the end of the blue graph is traced to the vertical axis, the value is found to be approximately 51,000,000bits/sec which corresponds to 51 Mbps.

If the end of the red graph which represents eight users is traced to the same vertical axis, it is found that the value is approximately 23,000,000 bits/secs, which is 23 Mbps. The results show that as the number of users by is doubled, the throughput is also decreased to more than half its original values for BSS mode network.

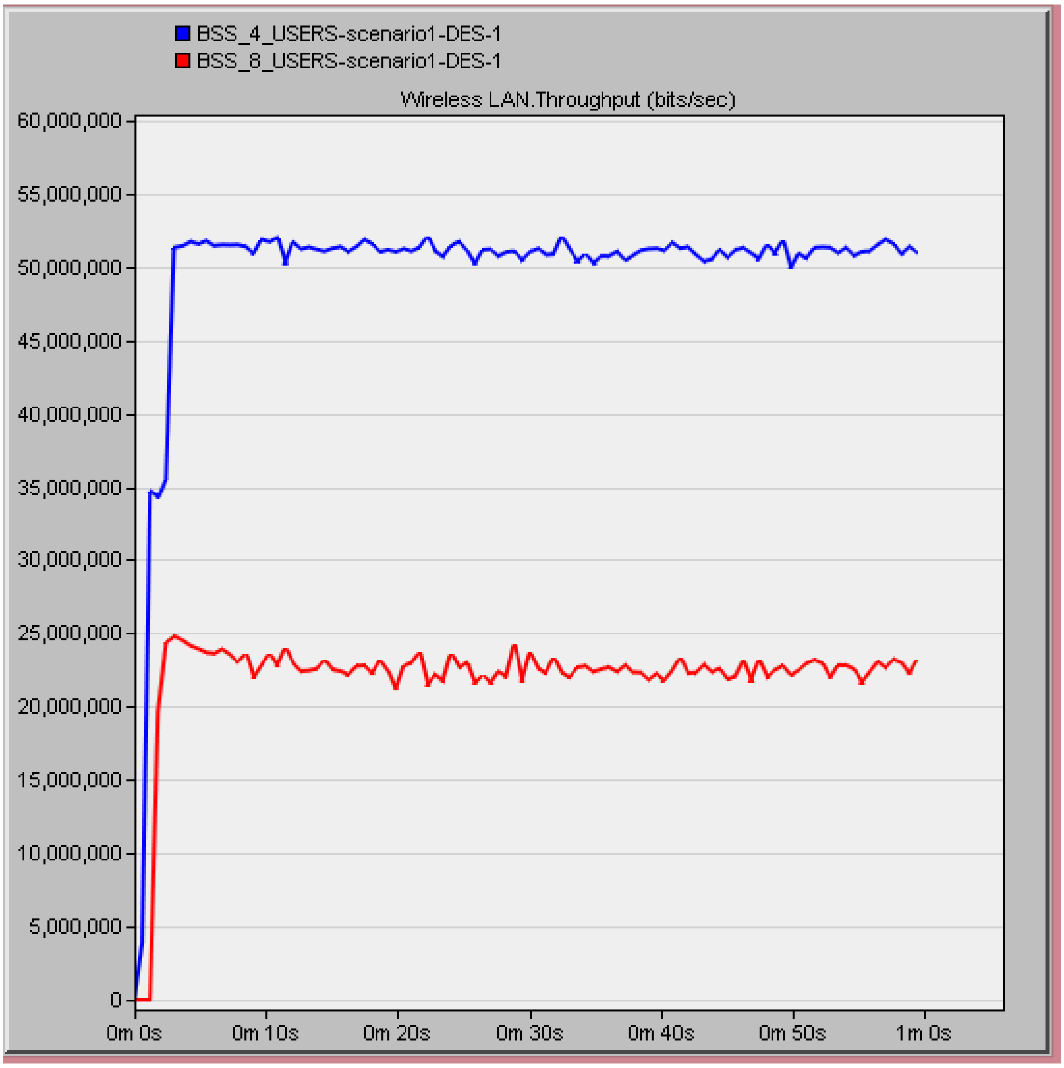

Figure 15. Throughput for BSS Case 1.

5.1.2 Scenario 1 Case 1 (WLAN Delay)

The graph in figure 16 shows the WLAN delay at varied number of users, the blue graph represents four users. The red graph represents eight users, if the end of both graphs are traced to vertical axis, it can be seen that the delay for four users is approximately 0.0075s while that of eight users is approximately 0.023s. The result shows that a higher number of users experienced more delay which eventually has an impact on the network as it throughput was also reduced to almost half than that of lower number of users.

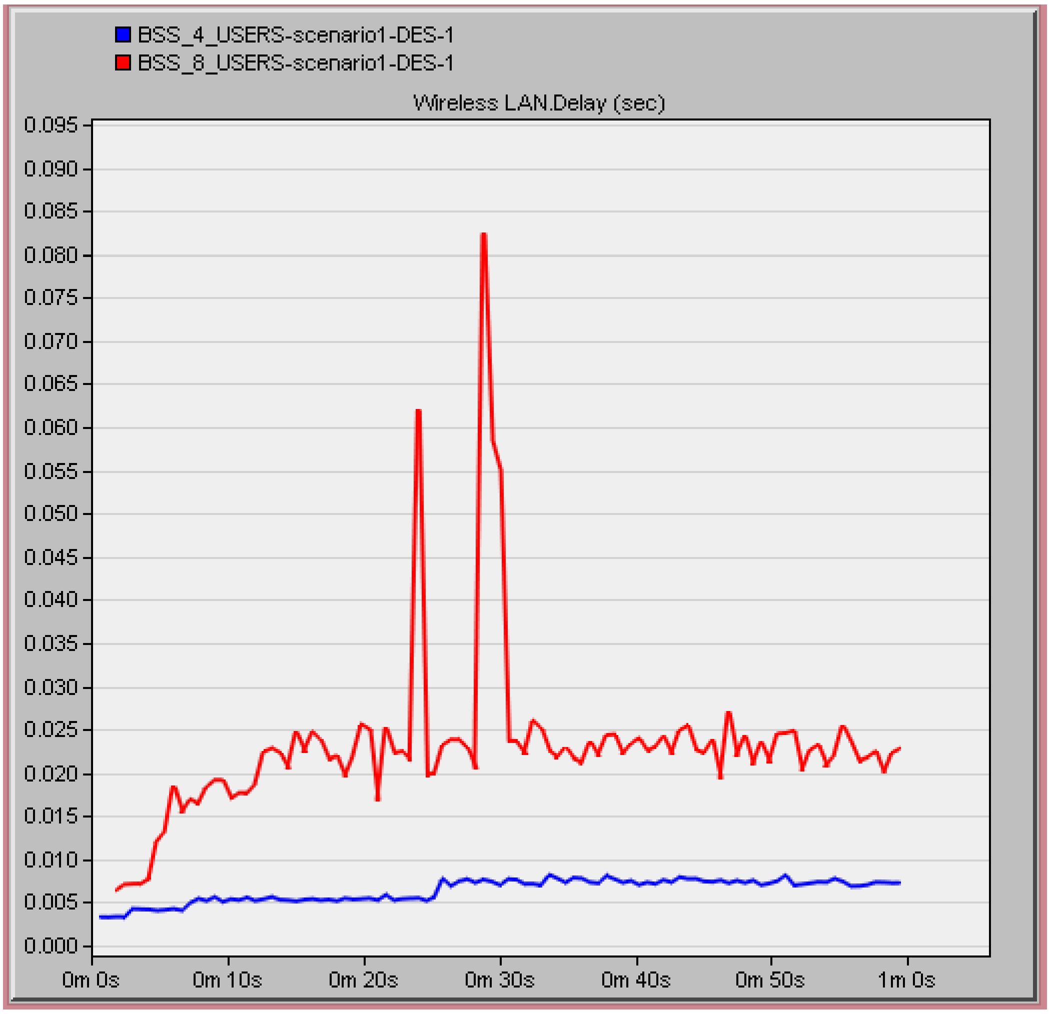

Figure 16. WLAN delay for BSS Case 1

5.2 Result and Analysis for Scenario 1 Case 2 (BSS)

In this case the data rate is changed while maintaining same number of users. The graph in figure 17 and figure 18 shows the WLAN throughput and WLAN delay obtained respectively.

5.2.1 Scenario 1 Case 2 (WLAN Throughput)

As it can be seen from the graph in figure 17 below, the blue graph represents data rate at 13 Mbps while the red graph represents data rate at 65 Mbps. If the end of both red and blue graphs is traced to the vertical axis it can be seen that at 13 Mbps the throughput is approximately 12 Mbps while at 65 Mbps the throughput equals 51 Mbps. The graph of data rate at 65 Mbps rises sharply above that of data rate at 13 Mbps. This means that at a lower data rate for a BSS network, the throughput is reduced

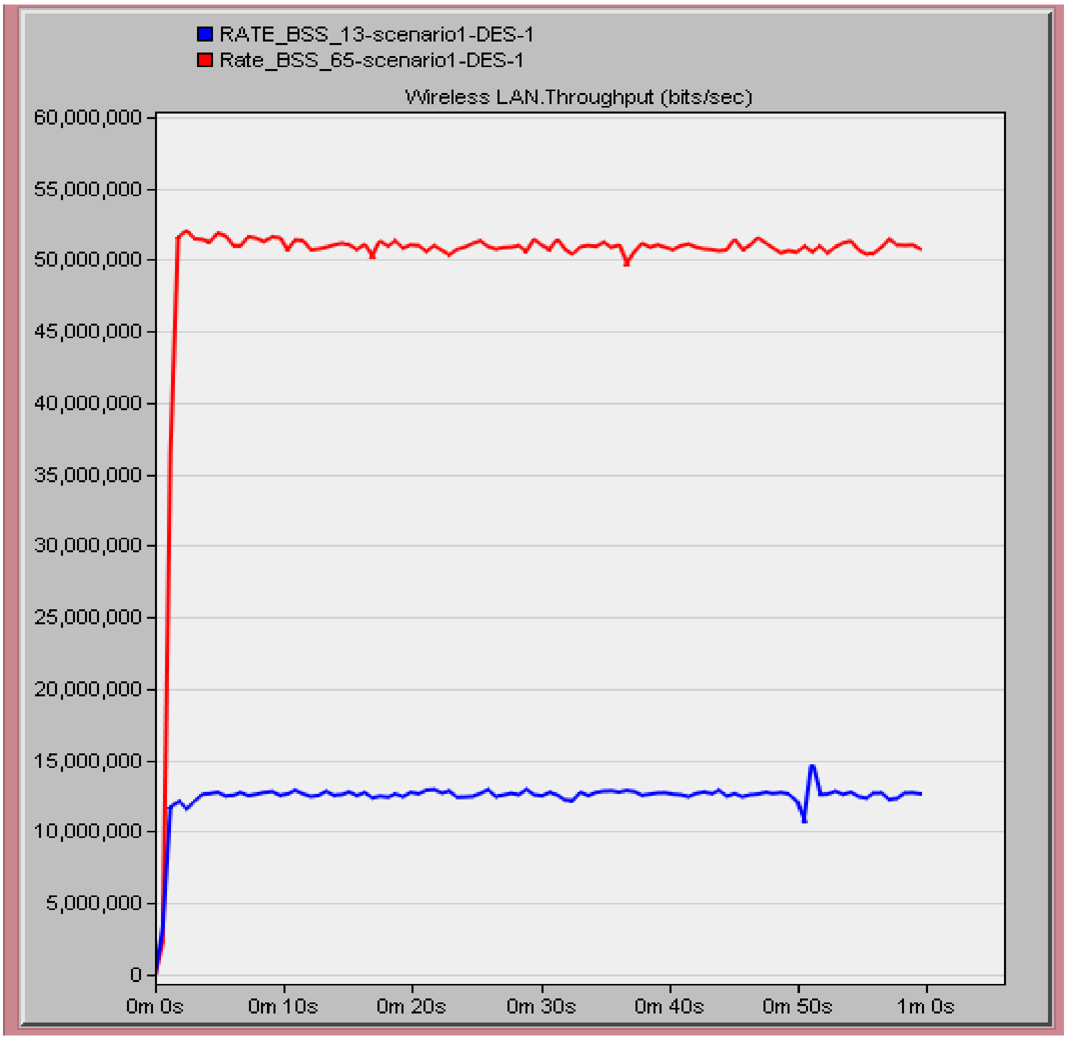

Figure 17. WLAN Throughput for BSS Case 2

5.2.2 Scenario 1 Case 2 (WLAN Delay)

From the graph in figure 18 below, it can be seen that the lower data rate i.e. the blue graph has delay of approximately 0.046 while the higher data rate has a delay of approximately 0.007. This shows the lower data rate the lower the rate at which bits are transferred; hence leading to more delay in the network which eventually affect the throughput.

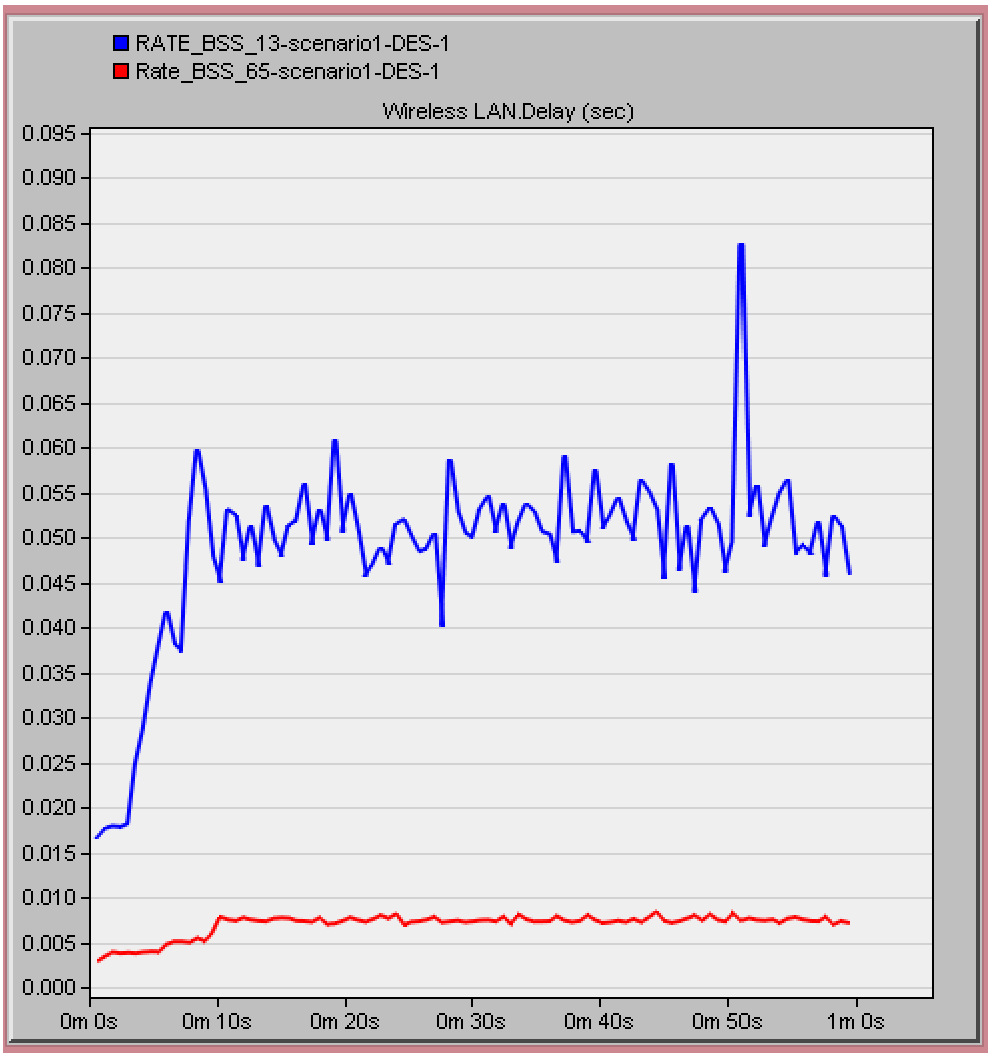

Figure 18. WLAN delay for BSS Case 2

5.3 Results for Scenario 1

Table 5 and 6 below show the results obtained for both case one and case two for BSS.

Table 5. Result for case1 BSS

Parameters	4 users	8 users
Throughput (Mbps)	51	23
WLAN Delay (sec)	0.0075	0.023

Table 6. Result for case2 BSS

Parameters	13 Mbps	65 Mbps
Throughput (Mbps)	12	51
WLAN Delay (sec)	0.046	0.007

5.4 Analysis and Results for Scenario 2 Infrastructure Mode (ESS)

After the simulation, the graphs in figure 19 and figure 20 below were obtained for throughput and delay for variations in number of users, i.e. case 1 scenario 2

5.4.1 Scenario 2 Case 1 (WLAN Throughput)

From the graph in figure 19 (below), by tracing both the red and blue graphs to vertical axis it can be seen that, at four users the throughput equals 45 Mbps. As the number of users is increased to eight from four, the throughput dropped to 37 Mbps, this signifies that as more users were on the network its throughput reduced. It can also be seen that both graphs rise rapidly before becoming stable.

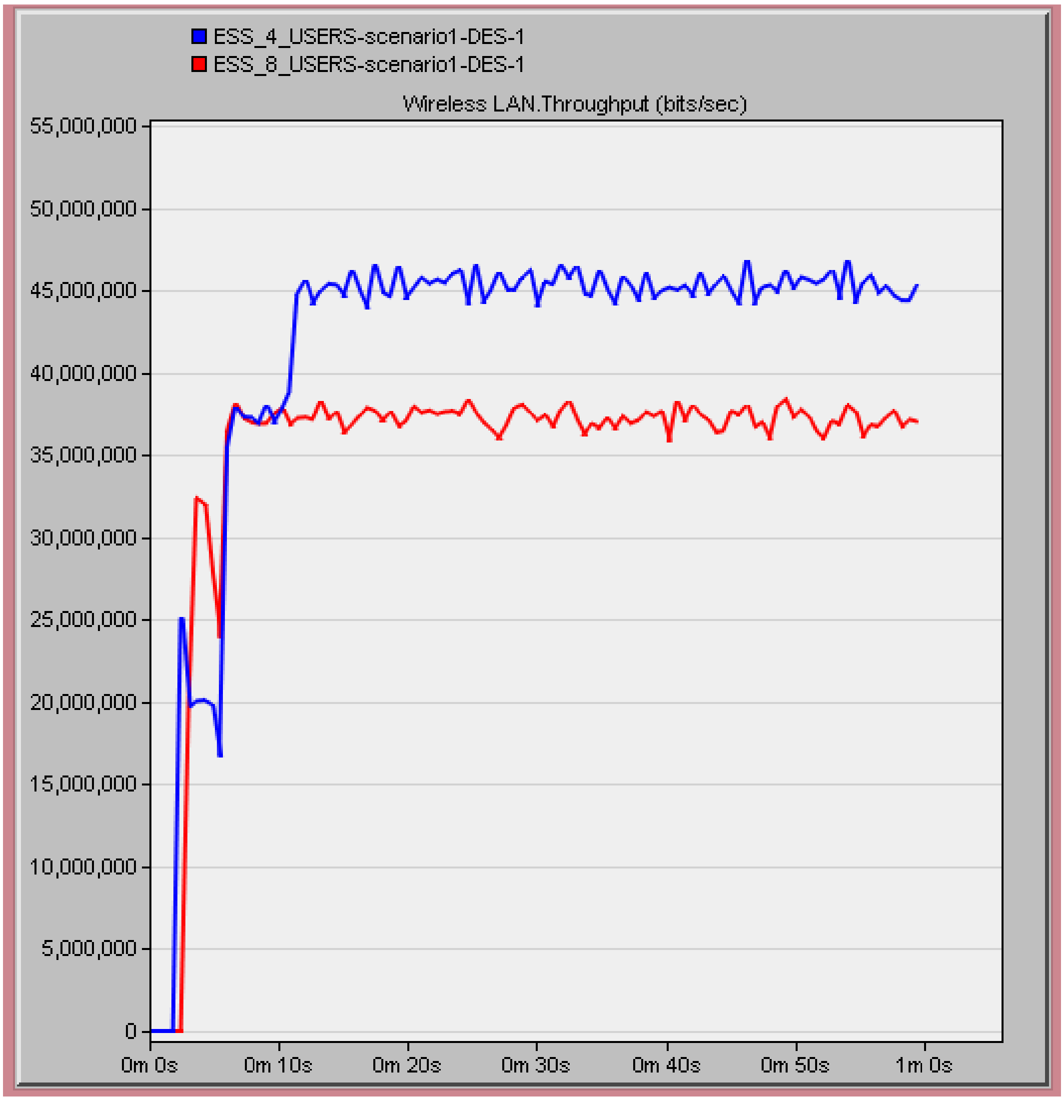

Figure19. WLAN Throughput for ESS Case 1

5.4.2 Scenario 2 Case 1 (WLAN Delay)

The WLAN delay graph as shown in figure 20 (below) shows that at four users, the delay for ESS is 0.0054. When the number of users is increased from four to eight, the delay rises to 0.014. It shows that as more users descend on the network, the delay experience also increases.

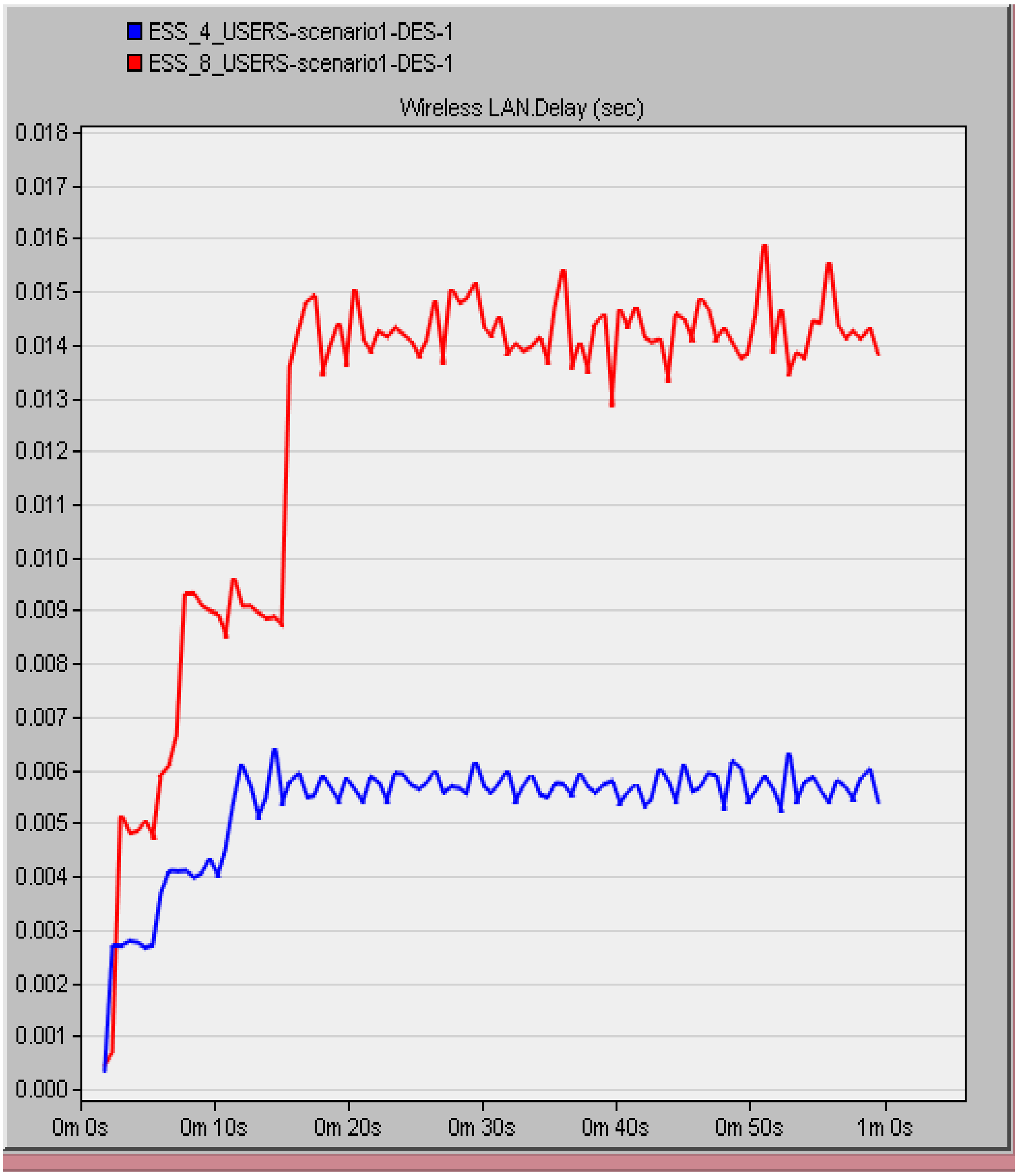

Figure20. WLAN Delay for ESS Case 1

5.5 Result and Analysis for Scenario 2 Case 2 (ESS)

5.5.1 Scenario 2 Case 2 (WLAN Throughput)

Figure 21 (below) shows the throughput graph obtained at varied data rate, tracing both blue and red graphs to the vertical axis. At 65 Mbps of data rate, the throughput obtained equals 35 Mbps and as the data rate drops to 13 Mbps, the throughput also drops to 12,5 Mbps. At higher data rates, the graph rises rapidly above the lower data rates graph before becoming stable.

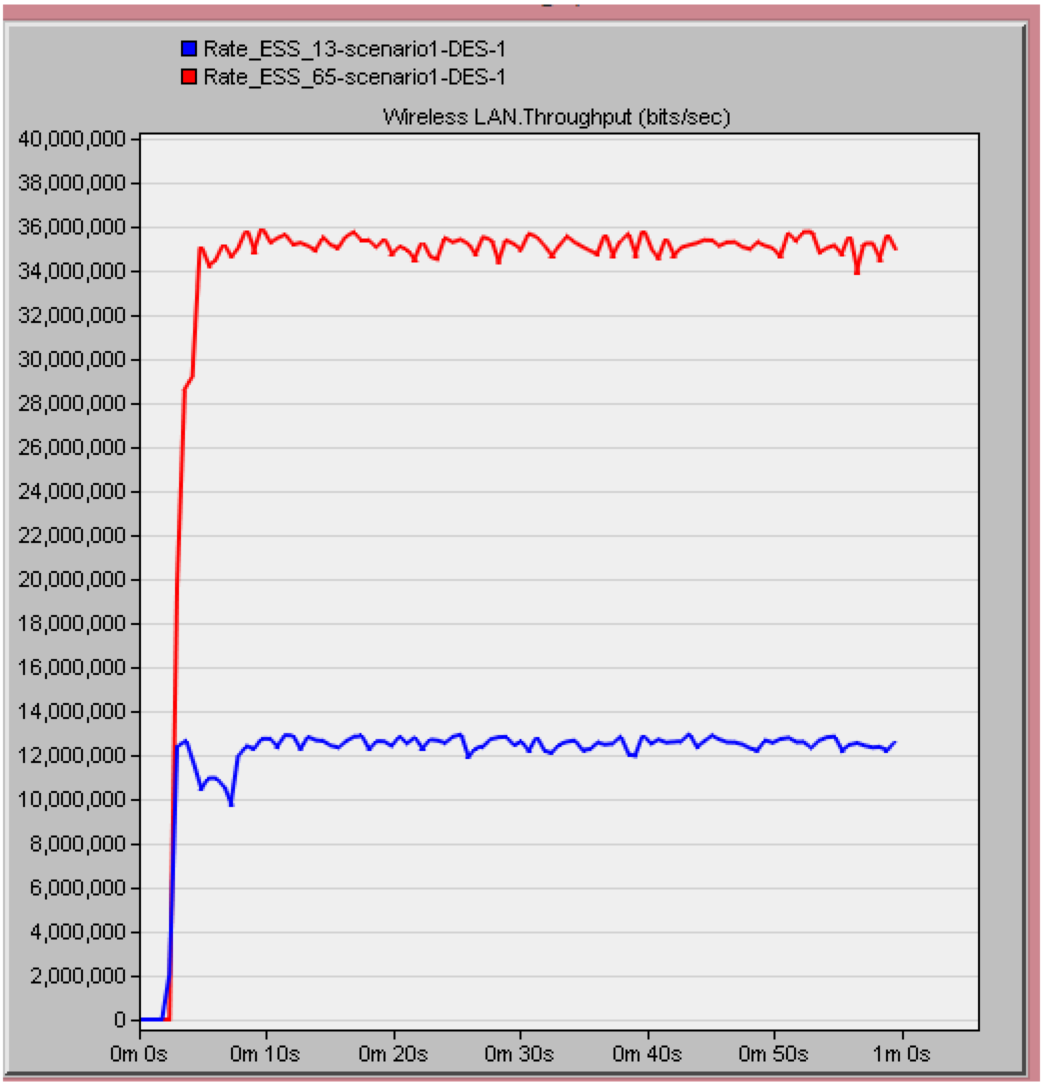

Figure21. WLAN Throughput for ESS Case 2

5.5.2 Scenario 2 Case 2 (WLAN)Delay

Observing the graph in figure 22 below, the delay obtained at 65 Mbps equals 0.0035, while that obtained at 13 Mbps equals 0.025. The result shows that for an ESS network, when data rate is high, data will be transferred at high speed, hence experiencing a low delay.

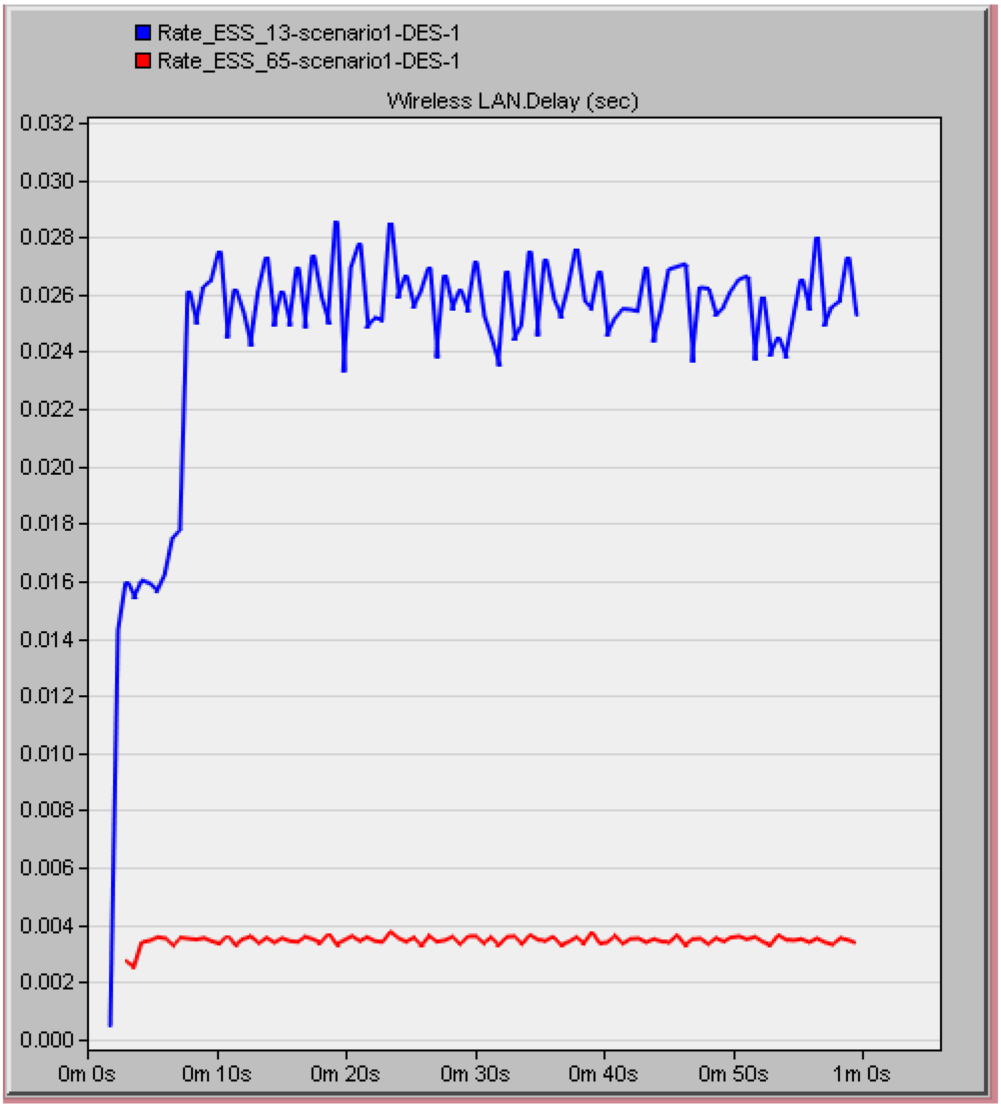

Figure22. WLAN Delay for ESS Case 2

5.6 Results for Scenario 2

Table 7 and 8 below show the results obtained for both case one and case two for scenario 2 (ESS).

Table 7. Result for case1 ESS

Parameters	4 users	8 users
Throughput (Mbps)	45	37
WLAN Delay (sec)	0.0054	0.014

Table 8. Result for case2 ESS

Parameters	13 Mbps	65 Mbps
Throughput (Mbps)	12.5	35
WLAN Delay (sec)	0.025	0.0035

6 CONCLUSIONS

In this thesis work the performances of two types of WLAN topologies, BSS and ESS, have been evaluated based on performance metrics, throughput and delay. We have investigated how these two types of WLAN topologies respond to an application that requires timely packet and data delivery with sufficient bandwidth. From the results obtained after the simulation, it was shown that at different scenarios the performance metric changes.

Ad hoc network was dropped from implementation as its throughput is too low to be implemented. According to Dr. Jarmo Prokkola of Converging Networks Laboratory, IEEE 802.11 is not a very good protocol for ad hoc networks.

It can, therefore, be concluded that as the number of users increases, the throughput is reduced in both BSS and ESS. As the number of users increases, there is an increase in delay for both BSS and ESS. When the data rate is increased in both BSS and ESS, there is an increase in throughput as data are delivered more precisely and at a faster rate.

When the number of users doubles, the throughput in BSS dropped by approximately 50% while at the same in ESS, its throughput only dropped by approximately 15%. The lowest value of delay experience is for ESS at 65 Mbps data rate. The general throughput of BSS is encouraging at four users, but gradually loses its QoS as the number of users increases.

It can now be concluded that ESS would be suitable for a large network with more users and that ESS has also managed to maintain its QoS.

6.1 Future Work

Future work for this thesis work would be to investigate how both BSS and ESS respond when implemented with mobile trajectory, in such a way that the mobile nodes can move at a defined speed and along a defined trajectory path while the performance metrics are measured.

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