Journal, Advances in Mathematical & Computational Sciences
Vol. 8 No. 3, September, 2020
www.mathematics-computationaljournal.info

Journal of Advances in Mathematical & Computational Sciences
An International Pan-African Multidisciplinary Journal of the SMART Research Group
International Centre for IT & Development (ICITD)
Southern University Baton Rouge, LA, USA

https://www.isteams.net/socialinformaticsjournal
DOI: dx.doi.org/10.22624/AIMS/MATHS/ V8N3P3
CrossREF Member Listing - https://www.crossref.org/06members/50go-live.html

A Trio Model for Network Performance Evaluation

Nzadon, D.T[1], Adeyemo, O. A.[2] & Aweh, O. M.[3]
[1, 2,3] Department of Mathematical and Physical Sciences (Computer Science programme)
College of Sciences
Afe Babalola University
Ado-Ekiti, Ekiti State, Nigeria.
E-mail: befittingcrown@gmail.com

ABSTRACT

Performance evaluation is used in computer network communication as a means of assessing the performance of computer networks. Increase in large networks increases routed traffic and reduces the stability of the network. Other factors that lead to the degradation of service performance in networks are network congestion, link failures, and routing instabilities. Literature also has it that most of these disruptions occur during routing changes and a few hundred milliseconds of disruption are enough to cause a disturbance in voice and video. To effectively and efficiently distribute data, the choice of routing protocol becomes a very critical factor in determining the performance of a network over time. This study through an online survey, determined some of the most popular protocols currently being deployed such as the Routing Information Protocol (RIP), the Enhanced Interior Gateway Routing Protocol (EIGRP) and the Open Shortest Path First (OSPF) and standard metrics (throughput, jitter and latency). The Optimized Network Engineering Tool (OPNET) simulation environment was utilized for this study. The study tested the model by varying the traffic of real time applications such as video streaming, electronic mail, database application, Remote Login application, Hypertext Transfer Protocol (HTTP), File Transfer Protocol (FTP), email application and voice conferencing. The evaluation was based on the network topology employed by the Integrated Services Unit of the Afe Babalola University as well as the external communication links and nodes. The study concluded that OSPF is better suited for high load Networks, while RIP is better suited for low load networks. Consequently, EIGRP generally performed well for both low and high load networks and should be used as an effective tradeoff between the two other routing protocols.

Keywords: OPNET, RIP, Protocols, Trio Model, Network, Performance, Evaluation.

Nzadon, D.T., Adeyemo, O. A.. & Aweh, O. M. (2020): A Trio Model for Network Performance Evaluation. Journal of Advances in Mathematical & Computational Sc. Vol.8, No. 3. Pp 23-36. DOI: dx.doi.org/10.22624/AIMS/MATHS/V8N3P3.
Available online at www.isteams.net/mathematics-computationaljournal.

1. INTRODUCTION

A computer network is a set of devices (often referred to as nodes) connected by communication links. A node can be a printer, a computer, or any other device capable of sending and/or receiving data generated by other nodes on the network (Marsic, 2013). The best-known computer network is the Internet. Computer networks differ in the physical media used to transmit their signals, the communications protocols to organize network traffic, the network's size, topology and organizational intent. (Ahlawat & Anshul, 2014). Computer networks are expected to attain some level of performance and generally, performance is the ability of a network element (e.g., an application, a host or a router) to provide some level of assurance for consistent network data delivery. However, some applications are more stringent about their performance requirements than other applications. There are three typical techniques for measuring computer systems performance. These are measurement, analytical and simulation methods. A metric is defined as a value utilized by a routing protocols to allocate a cost for reaching the destination and it determines the best path in case of multiple paths to the same destination (Michel, 2003). It is therefore imperative that the appropriate routing protocol is chosen in order to ensure optimal network performance.

2. LITERATURE REVIEW

In a study by Manju (2010) conducted on a hybrid network that consisted of both LANs and WANs, the study used OPNET to implement two scenarios. The first scenario was a hybrid network with RIP Routing protocol, while the second scenario was a hybrid network with RIP and IGRP Routing Protocols. The study implemented HTTP and FTP applications to run on light load for both scenarios, and also focused on the FTP statistics in the Hybrid Network, and the impacts of factors such as download and upload response time, ATM Cell delay and Remote Login Response time were recorded. The investigations reveal that a Network having RIP & IGRP routing protocols is useful to increase the FTP download/Upload Response time.

In a similar study by Vasudha (2013) that evaluated the performance of Wireless and Wired computer networks with a combination of the conventional model of RIP and OSPF Routing protocols, the study used OPNET to evaluate performance parameters such as wireless LAN media access delay and throughput by varying conventional and the integrated proposed protocol. The investigations were analyzed through parameters like analysis of HTTP traffic sent and received, Client HTTP page, Object response time and Server HTTP task processing time. From the obtained results, the study gathered that there is a significant improvement in Server HTTP task proceeding time with the same server HTTP load. Similarly, the performance is observed to be better for combined RIP and OSPF dynamic routings protocol with significant change in client HTTP page and object response time, which has been reduced by the order of 2sec.

Nwankwo and G (2012) focused on the principles governing information exchange between nodes in a network and optimization of a data network using the right routing protocol. The study used throughput, reliability, IP traffic dropped, bandwidth and delay (cost) along links as the quantitative evaluation metrics. The study used OPNET to implement six different simulation scenarios and analysed three different traffic loads. The first three scenarios correspond to the simulations under the adaptive routing strategy (OSPF) while the other three scenarios correspond to the simulations under the conventional routing strategy (RIP).

The results of the study showed that the OSPF scenario provided better network throughput than the RIP scenario. Similarly, the study also showed that the OSPF scenario presented smaller transfer delays than the RIP scenario. Alex *et al*. (2013) theoretically compared the IPv4 and Ipv6 of popular routing protocols OSPF and EIGRP based on six parameters namely (hardware flexibility, network throughput, scalability into large networks, reducing routing overhead, configuration difficulty and rapid network convergence on topology changes) and identified the changes made to these protocols to incorporate IPv6. They further highlighted and discussed the new features and changes of these protocols, also the strengths and weaknesses of each protocol were also evaluated. The study's comparative analysis shows that EIGRP protocol has the advantage over OSPF in a number of key areas but is held back by its proprietary nature and costs while he OSPF protocol still maintains its popularity despite EIGRPs performance advantages and its complexity to configure. The study also found out that OSPF has advantages in large networks where its hierarchical nature increases scalability and due to the flexibility of the hardware which the protocol can be deployed upon.

In a study by Rana (2013) on Performance Analysis of RIP and OSPF in Network Using OPNET, five scenarios were created (three OSPF and Two RIP scenarios). The RIP scenarios utilized a star topology while the OSPF scenarios utilized a tree topology. The study showed that RIPS and RIPS v2 takes more time in convergence as compared to the OSPF single area and OSPF multi area. Also, at the start the OSPF multi stub area takes more time as compared to RIP due to the link failure utility, but as time passes and RIP network fully converged its convergence time increased. The result also shows that in any network environment convergence time of OSPF single area is greater as compare to OSPF multi area and OSPF multi stub area. Result shows that OSPF takes 13.495 seconds in convergence OSPF multi area and OSPF single area takes 12.683 seconds which approximately .812 seconds which means OSPF single area takes .812 seconds more to converge.

Adhikari (2013) used Cisco packet tracer to make to compare RIP and EIGRP routing protocols. The configuration setup include 2 routers connected to 2 computers via an Ethernet connection. The routers were then assigned IP addresses and RIP routing protocol was configured on one of the routers, while the other was configured with EIGRP. The "show neighbors" and "show IP route" where then used to determine some of the basic differences between the two routing protocols. This study concluded that in order to avoid some of the limitations of RIPv1, RIPv2, which allows Variable Length Subnet Masking (VLSM) and Classless Inter-domain Routing (CIDR) should be used. The study also showed that EIGRP keeps a topology table of the network and uses the DUAL algorithm to select a loop-free path. EIGRP also uses the notions of successor and feasible successor and the query process to achieve fast convergence which makes EIGRP a scalable routing protocol capable of fitting today's network requirements.

2.1 Problem Perspective

Increase in large networks increases routed traffic and reduces the stability of the network (Ahlawat & Anshul, 2014). Other factors that lead to the degradation of service performance in networks are network congestion, link failures, and routing instabilities (Thorenoor, 2010). Literature also has it that most of these disruptions occur during routing changes (Yang, 2000). A few hundred milliseconds of disruption are enough to cause a disturbance in voice and video. A disruption lasting a few seconds is long enough for interrupting web transactions (Catherine & Gianluca, 2008). Hence, during routing convergence data packets are dropped, delayed, and received out-of-order which results in a serious degradation in the network performance (Catherine & Gianluca, 2008). To effectively and efficiently distribute data, the choice of routing protocol becomes a very critical factor in determining the performance of a network over time (Zaumen, 2008). This has heightened the importance of performance evaluation and monitoring of networks. However most of the previous evaluation studies have simulated metrics in isolation.

This has resulted in conclusion that skewed to individual scenarios and contexts. This study will however utilize a trio model (latency, throughput and jitter) in order to produce a more universal evaluation result.

3. METHODOLOGY

This study considered the breakdown of the implementation from creating the project to building the topologies and setting various protocols and simulation parameters. The simulation method of network performance evaluation was adopted in this study. The Optimized Network Engineering Tool (OPNET) 18.0 was utilized as the simulation tool of choice due to the fact that it leverages three different simulation technologies (Network domain, node domain and process domain) to efficiently trade-off simulation detail and speed. OPNET also supports a fast discrete event simulation engine as well as an Integrated Graphical User Interface (GUI) based debugging and analysis. The design flow for the study is given in the algorithmic architecture in Figure 1 below.

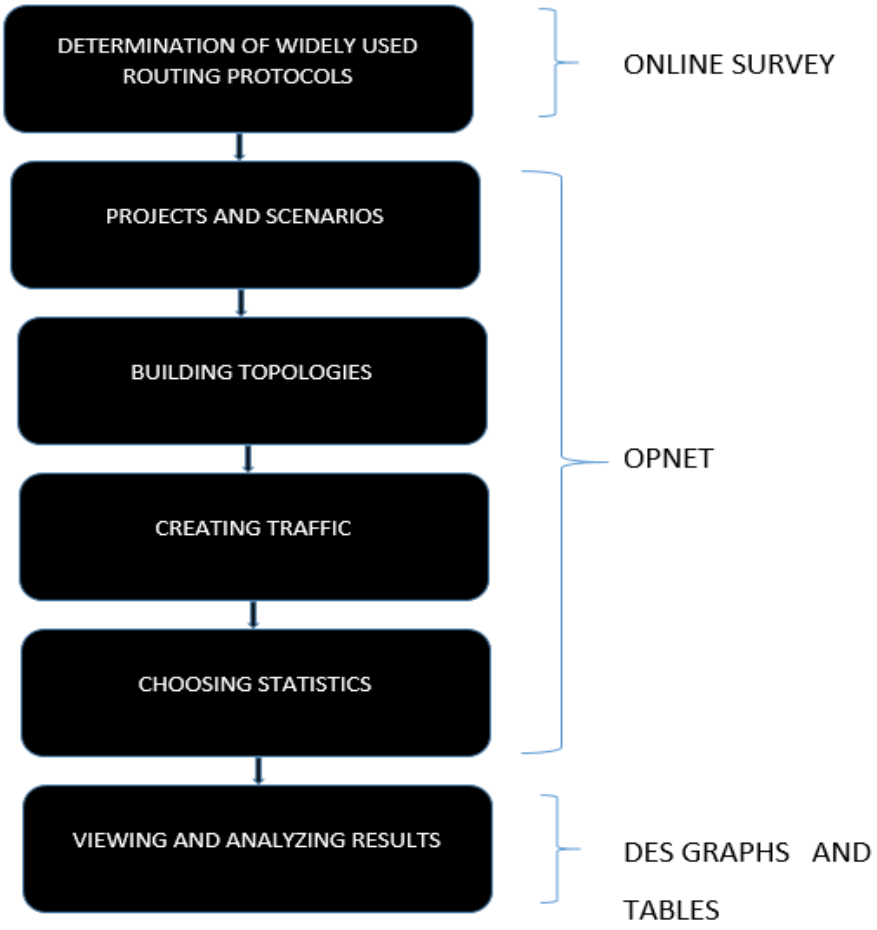

Figure 1: Adapted Architecture for the Study Source:
Source: OPNET Corporation, Slide 377 of "IT Guru Quick Start" (2004)

3.1 Determination of Widely Used Routing Protocols

An online survey was carried out to determine the most widely used routing protocols as well as metrics currently being deployed by enterprise networks in Nigeria. This survey revealed that the Routing Information Protocol (RIP), Open Shortest Path First (OSPF), and the Extended Interior Gateway Routing Protocol (EIGRP) were the most commonly deployed protocols. The survey also revealed throughput, jitter and delay as the most common metrics being employed.

3.2 Building the Topology

The topology utilised in this study mirrored the topology used by the Integrated Services Unit of the Afe Babalola University Ado-Ekiti, Nigeria, a private university, as test bed, as well as the hops (routers) required to get to a Gmail server. This was achieved by running a trace route to the mail server. The results of the trace route is depicted in Figure 2. The following devices and configuration utilities were utilized to setup the network topology for the purpose of this study:

i. Four Ethernet Workstations: used to represent workstations with client/server applications running over TCP/IP and UDP/IP.
ii. Two Ethernnet_16_Switches: Used to connect the Ethernet workstations and Ethernet servers to the Ethernet gateways (routers).
iii. Seven Ethernet Servers: used to support the various user defined applications traffic.
iv. One Sip_ Proxy_Server: Used to support the user defined voice application traffic.
v. Six Ethernet4_Gateways: used as a default gateway to route user application traffic to their destination servers.
vi. One Application Configuration Node: used to specify/select required application as well as generate different types of application traffic, this is a reliable application utility that supports a number of applications such as FTP, HTTP, E-mail, Data Base, Remote Login, Print, ...etc.
vii. One Profile Configuration Node: used to create user profiles. These profiles can be specified by different nodes in a network designed to implement the application traffic.
viii. One Failure Recovery Configuration Node: Used to specify failure events that introduce disturbances in the routing topology, leading to additional intervals of convergence activity.
ix. 100BaseT_LAN: used to represent a fast Ethernet LAN in a switched topology. It contains any number of clients as well as one server.
x. 100BaseT Duplex Link: used to connect the Ethernet Servers to the Ethernet switch, as well as the Ethernet workstations to the Ethernet switch.
xi. IP Cloud: The ip32_cloud node model represents an IP cloud supporting up to 32 serial line interfaces at a selectable data rate through which an IP traffic can be modelled.
xii. PPP_DS1 Duplex Link: Used to connect the gateways (routers) with each other.
xiii. PPP_E1 Duplex Link
xiv. PPP_DS3 Duplex Link

In specifying the applications to be used for this study, the Application definition node was configured to support 8 Rows (Eight applications are to be used in this study namely FTP application, HTTP application, Database application, Remote Login application, Email application, VOIP application, Video Conferencing application and Print application. In specifying the profiles to be used for this study, the Profile configuration node was configured to support 8 rows and each row was named with the following profiles (profile FTP, profile HTTP, profile Database, profile Remote Login, profile Email, profile VOIP, profile Video Conferencing and profile Print).

```
Microsoft Windows [Version 10.0.10240]
(c) 2015 Microsoft Corporation. All rights reserved.

C:\Users\NZADON>tracert gmail.com

Tracing route to gmail.com [216.58.223.197]
over a maximum of 30 hops:

  1    <1 ms    <1 ms    <1 ms  pfSense.localdomain [172.16.0.1]
  2     *       56 ms    62 ms  197.253.4.201
  3    50 ms    62 ms    54 ms  197.253.33.169
  4    72 ms    71 ms    73 ms  154.113.96.1
  5    79 ms     *       66 ms  if-01.NG-CLS-CC-01.ngn.mainonecable.com [41.75.80.61]
  6    71 ms     *       80 ms  if-01.NG-CLS-PE-01.ngn.mainonecable.com [41.75.80.2]
  7    73 ms   106 ms     *     10.0.100.5
  8    82 ms    79 ms    67 ms  72.14.217.212
  9     *       80 ms     *     216.239.57.5
 10     *       68 ms     *     los02s03-in-f5.1e100.net [216.58.223.197]
 11     *       62 ms    66 ms  los02s03-in-f5.1e100.net [216.58.223.197]

Trace complete.

C:\Users\NZADON>
```

Figure 2: Showing Trace Route Results

The above devices and configurations were then used to build the network topology as depicted in Figure 3. This topology was then duplicated for the OSPF, RIP and EIGRP scenarios respectively

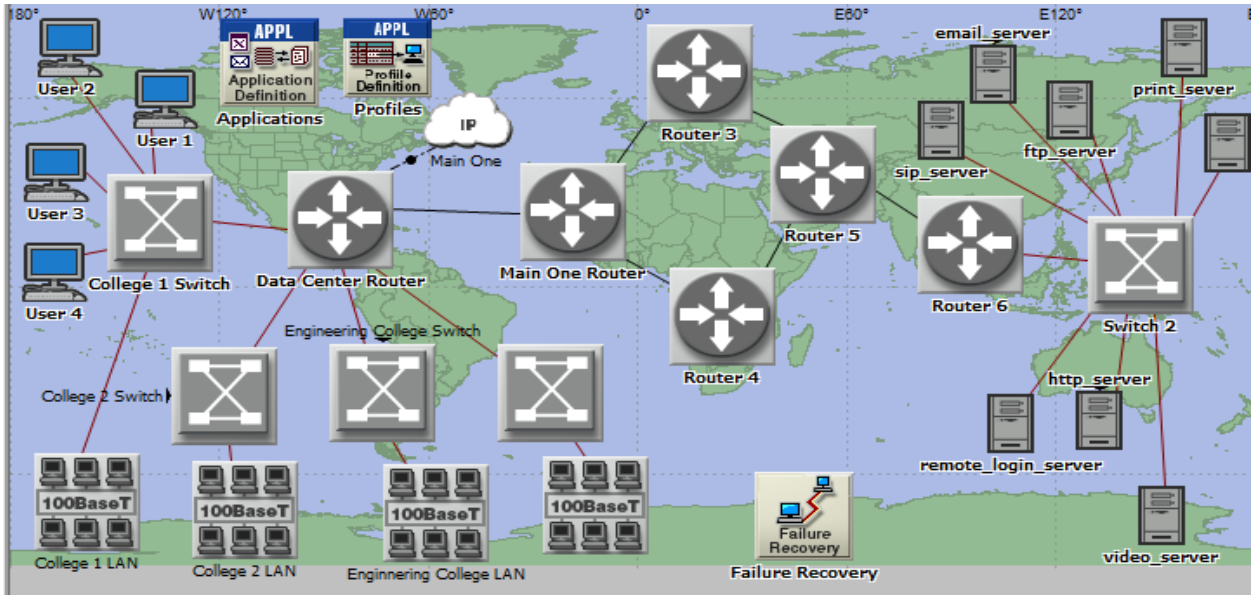

Figure 3: Network Topology Overview

3.3 Creating Traffic

The specifications in Table 1 were used to vary traffic for the various applications used in the OSPF Scenario of the simulation study. These same specifcations will also used for the RIP and EIGRP scenarios.

Table 1: Showing Traffic Values

OSPF	Database	Low Load	1 Hour
	Database	Medium Load	30 minutes
	Database	High Load	15 minutes
	Email	Low Load	1 Hour
	Email	Medium Load	30 minutes
	Email	High Load	15 minutes
	FTP	Low Load	1 Hour
	FTP	Medium Load	30 minutes
	FTP	High Load	15 minutes
	HTTP	Light Browsing	1 hour
	HTTP	Heavy Browsing	45 minutes
	HTTP	Searching	30 minutes
	HTTP	Image Browsing	15 minutes
	HTTP	Video Browsing	5 minutes
	Print	Text File	1 hour
	Print	B/W Images	30 minutes
	Print	Color Prints	15 minutes
	Remote Login	Low Load	1 hour
	Remote Login	Medium Load	30 minutes
	Remote Login	High Load	15 minutes
	Video Conferencing	Loe Resolution Video	1 hour
	Video Conferencing	High Resolution Video	30 minutes
	Video Conferencing	VCR Quality Video	15 minutes

3.4 Choosing Statistics

Two types of statistics were collected from this study, The global statistics which gives Information about the network as a whole (this includes throughput, jitter and delay) and Individual Statistics which gives information on the performance of Individual nodes and devices (Page Response time, dowload response time and traffic sent).

4. DISCUSSION OF FINDINGS

4.1 Throughput

This represents the average number of bits successfully received or transmitted by the receiver or transmitter by channel per unit. The Discrete Event Simulation (DES) graph on Figure 4 shows the delay of RIP, OSPF and EIGRP respectively.

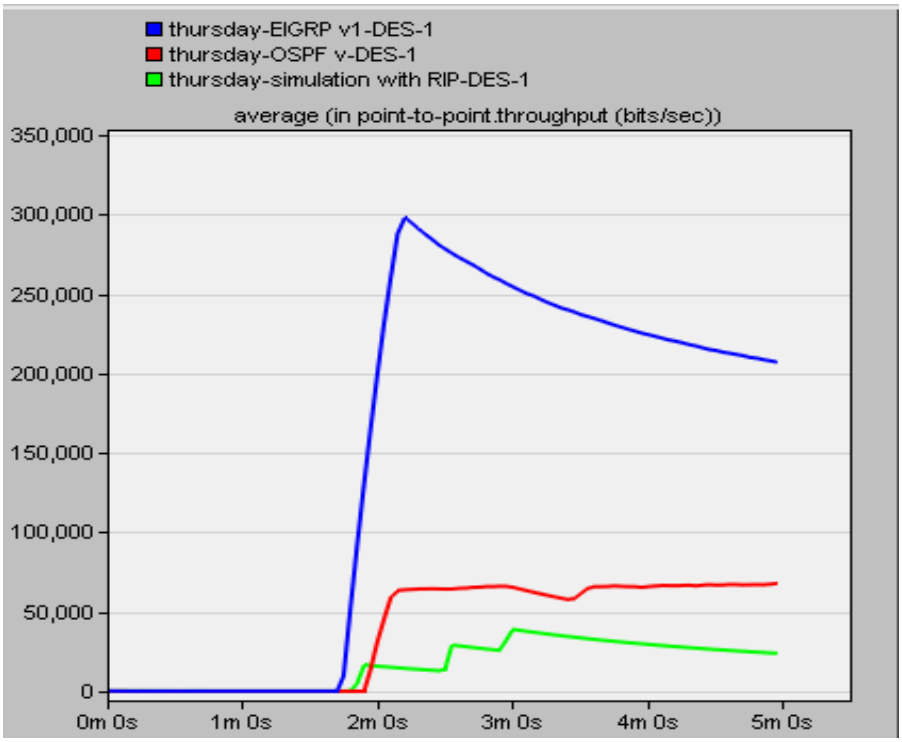

Figure 4: Throughput (bits/sec) at medium load of RIP, OSPF and EIGRP

Overall it can be seen that the OSPF protocol has higher throughput than the other two protocols. This means that the actual number of packets transmitted in bits/sec for networks using the OSPF protocol is quite higher than that of networks using either the RIP or EIGRP protocols.

4.2 Delay (Latency)

This represents the end to end delay of a packet that is sent from any node to another node in the k.network. The Discrete Event Simulation (DES) graph on Figure 5 shows the delay of RIP, OSPF and EIGRP respectively at high load. As can be seen from the graph EIGRP, RIP and OSPF have an identical delay at the onset. RIP has the lowest latency at about the midway point followed by OSPF and EIGRP. Towards the end of the simulation run time, it can be seen that OSPF has the lowest delay followed by RIP and EIGRP. This means that when applications are running on high load RIP and OSPF have a better delay.

However, for slightly higher run times OSPF is the recommended protocol of choice. This implies that for networks that run on low and medium application loads any of the three protocols (RIP, OSPF and EIGRP) can be used, however for networks that run on high loads, OSPF is preferable.

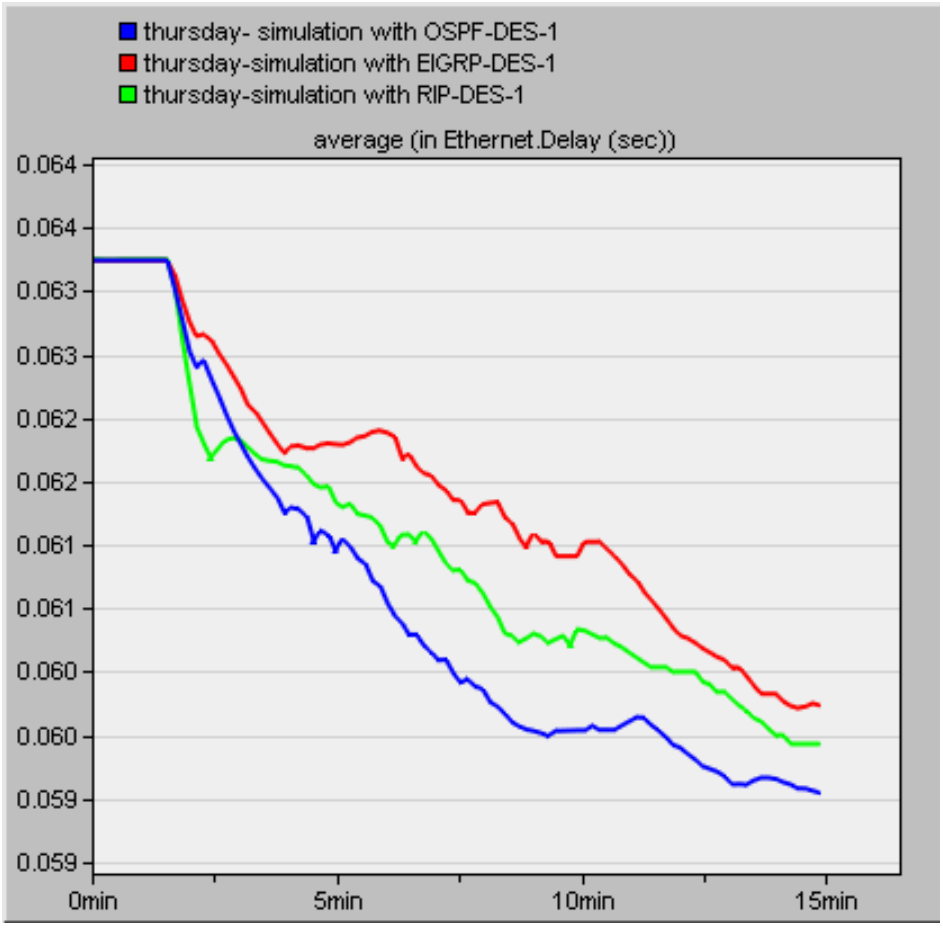

Figure 5: Delay (bits/sec) at high load of RIP, OSPF and EIGRP

4.3 Network Convergence Duration

Convergence time is a measure of how fast a set of routers reaches the state of convergence. It is a potential factor for a group of routers that connect in dynamic routing. When a routing protocol is enabled, routers attempt to exchange information from each other about the topology of the network. If any change occurs in the network that affects routing tables, then routers split the convergence temporarily until this change has been effectively communicated to all other routers. The Discrete Event Simulation (DES) graph on Figure 5 shows the convergence of RIP, OSPF and EIGRP respectively.

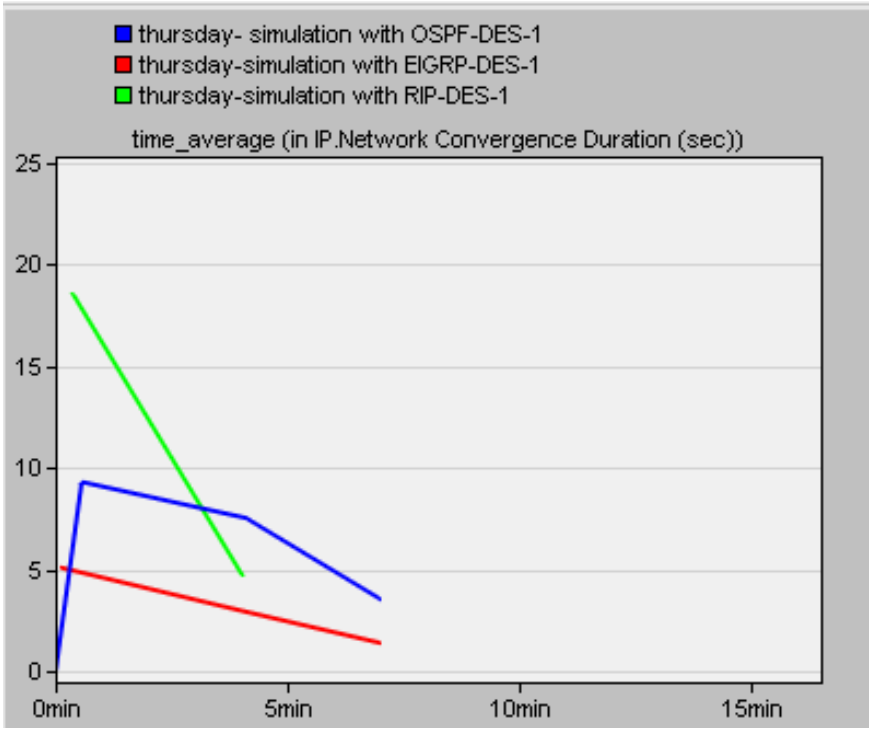

Fig. 6: Convergence Duration (sec) of RIP, OSPF and EIGRP

5.4 Packet Delay Variation (Jitter)

This is the variance among end to end delays for video packets. The Discrete Event Simulation (DES) graph on Figures 5 and 6 shows the jitter of RIP, OSPF and EIGRP respectively. Figure 7 shows the packet delay variation (jitter) of each protocol at Low Resolution Video Quality Load. As can be seen from the graph OSPF has the highest packet delay variation out of the 3 protocols, this is followed by RIP and finally EIGRP. This means that the EIGRP protocol is best suited to networks that use low resolution video quality load as it has the lowest packet delay variation out of the three protocols. A detailed chart showing the performance of the three protocols at various load levels is given in Table 2

Table 2: Comparison Table

PROTOCOL	APPLICATION	METRIC	LOAD LEVEL	RESULTS	RECOMMENDED PROTOCOL
EIGRP/OSPF/RIP		Throughput	Low Medium High		EIGRP EIGRP EIGRP
EIGRP/OSPF/RIP		Delay	Low Medium High		EIGRP/OSPF/RIP EIGRP/OSPF/RIP OSPF
EIGRP/OSPF/RIP		Jitter	Low Medium High		EIGRP OSPF OSPF
EIGRP/OSPF/RIP		Network Convergence			RIP
	Email	Download Response Time			
OSPF RIP EIGRP			Low	1.79 sec 1.83 sec 1.69 sec	EIGRP
			Medium		
OSPF RIP EIGRP				4 sec 2.6 sec 2.5 sec	EIGRP
OSPF RIP EIGRP			High	10 sec 16 sec 12 sec	OSPF
	Email	Upload Response Time			
OSPF RIP EIGRP			Low	2.35 sec 2.41 sec 2.27 sec	EIGRP
			Medium		
OSPF RIP EIGRP				3.1 sec 2.1 sec 2.1 sec	EIGRP/RIP
OSPF RIP EIGRP			High	8 sec 13 sec 20 sec	OSPF

	HTTP	Page Response Time			
OSPF RIP EIGRP			Low	2.165 sec 2.179 sec 2.205 sec	OSPF
OSPF RIP EIGRP			Medium	6.8 sec 5.2 sec 4.2 sec	EIGRP
OSPF RIP EIGRP			High	27 sec 39 sec 18 sec	EIGRP
	Remote Login	Response Time			
OSPF RIP EIGRP			Low	0.66 sec 0.65 sec 0.66 sec	OSPF/RIP/EIGRP
OSPF RIP EIGRP			Medium	0.67 sec 0.69 sec 4.2 sec	OSPF/RIP/EIGRP
OSPF RIP EIGRP			High	7.5 sec 11.5 sec 5.5 sec	EIGRP

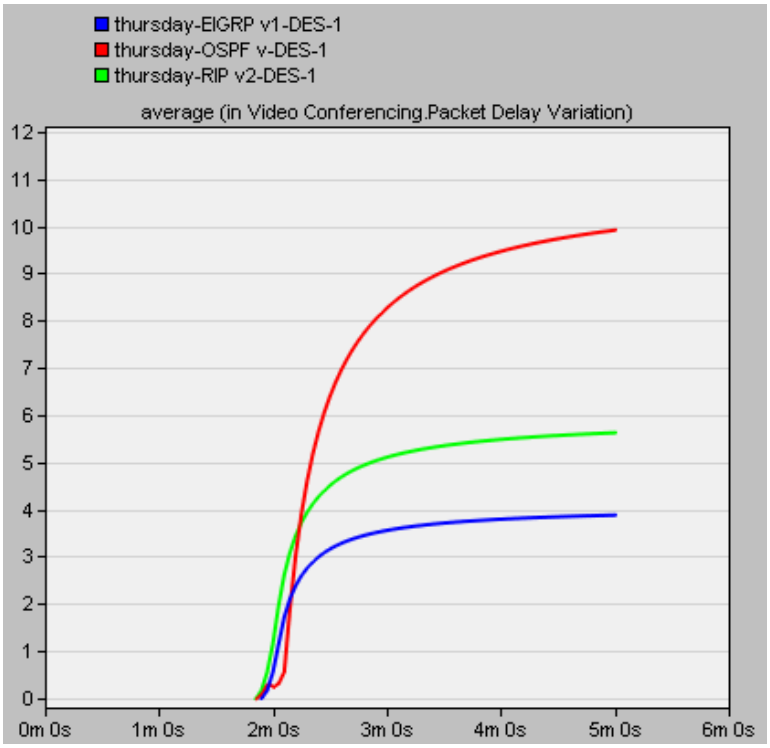

Fig. 7: Jitter at low resolution video quality load of RIP, OSPF and EIGRP

5. CONCLUSION, RECOMMENDATIONS AND FUTURE WORK

5.1 Conclusion

In other to effectively and efficiently distribute data, the choice of routing protocol is a critical factor in determining the performance of networks over time. This has heightened the importance of performance evaluation and monitoring of networks. However most of the previous evaluation studies have simulated metrics in isolation. This has resulted in conclusions that skewed to individual scenarios and contexts. This study used a simulation based approach to compare and analyze the performance of RIP, EIGRP and OSPF based on the quantitative metrics of latency, jitter and throughput for real time applications such as video streaming, electronic mail, database application, Remote Login application, Hypertext Transfer Protocol (HTTP), File Transfer Protocol (FTP) and voice conferencing by using the Optimized Network Engineering Tool (OPNET). In order to evaluate the performance of RIP, EIGRP and OSPF, a network topology was designed based on the topology that is employed by the Integrated Services Unit of the Afe Babalola University. Three network scenarios were also designed and configured with RIP, EIGRP and OSPF protocols, respectively and varying degrees on network traffic was propagated. The evaluation results show that OSPF is better suited to high load Networks, while RIP is better suited to low load networks. EIGRP generally performed well for both low and high load networks and should be used as an effective tradeoff between the two other routing protocols.

5.2 Recommendations

The following recommendations are made based on the results obtained in this study:

- The Integrated Services Unit of the University should utilize the OSPF protocol for the course registration portal as well as the HTTP server as they deal with high traffic.
- RIP should be utilized for the results portal as it deals with be used for low traffic load.
- EIGRP should be used as an effective trade-off between RIP and OSPF

5.3 Suggestions for Further Studies

In the future, a research study can be done on performance evaluation by employing more than one simulator and comparing the results in other to get a more universal outlook. In the same vein, emulation and measurement tools can also be employed.

REFERENCES

Adhikari, J. P. (2013). Performance Analysis of Protocols RIP & EIGRP. *International Journal of Innovative Technology and Exploring Engineering, 2*(5), 2-6.

Ahlawat, S., & Anshul, A. (2014). An Introduction to Computer Networking. *Internation Jounal of Computer Science and Information Technology, 2*(2).

Catherine, B., & Gianluca, L. (2008). Impact of Link Failures In VoIP Performance. *Proceedings of NOSSDAV Workshop* (pp. 2-3). Florida, U.S.A: ACM Press.

Manju, S. (2010). Design and Implement the Hybrid Network for differnt IP Routing Protocols and Comparative Study Thereof . *Information Assurance and Security Letters , 35*(4), 1-8.

Marsic, I. (2013). *Computer Networks: Performance and Quality of Service.* New Jersey: Rutgers University Press.

Michel, F. P. (2003). *Computer Systems Performance Evaluation and Prediction.* San Fransico: Digital Press.

Nwankwo, O., & G, N. (2012). Evaluation And Implementation Of The Open Shortest Path First (OSPF) Routing Protocol. *International Journal of Emerging Technology and Advanced Engineering, 2*(12), 2-6.

Thorenoor, S. (2010). Routing Protocol Implementation Decision between EIGRP, OSPF and RIP Based on Technical Background Using OPNET Modeler. *Second International Conference on Computer and Network Technology.* Bangkok, Thailand: IEEE.

Vasudha, B. (2013). Performance Issues and evaluation considerations of web traffic for RIP and OSPF dynamic routing protocols for hybrid network using OPNET. *International Journal of Advanced Research in Computer Science and Software Engineering., 2*(9), 3-6.

Zaumen, G.-L.-A. J. (2008). Area Based loop free Internet Routing. *The Conference on Computer Communication.* Toronto, Canada: IEEE.