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Evaluation of a Hybrid Network Using OPNET Simulator

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Abstract— In a hybrid network, the transmission of data relies on the routing protocol that selects the most effective routes between any two or more nodes. The differing types of routing protocols which are wired and wireless are applied to the specific network environment. This project work is titled evaluation of hybrid network using OPNET. The OPNET 14.5 was employed to implement the network systems using design algorithmic architecture and the network was simulated with different parameters before the evaluation and analysis of results obtained. The three scenarios each with one routing protocol (OSPF, EIGRP, and AODV) was simulated and Evaluation of these routing protocols is performed based on the quantitative metrics such as Convergence time, Ethernet delay, CPU utilization, Point-to-Point network throughput, and Packet dropped (Loss), HTTP (web) page response, FTP upload response, E-mail download response, and Voice end-to-end delay through the simulated network models. The results of each simulated scenario were captured in a DES graph and also with the corresponding table of the results. For convergence duration and activity of the three protocols (AODV, OSPF & EIGRP), it was found that EIGRP has the fastest routing protocol than OSPF. In case of the network delay, the results show that the EIGRP has less latency compared to OSPF which has little high latency. According to the CPU utilization, the results found that the CPU usage in the network is falling between 11% - 12%. Also, a network throughput result for a selected object was shown the actual amount of traffic flow (packet/sec) and lastly, IP packet drop (loss) in EIGRP is less than for that in OSPF. Using the applications like HTTP, FTP, E-mail, and Voice in the network, the EIGRP is recommended in wired transmission while AODV in wireless transmission of the hybrid network.

Keywords— Network Convergence, Open Shortest Path, Enhanced Interior Gateway Routing Protocol, Ad-hoc On Demand Distance Vector, Nodes, OPNET simulator.

INTRODUCTION

As enterprise network technology continues to evolve, the necessity for businesses to effectively manage and optimize the performance of their networks has increasingly become more vital to business success [1]. Over the years, the increase in networks has resulted in a lot of issues [2]. A lot of users and devices connect to networks more than ever before [3]. Additionally, there are increased demands upon networks enterprises, reports show bandwidth usage has been growing at a steady rate, and consultants expect bandwidth usage to extend at an [1] even faster rate due to developments like Software Defined Networks

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(SDNs), public and private cloud, and gigabit Ethernet [2]. Networks with large traffic flowing through them have also led to increased security problems for information technology departments of enterprises. While the factors that have an impact on the performance of networks will change, one factor that will not change is how well networks function, which is the importance of network performance execution [1] Most IT groups hear statements like "The network is slow," "I cannot gain access to the network," or "That application simply won't work on our network - I don't even bother" multiple times per week. These statements square measure all signs of a poor activity network [1].

Forwarding of Internet Protocol (IP) packets is the main purpose of internet routers [4]. The speed by which forwarding decisions are created at each router or "hop" may be a basic limit on the performance of the network. The employment of classless Inter-Domain Routing complicates the operation method, requiring an operation engine to travel wanting a routing table containing variable-length address prefixes to seek out the longest matching prefix for the destination address in each packet header and retrieve the corresponding forwarding information [5]. In superior routers, each port employs a separate longest prefix match (LPM) computer program. Routing protocols use one of two basic strategies to communicate/ propagate routing information:

i. Distance vector routing protocols work by passing copies of their routing tables to their neighbors.
ii. Link State routing protocols work by advertising a listing of neighbors and therefore the network attachment state to their neighbors till all routers have a duplicate of all the lists, routers then run the Shortest Path initial rule to investigate all ways and verify the most effective ways obtainable.

RELATED LITERATURE

In a study titled Performance Evaluation of Hybrid Network, Using EIGRP & OSPF for Different Applications, [7] investigates campus environment Hybrid Network. The study examined the performance of a Hybrid Network using OSPF & EIGRP routing Protocols with different applications like Email, Client Print, WLAN throughput, and many more. Two protocols OSPF & EIGRP were selected for both scenarios & browsing behaviours for an email application and used this model in a simulation study addressing the performance of the Hybrid network. The study concentrated on the Email & WLAN statistics in the Hybrid Network, and the impacts of factors such as Email Download Response Time, WLAN Throughput, and Remote Login Response time have been seen. The investigations reveal that Networks deploying OSPF routing protocols is useful to improve the Email Download Response time. Thus, it is evident that the use of OSPF is suggested for downloading processes. The results also reveal that in the case of Remote Login response time, performance is better with the OSPF routing protocol. The observed results indicate that Email download response time with EIGRP is recorded from 1.47ms to 29.39ms with OSPF being recorded between 1.27ms & 29.34ms. The results disclose that in the case of Remote Login response time, performance is a better OSPF routing protocol. It has also been observed that there is a minimal decrease in general throughput of WLAN with EIGRP and is of the order of 956.12 bits/sec with RIP networks [7] & 1738.12 bits/sec with

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OSPF from the above investigation we conclude that the overall performance is better with OSPF routing protocol networks.

Authors [8] in a study titled 'Comparative Analysis of Protocol RIP, OSPF, RIGRP and IGRP for Service Video Conferencing, E-mail, FTP, and HTTP". The authors analyzed the available routing protocols: RIP, OSPF, IGRP, and EIGRP for, packets delay variation, packets end-to-end delay, download response time, upload response time, page response time and object response time, convergence, and queuing delay, the simulator was run under Best Effort method by varying the simulation time with the observed parameters. The study was based on OPNET simulation of a real scenario for each of these parameters considered in three instances of failure link. The study presents a comprehensive result for each protocol using the parameters above. The study concluded that EIGRP is the best choice for Video Conferencing, FTP, E-mail, and HTTP, as well as convergence. The study also recommends the EIGRP routing protocol to deploy in small to medium-sized networks.

RESEARCH METHODOLOGY

OPNET simulator is constructed on top of a discrete event system (DES) and it simulates the system behavior by modeling every event within the system and processes it through user-defined processes. OPNET is extremely powerful software to simulate the heterogeneous network with numerous protocols. It has many distinct ways of creating topologies. Modeler supports almost all network varieties and technologies. OPNET runs on top of a c compiler and provides a GUI. This study is going to be achieved by following the sequence of systematic steps for evaluating networks as conferred by the OPNET design algorithm diagram Figure 1.

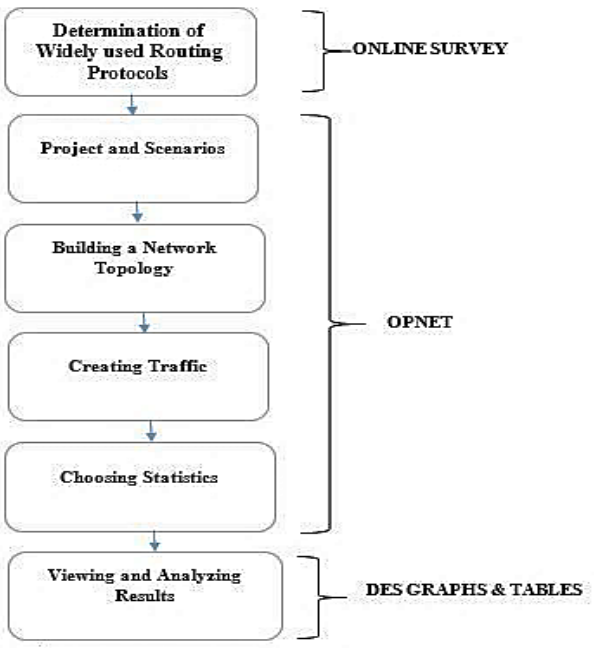

Figure 1: OPNET Design Algorithm

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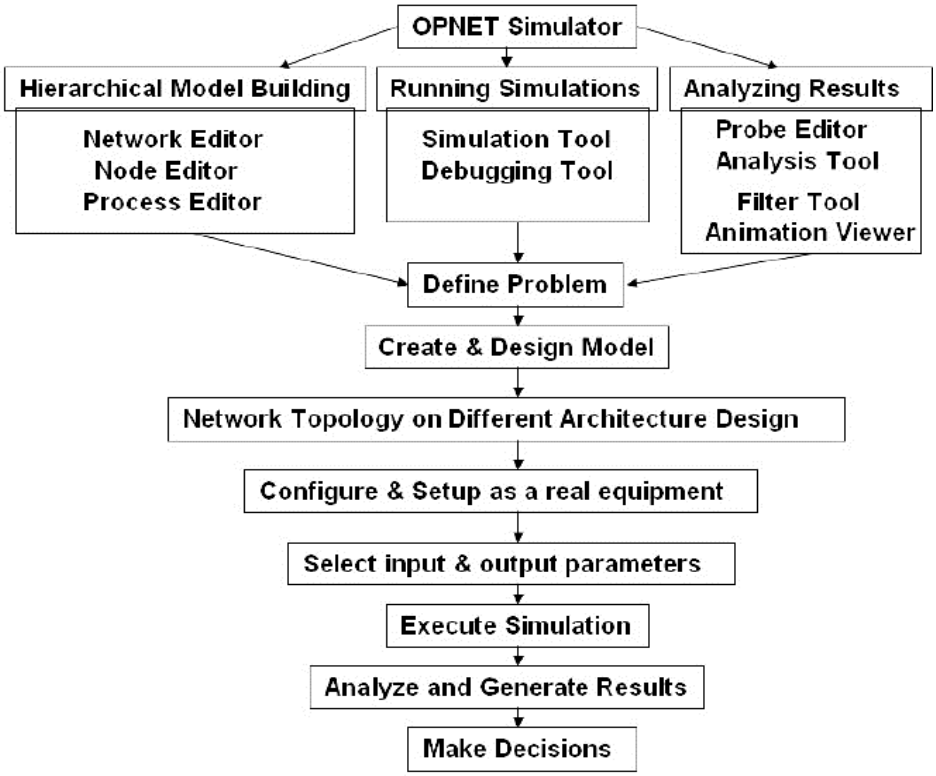

Figure 2: Block diagram of Functionality and Characteristics of OPNET Architecture

BUILDING A NETWORK TOPOLOGY

Network topology of the adopted design of Radio Gotel, Yola was then created in OPNET virtual environment using appropriate parameters through all connected devices. The topology was shown in figure 3 below.

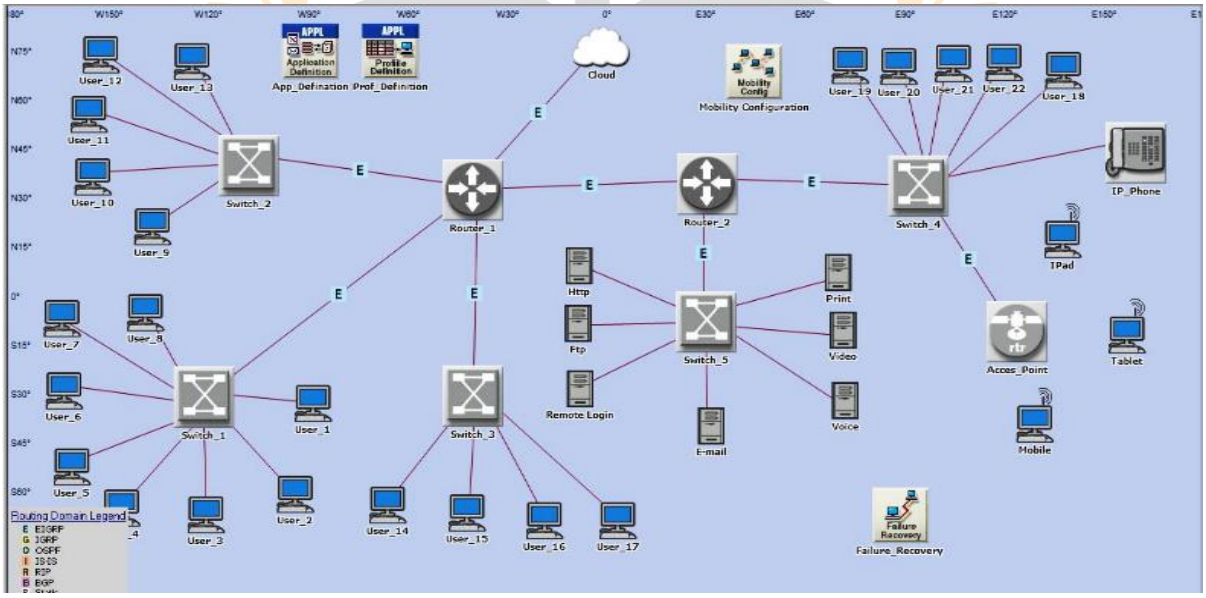

Figure 3: Network Topology overview

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CONFIGURATION AND SET UP IN OPNET SIMULATOR

Two main configurations must be configured in the network scenario:

i. Application Configuration

ii. Profile Configuration

The application configuration is the most important node in the network design. By default, the application configuration has a maximum of sixteen services, which are supported by the OPNET. These are HTTP, FTP, e-mail, print, remote login, video, and voice applications. To configure the application node right-click on the node, select Edit Attributes a dialogue box will open; set the name field value to the application. Expand the Application Definitions rows, select the number of rows (for this scenario is 7), and all the applications names with required settings were implemented. While the profile configuration allows defining a user or a group of users to the application services supported by the network. The profile node can be configured by expanding the profile configuration row. To configure the profile configuration right-click on it, select Edit Attributes a dialogue box will appear. Change the name field value to profiles. Expand the profile configuration row, select edit. During the specification of application definitions to be used for this project work, the Application definition node was configured to support 7 Rows (Seven applications are to be used in this project namely Server_Http, Server_Ftp, Server_E-mail, Server_Voice, Server_Print, Server Video, and Server_Remote Login applications.

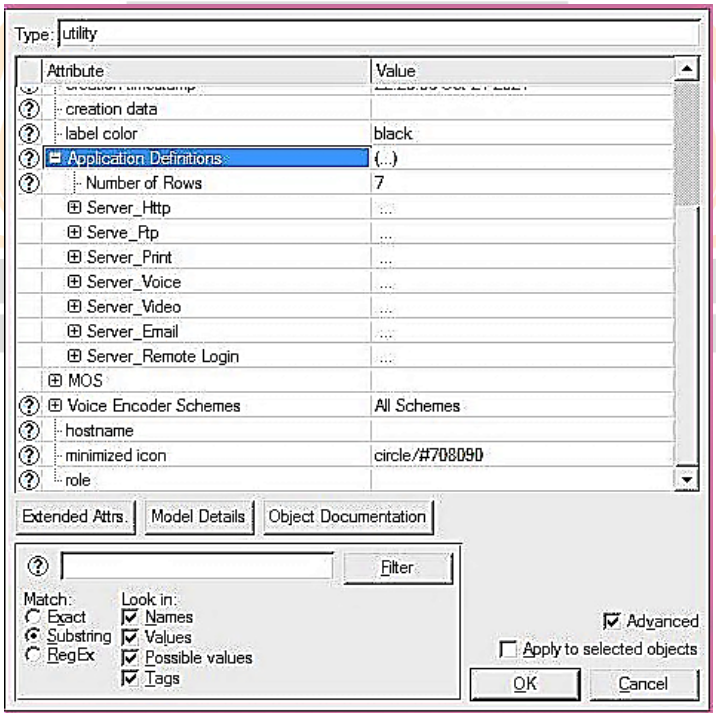

Figure 4: Application Definition Specification

Also, in specifying the profile's definition used for this project, the Profile configuration node was configured to support 7 rows, and each row was named with the following profiles (HTTP profile, e-mail profile, Voice profile, Print profile, Remote Login profile, Ftp profile and Video conferencing profile).

Configuration of Parameters on Other Devices

Other devices such as routers, Ethernet workstations, access points, mobile nodes, and failure/recovery nodes. All the configurations parameters were done through the attributes of the devices.

Creating A Traffic Flow and Configuration of Node Applications

Traffic in OPNET modeling can be categorized into two groups: explicit DES traffic and background traffic. Explicit traffic includes traffic based on the application model, traffic based on traffic generation parameters, and self-similar traffic based on a raw packet generator (RPG) model. Background traffic includes traffic based on baseline load and traffic based on traffic flow.

Steps for Creating a Traffic flows

On the menu bar of a network scenario, click on Traffic => Create traffic flow => IP unicast Traffic => Best effort => Create

CONFIGURING WEB (HTTP) APPLICATIONS

To configure a web browsing application, the application named HTTP was selected from the list of built-in models. OPNET provides pre-set configurations such as Light Browsing, Heavy Browsing, Searching, or Image Browsing. For the targeted network environment, light and heavy browsing were selected. Table 1 shows the preset configurations parameters of the selected web applications. HTTP Specification which defines the version of the HTTP protocol, Page Inter-arrival Time which specifies time in seconds between consecutive webpage downloads, and type of service specifies traffic shaping policy adapted.

Table 1: Light Web Browsing Configuration

Attribute	Value
HTTP specification	HTTP 1.1
Page inter-arrival time (second)	Exponential (720)
Type of service	Best effort

CONFIGURING FTP APPLICATIONS

To configure the FTP application, the application named FTP was selected from the list of built-in models. OPNET also provides preset configurations for FTP applications. The preset FTP configurations include Low Load, Medium Load, and High Load. The Inter-Request Time parameter is the time in seconds between consecutive FTP requests. The File Size defines the size in bytes of the FTP file to be transferred. Table 1.

Table 2: Light File Transfer Configuration

Attribute	Value
Inter Request time (seconds)	Exponential (3600)
File size (bytes)	Constant (1000)
Type of service	Best effort

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CONFIGURING E-MAIL APPLICATIONS

To configure an e-mail application, the application named e-Mail was selected from the list of built-in models. OPNET provides preset configurations for e-mail applications as well. The pre-set e-mail configurations include Low Load, Medium Load, and High Load.

The model also allows custom configuration via parameters such as Send(Receive) Inter-arrival Time which specifies the amount of time in seconds between consecutive sent (receive) operations, send(Receive) Group Size which determines the number of emails messages per single sent(receive) operation, and E-Mail Size which defines the size of the email message in bytes.

The e-mail configurations for selected loads are shown in Table 3.4 show how to configure an e-mail application.

Table 3: Low Load Email Configuration

Attribute	Value
Send inter-arrival time (second)	Exponential (3600)
Send group size	Constant (3)
Receive inter-arrival time (second)	Exponential (3600)
e-mail size (bytes)	Constant (500)
Type of service	Best effort

LINKS VERIFICATION

Before running a simulation, links verification was carried out to ensure that

- Point-to-point and others link connections are valid.
- Enough transmitters and receivers to support all of the incoming and outgoing links.
- Data rates of the connected transmitter and receiver match the data rate of the link.
- Transceivers support the attached link technology.

By pressing ctrl + l on the keyboard you can easily access a link verification window as shown in fig. 5 below.

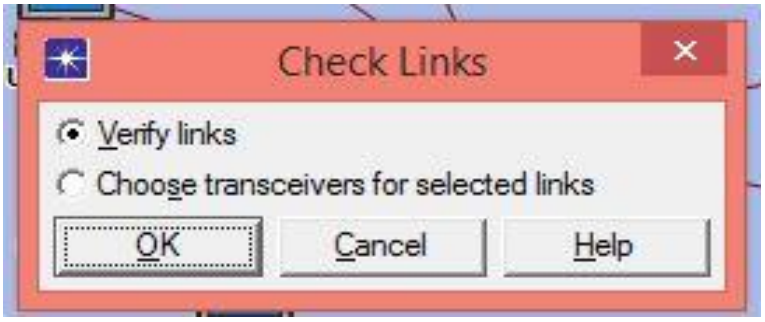

Figure 5: Links Verification window

For this network scenario, the links verification was successful and there are no errors in all the links.

SIMULATION & DISCUSSION OF RESULT

The results after simulating the three scenarios are presented in graphs form. All graphs show the results obtained in the three network scenarios (OSPF, EIGRP, and AODV) routing protocol for both wired and wireless (Hybrid).

The network convergence duration, network Convergence activity, Traffic sent (Packet/sec), CPU utilization, Ethernet Delay, Throughput, Page, and Object response of HTTP application, were determined as shown.

NETWORK SCENARIOS IMPLEMENTATION TOOL

Among the various simulators available, Optimized Network Engineering Tools (OPNET) Edition is a simulator that is comprehensive and technology-neutral in its capabilities. OPNET enables the network designers to create a virtual network consisting of relevant hardware, protocols, and application software. This virtual network is a pure software entity that can run on an individual workstation.

The network devices like routers, switches, etc. can be modeled in OPNET virtual network. This network can be scaled from a small LAN to a wide area network. Once a virtual network has been created it can be manipulated according to the need of the application.

The network devices can be changed, removed, or inserted into the virtual network as desired to find out the most appropriate configuration and also implement the given application. The effects of various manipulations can be quantifiably examined and analyzed. OPNET simulator is built on top of a discrete event system (DES) and it simulates the system behavior by modeling each event in the system and processing it through user-defined processes. OPNET is a very powerful software to simulate heterogeneous networks with various protocols.

It has several distinct methods of creating topologies. Modeler supports almost all network types and technologies. OPNET runs on top of a C compiler and provides a GUI. OPNET Modeler is based on a series of hierarchical editors that directly parallel the structure of real networks, equipment, and protocols. These editors are Project editors, node editors, and process editors. OPNET provides the set of complete tools and a complete user interface for topology design and development.

RESULTS OF THE SIMULATED PARAMETERS

Network Convergence Duration

EIGRP, OSPF, and AODV protocols were modeled to compare their convergence duration and activity and their impact on the network in the three scenarios. The simulation model was created and simulation time was set for 20 Minutes and both protocols were configured in three different scenarios simultaneously. The Discrete Event Simulation (DES) graph is shown in figure 6 and the corresponding table of convergence time of the three routing protocols.

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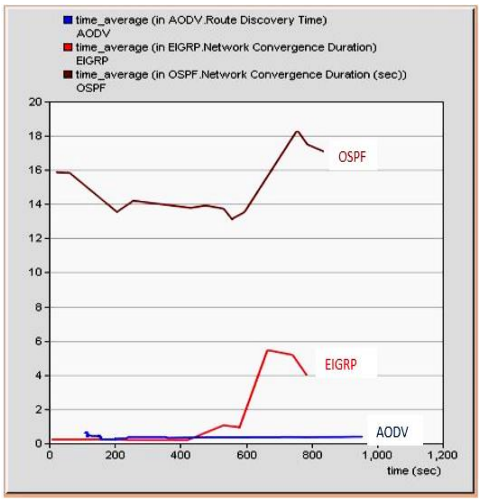

Figure 6: Convergence Duration of AODV. EIGRP & OSPF

Table 4: Convergence duration

S/No	Protocols	Simulation Time	Convergence Duration (Sec)
1.	AODV	20 Minutes	0.5 sec
2.	EIGRP	20 Minutes	3.8 sec
3.	OSPF	20 Minutes	4.0 sec

Based on the results obtained in the above graph and table, it shows that AODV converges at 0.5 seconds, EIGRP converges at 3.8 seconds and OSPF converges at 4.0 seconds. During the simulation, the OSPF has some delay in time for it to start to converge in the network as seen in the graph. AODV converges faster than EIGRP & OSPF. From the analysis of the above results, we can notice that in hybrid networks wireless can reach a destination faster due to the nature of transmission.

HTTP (WEB) APPLICATION

HTTP was simulated and the DES graphs are shown below with their corresponding tables.

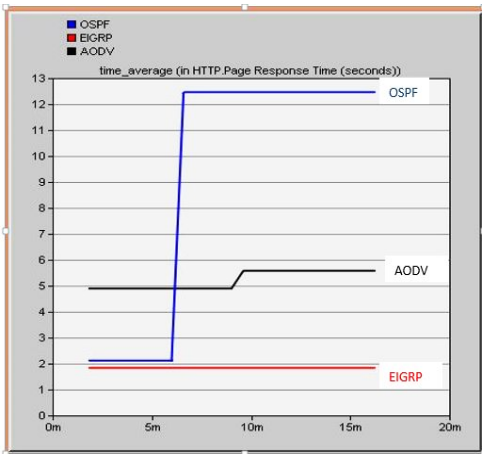

Figure 7: Page response time (HTTP) at low load

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Table 5: HTTP (web) response of EIGRP, OSPF, & AODV

S/N.	Protocol	Time for Simulation	Page Response (sec)
1.	EIGRP	20 minutes	1.9 sec
2.	OSPF	20 minutes	12.5 sec
3.	AODV	20 minutes	5.6 sec

The above DES graph in fig. 7 with its corresponding values in Table 2 shows the page response time for the three routing protocols (EIGRP, OSPF, and AODV) at heavy load for 20 minutes' simulation time. It was observed that the page response time of EIGRP is about 1.9 seconds, which is lower than the AODV & OSPF. This shows that the network uses the EIGRP routing protocol for WEB (HTTP) on low load is has a quick rate of transmission of data than the AODV & OSPF. There is a hybrid network that is recommended to use an EIGRP routing protocol.

FTP (FILE TRANSFER PROTOCOL) UPLOAD RESPONSE

The FTP uploads response (second) at load application is shown in DES graph figure 8 below.

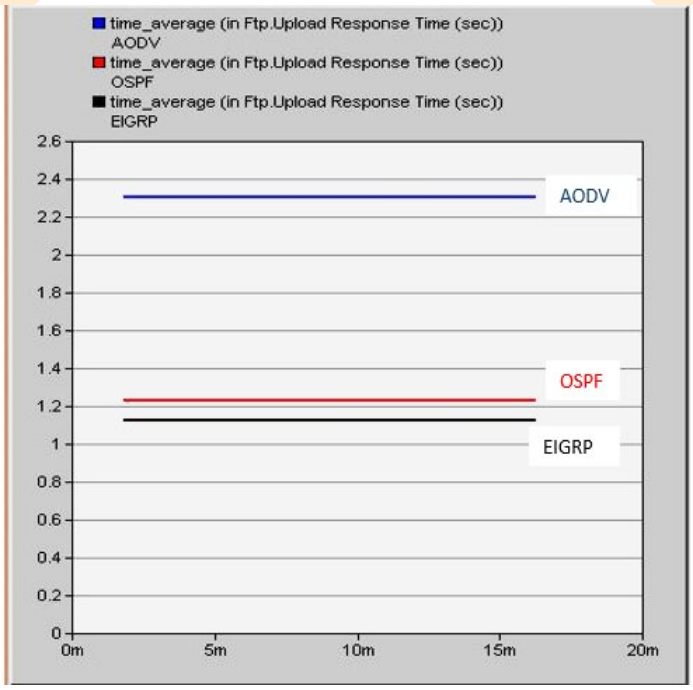

Figure 8: FTP Upload response at low load

Table 6: Upload response time of FTP under low load

S/N.	Protocol	Time for Simulation	Upload Response (sec)
1.	EIGRP	20 minutes	1.17 sec
2.	OSPF	20 minutes	1.22 sec
3.	AODV	20 minutes	2.26 sec

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The above DES graph in fig. 8 with its corresponding values in Table 3 shows the upload response time for the three routing protocols (EIGRP, OSPF, and AODV) at a low load for 20 minutes' simulation time. It was observed that the upload response time of EIGRP is about 1.17 seconds, which is lower than the AODV & OSPF. This shows that the network uses the EIGRP routing protocol for upload on low load is has a quick rate of transmission of data than the AODV & OSPF. There is a hybrid network that is recommended to use an EIGRP routing protocol.

E-MAIL DOWNLOAD RESPONSE

The DES graph result on download response of e-mail application at low load configuration is shown in figure 9 below.

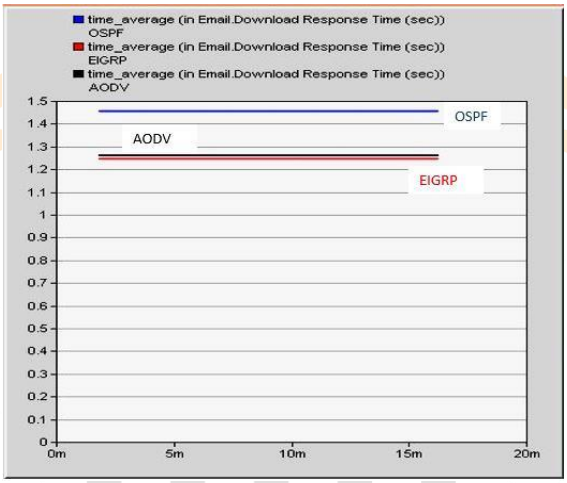

Figure 9: E-mail Download response time at low load

Table 7: Download response time of E-mail under low load

S/N.	Protocol	Time for Simulation	Download response time (sec)
1.	EIGRP	20 minutes	1.25 sec
2.	OSPF	20 minutes	2.26 sec
3.	AODV	20 minutes	1.26 sec

The above results show that the download response in EIGRP has a faster time (1.25 sec), followed by AODV with a slight difference (1.26 sec) and OSPF with 2.26 seconds. Based on the results obtained, the EIGRP has more advantages in download response than the OSPF & AODV.

COMPARISON OF THE SIMULATED RESULTS

After successful simulation of the chosen routing protocols of the designed hybrid network with a different scenario, the comparison of the simulated parameters of the selected application was summarized in Table 8 below.

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Table 8: Comparison of the obtained results

Protocol	Application	Metric	Load Level	Results	Recommended Protocol
AODV		Network Convergence time		0.5 sec	AODV
EIGRP				3.8 sec	EIGRP
OSPF				4.0 sec	
AODV	HTTP	Page response	Low load	5.6 sec	AODV
EIGRP				1.9 sec	EIGRP
OSPF				12.5 sec	
AODV	FTP	Upload response	Low Load	1.22 sec	AODV
EIGRP				1.17 sec	EIGRP
OSPF				2.26 sec	
AODV	E-mail	Download response	Low load	1.26 sec	AODV
EIGRP				1.25 sec	EIGRP
OSPF				2.26 sec	OSPF

According to the comparison for the three routing protocols, EIGRP and AODV routing protocols will be more effective in hybrid networks.

CONCLUSION

After the designed network topology, the study analyzed the performance of three major types of routing protocols: OSPF, EIGRP, and AODV using OPNET. Three scenarios had been used in simulating each routing protocol in the network topology. Firstly, the first scenario was implemented with the OSPF routing protocol and other parameters. After it was simulated, the network convergence duration, convergence activity, latency, CPU utilization, throughput, IP traffic dropped (Pkts/sec) to compare the difference in their performance of the selected protocols.

The simulated results were captured and recorded in form of graphs, as shown above, the results two or more results were combined in one graph. The obtained results of the simulation were compared first for convergence duration and activity of the three protocols (AODV, OSPF & EIGRP). In case of the network delay, the results show that the EIGRP has less latency compared to OSPF which has little high latency. According to the CPU utilization, the results found that the CPU usage in the network is falling between 11% - 12%. Also, a network throughput result for a selected object was shown the actual amount of traffic flow (packet/sec) and lastly, IP packet drop (loss) in EIGRP is less than for that in OSPF. Using the applications like HTTP, FTP, E-mail, and Voice in the network, the EIGRP is recommended in wired transmission while AODV in wireless transmission in the hybrid network.

Based on the analyzed results for the obtainable network topology, it concluded that EIGRP is the best choice for the hybrid network since it has the fastest network convergence and EIGRP uses the bandwidth efficiently.

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RECOMMENDATION

Based on the simulated results and comparisons of the three network scenarios of the hybrid network, the following recommendations were made:

- The Radio Gotel Yola & any enterprise network is recommended to use EIGRP & AODV routing protocols in data transmission.
- The hybrid network should be maintained in performing different applications based on the latest technology devices we have in the communication system since it dealt with wireless where data speed will be upgraded.
- The network should be updated always to overcome the security challenges in network operation.

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