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Compare the Performance of Dynamic Routing Protocols based Throughput, Queuing Delay and Bandwidth Utilization using OPNET Modeler

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مقارنة أداء بروتوكولات التوجيه الديناميكي بناءً على الإنتاجية، وتأخير الانتظار، واستخدام عرض النطاق الترددي باستخدام برنامجOPNET

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الملخص

تتناول هذه الورقة البحثية أداء ثلاثة بروتوكولات توجيه ديناميكية شائعة **RIP :**و **OSPF**و **.EIGRP**وتهدف إلى مساعدة مديري الشبكات في اختيار البروتوكول الأنسب لاحتياجاتهم الخاصة. تحلل الورقة عوامل حاسمة مثل معدل نقل البيانات، وتأخير الانتظار، ومتطلبات عرض النطاق الترددي، وغيرها. ومن خلال دراسة محاكاة تفصيلية باستخدام برنامج**OPNET** ، يقارن المشروع أداء كل بروتوكول عبر هذه المعايير. وتُظهر النتائج أن بروتوكول **EIGRP** يتميز بمعدل نقل بيانات أعلى ومتطلبات عرض نطاق ترددي أقل مقارنةً ببروتوكولي **RIP** و**.OSPF**

وتقدم هذه الورقة رؤى قيّمة لمتخصصي الشبكات من خلال تقييم بروتوكولات التوجيه الشائعة هذه، وتسليط الضوء على العوامل الرئيسية التي يجب مراعاتها عند اتخاذ قرارات التنفيذ.

الكلمات الدالة: EIGRP، OSPF، RIP، بروتوكول التوجيه الديناميكي، الإنتاجية، تأخير الانتظار واستخدام النطاق الترددي، OPNET.

Abstract

This paper investigates the performance of three common dynamic routing protocols: RIP, OSPF, and EIGRP. The goal is to assist network administrators in choosing the most suitable protocol for their specific needs. Analyzes critical factors like Throughput, Queuing Delay and bandwidth requirement

etc.. Through a detailed simulation study using OPNET, the project compares the performance of each protocol across these parameters. The findings demonstrate that EIGRP higher throughput, lower bandwidth requirements, compared to RIP and OSPF.
This paper provides valuable insights for network professionals by evaluating these popular routing protocols and highlighting the key factors to consider when making implementation decisions.

Keywords: EIGRP, OSPF, RIP, Dynamic Routing Protocol, Throughput, Queuing Delay and Bandwidth Utilization, OPNET.

Introduction

In practical, large-scale networks, Internet service providers rely on dynamic routing protocols to keep their routing tables updated. A TCP/IP-based network enables data packets to be routed efficiently based on their IP address. Routers in the network are used to control and forward data. In packet transmission, the routing function is to move traffic across networks, and routers must be aware of the next destination to which the traffic should be rerouted to reach its final destination. For routers to distribute data effectively and efficiently, the choice of routing protocol becomes a critical factor in determining the success of the network over time. Factors that distinguish one routing protocol from another include its speed of adaptation to topology changes (so-called convergence), its ability to choose the optimal path from among multiple paths, and the amount of network traffic the routing protocol generates. Additionally, the choice between standard and proprietary protocols, ease of management, throughput, latency, and bandwidth utilization all contribute to the complexity of the decision-making process.[1]
This paper focuses on the application of dynamic routing protocols in computer networks and network technologies. It compares and evaluates the performance of three dynamic routing protocols, RIP, OSPF, and EIGRP, based on various criteria.

I. METHODOLOGY

The implementation methodology for this paper includes the following steps:
1. Use the OPNET simulation tool to design six different types of networks in terms of size and type (Mesh , Ring , Tree):
 -Design 3 small networks, each consisting of 10 routers.
 -Design 3 large networks, each consisting of 40 routers.
2. Configure failure and recovery scenarios in each network To determine the strength of the routing protocols.
3. Implementing High-Definition Video Conferencing Applications across six network topologies to simulate real-world sessions. The aim is to test routing protocols under high-definition video traffic, assessing their performance under challenging conditions. This will help evaluate the strength and efficiency of the protocols in managing complex traffic and data transmission.
4. Identify the three performance metrics to be used in the research:
- Throughput.
- Queuing Delay.
- Bandwidth Utilization.
5. Configure the routing protocols RIP, OSPF, and EIGRP for all networks.
6. Start the simulation, collect and analyze the results, and provide recommendations.
By this methodology, we aim to provide insights into the performance of the dynamic routing protocols and facilitate the decision-making process for selecting the most suitable protocol.

II. THE PROPOSED MODEL

In this paper, design and implementation of the simulation environment used to analyze the performance of the dynamic routing protocols EIGRP, OSPF, and RIP. The simulation environment was built using OPNET Modeler it is the main scenario.
1. Throughput: The average number of packets successfully routed to their destination per second between two points. Higher throughput indicates better network performance.
2. Queuing Delay: The time packets spend waiting in the router's queue before being processed and forwarded. Shorter queuing delay is preferable. as it indicates less congestion and faster packet delivery.[7]
3. Bandwidth Utilization: This metric represents the percentage of available bandwidth used on a specific link. A value of 100% indicates full utilization. It is a measure of how much of the network's total capacity is being used. If utilization is excessively high, it can lead to congestion.[7]

1. Scenario

1.1 Small Topologies

1.1.1 Small Mesh

In a small mesh topology, each node directly connects to approximately three others. This topology is ideal for simulating small, interconnected networks

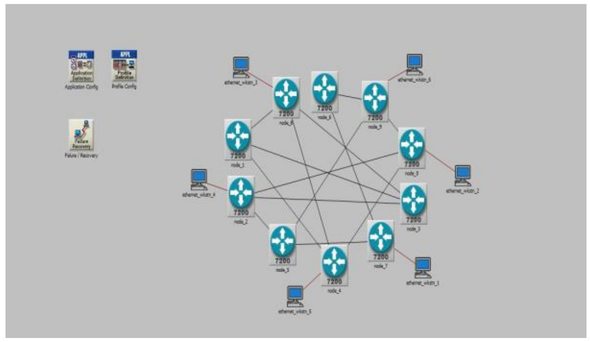

Figure 4: Small Mesh Topology

- **Small Ring**

A small ring topology consists of a circle of nodes, each connected to its two immediate neighbors This simple, closed-loop structure is suitable for facilitating communication among a small, interconnected set of entities.

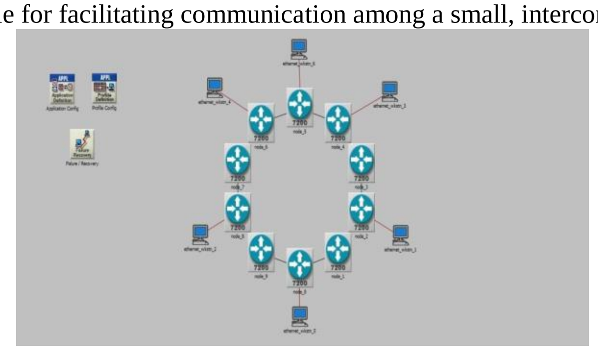

Figure 5 : Small Ring Topology

- **Small Tree**

A small tree topology resembles a hierarchical structure where nodes branch out from a central hub, resembling a tree This topology efficiently manages data flow in smaller networks.

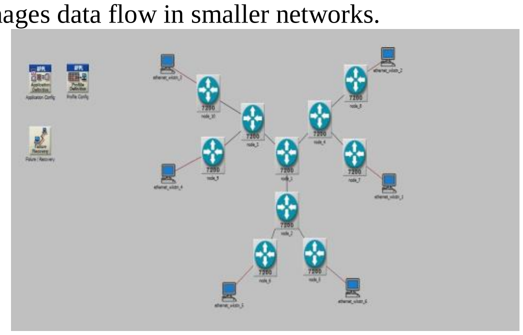

Figure 6 : Small Tree Topology

1.2 Large Topologies

1.2,1 Large Mesh

In a large mesh topology, each node connects to roughly five others, creating a complex, interconnected mesh.

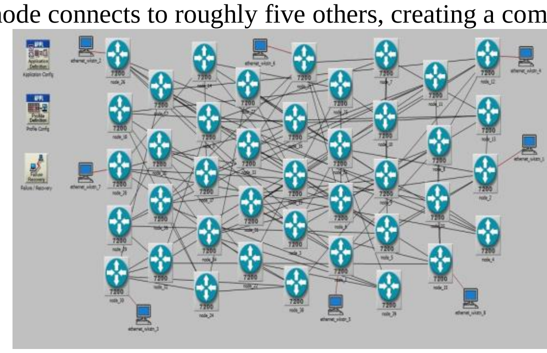

Figure 7 : Large Mesh Topolog

- **Large Ring**

A large ring topology consists of a ring with a significantly larger number of nodes.

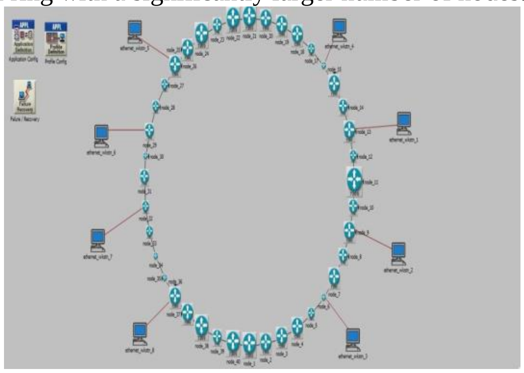

Figure 8 : Large Ring Topology

- **Large Tree**

A large tree topology resembles a massive hierarchical structure with numerous branches extending from a central hub, resembling a giant tree This topology efficiently manages data flow in extensive networks.

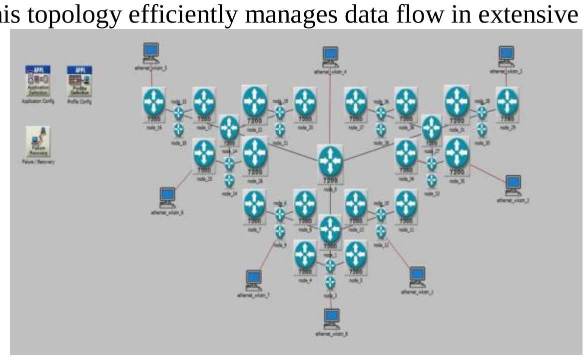

Figure 9 : Large Tree Topology

To evaluate the performance of the routing protocols, a set of statistics were collected for comparison. The metrics were collected by right-clicking on an empty space in the OPNET Modeler interface and selecting "choose Individual DES statistics." The following metrics were selected:

- Throughput (packets Per sec).
- Queuing delay (sec).
- Bandwidth utilization (%).

IV. EXPERIMENTAL RESULTS

analyze the simulation results for the six different networks using OPNET Modeler. The purpose of this chapter is to evaluate and compare routing protocols through the results obtained from scenario simulations for the dynamic routing protocols EIGRP, OSPF, and RIP for each topology. These results will be presented in the form of graphs and numerical values. Finally, we will analyze the data extracted from these graphs to draw conclusions about the performance of each routing protocol within different network topologies.

- Throughput
- Small Networks Results
- Small Mesh EIGRP (0.8889), OSPF (0.4815), RIP (0.1667).

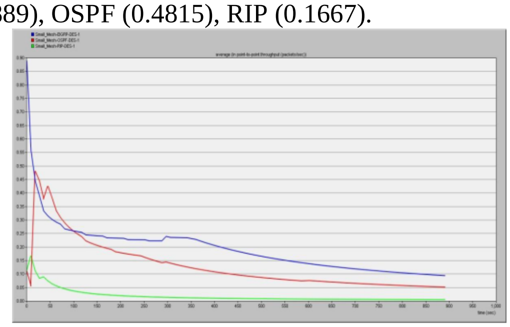

Figure 10 : Small Mesh - Throughput (packets per second)

- **Small Ring :**

EIGRP (0.7778), OSPF (0.6296), RIP (0.1111).

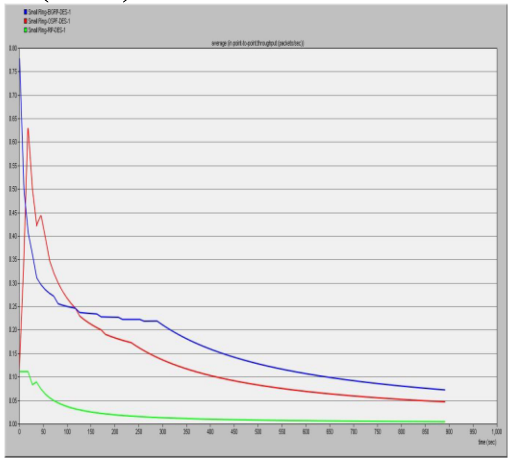

Figure 11 : Small Ring - Throughput (packets per second)

- **Small Tree:**

EIGRP (1), OSPF (0.703704), RIP (0.16667).

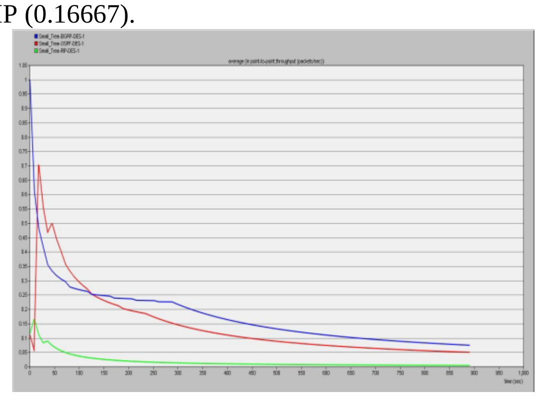

Figure 12 : Small Tree - Throughput (packets per second)

- **Small Networks Analysis**

Network Topology	EIGRP (packets/sec)	OSPF (packets/sec)	RIP (packets/sec)	Analysis
Small Mesh	0.8889	0.4815	0.1667	EIGRP achieves higher throughput than OSPF and RIP.
Small Ring	0.7778	0.6296	0.1111	Also EIGRP achieves higher throughput than OSPF and RIP.
Small Tree	1	0.703704	0.16667	Also EIGRP achieves higher throughput than OSPF and RIP.

Table 5: Throughput Analysis - Small Networks Comparison

Large Networks Results

Large Mesh :

EIGRP (4.1111), OSPF (2.296296), RIP (0.3333).

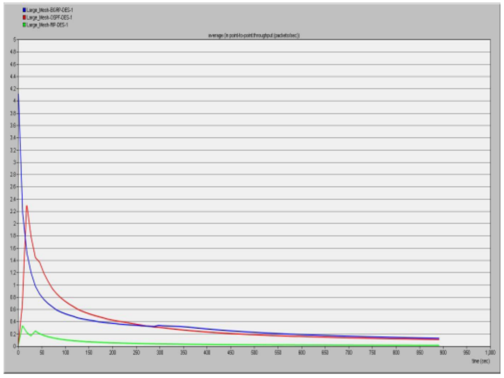

Figure 13 : Large Mesh - Throughput (packets per second)

Large Ring : EIGRP (2.444444), OSPF (1.037037), RIP (0.155556).

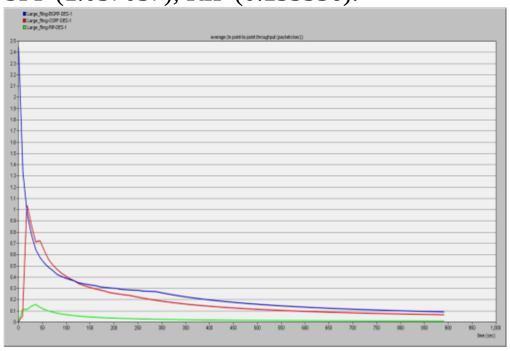

Figure 14 : Large Ring - Throughput (packets per second)

Large Tree: EIGRP (1.666667), OSPF (1.185185), RIP (0.222222).

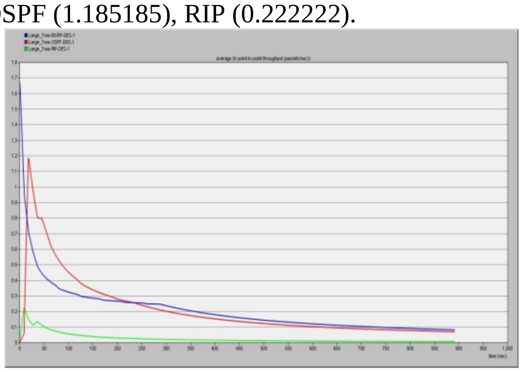

Figure 15 : Large Tree - Throughput (packets per second)

- **Large Networks Analysis**

Network Topology	EIGRP (packets/sec)	OSPF (packets/sec)	RIP (packets/sec)	Analysis
Large Mesh	4.1111	2.296296	0.3333	EIGRP achieves higher throughput than OSPF and RIP.
Large Ring	2.444444	1.037037	0.155556	Also EIGRP achieves higher throughput than OSPF and RIP.
Large Tree	1.666667	1.185185	0.222222	Also EIGRP achieves higher throughput than OSPF and RIP.

Table 6 : Throughput Analysis – Large Networks Comparison

Queuing Delay

Small Networks Results

Small Mesh : EIGRP (0.00001098), OSPF (0.00001491), RIP (0.00004632).

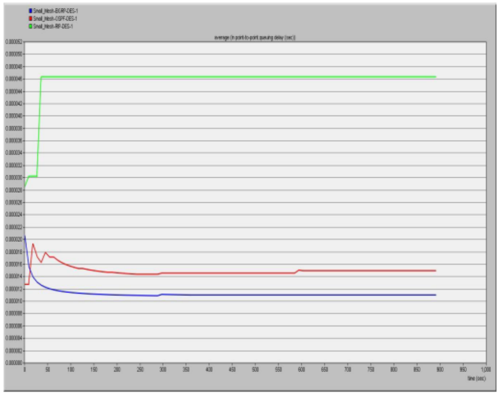

Figure 16 : Small Mesh - Queuing Delay (second)

Small Ring : EIGRP (0.00001072), OSPF (0.00001423), RIP (0.00003559)..

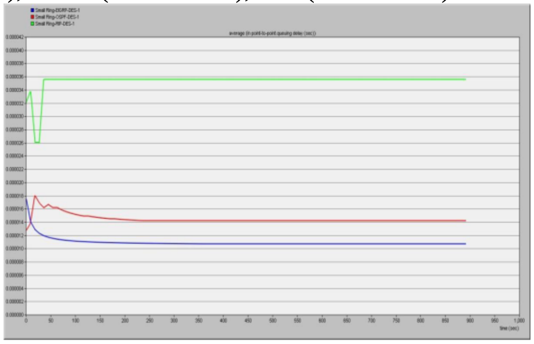

Figure 17 : Small Ring - Queuing Delay (second)

Small Tree: EIGRP (0.00001111), OSPF (0.0001404), RIP (0.00003737).

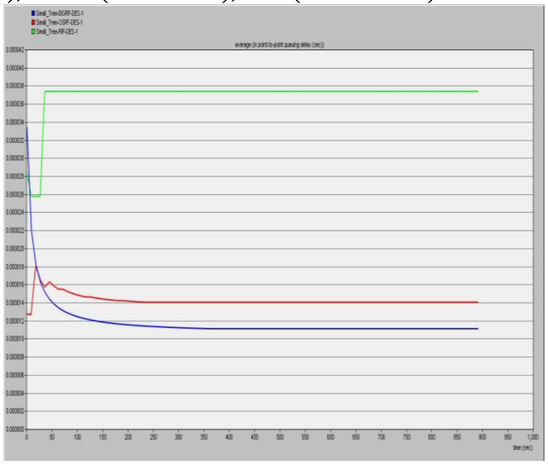

Figure 18 : Small Tree - Queuing Delay (second)

Small Networks Analysis

Network Topology	EIGRP (sec)	OSPF (sec)	RIP (sec)	Analysis
Small Mesh	0.00001098	0.00001491	0.00004632	EIGRP has the lowest queuing delay, followed by OSPF, while RIP having the highest delay.
Small Ring	0.00001072	0.00001423	0.00003559	EIGRP has the lowest queuing delay compared to OSPF and RIP.
Small Tree	0.00001111	0.0001404	0.00003737	Again, EIGRP has the lowest queuing delay

Table 7 : Queuing Delay Analysis - Small Networks Comparison

- **Large Networks Results**

Large Mesh : EIGRP (0.00001617), OSPF (0.00001685), RIP (0.0002061).

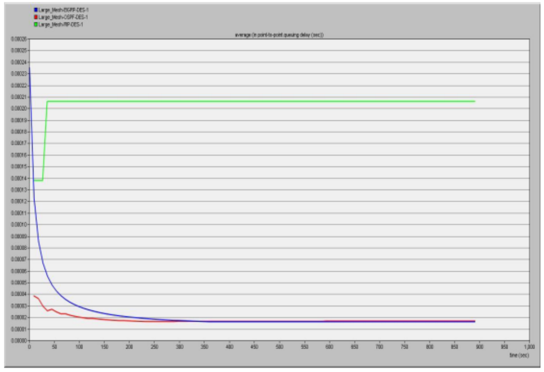

Figure 19 : Large Mesh - Queuing Delay (second)

Large Ring : EIGRP (0.00001072), OSPF (0.00001547), RIP (0.00005556).

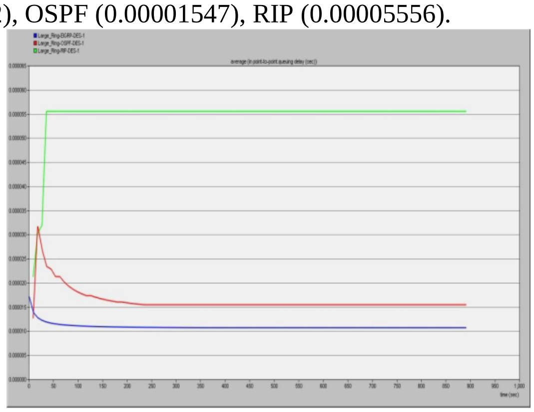

Figure 20 : Large Ring - Queuing Delay (second)

Large Tree: EIGRP (0.0000121), OSPF (0.0000149), RIP (0.0001085).

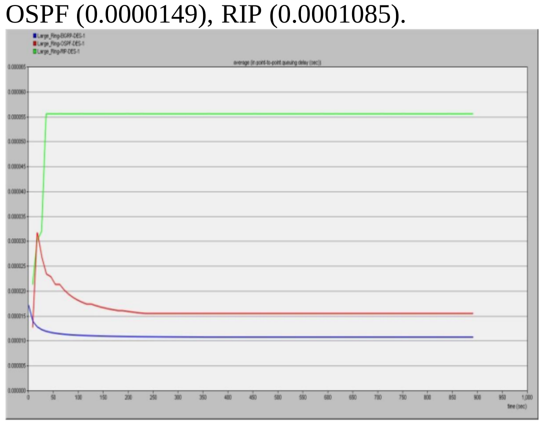

Figure 21 : Large Tree - Queuing Delay (second)Large Networks Analysis

Network Topology	EIGRP (sec)	OSPF (sec)	RIP (sec)	Analysis
Large Mesh	0.00001617	0.00001685	0.0002061	EIGRP has the lowest queuing delay, followed by OSPF, while RIP having the highest delay.
Large Ring	0.00001072	0.00001547	0.0000555 6	EIGRP has the lowest queuing delay compared to OSPF and RIP.
Large Tree	0.0000121	0.0000149	0.0001085	Again, EIGRP has the lowest queuing delay

Table 8 : Queuing Delay Analysis - Large Networks Comparison

Bandwidth Utilization

Small Networks Results

Small Mesh : EIGRP (0.001462), OSPF (0.001162), RIP (0.0005136).

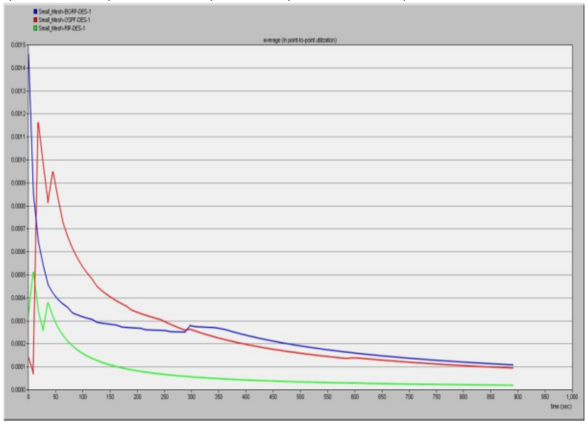

Figure 22 : Small Mesh - Bandwidth Utilization (%)

Small Ring : EIGRP (0.001146), OSPF (0.001282), RIP (0.000372).

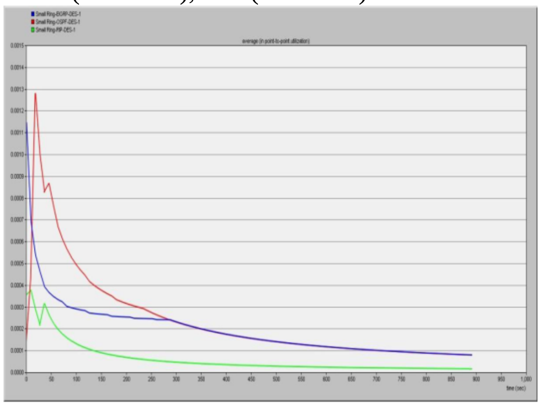

Figure 23 : Small Ring - Bandwidth Utilization (%)

Small Tree: EIGRP (0.001500), OSPF (0.001532), RIP (0.0004143).

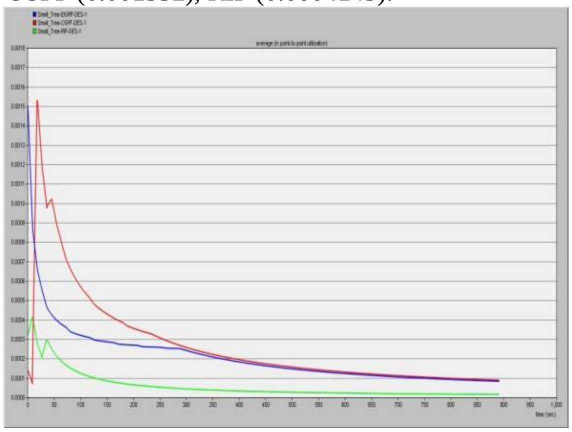

Figure 24 : Small Tree - Bandwidth Utilization (%)

- **Small Networks Analysis**

Network Topology	EIGRP (%)	OSPF (%)	RIP (%)	Analysis
Small Mesh	0.1462	0.1162	0.05136	Both EIGRP and OSPF have higher bandwidth utilization than RIP. However, EIGRP shows the highest utilization.
Small Ring	0.1146	0.1282	0.0372	Both EIGRP and OSPF have higher bandwidth utilization than RIP. However, OSPF shows the highest utilization.
Small Tree	0.1500	0.1532	0.04143	Both EIGRP and OSPF have higher bandwidth utilization than RIP.

Table 9 : Bandwidth Utilization Analysis - Small Networks Comparison

- **Large Networks Results**

Large Mesh : EIGRP (0.008900), OSPF (0.007965), RIP (0.002478)

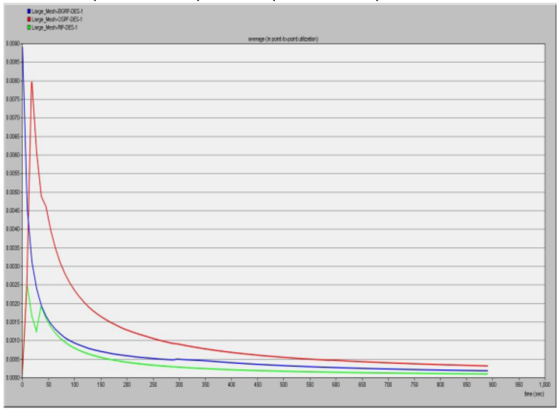

Figure 25 : Large Mesh - Bandwidth Utilization (%)

Large Ring : EIGRP (0.003493), OSPF (0.004090), RIP (0.000689).

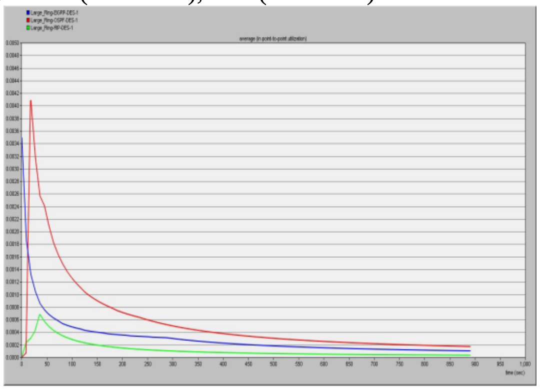

Figure 26 : Large Ring - Bandwidth Utilization (%)

Large Tree: EIGRP (0.003229), OSPF (0.003958), RIP (0.001089).

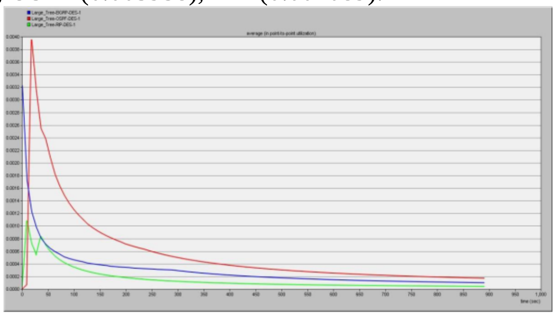

Figure 27 : Large Tree - Bandwidth Utilization (%)

- **Large Networks Analysis**

Network Topology	EIGRP (%)	OSPF (%)	RIP (%)	Analysis
Large Mesh	0.8900	0.7965	0.2478	Both EIGRP and OSPF have higher bandwidth utilization than RIP. However, EIGRP shows the highest utilization.
Large Ring	0.3493	0.4090	0.0689	Both EIGRP and OSPF have higher bandwidth utilization than RIP. However, OSPF shows the highest utilization.
Large Tree	0.3229	0.3958	0.1089	Both EIGRP and OSPF have higher bandwidth utilization than RIP.

Table 10 : Bandwidth Utilization Analysis - Large Networks Comparison

V. CONCLUSIONS

1. OSPF generates more protocol traffic than EIGRP and RIP across all networks, while RIP generates less traffic. We explain that by saying that OSPF uses a more complex algorithm based on link state advertisements (LSAs), which create a detailed map of the network. This requires routers to send more traffic than simpler protocols like RIP and EIGRP.
2. Routing protocols in Mesh networks generate more routing traffic than other types of networks. We can explain this by saying that each router in a mesh network is directly connected to a large number of neighbors, which increases the level of interconnection and complexity, forcing routing protocols to have higher traffic to exchange neighbor messages and achieve convergence. In contrast, tree and ring networks have a more organized structure, which helps reduce the traffic required.
3. we find that EIGRP significantly outperforms both OSPF and RIP in terms of throughput within small and large networks. This indicates that EIGRP is the most efficient protocol for data transfer.
4. EIGRP has the lowest queuing delay compared to OSPF and RIP in all networks, making it the fastest protocol for sending packets and avoiding congestion.
5. As for bandwidth efficiency utilization, OSPF and EIGRP are similar and they has a much higher bandwidth efficiency utilization than RIP. OSPF shows higher bandwidth utilization on ring and tree networks, while EIGRP shows higher bandwidth utilization on mesh networks.

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