Comparative Study of EIGRP and OSPF Protocols based on Network Convergence

Ifeanyi Joseph Okonkwo[1]
Imperial College London
London, United Kingdom

Ikiomoye Douglas Emmanuel[2]
University of Salford
Manchester, United Kingdom

Abstract*—Dynamic routing protocols are one of the fastest growing routing protocols in networking technologies because of their characteristics such as high throughput, flexibility, low overhead, scalability, easy configuration, bandwidth, and CPU utilization. Albeit convergence time is a critical problem in any of these routing protocols. Convergence time describes summary of the updated, complete, and accurate information of the network. Several studies have investigated EIGRP and OSPF on the internet; however, only a few of these studies have considered link failure and addition of new links using different network scenarios. This research contributes to this area. This comparative study uses a network simulator GNS3 to simulate different network topologies. The results are validated using Cisco hardware equipment in the laboratory. The network topology implemented in this research are star and mesh topology. The results are validated using Cisco hardware equipment in the laboratory. Wireshark is effectively used in capturing and analyzing the packets in the networks. This helps in monitoring accurate time response for the various packets. The results obtained from Wireshark suggest the EIGRP has a higher performance in terms of convergence duration with a link failure or new link added to the network than the OSPF routing protocol. Following this study EIGRP is recommended for most heterogeneous network implementations over OSPF routing protocol.

Keywords*—*OSPF (Open Shortest Path First); EIGRP (Enhanced Interior Gateway Routing Protocol); routing; protocol; network; convergence; topology; routers; packets; Wireshark

I. Introduction

Computer networking is now a fundamental part of life, especially the use of the internet. As new technologies emerge, the demand for wireless mobile computing is growing fast, thus the need for efficient routing protocols [1]. These protocols define the mechanism by which routers acquire information about the performance of the network topology, verify and identify the optimal route that a packet will take to arrive at its destination. Hence, routing algorithms are crucial because they select the best path for communication in a heterogeneous network. Routing is the entire process of selecting the optimal route for the transmission of data packets from source to destination [2]. The process includes routers advertising their known IP networks, the administrative cost to its neighbor or adjacent routers, in this way the neighbor's routers gain knowledge of the characteristics and the topology of the network, then update the routing table. The administrative cost is the number of hops, link speed and latency [3].

There has been different research about routing protocols, especially on EIGRP and OSPF routing protocol in terms of convergence time. This research in routing protocols has been predominant because of the increasing demand of data transmission over a reliable network connection amongst enterprise companies, therefore network resilience/redundancy has been the key in curbing link failures. If there is a link failure in the network, the routing protocols are expected to identify the failure and converge to form a new topology for the continuous flow of packets in the network. Despite the wide research and interest made, many problems about routing protocols are yet to be solved in terms of convergence rate, which can yield optimal routing to deliver high throughput in heterogeneous networks. Hence, this work focuses on analyzing several scenarios of link failures, measuring their convergence rate, and identifying changes in the network topology when using EIGRP and OSPF routing protocol [4]. The rate of convergence occurs when all the routers in the network have an updated, complete, and accurate information on the network. The convergence rate includes the total time required by all the routers to calculate the optimal path, update their routing tables, and share the routing information with neighboring routers in the network.

The remainder of this study is planned as follows. In Section II, present a brief literature of recent work and background knowledge of Routing Information Protocol (RIP), OSPF and EIGRP. Section III describes the methodology, where the network topology such as star and mesh are designed. Section IV presents the design parameters and metrics, which includes the Hello interval, hop count and interface cost. Section V are the Wireshark results and Section VI is the presentation and analyses of the results. Finally, the work is concluded in Section VII.

II. Background

Dynamic routing protocols allow changes in the network topology because of the update in routing tables. Dynamic routing protocol is divided into distance vector routing protocols and link state routing protocols. Distance vector routing protocols calculate the administrative cost of a packet arriving at a destination based on the number of routers the packet passes through, these include Routing Information Protocol (RIP) and EIGRP) [5]. Whilst, Link state routing protocol is building a complete topology of the network and calculates the optimal path from the topology for all interconnected networks, these include Intermediate System to

Intermediate System (IS-IS) and Open Shortest Path First (OSPF) [3].

There are series of research in convergence time, packet loss and throughput of OSPF, EIGRP and RIP routing protocol. Each of this research work has a unique role they play in network efficiency. The first research work was the Advanced Research Projects Agency Network (ARPANET) in 1969, which is the foundation of most routing algorithms [6]. Furthermore, [7] designed a star network topology consisting of a switch, eight cisco routers and 14 hosts using the cisco packet tracer to determine the convergence time. In a similar context [8] determines a comparative study of RIP, OSPF and EIGRP using ring topologies on GNS3 network simulator. The design comprises five routers connected in a ring topology with a personal computer that makes use of networking management tools to manage the information in the network. Also, [9] evaluates dynamic routing protocols for real time applications such as voice, video based on convergence time, end to end delay by using Cisco Packet Tracer[1] and OPNET simulator. The design is implemented using ten routers with two switches and ten personal computers using a mesh topology. Author in [10] analyze EIGRP and OSPF protocol with OPNET for real time application with a focus on large, realistic and scalable networks. Lastly [11], did a comparison of OSPF and EIGRP in a small IPv6 Enterprise Network. Hence, within the best of our knowledge of the literature presented. There is yet to be a deep analysis of OSPF and EIGRP considering the scalability, resilience, and validation of simulator results with Cisco active devices.

A. Routing Information Protocol (RIP)

RIP is the first routing protocol implemented in the TCP/IP and uses the variants of the Bellman-Ford algorithm that was designed by Richard Bellman and Lester Ford in 1958[2]. They perform three functions, discovering the neighbor router addresses, downloading of the routes, and updating the routing table and the cost associated with each route. The first RIP was designed in 1969; it has three versions RIPv1, RIPv2, and RIPng. The latest version of RIPv2 and RIPng works in IPV6 autonomous based systems. The implementation of the exchange of information through the User Datagram Protocol (UDP) and each router is limited to several routers in the network around it. The RIP applies a hop count mechanism to determine the optimal path for packet routing and a maximum of 16 hops is applied to avoid routing loops in the network[2].

B. Open Shortest Path First (OSPF)

OSPF is one of the widely used link state routing protocols. It operates by routing network packets by gathering link state information from neighboring routers thus, computing a map of the network. OSPF sends different messages, which include the hello messages, link state request, updates, and database description packets[3]. OSPF operates with Dijkstra's algorithm, which focuses on the distribution of routing information in a single autonomous system. There are different versions of OSPF; the first version was designed in 1989, which is known as OSPFv1 published in RFC 1131, in 1998 the second version OSPFv2 published in RFC 2328 and in 1999, the OSPFv3 is designed specifically to accommodate the IPv6 published in RFC 5340[4]. OSPF calculations are computed periodically on the link state advertisement (LSA) received in the network and protocol information [12]. A change in the topology is detected quickly; hence, it is fast, flexible, and scalable in terms of configuration parameters. The metric represents the path cost between interfaces in OSPF and that define the speed, bandwidth from nodes to another in the network [3].

C. Enhanced Gateway Routing Protocol (EIGRP)

The Enhanced Gateway Routing Protocol is a hybrid routing protocol developed in 1994. EIGRP focuses on Classless Inter-Domain Routing/Variable length Subnet Mask, route summarization with discontinuous networks and supports load balancing across six routes to a single destination. The EIGRP is designed based on the DUAL (Diffusing Update Algorithm) algorithm and uses multicast for routing updates [13]. The DUAL algorithm is used in obtaining route freedom every time throughout different routing computation and uses the reliable transport protocol to ensure the successful delivery of each packet [13].

III. Methodology

In the design of network scenarios, there are two network topologies implemented. These topologies are used in determining the convergence time of EIGRP and OSPF routing protocol. In the analyses, design of four, six, eight till twenty routers are implemented for both Star and Mesh topologies for EIGRP and OSPF routing protocol using a network simulator and Cisco hardware equipment.

A. Star Topology

In this topology, all the devices are connected to a central hub or switch in a point-to-point connection. The advantage of this topology, it is easy to troubleshoot and isolate problems. It is easily expanded without disruption of the network topology. In this design, the use of loop backs is implemented because a star topology is based on a single network, but since routing applied to a heterogeneous network, it allows hop-to-hop transmission of data. Hence, loop back helps in creating a virtual subnet in the network and each virtual subnet has a network ID as a result making the network to be heterogeneous [14]. Fig. 1 shows a simple design of six routers with the loopback network as virtual subnets.

B. Mesh Topology

Mesh topology is a topology where all devices are connected to each other. Hence, they have a high level of redundancy. They are rarely implemented in today's networks because of the cabling cost, wiring which is complicated and the problem faced in troubleshooting the network at failure. There are two variations of mesh topology, full and partial mesh topology, in this design a partial mesh topology is implemented because of the number of ports in the routers [15]. Fig. 2 shows a diagram showing partial mesh topology designed to be used in the network.

[1] Cisco Packet Tracer: https://www.netacad.com/courses/packet-tracer
[2] RFC 2453, RIP Version 2 https://tools.ietf.org/html/rfc2453
[3] RFC 2328, OSPF Version 2 https://tools.ietf.org/html/rfc2328
[4] RFC 5340, OSPF for IPv6 https://tools.ietf.org/html/rfc5340

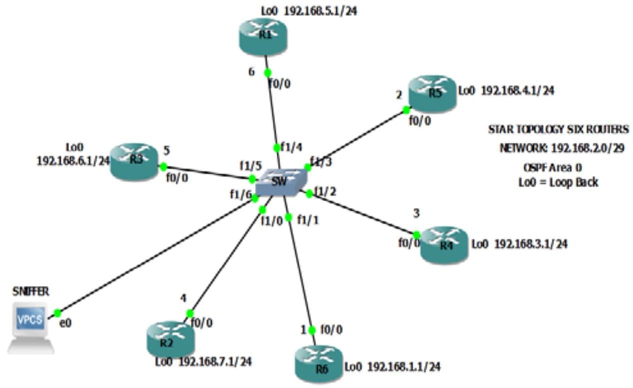

Fig. 1. Design of Star Topology for Open Shortest Path First Routing Protocol using Loop Back.

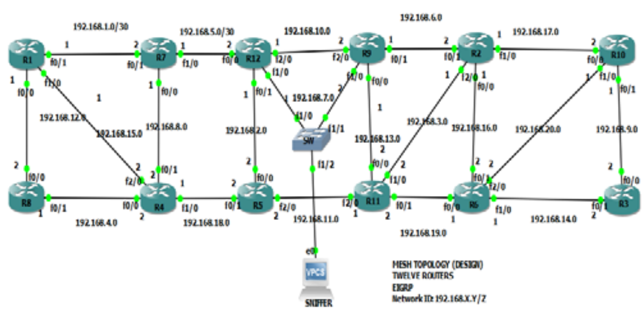

Fig. 2. Design of Mesh Topology for Enhanced Interior Gateway Routing Protocol.

IV. Design Parameters and Metrics

In the design of the EIGRP and OSPF Routing Protocols, there are parameters that are considered in the design such as the interface cost, hello interval, and maximum hops. These parameters are key in the implementation of the EIGRP and OSPF Routing Protocols in both the network simulator and hardware implementation.

A. Open Shortest Path First Routing Protocol

In the OSPF routing protocol, the cost associated with the interfaces depends on the network cables used in the design. In each of the topology designs, the interface cost is equal to one (1) because Fast Ethernet is implemented and for the hello interval ten seconds is used. The router dead interval and transmission delay are set to be 40 and one seconds respectively [16]. OSPF routing protocol does not have a maximum number of hops. See Table I for setup.

B. Enhanced Interior Gateway Routing Protocol (EIGRP)

In EIGRP, the cost associated with the interfaces is one (1) for both software and hardware implementation. Since Fast Ethernet link is used so the cost is equal to one (1) while in the hello interval is ten seconds and the hold time is three times the hello interval. The split horizon is enabled to avoid advertisement of route to the neighbor from which route was learned [17]. See Table II for setup.

C. Convergence Duration

The convergence duration occurs when all the routing tables in all the routers in each network are consistent. In OSPF, convergence duration involves the total time taken for all the routers to exchange the database description packets among the routing tables on the network. These include determining the best path and sharing the complete information in all the routers in the network. In EIGRP, the convergence time is the total time taken for the updates packets and acknowledgment packets to distribute the routing information among the different routers in the network. Furthermore, the complete time required for each router in the network to have complete information on the neighboring routers defines the convergence time. In addition, it comprises the speed of transmission and calculation of the optimal paths taken [18].

D. Convergence Startup Time

This is a measure of how fast and precise individual routers in a group or network are connected dynamically to exchange their routing among themselves for the first time in the network. This is very important because the faster the network converges the faster it can start its routing process.

E. Convergence Failure

This is a measure of how fast and precise time taken for individual routers in a network to converge dynamically or adapt to changes in the network such as node failure, loop back or any other factor that causes a network to fail.

F. Convergence New Link

This is to measure how fast and precise time taken for individual routers in a network to converge dynamically or recover from changes in the network as a result of adding a new link or nodes. Hence, in the addition of a new link or node, the convergence time will be changed [19], owing to determination of the new convergence time.

TABLE I. Design Parameters Value for OSPF Routing Protocol

Parameters	**Implemented**
Interface Cost	1.00
Hello Interval	10.00 seconds
Router Dead Interval	40.00 seconds
Transmission Delay	2.00 seconds
Retransmission Interval	5.00 seconds
Number of Hops	Unlimited

TABLE II. Design Parameters Value for Enhanced Interior Gateway Routing Protocol

Parameters	**Implemented**
Interface Cost	1.00
Hello Interval	10.00 seconds
Hold Time	30.00 seconds
Split Horizon	Enabled
Number of Hops (limited)	100

G. Graphical Network Simulator (GNS3)

GNS3[5] (1.5.4) is an open source software with no limitation of the number of devices that will be used in the environment. It mimics a real-time network scenario simulation for pre-deployment without the need for hardware. Omnet++, NS2, and OPNET are also powerful open source software that can be used in designing network models. They are built on the platform of a discrete event simulator. Which is used in networking research and provides a comprehensive development environment to support user-defined models [18]. However, GNS3 comes with an inbuilt Wireshark for packet capturing and monitoring.

H. Wireshark

Wireshark[6] is a powerful computer software used for network packet analyzer. The network packet analyzer verifies and captures network packets and displays comprehensive information of the packet data. Some useful features include capturing live packet data, displaying packets with detailed information, filter packets, search, and create various statistics about the packet data. In this work, Wireshark comes inbuilt with GNS3, making the capture of the packet data to be more realistic and effective than using extra hardware to capture the information of the packets [20]. Wireshark is proposed ahead of other monitoring devices because it captures network failures, recovery, and jitter performance of the two protocols. Therefore, Wireshark is used in the hardware implementation and importantly, Wireshark does not require any external component for the capturing of packets [20].

I. Cisco Packet Tracer

The Cisco Packet[7] Tracer is an innovative network and technology tool developed by Cisco Networking Academy. It provides a combination of realistic simulation and visualization experiences for different user's collaborations. In this work, it is used in designing the network topology that will be used for analysis or reference models.

V. Wireshark Result

The Wireshark results helps in checking the network configuration, a design implemented using the EIGRP and OSPF routing protocol. The results monitored or obtained are expected to mimic most of the characteristics highlighted in the background knowledge of OSPF and EIGRP.

A. Open Shortest Path First Routing Protocol Result

The convergence startup time is the duration of the first Database description till the last link-state acknowledgement packets are displayed in Fig. 3.

The database description provides information of each router in the network. Wireshark monitors the entire exchange of the packets in the different topology designed in the network. The results show the Hello, Database Description packets when implementing OSPF (Simulator). The link-state request, updates, and acknowledgment operate synonymously. The link-state request sends a specific request to nodes in the network when the request is sent. The network updates itself to identify the changes in topology and reply with an acknowledgment.

B. Enhanced Interior Gateway Routing Protocol Result

The Enhanced Interior Gateway Routing Protocol packets are different from the ones obtained in Open Shortest Path First Routing Protocol. The convergence duration occurs when the hello packets have been distributed in the entire nodes in the network followed by the updates and acknowledgement packets. The monitoring software (Wireshark) captures all the Hello, updates and acknowledgment packets in the network that leads to convergence between the routers. Enhanced Interior Gateway Routing Protocol operates such that whenever there are changes in the link or nodes in the network, it will send out a query packet that will have an equivalent reply. This occurs because of a shutdown or failure in any of the links or nodes (routers) in the network. The result is shown in Fig. 4.

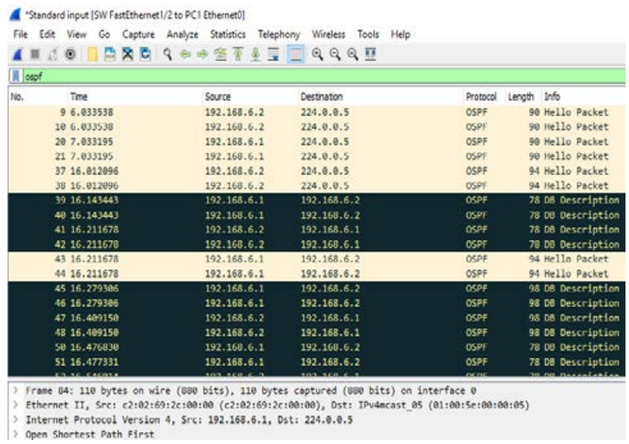

Fig. 3. Wireshark Results of updates and Acknowledgement Packets for OSPF.

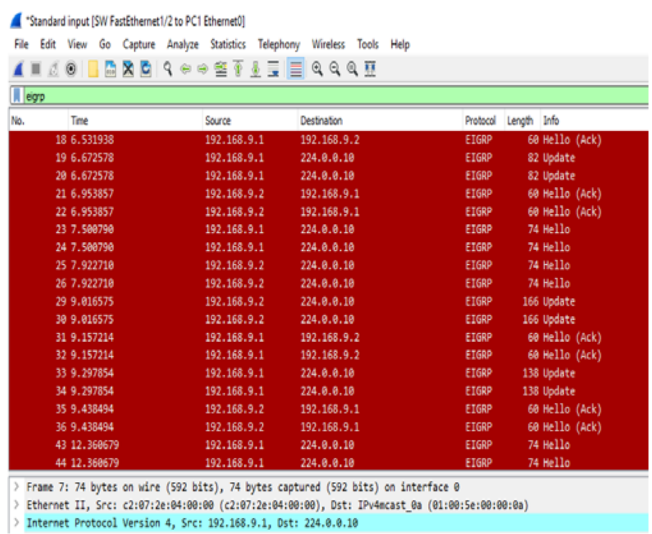

Fig. 4. Wireshark Results of updates and Acknowledgement Packets for EIGRP.

[5] https://gns3.com/
[6] https://www.wireshark.org/
[7] https://www.netacad.com/courses/packet-tracer

VI. Result and Discussion

In the design of the EIGRP and OSPF Routing Protocols, two topologies are examined (Star and Partial Mesh) which are widely used in today's networking for both software and hardware implementation.

A. OSPF Routing Protocol (Star Topology) Software

The average convergence duration at the start of the network and when one of the links fail of star topology using OSPF increases as the number of resources increases. The results shows that when the number of routers is less than ten (10), it takes less than 15.5 milliseconds for the routers to converge, the same occurs when one of the links fails in any of the designs. Meanwhile, when a new link is installed in the network, it requires a longer time to converge, though this does not transpire in all cases, see Fig. 5.

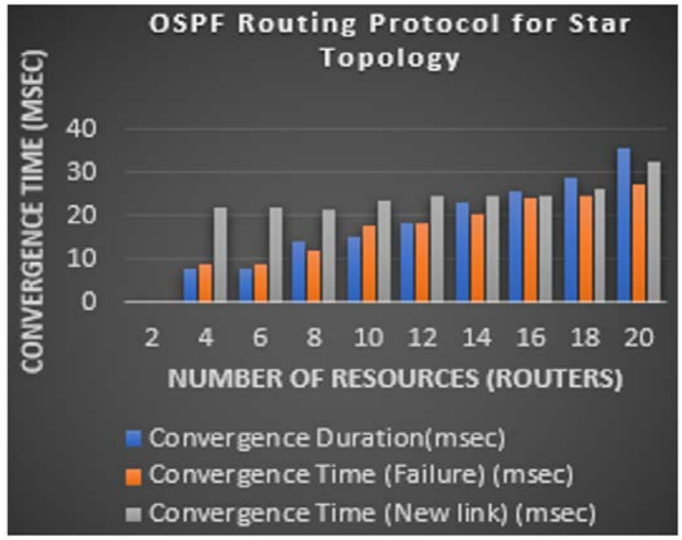

Fig. 5. OSPF Results for Star Topology – Software.

B. OSPF Routing Protocol (Mesh Topology) Software

The results show that when a new link is added to the network, it requires less time for the network to converge. More than 90% of the time, it requires less than 20 milliseconds for the network to converge when new nodes are added. The time required for the network to converge at a start and when a link fails are relatively the same. Moreover, it takes less than 9% of the time for the difference between the convergence time at the start and when a link fails in each of the numbers of resources. Furthermore, the result obtained shows that mesh topology takes a longer time to converge at the start and when there is a link failure especially as the number of routers increases in the network, see Fig. 6.

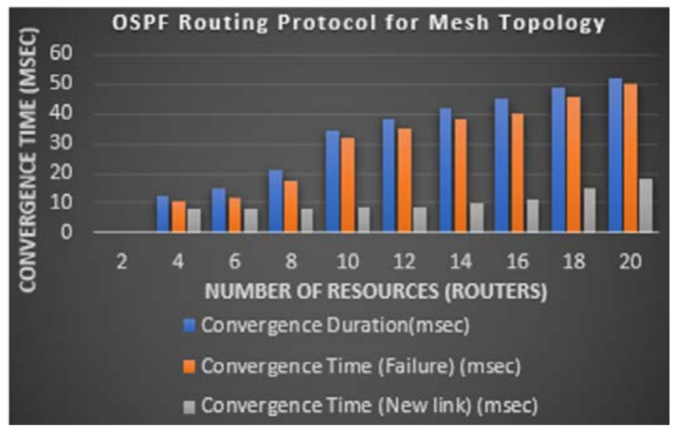

Fig. 6. OSPF Results for Mesh Topology – Software.

C. OSPF Routing Protocol (Star Topology) Hardware

The result is the same as the simulated result obtained in (A) above, just a slight difference which is negligible. When the number of routers is twelve (12) the convergence time is 19.85 milliseconds which is slightly higher than the simulator results with 1.2 milliseconds. Whereas when a link fails, the time required for it to re-converge is 20.23 milliseconds which is approximately 20.0 milliseconds. When a new node is added to the network the time difference between the simulated and hardware result is 3 milliseconds. The GNS3 result is slightly different from the hardware result with about 10% which might be from errors of configuration or computer bugs that is associated with GNS3, see Fig. 7.

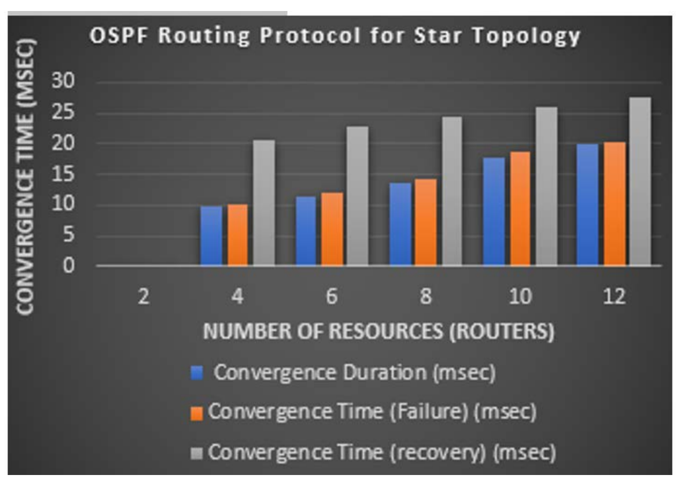

Fig. 7. OSPF Results for Star Topology (Hardware).

D. OSPF Routing Protocol (Mesh Topology) Hardware

The time taken for the convergence duration is high when compared with the simulator results obtained. When a new link is added to the network, it takes 17.85 milliseconds for the network to converge while in the simulator is 8.98 milliseconds. Furthermore, the results obtained in the hardware simulation have a stable slope and consistent trend than the results obtained using GNS3. In each of the network scenarios or number of resources the convergence duration, the time when a link fails, and new links are added to the network is higher in the hardware implementation than the simulator results obtained, see Fig. 8.

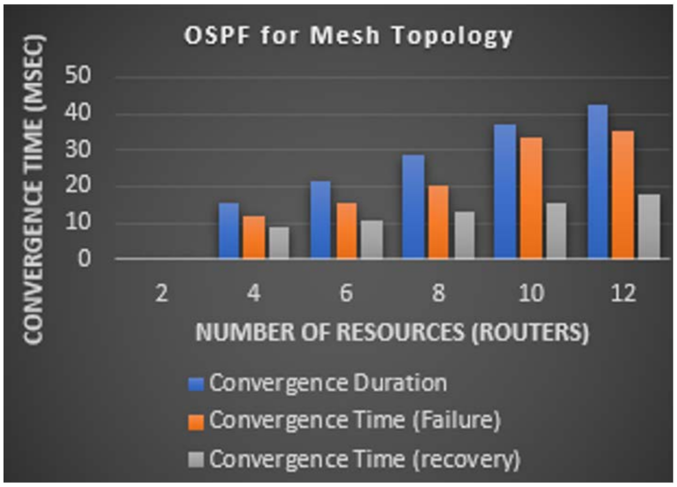

Fig. 8. OSPF Results for Mesh Topology (Hardware).

E. EIGRP (Star Topology) Software

The result obtained is consistent all through the different convergence time. It takes an average of 5.25 milliseconds for the network to converge, the same time it requires when a link fails, or a new link is added to the network. Furthermore, it takes an average of 26.25 milliseconds for the network to converge when a link fails or when a new link is added to the network when the number of resources is twenty 20 (maximum). The results indicate that the higher the resources the slower the network takes to converge in each network scenario. The average convergence time in EIGRP is faster compared to the OSPF routing protocol when using the same number of resources, settings, and devices, see Fig. 9.

F. EIGRP (Mesh Topology) Software

The results described the mesh topology to have the best convergence duration, time when a link failure and new links are added to the network. It takes an average of 1.8milliseconds for the network to converge when the number of resources is 4. The same time (1.8milliseconds) is required when a link fails, or a new link is added to the network. The results describe that as the number of resources increases, the convergence time increases representing a straight-line graph, see Fig. 10. Furthermore, the results described that EIGRP has a higher convergence period or performance in all the network scenarios than any of the topologies implemented in simulated and hardware devices.

G. EIGRP (Star Topology) Hardware

Considerably, it takes a longer time for the network to converge compared to when a link is shut, or a new link is added to the network. It requires an average of 17.54milliseconds for the network to converge at the beginning while it requires less than 14.00milliseconds to converge when a link failure or a new link is added to the network, see Fig. 11. This might be because of the implementation of virtual subnets (loop back) in the star topology. On the average, the results obtained from the hardware implementation are better than the simulator with about 10% in terms of convergence duration, the time when a link fails, and a new link is added to the network.

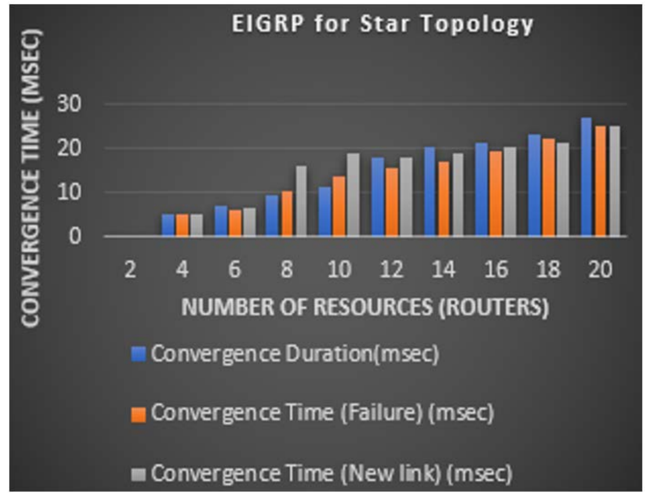

Fig. 9. EIGRP Result for Star Topology (Software).

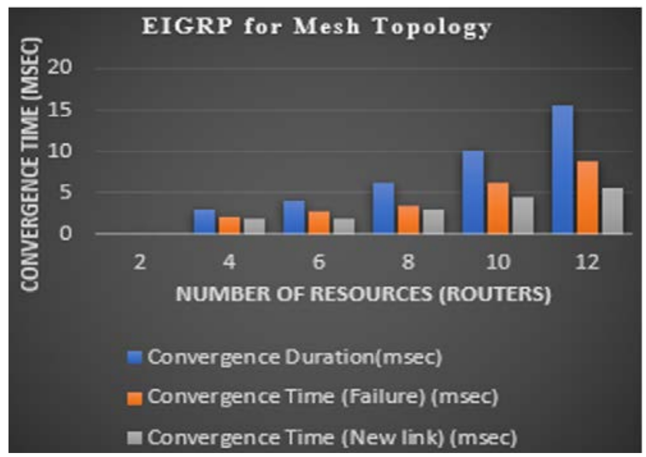

Fig. 10. EIGRP Result for Mesh Topology (Software).

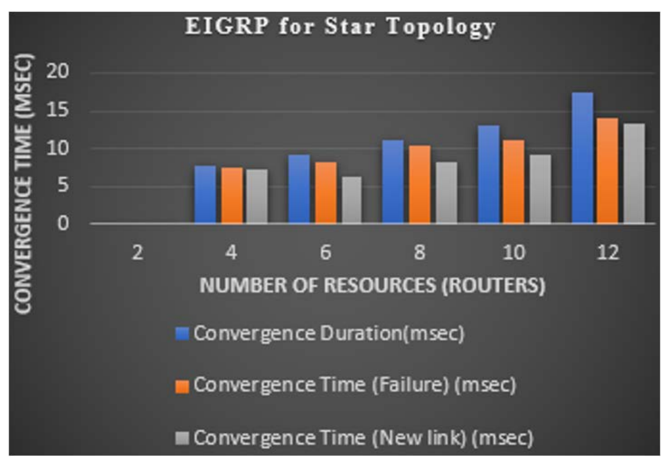

Fig. 11. EIGRP Result for Star Topology (Hardware).

H. EIGRP (Mesh Topology) Hardware

The mesh topology using the EIGRP provides the best performance for convergence duration, the time when a link fails, and new links are added to the network. The hardware results obtained are not different from the simulator results. The slight difference occurs in the convergence duration with about 3.0 milliseconds when the network is flooded with twelve routers. Because the convergence time of the failure of a link and when a new link is added does not change. The results indicate that EIGRP performs better in convergence time since both software and hardware implementation provides less than 10.0milliseconds for the network to converge when a link fails, and a new link added to the network, see Fig. 12.

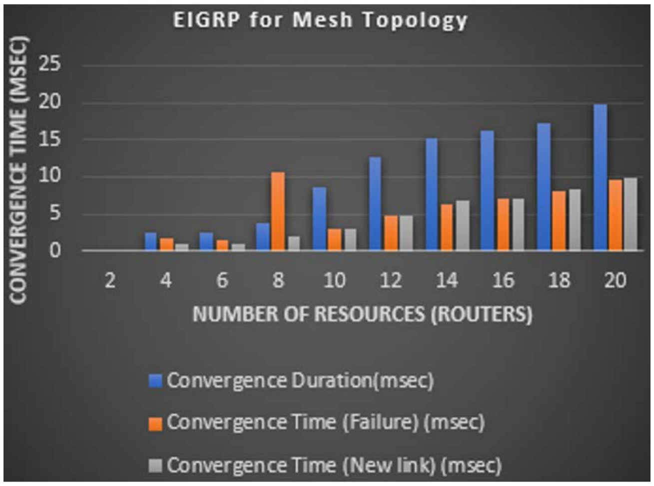

Fig. 12. EIGRP Result for Mesh Topology (Hardware).

VII. Conclusion

A reflective summary of these experiments enables the justification and analyses of EIGRP and OSPF routing protocol using GNS3 and Cisco IOS devices using different network scenarios. The EIGRP uses DUAL which helps in recalculating a given route globally to avoid routing loop, so it has the attributes of a link state and distance vector routing protocol. This ensures a faster convergence time in all the topologies when using GNS3 and Cisco IOS devices. This experiment contributes to the existing knowledge by identifying that: mesh topology has the best topology for convergence time ahead of star topology. Based on the result obtained, it clearly states that hardware implementations of routing protocol are better than using a network simulator. Because the network simulator has computer bugs, runtime failure, updates and simulation errors which influence the results obtained when implementing EIGRP and OSPF routing protocol. The conclusion described in the network scenarios indicates that EIGRP has a higher performance in convergence duration, the time when a link fails, and new links added to the network than OSPF routing protocol. This is because EIGRP does not perform routing updates that require longer time compared to the OSPF routing protocol.

Also, this research cannot be limited to only OSPF and EIGRP, further analysis to BGP comparison with the above protocol to see their different performance will be a good research. Also, with the transition from IPV4 to IPV6, research on how the protocol changes or adaptation in terms of convergence time with the versions of IPV4 and IPV6 can be examined. Finally, the Latency and Quality of Service are vital areas of research in both EIGRP and OSPF routing protocol.

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