Emerging Information Science and Technology
Vol. 3, No. 2, (2022), pp. 66-77

Evaluating the Hybrid Multi-Protocol Label Switching (MPLS) on the Enhanced Interior Gateway Routing Protocol (EIGRP)

Ridho Novradinata*, Slamet Riyadi, and Ronald Adrian

Universitas Muhammadiyah Yogyakarta, Jln.Brawijaya, Tamantirto, Kasihan,
Bantul, Yogyakarta 55183, Indonesia
**Corresponding author: ridho.n.ft16@mail.umy.ac.id*

Abstract

The development of technology and communication is expanding rapidly. In this case, the internet has become a vital necessity in globalization. Technological innovations are required to create a seamless, fast, and secure communication system. This research aims to evaluate the Enhanced Interior Gateway Routing Protocol (EIGRP) implementation by applying the Multiprotocol Label Switching (MPLS) technology. This study adhered to several stages in the Network Development Life Cycle (NDLC) method. The results of the two technology combinations, EIGRP and MPLS, demonstrated MPLS network simulation testing in several dynamic routing systems: EIGRP and OSPF, identified through the Quality of Service (QoS) value. It revealed that the best performance was EIGRP with a throughput of 2152.5 bps, delay of 335.6 ms, and jitter of 411 ms. Furthermore, MPLS and EIGRP network redundancy was better applied in the mesh topology with a multi or backup link than in the linear topology with a single link.

Keywords: *Enhanced Interior Gateway Routing Protocol (EIGRP), linear topology, mesh topology, Multiprotocol Label Switching (MPLS), Quality of Service (QoS)*

1. Introduction

The rapid advancement of Indonesian Information Technology (IT) and competition in the globalization era require innovations that can benefit the community. Computer networks require routing as communication lines between routers. The routing types include dynamic and static routing. Dynamic routing is inseparable from operational time efficiency. It differs from static routing, which requires routing reconfiguration when a problem occurs on the link connecting routers in a communication system.

This research focused on using the Enhanced Interior Gateway Routing Protocol (EIGRP) [1]. EIGRP was utilized for its better performance than other types of dynamic routing. The deterministic algorithm of the best EIGRP route is better than that of other types of dynamic routing. Besides, EIGRP has less source memory when performing the routing process. Meanwhile, Multi-Protocol Label Switching (MPLS) [2] is a forwarding packet on a high-speed backbone network, of which the working mechanism is created from a combination between circuit-switching and packet-switching by adopting the advantages of the two technologies.

Furthermore, the availability of a fast and secure internet connection is indispensable to support reliable communication. Research on evaluating the Quality of Service (QoS) performance of MPLS on EIGRP has been conducted. However, the results are incomplete. Therefore, this study aims to evaluate the performance of MPLS implementation on EIGRP more comprehensively.

EIGRP routing is one of the types of dynamic routing that is used in building a communication system/internet network system in several agencies. In previous studies, EIGRP routing has been shown to obtain better performance compared to other types of dynamic routing, such as: OSPF and RIPv2 [3].

As technology develops, it is felt that EIGRP routing can be combined with other technologies to obtain better performance results. As for previous research that is felt to be used as a technology to improve the performance of EIGRP routing which is the best choice of several other types of dynamic routing. Discussion of technologies that can improve the performance of EIGRP routing, in a study entitled "Analysis Comparison Of QoS MPLS And Rpr At Transport Network Of Metro Ethernet". This article discusses a comparison of QoS values on metro ethernet networks that use MPLS and RPR technology to get better throughput, delay and packet loss values by using MPLS than using RPR [4].

MPLS technology has undergone several evolutions starting in 1997 by the IETF (Internet Engineering Task Force) which formed the MPLS working group to standardize the general methods developed in MPLS technology. With the development of this technology is expected to improve network performance on a large scale. MPLS (Multi-Protocol Label Switching) is a network architecture developed by the IETF (Internet Engineering Task Force) to integrate the label swapping mechanism at layer two and routing mechanism at layer three [5].

2. Method

2.1. System Development Method

In the network design, this research underwent several stages in the Network Development Life Cycle (NDLC) method [7]. It specifically focused on requirement analysis, design, and prototype simulation.

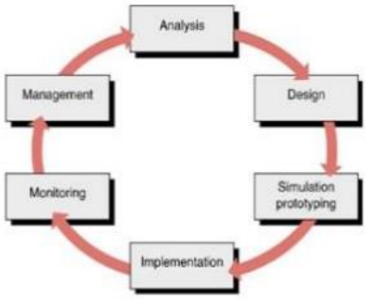


Figure 1 Network Development Life Cycle (NDLC)

2.2. Network Design with Topology

The network design included the stage for establishing and researching a network. This design was based on the requirement analysis identified in the previous phase. The most vital aspect of this design was creating the best and optimal performance in the simulation. Furthermore, the physical and logical topology was determined based on the problem formulation. Initially, an IP address had to be well-set up for network development. Then, the topology design was carried out that best fitted the problem formulation. The final stage was determining protocols for this simulation, covering the routing protocols in the IP address for linear topology with OSPF, linear topology with EIGRP, mesh topology with EIGRP, and MPLS configuration.

2.3. Prototype Simulation

This study employed the Software Development Life Cycle (SDLC) model. This simulation was performed on GNS3 software [8]. Wireshark software was applied to capture packets delivered and determine the QoS value. Furthermore, the simulation was carried out on several routing protocols, EIGRP and OSPF, to disclose the best performance. Upon identifying the routing protocol with the best performance, the simulation was demonstrated on the MPLS network with the best routing. It aimed to compare the performance between networks with MPLS with the best dynamic routing type and those without it. Afterward, the MPLS with the best dynamic routing type was run in linear and mesh topologies. Furthermore, the examination was conducted on a linear topology that applied MPLS and EIGRP by pinging from the endpoint PC1 to PC2 and carrying out bidding or packet capture using Wireshark. Subsequently, the assessment was performed on the mesh topology with the same procedure. This assessment was carried out for a minute for each pinging at several bandwidth levels: 1Mbps, 5Mbps, 10Mbps, 20Mbps, 50Mbps, and 100Mbps.

3. Results

3.1. Network Design Topology

This study employed three topology models in three scenarios; two performance testing scenarios without MPLS with OSPF and EIGRP to identify the best routing and the MPLS performance testing scenario with EIGRP. Furthermore, it analyzed the performance redundancy of each topology applying MPLS and EIGRP. In the first model, this study utilized OSPF with a linear topology to compare to EIGRP to discover the best performance that could be combined with MPLS. Figure 2 demonstrates that PC1 and PC2 were connected through a single link passing through router PE1, router P1, router P2, and router PE2, applying OSPF to communicate.

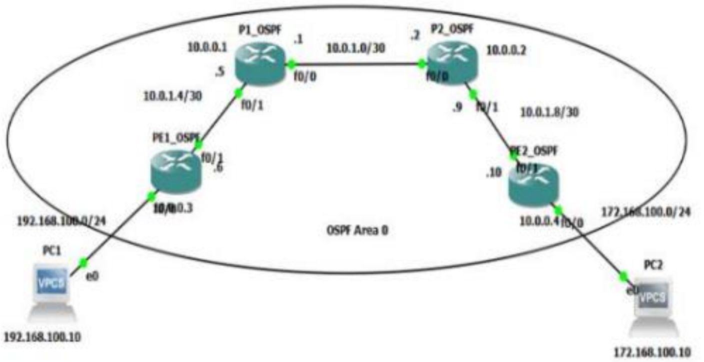


Figure 2 Linear Topology with OSPF

Meanwhile, Figure 3 displays that PC1 and PC2 were connected through a single link passing through router PE1, router P1, router P2, and router PE2, applying EIGRP.

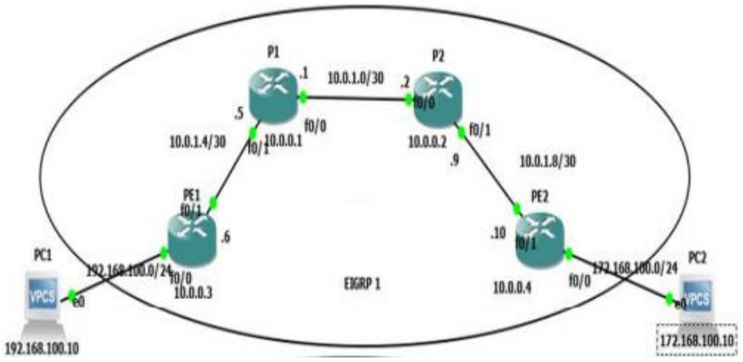


Figure 3 Linear Topology with EIGRP

MPLS and EIGRP were applied in a linear topology in the second model. Figure 4 demonstrates that PC1 and PC2 were connected via a single link, passing through router PE1, router P1, router P2, and router PE2, applying MPLS to communicate and EIGRP as the routing protocol.

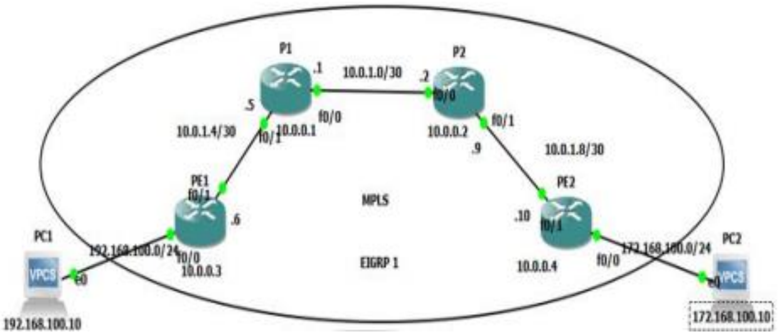


Figure 4 MPLS Linear Topology with EIGRP

Subsequently, in the third model, a mesh topology was employed. Figure 5 depicts that PC1 and PC2 were connected via a single link passing through router PE1_EIGRP. From router PE1_EIGRP to router PE2_EIGRP, two links existed, connecting router PE1_EIGRP, router P1_EIGRP, router P2_EIGRP, and router PE2_EIGRP. Router PE2_EIGRP and PC2 were connected through a single link. In this design, router PE1, router P1, router P2, and router PE2 applied MPLS to communicate and EIGRP as the routing protocol.

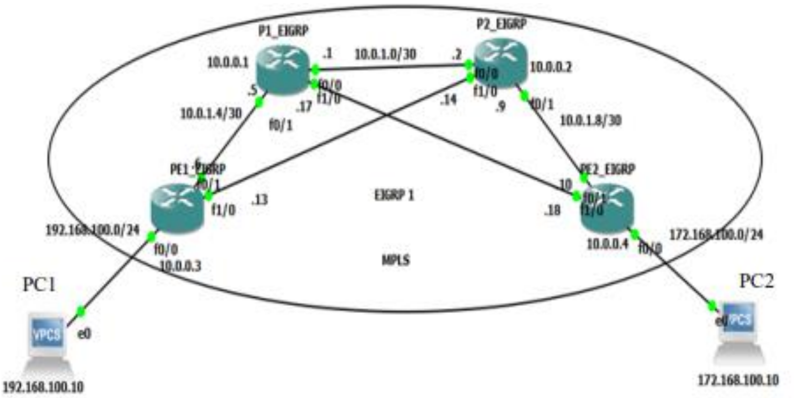


Figure 5 MPLS Mesh Topology with EIGRP

The subsequent stage was preparing the routing protocol and IP address. The routing employed referred to the ones in the previous studies. The MPLS network structure utilized EIGRP and OSPF, categorized as dynamic routing with linear and mesh topologies. Meanwhile, a list of interfaces and IP addresses in this system design are as follows.

Table 1 IP Address Configuration of Each Router Interface in Linear Topology with OSPF

Device	F0/0	F0/1	F1/0	Lo0
PE1_OSPF	192.168.100.1/24	10.0.1.6/30	10.0.1.13/30	10.0.0.3
P1_OPSF	10.0.1.1/30	10.0.1.5/30	10.0.1.17/30	10.0.0.1
P2_OSPF	10.0.1.2/30	10.0.1.9/30	10.0.1.14/30	10.0.0.2
PE2_OSPF	172.168.100.1/24	10.0.1.10/30	10.0.1.18/30	10.0.0.4

Table 2 IP Address Configuration of Each End Device

Interface in Linear Topology with OSPF

Device	Interface	IP Address
PC1	Ethernet 0	192.168.100.10/24
PC2	Ethernet 0	172.168.100.10/24

Table 3 IP Address Configuration of each router interface in Linear Topology with EIGRP

Device	F0/0	F0/1	Lo0
PE1	192.168.100.10/24	10.0.1.6/30	10.0.0.3
P1	10.0.1.1/30	10.0.1.5/30	10.0.0.1
P2	10.0.1.2/30	10.0.1.9/30	10.0.0.2
PE2	172.168.100.10/24	10.0.1.10/30	10.0.0.4

Table 4 IP Address Configuration of Each End Device Interface in Linear Topology with EIGRP

Device	Interface	IP Address
PC1	Ethernet 0	192.168.100.10/24
PC2	Ethernet 0	172.168.100.10/24

Table 5 IP Address Configuration of Each Router Interface in Mesh Topology with EIGRP

Device	F0/0	F0/1	F1/0	Lo0
PE1_OSPF	192.168.100.1/24	10.0.1.6/30	10.0.1.13/30	10.0.0.3
P1_OPSF	10.0.1.1/30	10.0.1.5/30	10.0.1.17/30	10.0.0.1
P2_OSPF	10.0.1.2/30	10.0.1.9/30	10.0.1.14/30	10.0.0.2
PE2_OSPF	172.168.100.1/24	10.0.1.10/30	10.0.1.18/30	10.0.0.4

Table 6 IP Address Configuration of Each End Device Interface in Mesh Topology with EIGRP

Device	Interface	IP Address
PC1	Ethernet 0	192.168.100.10/24
PC2	Ethernet 0	172.168.100.10/24

3.2. Prototype Simulation and Examination

The prototype simulation and examination were where the topology design was simulated in the GNS3 software. This stage was divided into three parts: a prototype simulation without MPLS in linear topology with OSPF and EIGRP, a prototype simulation with MPLS in linear topology with EIGRP, and a prototype simulation with MPLS in mesh topology with EIGRP. Furthermore, during the simulation in the GNS3 software, packet delivery from the endpoint PC1 to PC2 with several scenarios was examined. The packet capture was later conducted using the Wireshark software.

3.3. Performance Analysis Results based on Quality of Service Measurement Parameter

The measurement data were generated using Wireshark software according to QoS parameters by referring to its quality index from research entitled "Analysis of Quality of Service on Internet Networks (Case Study: UPT Jampang Kulon Mining Engineering Test Workshop – LIPI))"[4] as follows:

3.4. Throughput

Throughput refers to data transfer with speed calculated in bits per second (bps). Throughput calculation was conducted with the formula of the total packets successfully delivered at the destination point during a certain time interval, which was then divided by that time interval. The formula for throughput calculations is as follows.

$$\text{Throughput (bps)} = = \frac{Inventory\ (I) \quad Inventory\ (I)}{Time\ Interval\ (T) Time\ Interval\ (T)}$$

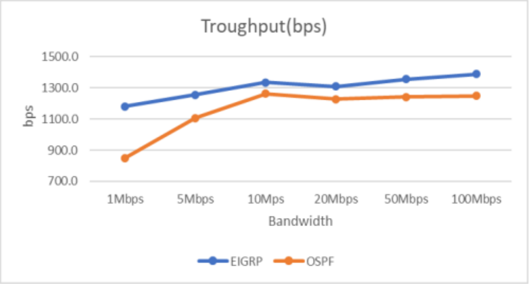


Figure 6 Throughput Measurement Results of EIGRP and OSPF

Figure 6 exhibits that the throughput results were obtained from a minute examination of ICMP packet delivery from endpoint PC1 to PC2 with several bandwidth levels: 1 Mbps, 5 Mbps, 10 Mbps, 20 Mbps, 50 Mbps, and 100 Mbps on the non-MPLS network with EIGRP and OSPF. The highest throughput value was obtained from examining the non-MPLS network with EIGRP.

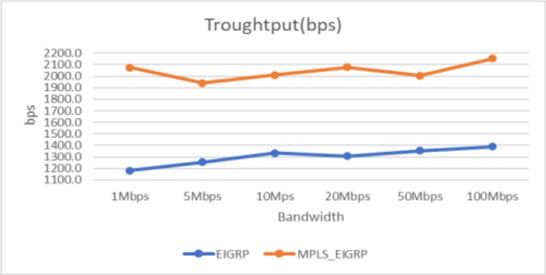


Figure 7 Throughput Measurement Results on the MPLS Network with EIGRP and the non-MPLS Network with EIGRP

A minute examination of ICMP packet delivery from endpoint PC1 to PC2 with several bandwidth levels: 1 Mbps, 5 Mbps, 10 Mbps, 20 Mbps, 50 Mbps, and 100 Mb, and EIGRP yielded throughput results as illustrated in Figure 7. The MPLS network with EIGRP depicted the greatest throughput value.

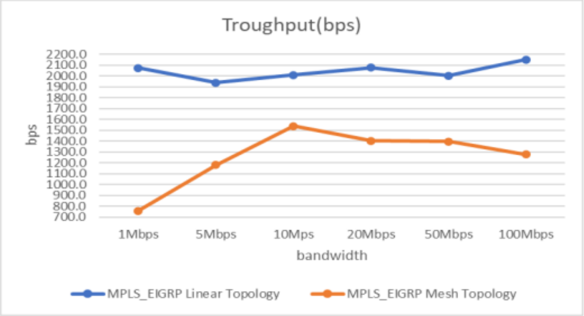


Figure 8 Throughput Measurement Results on the MPLS Network

with EIGRP in Linear and Mesh Topologies

As Figure 8 demonstrated, the throughput results were acquired from a minute examination of ICMP packet delivery from endpoint PC1 to PC2 with several bandwidth levels: 1 Mbps, 5 Mbps, 10 Mbps, 20 Mbps, 50 Mbps, and 100 Mbps on the network MPLS with EIGRP in linear and mesh topologies. The MPLS network with EIGRP in the linear topology exhibited the highest throughput value.

3.5. Delay

The time allocated to travel from the origin to the destination point can be affected by distance, physical media, congestion, and long processing times. The delay (Latency) was calculated with the following formula.

$$\text{Delay} = \frac{Total\ Delay \qquad Total\ Delay}{Total\ Packet\ ReceivedTotal\ Packet\ Received}$$

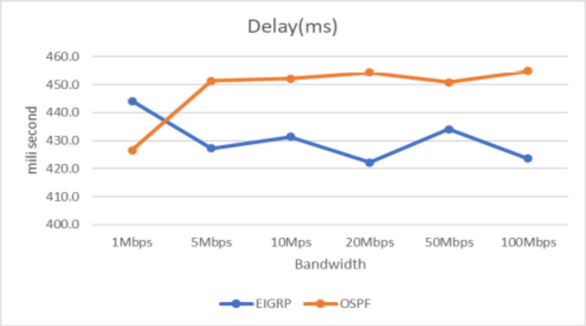


Figure 9 Results of EIGRP and OSPF Delay Calculation

A minute examination of ICMP packet delivery from endpoint PC1 to PC2 with several bandwidth levels: 1 Mbps, 5 Mbps, 10 Mbps, 20 Mbps, 50 Mbps, and 100 Mbps on the non-MPLS network with EIGRP and OSPF produced delay values as displayed in Figure 9. The best delay was obtained from examining the non-MPLS network with EIGRP.

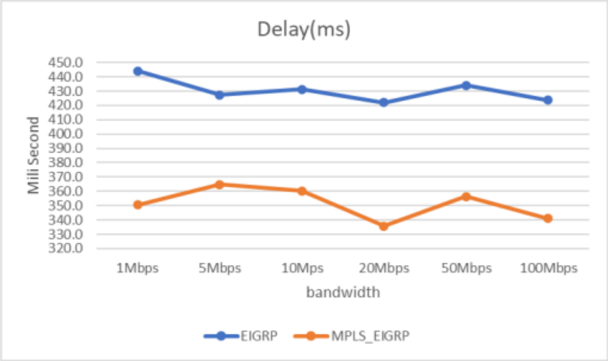


Figure 10 Results of Delay Calculation on the MPLS network with EIGRP and the non-MPLS network with EIGRP

Figure 10 exhibits that the delay results were generated from a minute examination of ICMP packet delivery from endpoint PC1 to PC2 with several bandwidth levels: 1 Mbps, 5 Mbps, 10 Mbps, 20 Mbps, 50 Mbps, and 100 Mbps on the MPLS network with EIGRP and the non-MPLS network with EIGRP. The MPLS network with EIGRP yielded the best delay.

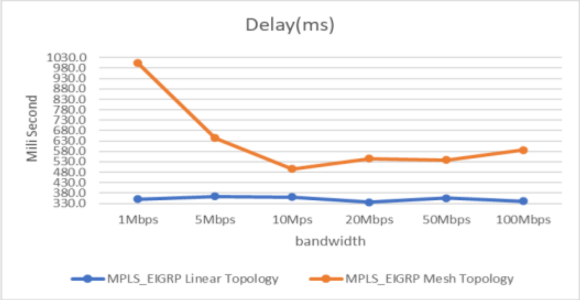


Figure 11 Results of Delay Calculation on the MPLS Network with EIGRP in Linear and Mesh Topologies

Figure 11 demonstrates that the delay results obtained from a minute examination of ICMP packet delivery from endpoint PC1 to PC2 with several bandwidth levels: 1 Mbps, 5 Mbps, 10 Mbps, 20 Mbps, 50 Mbps, and 100 Mbps on the MPLS network with EIGRP in linear and mesh topologies. The best delay was obtained from examining the MPLS network with EIGRP in the linear topology.

3.6. Jitter

Several aspects can influence jitters, such as variations in time delay, data processing time, and the packet recollecting time at the destination point. The jitter was calculated using the following formula.

$$\text{Jitter} = \frac{Total\ Delay\ VariationTotal\ Delay\ Variation}{Total\ Packet\ ReceivedTotal\ Packet\ Received}$$

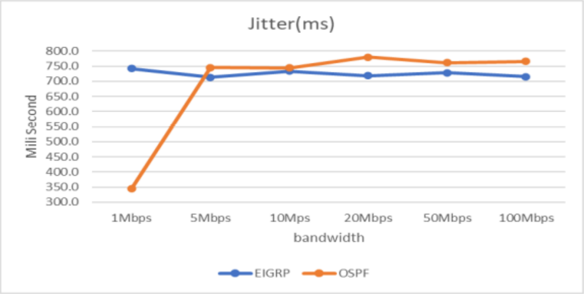


Figure 12 EIGRP and OSPF Jitter Measurement Results

Figure 12 displays the jitter results generated from a minute examination of ICMP packet delivery from the endpoint PC1 to PC2 with several bandwidth levels: 1 Mbps, 5 Mbps, 10 Mbps, 20 Mbps, 50 Mbps, and 100 Mbps on the non-MPLS network with EIGRP and OSPF. The non-MPLS network with EIGRP produced the best jitter.

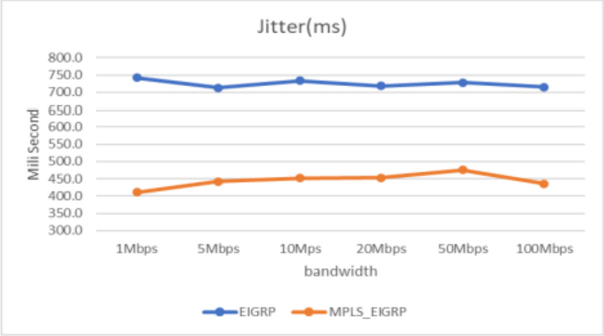


Figure 13 Results of Jitter Measurement on the MPLS Network

with EIGRP and Non-MPLS Network with EIGRP

A minute examination of ICMP packet delivery from the endpoint PC1 to PC2 with several bandwidth levels: 1 Mbps, 5 Mbps, 10 Mbps, 20 Mbps, 50 Mbps, and 100 Mbps on the MPLS network with EIGRP and the non-MPLS network with EIGRP yielded jitter results as demonstrated in Figure 13. The best jitter value was acquired from examining the MPLS network with EIGRP.

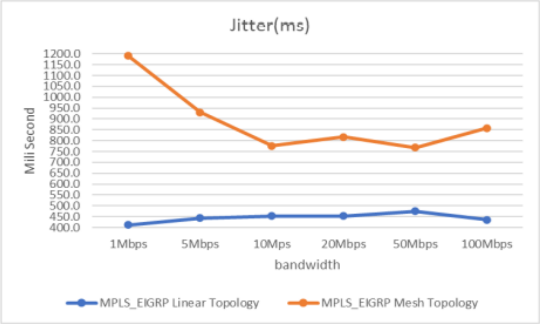


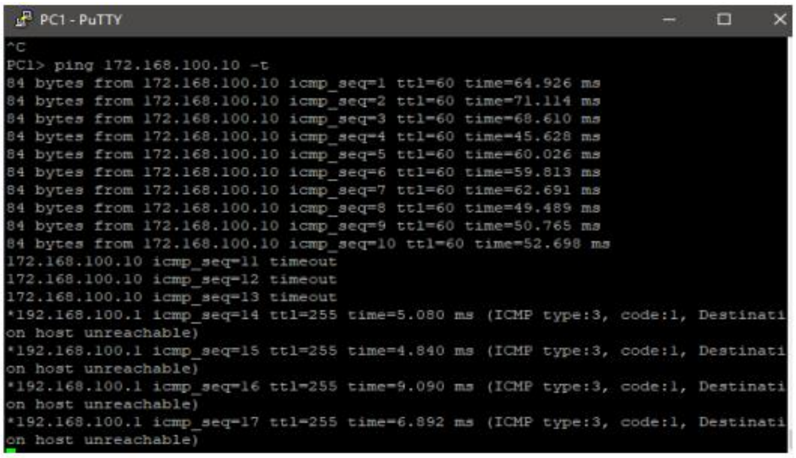
Figure 14 Results of Jitter Measurement on the MPLS Network

with EIGRP in Linear and Mesh Topologies

Figure 14 depicts the Jitter results obtained from a minute examination of ICMP packet delivery from the endpoint PC1 to PC2 with several bandwidth levels: 1 Mbps, 5 Mbps, 10 Mbps, 20 Mbps, 50 Mbps, and 100 Mbps on the MPLS network with EIGRP in linear and mesh topologies. The MPLS network with EIGRP in the linear topology produced the best jitter.

3.7. Results of Performance Analysis based on Redundancy Parameters

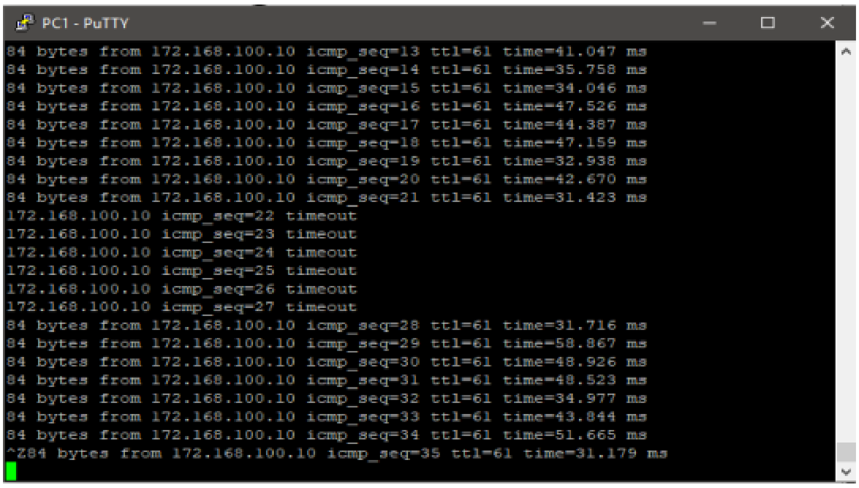
Redundancy in a network is required to support the operation without any obstacles [9,10]. It is one of the topics identified in this study, as it becomes the key to the reliability or performance of a network examined in two scenarios. Figure 15 displays that when one link was disconnected on the MPLS network with EIGRP in the linear topology, the data transfer on the network was discontinued without any backup or alternative routes. In contrast to Figure 16, when one link was disconnected on the MPLS network with EIGRP in the mesh topology, the data transfer was temporarily suspended until the router discovered a backup or alternative route, and the data transfer was re-processed without any obstacles in the operating network.



```
^C
PC1> ping 172.168.100.10 -t
84 bytes from 172.168.100.10 icmp_seq=1 ttl=60 time=64.926 ms
84 bytes from 172.168.100.10 icmp_seq=2 ttl=60 time=71.114 ms
84 bytes from 172.168.100.10 icmp_seq=3 ttl=60 time=68.610 ms
84 bytes from 172.168.100.10 icmp_seq=4 ttl=60 time=45.628 ms
84 bytes from 172.168.100.10 icmp_seq=5 ttl=60 time=60.026 ms
84 bytes from 172.168.100.10 icmp_seq=6 ttl=60 time=59.813 ms
84 bytes from 172.168.100.10 icmp_seq=7 ttl=60 time=62.691 ms
84 bytes from 172.168.100.10 icmp_seq=8 ttl=60 time=49.489 ms
84 bytes from 172.168.100.10 icmp_seq=9 ttl=60 time=50.765 ms
84 bytes from 172.168.100.10 icmp_seq=10 ttl=60 time=52.698 ms
172.168.100.10 icmp_seq=11 timeout
172.168.100.10 icmp_seq=12 timeout
172.168.100.10 icmp_seq=13 timeout
*192.168.100.1 icmp_seq=14 ttl=255 time=5.080 ms (ICMP type:3, code:1, Destinati
on host unreachable)
*192.168.100.1 icmp_seq=15 ttl=255 time=4.840 ms (ICMP type:3, code:1, Destinati
on host unreachable)
*192.168.100.1 icmp_seq=16 ttl=255 time=9.090 ms (ICMP type:3, code:1, Destinati
on host unreachable)
*192.168.100.1 icmp_seq=17 ttl=255 time=6.892 ms (ICMP type:3, code:1, Destinati
on host unreachable)
```

Figure 15 Redundancy Examination Results in the Link

Discontinuation of Linear Topology



```
84 bytes from 172.168.100.10 icmp_seq=13 ttl=61 time=41.047 ms
84 bytes from 172.168.100.10 icmp_seq=14 ttl=61 time=35.758 ms
84 bytes from 172.168.100.10 icmp_seq=15 ttl=61 time=34.046 ms
84 bytes from 172.168.100.10 icmp_seq=16 ttl=61 time=47.526 ms
84 bytes from 172.168.100.10 icmp_seq=17 ttl=61 time=44.387 ms
84 bytes from 172.168.100.10 icmp_seq=18 ttl=61 time=47.159 ms
84 bytes from 172.168.100.10 icmp_seq=19 ttl=61 time=32.938 ms
84 bytes from 172.168.100.10 icmp_seq=20 ttl=61 time=42.670 ms
84 bytes from 172.168.100.10 icmp_seq=21 ttl=61 time=31.423 ms
172.168.100.10 icmp_seq=22 timeout
172.168.100.10 icmp_seq=23 timeout
172.168.100.10 icmp_seq=24 timeout
172.168.100.10 icmp_seq=25 timeout
172.168.100.10 icmp_seq=26 timeout
172.168.100.10 icmp_seq=27 timeout
84 bytes from 172.168.100.10 icmp_seq=28 ttl=61 time=31.716 ms
84 bytes from 172.168.100.10 icmp_seq=29 ttl=61 time=58.867 ms
84 bytes from 172.168.100.10 icmp_seq=30 ttl=61 time=48.926 ms
84 bytes from 172.168.100.10 icmp_seq=31 ttl=61 time=48.523 ms
84 bytes from 172.168.100.10 icmp_seq=32 ttl=61 time=34.977 ms
84 bytes from 172.168.100.10 icmp_seq=33 ttl=61 time=43.844 ms
84 bytes from 172.168.100.10 icmp_seq=34 ttl=61 time=51.665 ms
^Z84 bytes from 172.168.100.10 icmp_seq=35 ttl=61 time=31.179 ms
```

Figure 16 Redundancy Examination Results in the Link

Discontinuation of Mesh Topology

Following Figures 15 and 16 regarding the redundancy performance examination on the MPLS network with EIGRP, the mesh topology generated a better redundancy performance than the linear topology.

4. Conclusion

This study's design, simulation, and analysis results implied that the Naïve Bayes algorithm could be utilized to predict the enrollment of prospective students at Universitas Muhammadiyah Yogyakarta.

1. EIGRP demonstrated the best performance in the MPLS network simulation examination by identifying the QoS value.
2. Examining the non-MPLS network with EIGRP and the MPLS network with EIGRP based on QoS parameters generated the following throughput, delay, and jitter values.
    a. The throughput examination obtained the highest number of bits successfully received at the destination point: 1388 bps in the non-MPLS network with EIGRP and 2152 bps in the MPLS network with EIGRP. In short, the MPLS network with EIGRP produced a better result than the non-MPLS network with EIGRP.
    b. The delay examination obtained the smallest value at each bandwidth level set at the two network scenarios: 422.2 ms in the non-MPLS network with EIGRP and 335.6 ms in the MPLS network with EIGRP. In other words, the MPLS network with EIGRP yielded a better result than the non-MPLS network with EIGRP.
    c. The Jitter examination acquired the smallest value at each bandwidth level set in the two network scenarios: 713 ms in the non-MPLS network with EIGRP and 411 ms in the MPLS network with EIGRP. In conclusion, the MPLS network with EIGRP gained a better result than the non-MPLS network with EIGRP.
3. The examination of the MPLS network with EIGRP on linear and mesh topologies based on QoS parameters disclosed the following throughput, delay, and jitter values.
    a. The throughput examination obtained the highest number of bits successfully received at the destination point and set at the two network scenarios: 2152.5 bps in the MPLS network with EIGRP in the linear topology and 1539 bps in the MPLS network with EIGRP in the mesh topology. Therefore, the linear topology possessed the best performance.
    b. The delay examination acquired the smallest value at each bandwidth level set at the two network scenarios: 335.6 ms of the MPLS network with EIGRP in the linear topology and 495.2 ms of the MPLS network with EIGRP in the mesh topology. Hence, the linear topology depicted the best performance.
    c. The Jitter examination generated the smallest value at each bandwidth level set at the two network scenarios: 411.0 ms of the MPLS network with EIGRP in the linear topology and 767.5 ms of the MPLS network with EIGRP in the mesh topology. Thus, the linear topology exhibited the best performance.
4. Following the redundancy aspect, the MPLS network with EIGRP in the mesh topology demonstrated a better performance than the MPLS network with EIGRP in the linear topology due to the multi or backup links of the mesh topology. Meanwhile, the linear topology only possessed a single link.

References

[1] Malhotra, Ravi. "Enhanced Interior Gateway Routing Protocol (EIGRP)." IP Routing, O'Reilly Media Publisher (2002): 70.

[2] Le Faucheur, Francois, et al. Multi-protocol label switching (MPLS) support of differentiated services. No. rfc3270. 2002.

[3] Dey, G.K., Ahmed, Md.M., Ahmmed, K.T., 2015. Performance analysis and redistribution among RIPv2, EIGRP & OSPF Routing Protocol, in: 2015 International Conference on Computer and Information Engineering (ICCIE). Presented at the 2015 International Conference on Computer and Information Engineering (ICCIE), IEEE, Rajshahi. Bangladesh, pp. 21–24. https://doi.org/10.1109/CCIE.2015.7399308(diakses pada 19 Maret 2020).

[4] Sitorus, H.S., n.d. Analisis Perbandingan QoS MPLS dan RPR pada Jaringan Transport Metro Ethernet 4.

[5] Rahmawati, I.D., Saleh, A., Winarno, I., 2011. Analisa QoS pada Jaringan MPLS IPv6 Berbasis Routing OSPF. EEPIS Final Project.

[6] Wulandari, R., 2016. Analisis QoS (Quality Of Service) Pada Jaringan Internet (Studi Kasus : Upt Loka Uji Teknik Penambangan Jampang Kulon – LIPI). JuTISI 2. https://doi.org/10.28932/jutisi.v2i2.454 (diakses pada 22 Maret 2020).

[7] Rianafirin, Kartika, and Mochamad Teguh Kurniawan. "Design network security infrastructure cabling using network development life cycle methodology and ISO/IEC 27000 series in Yayasan Kesehatan (Yakes) Telkom Bandung." 2017 4th International Conference on Computer Applications and Information Processing Technology (CAIPT). IEEE, 2017.

[8] Neumann, Jason C. The book of GNS3: build virtual network labs using Cisco, Juniper, and more. No Starch Press, 2015.

[9] Costa, Daniel G., Francisco Vasques, and Paulo Portugal. "Enhancing the availability of wireless visual sensor networks: Selecting redundant nodes in networks with occlusion." Applied Mathematical Modelling 42 (2017): 223-243.

[10] Blum, Jeremy J., Azim Eskandarian, and Lance J. Hoffman. "Challenges of intervehicle ad hoc networks." IEEE transactions on intelligent transportation systems 5.4 (2004): 347-351.