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INTERIOR GATEWAY PROTOCOL ROUTING PERFORMANCE COMPARISON OF THE VIRTUAL PRIVATE NETWORK BASED ON MULTI PROTOCOL LABEL SWITCHING AND DIRECT-LINK BACKUP

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Abstract -- *The stability and convergence time become an essential factor in network availability performance. Multiprotocol Label Switching (MPLS) is one of the Virtual Private Network (VPN) technologies that can support the quality of communication media on the high-speed backbone network. Therefore, it is necessary to determine the proper protocol routing in espousing VPN technology based on MPLS supported by direct-link backup to improve network availability in the Data Center. The purpose of this study is comparing the convergence time and Quality of Service (QoS) among the three IGP protocols routing, namely Routing Information Protocol version 2 (RIP), Open Shortest Path First (OSPF), and Enhanced Interior Gateway Routing Protocol (EIGRP) based on two autonomous system number using Ring topology design between Data Center and DRC. Network scenario is created using the Graphic Network Simulator (GNS3) application to measure convergence time and QoS parameters of the three protocols routing and the use of MPLS-TE and RR in enhancing MPLS backbone performance. The results revealed that QoS in the three protocols routing has a good quality level according to TIPHON's standard with the number of indexes up to 3.25 (Good). On the other hand, the fastest convergence time when interruption on the main link (VPN) is EIGRP with convergence time for about 15 seconds.*

Keywords: *Convergence Time; QoS; IGP; MPLS; Ring Topology*

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INTRODUCTION

Virtual Private Network (VPN) is defined as a private data network that utilizes public network infrastructure, maintains privacy through the use of tunneling and security protocols [1]. That technology is an important part of considering the network security aspects of public network infrastructure [2, 3, 4, 5]. In this study, we implemented VPN technology based on Multi-Protocol Label Switching (MPLS) used by the service provider [3][6]. MPLS works not only by the destination of IP address but also by forwarding packets based on small labels.

The high level of network availability in the Data Center is a significant challenge in providing reliable data traffic. Some companies have DRC design as a Data Center backup to reduce system failures but do not consider downtime when a connection failure occurs. The stability of the network plays an essential role in the client connection to the server [7]. The selection of routing protocols in the construction and design of the network is required to provide data traffic recovery on the Data Center.

The implementation of MPLS service using Interior Gateway Protocol (IGP) consists of RIP version 2, OSPF, and EIGRP [8] as internal routing at the customer side (CE). The convergence time is a significant characteristic of routing protocols which can be used to determine how fast the router gets routing table updates from other routers against topology changes due to connection failure [9][10] Convergence time and Quality of Service (QoS) become the comparison parameters for the performance of three routing protocols on Customer Edge (CE). The process of changing routes to backup links when a connection failure occurs on the main link (MPLS) Data Center becomes a focus in this study.

We want to review further the IGP routing protocol in determining the data traffic path based on available network resources [11]. In this research, we designed and simulated Data Center and DRC network architecture by comparing convergence time and QoS parameters to achieve the best stability and speed of route change. We hope this simulation method can improve network stability and reduce downtime when route changes to choose available network connections (backup link).

The methods to optimize MPLS services for the corporate environment have been studied in various aspects. In the study [12, 13, 14]. Traffic Engineering parameter can be used to improve QoS on MPLS services. The parameters are proved to be more effective and efficient. According to [15] another parameter is required to improve the scalability of MPLS services by the number of routing states maintained by each Provider Edge (PE) router by adding the Reflector Route parameter.

The utilization of MPLS technology in the company has been further investigated in [1][16]. The result of this research shows that MPLS technology is suitable for the company environment because it can connect the head office and some branch offices with good equality on the provider side.

The application of MPLS technology on the customer side needs to be supported by the selection of proper routing protocol. In the study [9, 10, 17, 18, 19, 20, 21] have tested the IGP routing protocols with several topologies. The testing processes are focused on QoS and failover times when a connection failure occurs.

This research simulates Ring topology and several parameters of QoS based on TIPHON standardization [21][22]. The parameters have become the network performance measurement standard as a collective effort that determines the level of service user satisfaction.

This study investigates how the IGP routing protocol works when there is a connection failure on the main link (MPLS) and make a route change on the backup link on the Ring topology. We tested the performance of three IGP routing protocols, including RIP ver 2, OSPF, and EIGRP based on convergence time and QoS parameters (Delay, Jitter, Packet Loss, and Throughput). Additional parameters are used in each routing protocol for the data flow using a scenario that has been made.

The paper is organizing as follows. In the next section, the device requirements and the topology design are described. In section 3, the analysis of the parameters tested by using predefined standards is presented. Section 4 discusses the conclusion derived from the simulation design.

METHOD

This research applies the simulation design method. The stages of network design use the Graphical Network Simulator (GNS3) application, including four phases that can be seen in Figure 1. GNS3 provides the scope of modeling and simulation to design network communication protocols and enables users to configure network components in virtual machines. The network components are running on a similar OS with the original network components.

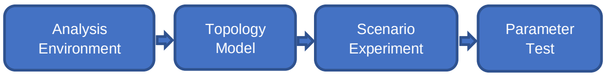


Figure 1. Research Methodology

Analysis of Environment

The design of VPN backbone network topology is based on MPLS technology using Ring and Mesh which have a certain specification is listed in Table 1.

Table 1. Hardware and software specifications

Category	Specification	Description
Hardware	System Manufacturer	ASUSTek Computer Inc
	System Model	X450LCP
	BIOS	Ver. : 04.06.05
	Processor	Intel(R) Core(TM) i5-4200U CPU @ 1.6 Ghz (4 Cpus)
	Operating System	Windows 10 Pro 64-bit
	Memory	12288 MB
	Hardisk	500GB
Software	Network Simulator	GNS3 2.1.3
	Virtual Machine	VirtualBox 5.2.8
	Network Tools	Wireshark 2.4.3

Topology Model

The topology design created using the Full Mesh topology in the service provider to build MPLS-based VPN backbones. On the other hand, Ring topologies built in the Company Data Center. There are four locations in the company, namely Data Center, DRC, Regional Headquarters and branch offices. The computers have connected using a switch access device. Data Center, DRC and Regional Headquarters have two connection lines as backups if the main connection line experiences down. When the main connection lost, the Core Switch device will be used to maintain routing protocol. The measurement process is carried out at the Data Center and DRC locations, according to Figure 2.

The provider uses a router for MPLS and QoS features, which connected and synchronized with an optical network (SDH/SONET). On the other hand, the customer is using Gigabit Ethernet and FastEthernet connection based on HSRP and port-channel features, as shown in Table 2.

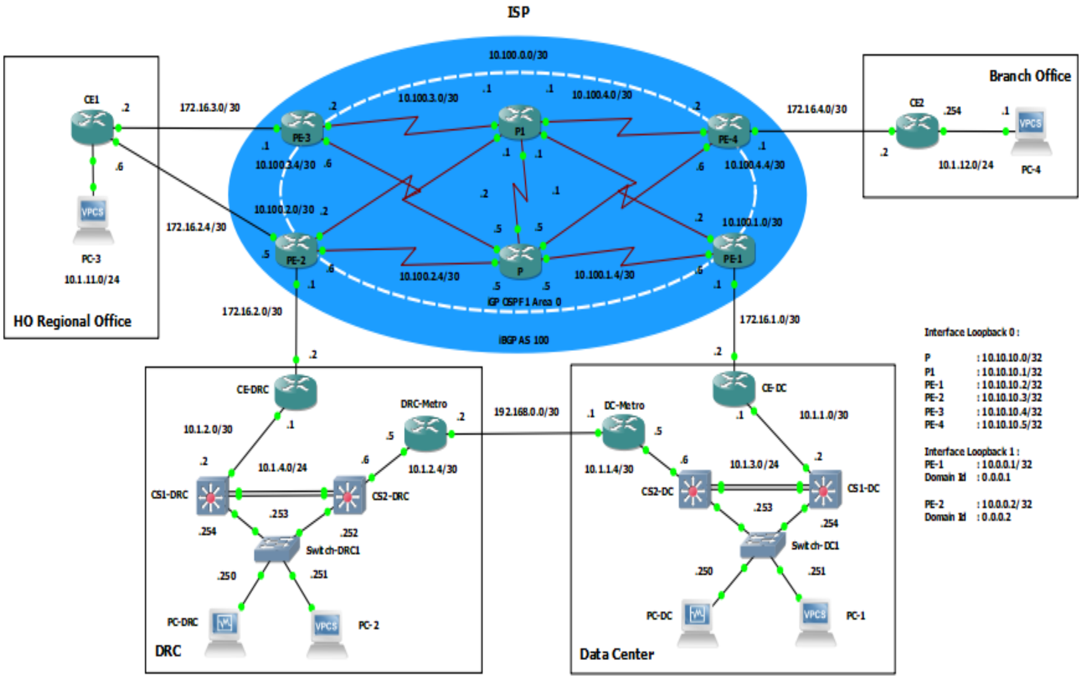


Figure 2. Network Topology Design

Table 2: Device specification

Location	Device Type	OS Version	Information
ISP	Cisco C7200 VXR NPE-400	C7200-jk9s-mz.124-13b.image	P and PE
Data Center	Cisco C7200 VXR NPE-400	C7200-jk9s-mz.124-13b.image	CE
	Cisco C3600	C3640-a3jz-mz.3640.image	CS and SW
	PC	Windows 10 Pro 64-bit	PC-DC
DRC	Cisco C7200 VXR NPE-400	C7200-jk9s-mz.124-13b.image	CE
	Cisco C3600	C3640-a3jz-mz.3640.image	CS and SW
	PC	Windows 7 32-bit	PC-DRC
HO Regional	Cisco C7200 VXR NPE-400	C7200-jk9s-mz.124-13b.image	CE-1
Branch Office	Cisco C7200 VXR NPE-400	C7200-jk9s-mz.124-13b.image	CE-2

Experimental Scenario

The measurement of network performance simulation was done by measuring several parameters, namely convergence time, delay, jitter, packet loss, and throughput. Along with this, it was necessary to test the connections between devices in the test scenario. Connectivity testing was performed end-to-end between end devices in each location and for routes which are passed through normal conditions is via the primary data connection (MPLS). The stages of the test scenario can be seen in Figure 3, and the simulation parameters can be seen in Table 3.

Table 3: The Simulation Parameter

Parameter	Value
Simulator Application	GNS 3
Network Interface Type	Wired
Simulation Time	2, 5 and 10 Minutes
Topology Type	Ring (LAN) and Full Mesh (WAN)
Routing Protocol (PE)	OSPF and iBGP
Routing Protocol (CE)	RIP Ver 2, OSPF and EIGRP
WAN Config	TE and RR
LAN Config	VLAN, HSRP, and Port-Channel
Network Test	QoS and Convergence Time
Traffic Type	ICMP (Ping)
Nodes	24 Node
Bandwidth	100 Mbps (Data Center dan DRC)

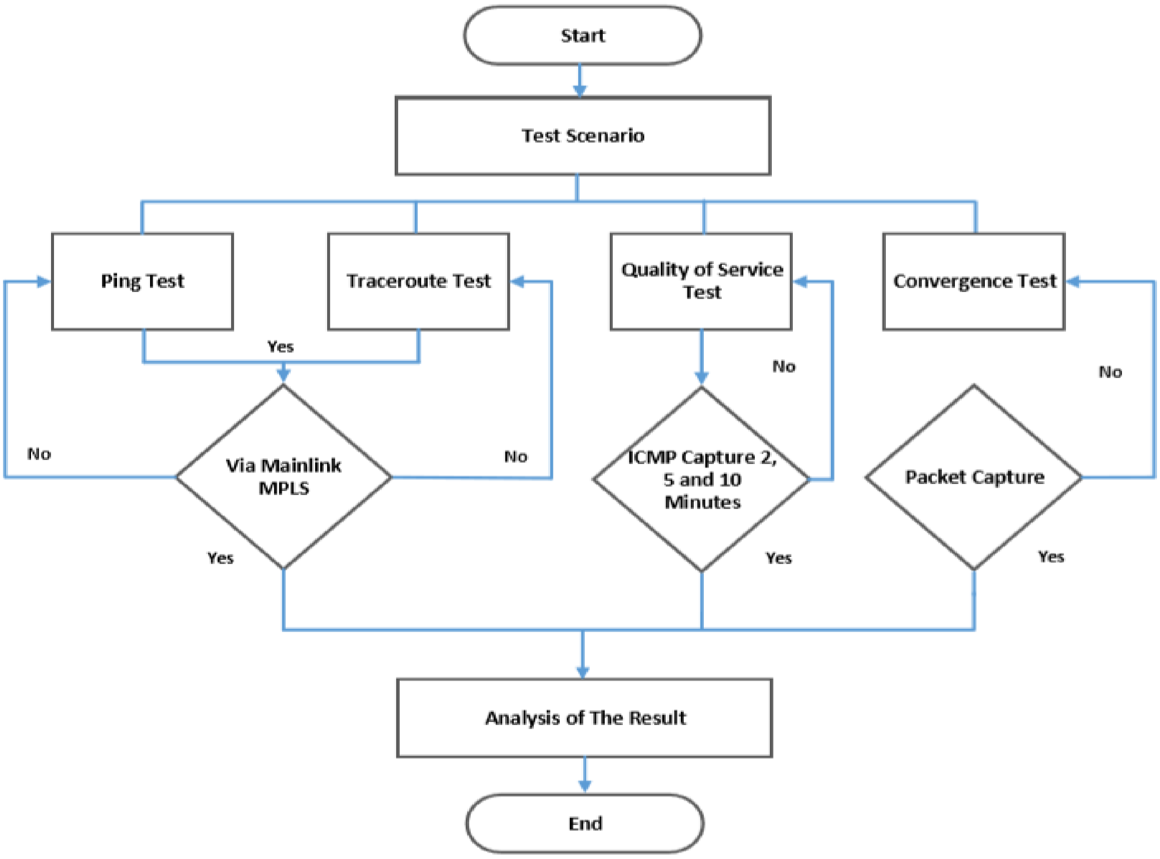


Figure 3. Stages of Network Simulation

Testing Parameters

We adopted the QoS parameters stated in [23][24] to set the criteria of results based on the length of time of the test. We also added the convergence time parameters presented in [9, 10, 17, 19, 20, 25] as one of the determinants of routing protocol performance in the network.

Quality of Service (QoS)

Quality of Service (QoS) is the overall effect associated with network performance as a collective effort of service performance that determines the satisfaction level of a service user. In the field of performance testing for Data-Packet-Net (DPNs) to measure performance characteristics of various network segments in real-time in managing network traffic, four basic measurements provide various information related to some aspects of performance [26]. These four basic measures are Delay, Jitter, Packet Loss, Throughput.

Delay

Delay/Latency is defined as the average time required for data packets to transmit data from one point of DPN (sender) to another point of DPN (receiver) [13, 18, 19, 26, 27, 28]. We use (1) to calculate the end to end delay. Table 4 shows the delay standard based on TIPHON.

Mathematical Equation of Delay:

$$\text{Delay} = \frac{\text{Total Delay}}{\text{Total Packet Received}} \quad (1)$$

Table 4: Delay Standard based on TIPHON

Latency Category	Delay
Very Good	< 150 ms
Good	150 s/d 300 ms
Medium	300 s/d 450 ms
Bad	> 450 ms

Jitter

Jitter is defined as a variation in the latency, which is measured between two endpoints in the DPN during a specific period [21][26][28]. We use (2) to calculate the average Jitter.

Mathematical Equation of Jitter:

$$\text{Jitter} = \frac{\text{Total Delay Variation}}{\text{Total Packet Received -1}} \quad (2)$$

The total delay variation is obtained from the sum:

$$\text{(Delay 2–Delay 1) + .. + (Delay n–Delay (n-1)} \quad (3)$$

According to (2), Total Delay Variation is calculated by summing the difference of each delay as in (3), while the standard of jitter measured based on TIPHON in Table 5.

Table 5. Jitter Standard based on TIPHON

Degradation Category	Peak Jitter
Very Good	0 ms
Good	0 s/d 75 ms
Medium	76 s/d 125 ms
Bad	125 s/d 255 ms

Packet Loss

Packet Loss is the percentage of lost data packets between two DPN points that can occur due to collision and congestion on the network [26] [21][28]. The standard for packet loss tolerance based on TIPHON can be seen in Table 6.

Table 6. Packet Loss Standard based on TIPHON

Degradation Category	Packet Loss	Index
Very Good	0 %	4
Good	3 %	3
Medium	15 %	2
Bad	25 %	1

Mathematical Equation of Packet Loss:

$$\text{Packet Loss} = \frac{(\text{Total Tx - Total Rx})}{\text{Total Tx}} \times 100\ \% \quad (4)$$

According to (4), Total Tx is the total packet of data sent, and Total Rx is the total packet of data received.

Throughput

Throughput is the maximum value of the bits number per second, which is transmitted between two points on the DPN segment in both directions [20] [27]. We use (5) to calculate throughput based on Table 7.

$$\text{Throughput} = \frac{\text{Total Packet Received}}{\text{Duration of Observation}} \quad (5)$$

Table 7. Throughput based on TIPHON

Throughput Category	Throughput	Index
Very Good	75 – 100 %	4
Good	50 – 75 %	3
Medium	25 – 50 %	2
Bad	> 25 %	1

Convergence Time

Convergence time speed is one of the important factors in determining the redirection time of route when there is a reduction on the main route (regular) [8] [9][16][24]. Convergence time for each routing protocol is different, and route determination depends on the algorithm routing that has been used. In this simulation, we use (6) to calculate the length of convergence time.

Mathematical Equation of Convergence:

$$\text{Convergence} = \text{Packet Time Rx} - \text{Packet Time Tx} \quad (6)$$

According to (6), Rx is the first time the packet reply occurs during downtime, and for Tx is the first time the RTO (Request Time Out) packet occurs during downtime. Downtime occurs when the main link MPLS Data Center failure on the simulation topology.

RESULT AND DISCUSSION

In this section, we will conduct an evaluation and analysis of the test results that have been obtained based on the simulation topology design in Figure 2 and the testing parameters.

End to End Connection

The test results in Table 8 show the results for each node already connected following the ping and traceroute scenarios. The best route selection proves that:

1. RIP version 2 determines the best path by selecting the lowest metric value.
2. OSPF uses the lowest cost value to select the best path and use the sham-link parameter in PE so that the MPLS link is considered as INTRA_AREA.
3. EIGRP determines successor with several parameters of one of them with the same ASN. When there are different ASNs are regarded as external EIGRP.

Table 8. The Result of Network Connectivity Test

End Device	Connectivity Test (Ping and Traceroute)			
	PC-DC	PC-DRC	PC HO Regional	PC Brach Office
PC-DC	-	OK	OK	OK
PC-DRC	OK	-	OK	OK
PC HO Regional	OK	OK	-	OK
PC Brach Office	OK	OK	OK	-

QoS Testing Results

Figure 4 showed the observation results for the three routing protocols have a very good index value based on TIPHON standards in Table 4, with an average rating between 114 and 141 ms. The best delay average is EIGRP routing with 2 minutes (115 ms), 5 minutes (114 ms) and 10 minutes (114 ms) test time. The result showed that end-to-end delay protocol EIGRP is better than RIP version 2 and OSPF with the same number of bandwidth. The condition is because EIGRP is independent of periodic routes and keeps the actual route to all destinations.

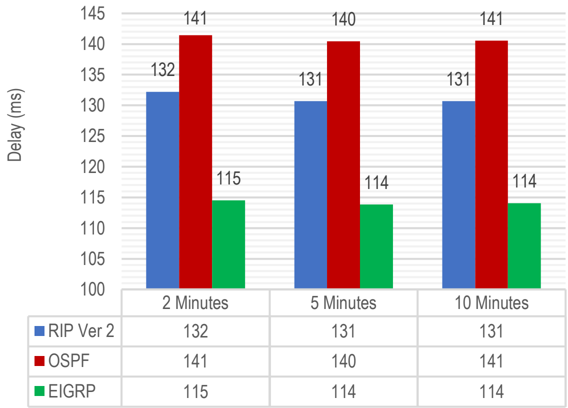


Figure 4. The Delay Comparison Result Based on Time Test

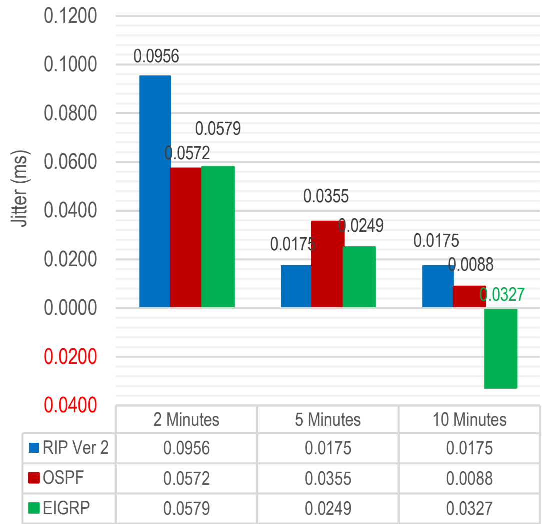


Figure 5. The Jitter Comparison Results Based on Test Time

[Figure 5](#) showed that the average value of jitter has a very good index value. Referring to the TIPHON standard index value in Table 5, the mean value of jitter in 10 trials for a 2 minutes test is OSPF (0.0572 ms), 5 minutes test is RIP version 2 (0.0175 ms) and 10 minutes test is EIGRP (-0.0327 ms). The minus jitter value occurred due to packet disturbance so the distance between 2 packets is not equal if the delay of first packet delivery time is greater than the second packet. The jitter will be negative if the first packet time delay is smaller than the second packet of the jitter value is positive. EIGRP shows that the average value of the EIGRP index has better jitter stability than OSPF and RIP version 2. There is a small number of 2 minutes which have a difference of 0.0007 ms from OSPF and the 5 minutes test has a difference of 0.0074 ms from RIP version 2. This result showed queue packets on EIGRP less than OSPF and RIP Ver 2 because EIGRP has very low usage of network resources during normal operation.

Figure 6 showed the low packet loss rate for the three routing protocols. These results are matched with TIPHON standards, as listed in Table 6, which show excellent index values. Based on the observation result for the 2 minute test time, the OSPF has 0.00084% packet loss. Furthermore, for the 5-minute test time, RIP version 2 has 0.00101% packet loss, and for the 10-minute test time, OSPF and RIP version 2 have a similar rate (0.00051%).

The measurement result between the three routing protocols is relatively the same, which is about 0.0011%. The IGP protocol from the MPLS network is used to create LSPs between the CE to PE routers. So when the routing protocol between CE and PE is changed, it does not affect the QoS results.

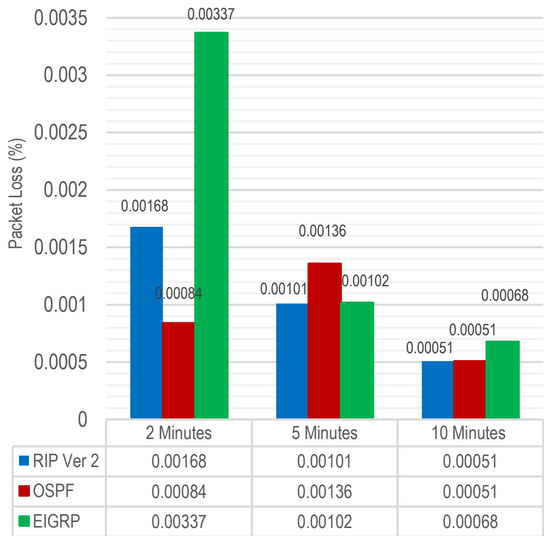
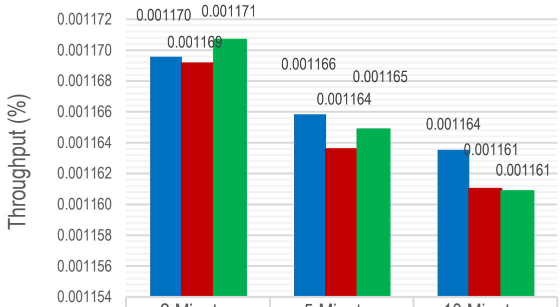


Figure 6. The Comparison Results of Packet Loss Based on Test Time

Figure 7 showed average results with bad index values (TYPES) according to TIPHON standards in Table 7. Better value results for 2 min test time ie EIGRP (0.00337%), 5 minutes ie RIP version 2 (0.001166%) and 10 minute ie RIP version 2 (0.001164%). This result is caused because the data packet sent every second is too small (ICMP Packet form), so it is not proportional to the large bandwidth available.



	2 Minutes	5 Minutes	10 Minutes
RIP Ver 2	0.001170	0.001166	0.001164
OSPF	0.001169	0.001164	0.001161
EIGRP	0.001171	0.001165	0.001161

Figure 7. The Comparison Results of Throughput Based on Test Time

Based on the recapitulation results in Table 9, Table 10, and Table 11 for the QoS test parameters, the MPLS connection had good quality with the result of the average index value of 3.25 for the three routing protocol.

Convergence Time Test Results

Figure 8 showed that EIGRP routing has the fastest convergence time up to 15 seconds, followed by OSPF routing (43 seconds) and RIP version 2 (3 minutes 16 seconds). The condition is because EIGRP routing uses a simpler algorithm than OSPF so that when a major connection fails or a topology change does not take long to build a new routing table. Meanwhile, RIP version 2 took longer convergence time because the updates on the RIP routing table are not directly deleted (hold-down timer effect), and RIP will not receive new updates for routes until the timer expires dead (time default 180 seconds).

Table 9. Recapitulation of QoS Parameter on the Protocol Routing RIP version 2

No	Parameter	Test Time (2 m)	Index	Test Time (5 m)	Index	Test Time (10 m)	Index
1	Delay	132 ms	4	131 ms	4	131 ms	4
2	Jitter	0.0956 ms	4	0.0175 ms	4	0.0175 ms	4
3	Packet Loss	0.00168%	4	0.00101 %	4	0.00051 %	4
4	Throughput	0.001170 %	1	0.001166 %	1	0.001164 %	1
The Average Number			3.25		3.25		3.25
Index Information			Good		Good		Good

Table 10. Recapitulation of QoS Parameter on the Protocol Routing OSPF

No	Parameter	Test Time (2 m)	Index	Test Time (5 m)	Index	Test Time (10 m)	Index
1	Delay	141 ms	4	140 ms	4	141 ms	4
2	Jitter	0.0572 ms	4	0.0355 ms	4	0.0088 ms	4
3	Packet Loss	0.00084%	4	0.00136 %	4	0.00051 %	4
4	Throughput	0.001169%	1	0.001164 %	1	0.001161 %	1
The Average Number			3.25		3.25		3.25
Index Information			Good		Good		Good

Table 11. Recapitulation of QoS Parameter on the Protocol Routing EIGRP

No	Parameter	Test Time (2 m)	Index	Test Time (5 m)	Index	Test Time (10 m)	Index
1	Delay	115 ms	4	114 ms	4	114 ms	4
2	Jitter	0.0579 ms	4	0.0249 ms	4	-0.0327 ms	4
3	Packet Loss	0.00337 %	4	0.00102 %	4	0.00068 %	4
4	Throughput	0.001171 %	1	0.001165 %	1	0.001161 %	1
The Average Number			3.25		3.25		3.25
Index Information			Good		Good		Good

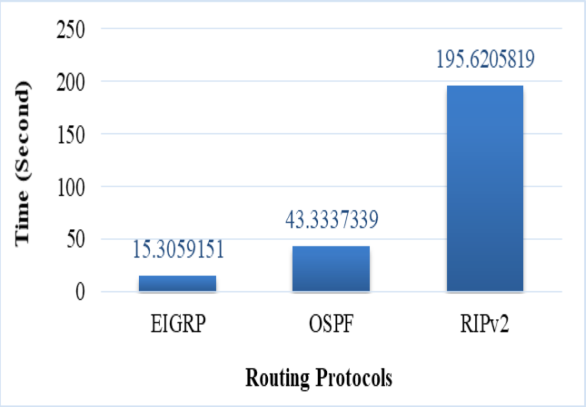


Figure 8. The Comparison Result of Convergence Time

CONCLUSION

This research aims to improve data traffic stability in the use of an MPLS-based VPN network simulated on Ring topology. The simulation results have proved that the performance of the three routing protocols has good index value according to the TIPHON standard, with the average index up to 3.25. The best average comparison result for each QoS parameter in 3 times testing of IGP routing is EIGRP. In observation of convergence time has obtained results that can support the high level of network availability in the Data Center through the availability of network resources. The fastest recovery rate when connection failure occurred was EIGRP with an average time of 15 seconds. QoS parameter testing resulted that the less optimum was throughput. The situation is because the size of each packet sent by the 32 bytes ICMP protocol is the default buffer size of the Windows operating system, so it is not sufficient to provide load and throughput measurements on the network. The experiment results of the parameter, which has a negative value for 10 minutes of test times for EIGRP, are due to the difference in packet delivery delay. In the next study, it is expected to add a rollback routing update scenario when the primary data link returns to normal. These stages are obtaining accurate results for convergence time when changes occur with rollback scenarios.

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