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Performance Analysis of First Hop Redundancy Protocols on Computer Networks Based in Star Topology

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Abstract

Minimizing the cost of network service failures requires several additional network devices that can take over the function of the leading network if the device fails. The solution to improve network availability and reliability is using the First Hop Redundancy Protocol (FHRP). This research analyses the FHRP protocol experiment using the Hot Standby Router Protocol (HSRP), Virtual Router Redundancy Protocol (VRRP), and Gateway Load Balancing Protocol (GLBP) methods combined with the OSPF and EIGRP dynamic routing protocols, as well as the results of the investigation of implementing the backbone network in the form of a star topology based on the performance of the FHRP protocol management with the test parameters delay, packet loss, throughput. According to the test results conducted by combining the FHRP protocol with EIGRP and OSPF routing, the VRRP method combined with EIGRP routing provides better output parameters than other methods, such as the difference in delay between VRRP and HSRP is 0.16 ms, 0.18 ms with GLBP with a combination of EIGRP routing. While in OSPF routing, the delay difference between VRRP and HSRP is 0.22 ms and 0.24 ms in GLBP. For packet loss testing parameters, when the primary network route is disconnected, there is an increase in packet loss of 1.01% for VRRP, 3.05% for HSRP with a combination of EIGRP routing, and 0.2% for VRRP, 0.4% for HSRP with a combination of OSPF routing.

Kata kunci*: FHRRP, Routing, EIGRP, OSPF, Parameter*

Abstrak

Meminimalkan biaya kegagalan layanan jaringan membutuhkan beberapa perangkat jaringan tambahan yang dapat mengambil alih fungsi jaringan utama jika perangkat tersebut gagal. Solusi untuk meningkatkan ketersediaan dan keandalan jaringan adalah dengan menggunakan First Hop Redundancy Protocol (FHRP). Penelitian ini menganalisa percobaan protokol FHRP dengan menggunakan metode Hot Standby Router Protocol (HSRP), Virtual Router Redundancy Protocol (VRRP), dan Gateway Load Balancing Protocol (GLBP) yang digabungkan dengan protokol routing dinamis OSPF dan EIGRP, serta hasil investigasi implementasi jaringan backbone berbentuk topologi star berdasarkan performa manajemen protokol FHRP dengan parameter uji delay, packet loss, throughput. Berdasarkan hasil pengujian yang dilakukan dengan mengkombinasikan protokol FHRP dengan routing EIGRP dan OSPF, metode VRRP yang dikombinasikan dengan routing EIGRP memberikan parameter output yang lebih baik dibandingkan metode lainnya, seperti selisih delay antara VRRP dengan HSRP sebesar 0.16 ms, 0.18 ms dengan GLBP dengan kombinasi routing EIGRP. Sedangkan pada routing OSPF, selisih delay antara VRRP dan HSRP adalah 0.22 ms dan 0.24 ms pada GLBP. Untuk parameter pengujian packet loss, ketika rute jaringan utama terputus, terjadi peningkatan packet loss sebesar 1.01% untuk VRRP, 3.05% untuk HSRP dengan kombinasi routing EIGRP, dan 0.2% untuk VRRP, 0.4% untuk HSRP dengan kombinasi routing OSPF.

Keywords*: FHRRP, Routing, EIGRP, OSPF, Parameter*

1. INTRODUCTION

The development of information technology is also bringing revolutionary changes in business worldwide. Many businesses and business processes are connected to information technology because it has become a kind of necessity to compete. The computer network is a factor that makes the rapid development of technology and information services. Computer networks serve as a business continuity that makes all applications and services accessible to clients or employees. In the business continuity of a company or agency, it is expected that the network is always available 24 hours a day throughout the year, which means the minimum availability is expected to be

99.999% to serve employees, customers, and business partners [1]. In most cases, network outage data is unacceptable to a company or agency, and a two-minute downtime due to a network failure can cause huge losses, so that every company or agency requires technology and protocols related to high network reliability and availability, high reliability and network availability are interrelated with each other [2]. This is very necessary for the continuity of a business.

In order to maintain the desired level of availability and reliability of services and minimize the cost of failure or service of network devices, there needs to be some additional network devices or devices that can take over the functions of the leading network if the primary device fails, so that if one of the network devices fails, the service will still be available. A routing protocol is needed to support the reliability and availability aspects of network applications and services that determine how data is transferred in the computer network field. The routing protocol determines the communication model between one router and another and the data transfer process from one router to another until it reaches the destination [3], [4].

In addition, one of the main aspects of network reliability and availability involves redundancy in a network design. Network redundancy is a concept to maintain reliability and availability on the network and is an effective method widely used for indicators of network reliability and availability in technical systems [5]. Redundancy in the network serves as a backup mechanism. If the network fails, it will immediately take over the network functions. In general, redundancy involves two or more router devices implemented as backups or backups. In internet protocol (IP) networks, there are several solutions to improve network availability and reliability by creating redundant links between switches and routers using the First Hop Redundancy Protocol (FHRP) [6]. FHRP is used when two or more gateways are connected to the network. If one router is down, the other router will provide redundancy and service to the network [7]. FHRP is a network protocol that protects the default gateway by allowing two or more routers to provide load balancing and redundancy in a failure on the active router or main router [8].

First Hop Redundancy Protocol (FHRP) provides default gateway redundancy for OSI layer three host IPs. Two or more routers can share the same virtual IP address. This virtual IP address is configured on the end device as the default gateway. The router group consists of an active router and one or more backup routers [9]. CISCO provides three FHRP protocol methods, but these three methods fall into two different categories [10]. The methods are Hot Standby Router Protocol (HSRP), Virtual Router Redundancy Protocol (VRRP), and Gateway Load Balancing Protocol (GLBP) [11]. Several related studies regarding the First Hop Redundancy Protocol (FHRP) system have been carried out. In a previous study [12], this study was conducted to minimize failure on TCP/IP networks by comparing delay, packet loss, and throughput using VRRP, HSRP, and GLBP methods. This research shows that the GLBP method has the best performance compared to the VRRP and HSRP methods, especially in packet loss and throughput testing. Besides [13], conducted research comparing the VRRP and GLBP methods using the RIPv2 and OSPF routing protocols with a ring topology. This study indicates that the VRRP method when using a routing protocol with ring topology, the VRRP method is better than the GLBP method. In a previous study [14], evaluating and analyzing the performance of FHRP in a star topology and using an EIGRP routing protocol that was applied to six router devices, the results showed that the VRRP method had service quality delay, packet loss, and better throughput than the HSRP and GLBP methods. The purpose of this study is to analyze the HSRP, VRRP, and GLBP methods and obtain network performance and implement and combine dynamic routing protocols into these methods. Furthermore, the results obtained will be compared to network performance using the main router and a backup router if the primary router is down.

2. METHODS

2.1 Network Simulation Model

In this study, the FHRP system's design will be carried out. A data communication simulation on the network will be carried out to analyze the performance of the FHRP protocol by conducting simulation experiments on the VRRP, GLBP, and HSRP methods using a star topology and combining OSPF and EIGRP routing to the network topology that will use [15]. Furthermore, system configuration will be carried out for each VRRP, GLBP, and HSRP method. The next stage will be a test simulation to get results from the performance of the VRRP, GLBP, and HSRP methods. This experiment determines the performance of FHRP when combined with routing on each master router and backup router on the FHRP protocol. Figure 1 shows the flow of the FHRP protocol simulation experiment used in this study to obtain the parameters of the results in this study.

The initial stage of this research is to design and design the FHRP topology using three routers, one switch, and two PCs as hosts. The FHRP protocol designed in this study will simulate GNS3 software using a router [16]. After designing the FHRP topology, configure each router with the VRRP, HSRP, and GLBP methods. Each method in the FHRP protocol has different configurations and working principles, so configuration and testing are carried out individually. Each router configured with each method will be tested for validation to determine whether each router is connected. The next stage will be testing network simulations on each method of HSRP, VRRP, and GLBP using GNS3 and Wireshark software to obtain analysis and test results of output parameters of each method in the FHRP protocol.

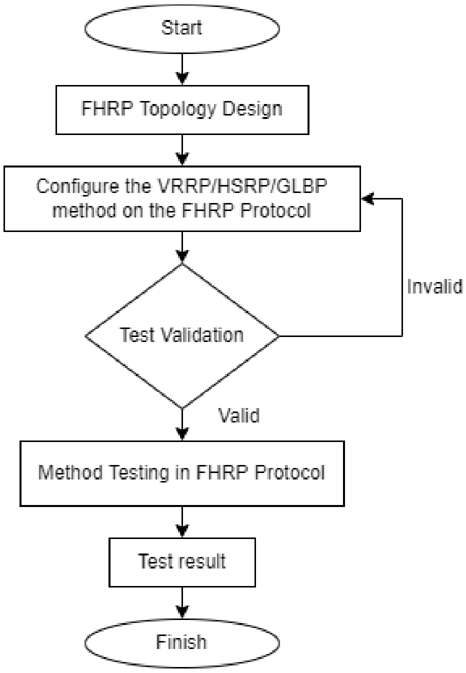

Figure 1. FHRP Topology Design Flowchart

2.2 FHRP Network Topology Design

The design of the FHRP network topology in this study is shown in Figure 2. The topology uses three routers, two switches, and two personal computers as hosts to test network connections. The FHRP protocol works based on the priority value. The router with the highest priority will select as the main router, and the other routers are in standby status as backup routers. The default priority is 100, which ranges from 0-255. Router 2 is the main router with a priority value of 100, and router three is a backup router with a priority value of 10. The master router and backup router on the FHRP protocol will combine with the EIGRP routing protocol and OSPF. Furthermore, the FHRP topology design will apply to a backbone network arranged in the form of a star topology with six routers, and each router will combine with OSPF and EIGRP routing. Figure 3 is a topology design for the FHRP protocol that will apply to the star topology as a backbone network.

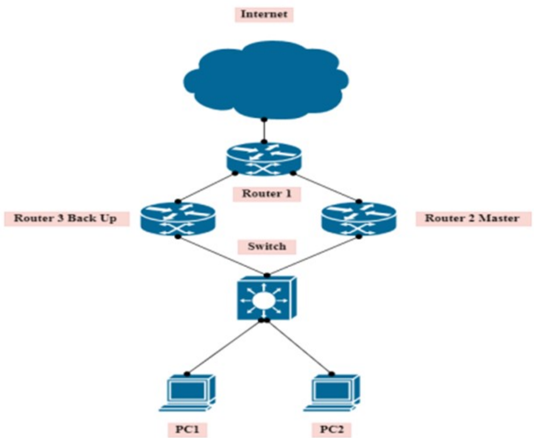

Figure 2. FHRP Topology Design

2.3 FHRP Testing Mechanism

This research was conducted using Graphical Network Simulator 3 (GNS) software and Wireshark. GNS3 allows designing and testing virtual networks on PCs, including Cisco IOS and Juniper networks [17]. The FHRP protocol simulation process is run with the ping command or Internet Control Message Protocol (ICMP) between PC1 and PC2 as clients or hosts to router two and PC1 and PC2 to router three with the condition when the primary router is down. In applying the FHRP protocol on the backbone network in a star topology with six CISCO routers, OSPF and EIGRP routing are used as internal routing. Each router will perform a ping or ICMP command to the main router and backup router in the FHRP protocol to obtain a better combination of building redundancy, load balancing, failover, and backup by analyzing the performance results of the FHRP protocol and the routing protocol that has a better performance based on applied parameters. Testing the FHRP method was carried out in two experiments: designing the FHRP topology and implementing the FHRP topology experiment to the backbone network with the EIGRP and OSPF routing protocols the star topology on the backbone network. Quality of service is the ability of a network to provide good data services on a network. As for analyzing the performance of the FHRP system using redundancy, load balancing, and active-standby router methods, the following equation is used [18].

$$Delay\ Average = \frac{Package\ Delivery\ Time}{Total\ Package} \quad (1)$$

$$Packet\ Loss(\%) = \left(\frac{Lost\ Package}{Total\ Package} \times 100\%\right) \quad (2)$$

$$Throughput(Kbps) = \frac{Amount\ of\ Data\ Sent}{Data\ Delivery\ Time} \quad (3)$$

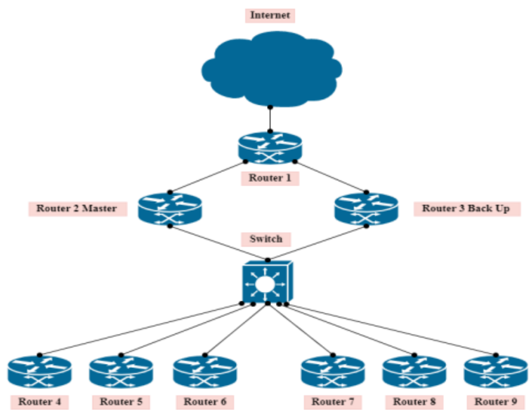

Figure 3. Star Topology Design with FHRP Protocol

The test parameters are shown in Table 1, while the IP allocation for each EIGRP and OSPF protocol router and IP on eight router devices can be seen in Table 2 below, using IP in class A as addressing.

Tabel 1. Test Parameters

Link Router	Fast Ethernet/Gigabyte Ethernet
Router series	Cisco 3640
Packet sent	512 Kbps
Testing and Simulation Time	120 seconds
Master router disconnection time	30 seconds
Software	GNS3 – Wireshark
Priority router	100

Tabel 2. IP allocation on router

Router	Fast Ethernet 0/0	Fast Ethernet 0/1	Fast Ethernet 1/0
R1	20.2.1.1	10.64.0.1	30.2.1.1
R2	20.2.1.2	10.64.0.2	30.2.1.2
R3	20.2.1.3	10.64.0.3	30.2.1.3
R4	20.2.1.4	10.64.0.20	30.2.1.4
R5	20.2.1.5	10.64.0.21	30.2.1.5
R6	20.2.1.6	10.64.0.22	30.2.1.6
R7	20.2.1.7	10.64.0.23	30.2.1.7
R8	20.2.1.8	10.64.0.24	30.2.1.8
PC1		10.64.0.20	
PC2		10.64.0.21	

Based on the equations used in this study, the results obtained are a combination of performance redundancy, load balancing, failover, and backup routers and protocol performance in FHRP when combined with EIGRP and OSPF routing in a star topology. This research was conducted by applying two scenarios, and the first scenario was to test the designed FHRP system. The second scenario was implementing the FHRP system to a star topology with the number of packets sent at 512 Kbps for each test scenario. The simulation time was carried out for 120 seconds.

3. RESULTS AND DISCUSSION

This study aims to analyze and compare the methods of FHRP protocols and experiments to implement the HSRP, VRRP, and GLBP methods on a backbone network topology in the form of a star topology carried out using network simulation software Graphical Network Simulator 3 (GNS3) and Wireshark. This research will be carried out in two stages, and the first stage is to analyze and compare the HSRP, VRRP, and GLBP methods with the design FHRP topology. The next stage in this research is to apply the FHRP topology to a backbone network in the form of a star topology with routing used by EIGRP and OSPF.

3.1 Protocol Address Resolution Protocol (ARP)

In this study, data communication in the VRRP, GLBP, and HSRP protocols for each host or PC communicate with each other via MAC addresses. If the destination MAC address is unknown, the router will send an Address Resolution Protocol (ARP) to get the MAC to the address by using the IP address. ARP messages are sent from the router in the form of broadcasts. Figure 4 is the screen capture result of an ARP request on one of the tested FHRP systems, as shown in the black box indicated by the sentence 10.64.0.3, where the destination MAC address will respond if it has received a broadcast message from ARP. It can be seen that ARP is in charge of translating IP addresses into physical MAC addresses.

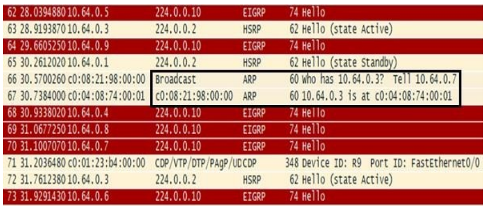

Figure 4. Star ARP Capture Packet Frames in HSRP

3.2 FHRP Average Delay Test Results

Testing the delay parameter aims to determine the average time between data packets sent from the internet to the client. The results of calculating the average delay of the FHRP protocol combined with the EIGRP routing protocol are shown in Figure 5, while the OSPF routing protocol is shown in Figure 6. The average delay is 0.555 ms for the VRRP method, 0.715 ms for the HSRP method, and 0.74 ms for the GLBP method with PC1 and PC2 hosts combined with EIGRP routing. The average delay difference between VRRP and HSRP is 0.16 ms or 22.3% greater than the VRRP delay. At the same time, the difference between VRRP and GLBP delay is 0.185 ms or 25% greater than GLBP delay than VRRP delay. The difference between HSRP and GLBP delays is 0.025 ms or 2.8% greater than the GLBP and HSRP delays.

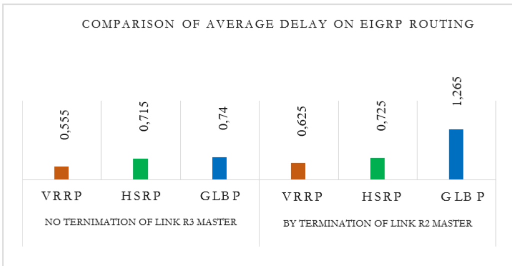

Figure 5. Comparison of FHRP Average Delay in EIGRP Routing

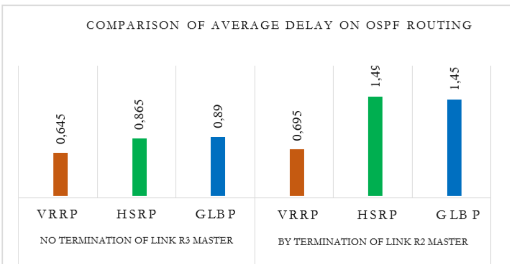

Figure 6. Comparison of FHRP Average Delay in OSPF Routing

The average delay when the FHRP topology applies with a star network topology combined with EIGRP routing during normal network conditions is 0.492 ms for the VRRP method, 0.625 ms for the HSRP method, and 0.601 for the GLBP method. At the same time, the average delay by combining OSPF routing is 0.605 ms for VRRP, 0.785 ms for HSRP, and 0.818 for GLBP. The difference in VRRP delay combined with EIGRP and OSPF routing is 0.113 ms or 18.6%, 0.16 ms or 20.3% for the HSRP delay, and 0.217 ms or 26.5% for the difference in EIGRP and OSPF delays with the GLBP method. Figure 7 compares the average delay obtained in EIGRP routing, while Figure 8 shows OSPF routing with normal network conditions and link termination applied to star network topology.

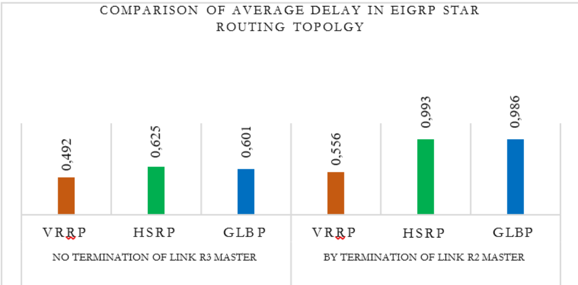

Figure 7. Average Delay in EIGRP Star Routing Topology

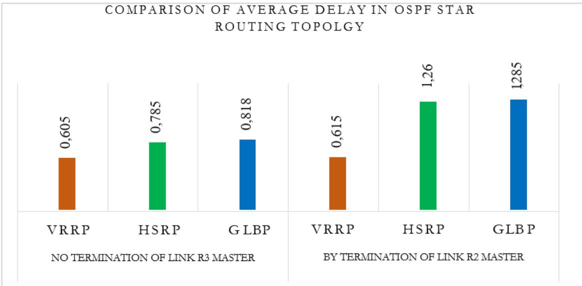

Figure 8. Average Delay in OSPF Star Routing Topology

Based on the data above, it is found that the delay in the FHRP protocol that applies to the backbone network with a combination of EIGRP routing has a more negligible delay than OSPF routing. At the same time, when the link is disconnected on router R3 as the master router and the network functionality is taken over by router R2, the result is an increase in delay in each method. Naturally, this is caused by the disconnection of the link resulting in a failover and delaying the data communication process. However, the average delay value obtained from the calculations in both conditions is less than 150 ms, so it is still quite reasonable based on the ITU-T G.114 standard.

3.3 FHRP Protocol Packet Loss Parameters

Testing packet loss parameters aims to determine the number of data packets lost during communication between the internet and the client. In implementing an IP address-based network, the value of packet loss is expected to be minimum. Generally, packet loss occurs because the packet sent fails to reach its destination. The results of the FHRP packet loss calculation combined with the EIGRP routing protocol are shown in Figure 9, while the OSPF routing protocol is shown in Figure 10. The average value of packet loss in the FHRP protocol combined with EIGRP routing when the network is in normal conditions, it is found that the VRRP method has a better average packet loss value than the HSRP and GLBP methods, which is 2.945% 6.9% HSRP method, and 6.16% for the GLBP method. While the average value of packet loss in the FHRP protocol combined with OSPF routing when the network is in normal conditions, it is found that the VRRP method has a better average packet loss value than the HSRP and GLBP methods, namely 2.9%, 7, 45% for the HSRP method and 8% for the GLBP method. When the FHRP protocol is combined with EIGRP routing and OSPF routing, there is no difference in the average value of packet loss with the VRRP method.

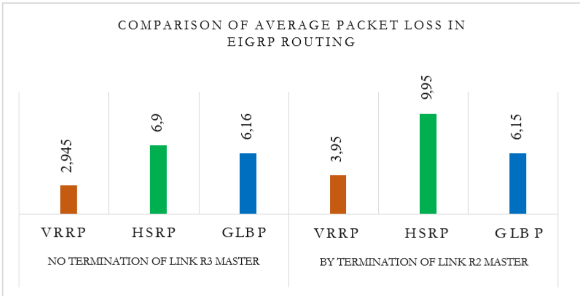

Figure 9. Comparison of Average Packet Loss in EIGRP Routing

However, using the HSRP and GLBP methods, the average packet loss value using EIGRP routing is better than the average packet loss value for OSPF routing. The average packet loss results for the FHRP protocol combined with EIGRP routing, as shown in Figure 11, and the average packet loss for the FHRP protocol combined with EIGRP routing is shown in Figure 12.

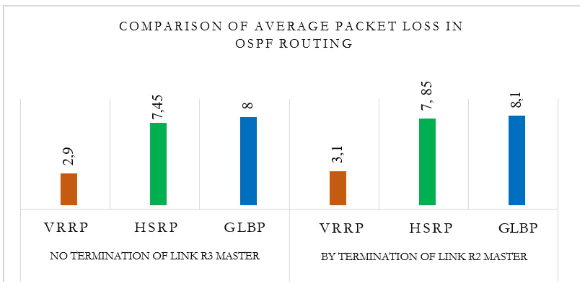

Figure 10. Comparison of Average Packet Loss in OSPF Routing

The average value of packet loss in link termination conditions, the increase in packet loss value in the VRRP and HSRP methods combined with EIGRP routing has increased by 1.01%. While in

VRRP and 3.05% in HSRP and VRRP methods combined with OSPF routing, the increase in packet loss is 0.2% and 0.4% in the HSRP method. The average value of packet loss when the FHRP topology is applied to the backbone network with EIGRP routing is 2.9%, 3.13% with OSPF routing for the VRRP method, 6.4%, and 6.58% in the HSRP method, 6.03%, and 8.03% in the GLBP method. There is a difference in average packet loss of 0.23%, 0.18% for the HSRP method, and 2% for the GLBP method. Then it is found that the average value of packet loss with EIGRP routing is more when compared to using OSPF routing. Figure 11 compares the average packet loss obtained in EIGRP routing. On the other hand, Figure 12 compares the average packet loss obtained in OSPF routing with normal network conditions and with link breaks applied to the star network topology.

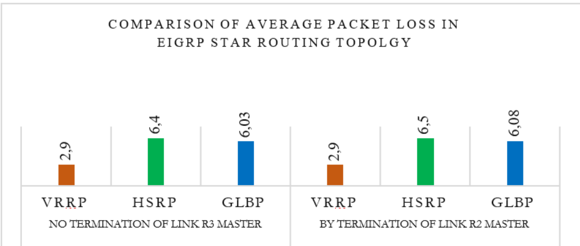

Figure 11. Average Packet Loss in EIGRP Star Routing Topology

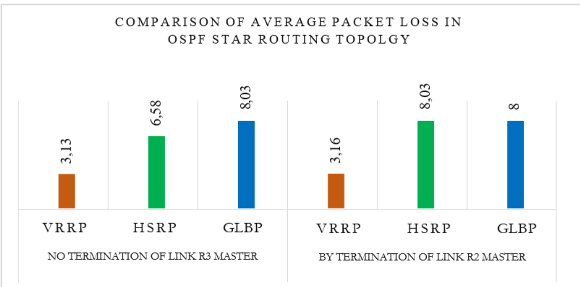

Figure 12. Average Packet Loss in OSPF Star Routing Topology

Whenever the network is disconnected from router R3, and the network service functionality is taken over by router R2, the average packet loss value obtained does not increase the average packet loss. However, this happens because the FHRP method sends advertisement messages to EIGRP and OSPF routing so that EIGRP and OSPF routing can immediately determine the route to forward the destination packet without increasing the average packet loss value. The average packet loss value obtained in both conditions meets the tolerance standards set by ITU-T, which is 10%-30%. Therefore, the average packet loss value obtained in each method is still relatively good when without disconnection and disconnection of the link on the primary router.

3.4 FHRP Protocol Throughput Parameters

A throughput calculation aims to determine the actual ability of the network to transmit data per unit of time after the implementation of the FHRP protocol. Usually, throughput is associated with bandwidth. The calculation results of the throughput value of the FHRP protocol combined with EIGRP routing are shown in Figure 13, while OSPF routing is shown in Figure 14.

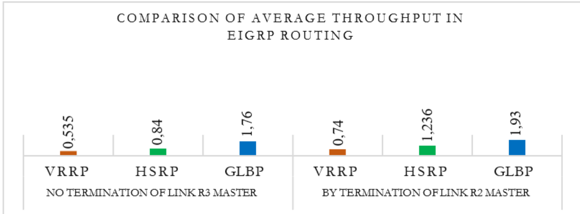

Figure 13. Comparison of Average Throughput in EIGRP Routing

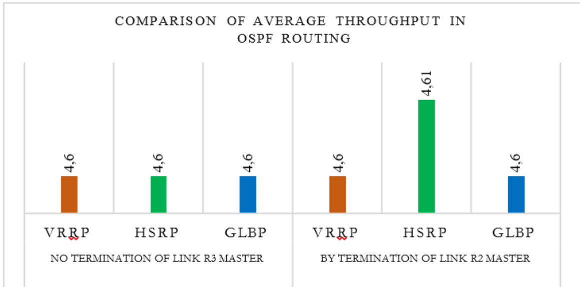

Figure 14. Comparison of Average Throughput in OSPF Routing

The average throughput value in the FHRP protocol combined with EIGRP routing obtained the average throughput of the VRRP method of 0.535, 0.84 the average throughput of the HSRP method, and 1.76 the average throughput of the GLBP method. The difference in the average throughput of VRRP and HSRP is 0.305 or 36% greater than the average throughput of the HSRP method. Meanwhile, for the average value of VRRP and GLBP throughput, there is a difference of 1,225, which indicates that the average value of VRRP throughput is smaller than the average value of HSRP and GLBP throughput. When the R3 router is disconnected, there is an increase in the average throughput value combined with EIGRP routing.

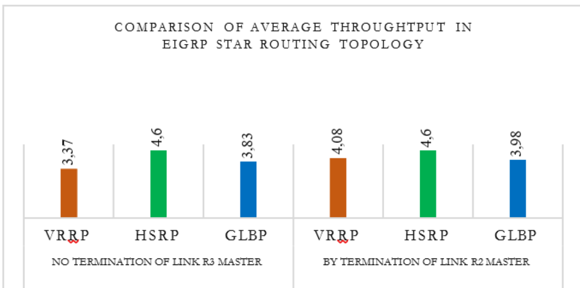

Figure 15. Average Throughput in EIGRP Star Routing Topology

The increase or decrease in the throughput value is caused by the cessation of the data transfer process during failover from router R3 as the master to router

R2 as a backup. This condition can cause some data packets to be lost so that when the regular network returns, a request for retransmission of packets occurs, which increases the throughput value. Meanwhile, the average throughput of the FHRP topology combined with OSPF routing does not increase the average throughput value even though there is a link break in R3. This happens because OSPF routing uses the concept of a routing hierarchy which makes bandwidth usage more efficient than EIGRP routing. The comparison of the average throughput with normal network conditions and with link termination applied to a star network topology with EIGRP routing is shown in Figure 15. Meanwhile, that combined with OSPF routing is shown in Figure 16.

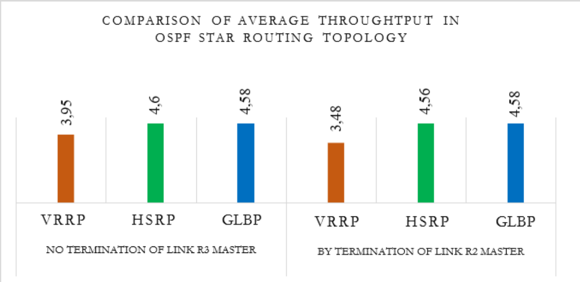

Figure 16. Average Throughput in OSPF Star Routing Topology

In the event that the R3 router link is lost, there is an increase in the average throughput value in the VRRP method combined with EIGRP routing by 0.71 bit/ms, but there is no increase in the average throughput value in the HSRP and GLBP methods. The absence of an increase in the average throughput value in the HSRP and GLBP methods shows that this method is better prepared to deal with failures on the main line compared to the VRRP method. Thus, the FHRP protocol combined with OSPF routing can manage average throughput values better than EIGRP routing.

4. CONCLUSION

Based on the results of tests carried out by combining the FHRP protocol with EIGRP routing and OSPF, as well as implementing it to a star network topology, network services on the primary router obtained an increase in delay, packet loss, and throughput in each FHRP protocol method both when combined with EIGRP routing and routing OSPF. Therefore, when referring to the ITU-T standard, the increase in delay and packet loss obtained when the primary router network service is disconnected is still relatively good. Then the result is that the VRRP method combined with EIGRP routing provides better output parameters than other methods, such as the delay difference between VRRP and HSRP is 0.16ms, 0.18ms with GLBP with a combination of EIGRP routing. While in OSPF routing, the difference between VRRP and HSRP delays is 0.22 ms and 0.24 ms in GLBP. For packet loss testing parameters, when the primary network route is disconnected, there is an increase in packet loss of 1.01% for VRRP, 3.05% for HSRP combined with EIGRP routing, and 0.2% for VRRP, 0.4% for HSRP combined with OSPF routing.

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