

Comparative Analysis of PCC and ECMP Methods in Load Balancing using GNS3 Simulator

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Abstract

Judging from daily activities, human beings heavily rely on the internet for communication purposes and exchange information using either social media applications or browsers, consistently fast internet speeds are incredibly beneficial for performing tasks and activities, particularly for students and professionals. A sluggish internet connection can be frustrating and may lead to interruptions in online activities and tasks if it persists. Hence, this study examines a comparative evaluation of two approaches, Per Connection Classifier (PCC) and Equal Cost Multi-Path (ECMP) in Load Balancing through GNS3 simulation. Load balancing, as a method for evenly distributing traffic loads, and failover, as a backup mechanism when the main connection experiences problems. GNS3 is a graphical network simulator program that can transmit more complex network topologies compared to other simulators, for example Cisco Packet Tracer. The primary aim of this study is to comprehend how efficiently both techniques distribute traffic loads, maintaining smooth internet access, and increasing reliability. The PCC method produces better throughput, delay and jitter compared to the ECMP method, even though it has slightly different values for each QoS parameter. In testing traffic distribution, the PCC method outperforms the ECMP method. The PCC method can distribute traffic evenly across both ISP lines when downloading and uploading data packets. Meanwhile, the ECMP method can only carry out download and upload activities on one traffic path.

Keywords: ECMP, GNS3, Internet, Load Balancing, PCC

1 Introduction

In the increasingly developing digital era, the presence of the internet has now become an essential necessity in everyday life. In this context, having stable and fast internet access becomes crucial. The internet is not only used for entertainment purposes but also serves as the foundation for many essential activities, including work, education, healthcare, and communication. Stable internet access enables users to quickly access information, communicate efficiently, and participate in various online platforms without interruptions. When facing internet connection issues, one solution that can be taken is to utilize the use of more than one Internet Service Provider (ISP) to maintain the smoothness and performance of the internet.

According to Rahmad & Diah [1], the implementation of Load Balancing can optimize traffic load distribution on the proxy, thus reducing server workload. Consequently, it is expected that users can access internet facilities more smoothly, and the risk of downtime can be minimized. Load balancing can evenly distribute traffic load on both connection paths or links, ensuring stable internet availability [2]. Load balancing is the process of redistributing workload in distributed systems such as cloud computing, ensuring that no computing machine is overloaded, under-loaded, or idle. Load balancing aims to accelerate various limited parameters such as response time, execution time, system stability, etc [3].

There are many methods used in load balancing techniques including PCC, NTH, and ECMP. Each load balancing method has its advantages, disadvantages, and unique characteristics, which is why the author is interested in conducting a comparative analysis of the performance of these two methods. This analysis aims to determine which method is more effective based on performance parameters tested using Quality of Service (QoS). This study uses the GNS3 application to run

simulations integrated with Mikrotik OS to configure load balancing and perform performance comparison analysis.

PCC categorizes traffic flows passing through or exiting the router into several groups. This division can be based on source address (src-address), destination address (dst-address), source port (src-port), and destination port (dst-port). When a traffic connection starts, the router will maintain information about the gateway path used. This allows data packets related to previous connections to be forwarded through the same gateway path [4].

Equal Cost Multi-Path (ECMP) is a method for alternately selecting exit paths through gateways. For example, if there are two gateways, packets will be given out through both with balanced loads [5]. Packet sender machines identify the next path based on the number of hops. All paths between each node have identical routing values, resulting in traffic from data being evenly distributed [6].

GNS3 (Graphical Network Simulator 3) is an Open Source graphical network simulator that allows network emulation from simple to complex. GNS3 is promoted by a user-friendly graphical user interface (GUI) that allows configuring network components on virtual machines running the same operating system as the original network components [7]. GNS3 is much more flexible compared to other vendor-specific network simulators (such as Cisco Packet Tracer), where GNS3 can handle more complex network topologies [8]. GNS3 supports various network vendors, while Cisco Packet Tracer focuses on Cisco devices. GNS3 also offers extensive device emulation through integration with virtual machines, while Cisco Packet Tracer has limitations in device emulation [9]. Therefore, in this study, the simulation is conducted using GNS3.

The application can operate on various operating systems such as Windows, Linux, and Mac OS [10]. Overall, GNS3 has three main concepts: simulation, emulation, and virtualization. Simulation allows representing network behavior and its components in a concise manner, while emulation mimics network behavior to support its operation. One advantage of GNS3 is its ability to integrate with existing physical networks. GNS3 can emulate network interfaces, routers, hubs, and other network devices [11].

In this context, conducting a comparative analysis between the PCC Method and the ECMP Method becomes highly relevant to understand their strengths, weaknesses, and performance in specific situations and conditions. The use of GNS3 (Graphical Network Simulator-3) as a simulation tool provides an opportunity to test and compare these load balancing methods in a controlled environment before implementing them in real networks. By understanding the differences and characteristics of each method, this research is expected to provide valuable insights for professionals and researchers in the field of computer networking to make informed and intelligent decisions in selecting the appropriate load balancing method that fits their specific network needs.

2 Literature Review

Some previous studies relevant to this research are Pakiding et al., [12] with the title "Simulation Comparison of Load Balancing with PCC, ECMP, and NTH Methods using GNS3." This research analyzed the characteristics, advantages, and disadvantages of the three load balancing methods. Implementation was done using Mikrotik CHR in network topology simulation on the GNS3 application. Testing was conducted with several QoS parameters, namely delay, jitter, throughput, and packet loss. The results of this research indicate that the PCC method is the best method in QoS testing, and in the traffic distribution, the PCC and NTH methods have similar traffic path distribution.

A study by Nerissa & Billy [13] titled "Analysis of Licensing for PCC, NTH, and ECMP Methods for Load Balancing and Failover." This research implemented failover and load balancing using PCC, NTH, and ECMP methods and analyzed the latency of these three methods. The conclusion of this research is that the NTH and ECMP methods are able to evenly distribute bandwidth to each user. However, there are issues with connection stability and packet delivery, which still experience packet loss.

In 2019, Azriel Christian et al., [14] completed a study titled "Comparison Analysis of Load Balance Simulation using ECMP and PCC Methods in the Implementation of Bandwidth Congestion Management HTB (Case Study: Immanuel Christian University, Yogyakarta)." Based on the comparison results tested using the TIPHON standard, it was concluded that PCC is superior to

ECMP when the network experiences congestion. Although their throughput rating is the same at 100%, there are differences in the level of packet loss and jitter. With PCC, the packet loss rate reaches 15% in the moderate category, with a jitter value of 15.69 ms in the good category. Meanwhile, with ECMP, the packet loss rate reaches 58% in the poor category, with a jitter value reaching 98.2 ms.

A study by Nugroho et.al., [15] titled "Quality Analysis of Service Load Balancing using PCC, ECMP, and NTH Methods." This study aims to compare the performance of load balancing methods PCC, ECMP, and NTH to identify which method is most optimal for load balancing implementation. The results show that the PCC method has a lower Packet Loss value (better) than the ECMP and NTH methods, while the ECMP method has better stability in throughput, delay, and jitter values compared to the PCC and NTH methods.

From several previous studies mentioned, it can be concluded that the analysis of various load balancing methods, such as PCC, NTH, and ECMP, has significant implications in the context of network management. Research indicates that each method has its own strengths and weaknesses, as well as differing performance depending on specific network conditions. The PCC method is often considered the preferred choice in quality of service (QoS) testing, with lower packet loss rates and good traffic distribution performance. However, the NTH and ECMP methods can also provide even bandwidth distribution to users, although there are still issues regarding connection stability and packet loss. The research objectives include designing a load balancing system using PCC and ECMP methods using the GNS3 application, with the hope of achieving optimal performance.

3 Research Method

In this study, the author applies the Network Development Life Cycle (NDLC) approach. NDLC is a methodological approach applied in the process of designing computer networks. NDLC is a model that illustrates the cycle of the design or development process of a computer network system [16]. NDLC involves several steps in developing a network system, with the aim of reducing the risk of failure in subsequent stages [17]. The flow of the stages in the NDLC method can be seen in Figure 1.

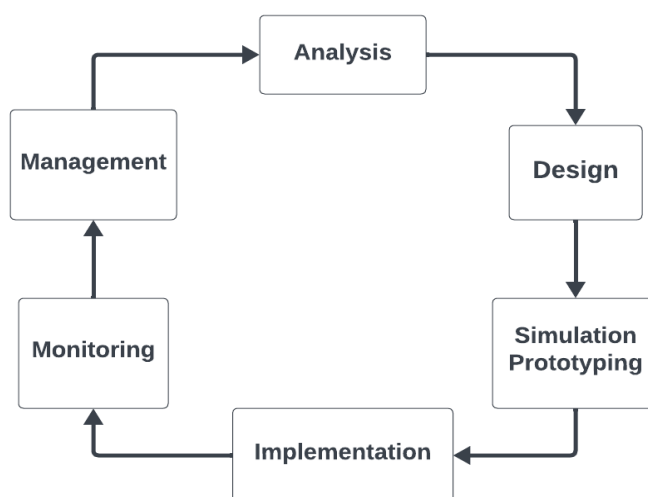


Figure 1. NDLC Research Methodology

Here are some explanations about each stage in the NDLC method:

1) Analysis.

At this stage, an analysis is carried out regarding the hardware and software requirements needed to support the implementation of load balancing using the PCC and ECMP methods. The tools needed during the research process can be seen in Table 1.

Table 1. Device Specifications Required

No	Device Specifications	Information
1.	Mikrotik CHR7.7.1	The router used for implementation of the PCC method load balance technique
2.	GNS3 Application	GUI-based network simulator used in creating network topologies
3.	Windows 11	User's laptop operating system
4.	Router OS v.7.8	It is a MikroTikCHR7.7.1 operating system
5.	WinBox versi 3.37	The tools used make configuration settings on the proxy

2) Design.

After completing the requirement analysis, the next step is the design phase. In this stage, a network topology connected to demonstrate how this project will be created will be designed.

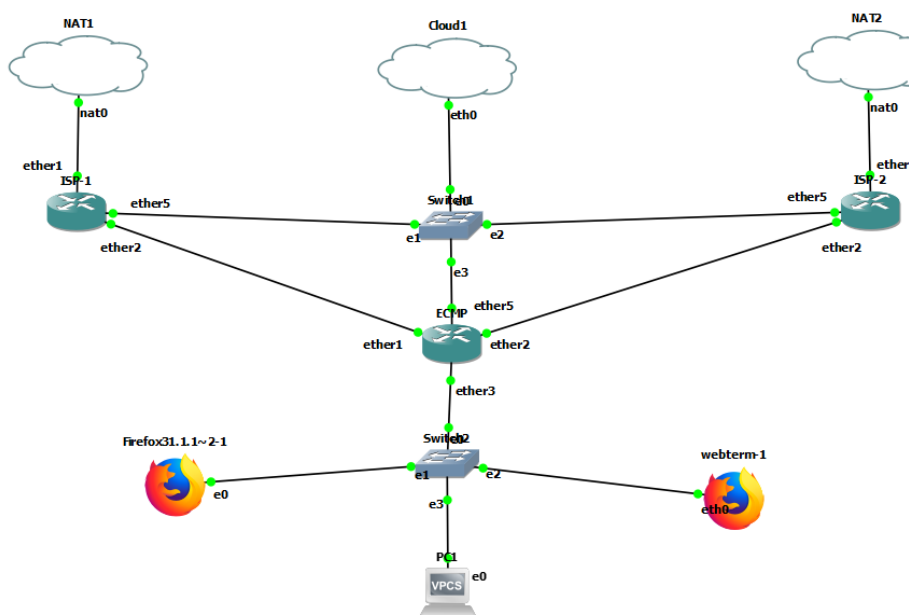


Figure 2. Network Topology Design

Figure 2 depicts the topology utilized in the research, created using the GNS3 application. GNS3, short for Graphic Network Simulator-3, is one of the software tools for simulating computer networks that has a graphical user interface (GUI) and resembles Cisco Packet Tracer. The main feature of GNS3 is its ability to design high-quality and complex network topologies. GNS3 supports various platforms such as Cisco IOS routers, IPS firewalls, PIX, ASA, and JUNOS devices [18].

3) Simulation Prototyping.

In this stage, designing for each load balancing method is carried out using the GNS3 simulation application. The aim is to evaluate the performance of the designed network and to be used as presentation material.

4) Implementation.

In this stage, the implementation of the analysis results, the creation of network topology, and the design of the simulation will be carried out, which will then be implemented using the PCC and ECMP load balancing methods. Both methods will allocate bandwidth of 10Mbps for each ISP. The overall research design flow is depicted in the Flowchart in Figure 3, illustrating the stages that will be conducted during the research.

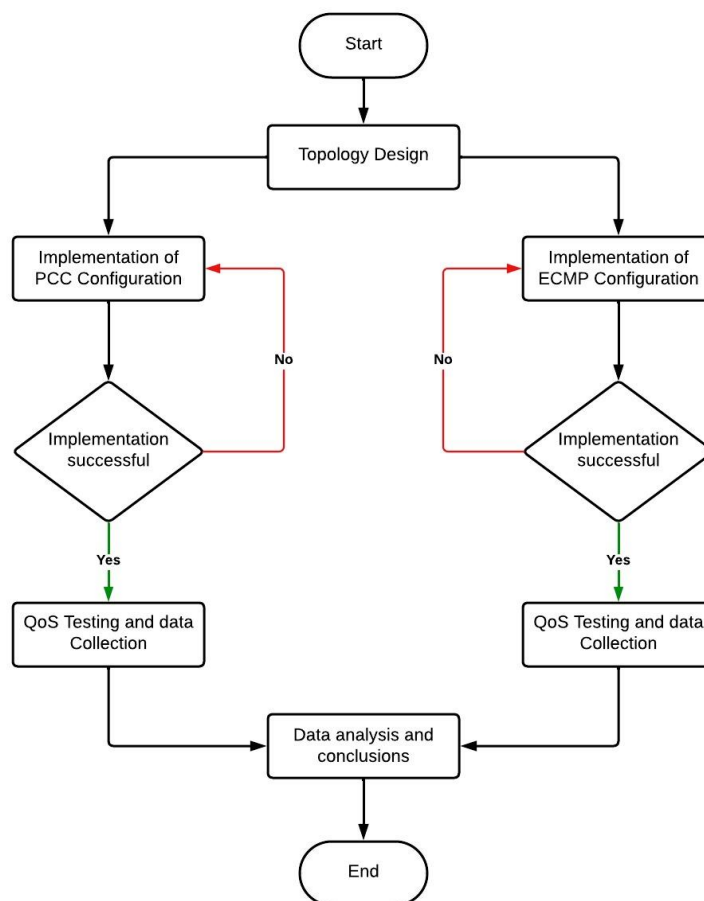


Figure 3. Flowchart of the general design of load balancing using the PCC and ECMP methods

Figure 3 illustrates a flowchart serving as a visual representation of the stages conducted throughout the research. This flowchart illustrates the general workflow of this research, along with detailed explanations for each step:

a. Topology Design

The topology design used is as shown in , utilizing two internet links, MikroTik, a switch, and several clients such as PC1, Firefox, and Webterm.

b. Network Configuration and Implementation

Network configuration in this research will involve configuring load balancing using the PCC and ECMP methods.

c. Network Testing

In this stage, testing is conducted with the assistance of network analysis applications such as Wireshark. The testing is performed alternately between the load balancing configuration using the PCC method and then continuing with the load balancing configuration using the ECMP method.

5) Monitoring.

The monitoring stage is where the computer network can function according to the author's objectives. The author will monitor the performance of each load balancing method by testing using network analysis applications, such as Wireshark. The results will serve as the basis for compiling a comparison table, which will determine the best load balancing method between the two methods being compared.

Service quality in networks, often related to data and multimedia flows, is crucial in the context of computer networks. Data flow plays a key role in determining service quality, which is the main focus of Quality of Service (QoS) [19]. QoS is a term commonly used to describe network service characteristics and assess the quality of service provided. With QoS, bandwidth can be optimized to improve the quality of internet service enjoyed by users [20]. Various characteristics, including Packet Loss, Delay, Throughput, and Jitter, can indicate the performance quality of internet access in a network [21].

a. Throughput

Throughput refers to the efficiency of data transfer, usually measured in bytes per second (bps). Another definition is as the number of packets that arrive and are recorded at the packet destination during a certain period of time, which is then divided by the duration of that time interval. Increased throughput correlates with improved performance of computer networks [22]. Index and category measurements on throughput parameters are shown in Table 2.

Table 2. Measurement of throughput parameters according to TIPHON

No	Throughput Category	Throughput	Index
1.	Excellent	>1200 Kbps	4
2.	Good	700 - 1200 Kbps	3
3.	Medium	338 – 700 Kbps	2
4.	Poor	<338 Kbps	1

b. Delay

Delay refers to the time it takes for data to move from its source to its destination. Factors affecting delay include distance, physical media, congestion levels, and extended processing durations. Index and category measurements on delay parameters are shown in Table 3.

Table 3. Measurement of delay parameters

No	Delay Category	Delay Magnitude	Index
1.	Excellent	<150m/s	4
2.	Good	150m/s – 300m/s	3
3.	Medium	300m/s – 400m/s	2
4.	Poor	>400m/s	1

c. Jitter

Jitter is the fluctuation or variation in the arrival time of data packets, which is the changes in delay time that occur during the transmission process from one point to another destination point. Index and category measurements on jitter parameters are shown in Table 4.

Table 4. Measurement of jitter parameters

No	Jitter Category	Peak jitter	Index
1.	Excellent	0 ms	4
2.	Good	0 ms - 75ms	3
3.	Medium	75ms – 125ms	2
4.	Poor	125ms – 225ms	1

d. Packet Loss

Packet Loss is the amount of data packets that fail to reach the final destination. Benchmark categories and indices for measuring QoS packet loss parameters are shown in Table 5.

Table 5. Measurement of packet loss parameters

No	Degradation	Packet loss	Index
1.	Excellent	0 – 2 %	4
2.	Good	3 – 14 %	3
3.	Medium	15 – 25 %	2
4.	Poor	>25 %	1

6) Management.

In this stage, management and maintenance are carried out for the system to ensure the absence of arising issues and its smooth operation, aiming for long-term sustainability, and ensuring the system's reliability is maintained.

4 Results and Analysis

In this study, the author designs and implements a load balancing network using the GNS3 (Graphical Network Simulator 3) simulator with two Internet Service Providers (ISPs), each having a bandwidth of 10Mbps, with a 1:1 ratio. The aim of this study is to compare the performance of the PCC and ECMP methods. Testing is conducted using Winbox version 3.37 for load balancing configuration.

Implementation of the PCC Method

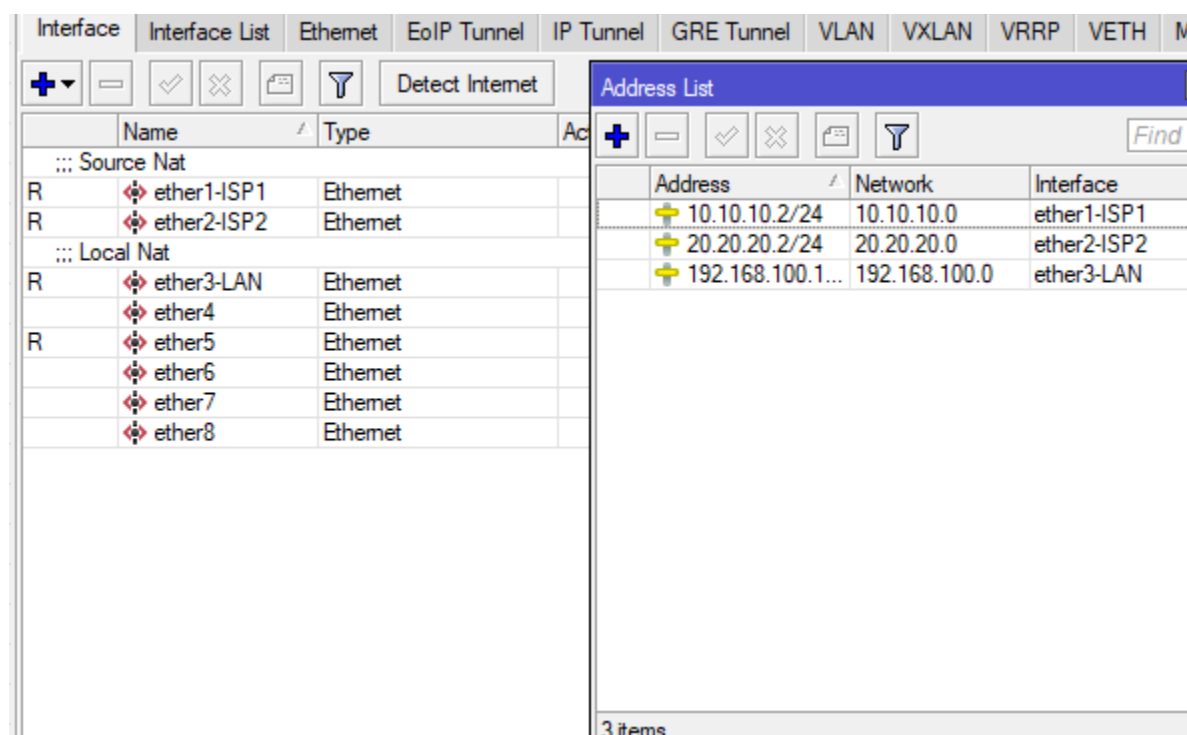


Figure 4. Results of the configuration of the interface list and input of IP Address

In Figure 4, IP address settings are performed on each active interface according to the topology. For this configuration, interface ether1-ISP1 is assigned the IP address 10.10.10.2/24, interface ether2-ISP2 is assigned the IP address 20.20.20.2/24, and interface ether3-LAN is assigned the IP address 192.168.100.1/24.

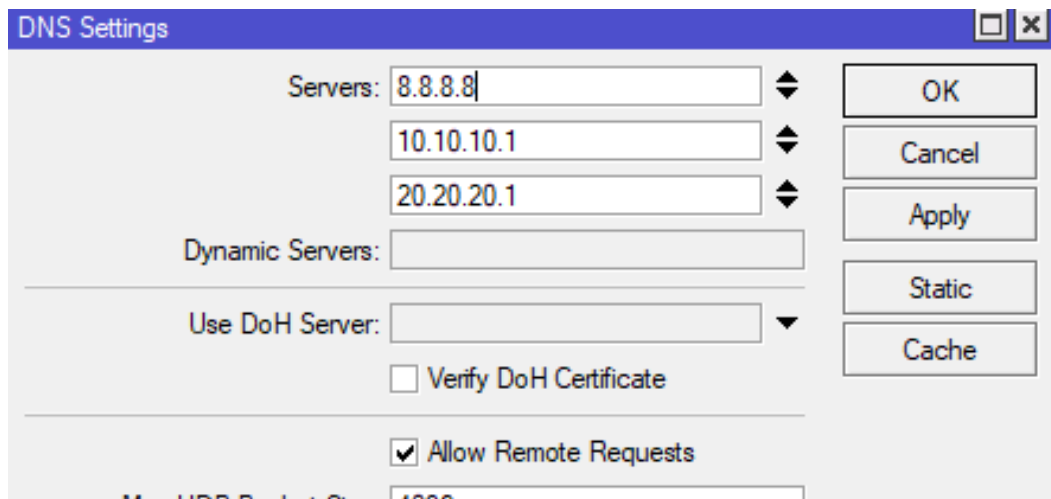


Figure 5. Results of the DNS (Domain Name System) configuration

In figure 5, configure the DNS server by giving '8.8.8.8' as the default, '10.10.10.1' and '20.20.20.1' The IP of each ISP is used as the server. DNS configuration aims to map hostnames of websites on the internet to IP addresses.

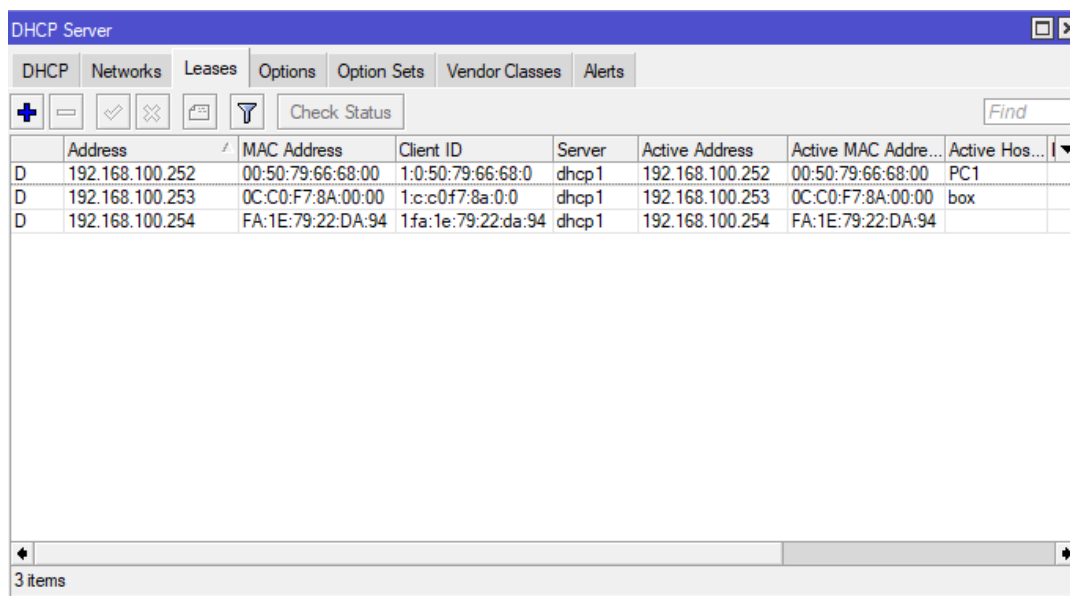


Figure 6. Results of the DHCP Server configuration

Figure 6 is the result of the DHCP server configuration carried out on the LAN network interface so that each client gets an IP Address automatically. This configuration results in PC1 obtaining the IP Address 192.168.100.252, Firefox31.1.1 obtaining the IP Address 192.168.100.253, and Webterm-1 obtaining the IP Address 192.168.100.254.

#	Action	Chain	[S:]	[D:]	Src. Port	Dst. Port	In. Interface	Out. Interface	Bytes	Packets
0	mas...	srcnat					ether1-ISP1		138 B	2
1	mas...	srcnat					ether2-ISP2		138 B	2

Figure 7. Results of the NAT (Network Address Translation) configuration

Figure 7 shows the configuration Firewall-NAT settings are applied to the ether1-ISP1 interface connected to ISP1 and the ether2-ISP2 interface connected to ISP2 on the backup router so that every client can access the internet. NAT configuration aims to change the source address of packets by performing translation into a public IP address. This NAT configuration setting uses chain=srcnat, action=masquerade, and the interfaces to be NAT'ed are the outbound interfaces ether1-ISP1 and ether2-ISP2.

#	Action	Chain	Src. Address	Dst. Address	S... D...	Pr...	Src. Port	D...	In. Interface	Out. Int...	In. Inter...	Out. Int...	Bytes	Packets
::: Bypass IP Address In and Out														
0	acc...	prerouting		30.30.30.0/24									1064 B	19
1	acc...	prerouting		10.10.10.0/24									6.1 KiB	111
2	acc...	prerouting		192.168.10.0/24									0 B	0
::: Mark Routing each ISP														
3	mar...	prerouting							ether1-ISP1				6.5 KiB	37
4	mar...	prerouting							ether2-ISP2				8.3 KiB	73
::: Konfigurasi PCC														
5	mar...	prerouting							ether3-LAN				14.4 KiB	45
6	mar...	prerouting							ether3-LAN				57.0 KiB	178
::: Mark routing Out through ether3-LAN to each ISP														
7	mar...	prerouting							ether3-LAN				14.1 KiB	44
8	mar...	prerouting							ether3-LAN				53.5 KiB	167
::: Mark Routing Output														
9	mar...	output											16.6 KiB	303
10	mar...	output											16.6 KiB	303

Figure 8. Results of the firewall mangle configuration for the PCC method

Figure 8 displays the result of the PCC method mangle configuration, the mangle configuration in the PCC method plays a role in managing packets destined for the router. In the PCC configuration, adjustments are made based on the address and port on both ISPs, with a divisor value of 2 and a remainder value of 0 for ISP1, and a remainder value of 2 for ISP2. Mark routing configuration is done for connections originating from outside and those heading to the router for each ISP. Additionally, mark routing configuration is performed for connections going out to or coming from the internet through the ether3-LAN interface using chain=output for each ISP, based on the assigned mark connection.

	Dst. Address	Gateway	Distance	Pref. Source
AS	0.0.0.0/0	20.20.20.1	1	
AS	0.0.0.0/0	10.10.10.1	1	
S	0.0.0.0/0	10.10.10.1	2	
S	0.0.0.0/0	20.20.20.1	2	
DAC	10.10.10.0/24	ether1-ISP1	0	
DAC	20.20.20.0/24	ether2-ISP2	0	
DAC	192.168.100.0...	ether3-LAN	0	

7 items out of 15 (1 selected)

Figure 9. Routing Configuration

Figure 9 is the result of the mark routing configuration using the PCC method. The configuration uses the gateway IP Address of ether1-ISP1 with mark routing "to-ISP1" for those directed to ISP1 and uses the gateway IP Address of ether2-ISP2 with mark routing "to-ISP2" for those directed to ISP2.

Implementation of the ECMP Method

Name	Type	Actual MTU	Address	Network	Interface
ether1-ISP1	Ethernet	1500	10.10.10.2/24	10.10.10.0	ether1-ISP1
ether2-ISP2	Ethernet	1500	20.20.20.2/24	20.20.20.0	ether2-ISP2
ether3-LAN	Ethernet	1500	192.168.100.1...	192.168.100.0	ether3-LAN

3 items

Figure 10. Results of the interface list configuration and IP Address for the ECMP method

In figure 10, we can see the results of the input of IP addresses displayed on the active interfaces. For the configuration, ISP1 has an IP Address of 10.10.10.2/24, ISP2 has an IP Address of 20.20.20.2/24, and for LAN, it has an IP Address of 192.168.100.1/24.

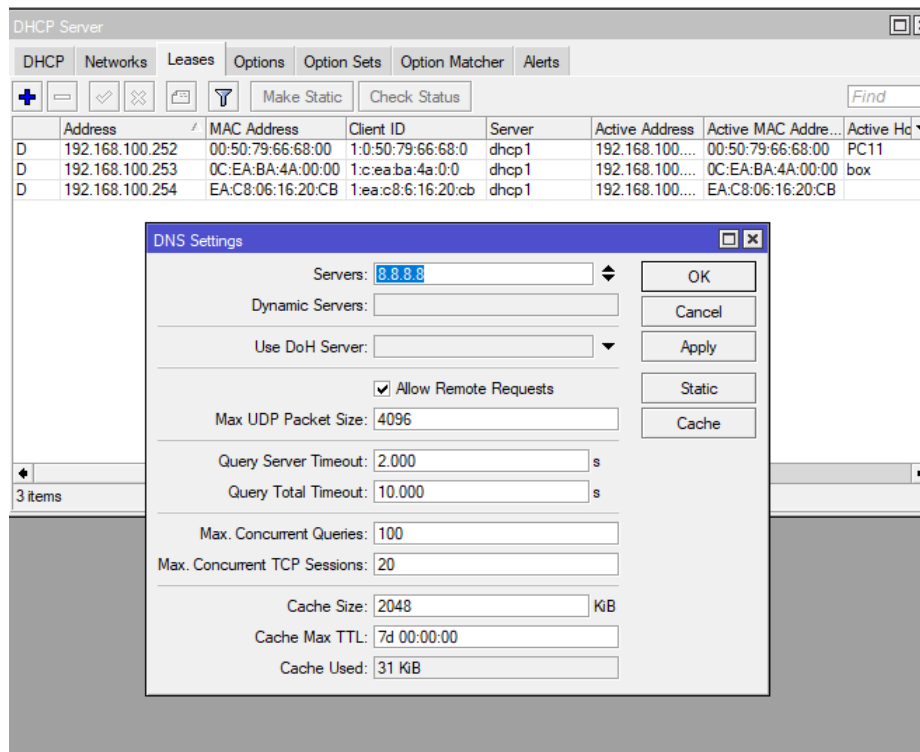


Figure 11. Results of the DHCP Server and DNS Server configuration

Figure 11 displays the configuration results of the DHCP Server configuration, that can be seen on the ether3-LAN interface so that clients can obtain IP Addresses automatically. PC11 obtains the IP Address 192.169.100.252/24, Firefox31.11 obtains the IP Address 192.169.100.253/24, and Webterm-1 obtains the IP Address 192.169.100.254/24. Configuring the DNS Server is used to map hostnames from websites on the internet.

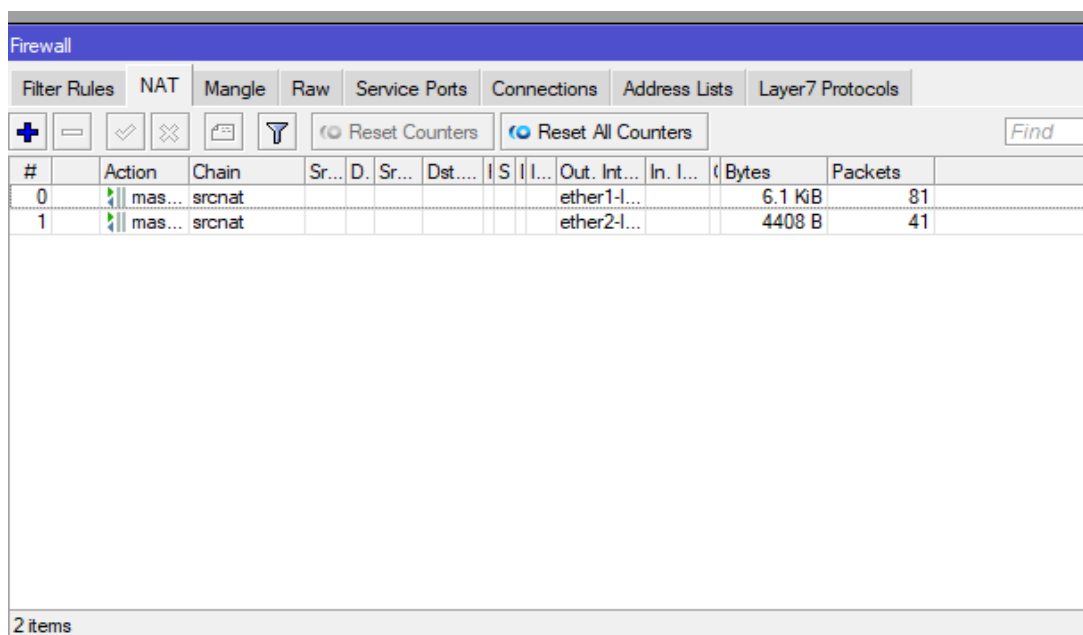


Figure 12. Results of the NAT (Network Address Translation) configuration

Figure 12 is the NAT configuration applied to every interface on the backup router to allow each client to access the internet. NAT is responsible for changing the source address of packets by translating them into public IP addresses.

#	Action	Chain	S	D	S	I	Proto...	Src. Port	Dst. Port	In. Inter...	Out. Int...	In. Inter...	Out. Int...	Bytes	Packets
0	mark conn...	input								ether1-I...				25.2 KiB	214
1	mark conn...	input								ether2-I...				5.7 KiB	78
2	mark routing	output												1224 B	11
3	mark routing	output												448 B	8

Figure 13. Results of the ECMP mangle configuration

Figure 13 displays the results of the mangle configuration using the ECMP method. The configuration marks incoming and outgoing packets according to their respective ISPs, using the input chain for traffic entering through ISP1 and ISP2, namely on ether1-ISP1 and ether2-ISP2. It uses the output chain for their exit based on their entry path.

	Dst. Address	Gateway	Distance	Pref. Source
AS+	0.0.0.0/0	20.20.20.1	1	
AS+	0.0.0.0/0	10.10.10.1	1	
AS	0.0.0.0/0	10.10.10.1	1	
AS	0.0.0.0/0	20.20.20.1	1	
S	0.0.0.0/0	10.10.10.1	2	
S	0.0.0.0/0	20.20.20.1	2	
DAC	10.10.10.0/24	ether1-ISP1	0	
DAC	20.20.20.0/24	ether2-ISP2	0	
DAC	192.168.100.0...	ether3-LAN	0	

Figure 14. Results of the routing configuration in the ECMP method

In Figure 14, the results of the routing configuration using the ECMP method are displayed, which aims to manage the routing path. In the ECMP method, routing is done only on each active ISP path, using the gateway of each ether interface on each ISP, and creating new routing marks for failover. The "AS+" symbol indicates that ECMP is actively utilizing both gateways on each ISP.

Testing Quality of Service (QoS)

In QoS testing, measurements are taken on several parameters including throughput, delay, jitter, and packet loss. This testing is conducted through a network analysis application, namely Wireshark. Each method, PCC and ECMP, is tested 10 times with an estimated testing time of 3 minutes. The average results of QoS measurements based on the measurement rules for each parameter described in the monitoring stage method are shown in Table 6.

Table 6. Average QoS Measurement Results

Degradation	Average			
	PCC	Description	ECMP	Description
Throughput (Kbps)	7900,9	Excellent	7747,8	Excellent
Packet Loss (%)	6,24	Good	6,08	Good
Delay (ms)	0,839	Excellent	0,847	Excellent
Jitter (ms)	0,897	Good	0,995	Good

a. Throughput

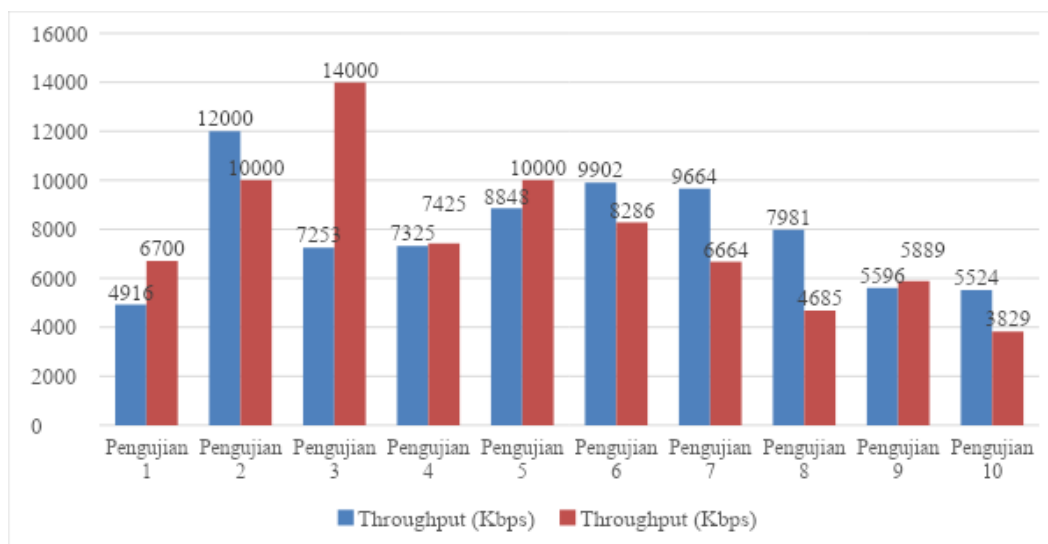


Figure 15. Results of Throughput analysis from 10 testing sessions

Figure 15 displays the results of QoS throughput parameter measurements carried out 10 times. From the average QoS testing data and the throughput analysis graph of both methods, it can be seen that the PCC method achieves a higher average value, which is 7900.9 Kbps, compared to the ECMP method, which reaches 7747.8 Kbps.

b. Packet Loss

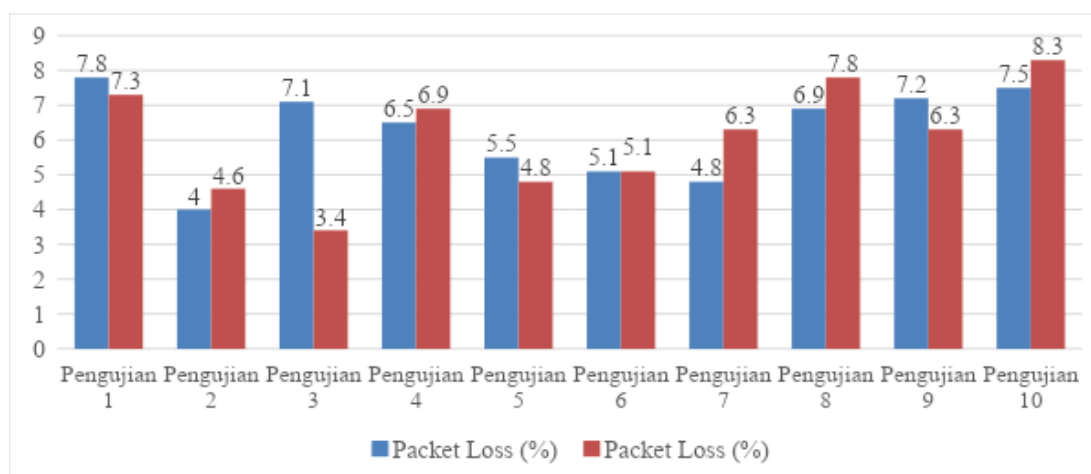


Figure 16. Results of Packet Loss analysis from 10 testing sessions

Figure 16 is the result of QoS measurements on packet loss parameters. Based on the average QoS testing data and the packet loss analysis graph of both methods, it can be observed that the ECMP method shows a lower average value (better performance), which is 6.08%, compared to the

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PCC method, which reaches 6.24%. However, both methods achieve a good index. The highest packet loss values for each method are 8.3% for the ECMP method in the eighth test and 7.8% for the PCC method in the first test.

c. Delay

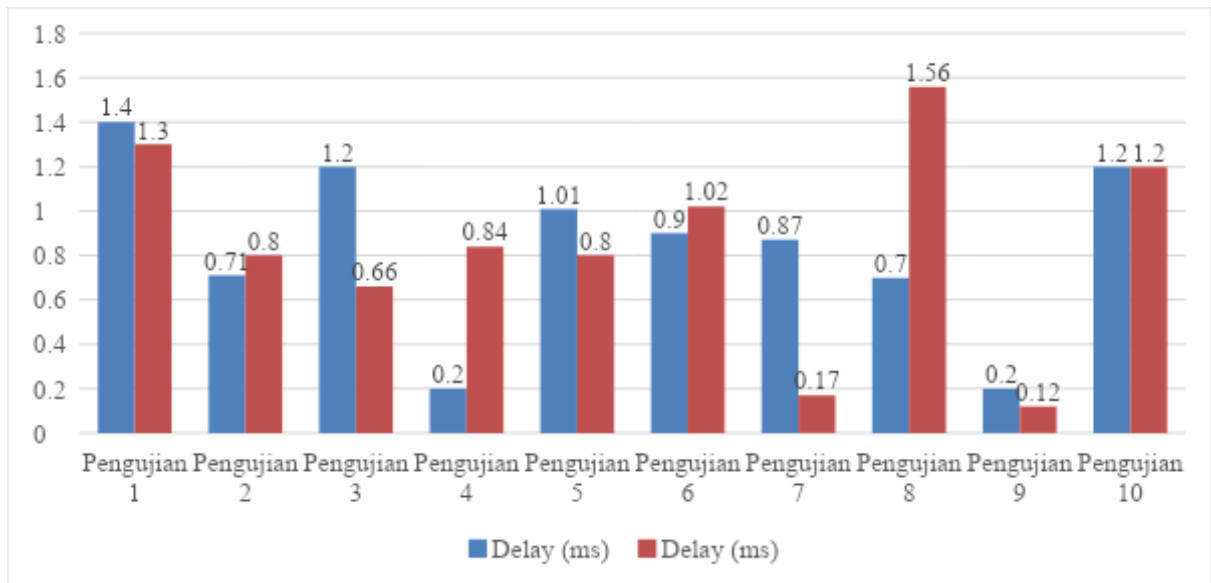


Figure 17. Results of Delay analysis from 10 testing sessions

Figure 17 is the result of QoS measurements on delay parameters. Based on the average QoS testing data and the delay analysis graph for both methods, it can be seen that the PCC method shows a lower average value (better performance), which is 0.839 ms, compared to the ECMP method which reaches 0.847 ms. The highest delay for each method is 1.56 ms for the ECMP method and 1.4 ms for the PCC method.

d. Jitter

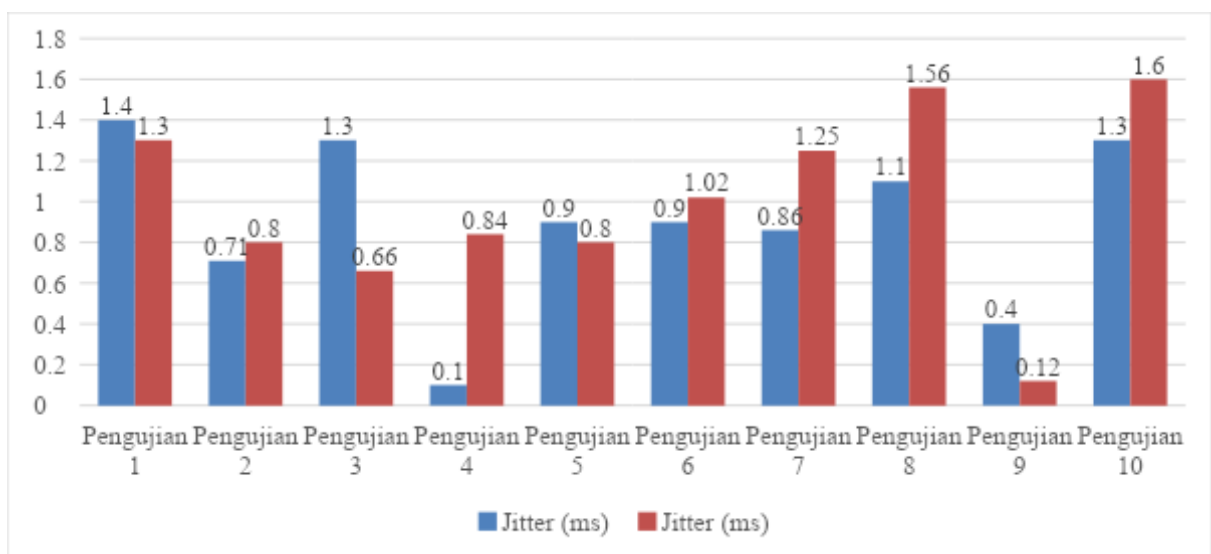


Figure 18. Results of Jitter analysis from 10 testing sessions

Figure 18 is the result of QoS measurements on jitter parameters. Based on the average QoS testing data and the delay analysis graph for both methods, it can be seen that the PCC method shows a lower average value (better performance), which is 0.839 ms, compared to the ECMP method which

reaches 0.847 ms. The highest delay for each method is 1.56 ms for the ECMP method and 1.4 ms for the PCC method.

From the average QoS measurement data and the jitter analysis graph, it can be observed that the PCC method has a lower jitter value, which is 0.897 ms, compared to the ECMP method with a value of 0.995 ms. However, both methods have good index values. The highest jitter value for each method is 1.4 ms for the PCC method and 1.6 ms for the ECMP method.

Traffic Distribution Measurement

This testing can be performed through various online services. NSF suggests several types of services to test network speed, such as Measurement Lab, Speedtest by Ookla, and Fast.com [23]. In this test, the author used the speedtest website, namely fast.com, then observed the interface of each method on the traffic heading to both ISPs to determine the traffic distribution. The following are the results of the conducted test:

a. Download testing on each method

Table 7. Results of download activity measurements that occurred in both methods

	Ether1 (Rx)	Ether2 (Rx)	Ether3 (Tx)
PCC	10,3 Mbps	10,4 Mbps	20,7 Mbps
ECMP	9,6 Mbps	0,0021 Mbps	9,612 Mbps

Table 7 displays the results of traffic distribution measurements carried out in the download activity section. In the PCC method, the Rx value obtained on Ether1 is 10.2 Mbps, on Ether2 is 9.6 Mbps, and on Ether3 is 19.7 Mbps. These results indicate that traffic distribution in the PCC method is balanced because both ISP paths function well during activity.

In the ECMP method, the Rx value obtained on Ether1 is 9.6 Mbps, on Ether2 is 0.0021 Mbps, and on Ether3 is 9.6021 Mbps. These results indicate that traffic distribution in the ECMP method is uneven because only one ISP path is used, which is on Ether1.

b. Upload testing on each method

Table 8. Results of upload activity measurements that occurred in both methods

	Ether1 (Tx)	Ether2 (Tx)	Ether3 (Rx)
PCC	4,0 Mbps	3,2 Mbps	7,2 Mbps
ECMP	0,3462 Mbps	4,3 Mbps	4,6462 Mbps

Table 8 displays the results of traffic distribution measurements carried out in the upload activity section. In the PCC method, the Tx value obtained on Ether1 is 4.0 Mbps, on Ether2 is 3.2 Mbps, and on Ether3 is 7.2 Mbps. These results indicate that traffic distribution during upload activities using the PCC method can be evenly divided across both ISP paths when performing activities simultaneously.

In the ECMP method, the Tx value obtained on Ether1 is 0.3462 Mbps, on Ether2 is 4.3 Mbps, and on Ether3 is 4.6462 Mbps. These results indicate that traffic distribution during upload activities using the ECMP method is uneven because it only uses one ISP path.

Based on the results of the traffic distribution test for download and upload activities previously conducted with load balancing methods, it can be concluded that the PCC method is better than the ECMP method. This is because the PCC method can evenly distribute traffic across both ISP paths during both download and upload activities. Meanwhile, in the ECMP method, the distribution of traffic during download and upload activities is uneven because it only uses one ISP path during its activities.

5 Conclusion

Based on the objectives of this research, which involve designing a load balancing system using the PCC and ECMP methods with GNS3 to achieve optimal performance between the two methods, it

can be concluded that the results of this research identify the strengths and weaknesses of each load balancing method through QoS testing and traffic distribution. In QoS testing with parameters such as throughput, packet loss, delay, and jitter repeated 10 times, the PCC method achieved an average throughput value of 7900.9 Kbps, while the ECMP method reached 7747.8 Kbps. For the packet loss parameter, the average value of the PCC method is 6.24%, while the ECMP method is 6.08%. For the delay parameter, the average value of the PCC method is 0.839 ms and the ECMP method is 0.847 ms. Meanwhile, for the jitter parameter, the average value of the PCC method is 0.897 ms and the ECMP method is 0.995 ms. The PCC method shows better performance in throughput, delay, and jitter compared to the ECMP method, while the comparison of packet loss, delay, and jitter values in both methods does not have significant differences. Additionally, the index values in both methods are still in the good category and can be tolerated. In terms of traffic distribution, the PCC method is able to evenly distribute traffic across both of its ISP paths during download and upload activities. On the other hand, the ECMP method can only perform download and upload activities on one traffic path. Thus, based on the results of QoS testing and traffic distribution, it can be concluded that the PCC method performs better than the ECMP method.

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