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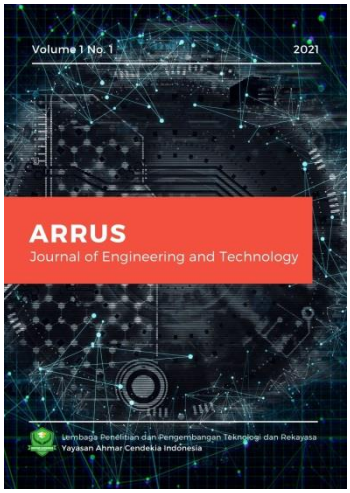

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RESEARCH ARTICLE

Implementation of Load Balancing Using PCC (Per-Connection Classifier) Method with Failover Based on MikroTik Router (Case Study at RSUD Siti Fatimah)

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Abstract: The rapid advancement of information technology, particularly in computer networking, has played a crucial role in supporting the operations of various institutions, including hospitals. RSUD Siti Fatimah is one such institution that leverages computer network technology to enhance performance and the quality of patient care. However, the hospital faces challenges with congested and slow network connections, which can hinder operational efficiency. To address this issue, a load balancing solution based on MikroTik was implemented using the Per-Connection Classifier (PCC) method, allowing the distribution of load across two ISPs for a more stable and faster connection. The PCC method was chosen for its ability to enhance connection speed and distribute network load evenly between the two gateways, thereby preventing overload. Additionally, a failover technique was applied to ensure that if one ISP connection fails, the network traffic is automatically switched to the other ISP, keeping the network operational without interruption. The implementation of this solution is expected to improve network efficiency and enhance healthcare services at RSUD Siti Fatimah.

Keywords: Load Balancing, PCC, MikroTik Router

1. INTRODUCTION

In the rapidly evolving era of information technology, the need for reliable and efficient connectivity has become essential, especially in complex network environments like hospitals. Siti Fatimah Regional Public Hospital, as a healthcare service institution, requires a network infrastructure that can guarantee fast and stable internet access to support medical applications and patient management systems.

With over 900 employees and 400 devices connected to the network, the reliability and availability of connectivity are vital. To address the challenges of a dense network, the concept of load balancing using the Per-Connection Classifier (PCC) method has been implemented. This method allows for even distribution of traffic across multiple connection paths, reducing the risk of system failure.

Additionally, a failover concept is utilized to ensure service continuity in case one of the connection paths experiences disruptions. This research focuses on the implementation of the PCC method with failover using MikroTik Router at Siti Fatimah Regional Public

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Hospital, with the hope of enhancing network performance and supporting hospital operations more efficiently.

2. Literature Review

2.1. *Load Balancing*

Load balancing is a technique for distributing the traffic load across two or more connection paths evenly, allowing for optimal traffic flow, maximizing throughput, minimizing response time, and avoiding overload on any single connection path[6].

In general, load balancing can be defined as a technique used to separate two or more network links. By having multiple links, the optimization of resource utility, throughput, and response time improves, as each link can back up the others if one connection link goes down or is interrupted.

2.2. *PCC (Per-Connection Classifier*

Equal Cost Multi Path (ECMP) is an outbound routing selection method using Peer Connection Classifier (PCC), developed by MikroTik and introduced in MikroTik Router OS version 3.24[2]. PCC selects a field from the IP header and, with the help of a hashing algorithm, converts the selected field into a 32-bit value. This value is then divided by a certain denominator, and the remainder is compared to a specific value; if they match, the packet is captured. Rules can be created by selecting information from the src-address, dst-address, src port, or dst port from the IP header[11].

Peer Connection Classifier (PCC) specifies a packet to a particular connection gateway. PCC groups the connection traffic entering or exiting the router into several categories. This grouping can be differentiated based on src-address, dst-address, src-port, and/or dst-port. MikroTik remembers the gateway path taken at the beginning of the connection traffic, so subsequent data packets related to the earlier packets will be routed through the same gateway path. However, because the PCC method routes packets through the same gateway, it has a disadvantage: it can lead to overload on one of the gateways.

2.3. *Firewall*

A firewall is a security system that uses a device or system placed between two networks, with the primary function of filtering incoming access. A firewall can be hardware or software, or it can consist of a set of rules or procedures established by an organization. It can also be described as a system or device that allows network traffic considered safe to pass through while preventing unsafe network traffic.

Typically, firewalls are implemented on a dedicated machine that operates at the gateway between a local network and other networks. Firewalls are commonly used to control access for anyone seeking to connect to a private network from external parties. Today, the term 'firewall' has become a general term referring to systems that regulate communication between two different networks.

A firewall is designed to protect the network from 'external threats.' It is usually used to safeguard a LAN from various attacks from outside sources. Attacks can target specific hosts, potentially causing data corruption or making services inoperable.

2.4. *NAT(Network Address Translation)*

Firewall NAT (Network Address Translation) is a process of mapping IP addresses where network devices assign a public IP address to local network devices, allowing multiple private IP addresses to access a public IP. This is necessary because private IP addresses cannot be routed to the internet (non-routed). NAT translates the IP addresses so that local network IPs can access public IPs on the internet. The widespread use of this method is due to the limited availability of IP addresses, the need for network security, and the ease and flexibility in network administration (Fatimah, 2009).

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2.5. *Routing*

Routing is the process of forwarding data packets from one network to another across an internet network. It can also refer to merging multiple networks so that data packets can traverse from one network to another. To accomplish this, a network device known as a router is used. The router receives packets intended for networks outside the first network and forwards the received packets to other routers until they reach their destination. Thus, a router acts as a bridge between two or more networks to transmit data from one network to another.

If static routing is used, the configuration must be done manually, requiring the administrator to add or remove static routes whenever there are changes in topology. In large-scale networks, static routing can be very time-consuming for network administrators to update the routing table. Therefore, static routing is only suitable for small networks, while dynamic routing is more appropriate for large-scale networks[5].

2.6. *TCP/IP (Transmission Control Protokol/Internet Protokol)*

TCP is a set of protocols designed to facilitate communication functions in computer networks. TCP/IP consists of a collection of communication protocols responsible for specific aspects of data communication. Thus, TCP/IP enables a group of computers to communicate and exchange data within a network. TCP/IP can be easily implemented on any type of computer and network interface because most of the protocols in this suite are not specific to any one type of equipment.

The TCP protocol is responsible for data transmission in segments. The TCP protocol model is referred to as a connection-oriented protocol, in contrast to the User Datagram Protocol (UDP) model, which is known as a connectionless protocol[3]. In the context of data communication in a computer network, there is a mechanism for transmitting data from the source computer to the destination computer. However, the sending process is not as straightforward as it may seem.

One reason is that the destination computer may be far from the source computer, which means that data packets can be lost or corrupted during transmission. Another reason could be that the destination computer is busy sending or waiting for data from another source. Therefore, it is crucial that the transmitted data packets arrive intact without damage. To manage this data communication mechanism, a process known as a protocol is necessary. A protocol is a software component that is integrated into the operating system[6].

When performing its functions, a protocol operates under several principles. The operational principles of the TCP protocol will serve as a reference for program developers or network administrators when selecting the appropriate protocol for data transmission[6].

2.7. *ISP (Internet Service Provider)*

An Internet Service Provider (ISP) is a company or organization that provides Internet services to corporate customers. ISPs are often associated with telecommunications companies, as they used to offer their products through telephone networks. They provide services such as internet connectivity, domain name registration, and hosting. Examples of telecommunications companies that offer internet services include Telkom Indonesia, Indosat, and others.

As technology has evolved over time, ISPs have expanded their offerings beyond just telephone networks to include radio and wireless technologies as well.

2.8. *Bandwidht*

In general, bandwidth can be likened to a water pipe with a certain diameter. The larger the bandwidth, the larger the diameter of the pipe, allowing for an increased volume of water (in this case, data in the literal sense) to flow. The greater the bandwidth of a medium, the higher the data transfer speed it can accommodate.

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According to experts, the definition of bandwidth is as follows:

1. Bandwidth is the width of communication between channels measured in specific units.

2. Bandwidth is the range of frequencies transmitted without causing signal degradation.

Bandwidth is a measure of the data transfer rate for downloads and uploads commonly used in communication networks, calculated in bits per second between a server and a client.

The function of bandwidth is to calculate the amount of data transfer for users accessing a server. When related to a website, the amount of bandwidth used is equal to the total data accessed by each visitor to the site.

Bandwidth can be categorized into two types:

1. **Digital Bandwidth:** This is the amount or volume of data that can be transmitted through a communication channel in bits per second without distortion.

2. **Analog Bandwidth:** This is the difference between the lowest and highest frequencies in a frequency range, measured in Hertz (Hz) or cycles per second, determining how much information can be transmitted at any given moment.

Bandwidth allocation or reservation is a process for determining the amount of bandwidth assigned to users and applications within a network. This includes setting priorities for various types of data streams based on their importance and sensitivity to delays. This allows for the efficient use of available bandwidth, and when the network slows down, lower-priority data streams can be halted, ensuring that critical applications continue to run smoothly.

2.9. Winbox

Winbox is a utility used to remotely access MikroTik servers in GUI mode. If you want to configure MikroTik in text mode, you can access it through a PC. However, if you prefer to configure MikroTik using the GUI method, you can use Winbox, which is accessed from a client computer. Configuring MikroTik through Winbox is more commonly used because it is generally easier compared to configuration via text mode.

3. Research Method and Materials

3.1. Research Data

This research requires data to uncover facts, ensuring the study achieves its objectives. The types of data collected in this research are primary and secondary data, including:

a) Primary Data

1. Parameters such as throughput, latency, and packet loss were measured from various points in the RSUD Siti Fatimah network after the implementation of load balancing. Measurements can be performed using network monitoring software.
2. Configuration data of the MikroTik Router, including PCC rules, failover settings, and other related network configurations.
3. Data regarding service availability over time (uptime) during the load balancing implementation, including information about downtime during failover events.

b) Secondary Data

1. Data related to the existing network structure at RSUD Siti Fatimah, along with documentation of device configurations.
2. Statistical data on network usage before the implementation of load balancing, including bandwidth usage and connection load.

3.2. Research Methodology

https://doi.org/10.35877/jetech3112

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To produce quality research that meets its objectives, a suitable research methodology is established, outlining the steps taken in the study. The following is a research method that uses action research.

Action research is a research method focused on solving practical problems within the context of everyday life. This method is used to test, develop, discover, and create new actions, so that when these actions are applied in practice, the work process becomes easier, and faster, and yields more high-quality results.

Below is an outline of the action research methodology illustrated through the research flow:

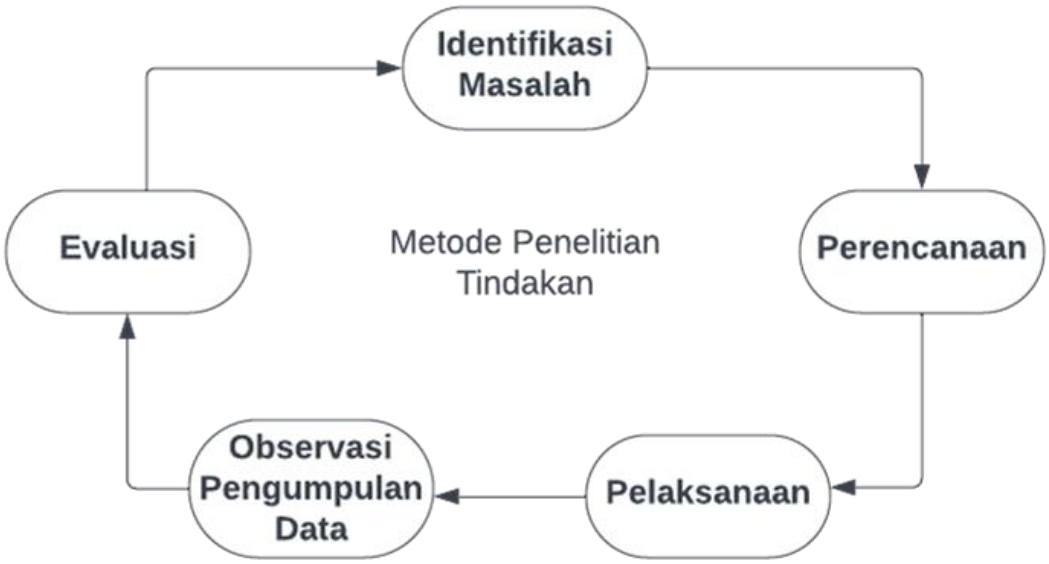

Figure 1: Action Research Methodology

In Figure 1, there are the general stages of action research, which serve as a guide for researching to achieve its objectives. The stages of this research are as follows:

1. Problem Identification

   Action research begins with identifying a specific problem or challenge within a practical context. This problem typically arises in workplaces, classrooms, or everyday environments.

2. Planning

   An action plan is created to address the identified problem. This plan must be clear and detailed, outlining concrete steps to be taken to achieve change or improvement.

3. Implementation

   The planned steps are applied in the field. This process involves active participation from practitioners or community members involved in the research.

4. Observation and Data Collection

   Data is continuously collected during the implementation of the action. Data collection may involve observations, interviews, surveys, or various qualitative and quantitative research techniques.

5. Evaluation

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Researchers engage in an evaluation process, where they consider the results of the actions and their impact on the identified problem. This evaluation helps to understand what worked and what needs improvement. Based on the results, actions can be assessed. If the outcomes are positive, the methods or actions can be further applied. However, if the desired changes have not been achieved, modifications to the plan or strategy can be made to enhance effectiveness.

3.3. *Software Requirements*

Software analysis aims to accurately select the software that will be used for configuring load balancing, ensuring it operates effectively and efficiently. Below are descriptions of the software required that will be used for configuring load balancing:

Table 1: *Software Requirement*

No	Software	Keterangan
1.	Mikrotik Winbox v.3.24	Software untuk melakukan remote GUI ke router mikrotik
2.	Windows 10 OS	Sebagai sistem operasi
3.	Beberapa Website Test Speed Bandwith	Sebagai alat uji kecepatan

3.4. *Hardware Requirements*

The hardware requirements for designing the load balancing configuration are as follows:

Table 2: *Hardware Requirement*

No	Perangkat	Jumlah	Spesifikasi Unit
1	Mikrotik RB952	1	CPU QCA9531 650MHz Main Storage/NAND 16MB RAM 64MB LAN Ports 5 Integrated Wireless 1 POE Output Yes, Port 5
2	PC Client Unit Instalasi Sistem Informasi dan Bagian Umum	20	Komputer Desktop dan Laptop
3	Modem ISP	2	- Biznet - Indihome
4	Switch Hub	2	24 Port

3.5. *System Design*

At the system analysis stage that will be designed, I have obtained the detailed specifications that will be developed. In this design phase, I will create a network topology diagram of the system to be built, in order to implement load balancing using the various load balancing methods as explained in the previous chapter.

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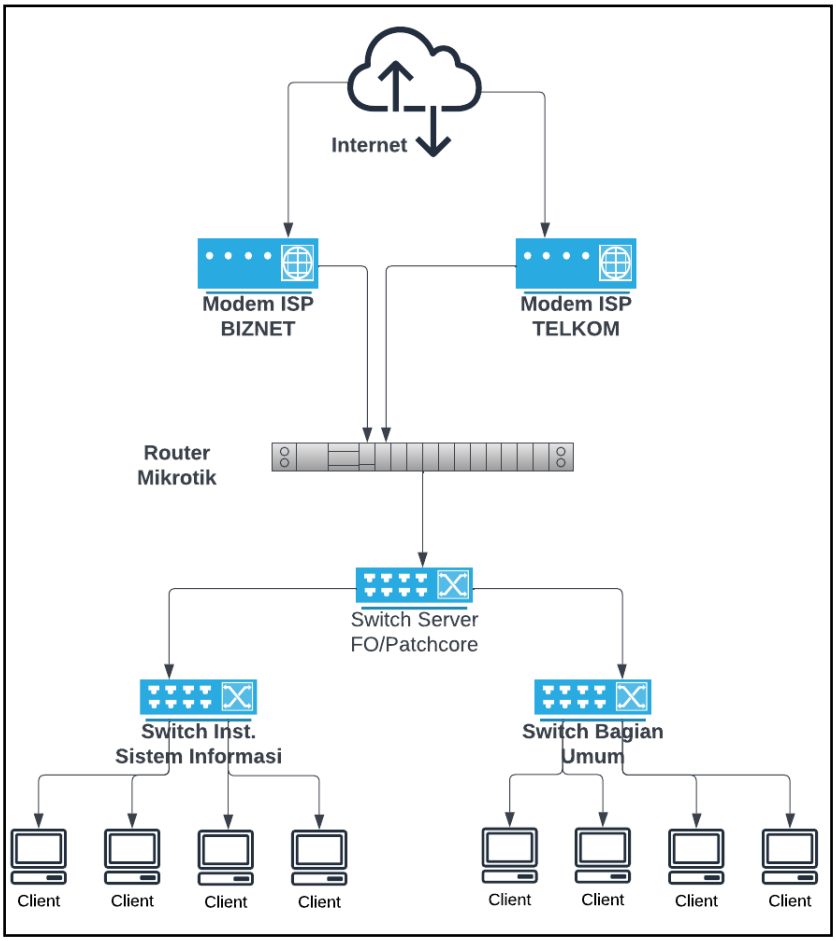

Figure 2: Load Balancing System Topology Design with Two ISPs

Table 3: List of IP Addresses

Perangkat	Interface	IP Address	Gateway
Mikrotik RB952	ISP-1 (eth2)	10.10.10.2	10.10.10.1
	ISP-2 (eth3)	192.168.0.2	192.168.0.1
	Lokal (eth4)	192.168.80.1/24	192.168.80.0
		192.168.81.1/24	192.168.81.0
Switch Hub	Ethernet	-	-
PC Client Instalasi Sistem Informasi	Ethernet	192.168.80.2 - 192.168.80.12	192.168.80.1
PC Client Bagian Umum	Ethernet	192.168.81.2 - 192.168.81.12	192.168.81.1

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3.6. *System Implemntation*

The following are the steps I took for the implementation of the system to be developed:

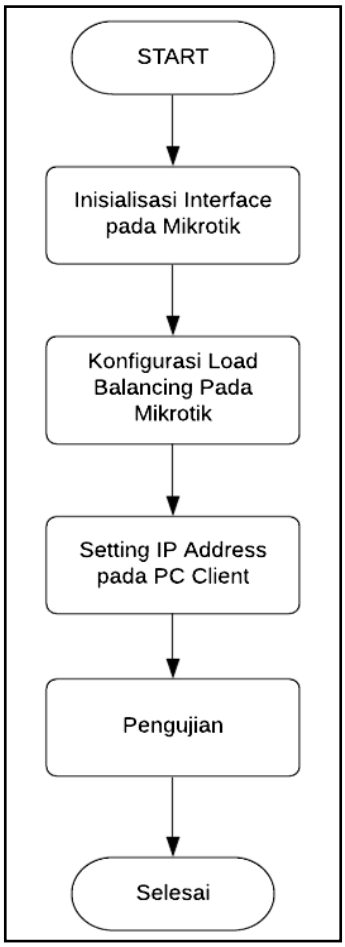

Figure 3: Diagram of the Steps for System Implementation

4. Results and Discussion

4.1. Load Balancing Testing

In the testing phase, I will measure how well the implemented system performs optimally. The testing method involves assessing the performance of the load balancing system as well as the quality of the network used for load balancing.

4.2. Browsing Testing

At this stage, I performed browsing using PC client1, targeting the website www.youtube.com. This activity serves as a sample of browsing from the client. The testing was conducted on both load-balancing methods that I designed. In the first test, I used the Nth load balancing technique. The fundamental characteristic of the Nth method is that the router divides the connection paths based on the order of the queue from the sources attempting to access the internet. Since there are two (2) internet connections, the queue created consists of these two. Below are the results of monitoring the connection that occurred when PC client1 browsed the website www.youtube.com:

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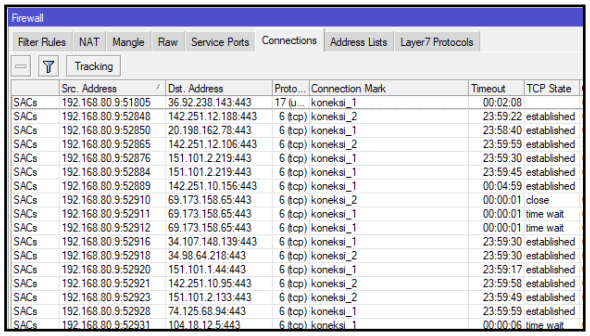
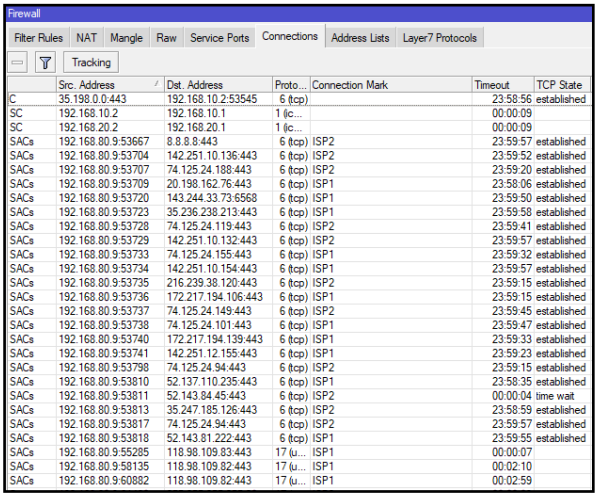


	Src. Address	Dst. Address	Proto...	Connection Mark	Timeout	TCP State
SACs	192.168.80.9:51805	36.92.238.143:443	17 (u...	koneksi_1	00:02:08	
SACs	192.168.80.9:52848	142.251.12.188:443	6 (tcp)	koneksi_2	23:59:22	established
SACs	192.168.80.9:52850	20.198.162.78:443	6 (tcp)	koneksi_1	23:58:40	established
SACs	192.168.80.9:52865	142.251.12.106:443	6 (tcp)	koneksi_2	23:59:59	established
SACs	192.168.80.9:52876	151.101.2.219:443	6 (tcp)	koneksi_1	23:59:30	established
SACs	192.168.80.9:52884	151.101.2.219:443	6 (tcp)	koneksi_1	23:59:45	established
SACs	192.168.80.9:52889	142.251.10.156:443	6 (tcp)	koneksi_1	00:04:59	established
SACs	192.168.80.9:52910	69.173.158.65:443	6 (tcp)	koneksi_2	00:00:01	close
SACs	192.168.80.9:52911	69.173.158.65:443	6 (tcp)	koneksi_1	00:00:01	time wait
SACs	192.168.80.9:52912	69.173.158.65:443	6 (tcp)	koneksi_1	00:00:01	time wait
SACs	192.168.80.9:52916	34.107.148.139:443	6 (tcp)	koneksi_1	23:59:30	established
SACs	192.168.80.9:52918	34.98.64.218:443	6 (tcp)	koneksi_2	23:59:30	established
SACs	192.168.80.9:52920	151.101.1.44:443	6 (tcp)	koneksi_1	23:59:17	established
SACs	192.168.80.9:52921	142.251.10.95:443	6 (tcp)	koneksi_2	23:59:58	established
SACs	192.168.80.9:52923	151.101.2.133:443	6 (tcp)	koneksi_2	23:59:49	established
SACs	192.168.80.9:52928	74.125.68.94:443	6 (tcp)	koneksi_1	23:59:59	established
SACs	192.168.80.9:52931	104.18.12.5:443	6 (tcp)	koneksi_1	00:00:06	time wait

Figure 4: The Results of Browsing Tests on PC Client1 (Nth)

From the results of the above test, it was found that when accessing the website www.youtube.com, the MikroTik router distributed the connections evenly and alternately. This is evidenced by the connection paths taken by IP 192.168.80.9 alternating between Connection_1 and Connection_2 in succession. In the next test, using the PCC load balancing technique, I also used PC client1 to access the website www.youtube.com. Since PCC remembers the paths taken at the start of the connection traffic, I will clear the route cache on the router before browsing. This is done to ensure that the router performs the load balancing process from the beginning. Below are the results of the connection monitoring that occurred when PC Client1 was browsing:



	Src. Address	Dst. Address	Proto...	Connection Mark	Timeout	TCP State
IC	35.198.0.0:443	192.168.10.2:53545	6 (tcp)		23:58:56	established
SC	192.168.10.2	192.168.10.1	1 (ic...		00:00:09	
SC	192.168.20.2	192.168.20.1	1 (ic...		00:00:09	
SACs	192.168.80.9:53667	8.8.8.8:443	6 (tcp)	ISP2	23:59:57	established
SACs	192.168.80.9:53704	142.251.10.136:443	6 (tcp)	ISP2	23:59:52	established
SACs	192.168.80.9:53707	74.125.24.188:443	6 (tcp)	ISP2	23:59:20	established
SACs	192.168.80.9:53709	20.198.162.76:443	6 (tcp)	ISP1	23:58:06	established
SACs	192.168.80.9:53720	143.244.33.73:6568	6 (tcp)	ISP1	23:59:50	established
SACs	192.168.80.9:53723	35.236.238.213:443	6 (tcp)	ISP1	23:59:58	established
SACs	192.168.80.9:53728	74.125.24.119:443	6 (tcp)	ISP2	23:59:41	established
SACs	192.168.80.9:53729	142.251.10.132:443	6 (tcp)	ISP2	23:59:57	established
SACs	192.168.80.9:53733	74.125.24.155:443	6 (tcp)	ISP1	23:59:32	established
SACs	192.168.80.9:53734	142.251.10.154:443	6 (tcp)	ISP1	23:59:57	established
SACs	192.168.80.9:53735	216.239.38.120:443	6 (tcp)	ISP2	23:59:15	established
SACs	192.168.80.9:53736	172.217.194.106:443	6 (tcp)	ISP1	23:59:15	established
SACs	192.168.80.9:53737	74.125.24.149:443	6 (tcp)	ISP2	23:59:45	established
SACs	192.168.80.9:53738	74.125.24.101:443	6 (tcp)	ISP1	23:59:47	established
SACs	192.168.80.9:53740	172.217.194.139:443	6 (tcp)	ISP1	23:59:33	established
SACs	192.168.80.9:53741	142.251.12.155:443	6 (tcp)	ISP1	23:59:23	established
SACs	192.168.80.9:53798	74.125.24.94:443	6 (tcp)	ISP2	23:59:15	established
SACs	192.168.80.9:53810	52.137.110.235:443	6 (tcp)	ISP1	23:58:35	established
SACs	192.168.80.9:53811	52.143.84.45:443	6 (tcp)	ISP2	00:00:04	time wait
SACs	192.168.80.9:53813	35.247.185.126:443	6 (tcp)	ISP2	23:58:59	established
SACs	192.168.80.9:53817	74.125.24.94:443	6 (tcp)	ISP2	23:59:57	established
SACs	192.168.80.9:53818	52.143.81.222:443	6 (tcp)	ISP1	23:59:55	established
SACs	192.168.80.9:55285	118.98.109.83:443	17 (u...	ISP1	00:00:07	
SACs	192.168.80.9:58135	118.98.109.82:443	17 (u...	ISP1	00:02:10	
SACs	192.168.80.9:60882	118.98.109.82:443	17 (u...	ISP1	00:02:59	

Figure 5: The Results of Browsing Tests on PC Client1 (PCC)

At this stage, I monitored the network system using the applications or tools available in Winbox. The results of the monitoring can be viewed in the interface list menu. Here are the results:

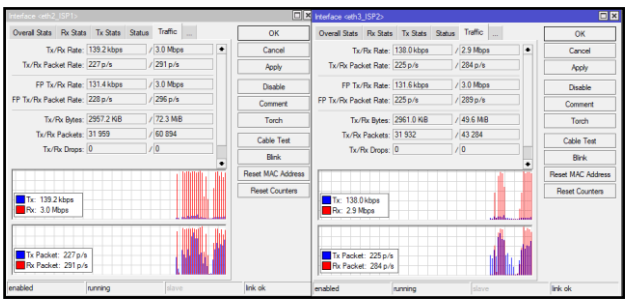


Figure 6: Connection Graph for Each ISP Gateway (Nth Load Balance)

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The parameters observed from both traffic in this interface list are the average transmitted packet size (Tx/Upload) from each ISP gateway. From Figure 4.15, it is evident that the Nth load balancing method successfully distributes packets and bytes almost equally across both interfaces. This result concludes that the Nth load balancing method can evenly distribute transmitted packets across each gateway.

In contrast, with PCC load balancing, the packet sizes between ISP1 and ISP2 are not balanced. This is because PCC only distributes the load based on the active connections, not the packet sizes. As a result, each connection sends packets of varying sizes, leading to an imbalance in the packet sizes transmitted through each interface. Below are the monitoring results of the packet sizes transmitted through each gateway.

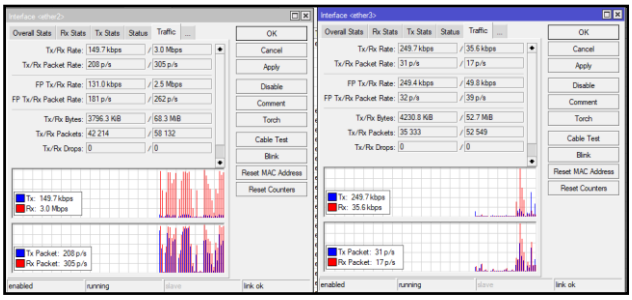

Figure 7: Connection Graph for Each ISP Gateway (PCC Load Balance)

From the two connection graphs above, it is also evident that the bandwidth between the two ISPs that have been load balanced shows a significant difference. This is because the PCC method distributes the load based on the active connections rather than the packet sizes.

4.3. Failover Testing

At this stage, I conducted tests on each load balancing method, both Nth load balancing and PCC load balancing, to evaluate the failover performance of the implemented system. The purpose of failover is to address disconnections or interruptions in the connection from one of the ISPs. With this failover feature, if one connection path from either ISP is interrupted, the system still has one ISP as a backup source for internet connectivity.

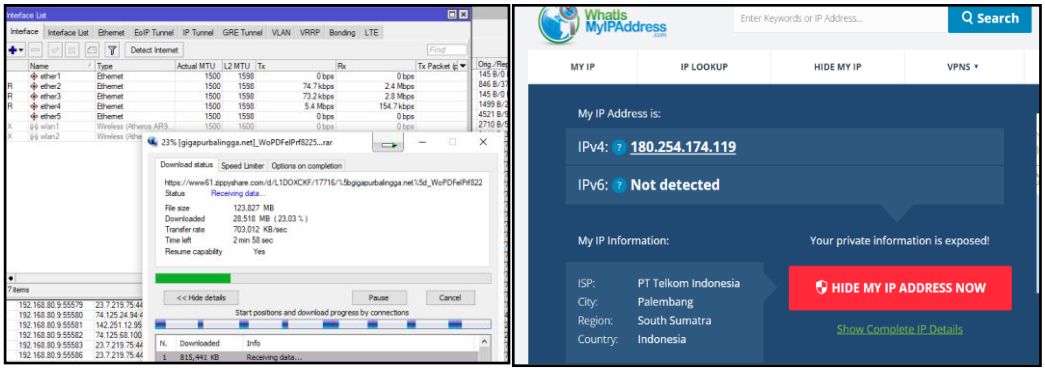

Figure 8: Download Testing and Download Connection Paths

The testing was conducted by downloading a large file accessed through PC client2 using IDM (Internet Download Manager). Initially, both ISPs remained connected to the router. The initial gateway during the download process was 180.254.174.119, which is the connection path from ISP1. While downloading, I attempted to disconnect the connection from ISP1 that was linked to the router. Below are the results of the failover test:

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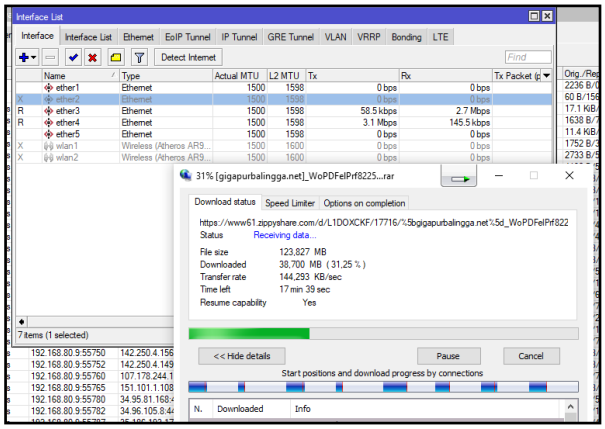

Figure 9: Download Testing After ISP_1 Disconnection

From the results of the above testing, it was found that the download process continued without any connection disruptions, as ISP2 automatically became the default gateway to back up the overall network performance. This was confirmed by checking the IP through the IP checker website, www.whatsmyipaddress.com. It was observed that during the initial download process, the connection was still using ISP1, which is Telkom, with the gateway IP 180.254.174.119. After disconnecting from ISP1, the download continued, but it switched to ISP2, MyRepublic, with the IP 103.47.132.54.

4.4. Speed Test Evaluation

In the speed test evaluation, we will determine the download and upload speeds, as well as the ping values for each load balancing method. The speed test was conducted by accessing the website www.speedtest.net. The results of the speed test for the Nth method can be seen in the following image.

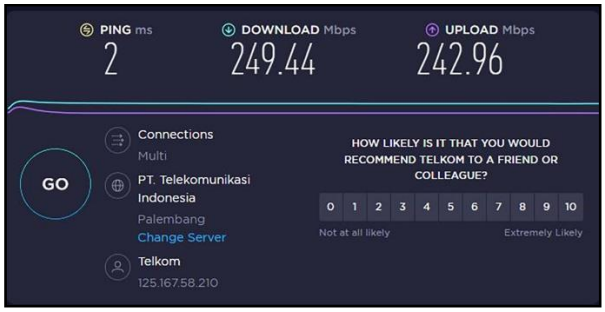

Figure 10: Speed Test Evaluation for the Nth Method

From the results of the above testing, it was found that the bandwidth for each ISP is 200 Mbps and 50 Mbps. However, the results from the speed test after implementing the Nth load balancing method, as shown in the image above, are 249.44 Mbps download, 2.42 Mbps upload, and a ping of 2 ms. This aligns with the load balancing method, which distributes the load evenly across both ISPs, allowing for a maximum combined bandwidth of 249.44 Mbps.

Next, a load usage test was conducted for the client using the Nth method. This testing involved monitoring the traffic levels on both ISP1 and ISP2, with samples taken during working hours at one-hour intervals. The results of this testing can be seen in Table 4.1 below.

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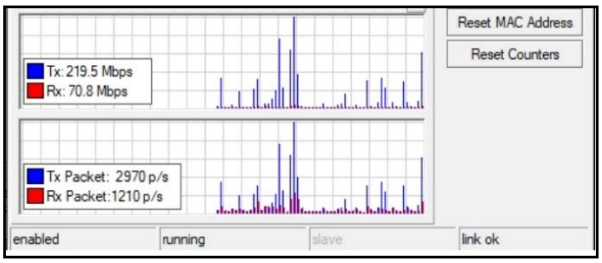

Figure 11: Traffic for Speed Test Evaluation

Table 4: Traffic Speed Testing for ISP Load Using the Nth Method

NO	Waktu	ISP 1		ISP 2	
		Downloads (RX)	*Uploads(RX)*	*Downloads (RX)*	*Uploads(RX)*
1	08:00	3,4 Mbps	327 Kbps	3,2 Mbps	367 Kbps
2	09:00	8,9 Mbps	808 Kbps	9,1 Mbps	795 Kbps
3	10:00	9,3 Mbps	341 Kbps	9,5 Mbps	466 Kbps
4	11:00	7,5 Mbps	405 Kbps	7,8 Mbps	389 Kbps
5	12:00	4,6 Mbps	257 Kbps	4,2 Mbps	267 Kbps
6	13:00	5,1 Mbps	211 Kbps	4,9 Mbps	233 Kbps
7	14:00	9,6 Mbps	870 Kbps	9,1 Mbps	769 Kbps
8	15:00	8,9 Mbps	912 Kbps	9,1Mbps	942 Kbps
9	16:00	5,5 Mbps	327 Kbps	5,9 Mbps	367 Kbps

From Table 4, it can be observed that the traffic shows an even distribution between ISP1 and ISP2. Subsequently, a comprehensive bandwidth test was conducted for both ISP1 and ISP2 using the PCC method, and the results can be seen in the image below.

Figure 12: Speed Test Evaluation for the PCC Method

The results after implementing the PCC load balancing method can be seen in the image above, showing a download speed of 46.59 Mbps, an upload speed of 42.95 Mbps, and a ping of 2 ms. The speed test result for the PCC method is 46.59 Mbps, which is due to PCC distributing the network based on the gateway queue, with the gateway in this case being ISP2.

Next, a load usage test was conducted for the client using the PCC method. This testing involved monitoring the traffic levels on both ISP1 and ISP2, with samples taken during working hours at one-hour intervals. The results of this testing can be seen in Table 4 below.

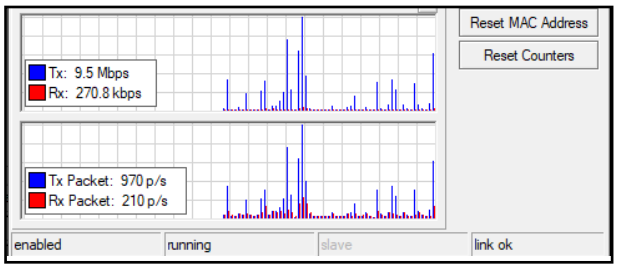

Figure 13: Traffic for Speed Test Evaluation

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Table 5: Traffic Speed Testing for ISP Load Using the PCC Method

NO	Waktu	ISP 1		ISP 2	
		Downloads (RX)	*Uploads(RX)*	*Downloads (RX)*	*Uploads(RX)*
1	08:00	4,2 Mbps	225 Kbps	1,8 Mbps	367 Kbps
2	09:00	7,9 Mbps	608 Kbps	5,2 Mbps	795 Kbps
3	10:00	9,1 Mbps	741 Kbps	8,4 Mbps	466 Kbps
4	11:00	8,5 Mbps	405 Kbps	6,7 Mbps	389 Kbps
5	12:00	4,6 Mbps	257 Kbps	4,2 Mbps	267 Kbps
6	13:00	5,1 Mbps	211 Kbps	4,9 Mbps	233 Kbps
7	14:00	9,3 Mbps	870 Kbps	8,9 Mbps	769 Kbps
8	15:00	8,5 Mbps	912 Kbps	5,3Mbps	942 Kbps
9	16:00	5,5 Mbps	327 Kbps	3,9 Mbps	367 Kbps

From Table 5, it can be seen that the traffic shows an uneven distribution between ISP1 and ISP2. The PCC method only distributes the load based on the active connections, not the packet sizes, resulting in each connection sending packets of varying sizes.

5. Conclusion

1. The system developed, using both the Nth load balancing and PCC load balancing methods, effectively addresses the issue of connection loss with one of the ISPs through the failover technique. This is evident from the automatic switching of connections to the gateway of the active ISP, ensuring that network performance remains stable.

2. The system is also capable of distributing connection paths evenly based on the size of request packets. However, it does not guarantee bandwidth balance, as it cannot separate or identify response packets.

3. In Nth load balancing, two gateways are used alternately according to a round-robin algorithm, while in PCC load balancing, a single connection uses the gateway based on the destination address.

4. The advantages of the Nth method include balanced load distribution since packets are allocated evenly according to the queue; however, the disadvantage is that the switching of gateways based on evenly distributed packets can sometimes cause delays. The advantage of the PCC method is that the client-server connection remains consistent because it stays on the same ISP path, only changing when the server destination differs. A drawback of the PCC method is the potential for overload on one path when multiple accesses coincide on the same route, resulting in a shared load.

References

E. R. Amalia, Nurheki, R. Saputra, C. Ramadhana, and E. H. Yossy, "Computer network design and implementation using load balancing technique with per connection classifier (PCC) method based on MikroTik router," Procedia Comput. Sci., vol. 216, pp. 103–111, 2023, doi: https://doi.org/10.1016/j.procs.2022.12.116.

S. A. Pasaribu and M. T. Unggul, "Comparison Analysis of Load Balance Performance Per Connection Classifier (Pcc) And Equal Cost Multi-Path (Ecmp) Networks for Multiple Path Networks," Int. J. Inf. Syst. Innov. Technol., vol. 1, no. 2, pp. 11–20, 2022.

E. B. Pablena, A. Salim, A. Raizaldi, Rizal, "Implementasi Load Balancing Metode PCC (Per Connection Classifier) untuk Oplimalisasi Internet dengan 2 ISP (Studi Kasis Pt. Zyrexindo Mandiri Buana Jakarta) J. Bidang Penelitian Informatika, vol. 1, no. 2, pp. 105-118, 2023.

https://doi.org/10.35877/jetech3112

ISSN [Print]: 2776-7914

D. A. Shafiq, N. Z. Jhanjhi, and A. Abdullah, "Load balancing techniques in cloud computing environment: A review," J. King Saud Univ. - Comput. Inf. Sci., vol. 34, no. 7, pp. 3910–3933, 2022, doi: https://doi.org/10.1016/j.jksuci.2021.02.007.

A. Tantoni, S. Fadli, and A. Hargianto, "Implementasi Load Balancing dengan metode NTH Menggunakan Mikrotik di SMKN 2 Kuripan," J. Automation Comput. Inform. Syst, 2021. https://jacis.pubmedia.id/index.php/jacis/article/view/16

M. Khaerudin, A. A. Hendharsetiawan, A. R. Mahbub, Tukino, S. Setiawati, "A Hotspot and Two Line ISP Load Balance and Failover Using the Mikrotik RB951UI 2HND with PCC Method," East Asian J. of Multidisciplinary Research vol. 2, no. 1, pp. 249-262, 2023. DOI: https://10.55927/eajmr.v2i1.2591

S. D. Suhendar, I. Ikbal, "Optimization of Load Blancing for Multi ISP Bandwidth Management Microtic with Android Based Configuration and Notification System in 27 Senior High School," [pdf] J. Ilmiah Komputer dan Informatika https://unikom.ac.id

D. Novianto, Y. S. Japriadi, "Comparative Analysis of Performance Between ECMP and NTH Methods in Implementation of Microtic-Based Dual Link Load Balancing Techniques," [pdf]. J. Tech. Acceptance. Model, vol. 12, no. 1, pp. 80-88, 2021, scholar.archive.org

W. Wiharti, I. L. Rimra, S. Rifka, I. Hidayatullah, A. F. Kasmar, "Load Balancing and Fail Over MikroTik Implementation Using Per Connection Classifier (PCC) on Two Internet Providers Interconnection," Int. J. of Adv. Sci. Comput. And Engineering, vol. 5, no. 2, pp. 129-135, 2023 https://doi.org/10.62527/ijasce.5.2.135