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Research article

Comparative Analysis of QoS of Load Balancing Network Using Equal Cost Multi Path And Per Connection Classifier Methods

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Abstract: High user traffic and suboptimal network management often result in slow internet performance. This study compares the Quality of Service (QoS) of Equal Cost Multi Path (ECMP) and Per Connection Classifier (PCC) load balancing methods at the Engineering Faculty Laboratory, Universitas Khairun. Using the Network Development Life Cycle (NDLC) framework, the implementation utilized a Mikrotik RB450GX4 router connected to two ISPs (Astinet and Indihome). Performance was evaluated based on throughput, delay, jitter, and traffic stability. Results demonstrate that both methods significantly improve network stability. Specifically, PCC excels in connection consistency and balanced traffic distribution based on address classification. Conversely, ECMP offers a simpler configuration with robust failover support. Ultimately, implementing these load balancing techniques enhances overall network service quality, providing an effective solution for managing multi-ISP environments in academic institutions.

Keywords: Load Balancing, ECMP, PCC, QoS

1. Introduction

The rapid advancement of information and communication technology has driven an increased demand for reliable and high-quality network services. As the number of internet users and web-based applications grows, the need for substantial bandwidth and stable connections has become crucial for both organizations and internet service providers [1]. However, bandwidth limitations and network capacity constraints often pose obstacles to delivering optimal service to users.

One solution to address these issues is the implementation of load balancing technology within computer networks [2]. Load balancing is a technique for distributing network traffic load evenly across multiple available connection paths or links. This approach enhances bandwidth utilization, reduces response time, and improves overall system reliability [3]. By applying load balancing, organizations can maximize existing network resources and deliver better Quality of Service (QoS) to users.

Quality of Service (QoS) serves as a critical parameter in assessing network service quality [4]. QoS measures various aspects of network performance, such as throughput, delay, packet loss, and jitter, which directly influence the user experience when accessing network services [5]. Proper implementation of load balancing is expected to enhance these QoS parameters, thereby providing a superior experience for end-users.

Various load balancing methods can be implemented in computer networks, including Equal Cost Multi-Path (ECMP) and Per Connection Classifier (PCC) [6]. The ECMP method operates by distributing network traffic evenly based on routing tables that share equal costs to the same destination [7]. ECMP utilizes a hash algorithm to determine which path each data packet will take, ensuring that packets originating from the same source and headed to the same destination consistently utilize the same path [8].

Conversely, the Per Connection Classifier (PCC) method performs load balancing by classifying connections based on a combination of source address, destination address, source port, and destination port [9]. PCC ensures that all packets belonging to the same connection traverse the same gateway, thereby maintaining connection integrity and preventing asymmetric routing issues [10]. The PCC method is claimed to be more effective in handling connections requiring persistence, such as video streaming, VoIP, and other real-time applications.

Several prior studies have examined the implementation of load balancing in computer networks. Research indicates that implementing load balancing can increase throughput by up to 80% compared to a single link connection [11]. Another study revealed that selecting the appropriate load balancing method significantly influences network performance, particularly regarding traffic distribution and connection stability [12].

However, limitations remain within these studies, particularly regarding a comprehensive direct comparison between ECMP and PCC methods concerning QoS parameters [13]. Most research has focused either on a single specific method or measured only a few QoS parameters, thus failing to provide a complete picture of the comparative performance of both methods under various network traffic conditions.

Furthermore, the increasingly diverse characteristics of modern internet traffic—driven by multimedia applications, cloud computing, and the Internet of Things (IoT)—require a deeper analysis of the effectiveness of each load balancing method in handling different traffic types [14]. The distinct working mechanisms of ECMP and PCC are predicted to have varying impacts on QoS, depending on the characteristics and patterns of the traffic traversing the network.

Based on these issues, research providing a comprehensive comparative analysis between ECMP and PCC methods in load balancing implementation is necessary, specifically regarding QoS parameters such as throughput, delay, packet loss, and jitter. This study is expected to contribute to the selection of the most suitable load balancing method for implementation within the network of the Informatics Engineering Study Program at Khairun University, tailored to its specific traffic characteristics, thereby optimizing overall network service quality [15].

2. Method

2.1 System Development Method

The proposed system development method is shown in Figure 1. Meanwhile, the PER CONNECTION CLASSIFIER (PCC) Load Balancing Packet Delivery Process is shown in Figure 2 and the EQUAL COST MULTI PATH (ECMP) Load Balancing Packet Delivery Process is shown in Figure 3.

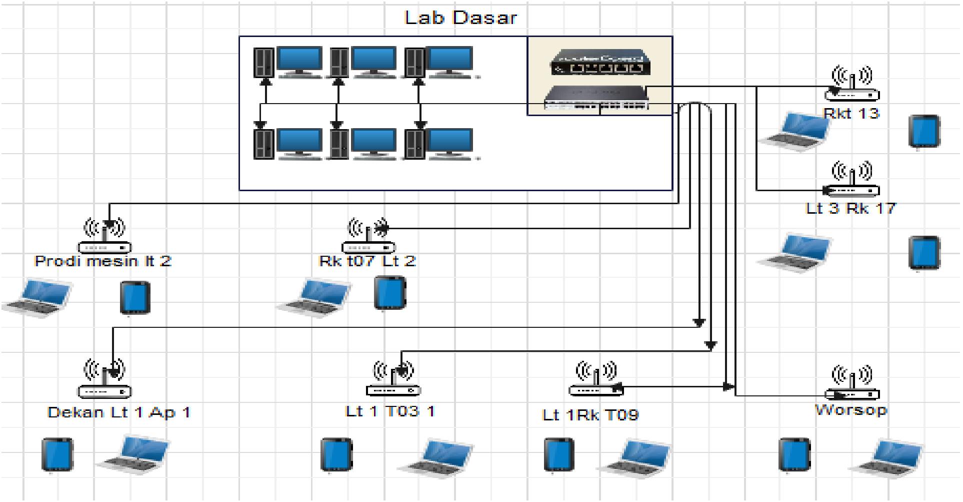


Figure 1. Network Topology with Load Balancing

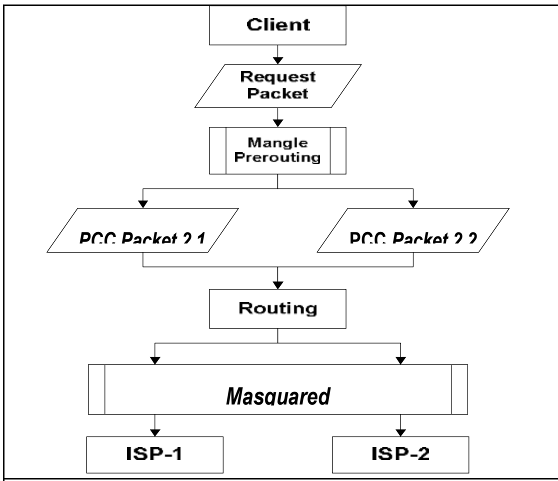


Figure 2. PCC Load Balancing Package Delivery Process Flow

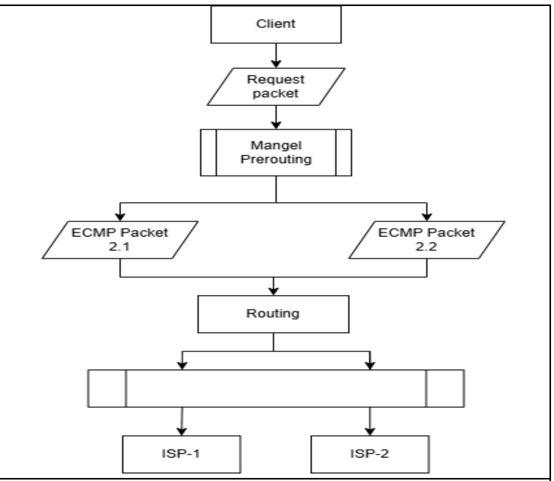


Figure 3. ECMP Load Balancing Packet Delivery Process Flow

After all simulation stages have been successfully completed, the next step is the implementation stage. This stage refers to the design stages that have been created and simulated. The following are the processes carried out during the implementation stage.

2.2 Mikrotik Interface Initialization

Interface initialization is useful to make it easier for authors to develop systems by giving names to each interface according to its function.

```
/interface Ethernet
set numbers="" comment="" disabled=no name="ether1-Astinet"
set numbers="" comment="" disabled=no name="ether2-Indibiz"
set numbers="" comment="" disabled=no name="LAN"
```

The "set" command configures the ether1 interface on the MikroTik router. This command activates the interface and names it ether1-Astinet. The same applies to the subsequent commands.

2.3 Assigning IP Addresses

At this stage, IP addresses will be assigned to each existing interface, both on the modem router, Mikrotik and from the client side on Mikrotik.

```
/ip address
        add   address=192.168.1.20/24   network=192.168.1.0   \   broadcast=192.168.1.255
        comment="LB By-ISP1" \ disabled=no interface=ether2-Astinet
        add address=10.80.30.2/30 network=10.80.30.0 \ broadcast=10.80.30.3 comment="LB
        By-ISP1" disabled=no interface=ether3-Indibiz
        add   address=192.168.12.1/24   network=192.168.12.0   \   broadcast=192.168.12.255
        comment="LB By-ISP1" \ disabled=no interface=bridge1-LAN
```

The first line means ordering to provide the ISP-1 interface with the IP address 192.168.1.20 with subnetting /24, namely 255.255.255.0, as well as the description of the following commands.

2.4 Mangel Configuration

a. PCC Load Balancing

In the mangle configuration stage using the PCC load balancing method, the author uses several mangle commands, namely:

1. Chain Prerouting is the process by which the router can manipulate packets before they are routed.
2. Chain Input is the process of inspecting packets entering and processing the router through one of its interfaces.
3. Chain Output is the process of inspecting packets already processed by the router that will be sent out before the routing process.

b. ECMP Load Balancing

The following are the steps for configuring the MikroTik mangle:

Begin by marking connections originating from outside the network or public interfaces that go to local addresses. This is done by setting connections originating from ISP1 to be marked "cm-ether1-AstiNet" and connections originating from ISP2 to be marked "cm-ether2-Indibiz". The configuration is as follows:

```
/ip firewall mangle
add action=mark-connection chain=input in-interface="ether1-Astinet" new-connection-mark="cm-ether2-
    Indibiz" passthrough=yes comment="LB pcc by all"
    add action=mark-connection chain=input in-interface="ether2-Indibiz" new-connection-mark="cm-
    ether1-AstiNet" passthrough=yes comment="LB pcc by all"
```

The next step is to assign routing marks to the path of the marked connection packets that will exit the router. Each connection marked with "cm-ether1-AstiNet" will be assigned the routing mark "to_ether1-AstiNet" and will be routed through the ISP1 interface. Each connection marked with "cm-ether2-Indibiz" will be assigned the routing mark "to_ether2-Indibiz" and will be routed through the ISP2 interface. The configuration can be seen in Figure 1.

```
;;; LB wan
4    mark connection   input      ether2-indibiz        6.1 KiB      110
;;; LB wan
5    mark connection   input      ether1-astinet     1180.5 KiB    8 966
;;; LB wan
6    mark routing      output                          26.4 MiB   27 101
;;; LB wan
7    mark routing      output                          15.4 MiB   15 481
```

Figure 4. Incoming and Outgoing Connection Marking

3. Result And Discussion

3.1. Load Balancing Testing

During the testing phase, the author will measure the optimal performance of the developed system by observing the load balancing system's performance and the quality of the network used for load balancing. The testing is based on the system design, which includes four stages: traceroute, browsing, and failover testing.

3.2. PCC Load Balancing and ECMP Load Balancing Browsing Testing

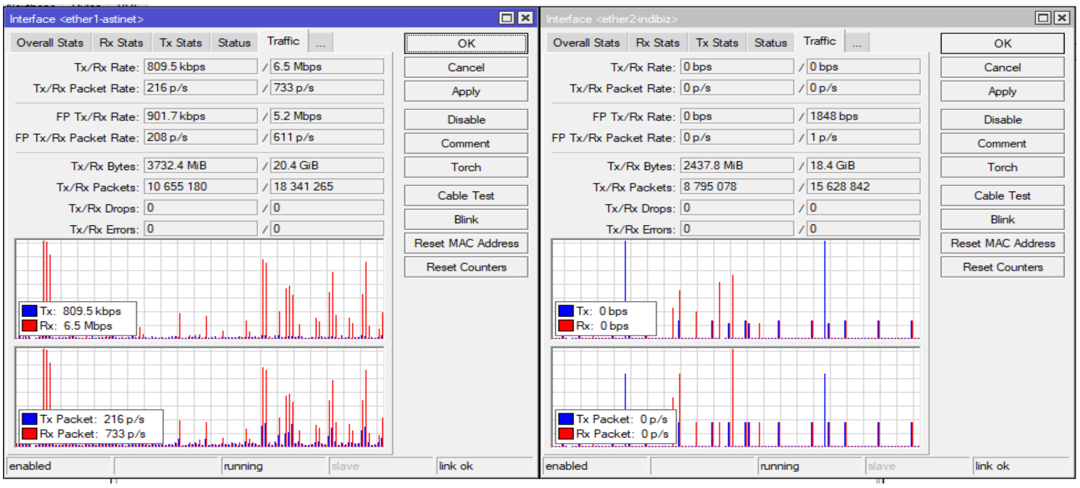
At this stage, a browsing test was conducted using PC client 1, targeting www.youtube.com. This activity served as a sample of client browsing activity. Testing was conducted on both designed load balancing methods.

From the test results above, it was found that when accessing the website www.youtube.com, the MikroTik router would divide the connection evenly and alternately. This is evident from the connection path traversed by IP 192.168.56.1, which alternates from ether2-Indibiz to ether1-AstiNet sequentially.

The Nth method of load balancing is also called the round robin method because the load is divided sequentially and alternately from one gateway to another. Therefore, the gateways used always alternate and are not fixed (random). This is determined in the mangle configuration, namely Nth. The first value indicates every and the second value indicates packet. Therefore, when translated from the script above, Nth in the second rule has a value of 2.1, meaning it will capture every first packet of two packets.

3.3. Connection Balance Testing

The parameters observed from both traffic streams in the interface list shown in Figure 5 are the average distribution of transmitted packets (Tx/Upload) from each ISP gateway. Figure 5 shows that PCC and Nth load balancing have successfully distributed packets and bytes almost equally across both interfaces. These results conclude that the PCC and Nth load balancing methods can distribute transmitted packets evenly across each gateway.



Interface <ether1-astinet>

Tx/Rx Rate: 809.5 kbps / 6.5 Mbps
Tx/Rx Packet Rate: 216 p/s / 733 p/s
FP Tx/Rx Rate: 901.7 kbps / 5.2 Mbps
FP Tx/Rx Packet Rate: 208 p/s / 611 p/s
Tx/Rx Bytes: 3732.4 MiB / 20.4 GiB
Tx/Rx Packets: 10 655 180 / 18 341 265
Tx/Rx Drops: 0 / 0
Tx/Rx Errors: 0 / 0

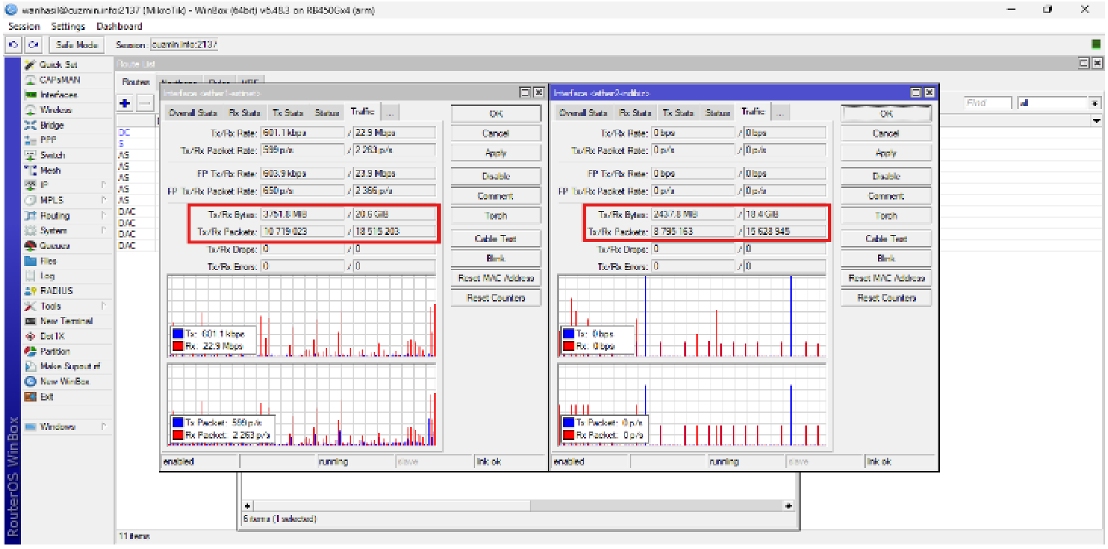
Interface <ether2-indibiz>

Tx/Rx Rate: 0 bps / 0 bps
Tx/Rx Packet Rate: 0 p/s / 0 p/s
FP Tx/Rx Rate: 0 bps / 1848 bps
FP Tx/Rx Packet Rate: 0 p/s / 1 p/s
Tx/Rx Bytes: 2437.8 MiB / 18.4 GiB
Tx/Rx Packets: 8 795 078 / 15 628 842
Tx/Rx Drops: 0 / 0
Tx/Rx Errors: 0 / 0

Figure 5. Connection Balance on each ISP Gateway

3.4. Load Testing On ISP Gateway

Figure 6 is the result of load testing on the ISP Gateway. There are 2 ISPs tested. The results of each tx, rx value for each ISP are also shown in Figure 7.



Tx/Rx Rate: 601.1 kbps / 22.9 Mbps
Tx/Rx Packet Rate: 599 p/s / 2 263 p/s
FP Tx/Rx Rate: 603.9 kbps / 23.9 Mbps
FP Tx/Rx Packet Rate: 650 p/s / 2 366 p/s
Tx/Rx Bytes: 3751.8 MiB / 20.6 GiB
Tx/Rx Packets: 10 719 023 / 18 515 203
Tx/Rx Drops: 0 / 0
Tx/Rx Errors: 0 / 0

Tx/Rx Rate: 0 bps / 0 bps
Tx/Rx Packet Rate: 0 p/s / 0 p/s
FP Tx/Rx Rate: 0 bps / 0 bps
FP Tx/Rx Packet Rate: 0 p/s / 0 p/s
Tx/Rx Bytes: 2437.8 MiB / 18.4 GiB
Tx/Rx Packets: 8 795 163 / 15 628 945
Tx/Rx Drops: 0 / 0
Tx/Rx Errors: 0 / 0

Figure 6. Connection Graph on each ISP Gateway

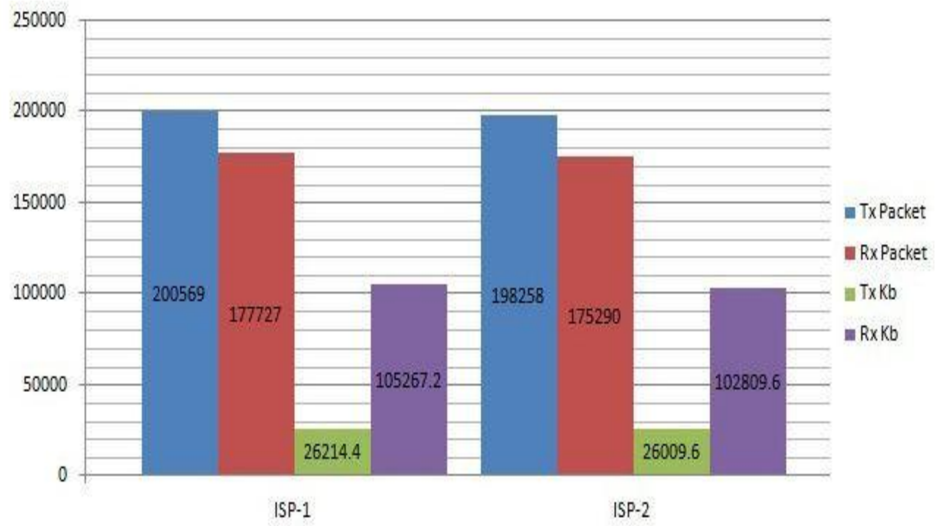


Figure 7. Comparison Diagram of ISP1 and ISP2

Analysis of Key Findings

1. ISP 1's Capacity Dominance: ISP 1 exhibits a significantly higher traffic load than ISP 2. In terms of Tx, ISP 1's traffic is almost 7.6 times larger than ISP 2's. This indicates that ISP 1 is likely used as a primary route or serves a user segment that is much more active in sending/uploading data.
2. Upload/Download Ratio Imbalance (Asymmetry)

- ISP 1: Has a higher Tx than Rx number. This is quite unique because general internet usage is typically higher in Rx (download). This indicates that ISP 1 may be used for seeding, server activities, or data delivery to the central hub (uplink).
- ISP 2: Shows a standard pattern of typical internet users, where Rx (105k) is much higher than Tx (26k). Its download ratio is almost four times its upload ratio.

3. Traffic Stability: Looking at the two data sets you provided (row 1 and row 2), both ISPs show slight decreases in the second data set:

- ISP 1 dropped by about 1.1%.
- ISP 2 dropped by about 0.8% (for Tx) and 2.3% (for Rx). These decreases are very small and normal, indicating stable network conditions at the time of testing.

3.5. Failover Testing

At this stage, the author tested each load balancer, including the PCC load balancer, to determine the failover performance of the system. The function of failover is to address disconnections or lost connections from one of the ISPs. With this failover, if one of the connection lines from each ISP is lost, the system still has one ISP as a backup source of internet connection. The testing can be seen in Figures 8 and 9.

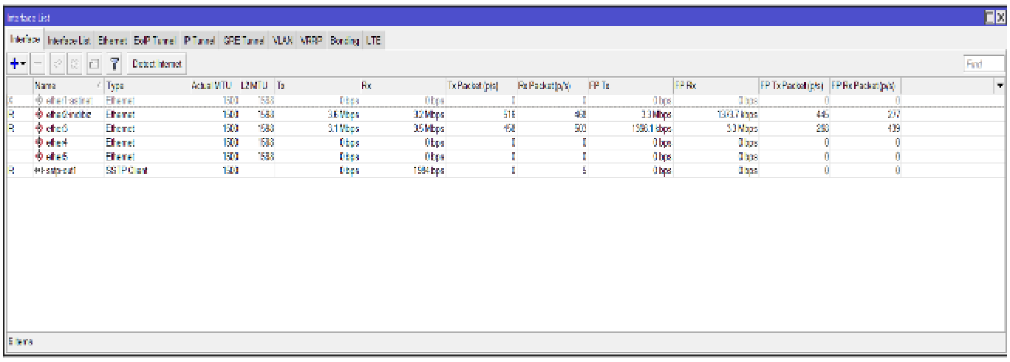


Figure 8. Failover Testing After ISP1 Disconnects

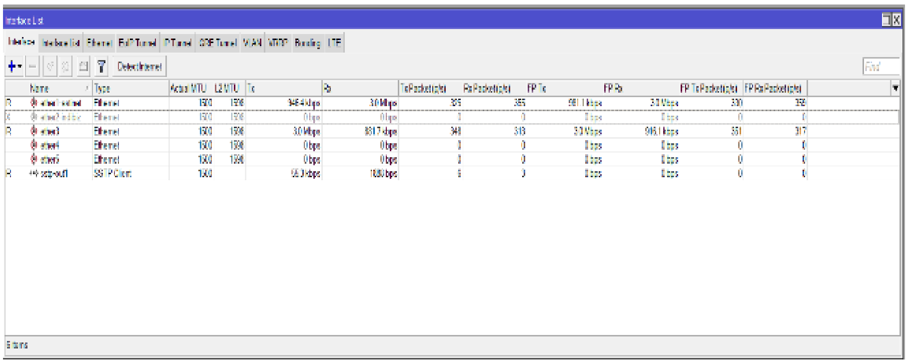
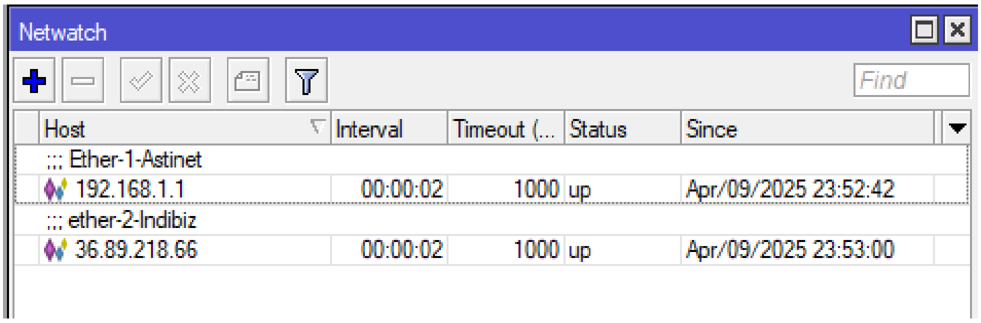


Figure 9. Failover Testing After ISP2 Disconnects

From the test results above, the results obtained are that the download process continues without any connection interruptions because ISP2 will automatically become the default gateway that backs up the overall network performance. This is evident from checking the IP via the IP checker site, www.whatsmyip.com. It can be seen that during the initial download process, it still uses the ISP1 connection path with gateway 192.168.1.1. And after disconnecting from ISP1, the download process continues, but through the ISP2 connection path with gateway 10.80.56.1. can be seen in Figure 10.



Host	Interval	Timeout (...	Status	Since
;;; Ether-1-Astinet				
192.168.1.1	00:00:02	1000	up	Apr/09/2025 23:52:42
;;; ether-2-Indibiz				
36.89.218.66	00:00:02	1000	up	Apr/09/2025 23:53:00

Figure 10. Netwatch Network Up

3.6. Speed Results After Applying PCC and ECMP Methods

The speed results after applying the PCC and ECMP methods can be seen in tables 1 and 2.

Table 1. Speed after applying the PCC method

No	Hari	Throughput	Packet Loss	Delay	Jitter

1	Senin	334 k	14,1 k	14,013283 ms	0,185501 ms
2	Selasa	188 k	0,2 k	29,944804 ms	1,310 ms
3	Rabu	146 k	0,3 k	33,238412 ms	5440 ms
4	Kamis	924 k	5,6 k	6,643429 ms	6,760 ms
5	Jumat	386 k	1,5 k	13, 742522 ms	9,380 ms

Table 2. Speed after applying the ECMP method

No	Hari	Throughput	Packet Loss	Delay	Jitter
1	Senin	183 k	1,1 k	32,368773 ms	3.420 ms
2	Selasa	760 k	0,8 k	8,104851 ms	1.670 ms
3	Rabu	861 k	0,0 k	8,477976 ms	0,836027 ms
4	Kamis	717 k	0,0 k	10,759078 ms	1.540 ms
5	Jumat	4,7 k	0,0 k	15,204525 ms	2,790 ms

The PCC and ECMP methods were analyzed by monitoring the response time on 10 user PCs using Wireshark with the following QoS parameters: throughput, delay, packet loss, and jitter. The following formula was used:

4. Conclusion

Based on the test results, the implementation of a load balancing system has been proven to significantly improve internet network performance and reliability by efficiently distributing traffic between the two ISPs. The combination of ISP1 and ISP2 not only serves as a failover mechanism, ensuring connection continuity when one link is down, but also optimizes bandwidth utilization by allocating the path based on the size of the requested data packet. Although this system cannot guarantee perfect bandwidth balance due to limitations in response packet identification, the cumulative results show a substantial increase in capacity compared to using either ISP alone.

Technically, the effectiveness of this combination is clearly demonstrated in the test data, where activating both ISPs simultaneously resulted in significantly superior and stable performance, with download rates reaching 22.03 Mbps and upload rates reaching 11.24 Mbps. Compared to using ISP1 alone (10.30 Mbps download) or ISP2 alone (10.18 Mbps download), this combination nearly doubled the download speed while maintaining a low jitter value of 37.00 ms. Thus, the simultaneous configuration of both ISPs is the best solution to obtain network quality that is more resilient to overload and provides a smoother and more scalable connection experience.

5. Reference

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