



Implementation of Load Balancing of Two PCC-Based Internet Interconnections on Mikrotik Routers

Syukron Ma'mun¹, Muhajir Syamsu², Vany Terisia³

¹²³ Information Technology, ITB Ahmad Dahlan

Corresponding Author: syukron.rizum@gmail.com

Abstract

The increasing need for reliable internet connectivity requires organizations to optimize network performance and availability. PT Solusi Integra Datakom uses two internet service providers (ISPs), but bandwidth utilization is not optimal because it still implements manual failover. This study aims to implement Per Connection Classifier (PCC)-based load balancing on MikroTik routers and evaluate its impact on network performance. The study uses a quantitative approach with an experimental method and a one-group pretest-posttest design. The study population is all data traffic passing through the company's dual-ISP network, while the sample is data from network performance measurements before and after PCC implementation selected using purposive sampling. The research instruments include MikroTik routers, two ISP connections, client devices, and the NPerf application. Data were analyzed using comparative descriptive analysis based on Quality of Service (QoS) parameters, namely throughput, latency, and jitter. The results show that download throughput increased from 30.73 Mbps to 94.80 Mbps and upload throughput increased from 6.02 Mbps to 81.56 Mbps. Additionally, latency decreased from 28 ms to 10 ms, and jitter decreased from 9 ms to 5 ms. Failover testing also demonstrated that connectivity remained stable even when one of the ISPs experienced an outage. In conclusion, the PCC method effectively improves bandwidth utilization, network stability, and service availability in a dual-ISP environment.

Keywords: Bandwidth Optimization, Failover, Load Balancing, MikroTik Router, Quality Of Service





INTRODUCTION

The advancement of digital transformation has increased the need for fast, stable, and reliable internet connections for organizations. The increased use of cloud-based services, online communications, and integrated information systems has led to significant network traffic growth. Therefore, effective network management is crucial for maintaining network performance and service quality (Syamsu et al., 2023; Amalia et al., 2022).

On the other hand, many organizations still rely on a single internet connection, making them vulnerable to service disruptions. This can lead to a single point of failure, resulting in operational disruptions when the ISP experiences issues. PT Solusi Integra Datakom has used two ISPs, but their utilization is still limited to a manual failover scheme, resulting in suboptimal bandwidth utilization (Panggabean et al., 2024).

As a solution, load balancing has become a widely used method to distribute network traffic evenly. Mikrotik's Per Connection Classifier (PCC) method can group and divide connections across multiple internet paths, resulting in more efficient bandwidth utilization. Previous research has shown that PCC can increase throughput and maintain connection stability under high traffic conditions (Pratama & Mirza, 2021; Wiharti et al., 2023).

However, previous research still has limitations because most of them focused only on traffic distribution or were conducted in simulated environments. Some studies also failed to comprehensively examine network redundancy and quality of service (QoS) after PCC implementation. Therefore, research evaluating PCC implementation in real-world operational environments is needed (Sadikin & Ramadhan, 2025; Surono et al., 2025).

Furthermore, multi-ISP networks without load balancing mechanisms can potentially experience traffic imbalances, resulting in increased latency and decreased network performance. Various studies have shown that uneven traffic distribution leads to suboptimal bandwidth utilization and unstable service quality. However, studies on PCC implementation in companies that previously used manual failover are relatively limited (Pragasta & W, 2025; Octavriana et al., 2025).

Based on these conditions, this study aims to implement the PCC method on a Mikrotik router to optimize two internet connections at PT Solusi Integra Datakom. This research is important because it can provide an overview of the effectiveness of PCC in improving bandwidth efficiency, connection stability, and network service quality based on throughput, latency, and jitter parameters.





METHOD

This study uses a quantitative approach with an experimental method to test the effect of Per Connection Classifier (PCC) implementation on network performance in a dual-ISP environment. Measurements were conducted before and after PCC implementation on Mikrotik routers using a one-group pretest-posttest design, so that changes in network performance can be observed objectively through Quality of Service (QoS) parameters including throughput, latency, and jitter (Creswell & Creswell, 2023; Sugiyono, 2022; Wiharti et al., 2023).

The population of this study was all data traffic passing through the PT Solusi Integra Datakom (Intrakom) internet network in a dual-ISP configuration. The research sample was determined using a purposive sampling technique, namely data from network performance measurements before and after the implementation of PCC load balancing. The sample selection was based on the research objective of obtaining relevant data to evaluate the effectiveness of traffic distribution and bandwidth utilization in multi-ISP networks (Sugiyono, 2022; Sudaryono, 2021).

The research instruments consisted of a Mikrotik router, two ISP connections, a client device, and the NPerf application, which was used to measure throughput, latency, and jitter. Data were collected through observation and measured experiments, then analyzed using a comparative descriptive method by comparing QoS values before and after PCC implementation. The effectiveness of the method was assessed based on increased throughput and decreased latency and jitter, indicating improved network service quality (Pratama & Mirza, 2021; Surono et al., 2025).

The research procedure began with identifying network issues that had not optimized the use of two ISPs, followed by a literature review on load balancing and the PCC method. The next stage included designing the network topology, configuring the Mikrotik router using mangle, NAT, and routing features, and implementing load balancing and failover mechanisms. After implementation was complete, network performance testing was conducted using NPerf. The test results were then analyzed to evaluate the effect of PCC on bandwidth efficiency, connection stability, and network service quality before finally being compiled into a research report (Syamsu et al., 2023; Panggabean et al., 2024; Sadikin & Ramadhan, 2025).

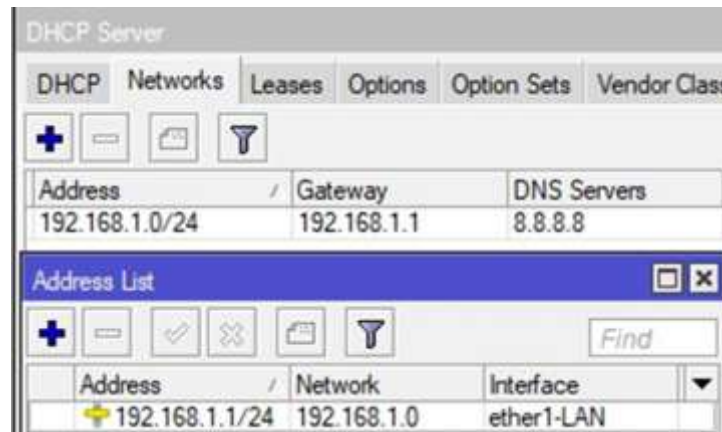
RESULTS AND DISCUSSION

LAN Interface Configuration

To connect to the client conducting the testing, we'll use the ether1 interface. This ether1 interface is a LAN interface, and all clients on this LAN interface will receive a DHCP IP address



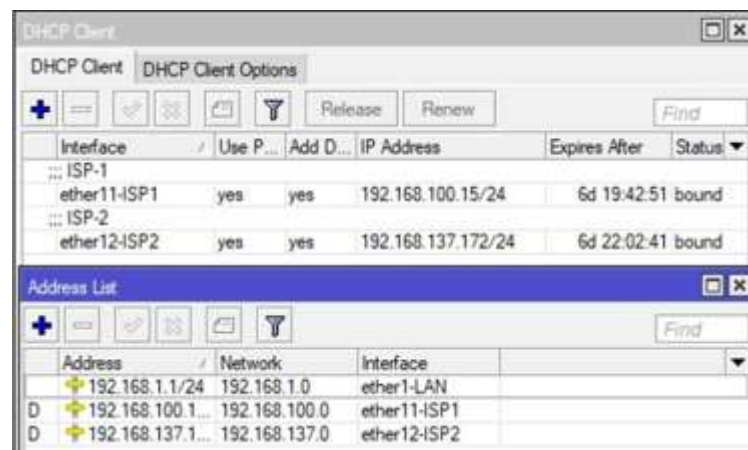
from Mikrotik in the range 192.168.1.1 - 192.168.1.254, with Mikrotik acting as both the DHCP Server and Gateway.



Picture1 LAN Interface Configuration

ISP Interface Configuration

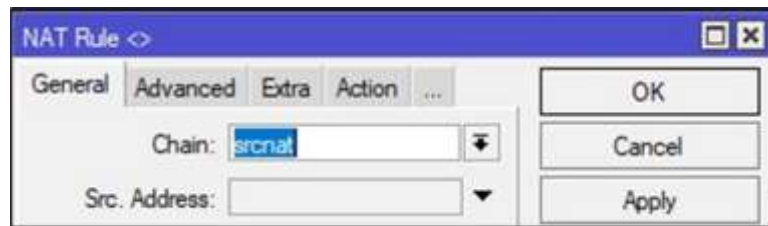
Configure the IP address on the ether11 and ether12 interfaces using DHCP, so that the IP address on the ether11 and ether12 interfaces that lead to the Moratel ISP and Telkom ISP get a Dynamic IP.



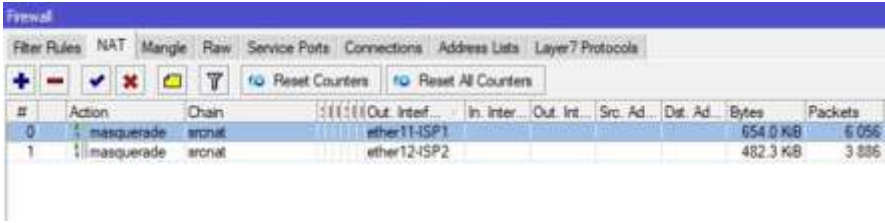
Picture2 ISP Interface Configuration

NAT Configuration

Before implementing PCC load balancing, the author first needs to configure NAT-Masquerade to connect to the internet. Here, we add both ISP interfaces to the Firewall>NAT configuration.



Picture3NAT Configuration

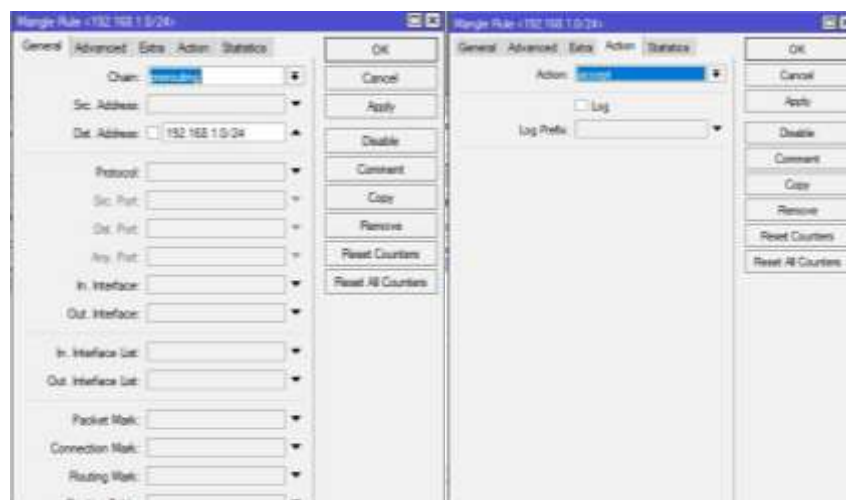


#	Action	Chain	Out. Intf.	In. Intf.	Out. Int.	Src. Ad.	Dst. Ad.	Bytes	Packets
0	masquerade	srcnat	ether11-ISP1					654.0 KiB	6,056
1	masquerade	srcnat	ether12-ISP2					482.3 KiB	3,886

Picture4NAT Configuration (Details)

Mangle Rules Configuration

The first mangle rule that must be configured is the mangle configuration with action=accept for connections that go to the interface that is directly connected to the router (destination address), which are the previously configured interfaces, namely ether1, ether11, and ether12.



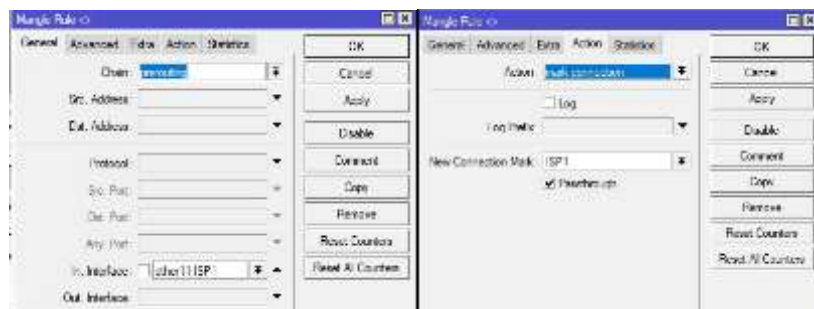
Picture5Destination Address Configuration



#	Action	Chain	Src. Address	Dst. Address	In. Interface	Out. Interface	In. Intf.	Out. Intf.	Src. Ad.	Dst. Ad.	Bytes	Packets
0	accept	srcnat	192.168.1.0/24								3049.2 KiB	45,333
1	accept	srcnat	192.168.137.0/24								1100.1 KiB	1,043,107
2	accept	srcnat	192.168.100.0/24								1881.4 KiB	1,881,075

Picture6Destination Address Configuration (Details)

At this stage, the author will create a mangle rule to mark incoming connections from the ISP interface, namely the ether11 and ether 12 interfaces. Where connections from the ether11 interface will be marked with the label ISP1 and ether12 will be marked with the label ISP2.

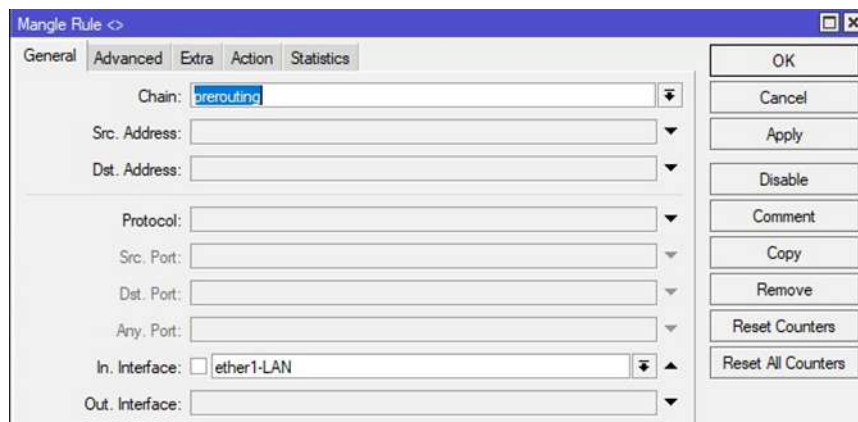


Picture7ISP1 Mark Connection Configuration

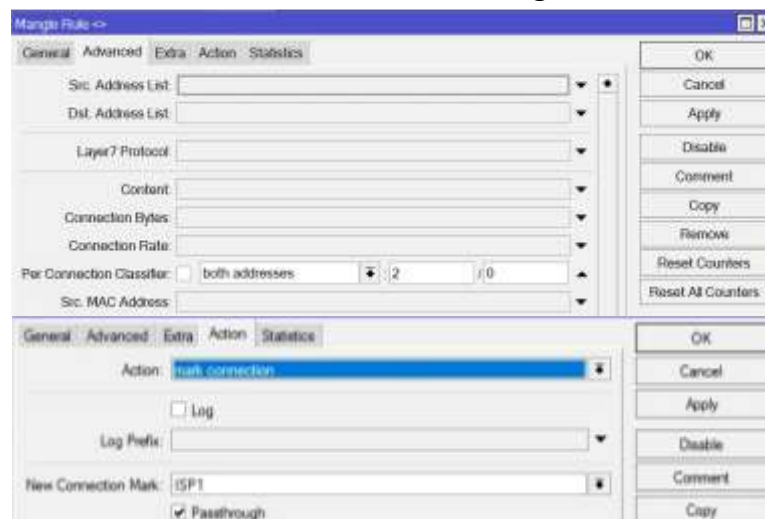


Picture8ISP2 Mark Connection Configuration

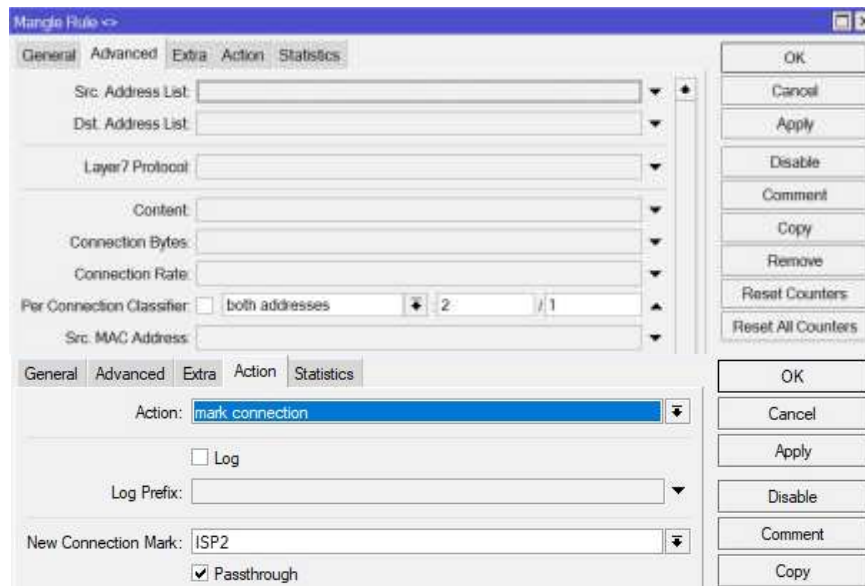
After the mark connection configuration has been created, connection requests from ISP1 (ether11) and ISP2 (ether12) will be consistently sent through the same interface, one after the other. Therefore, here, the author will configure a PCC mangle rule to split traffic so that connection requests can be sent simultaneously through both interfaces.



Picture9PCC ether1-LAN configuration

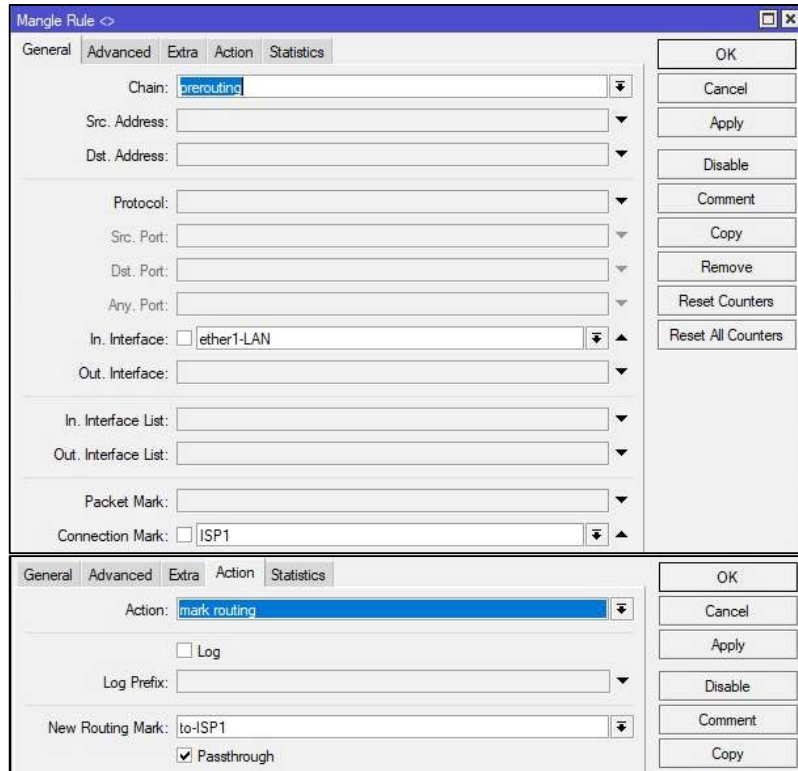


Picture10PCC ISP1 Configuration



Picture11 PCC ISP2 Configuration

After the PCC has been configured, the author then configures the routing mark which functions to provide a label to the packet so that Mikrotik knows that the packet is required to pass through the ISP1 or ISP2 route according to the PCC decision.



Mangle Rule <>

General Advanced Extra Action Statistics

Chain: prerouting

Src. Address:

Dst. Address:

Protocol:

Src. Port:

Dst. Port:

Any. Port:

In. Interface: ☐ ether1-LAN

Out. Interface:

In. Interface List:

Out. Interface List:

Packet Mark:

Connection Mark: ☐ ISP1

OK Cancel Apply Disable Comment Copy Remove Reset Counters Reset All Counters

General Advanced Extra Action Statistics

Action: mark routing

☐ Log

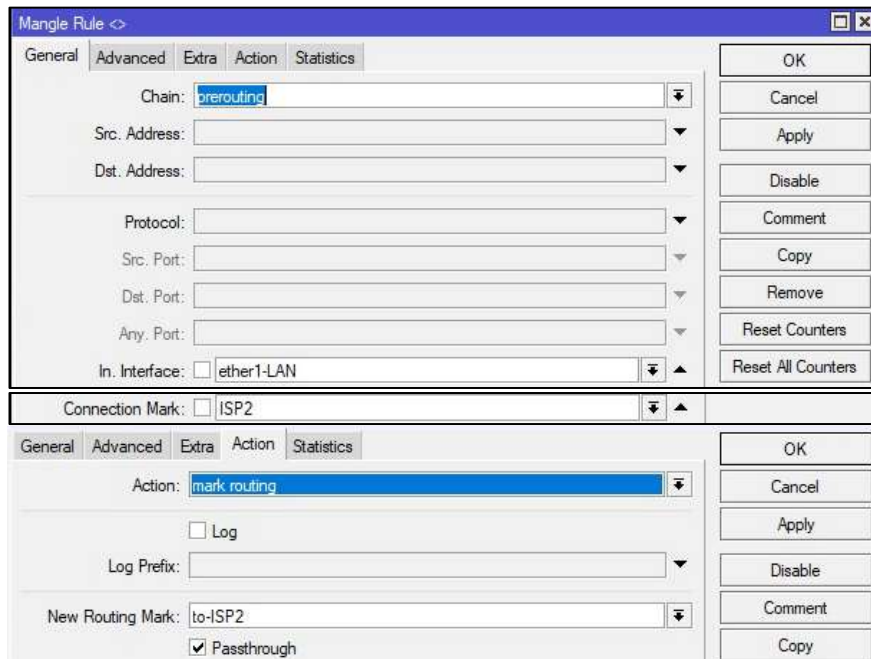
Log Prefix:

New Routing Mark: to-ISP1

☒ Passthrough

OK Cancel Apply Disable Comment Copy

Picture12ISP1 Mark Routing Configuration



Mangle Rule <>

General Advanced Extra Action Statistics

Chain: prerouting

Src. Address:

Dst. Address:

Protocol:

Src. Port:

Dst. Port:

Any. Port:

In. Interface: ☐ ether1-LAN

Out. Interface:

In. Interface List:

Out. Interface List:

Packet Mark:

Connection Mark: ☐ ISP2

OK Cancel Apply Disable Comment Copy Remove Reset Counters Reset All Counters

General Advanced Extra Action Statistics

Action: mark routing

☐ Log

Log Prefix:

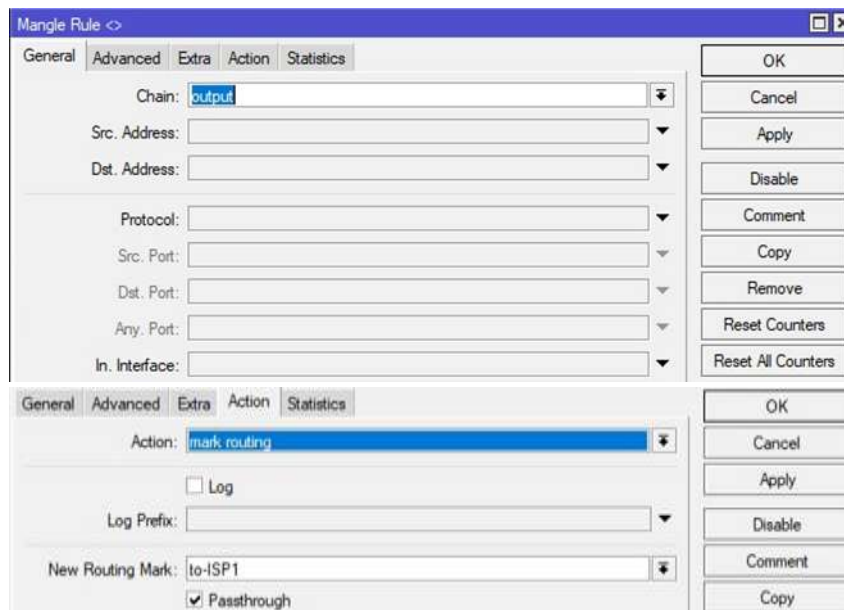
New Routing Mark: to-ISP2

☒ Passthrough

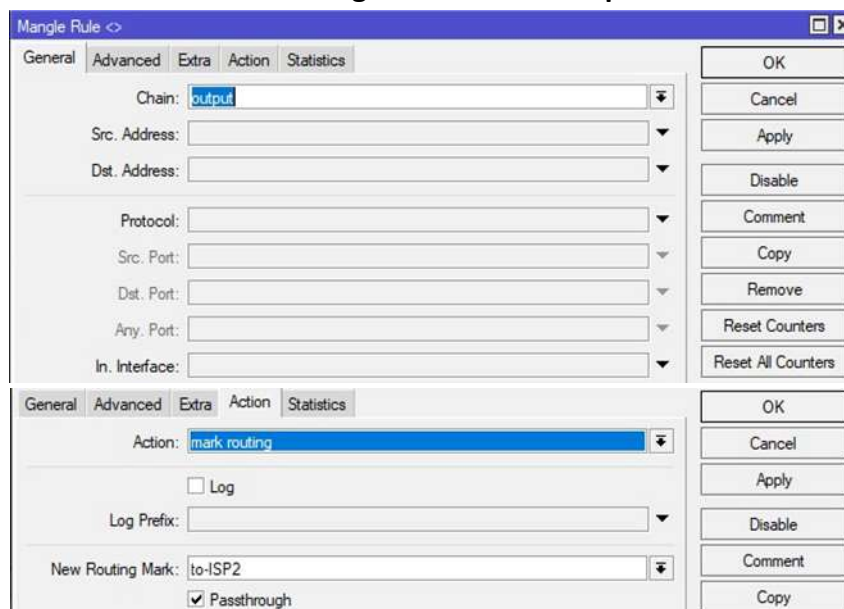
OK Cancel Apply Disable Comment Copy

Picture13ISP1 Mark Routing Configuration

Next, the chain=output configuration handles traffic originating from within the router itself. Without the mark-routing configuration in chain=output, the router might receive a request from ISP2 but attempt to respond via ISP1, resulting in a failed connection/timeout. Therefore, this configuration also ensures a correct response.



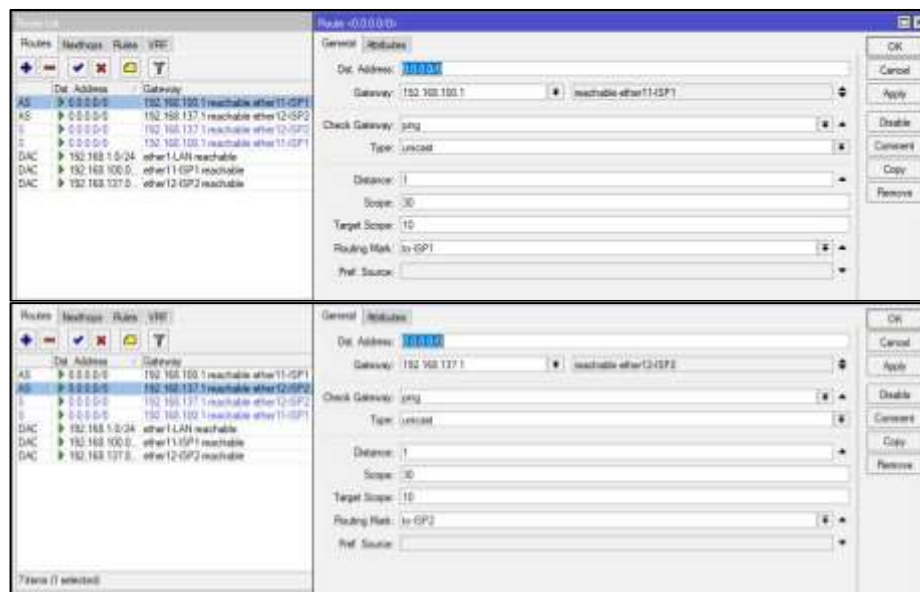
Picture14 Configuration chain=output ISP1



Picture15 Configuration chain=output ISP2

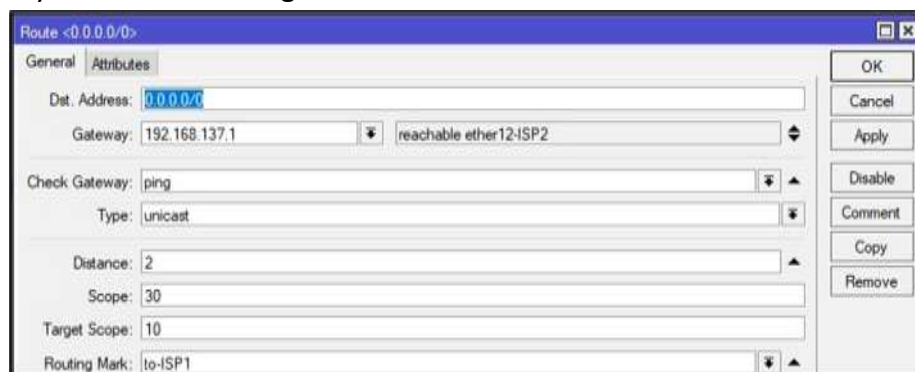
Routing Configuration

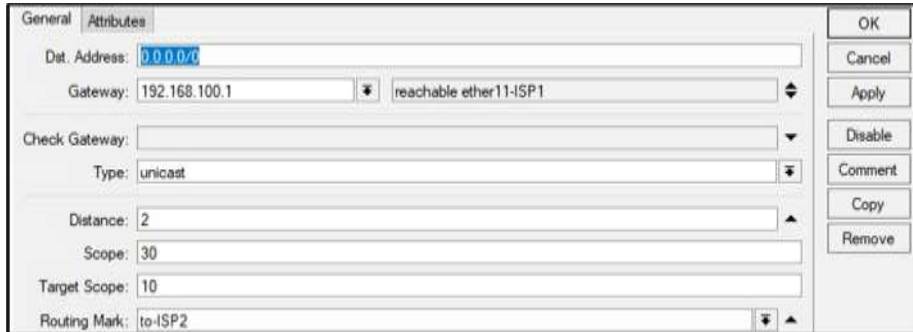
After Mangle has finished marking packets with routing tags, they still won't know their way out unless a routing configuration is in place. While Mangle is responsible for sorting and labeling packets, the routing table is responsible for directing them to the destination gateway.



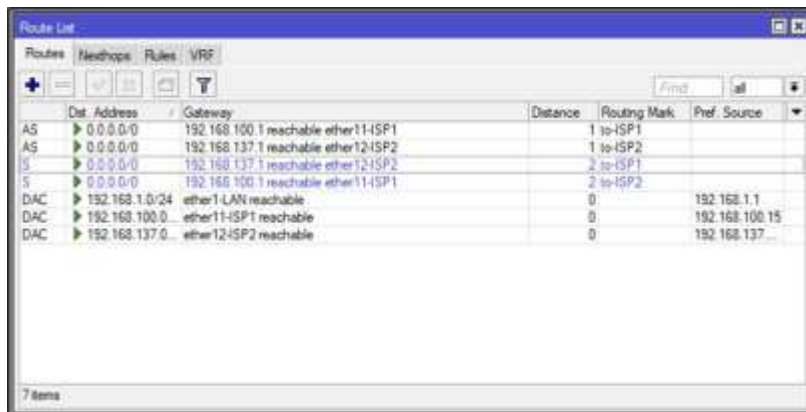
Picture16Routing Configuration to-ISP1 and to-ISP2

After that, the author configured failover so that if ISP1 goes down, routing markers pointing to ISP1 will be redirected to ISP2, and vice versa. This ensures the internet doesn't go down completely if one of the ISPs goes down.





Picture17Failover Configuration



	Dst. Address	Gateway	Distance	Routing Mark	Pref	Source
AS	0.0.0.0/0	192.168.100.1 reachable ether11-ISP1	1	to-ISP1		
AS	0.0.0.0/0	192.168.137.1 reachable ether12-ISP2	1	to-ISP2		
S	0.0.0.0/0	192.168.137.1 reachable ether12-ISP2	2	to-ISP1		
S	0.0.0.0/0	192.168.100.1 reachable ether11-ISP1	2	to-ISP2		
DAC	192.168.1.0/24	ether1-LAN reachable	0		192.168.1.1	
DAC	192.168.100.0	ether11-ISP1 reachable	0		192.168.100.15	
DAC	192.168.137.0	ether12-ISP2 reachable	0		192.168.137.	

Picture18Routing Table

Bandwidth Testing

DOWNLOAD 30.73 Mbps	UPLOAD 6.02 Mbps	LATENCY 28 ms	JITTER 9 ms
---------------------------	------------------------	---------------------	-------------------

Picture19Bandwidth Before Implementation

DOWNLOAD 94.80 Mbps	UPLOAD 81.56 Mbps	LATENCY 10 ms	JITTER 5 ms
---------------------------	-------------------------	---------------------	-------------------

Picture20BandwidthAfter Implementation

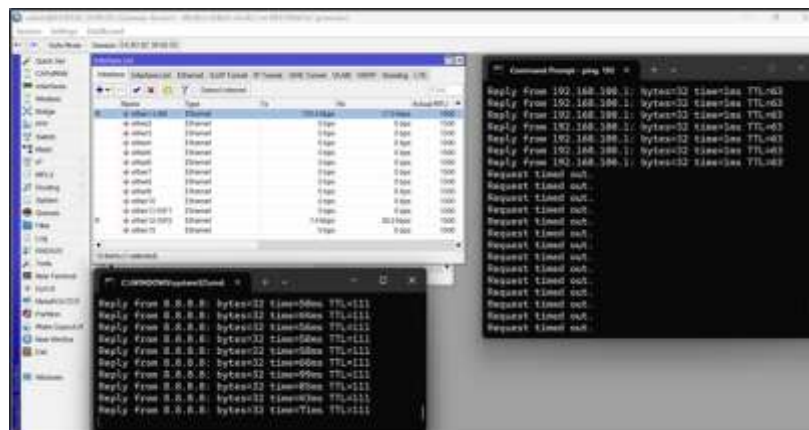
It can be seen that bandwidth increased in terms of throughput, latency, and jitter after implementing PCC load balancing. This is because we maximized bandwidth usage by using both ISPs. With greater bandwidth capacity, bottlenecks were overcome.

Failover Testing

This failover test is performed by simulating a disconnection of one of the internet lines (ISP interface). The goal of this test is to ensure that the system can automatically switch connections to an active internet line without significantly disrupting network connectivity.

First, we'll try shutting down one of the ISPs. In this case, we'll try to cause ISP1 (ether11) to experience downtime.

After ISP1 has experienced downtime, the next step is to perform a Ping test. This test is performed using the "Ping" tool. Ping is performed to two destinations: the first is to Google.com with the IP address 8.8.8.8, representing the Internet, and the second is to the Moratel ISP modem (ISP1) itself.



Picture21 Failover Testing

Test Results

1. Bandwidth Test Results

Based on the bandwidth test results above, testing was conducted under two conditions: before and after PCC load balancing was implemented on the Mikrotik router. The parameters analyzed included throughput, latency, and jitter.

Before load balancing was implemented, the download throughput was 30.73 Mbps and the upload throughput was 6.02 Mbps, with a latency of 28 ms and jitter of 9 ms. The lower throughput and higher latency and jitter indicate that network traffic is still dependent on a single internet connection, resulting in suboptimal network performance.

Meanwhile, after load balancing was implemented, the download throughput was 94.80 Mbps and the upload throughput was 81.56 Mbps. Furthermore, the latency was 10 ms and the jitter was 5 ms. These results indicate that the PCC load balancing mechanism is able to



distribute network traffic evenly across the two internet interconnection paths, significantly increasing data transfer speeds. Low latency and jitter also indicate a more stable and responsive network connection.

2. Failover Test Results

The failover test results above show that when ISP1 experiences downtime, the network connection remains operational, as indicated by the successful ping to google.com without interruption. This indicates that the system automatically redirects the connection to the still-active ISP2. Therefore, the failover mechanism on the Mikrotik router is operating as designed and is capable of maintaining network service continuity.

CONCLUSION

The results of the study indicate that the implementation of the Per Connection Classifier (PCC) method on a Mikrotik router is able to optimize the utilization of two internet interconnections simultaneously through load balancing and failover mechanisms. The implementation of PCC successfully distributes network traffic more evenly, thereby improving network performance based on Quality of Service (QoS) parameters. This is indicated by an increase in download throughput from 30.73 Mbps to 94.80 Mbps and upload throughput from 6.02 Mbps to 81.56 Mbps. In addition, the latency value decreased from 28 ms to 10 ms and jitter decreased from 9 ms to 5 ms. Failover testing also proved that when one ISP experienced disruption, the internet connection could still run through the other ISP without causing significant service interruptions. These findings indicate that the PCC method is effective in improving bandwidth usage efficiency, connection stability, and network service availability in a dual-ISP environment.

However, this study still has several limitations. Testing was only conducted in a single corporate network environment with two ISPs and using QoS parameters limited to throughput, latency, and jitter. Furthermore, the study did not compare the performance of PCC with other load balancing methods such as ECMP or Nth, so the relative effectiveness between the methods cannot be fully understood. Therefore, further research is recommended to involve more network scenarios, different numbers of ISPs, and add evaluation parameters such as packet loss, bandwidth utilization, and quality of service for specific applications. Practically, the results of this study can be a reference for network administrators and organizations that use multi-ISP connections in designing more efficient, reliable, and highly redundant network systems to support the ever-growing needs of communication and digital services.





REFERENCES

- Amalia, E. R., Nurheki, Saputra, R., Ramadhana, C., & Yossy, E. H. (2022). Computer network design and implementation using load balancing technique with per connection classifier (PCC) method based on MikroTik router. *Procedia Computer Science*, 216, 103–111. <https://doi.org/10.1016/j.procs.2022.12.116>
- Creswell, J. W., & Creswell, J. D. (2023). *Research design: Qualitative, quantitative, and mixed methods approaches* (6th ed.). Sage Publications.
- Octavriana, T., Joni, K., & Ibadillah, A. F. (2025). Optimalisasi jaringan internet dengan load balancing pada high traffic network. *Jurnal Teknik Informatika*, 14(1). <https://doi.org/10.15408/jti.v14i1.15018>
- Panggabean, J. F. R., et al. (2024). Jaringan komputer: Konsep, protokol, dan implementasi. YPAD Penerbit.
- Pragasta, Y., & W, Y. (2025). Penerapan teknologi load balancing pada router Mikrotik dengan metode Per Connection Classifier. *Digital Transformation Technology*, 5(2), 131–140. <https://doi.org/10.47709/digitech.v5i2.6834>
- Pratama, M. B., & Mirza, A. H. (2021). Implementasi load balancing menggunakan metode PCC (Per-Connection Classifier) dengan failover berbasis Mikrotik router (studi kasus di RSUD Siti Fatimah). *JACIS: Journal Automation Computer Information System*. <https://doi.org/10.47134/jacis>
- Sadikin, N., & Ramadhan, F. (2025). Implementasi load balancing 2 (dua) ISP menggunakan metode Per Connection Classifier (PCC). *Jurnal Maklumatika*, 5(2), 74–83. <https://doi.org/10.55864/maklumatika.v5i2.74>
- Sudaryono. (2021). *Metodologi penelitian: Kuantitatif, kualitatif, dan mix method* (2nd ed.). Rajawali Pers.
- Sugiyono. (2022). *Metode penelitian kuantitatif, kualitatif, dan R&D* (2nd ed.). Alfabeta.
- Surono, S., Setiarso, G., & Hadi, S. (2025). Implementation of failover recursive gateway and load balancing PCC method on internet networks at Universitas Semarang. *Journal of Artificial Intelligence and Software Engineering (J-AISE)*, 5(1), 36–45. <https://doi.org/10.30811/jaise.v5i1.6337>
- Syamsu, M., Jixiong, C., & Jie, L. (2023). Quality of service management solution becomes a software-defined network challenge. *Journal of Computer Science Advancements*, 1(4), 215–226. <https://doi.org/10.70177/jsca.v1i4.582>
- Syamsu, M., et al. (2023). Buku ajar jaringan komputer: Praktis & mudah disertai studi kasus. Eureka Media Aksara.
- Wiharti, W., Rimra, I. L., Rifka, S., Hidayatullah, I., & Kasmar, A. F. (2023). Load balancing and fail





over MikroTik implementation using Per Connection Classifier (PCC) on two internet providers interconnection. International Journal of Advanced Science Computing and Engineering, 5(2), 129–135. <https://doi.org/10.62527/ijasce.5.2.135>

